> memo

To:	Louis Mantini, Suwannee River Water Management District (SRWMD) Sean King, Ph.D., P.E., SRWMD
From:	Jiangtao (J.T.) Sun, P.E., Environmental Consulting & Technology, Inc. (ECT)
CC:	Robert Johnson, P.E., ECT
Date:	November 7, 2022 (Final)
Re:	Minimum Flows and Levels and Change Standards based on Southwest Florida Water Management District methods for Lake Santa Fe TWA: 19/20-061.009 ECT Project No. 220408-0100

1.0 INTRODUCTION

Under task work assignment (TWA): 19/20-061.009, Environmental Consulting and Technology, Inc. (ECT) was authorized by the Suwannee River Water Management District (SRWMD or District) to update the technical memorandum titled *Minimum Flows and Levels and Change Standards based on Southwest Florida Water Management District methods for Lake Santa Fe* that were originally created by Greenman-Pedersen, Inc. (GPI) in 2018.

This memo presents an evaluation of the minimum flows and levels (MFLs) for Lake Santa Fe in Alachua County, Florida. These MFLs are evaluated using methods developed by the Southwest Florida Water Management District (SWFWMD) and based on work performed by SRWMD staff, GPI, and ECT, including the recent updates of the Lake Alto and Lake Santa Fe water budget modeling (ECT 2022a). This MFL evaluation using the SWFWMD methods is for comparison purposes only. An event-based MFL approach developed by the St. Johns River Water Management District (SJRWMD) was used to establish the MFLs for Lake Santa Fe as described in the report entitled Minimum Recommended Lake Levels: Lake Santa Fe, Florida (ECT 2022b).

2.0 MINIMUM AND GUIDANCE LEVELS FOR LAKE SANTA FE

MFLs designate an environmentally protective hydrologic regime (i.e., hydrologic conditions that prevent significant harm) and identify levels and/or flows above which water may be available for reasonable–beneficial use. MFLs developed using the SWFWMD methodology define the high and average levels and their frequency necessary to protect relevant water resource values and prevent significant harm to aquatic and wetland habitats. The SWFWMD has developed specific methodologies for establishing MFLs for lakes, wetlands, rivers, estuaries, and aquifers, and has subjected the methodologies to independent, scientific peer-review. SWFWMD has also adopted minimum levels for specific waterbodies determined by rules thereof into its Water Level and Rates of Flow Rule (Chapter 40D-8, F.A.C.). Chapter 40D-8.624, F.A.C, effective on 06/01/2021 or earlier, provided for the establishment of Guidance Levels for lakes, which serve as advisory information for the SWFWMD, 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 SWFWMD (1999a, b), Leeper *et al.* (2001), and Hancock (2007). 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 acres of fringing cypress wetlands are classified as Category 3 Lakes.

Although Lake Santa Fe meets the specifications of a Category I Lake, Minimum and Guidance Levels for Lake Santa Fe were developed using the SWFWMD methodology for Category 3 Lakes for the purpose of identifying significant change standards used for lakes without structural alterations affecting lake levels, or the minimum qualifications in cypress coverage (SWFWMD 1999a, b; Leeper *et al.* 2001; Hancock 2007). Levels, standards, and additional information are provided in Table 1, along with lake surface areas for each level. Detailed descriptions of the development and use of the data are provided in subsequent sections of this memo.

Table 1. Minimum levels, guidance levels, and significant change standards for Lake Santa Fe.

Levels	Elevation (ft NAVD88)	Lake Area (Acres)
Lake Stage Percentiles		
Historic P10	140.23	5,560
Historic P50	139.43	5,203
Historic P90	137.88	5,119
Other Levels		
Historic Normal Pool	140.74	5,606
Control Point	140.20	5,558
Guidance Levels		
High Guidance Level	140.23	5,560
Low Guidance Level	137.88	5,119
Significant Change Standards		
Cypress Standard*	138.94	5,172
Dock-Use Standard	138.89	5,169
Wetland Offset Standard	138.63	5,156
Aesthetics Standard	137.88	5,119
Basin Connectivity Standard	133.70	4,917
Species Richness Standard	128.63	4,423
Recreation/Ski Standard	118.70	2,019

Levels	Elevation (ft NAVD88)	Lake Area (Acres)
Lake Mixing Standard	NA	NA
Minimum Levels		
High Minimum Lake Level	139.69	5,345
Minimum Lake Level	138.89	5,169

NA – not available/not appropriate
* Category 1 metric used for comparison purposes only.

