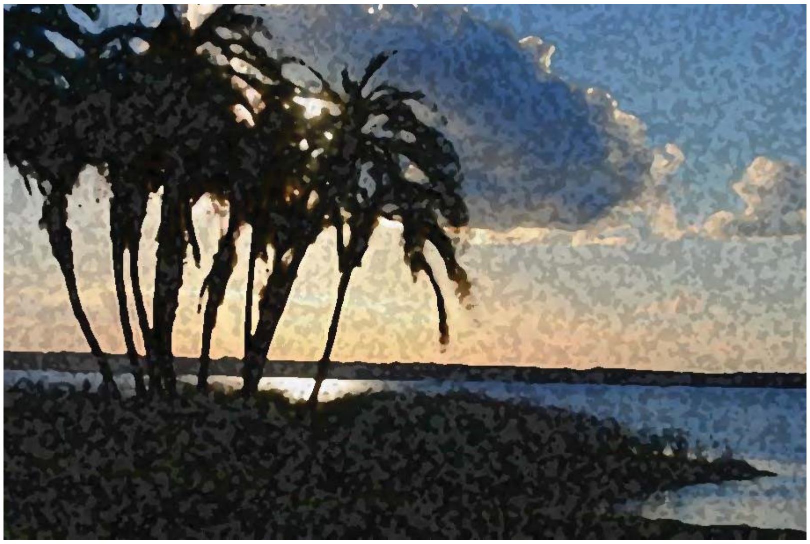
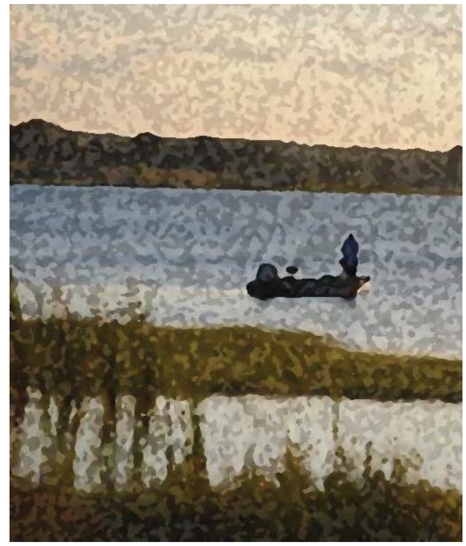
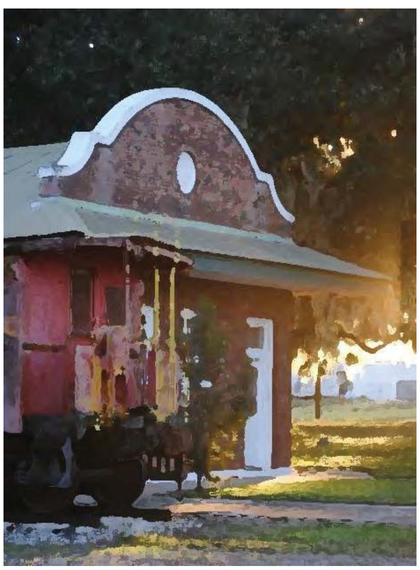
Revised Minimum and Guidance Levels for Lake Clinch in Polk County, Florida


December 2, 2015

Resource Evaluation Section
Water Resources Bureau

Southwest Florida
Water Management District

Revised Minimum and Guidance Levels for Lake Clinch in Polk County, Florida

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Resource Evaluation Section
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Contents

Executive Summary

This report describes the development of Minimum and Guidance levels for Lake Clinch in Polk County, Florida based on reevaluation of levels in Southwest Florida Water Management District rules that became effective in April 2017. Minimum levels are the levels at which further water withdrawals would be significantly harmful to the water resources of the area (Section 373.042(1)(b), F.S.). Adopted minimum levels are used to support water resource planning and permitting activities. Adopted guidance levels are used as advisory guidelines for construction of lakeshore development, water dependent structures, and operation of water management structures.

Section 373.0421(3), F.S., requires the periodic reevaluation and, as needed, the revision of established minimum flows and levels. Lake Clinch was selected for reevaluation based on development of modeling tools for simulating lake level fluctuations that were not available when levels currently adopted for the lake were developed. The adopted lake levels were also reevaluated to support ongoing assessments of minimum flows and levels in the Southern Water Use Caution Area, a region of the District where recovery strategies are being implemented to support recovery to minimum flow and level thresholds.

Revised Guidance and Minimum Levels for Lake Clinch were developed using current District methods for establishing minimum levels for Category 3 Lakes. The Minimum Levels were developed with consideration of and are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels (see Rule 62-40.473, F.A.C.). The levels are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD29) that must be equaled or exceeded specified percentages of time on a long-term basis. Table ES-1 identifies these elevations and includes generic descriptions for the levels in District rules (Rule 40D- 8.624, F.A.C). Differences between these current and previously adopted levels are primarily associated with application of a new modeling approach for characterization of historic water level fluctuations within the lake, i.e., water level fluctuations that would be expected in the absence of water withdrawal impacts given existing structural conditions.

Based on these results, the previously adopted Guidance and Minimum Levels for Lake Clinch were replaced by the current, revised levels. The District Governing Board approved the adoption of the Minimum and Guidance Levels (December 2015) identified in this report and replaced the previously adopted levels for the lake included in District rules.

Based on available measured and modeled water level records, the minimum levels for Lake Clinch are being met. In the event that levels are not met in the future, recovery strategies outlined in the Comprehensive Environmental Resources Recovery Plan for Southern Water Use Caution Area Recovery Strategy (Rule 40D- 80.073, F.A.C.) will apply for recovery of minimum levels for the lake.

Table ES-1. Minimum and Guidance Levels for Lake Clinch and level descriptions.

Minimum and Guidance Levels	Elevation (feet above NGVD29)	Level Descriptions
High Guidance Level	106.5	Advisory guideline for construction of lake shore development, water dependent structures, and operation of water management structures. The High Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ten percent of the time on a long-term basis.
High Minimum Lake Level	105.7	Elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis.
Minimum Lake Level	103.2	Elevation that the lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis.
Low Guidance Level	102.3	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.

Introduction

Reevaluation of Minimum and Guidance Levels

This report describes the development of revised minimum and guidance levels for Lake Clinch, in Polk County, Florida. The levels were developed based on the reevaluation of minimum and guidance levels approved by the Southwest Florida Water Management District Governing Board (see SWFWMD 2008) and adopted into District rules with an effective date of April 2017. The minimum and guidance levels represent needed revisions to the previously adopted levels.

Lake Clinch is one of six lakes located in Polk County selected for reevaluation in the 2015 through 2016. The reevaluation is based on development of modeling tools for simulating long term lake level fluctuations that were not available when the previously adopted levels were developed. The adopted lake levels were evaluated to support ongoing assessments of minimum flows and levels in the Southern Water Use Caution Area, a region of the District where recovery strategies are being implemented to support recovery to minimum flow and level thresholds.

Minimum Flows and Levels Program Overview

Legal Directives

Section 373.042, Florida Statutes (F.S.) directs the Department of Environmental Protection or the water management districts to establish minimum flows and levels

(MFLs) for lakes, wetlands, rivers and aquifers. Section 373.042(1)(a), F.S., states that "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 water level of an aquifer or surface water body as ".. the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area." 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.

Established MFLs are key components of resource protection, recovery and regulatory compliance, as Section 373.0421(2) F.S., requires the development of a recovery or prevention strategy for water bodies "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 established pursuant to S. 373.042." Section 373.0421(2)(a), 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 reevaluation and, as necessary, revision of established MFLs are required by Section 373.0421(3), F.S.

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

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

Rule 62-40.473, F.S., 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 as provided in Section 373.042(1), F.S." It further notes that, " .. a minimum flow or level need not be expressed as multiple flows or levels if other resource protection tools, such as reservations implemented to protect fish and wildlife or public health and safety, that provide equivalent or greater protection of the hydrologic regime of the water body, are developed and adopted in coordination with the minimum flow or level." The rule also includes provision addressing: protection of MFLs during the construction and operation of water resource projects; the issuance of permits pursuant to Section and Parts II and IV of Chapter 373, F.S.; water shortage declarations; development of recovery or prevention strategies, development and updates to a minimum flow and level priority list and schedule, and peer review for MFLs establishment.

Development of Minimum Lake Levels

Programmatic Description and Major Assumptions

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

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

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

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

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

Consideration of Changes and Structural Alterations and Environmental Values

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

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

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

- support development of lake guidance levels (described in the following paragraph).

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

Information regarding the development of adopted methods for establishing minimum and guidance lake levels is included in the SWFWMD (1999a, b) and Leeper *et al.* (2001). Additional information relevant to developing lake levels is presented by Schultz et al. (2005), Carr and Rochow (2004), Caffrey *et al.* (2006, 2007), Carr *et al.* (2006), Hancock (2006), Hoyer *et al*. (2006), Leeper (2006), Hancock (2006, 2007) and Emery *et al.* (2009). Independent scientific peer-review findings regarding lake level methods are summarized by Bedient *et al.* (1999), Dierberg and Wagner (2001) and Wagner and Dierberg (2006).

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

Categorical significant change standards and other available information are developed to identify criteria that are sensitive to long-term changes in hydrology and can be used for establishing minimum levels. For all lake categories, the most sensitive, appropriate criterion or criteria is/are used to develop recommend minimum levels. For Category 1 or 2 Lakes, a significant change standard, referred to as the Cypress Standard, is developed. For Category 3 Lakes, six significant change standards, including a Basin Connectivity Standard, a Recreation/Ski Standard, an Aesthetics Standard, a Species Richness Standard, a Lake Mixing Standard and a Dock-Use Standard are typically developed. Other available information, including potential changes in the coverage of herbaceous wetland and submersed aquatic plants is also considered when establishing minimum levels for Category 3 Lakes. The standards and other available information are associated with the environmental values identified for consideration in Rule 62-40.473, F.A.C., when establishing minimum flows or levels (Table 1). Descriptions of the specific standards and other information evaluated to support development of minimum levels for Lake Clinch and are provided in subsequent sections of this report.

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

Environmental Value	Associated Significant Change Standards and Other Information for Consideration
Recreation in and on the water	Basin Connectivity Standard Recreation/Ski Standard Aesthetics Standard Species Richness Standard Dock-Use Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Fish and wildlife habitats and the passage of fish	Cypress Standard Wetland Offset Standard Basin Connectivity Standard Species Richness Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Estuarine resources	NA - Not applicable for consideration for most priority lakes
Transfer of detrital material	Cypress Standard Wetland Offset Standard Basin Connectivity Standard Lake Mixing Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Maintenance of freshwater storage and supply	NA - Environmental value is addressed generally by development of minimum levels base on appropriate significant change standards and other information and use of minimum levels in District permitting programs
Aesthetic and scenic attributes	Cypress Standard Dock-Use Standard Wetland Offset Standard Aesthetics Standard Species Richness Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Filtration and absorption of nutrients and other pollutants	Cypress Standard Wetland Offset Standard Lake Mixing Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Sediment loads	Lake Mixing Standard Cypress Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Water quality	Cypress Standard Wetland Offset Standard Lake Mixing Standard Dock-Use Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Navigation	Basin Connectivity Standard Submersed Aquatic Macrophyte Information

Two Minimum Levels (high minimum lake and minimum lake levels) and two Guidance Levels (high and low guidance levels) are typically established for lakes. The levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD29), may include the following (refer to Rule 40D-8.624, F.A.C.).

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

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

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

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

The District is in the process of converting from use of the NGVD29 datum to use of the North American Vertical Datum of 1988 (NAVD 88). While the NGVD29 datum is used for most elevation values included within this report, in some circumstances notations are made for elevation data that was collected or reported relative to mean sea level or relative to NAVD88 and converted to elevations relative to NGVD29. The datum shift from NAVD88 to NGVD29 (see Table ES -1 and Table 7) was determined by actual surveys in the field at the location of the lake level gauge and was calculated based on third-order leveling ties from vertical survey control stations with known elevations above the North American Vertical Datum on 1988. The shift or conversion determined for Lake Clinch was 1.19 ft.

Data and Analyses Supporting Development of Minimum and Guidance Levels

Lake Setting and Description

Lake Clinch (Figure 1) is in the Peace River Basin in Polk County, Florida (Sections 29, 30, 31 and 32, Township 31S, Range 28E; Sections 5 and 6, Township 32 S, Range 28 E). The area surrounding the lake is categorized as the Iron Mountains subdivision of the Lake Wales Ridge in the Central Lake Physiographic District (Brooks 1981); a region of residual sandhills underlain by sand, gravel, and clayey sand. As part of the Florida Department of Environmental Protection's Lake

Bioassessment/Regionalization Initiative, the area has been identified as the Northern Lake Wales Ridge region and described as an area of numerous slightly alkaline, low to moderated nutrient (often with relatively high nitrogen concentration), clear-water lakes (Griffith *et al.* 1997).

The lake drains an area of 42.0 square miles (Florida Board of Conservation 1969). Surface inflows from two wetland areas occur periodically along the western shore, and from Crooked Lake along the northwest shore (Figure 2). Several stormwater systems also discharge into the lake. Surface outflow occurs along the eastern lakeshore through a control structure and a series of closed conduits and outfall ditch that drains to Reedy Lake. The capacity of the control structure and outfall conveyance was improved in 2007 as the result of the high lake level and associated flooding that occurred in 2005 in response to the high rainfall that occurred in both 2004 and 2005. The control structure is maintained by Polk County.

The "Gazetteer of Florida Lakes" (Florida Board of Conservation 1969, Shafer *et al.* 1986) lists the lake's area at 1207 acre. The United States Geological Survey 1953 (photorevised 1987) 1:24,000 Frostproof Quadrangle topographic map and the 1952 (photorevised 1988) 1:24,000 Babson Park Quadrangle map show the lake water level elevation at 103 ft, NGVD. This elevation corresponds to a lake surface area of 1,158 acres, based on a topographic map of the basin (Figure 3) generated in support of minimum levels development. Data used for production of the topographic map were obtained from field surveys of the lake basin elevation and LIDAR land surface elevation data collected in 2005.

Currently, there are no surface water withdrawal from the lake system permitted by the District; however, there are also numerous ground water withdrawals in the region (Figure 4). Monthly average water withdrawals from 2008 – 2012 within a two-mile radius of the lake centroid is 1.82 million gallons per day (mgd), and within a five-mile radius is approximately 13 million gallons per day (Figure 4) (Patterson 2015, Appendix A).

Although there are no cypress wetlands connected to the lake, the lake has significant stands of aquatic vegetation within the fringing littoral zone. Aquatic macrophytes observed include maidencane (*Panicum hemitomon*), torpedo grass (*Panicum repens*), cattail (*Typha* sp.), spatterdock (*Nuphar luteum*), water pennywort (*Hydrocotyle umbelatta*), primrose willow (*Ludwigia* sp.), spikerush (*Eleocharis* sp.), and pickerelweed (*Pontederia cordata*).

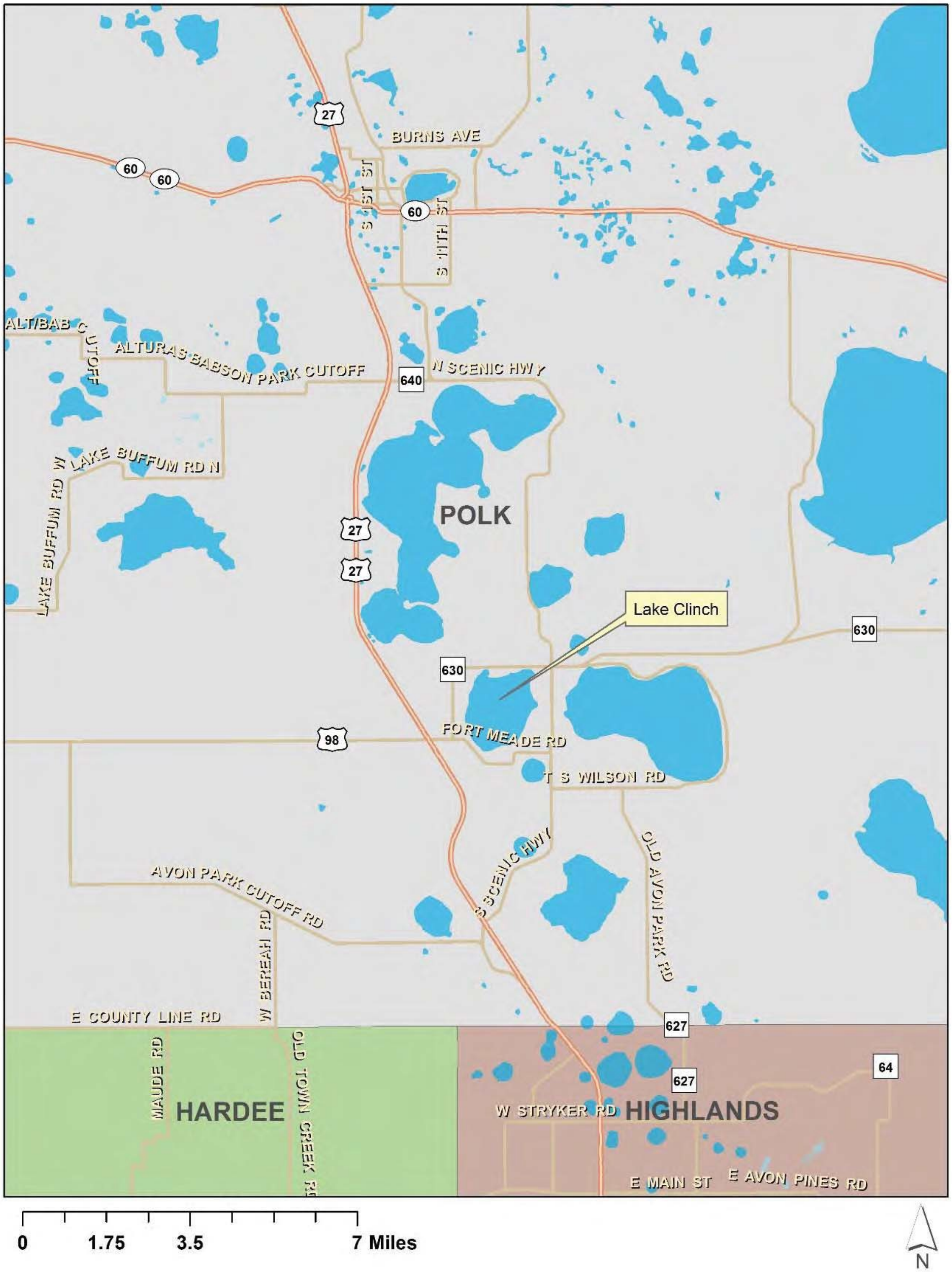


Figure 1. Location of Clinch Lake in Polk County, Florida

Figure 2. Location of water level gage, inlets and outlet, and sites where hydrologic indicators were measured during previous minimum level assessments.

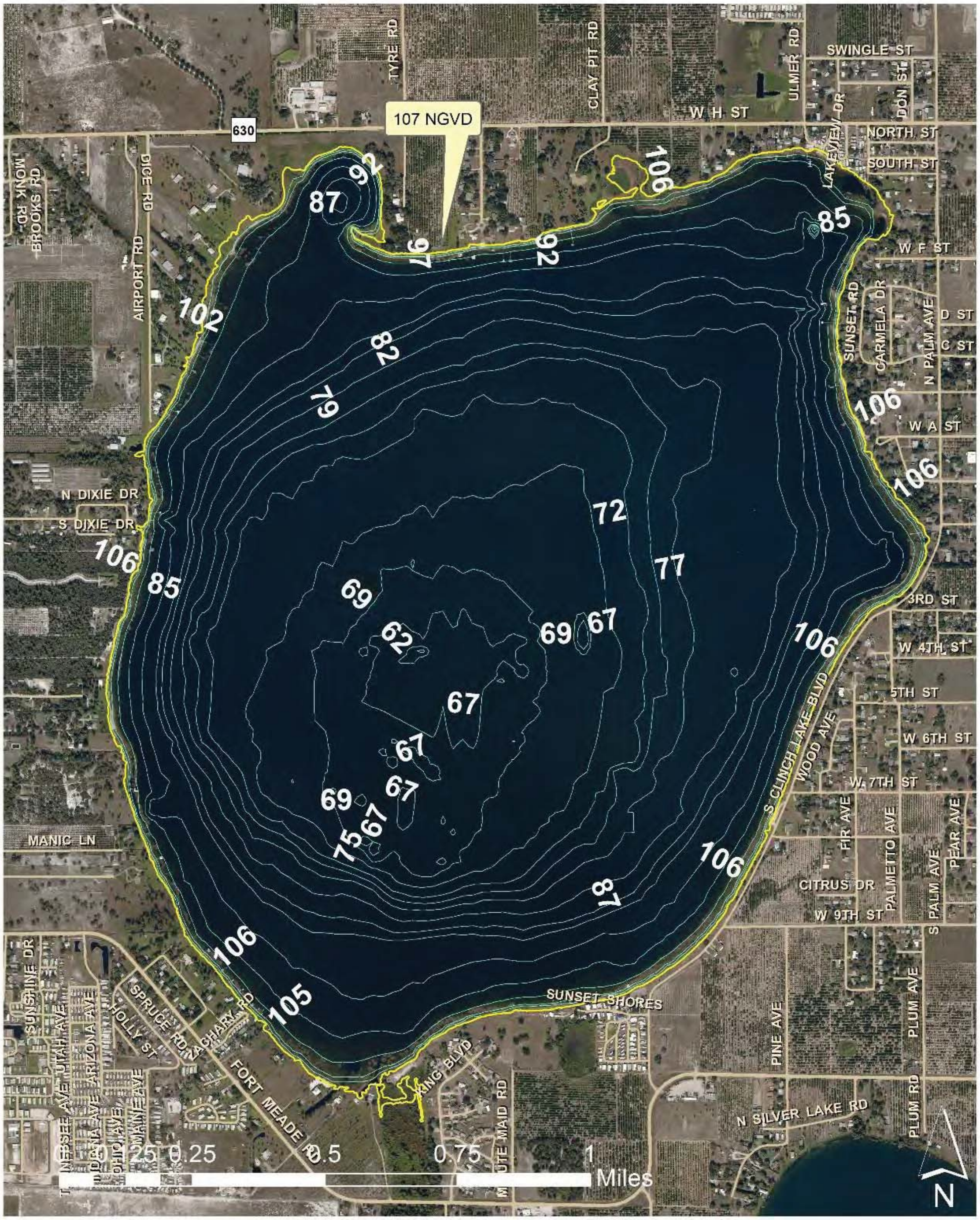


Figure 3. Bathymetric map of Lake Clinch in Polk County, with lake basin perimeter elevation of 107 (NGVD29) noted. All contour lines shown are NGVD 29 standard.

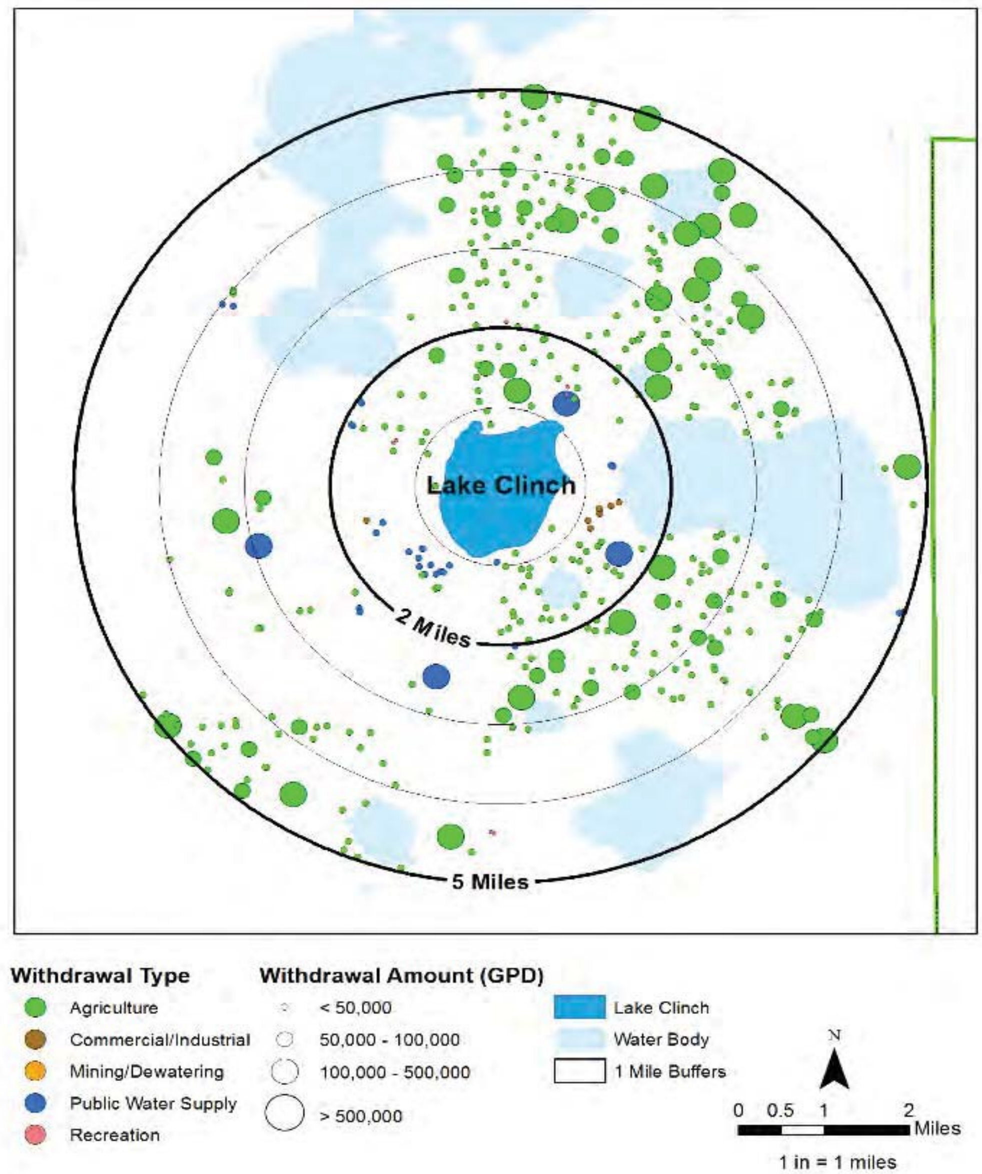


Figure 4. Permitted groundwater withdrawals within a one six-mile radius of Lake Clinch

Previously Adopted Minimum and Guidance 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, including Lake Clinch, had adopted into the District's Water Levels and Rates of Flow Rules (SWFWMD 1996).

Based on work conducted in the 1980s (see SWFWMD 1996), the District adopted management levels, including minimum and flood levels, for Lake Clinch in November 1984 (Table 2) and incorporated the levels into its Water Levels and Rates of Flow Rules (Chapter 40D-8, F.A.C.). As part of the work leading to the adoption of management levels, a Maximum Desirable Level of 106.00 feet above mean sea level was also developed for the lake, but was not adopted by rule.

Based on changes to sections of the Florida Statutes that address minimum flows and levels in 1996 and 1997, and the development of new approaches for establishing MFLs, District Water Levels and Rates of Flow rules were modified in 2000. The modifications included incorporation of rule language addressing MFLs development and the renaming of established levels as Guidance Levels, as indicated for Lake Clinch in Table 2. Subsequent revisions to District rules incorporated additional rule language associated with developing minimum lake levels.

Based on the approaches for establishing MFLs developed in the late 1990s and early 2000s, the District adopted recommended Guidance and Minimum Levels for Lake Clinch into its Water Levels and Rates of Flow rules in March 2006 (Table 3), and removed the previously adopted management levels for the lake from District rules. A Ten-Year Flood Guidance Level of 108.0 feet above NGVD that was adopted for the lake along with the other levels in March 2006 was subsequently removed from Chapter 40D-8, F.A.C., in 2007, when the Governing Board determined that flood-stage elevations should not be included in the District's Water Levels and Rates of Flow rules.

Ongoing development of methods for establishing MFLs has led the District to develop revised Minimum and Guidance Levels for the lake, as outlined in this report. Because the previously adopted Minimum and Guidance Levels were developed using methods that differ from those now in use, the levels do not necessarily correspond with the levels presented in this report. The Minimum and Guidance Levels presented in this report replaced all previously adopted levels.

Table 2. Previously adopted management and Guidance Levels for Lake Clinch.

Management Levels (as originally adopted)	Guidance Levels [a]	Elevation (feet above Mean Sea Level)
Ten (10) Year Flood Warning Level	Ten Year Flood Guidance Level	108.00
Minimum Flood Level	High Level	106.75
Minimum Low Management Level	Low Level	104.00
Minimum Extreme Low Management Level	Extreme Low Level	102.50

[a] Adopted management levels within District rules were renamed as Guidance Levels in 2000.

Table 3. Most Recent, Previously Adopted Minimum and Guidance Levels for Lake Clinch and as listed in Table 8-2 of subsection 40D-8.624, F.A.C.

Previous Minimum and Guidance Levels	Elevation in Feet NGVD 29
High Guidance Level	105.5
High Minimum Level	105.5
Minimum Level	104.4
Low Guidance Level	103.1

Methods, Results, and Discussion

Summary Data Used for Current Minimum and Guidance Levels Development

Minimum and Guidance Levels for Lake Clinch were developed using the methodology for Category 3 Lakes described in Rule 40D-8.624, F.A.C. The levels and additional information are listed in Table 4, 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 4. Minimum and Guidance Levels, lake stage exceedance percentiles, normal pool, control point, significant change standards and associated surface areas for Lake Clinch.

Levels	**Elevation in Feet NGVD 29**	**Lake Area (acres)**
Lake Stage Percentiles		
Current P10 (1984 to 2015)	106.3	1224
Current P50 (1984 to 2015)	104.3	1181
Current P90 (1984 to 2015)	101.6	1131
Historic P10 (1946 to 2015)	106.5	1235
Historic P50 (1946 to 2015)	104.0	1177
Historic P90 (1946 to 2015)	102.3	1144
Normal Pool and Control Point		
Low Floor Slab	108.6	1312
Normal Pool	107.7	1281
Control Point	105.3	1201
Significant Change Standards		
Dock-Use Standard	105.1	1197
Wetland Offset Elevation	103.2	1160
Aesthetics Standard	102.3	1144
Basin Connectivity Standard	97.7	1060
Species Richness Standard	95.1	1001
Lake Mixing Standard	77.0	445
Recreation/Ski Standard	74.7	363
Minimum and Guidance Levels		
High Guidance Level	106.5	1235
High Minimum Lake Level	105.7	1209
Minimum Lake Level	103.2	1164
Low Guidance Level	102.3	1144

Bathymetry

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

Stage-area-volume relationships were determined for the combined lake basins by building and processing a digital elevation model (DEM) of the lake basin and surrounding watershed. Lake bottom elevations and land surface elevations were used to build the model through a series of analyses using LP360 (by QCoherent) for ArcGIS, ESRI® ArcMap 10.2.2 software, the 3D Analyst ArcMap Extension, Python, and XTools Pro . The overall process involves merging the terrain morphology of the lake drainage basin with the lake basin morphology to develop one continuous 3D digital elevation model. The 3D digital elevation model is then used to calculate area of the lake and the associated volume of the lake at different elevations, starting at the largest size of the lake at its peak or flood stage, and working downward to the base elevation (deepest pools in the lake).

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

The DEM created from the combined elevation data sets was used to develop topographic contours of the lake basin (Figure 3) and to create a triangulated irregular network (TIN). The TIN was used to calculate the stage areas and volumes using a Python script file to iteratively run the Surface Volume tool in the Functional Surface toolset of the ESRI® 3D Analyst toolbox at one-tenth of a foot elevation change increments (selected stage-area-volume results are presented in Figure 10).

Lake Stage Data and Development of Exceedance Percentiles

Period of record (POR) lake stage data, *i.e.,* surface water elevations for Lake Clinch relative to NGVD 29 standard were obtained from the District's Water Management Information System (WMIS) data base, Site Identification (SID) number 23836 (Figure 2). Surface water level data have been recorded since January 1947 (Figure 5).

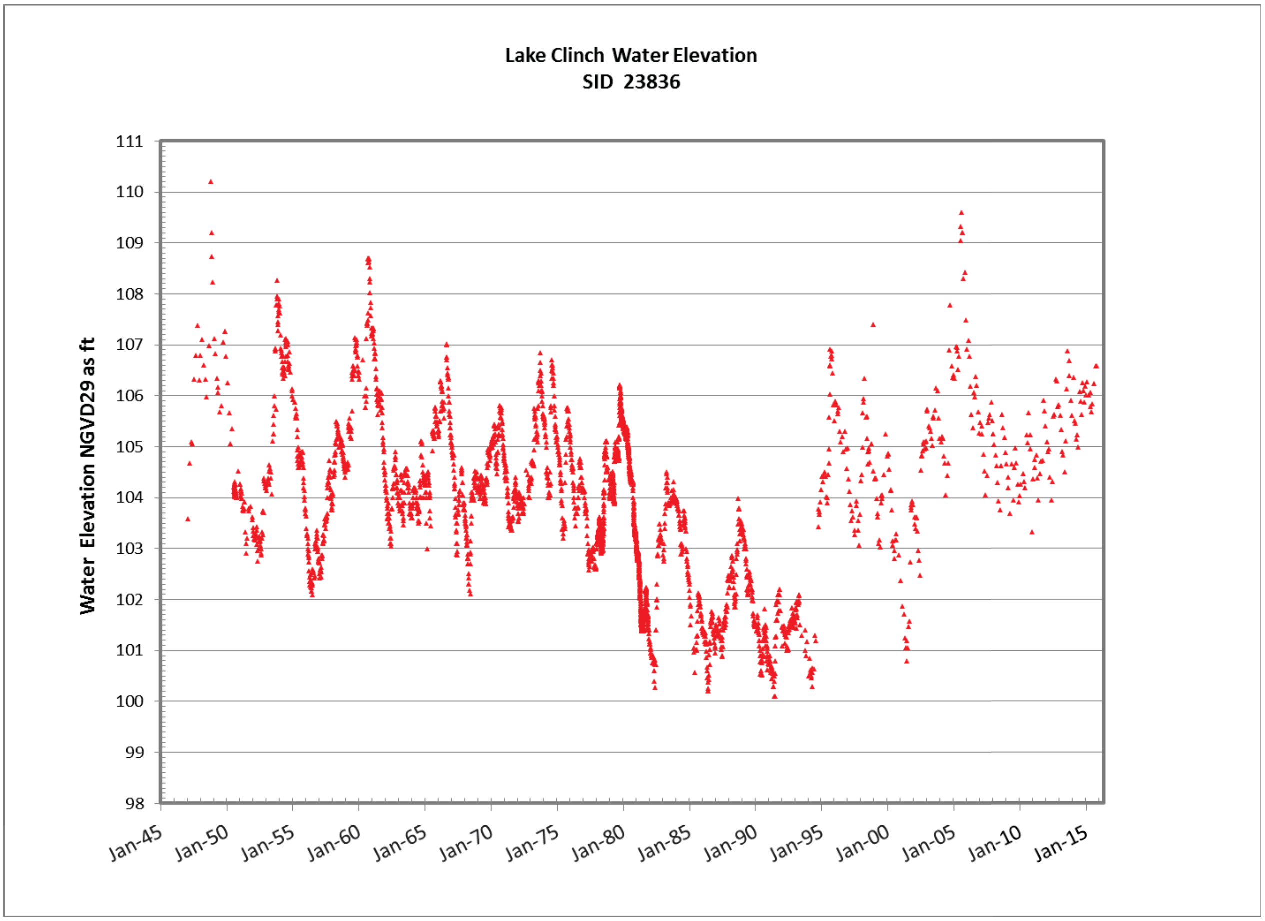


Figure 5. Water level data for Lake Clinch – 1947 through 2015.

The period of record (POR) high water level was 110.21 ft. (NGVD 29) as observed in October 1948. Similarly, the lake level reached 109.33 ft. in July 2005. The POR low water level was 100.1 ft. NGVD 29, as observed in June 1991. The approximate contour lines of the POR high (110.2 ft. NGVD) that occurred in 1948 is shown in Figure 6.

For the Minimum Levels determination, lake stage data are classified as "Historic" for long-term periods when there are no measurable impacts due to water withdrawals, and impacts due to structural alterations are 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" when hydrologic stresses due to water withdrawals and structural alterations are stable, and are representative of the current situation.

A Long-term Historic lake stage record is critical for establishing Minimum and Guidance Levels. Although the original MFL was developed for Lake Clinch (SWFWMD 2008) by applying the Highlands Ridge Reference Lake Water Regime (RLWR) statistics (Ellison 2002) to the observed lake stage record, specific information was not available at that time regarding the estimated drawdown in the surficial and Upper Floridan aquifer in response to groundwater withdrawals in the vicinity of Lake Clinch. This information was included in the reevaluation of the minimum levels (Patterson 2015).

Although the period of record of lake stage data (1947 to 1965) for Lake Clinch 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 (1947-2015) by using a predictive lake stage model in this case the Rainfall Line of Organic Correlation (LOC)(Ellison 2012). 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 used to produce a 60-year non-impacted lake stage record that serves as the basis for establishing historic lake-stage exceedance percentiles. A 60-year period is 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).