For the purpose of minimum level determinations, lake stage data is categorized as "Historic" for periods when there were no measurable impacts due to water withdrawals and impacts due to structural alterations that were similar to existing conditions. In the context of minimum levels development, "structural alterations" means anthropogenic 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.

2.1 LAKE STAGE DATA AND EXCEEDANCE PERCENTILES

A key part of establishing Minimum and Guidance Levels is the development of exceedance percentiles based on historic lake stage data.

A U.S. Geographical Survey (USGS) / District-operated long-term stage station USGS 02320601 Santa Fe Lake near Earleton, FL is located on the west lakeshore of the lake (Figure 1). This USGS/District-operated lake stage station provides the long-term historical lake stage values in a variety of frequencies from 7/11/1957 to current (Figure 2).

For Little Lake Santa Fe, a USGS / District-operated long-term stage station USGS 02320611 Little Santa Fe Lake was located on the west lake shore (Figure 1). Weekly stage data was manually measured from 2/15/1989 to 11/26/1993 by USGS and from 8/28/2000 to current by the District (Figure 2).

To avoid further confusion, Lake Santa Fe at this point and thereafter refers to the lake system including the “big” Lake Santa Fe to the south and Little Lake Santa Fe to the north, unless otherwise specified in this memo.

Figure 1. USGS/SRWMD Lake Stations at Lake Santa Fe and Little Lake Santa Fe.

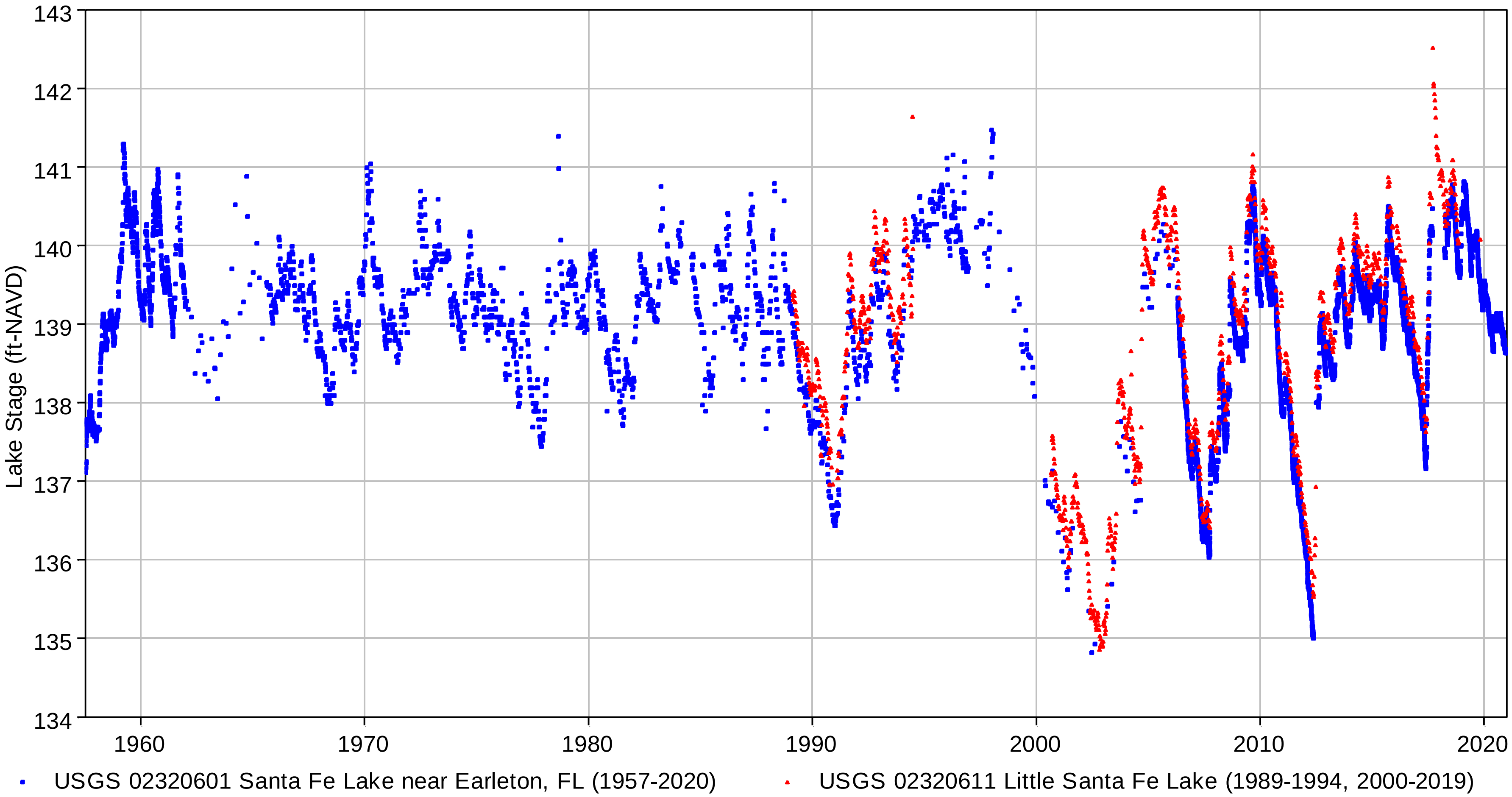

Figure 2. Observed Lake Stage Hydrographs at Lake Santa Fe and Little Lake Santa Fe (1957-2020)

To better represent the Historic conditions in the absence of groundwater withdrawals, the calibrated Lake Alto and Lake Santa Fe water budget model was used to run long-term simulations for an extended period of 55.7 years from April 25, 1960, to December 31, 2015 (ECT 2022a). Based on the reference timeframe (RTF) analysis results provided by the District, the groundwater level data set for the no-pumping scenario was created using the "measured" groundwater data set estimated at Lake Santa Fe. This "measured" groundwater dataset was estimated using data collected at the USGS Melrose station (USGS ID: 294313082024601 / SRWMD ID: S092307001) and the St. Johns River Water Management District (SJRWMD) Lake Brooklyn Wells near Keystone Heights (SJRWMD ID: 70078104). The term RTF data set is referred to as the "no-pumping" groundwater levels, which was created by adding the time-varying RTF adjustment factors to the "measured" groundwater level data set (ECT 2022a).

A technical memorandum "*Development of a Reference Timeframe Flow (RTF) Regime for the Minimum Flows and Minimum Water Levels (MFLs) Re-Evaluation of the Lower Santa Fe and Ichetucknee Rivers and Priority Springs*" was developed by the District in 2019 and published as Appendix D of a recent MFL report "*Minimum Flows and Minimum Water Levels Re-Evaluation for the Lower Santa Fe and Ichetucknee Rivers and Priority Springs*" (HSW 2021). This memo outlines the process used to develop reference timeframe flow and/or groundwater-head (head) time-series (e.g., "no-pumping" condition) at groundwater monitoring locations, springs and/or stream gage locations using observed and modeled data and an estimated time series of historic groundwater withdrawals. The model used in this analysis is the North Florida Southeast Georgia Groundwater Model, (NFSEG 1.1) (Durden *et al.* 2019).

The RTF groundwater level data set developed for the no-pumping scenario was input in the long-term model to simulate the Historic conditions (no-pumping scenario) as described in the Lake Alto and Lake Santa Fe water budget modeling report (ECT 2022a). Based on the daily model simulated lake stage data set for the no-pumping scenario (Figure 3), the Historic P10, P50, and P90 elevations were developed for Lake Santa Fe (Table 2 and Figure 4).