The development of the rainfall correlation model involved an inventory of rainfall stations sorted by distance to Lake Clinch and by period of record. A description of model methods including the specific rainfall gauges selected is provided in Appendix A. The resulting lake level rainfall model had a correlation coefficient of determination (r^2) equal to 0.92 based on use of a four-year linear decay series of daily rainfall values. A comparison of the modeled lake stage (1947 to 2015) to the observed lake stage (1947 to 2015) is shown in Figure 7.

The modeled Historic lake stage record was used to calculate Historic P10, P50, and P90 lake stage exceedance percentile elevations (Figure 8, Table 4). The Historic P10 elevation, the elevation the lake water surface equaled or exceeded ten percent of the time during the Historic period was 106.5 ft. The Historic P50 elevation, the elevation the lake water surface equaled or exceeded fifty percent of the time during the Historic period, was 104.0 ft. The Historic P90 elevation, the elevation the lake water surface equaled or exceeded 90 percent of the time during the Historic period was 102.3 ft.

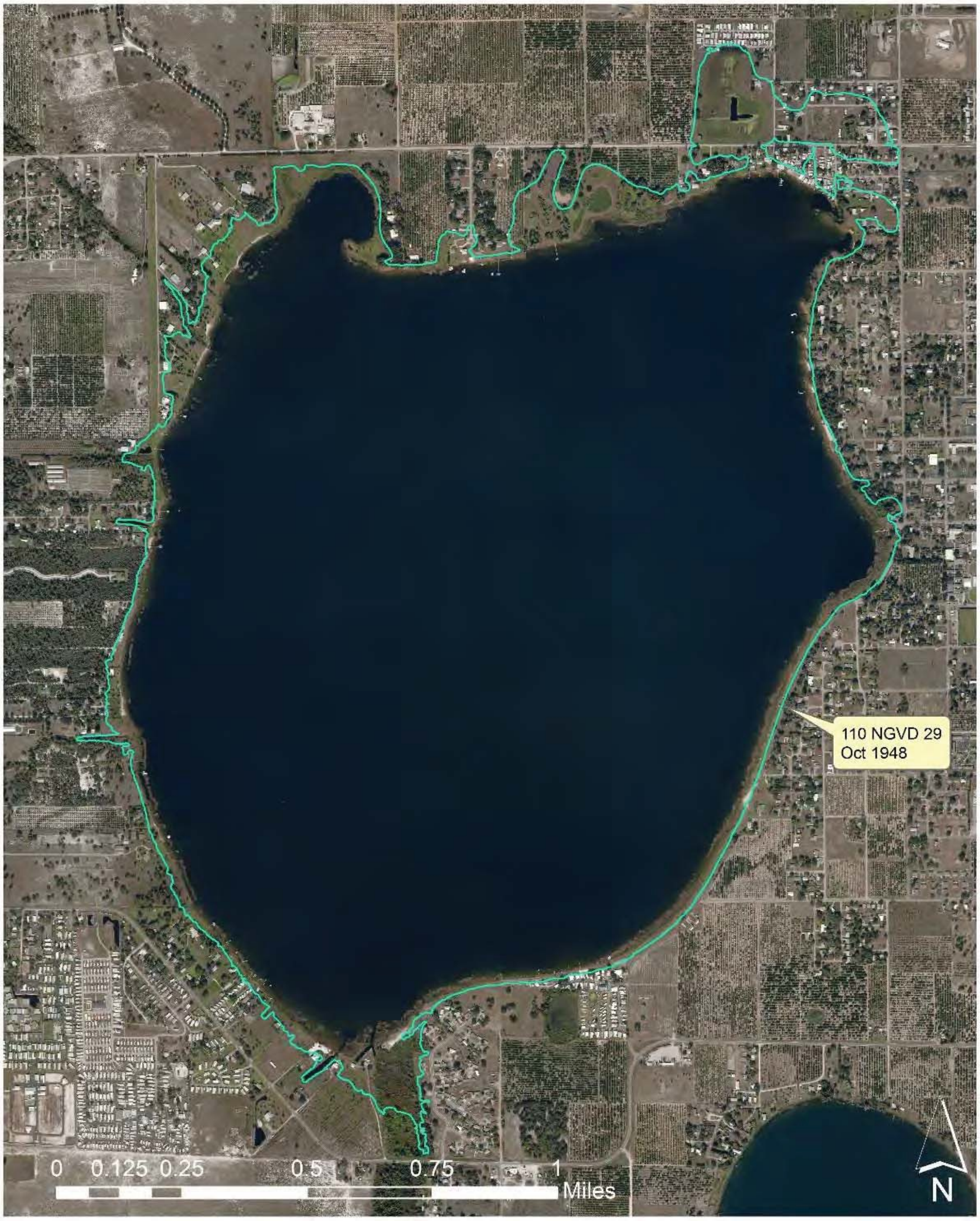


Figure 6. Approximate contour of the POR high level recorded for Lake Clinch shown on 2014 aerial imagery. This high level of 110 ft. NGVD 29 was recorded in October 1948.

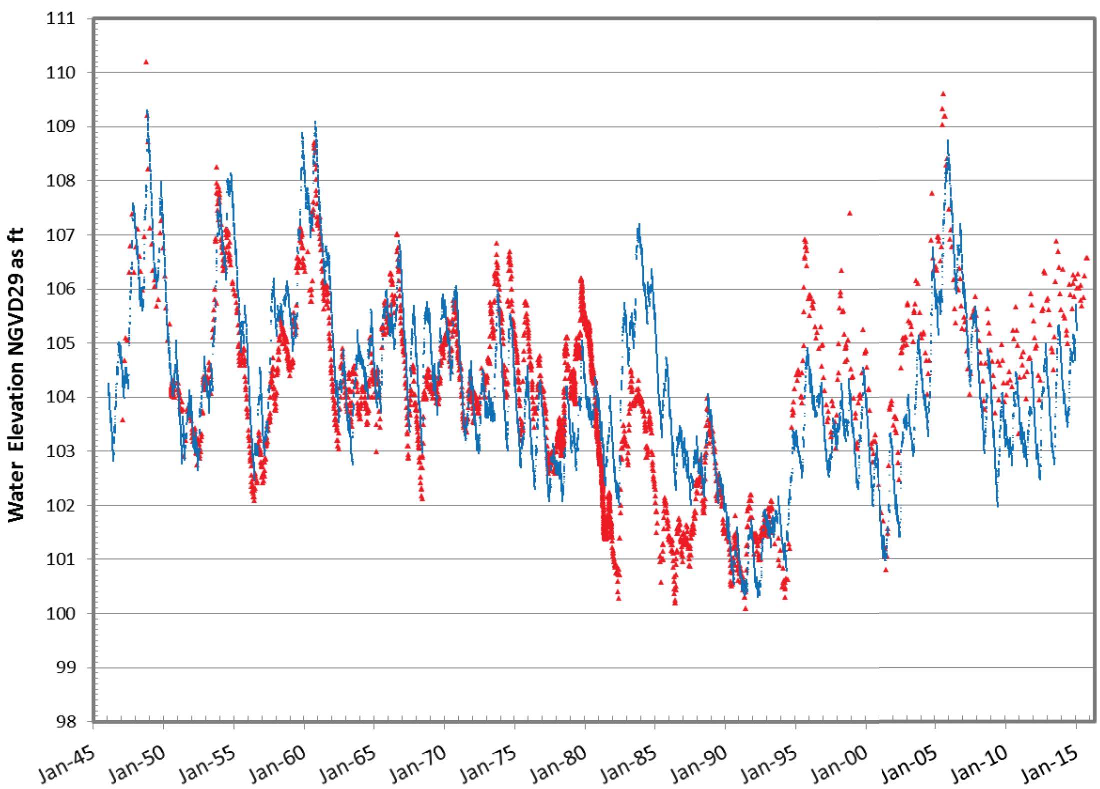


Figure 7. Observed and predicted long-term Historic water levels at Lake Clinch and for a calibration period from November 1988-December 2013 (water budget model period).

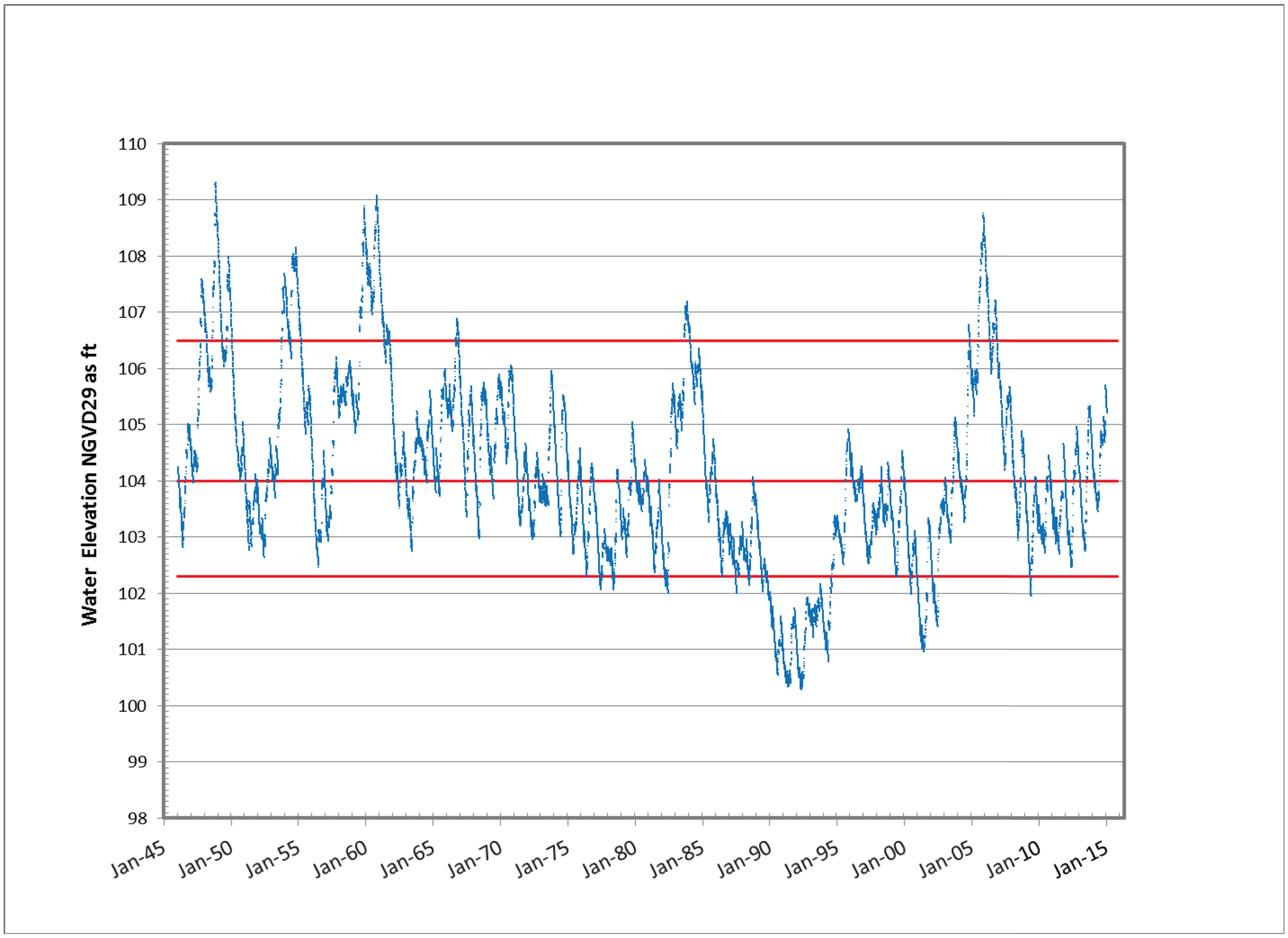


Figure 8. Historic water levels (hybrid results) used to calculate percentile elevations for Lake Clinch. Historic P10, P50, and P90 are depicted as horizontal lines.

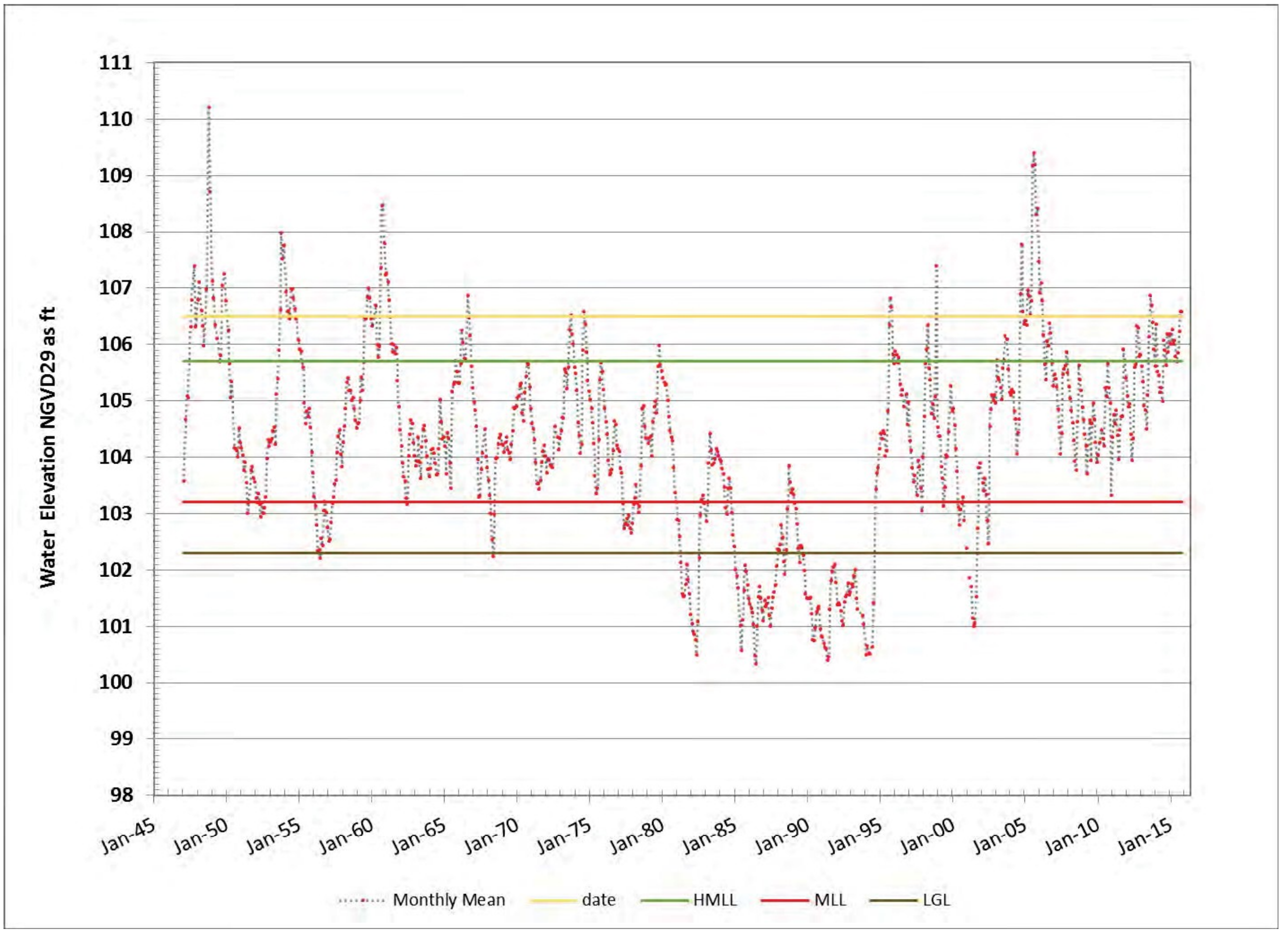


Figure 9. Observed monthly water levels and Minimum and Guidance Levels for Lake Clinch. Levels include the High Guidance Level (HGL), High Minimum Lake Level (HMLL), Minimum Lake Level (MLL), and the Low Guidance Level (LGL).

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. A Normal Pool elevation (Tables 4 and 5) was established for Lake Clinch at an elevation of 107.7 ft. NGVD 29. Although there are no cypress trees (*Taxodium sp.)* found on the lake, other biological indicators more common to sandhill lake systems were used to establish the Normal Pool. The Normal Pool elevation was established based on the median elevation of the waterward extent of pine (*Pinus* sp.), live oak (*Quercus virginiana*), cordgrass *(Spartina bakeri),* and saw palmetto (*Serenoa repens*) (Table 5).

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, conservation structure, ditch, culvert, or pipe) that is the principal control of water level fluctuations in the lake. A water conservation structure is located along the east shoreline of Lake Clinch adjacent to the Lake Clinch Park and public pier. The outfall structure consists of a 13' wide overflow weir conveyed into Lake Reedy by a 72" concrete pipe. The invert elevation of the structure is 105.34 ft. NGVD29 (Polk County 2015). The structure is fitted with one five foot slide gate that can be opened to increase the discharge capacity during potential flood events. Since the invert of the structure is below the Normal Pool elevation (107.7 ft. NGVD), the lake is considered Structurally Altered.

Table 5. Elevation data used for establishing the Category 3 Lake Normal Pool Elevation for Lake Clinch, Polk County, Florida. Data were collected in July 2001 by District staff.

Hydrologic Indicator	Elevation (ft., NGVD)
Base of cordgrass (*Spartina bakeri*)	106.96
Base of cordgrass (*Spartina bakeri*)	106.26
Base of cordgrass (*Spartina bakeri*)	107.79
Base of cordgrass (*Spartina bakeri*)	107.55
Base of cordgrass (*Spartina bakeri*)	107.60
Base of cordgrass (*Spartina bakeri*)	107.18
Base of cordgrass (*Spartina bakeri*)	103.90
Base of cordgrass (*Spartina bakeri*)	104.83
Base of cordgrass (*Spartina bakeri*)	104.68
Base of cordgrass (*Spartina bakeri*)	104.77
Base of cordgrass (*Spartina bakeri*)	104.72
Base of saw palmetto (*Serenoa repens*)	106.36
Base of saw palmetto (*Serenoa repens*)	108.89
Base of saw palmetto (*Serenoa repens*)	109.28
Base of saw palmetto (*Serenoa repens*)	109.57
Base of saw palmetto (*Serenoa repens*)	109.14
Base of saw palmetto (*Serenoa repens*)	108.64
Base of saw palmetto (*Serenoa repens*)	107.08
Base of pine *(Pinus sp.)*	107.02
Base of pine *(Pinus sp.)*	106.19
Base of pine *(Pinus sp.)*	106.51
Base of pine *(Pinus sp.)*	108.21
Base of pine *(Pinus sp.)*	108.29
Base of pine *(Pinus sp.)*	108.25
Base of pine *(Pinus sp.)*	107.26
Base of pine *(Pinus sp.)*	108.41
Base of pine *(Pinus sp.)*	109.57
Base of pine *(Pinus sp.)*	109.07
Base of pine *(Pinus sp.)*	108.91
Base of pine *(Pinus sp.)*	108.91
Base of live Oak (*Quercus virginiana)*	110.89
Base of live Oak (*Quercus virginiana)*	110.43
Mean	107.60
Median	107.70

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 long-term Historic model results, the High Guidance Level for Lake Clinch was established at **106.5 ft.** (Figure 9 and 12, Table 4). The lowest residential floor slab within the immediate lake basin (108.6 ft.) is 2.1 ft. higher than the High Guidance Level.

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, reference lake water regime statistics, which are differences between selected lake stage percentiles for a set of reference lakes. Based on long-term Historic model results, the Low Guidance Level was established at **102.3 ft**. (Figure 9 and 12, Table 4).

Lake Classification

Lakes are classified as Category 1, 2, or 3 for the purpose of Minimum Levels development. Systems with fringing cypress wetlands greater than 0.5 acres in size are classified as either as Category 1 or 2 lakes as described in Rule 40D-8.624, F.A.C. . Lakes without fringing cypress wetlands or with less than 0.5 acres of fringing cypress wetlands are classified as Category 3 Lakes. Based on the absence of lake-fringing cypress wetlands of 0.5 acre or more in size within the lake basin, Lake Clinch was classified as a Category 3 lake.

Significant Change Standards and Other Information for Consideration

Lake-specific significant change standards and other available information are considered for establishing minimum levels for Category 3 Lakes. The standards are used to identify thresholds for preventing significant harm to environmental values associated with lakes (refer to Table 1) in accordance with guidance provided in the Florida Water Resources Implementation Rule (Chapter 62-40.473, F.A.C.). Other information taken into consideration includes potential changes in the coverage of herbaceous wetland vegetation and aquatic plants.

Seven significant change standards for Category 3 lakes, including a Dock-Use Standard, a Basin Connectivity Standard, an Aesthetics Standard, a Recreation/Ski Standard, a Species Richness Standard, a Lake Mixing Standard, and a Wetland Offset

Standard are developed. These standards identify desired median lake stages that if achieved, are intended to preserve various environmental values (see Table 1).

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 water depth value for boat mooring, and use of historic lake stage data. The Dock-Use Standard was established at 105.1 ft. above NGVD, based on the elevation of sediments at the end of 90% of the 10 docks within the basin (101.4 ft. above NGVD, Table 6), a clearance value of two feet based on use of powerboats in the lake, and the difference between the Historic P50 and Historic P90 elevations (1.7 ft.). Based on the Historic water level record for the lake, the standard was equaled or exceeded 27 percent of the time, *i.e.*, the standard elevation corresponds to the Historic P27. This standard is not appropriate for the establishment of the minimum level since it is well above the elevation of both the Historic P50 and Current P50.

Table 6. Summary statistics and elevations associated with docks (n=45) in Lake Clinch based on measurements made by District staff in July 2001. Exceedance percentiles (P10, P50, P90) represent elevations exceeded by 10, 50 and 90 percent of the docks.

Summery Statistics	Elevation of Sediments at Waterward End of Docks (feet as NGVD 29)	Elevation of Dock Platforms (feet as NGVD 29)
90th Percentile (P10)	101.4	107.8
Median or 50th Percentile	99.7	105.9
10th Percentile (P90)	97.9	103.8
Maximum	102.0	110.4
Minimum	92.2	103.1

Because herbaceous wetlands are common within Lake Clinch basin, the **Wetland Offset Standard** was applied. 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 103.2 ft. NGVD was therefore established by subtracting 0.8 feet from the Historic P50 elevation (104.0 ft. NGVD). The wetland offset elevation was equaled or exceeded 72.7 percent of the time during the Historic period and therefore corresponds to the Historic P72.7.

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 is established at the Low Guidance Level, which is **102.3 ft.** for Lake Clinch. Because the Low Guidance Level was established at the Historic P90 elevation, water levels equaled or exceeded the Aesthetics Standard 90 percent of the time during the Historic period.

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 sub-basins, clearance water depths 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. The Basin Connectivity Standard was established at 97.7 ft., based on a critical high-spot elevation of 94.0 ft., a two-foot clearance value for use of powerboats on the lake, and the difference between the Historic P50 and Historic P90 elevations (1.7 ft.). Based on the modeled Historic water level record for the lake, the standard was equaled or exceeded 100 percent of the time.

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. The Species Richness Standard for Lake Clinch is established at **95.1 ft.** (see Figure 10 for a plot of lake stage versus lake surface area). Based on the Historic water level record for the lake, the standard was equaled or exceeded 100 percent of the time.

The **Lake Mixing Standard** is developed to prevent significant changes in patterns of wind-driven mixing of the lake water column and sediment re-suspension. The standard is established at the highest elevation at or below the Historic P50 elevation where the dynamic ratio (see Bachmann *et al.* 2000) shifts from a value of <0.8 to a value >0.8, or from a value >0.8 to a value of <0.8. The Lake Mixing Standard was established at 77.0 (see Figure 10). Based on the Historic water level record for the lake, the standard was equaled or exceeded 100 percent of the time.

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 as used in this case, a rectangular ski area 200 ft. in width and 2,000 ft. in length, and use of historic lake stage data. The Recreation/Ski Standard was established at 74.7 ft., based on a critical ski elevation of 73.0 ft. and the difference between Historic P50 and Historic P90 (1.7 ft.). Based on the modeled Historic water level record for the lake, the standard was equaled or exceeded 100 percent of the time.

Because the elevations of the Basin Connectivity Standard, Species Richness Standard, Lake Mixing Standard, and Recreation/Ski Standard are all well below the POR low level of 100.1 ft. NGVD, these standards are not considered appropriate for Lake Clinch.

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 11.5 or less feet).

Review of changes in potential herbaceous wetland area in relation to change in lake stage relative to the wetland area of the Historic P50 did not indicate that there would be a significant increase or decrease in the area of herbaceous wetland vegetation associated with use of the applicable significant change standards below the Historic P50 which includes the Wetland Offset Standard (103.2 ft. NGVD) and the Aesthetics Standard (102.3 ft. NGVD) (Figure 11). Review of changes in area available for submersed aquatic plant colonization relative to the area available at the Historic P50 change in lake stage also did not indicate that there would be a significant increase or decrease in the area of submersed aquatic plant vegetation at the elevation of the Wetland Offset Standard (103.2 ft. NGVD) and the Aesthetics Standard (102.3 ft. NGVD) (Figure 11).

It's noteworthy that a significant increase would occur in the area of potential herbaceous wetland vegetation at the elevation of standards that aren't considered appropriate for the lake system, including the Species Richness Standard (95.1 ft. NGVD), the Mixing Standard (77.0 ft. NGVD 29), and the Recreation/Ski Standard (74.7 ft. NGVD 29) (Figure 11). Similarly, a significant increase in the area of submersed aquatic plant vegetation would potentially occur at the elevation of the Basin Connectivity Standard (97.7 ft. NGVD), Species Richness Standard (95.1 ft. NGVD 29), the Mixing Standard (77.0 ft. NGVD), and the Recreation/Ski Standard (74.7 ft. NGVD 29). These projected changes further support that these standards are not appropriate for use of a minimum level due to reduction in open water habitat.

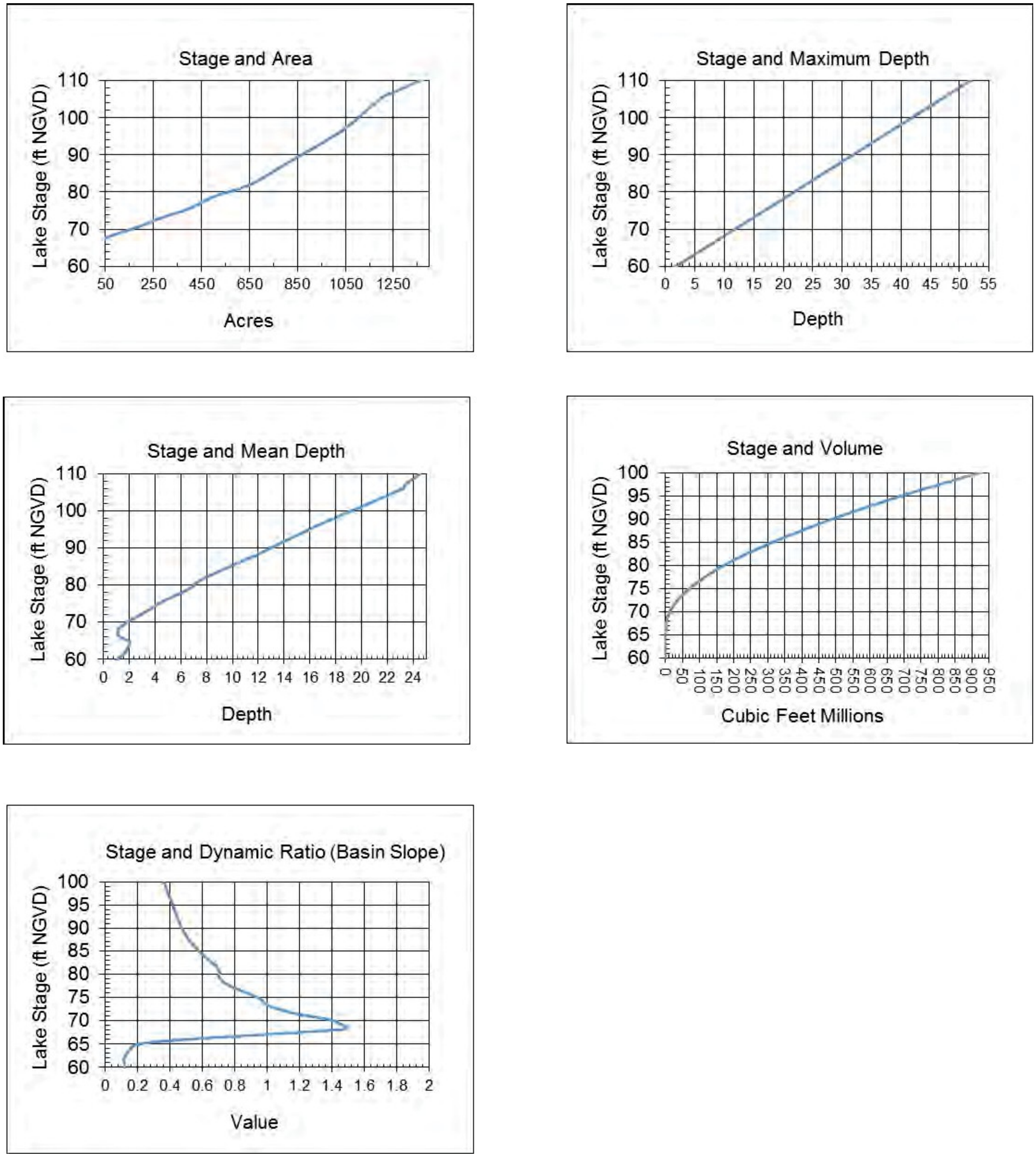
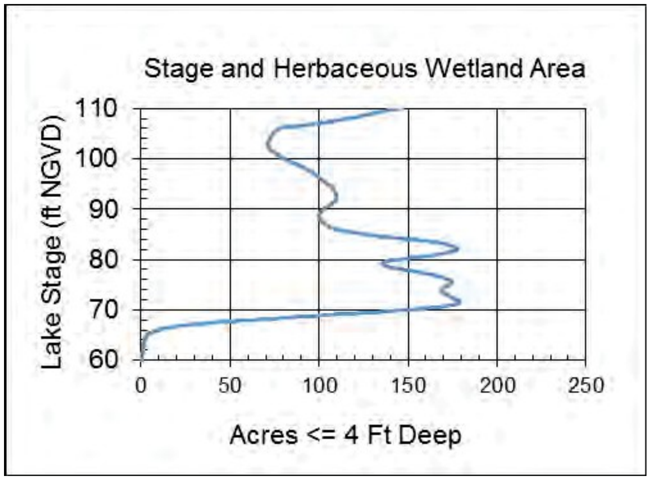


Figure 10. Mean depth, maximum depth, surface area volume, stage volume, and dynamic ratio (basin slope) in feet for Lake Clinch.



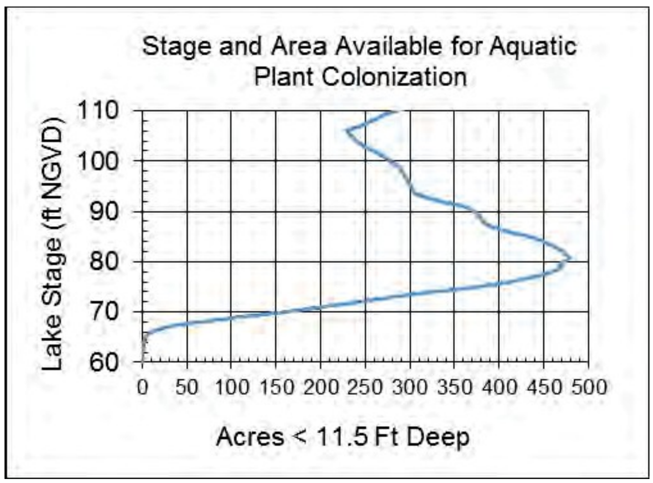


Figure 11. Area available for submersed macrophyte colonization and potential herbaceous wetland area of Lake Clinch and as a function of lake stage (water surface elevation).

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 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 Lake Clinch was established at 103.2 ft. NGVD 29, the elevation corresponding to the Wetland Offset Standard (Figures 9 and 13). The Minimum Lake Level was equaled or exceeded 72.7 percent of the time, based on the modeled Historic water level record and corresponds to the Historic P72.7. This level is expected to afford protection to the natural system and human-use values associated with the identified significant change standards and provide protection for wetlands occurring within the basin. The Minimum Lake Level for Lake Clinch is **103.2 ft**.

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 Lake Clinch, the High Minimum Lake Level was established at 105.7 ft. NGVD 29 (Figures 9 and 13), by adding the difference between the Historic P50 and Historic P10 (2.5 ft.) to the Minimum Lake Level (103.2 ft. NGVD 29). The High Minimum Lake Level at 105.7 ft. NGVD 29 was equaled or exceeded 17.2 percent of the time, based on the term modeled Historic water level record, and corresponds to the Historic P17.2. The High Minimum Lake Level for Lake Clinch is 105.7 ft.

The Minimum and Guidance levels for Lake Clinch are shown in Figure 9 along with lake stage elevation. The levels are also shown plotted as approximate contour lines on the 2014 aerial imagery with the Guidance levels shown in Figure 12 and the Minimum Level and High Minimum Level shown in Figure 13.

Many federal, state, and local agencies, such as the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, United States Geological Survey, and Florida's water management districts are in the process of upgrading from the National Geodetic Vertical Datum (NGVD29) standard to the North American Vertical Datum (NAVD88) standard. For comparison purposes, the MFLs for Lake Clinch and are presented in both datum standards (Table 7). The datum shift from NAVD88 to NGVD29 was determined by actual surveys in the field at the location of the lake level gauge and was calculated based on third-order leveling ties from vertical survey control stations with known elevations above the North American Vertical Datum on 1988. The shift or conversion determined for Lake Clinch and was 0.994 ft.

Table 7. Minimum and Guidance Levels for Lake Clinch relative to both NGVD29 and NAVD88.

Minimum and Guidance Levels	Feet NGVD29	Feet NAVD88
High Guidance Level	106.5	105.3
High Minimum Lake Level	105.7	104.5
Minimum Lake Level	103.2	102.0
Low Guidance Level	102.3	101.1

Consideration of Environmental Values

The minimum levels for Lake Clinch are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing MFLs (see Rule 62-40.473, F.A.C.). When developing MFLs, the District evaluates the categorical significant change standards and other available information as presented above. The purpose is to identify criteria that are sensitive to long-term changes in hydrology and represent significant harm thresholds. The Wetland Offset Standard was used for developing Minimum Levels for Lake Clinch based on its classification as a Category 3 Lake.

The Wetland Offset Standard is associated with protection of several environmental values identified in Rule 62-40.473, F.A.C., including: fish and wildlife habitats and the passage of fish, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, sediment loads and water quality (refer to Table 1).

Two additional environmental values identified in Rule 62-40.473, F.A.C., are also protected by the minimum levels for Lake Clinch. The environmental value, recreation in and on the water, is associated with the Aesthetic Standard developed for the lake. This standard is associated with an elevation lower than the Wetland Offset Standard elevation (102.3 ft. NGVD vs 103.2 ft. NGVD) indicating that it will be achieved at a higher frequency than the Wetland Offset Standard. The environmental value, maintenance of freshwater storage and supply is protected by the minimum levels based on the relatively modest potential changes in storage associated with the minimum flows hydrologic regime as compared to the non-withdrawal impacted historic condition. Maintenance of freshwater supply is also expected to be protected by the minimum levels based on inclusion of conditions in water use permits that stipulate that permitted withdrawals will not lead to violation of adopted minimum flows and levels.

Two environmental values identified in Rule 62-40.473, F.A.C., were not considered relevant to development of minimum levels for Lake Clinch. Estuarine resources were not considered relevant because the lake is not directly connected to any estuarine resources. Sediment loads were similarly not considered relevant for minimum levels development for the lake, because the transport of sediments as bedload or suspended load is a phenomenon typically associated with flowing water systems.

Assessment of the Minimum Level Status

The Minimum Lake Level and High Minimum Lake Level for Lake Clinch was assessed to determine if lake levels are fluctuating relative to both these levels in an appropriate manner (Appendix B). The methods used included using the prediction interval of the rainfall regression model developed to model the Historic data; and evaluating the cumulative median relative to the minimum level (Appendix B). Both methods indicated that the lake is at or above the Minimum Level of 103.2 ft. NGVD 29 and High Minimum Level of 105.7 ft. NGVD 29

Figure 12. Approximate location of water level (i.e., shoreline) associated with the Low Guidance Level (LGL) and High Guidance Level (HGL) for Lake Clinch relative to conditions during 2014.

Figure 13. Approximate location of water level (i.e., shoreline) associated with the Minimum Lake Level (MLL) and High Minimum Lake Level (HMLL) for Lake Clinch relative to conditions in February 2014.