*Table 2. Daily stage frequency percentiles for Lake Santa Fe based on no-pumping scenario model simulation (*4/25/1960 - 12/31/2015*).*

Percentile[1]	**Model-Simulated Lake Stage (ft NAVD88)**
Historic P10 (HP10)	140.23
Historic P50 (HP50)	139.43
Historic P90 (HP90)	137.88

[1] See definitions of P10, P50, and P90 below.

Definitions:

- "P10" means the elevation of the water surface of a lake or wetland that is equaled or exceeded 10% of the time as determined from a long-term stage frequency analysis.

- "P50" means the elevation of the water surface of a lake or wetland that is equaled or exceeded 50% of the time as determined from a long-term stage frequency analysis.
- "P90" means the elevation of the water surface of a lake or wetland that is equaled or exceeded 90% of the time as determined from a long-term stage frequency analysis.

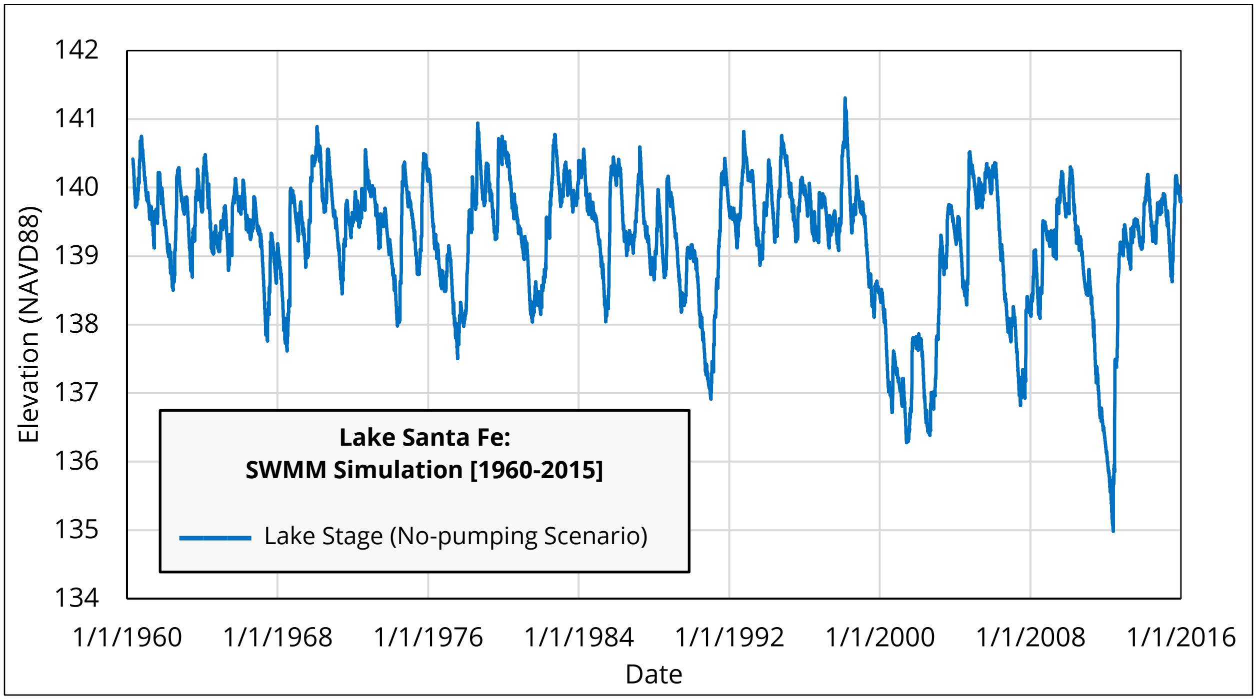

Figure 3. Hydrograph for Lake Santa Fe model simulated stage data for no-pumping scenario from 4/25/1960 to 12/31/2015.