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APPENDIX A

Technical Memorandum

December 12, 2015

TO: Keith Kolasa, Senior Environmental Scientist, Water Resources Bureau THROUGH: Jerry L. Mallams, P.G., Manager, Water Resources Bureau
FROM: Jason Patterson, Hydrogeologist, Water Resources Bureau
Mark D. Barcelo, P.E. Chief Professional Engineer, Water Resources Bureau
Subject: Lake Clinch Rainfall Regression Model and Historic Percentile Estimations

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Introduction

A rainfall regression model was developed to assist the Southwest Florida Water Management District (District or SWFWMD) in the establishment of minimum and guidance levels for Lake Clinch, located in southern Polk County, just east of the US Highway 27/US Highway 98 intersection in the City of Frostproof (Figure 1). This document discusses development of the model, hydrogeologic evaluations used to support model development, and derivation of lake stage percentiles used to help develop levels for the lake.

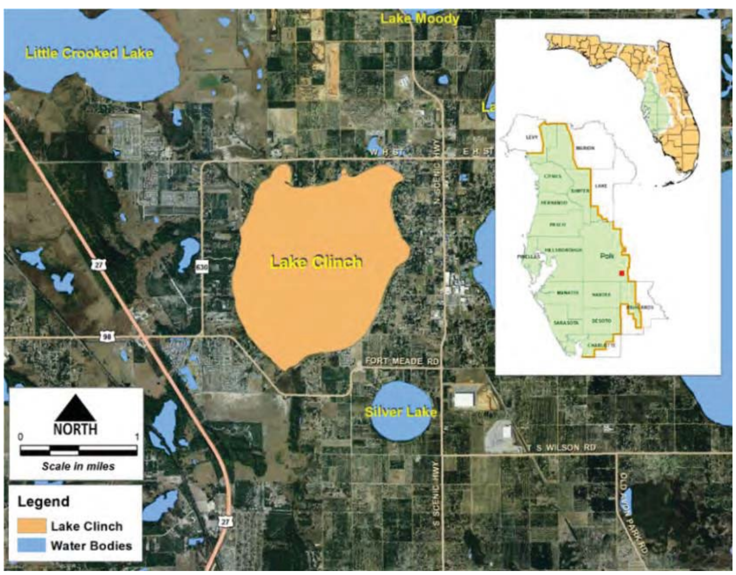

Figure 1. Location of Lake Clinch in southeastern Polk County, Florida

Background and Setting

Lake and Watershed Characteristics

Lake Clinch is located in southern Polk County, Florida. The lake is located approximately 5.7 miles north of the Polk-Highlands county line. The lake is roughly 1,240 acres with a local drainage basin of approximately 3,745 acres. (Civilsurv Design Group, Inc., 2015). The local drainage basin is within the greater Kissimmee River watershed according to the USGS National Hydrography Dataset (Figures 2 and 3). Surface inflows occur from the Crooked-Clinch Canal located at the northwest shore of Lake Clinch (Southwest Florida Water Management District, 2008). The canal is approximately 1.2 miles long and was observed flowing as recently as January of 2015 (Civilsurv Design Group, Inc., 2015). Additional surface inflows occur periodically from two wetland areas occur periodically along the western shore of the lake. Surface outflow occurs along the eastern lakeshore through a control structure and a 72-inch concrete pipe, to Reedy Lake (Civilsurv Design Group, Inc., 2015). Flows into and from the lake are shown in figure 4. There are no permitted surface water withdrawals from the lake.

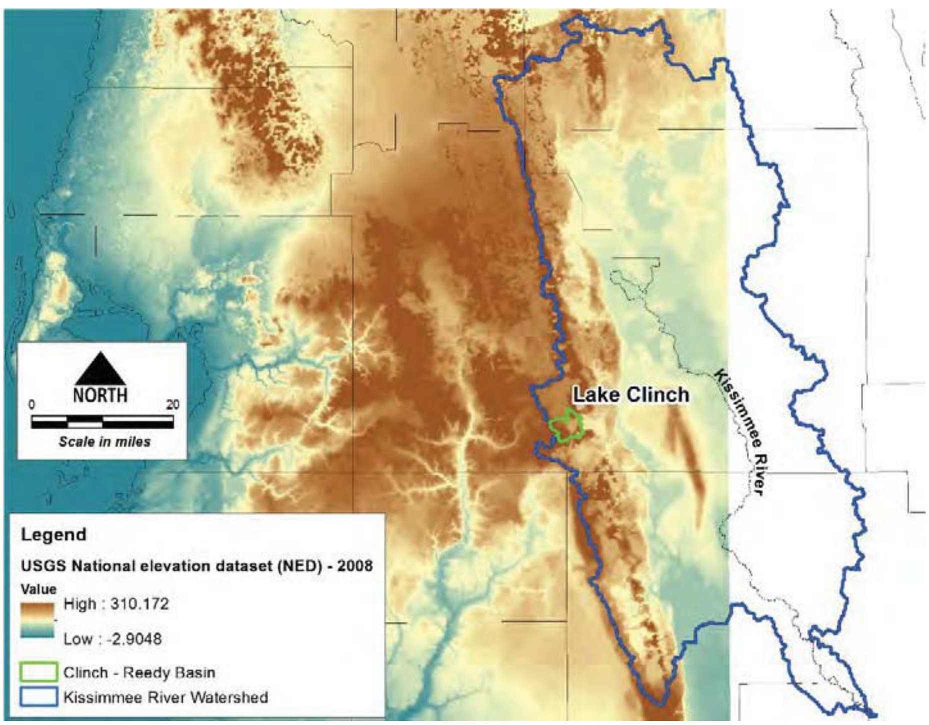

Figure 2. Watershed delineation and topography

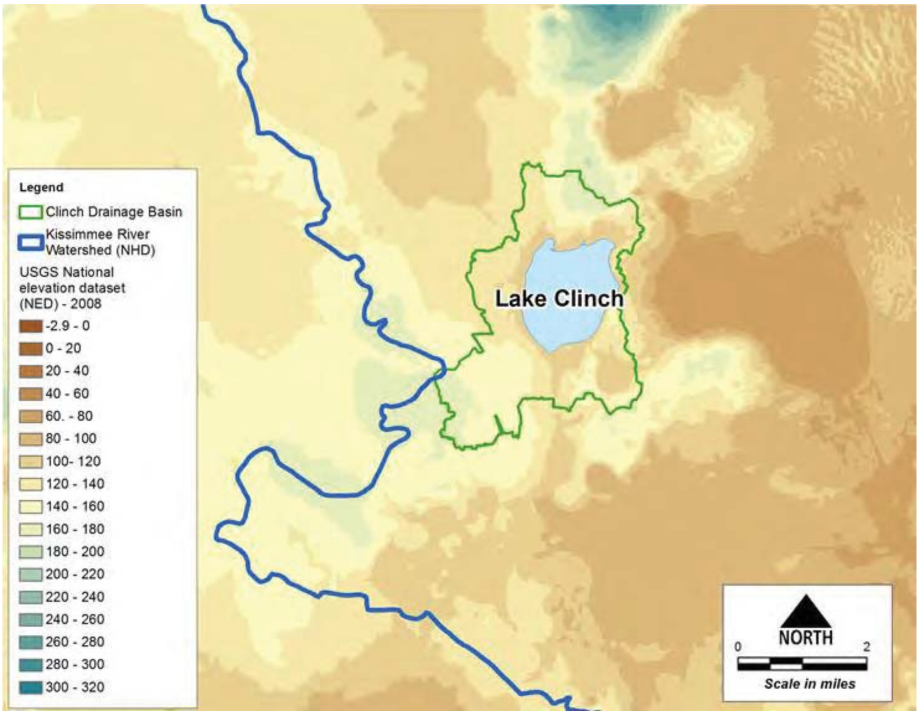

Figure 3. Drainage basin delineation and topography

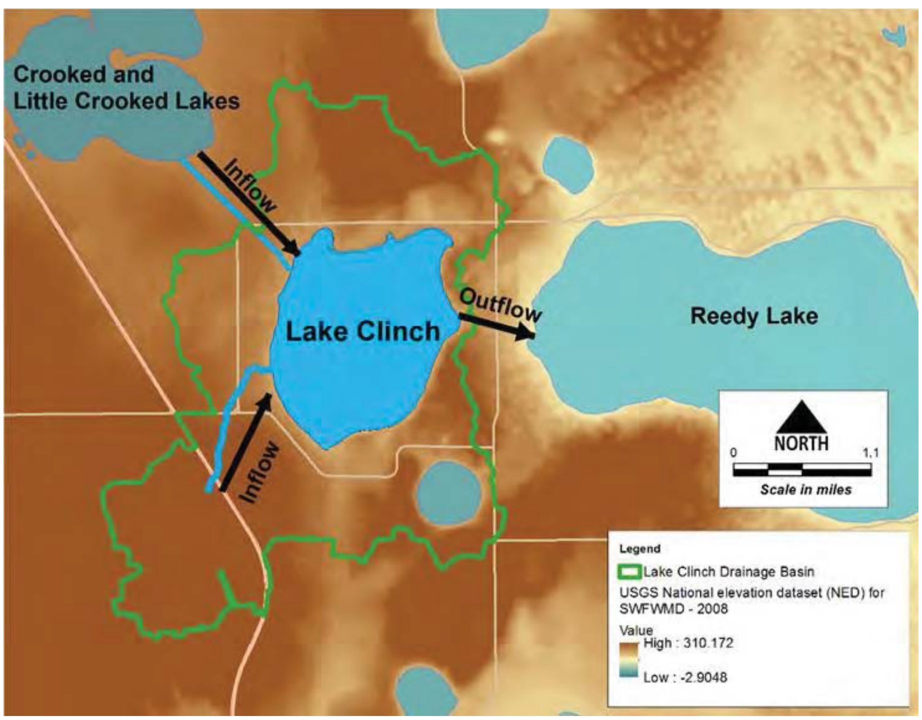

Figure 4. Lake Clinch surface inflow and outflow

Physiographic Setting

White (1970) classified the physiographic regions containing Lake Clinch as predominantly within the Polk Uplands and a small northeast portion of the lake within the Lake Wales Ridge. White describes the Polk Uplands as a “square area surrounded by lower ground on three sides” and “on the east it is bounded by the higher ground of the Lake Wales Ridge.” He states the Lake Wales Ridge is the “most prominent topographic feature of the Florida Peninsula.” Brooks (1982) categorized the area surrounding the lake as the Eastern Complex of the Central Ridge subdivision of the Lake Wales Ridge in the Central Lakes Physiographic District (Figures 5 and 6).

Brooks describes the Lake Wales Ridge as the “topographic crest of Central Florida” consisting of “residual sand hills, relic beach ridges and paleo sand dune fields.” As part of the Florida Department of Environmental Protection’s Lake Bioassessment/Regionalization Initiative, the area has been identified as the Northern Lake Wales Ridge region and described as an area of numerous slightly alkaline, low to moderated nutrient (often with relatively high nitrogen concentration), clear-water lakes (Griffith et al., 1997).

Nearly 200 lakes and ponds are located along the ridges and flanks of the Lake Wales Ridge (Barcelo and others, 1990). The orientation of the ridge is north-south and encompasses Lake, Orange, Osceola, Polk and Highlands counties. Surface topography is characterized by a series of north-south trending sand ridges that are separated by valleys. The surficial sands and other clastic materials are underlain by karstified carbonate rocks. Altitudes on the crest of the ridge range from about 150 to 300 feet above sea level. The southern part of the Lake Wales Ridge is divided into two secondary ridges by the intraridge valley. The southern half of the area is hydrologically distinct because there are many karst features and significant recharge to the Upper Floridan aquifer that occur through sinkholes (Yobbi, 1996).

Hydrogeologic Setting

The hydrogeologic system within the Lake Wales Ridge area includes an unconfined surficial aquifer underlain by an intermediate aquifer system (Spechler and Kroening, 2007). The intermediate aquifer system is referred to as the Hawthorn aquifer system in this memorandum. The lowermost hydrogeologic unit is the Floridan aquifer system, which has two major water bearing zones, Upper Floridan aquifer and Lower Floridan aquifer, separated by at least one less-permeable middle confining unit (Miller, 1983). The Hawthorn aquifer system is comprised of water-bearing and confining units and restricts the movement of water between the overlying surficial aquifer and underlying Upper Floridan aquifer; however, thickness and presence of the Hawthorn aquifer system is variable throughout the ridge because of past erosional processes and sinkhole formation (Spechler and Kroening, 2007).

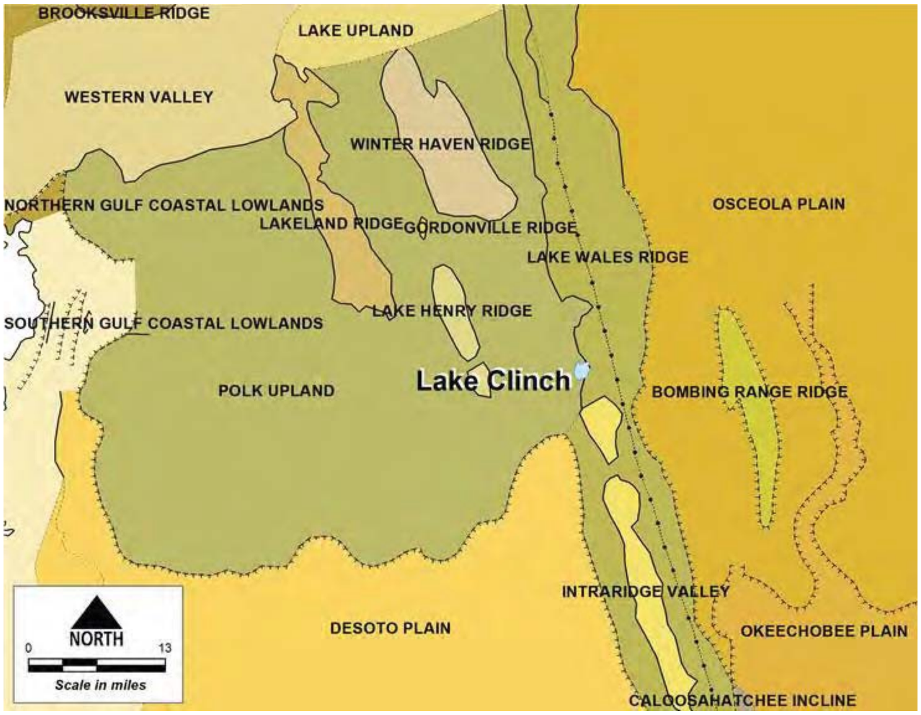

Figure 5. Physiographic Provinces (White, 1970) and topography.

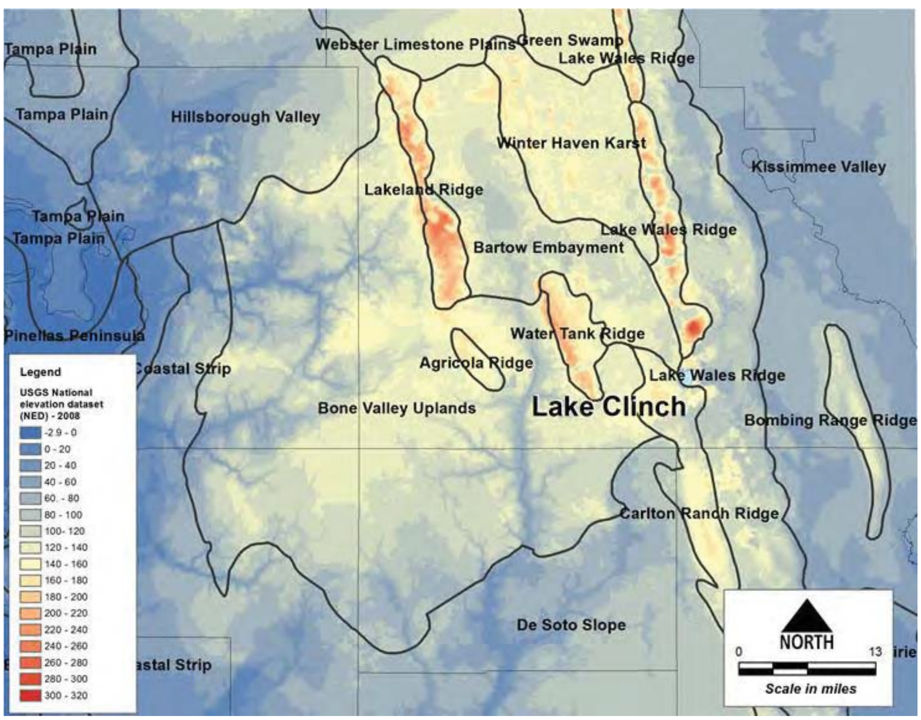

Figure 6. Physiographic Provinces (Brooks, 1981) and topography.

Hydrogeology and stratigraphy near Lake Clinch at ROMP CL-2 “Reedy Lake” well site are described in Decker (1986). This site is located approximately one and one-half miles east of the lake (Figure 7). The surficial aquifer at the site is described as undifferentiated surficial deposits consisting of quartz sands from land surface datum (LSD) to 237 feet below LSD (at 82 feet above NGVD 29). The Hawthorn aquifer system was identified from 237 to 377 feet below LSD and described as containing clay, dense limestone and an increased presence of dolomite with depth. The Upper Floridan aquifer was encountered at a depth of 377 feet below LSD. The well site is within one-tenth of a mile from the north shore of Reedy Lake. Reedy Lake appears to encompass several sinkholes. Decker (1987) described the ROMP CL-3 (Little Crooked Lake) well site. The site is located approximately one and one-quarter miles northwest of Lake Clinch, near the shoreline of Little Crooked Lake (Figure 7). The surficial aquifer at the site is described as undifferentiated surficial deposits consisting of quartz sands from LSD to 96 feet below LSD (at 128 feet above NGVD 29). The Hawthorn aquifer system extends from 96 feet to 226 feet below LSD and is a sand and greenish-gray clay unit with shell fragments underlain by dolomite from 129.7 to 151.7 feet. Between 151.7 and 216.8 feet below LSD, the rock material is described as mainly calcarenite. From 216.8 to 226 feet LSD, dolomite and lenses of clay were described and a clayey sandstone appears to define the unconformable contact between the Hawthorn aquifer system and the Upper Floridan aquifer. The stratigraphy at these well sites is typical of the area, as the surficial aquifer thickens toward the east, especially along the southern part of the Lake Wales Ridge where thickness can exceed 200 feet (Spechler and Kroening, 2007). Water level differences between the surficial and the Upper Floridan aquifer at the ROMP CL-2 and CL-3 sites are shown in figures 8 and 9. Similar water level elevations between the surficial aquifer and the Upper Floridan aquifer recorded at the CL-2 well site may be caused by little to no confinement by Hawthorn aquifer system east of Lake Clinch as the average water level for each aquifer are similar. A sinkhole at the CL-2 well site is another potential cause for similar water level elevations between the two aquifers. In contrast, water levels recorded at the CL-3 well site may indicate the Hawthorn aquifer system restricts the interaction between the surficial aquifer and Upper Floridan aquifer west of Lake Clinch. Coley Deep, an Upper Floridan aquifer monitoring well located approximately one-third of a mile east of Lake Clinch and Ridge WRAP CLP9, a surficial aquifer monitoring well located approximately three-fourths of a mile west of Lake Clinch are the closest wells to the lake and are shown in Figure 10.

Water levels collected at these wells between 1988 through 2014 indicate an average water level separation between the Ridge WRAP CLP9 well and the lake of 22.8 feet, with the Ridge WRAP CLP9 water levels being higher than those of the lake. The average water level separation between the Coley Deep well and the lake is 23.1 feet, with Lake Clinch water levels being higher than those of the Coley Deep well (Figure

11). The surficial water levels recorded at Ridge WRAP CLP9 are much higher than those of the lake, indicating the surficial hydraulic gradient near Lake Clinch is sloping towards the east. Yobbi (1996) states that in elevated areas, such as the Lake Wales Ridge, the water table generally is a subdued reflection of land surface topography.

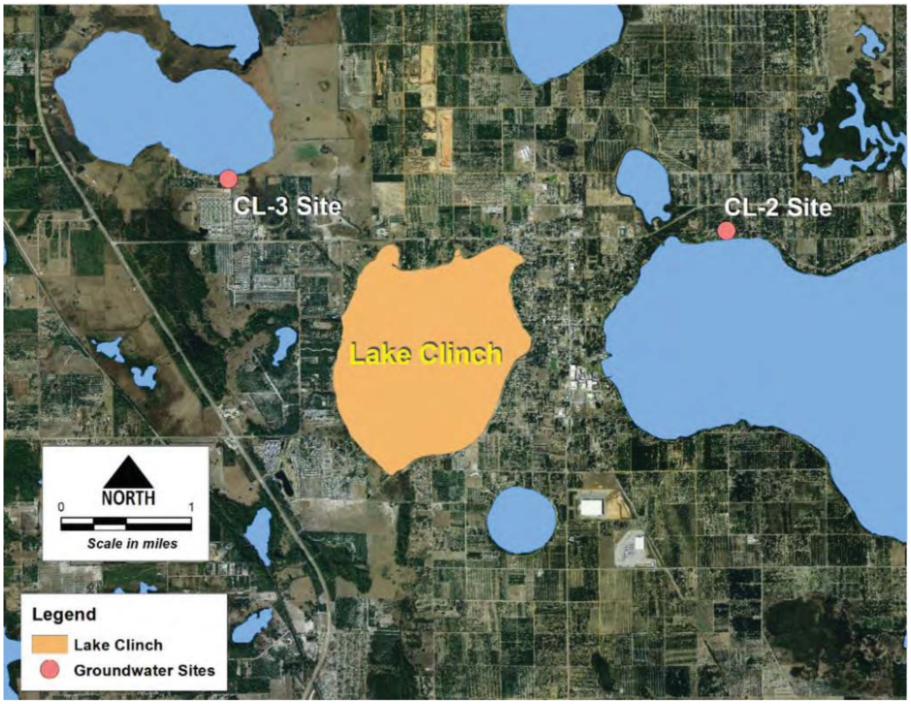

Figure 7. Location of ROMP CL-2 and CL-3 groundwater monitoring sites.

Land and Water Use

Land and water use in the area of Lake Clinch has changed over the years. Figures 12 and 13 show the land use around the lake in 1941 and the 2011 land use/land cover. Much of the land use in 1941 consisted of citrus groves, undeveloped land and some residential development on the east side of the lake (City of Frostproof). Irrigation of citrus groves became more prevalent in the 1960s in order to improve crop yield. Water use also increased through the 1960s and 1970s from the phosphate industry, centered approximately 25 miles to the west of Lake Clinch. Land use conversion from citrus to urban development has occurred. The estimated annual water use average from 2008 to 2012 within two miles of the lake center is 1.82 million gallons per day (mgd), of which approximately 67 percent is for agriculture, 29 percent is for public supply and the remaining 4 percent is for industrial/commercial and recreation/aesthetic uses (Figure 14 and Table 1). Within 5 miles of the lake, the estimated annual water use average from 2008 to 2012 is approximately 13 mgd, of which 92 percent is for agriculture use, 7 percent is for public supply and commercial/industrial and recreation uses account for 1 percent.

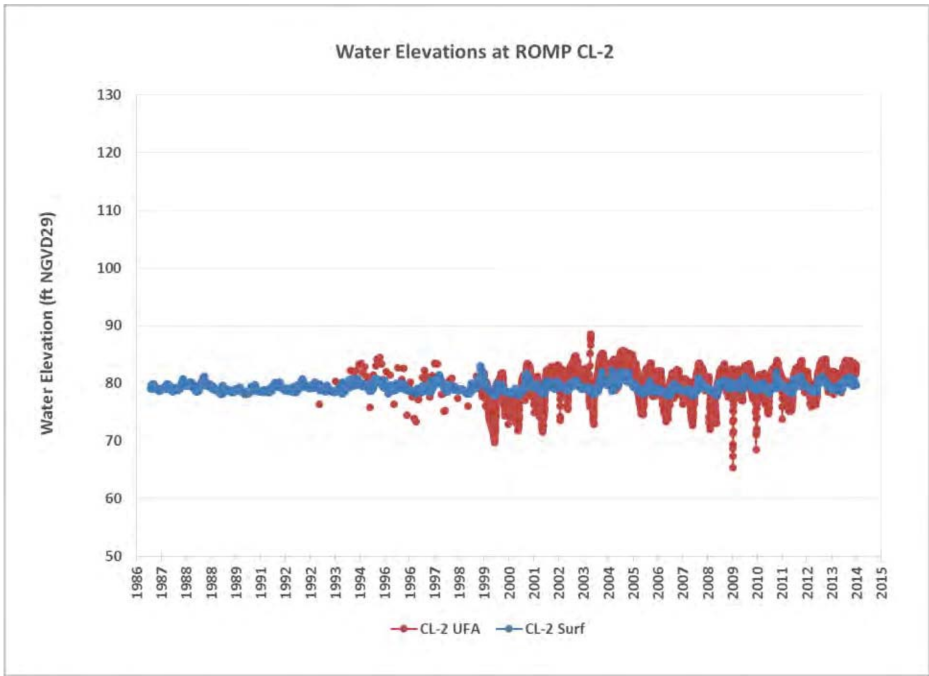

Figure 8. Surficial and Upper Floridan aquifer water elevations at ROMP CL-2 site.

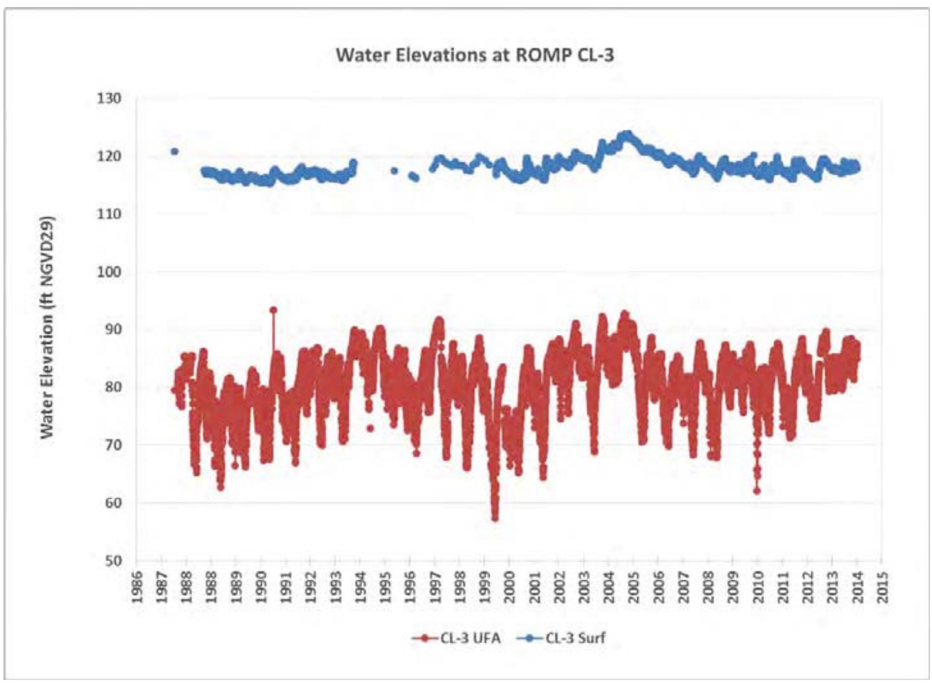

Figure 9. Surficial and Upper Floridan aquifer water elevations at ROMP CL-3 site.

Figure 10. Location of Ridge WRAP CLP-9 surficial well and Coley Deep Floridan aquifer well

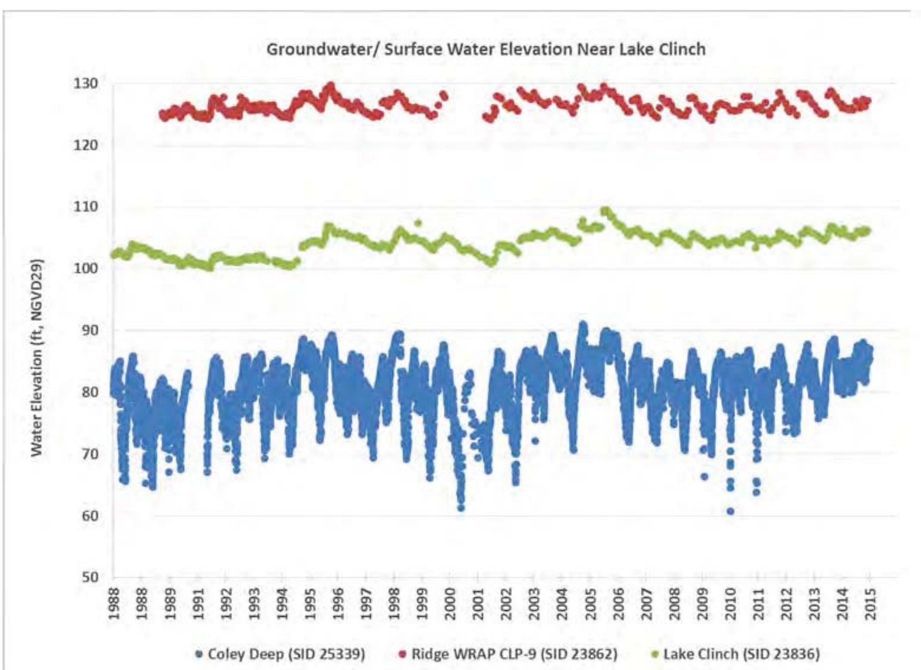

Figure 11. Water level elevations in Lake Clinch, Ridge WRAP CLP-9 surficial well and Coley Deep Upper Floridan aquifer (1988 - 2014).

Figure 12. Land use around the west and south portions of Lake Clinch in 1941 (left) and 2011 (right).

Figure 13. Land use around the north, east and south portions of Lake Clinch in 1941 (left) and 2011 (right).

Table 1. Water Use in the Lake Clinch area (2008-2012 average)

Water Use Within 2 Miles of Lake Clinch (GPD)			
Use Type	**SW**	**GW**	**Total**
Agriculture	54,376	1,227,520	1,281,895
Commercial/Industrial	64	22,688	22,752
Mining/Dewatering	-	-	-
Public Supply	21,576	530,396	551,972
Recreation	-	38,483	38,483
Total	-	1,819,086	1,895,102
Water Use Within 5 Miles of Lake Clinch (GPD)			
Use Type	**SW**	**GW**	**Total**
Agriculture	1,255,188	10,891,962	12,147,150
Commercial/Industrial	64	22,688	22,752
Mining/Dewatering	6,282	222	6,504
Public Supply	22,229	926,873	949,102
Recreation	-	44,019	44,019
Total	1,283,762	11,885,764	13,169,526

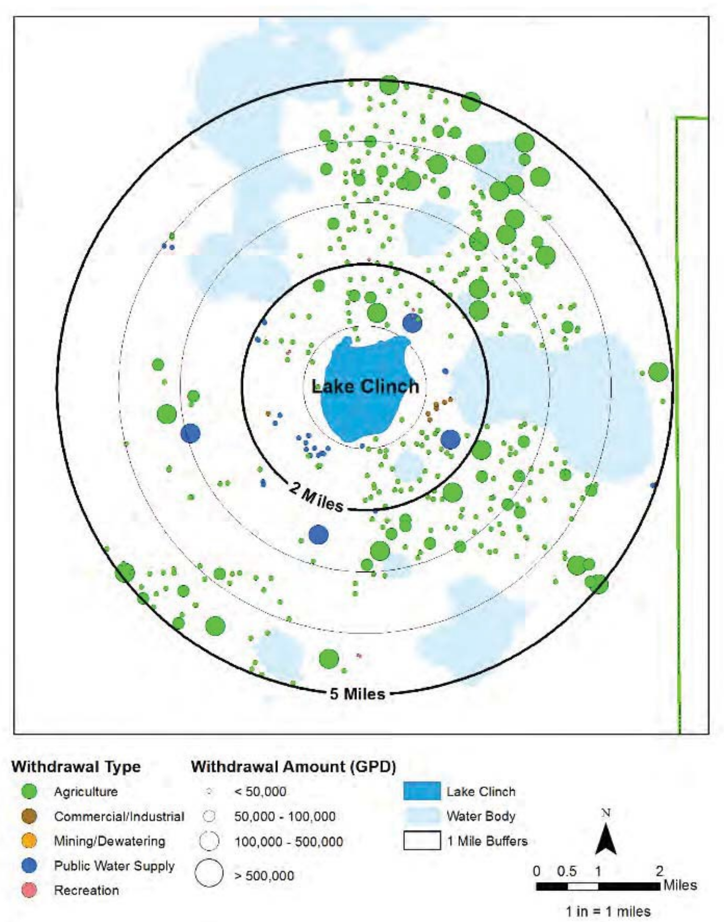

Figure 14. Lake Clinch and average groundwater and surface water withdrawal amounts over the period 2008-2012

Figure 15 presents total estimated and measured groundwater withdrawals in Polk County since the 1930s (updated from Southwest Florida Water Management District, 2006). Significant groundwater withdrawals began in the area during the 1940s and 1950s and peaked in the late 1960s and early 1970s. Groundwater withdrawals in Polk County have been relatively stable since the early-to-mid1990s, although this period includes both extreme dry (2000) and wet (2004/2005) conditions. Since 1994, estimated groundwater withdrawals in Polk County averaged about 218 mgd and ranged from a low of 172 mgd in 2011 to a high of 274 mgd in 2000.
Figure 16 summarizes groundwater withdrawals in the SWFWMD portion of Polk County since 1994 by major water use type. Over this period, withdrawals for agriculture and mining/dewatering have steadily declined. Public supply withdrawals, however, increased until 2006 but since that time have returned to withdrawal levels experienced during the 1990’s. Factors that have been cited for declines in agricultural water use include uncertainties associated with citrus greening and canker and increased urbanization, which is evidenced by reductions in citrus acreage that have occurred in the county.

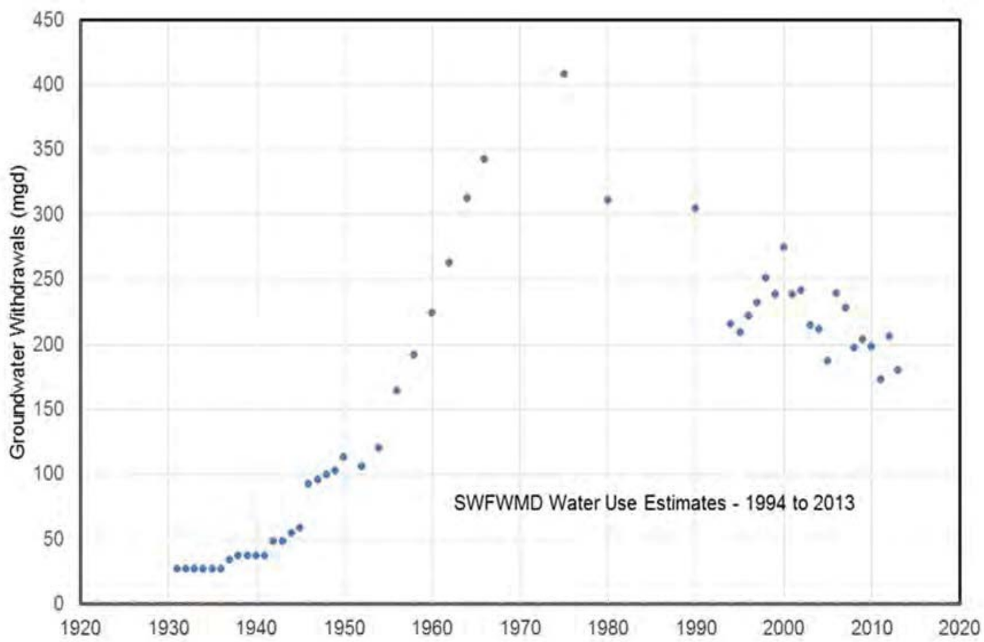

Figure 15. Total estimated and metered groundwater withdrawals in Polk County (1930 - 2013)

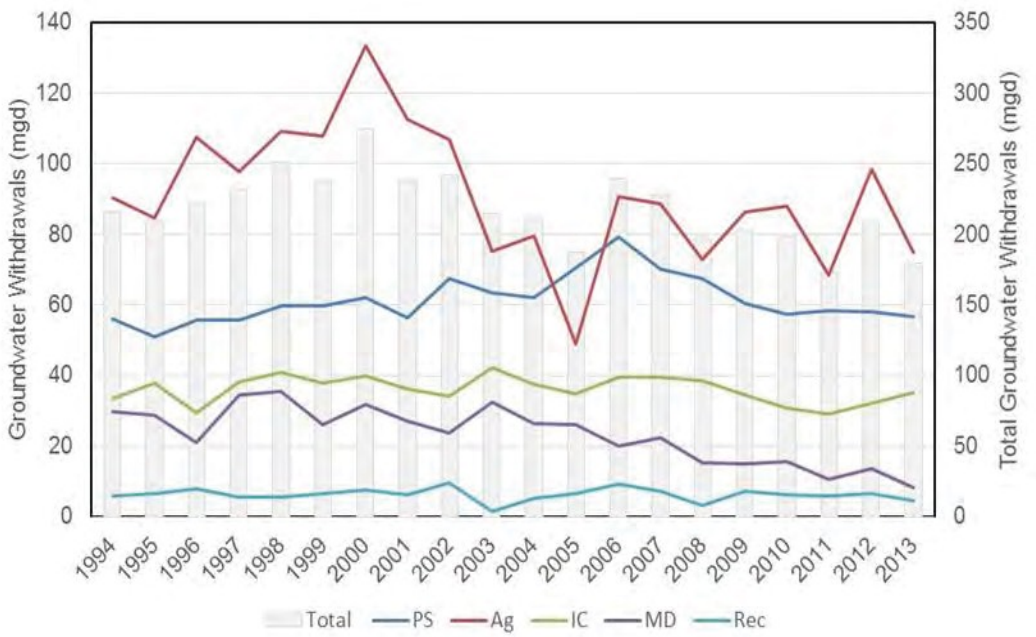

Figure 16. Estimated groundwater use in Polk County by use type (1994 – 2013)

With respect to public supply, the economic recession that began in 2006 has been cited as a potential influence in the recent reductions that have occurred. Because permitted groundwater withdrawal quantities have remained fairly constant (with the exception of how agriculture has been permitted in the Southern Water Use Caution Area (SWUCA) since 2003), the permanency of these declines is uncertain. As part of the SWUCA Recovery Strategy (SWFWMD, 2006), the District continues to work with users to develop alternative water supplies to meet water demands while reducing groundwater withdrawals when possible.