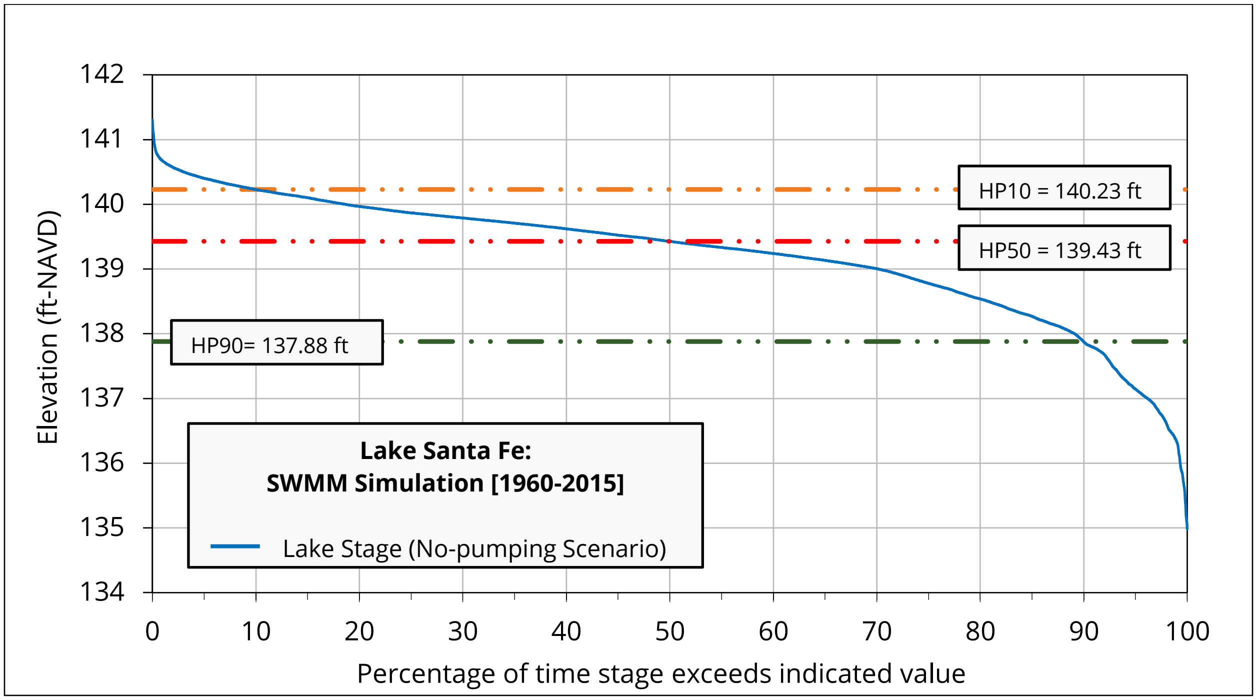

Figure 4. Exceedance probability chart for Lake Santa Fe model simulated stage data for no-pumping scenario, HP10, HP50, and HP90 from 4/25/1960 to 12/31/2015.

2.2 BATHYMETRY

Relationships between lake stage, inundated area, and volume can be used to evaluate expected fluctuations in lake size that may occur in response to climate, other natural factors, and anthropogenic impacts such as structural alterations or water withdrawals. Long term reductions in lake stage and size can be detrimental to many of the environmental values identified in the Water Resource Implementation Rule for consideration when establishing MFLs. Stage-area-volume relationships are therefore useful for developing significant change standards and other information identified in the methods for developing minimum lake levels.