Rainfall Regression Long-Term Historic Lake Percentile Estimation

The procedure to establish minimum and guidance levels for lakes is based on long- term lake stage percentiles. A first step in developing a rainfall regression model is the delineation of “Historic” and “Current” time periods. A Historic time period is a period when there are little to no groundwater withdrawal impacts on the lake, and the lake’s structural condition is similar or the same as the present day. In contrast, a Current time period is a recent long-term period during which withdrawals and structural alterations are stable. To identify Historic and Current time periods, an evaluation of hydrologic changes in the vicinity of the lake is completed to determine if the water body has been significantly impacted by groundwater withdrawals. Examples of hydrological changes that are reviewed include drainage modifications, dredging, filling and modifications to the lake outlets.

Stage data from the Historic period are typically used to establish a statistical relationship (regression) with rainfall. The rainfall regression model is then used to extend the available stage record (i.e., develop a 60 year or longer record) for calculation of long-term P10, P50 (median), and P90 lake stage percentiles. The P10, P50 and P90 are, respectively, the water level elevations equaled or exceeded 10, 50 and 90 percent of the time on a long-term basis. The rainfall regression model can then be used to evaluate whether the lake has been fluctuating consistently with changes in climate and to assess whether minimum levels are being met.

The rainfall regression method (Ellison, 2010) involves development of a Line of Organic Correlation (LOC) between lake stage and rainfall. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 1992). The magnitude of the slope of the LOC line is calculated as the ratio of the standard deviations of the x and y variables and its sign, i.e., whether it is positive or negative, determined by the sign (+ or -) of the correlation coefficient (r). The LOC approach, rather than a simple linear regression approach is preferable for the rainfall- regression method since it produces a result that better retains the variance (and therefore retains the "character") of the original data.

Rainfall for the LOC model is correlated to lake water-level data using inverse linearly-weighted rainfall sums. The weighted-sums ascribe higher weight to more recent rainfall and progressively less weight to rainfall in the past. For the rainfall regression method, weighted sums varying from 6 months to 10 years are used to develop separate models, and the model with the highest coefficient of determination (r^2) is chosen as the best-fit model.

Lake Clinch Water-Level Data and Identification of Historic Data

Period of record (POR) lake stage data (*i.e.,* surface-water elevations for Lake Clinch relative to NGVD 29 obtained from the District's Water Management Information System (WMIS) database, Site Identification (SID) number 23836) were evaluated for inclusion in the water level record used in the model (Figures 17 and 18). Surface-water elevations have been recorded since January 1947 with the early data collected by the U.S. Geological Survey and the more recent data collected by the SWFWMD (Figure 19).

Rain-Gage Data

Available rain-gage data were inventoried and sorted by distance from Lake Clinch, and by their POR, to locate the closest rain data to the lake for compilation of a long-term rainfall record that could be used to develop a rainfall regression LOC model to predict long-term lake levels. The rainfall data ultimately used in the model was based on gage distance, rainfall measurement, availability and ability to produce a model that calibrates well to measured lake levels.

Primary rainfall measurements used in the model between 1/1/1946 and 3/30/1987 were recorded at the Avon Park National Weather Service (SID 25508) station located approximately nine miles south of Lake Clinch. Data was collected at the Coley rainfall station, located 0.3 miles from Lake Clinch, from 4/1/1987 until 12/31/1993 and was the primary gage for this period. From 1/1/1994 through 12/31/2014, an average of data for four pixels coinciding with the lake were used. NEXRAD is a network of 160 high-resolution Doppler weather radars controlled by the NWS, Air Force Weather Agency and Federal Aviation Administration. Missing days of recorded rainfall from the two primary gages between 1/1/1946 through 12/31/1993 were infilled using rainfall data recorded at the Mountain Lake National Weather Service (SID 25147) station located approximately 12.5 miles north of the lake and Bereah rainfall station (SID 25171) located approximately 3.9 miles south of the lake. Gage locations are shown in Figure 19.

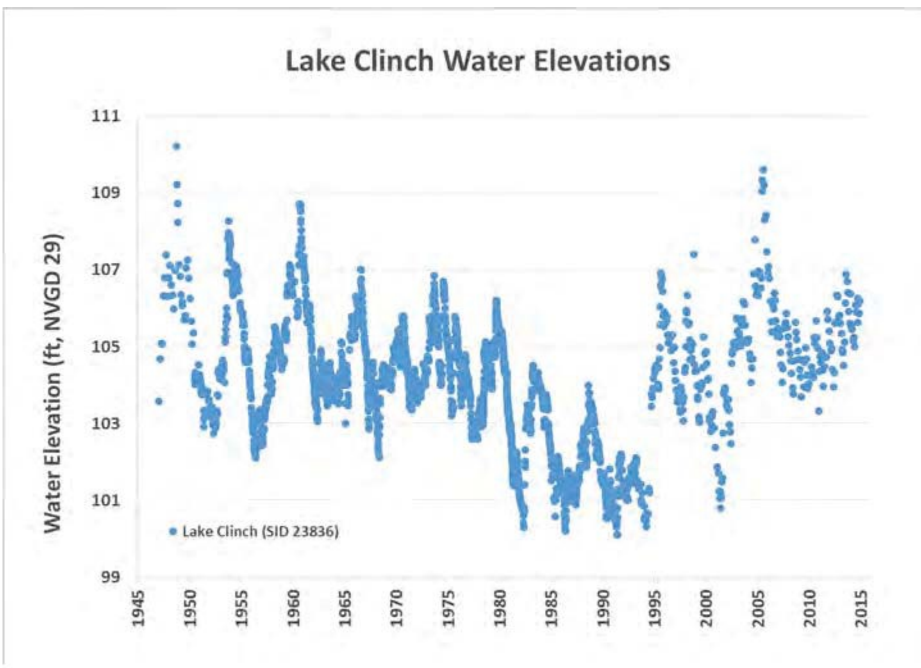

Figure 17. Lake Clinch water elevation data considered for the LOC model (1947 **– 2015).**

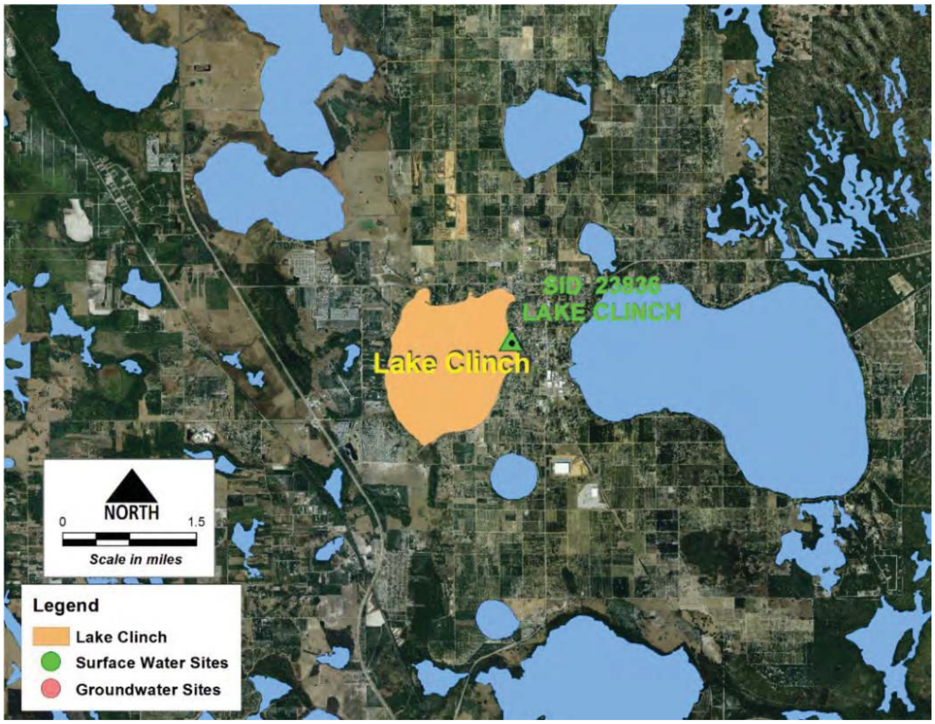

Figure 18. Location of Lake Clinch staff gage.

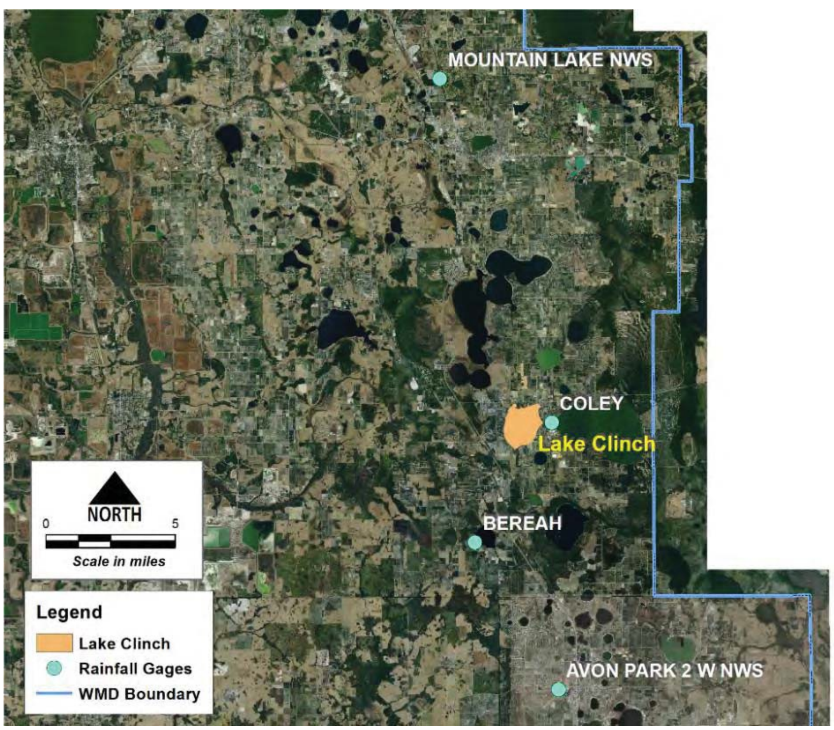

Figure 19. Rain gage locations for measurements used in the rainfall regression model for Lake Clinch.

Lake Clinch Rainfall Regression Model and Historic Percentiles

Rainfall data were correlated to lake water level data by applying a linear inverse weighted sum to the rainfall using a concept described by Merritt (2001). The weighted sum gives higher weight to more recent rainfall and less weight to rainfall in the past. In this application, weighted sums varying from 6 months to 10 years were separately used, the results were compared, and the weighted rainfall series with the highest coefficient of determination (r^2) was chosen as the best model.

A rainfall regression LOC model was developed using lake stage data and rainfall data from January 1, 1946 to December 31, 2014. The best-fit LOC model for predicting water levels in Lake Clinch exhibited a coefficient of determination (r^2) of 0.92 using a four-year rainfall decay series and may be simplified as:

$$y\hat{} = b_0 + sign[r] * b_i * X_i$$

where

$y\hat{}$ = *the estimate of lake stage expressed as an elevation in feet above NGVD 29*

b_0 = *the y intercept, in this case 92.62 feet above NGVD 29*

b_i = *the regression slope; in this case 0.11*

$sign[r]$ = *the algebraic sign (+ or -) of the correlation coefficient; in this case "+"*

X_i = the *inversely, linearly-weighted two-year cumulative rainfall sum in inches*

A time series plot of actual (i.e., observed) and modeled water levels for the 1946-1952 calibration period (Historic period) are shown in Figure 20. The time period selected for calibration was chosen because it is assumed groundwater withdrawals were not impacting the lake during this time. A comparison of measured and modeled percentiles for the calibration period is presented in Table 2. For the calibration period, the model-derived P10 percentile was 0.7 foot higher than the measured P10; the model-derived P90 percentile was the same as the measured P90; and the model- derived P50 percentile was 0.4 foot higher than the measured P50.

The best-fit LOC model and rainfall records were used to estimate water levels for Lake Clinch for the period from January 1, 1946 through December 31, 2014 (Figure 21). Observed data matched the model reasonably well for lake levels with exception to 1982 through 1987. During this time period, the model over predicted lake water levels by an average of 2.0 ft. indicating that other factors besides rainfall could have contributed to the lower than expected water levels. Additionally, between 1994 through 2014, the model under predicted lake water levels by an average of 0.9 ft. also indicating that other factors are contributing to higher than expected storage within the lake. Multiple rainfall gage combinations were examined in an attempt to improve the model; however, the match could not be improved. The modeled long-term Historic percentiles are presented in Table 3.

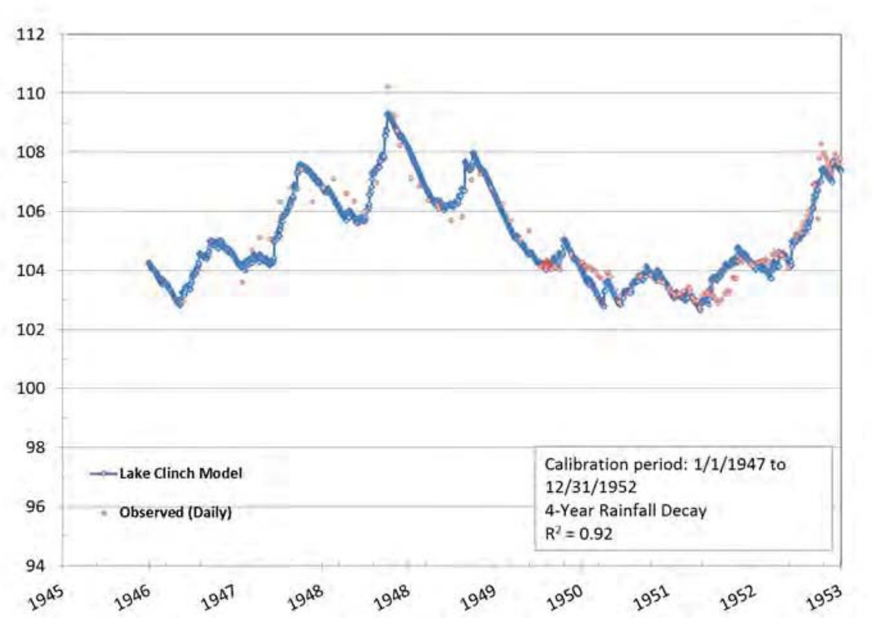

Figure 20. Lake Clinch LOC-modeled and actual (i.e., observed) water levels for the calibration period (1946 – 1952).

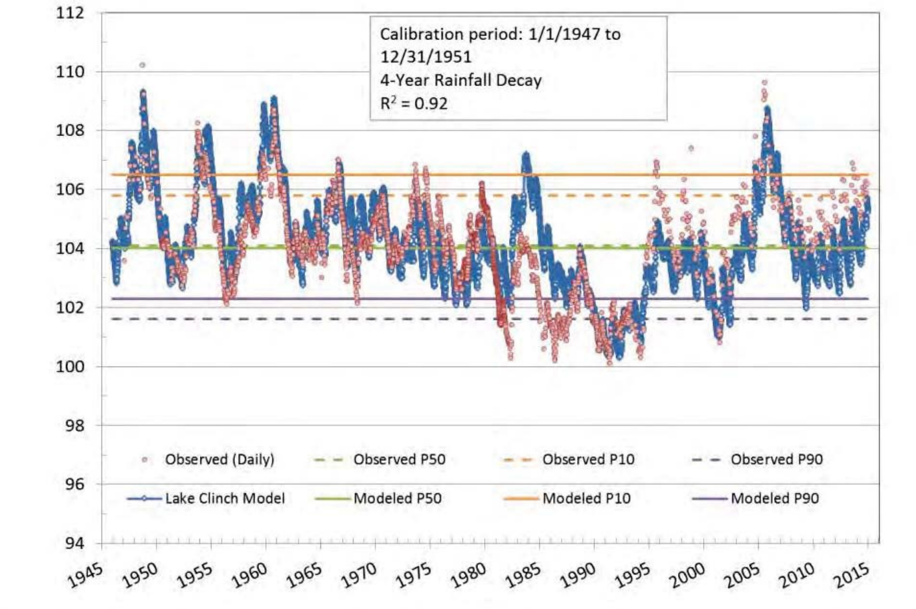

Figure 21. Lake Clinch LOC-model predicted and actual (i.e., observed) water levels for period from January 1, 1946 through December 31, 2014.

Table 2. Comparison of Lake Clinch calibration period percentiles.

Calibration Percentiles January 1, 1946 through December 31, 1952 (feet above NGVD 29)		
Percentiles*	**Observed**	**Model**
P10	106.8	107.5
P50	104.1	104.5
P90	103.2	103.2

* Percentiles listed include the water surface elevation equaled or exceeded ten (P10), fifty (P50) and ninety (P90) percent of the time

Table 3. Lake Clinch long-term Historic percentiles.

Lake Clinch Long-term Historic Percentiles* January 1, 1946 through December 31, 2014 (feet above NGVD 29)	
Percentiles*	
P10	106.5
P50	104.0
P90	102.3

* Percentiles listed include the water surface elevation equaled or exceeded ten (P10), fifty (P50) and ninety (P90) percent of the time

Conclusions

Lake Clinch is located on the Lake Wales Ridge physiographic region. In areas within the ridge the Hawthorn aquifer system restricts movement of water between the overlying surficial aquifer and underlying Upper Floridan aquifer. Although in many instances sinkhole lakes along the Lake Wales Ridge breach the Hawthorn aquifer system, it does not appear to be the case for Lake Clinch. Due to the clay confinement under the lake, the lake does not appear to be affected by groundwater withdrawals in the Upper Floridan aquifer.

Long-term water levels for Lake Clinch were simulated using a rainfall regression technique. A best-fit LOC rainfall regression model was calibrated to water-level data from January 1, 1946 through December 31, 1952 using weighted four-year cumulative rainfall sums in inches. The long-term Historic P50 of 104.0 feet NGVD29 and the Historic P10 of 106.5 feet NGVD29 were developed and used.

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APPENDIX B

Technical Memorandum

December 7, 2015
TO: Jerry L. Mallams, P.G., Manager, Water Resources Bureau FROM: Jason Patterson, Hydrogeologist, Water Resources Bureau
Keith Kolasa Senior Environmental Scientist, Water Resources Bureau

Subject: Lake Clinch Minimum Levels Status Assessment

Introduction

The Southwest Florida Water Management District (District) is reevaluated adopted minimum levels for Lake Clinch and revised the levels for the lake, in accordance with Section 373.042 and 373.0421, Florida Statutes (F.S). Documentation regarding development of the revised minimum levels is provided by Patterson and Barcelo (2015) and Kolasa and others (2015). Section 373.0421, F.S. requires that a recovery or prevention strategy be developed for all water bodies that are found to be below their minimum flows or levels, or are projected to fall below the minimum flows or levels within 20 years. In the case of Lake Clinch and other waterbodies with established minimum flows or levels in the Southern Water Use Caution Area (SWUCA), an applicable regional recovery strategy, referred to as the SWUCA Recovery Strategy, has been developed and adopted into District rules (Rule 40D-80.074, F.A.C.). One of the goals of the SWUCA Recovery Strategy is to achieve recovery of minimum flow and level water bodies such as Lake Clinch. This document provides information and analyses to be considered for evaluating the status of the revised minimum levels for Lake Clinch and any recovery that may be necessary for the lake.
Background

Lake Clinch is located in southeast Polk County, just east of the US Highway 27/US Highway 98 intersection in the City of Lake Frostproof. (Figure 1). The lake is within Kissimmee River watershed.

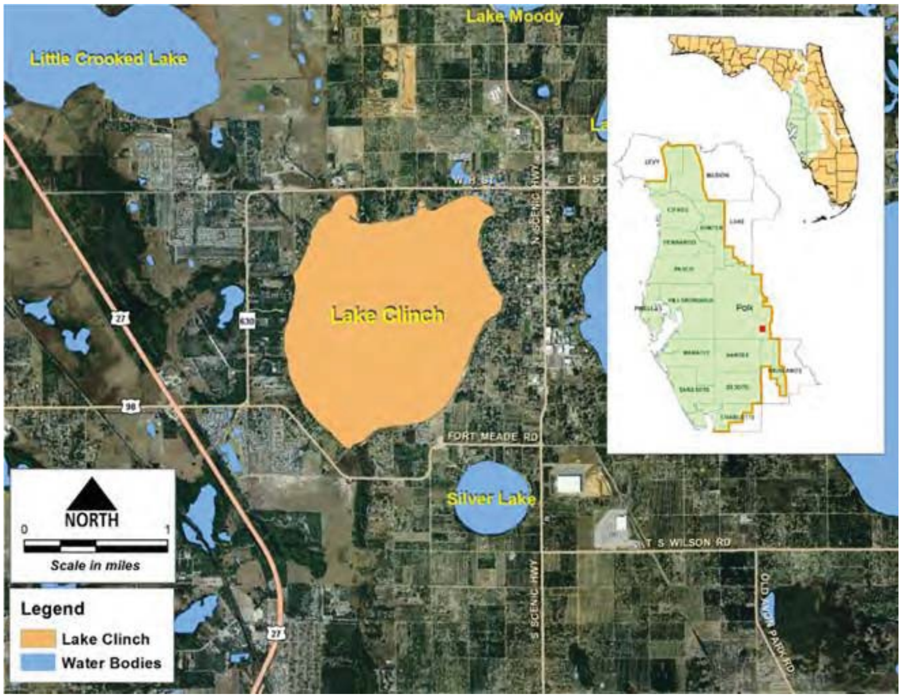

Figure 1. Location of Lake Clinch in Polk County, Florida

Revised Minimum Levels for Lake Clinch

Revised minimum levels for Lake Clinch are presented in Table 1 and discussed in more detail by Kolasa and others (2015). Minimum levels represent long- term conditions that if achieved, are expected to protect water resources and the ecology of the area from significant harm that may result from water withdrawals. The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. The High Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. The Minimum Lake Level therefore represents the required 50th percentile (P50) of long-term water levels, while the High Minimum Lake Level represents the required 10th percentile (P10) of long-term water levels. To determine the status of minimum levels for Lake Clinch or minimum flows and levels for any other water body, long-term data or model results must be used.

Table 1. Minimum Levels for Lake Clinch.

Minimum Levels	**Elevation in Feet** NGVD 29
High Minimum Lake Level	105.7
Minimum Lake Level	103.2

Status Assessment

The goal of a minimum levels status assessment is to determine if lake levels are fluctuating in accordance with criteria associated with adopted levels, i.e., to determine whether or not the minimum levels are being met. In addition to use of a rainfall regression model and/or other types of models, the process includes comparison of long-term water levels with adopted levels, review of periodic groundwater modeling updates, and, if necessary, investigation of other factors that could help explain lake level fluctuations. An assessment method used for evaluating the Minimum Lake Level (MLL) involves modification of an LOC model and associated prediction intervals based on elevations associated with the Historic P50 and the MLL. For this process, the intercept for the LOC model and prediction intervals are decreased in elevation based on the difference between the Historic P50 and the MLL (Figure 2). These modified, shifted lines represent a defined range of lake levels that would be expected to meet the MLL while exhibiting variation expected due to changes in rainfall.

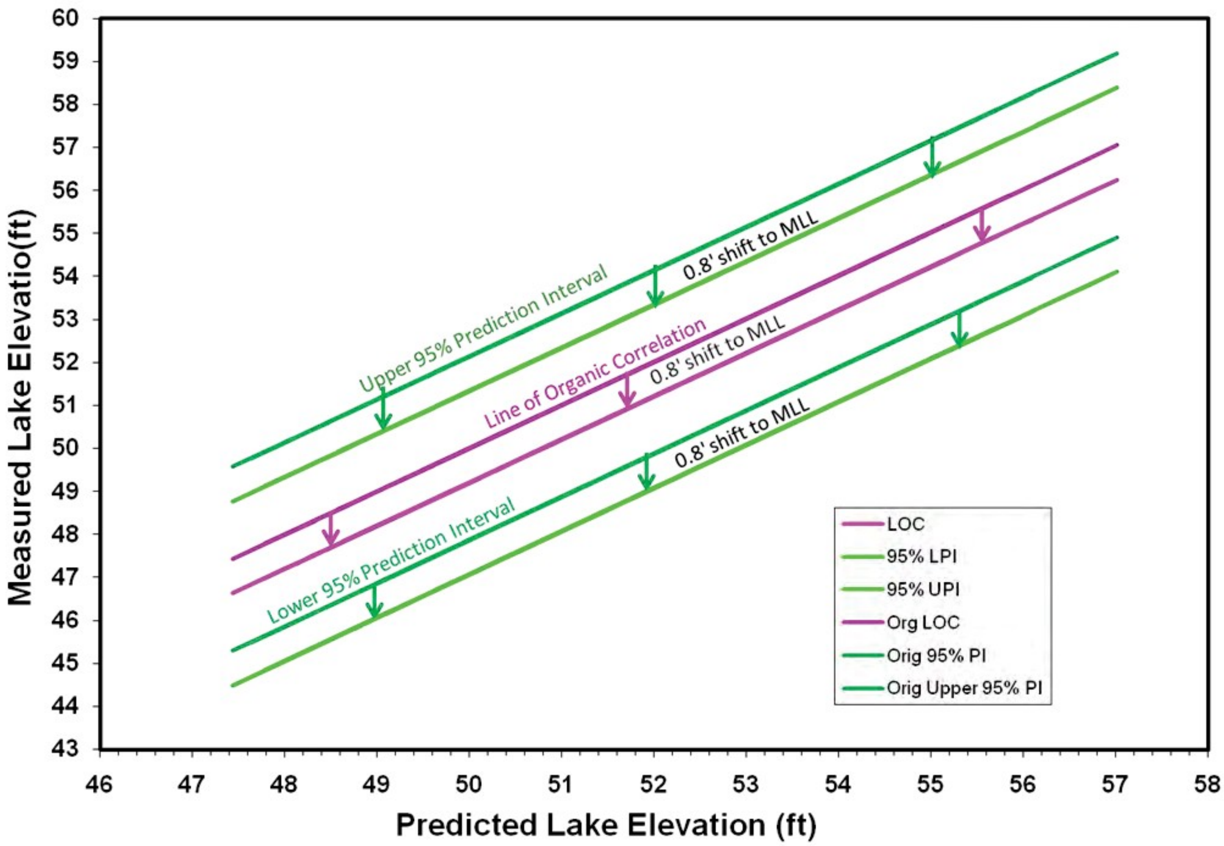

Figure 2. Example of the shifts to the prediction interval and LOC lines to reflect the MLL.

Prediction intervals for an LOC model are calculated for alpha equal to 0.025 (single tail) using the following equation (Helsel and Hirsch, 1992):

$$\left[\hat{y} - ts\sqrt{1+\frac{1}{n}+\frac{(x_0-\bar{x})^2}{SS_x}},\ \hat{y} + ts\sqrt{1+\frac{1}{n}+\frac{(x_0-\bar{x})^2}{SS_x}}\right]; \qquad \text{(Equation 2)}$$

where

$\hat{y} = b_0 + sign[r] * b_i * x_i$ *the estimate of y given* x_i (refer to Equation 1)

$t = \frac{\bar{x}-\mu_0}{s/\sqrt{n}}$ *students t distribution*

$s = \sqrt{s^2}$ *standard error of the regression*

$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n}$ *mean x*

$SS_x = \sum_{i=1}^{n} (x_i - \bar{x})^2 = \sum_{i=1}^{n} x_i^2 - n(\bar{x})^2$ *sums of squares*

The LOC model can also be used to update predicted daily or monthly lake levels which are then combined in an assessment plot along with a shifted LOC and prediction intervals to identify the number of predicted daily or monthly points that plot below the lower 95% prediction interval. For a 95% prediction interval it is expected that 2.5% of the points will plot below the lower prediction interval. However, such a strict interpretation may not be appropriate for MLL status assessments due to the variability in rainfall and the complexities in representing areal rainfall totals with point measurement taken at a gage site. Because of these and other factors such as limitations imposed on calibration to short time periods that may not include the entire range of water levels (extreme highs and record lows), the expected number of predicted water level values that may plot below the 95% prediction interval is doubled, to 5%. The occurrence of more than 5% of the predicted water level values below the lower prediction interval would suggest the lake is lower than can be accounted for based solely on rainfall, and may be affected by changes resulting from groundwater withdrawals or other factor(s).
The MLL for Lake Clinch (103.2 feet above NGVD29) is 0.9 feet below the modeled Historic P50. For assessment of the MLL status, the intercept of the LOC and prediction intervals were therefore shifted down 0.8 feet. Plotted regression model results versus observed levels for Lake Pasadena/Buddy since January 2010 lie mostly near the top of or above the shifted upper prediction interval (Figure 21), indicating the MLL is being met**.**

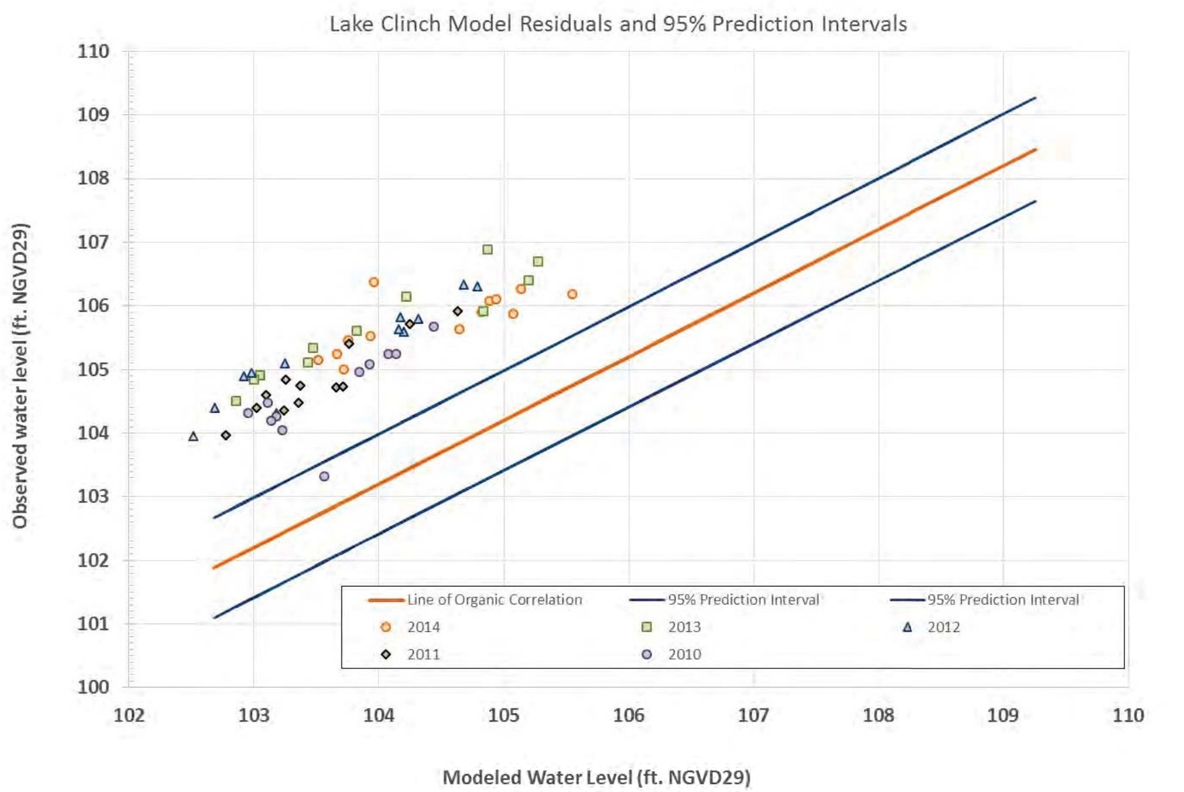

Figure 3. Lake Clinch MLL assessment prediction intervals and model versus observed data since 2007.

Use of observed lake data provides an empirical method for assessing whether the MLL and High Minimum Lake Level (HMLL) are being met. The MLL and HMLL represent long-term exceedance percentiles for the P50 and P10, respectively; so full assessment of the MLL and HMLL with actual percentiles requires data from a long period of record. Assessment of the MLL and HMLL for Lake Clinch using the record starting in 1966 allows for evaluation of the lake relative to the history of withdrawals in the area which have been variable through time. The cumulative median and cumulative P10 ended with values above the MLL and HMLL, respectively (Figure 4). Because of the thick confinement between the lake and the Upper Floridan aquifer the High Minimum Lake Level and Minimum Lake Level are also expected to be met for the next 20 year planning period. The long-term Historic P50 of 104.0 feet NGVD and the Historic P10 of 106.5 feet NGVD developed using model-predicted and observed water levels was used in conjunction with the wetland offset to develop of a MLL and HMLL of 103.2 and 105.7 feet NGVD, respectively (Kolasa, 2015).

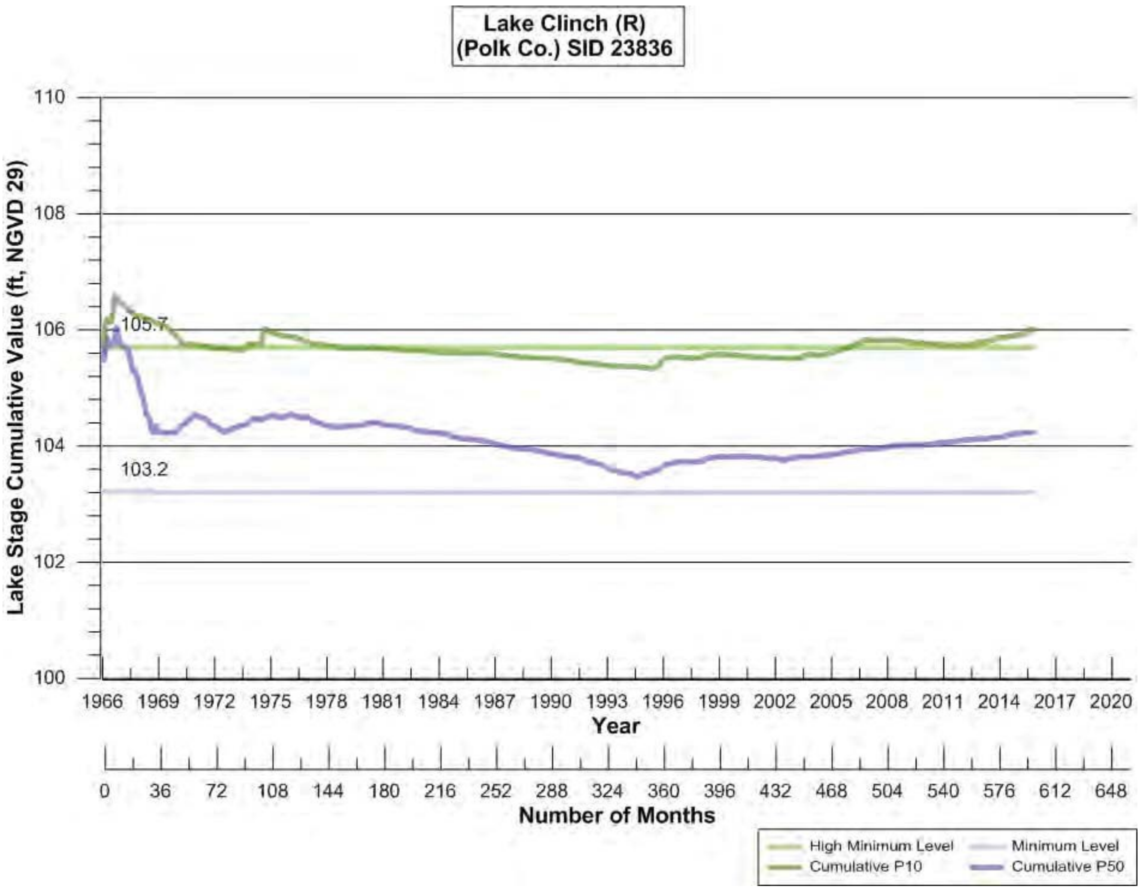

Figure 4. Lake Clinch observed data cumulative median (dark green line) and cumulative P10 (dark purple line) water levels starting in 1966 compared to the MLL of 103.2 (light purple) and 105.7 (light green) feet, NGVD.

Conclusions

Based on the information presented in this memorandum, it is concluded that Lake Clinch water levels are above the Minimum Lake Level, and above the High Minimum Lake Level for the lake.

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