The bathymetric maps of Lake Santa Fe were originally provided in scanned .TIFF format by SRWMD, which were created based on the survey data collected in 1976 (ECT 2016). The maps were georeferenced and digitized to ESRI shapefile format by ECT (Figure 5A). The elevation data on these maps are expressed as feet above the National Geodetic Vertical Datum of 1929 (ft NGVD29), which may be converted to the North America Vertical Datum of 1988 (NAVD88) by subtracting 0.85 feet. The shoreline was set at 140.32 ft NGVD29 or 139.47 ft NAVD88. The lowest point at the "big" Lake Santa Fe is below 113.0 ft NGVD29 or 112.15 ft NAVD88 at the lake center and the lowest point at Little Lake Santa Fe is below 119.0 ft NGVD29 or 118.15 ft NAVD88. The deepest point at the saddle point separating these two lakes was estimated at 131.0 ft NGVD29 or 130.15 ft NAVD88, i.e., the water depth at this location is approximately 10 feet (ECT 2022a).

Topography in the lake watershed can be characterized as mildly sloping and poorly drained, as graphically presented in the topographic digital elevation model (DEM) data (Figure 5B). The topographic DEM data was developed based on the Light Detection and Ranging (LiDAR) topographic survey data provided by USGS (NGC, 2011), SJRWMD, and SRWMD (ECT 2022a).

Stage-area-volume relationships were determined for Lake Santa Fe by building and processing DEM of the lake bathymetry using the 1976 SRWMD bathymetric survey data (below the shoreline elevation of 139.47 ft NAVD88) and the land surface elevations of the surrounding watershed using the 2011 USGS topographic DEM data (above the shoreline elevation) in ArcGIS (Figures 5A & 5B).

The resultant stage-area-volume relationships are listed in Table 3 for the lake bottom and land surface below 141.0 ft NAVD88. The relationships of stage versus surface area (2D area), bottom area (3D area), volume, mean depth, and maximum depth, are illustrated on Figures 6 through 10, respectively.

Table 3. Stage-area-volume table for Lake Santa Fe.

Elevation (ft NAVD88)	Area_2D (ft^2)	Area_3D (ft^2)	Volume (ft^3)	Area_2D (acres)	Area_3D (acres)
112.0	0.00	0.00	0.00	0.00	0.00
112.5	20,722,735.60	20,722,743.33	6,568,730.16	475.73	475.73
113.0	25,743,881.12	25,743,900.68	18,156,677.01	591.00	591.00
113.5	31,587,121.63	31,587,153.61	32,448,953.06	725.14	725.14
114.0	38,704,274.87	38,704,319.88	49,949,828.49	888.53	888.53
114.5	44,773,137.22	44,773,202.75	71,114,644.41	1,027.85	1,027.85
115.0	48,973,092.33	48,973,182.46	94,545,066.86	1,124.27	1,124.27
115.5	53,342,613.24	53,342,728.58	120,116,017.51	1,224.58	1,224.58
116.0	57,928,762.41	57,928,903.62	147,923,581.10	1,329.86	1,329.86
116.5	62,386,793.43	62,386,961.78	178,043,001.13	1,432.20	1,432.21
117.0	66,695,874.03	66,696,070.92	210,305,369.16	1,531.13	1,531.13
117.5	71,223,343.10	71,223,569.13	244,775,232.80	1,635.06	1,635.07
118.0	76,020,097.96	76,020,353.80	281,573,183.95	1,745.18	1,745.19
118.5	86,057,919.68	86,058,241.54	322,631,537.69	1,975.62	1,975.63
119.0	90,788,536.94	90,788,944.65	366,822,339.52	2,084.22	2,084.23
119.5	96,094,616.57	96,095,111.86	413,515,496.24	2,206.03	2,206.04
120.0	102,254,234.58	102,254,819.23	463,054,872.78	2,347.43	2,347.45
120.5	109,129,485.42	109,130,191.78	516,054,505.40	2,505.27	2,505.28
121.0	114,945,556.40	114,946,407.95	572,061,616.11	2,638.79	2,638.81
121.5	121,088,126.32	121,089,125.07	631,054,332.69	2,779.80	2,779.82
122.0	127,690,375.79	127,691,522.99	693,224,974.44	2,931.37	2,931.39
122.5	134,573,972.27	134,575,292.61	758,973,128.07	3,089.39	3,089.42
123.0	140,061,477.60	140,062,994.72	827,624,522.93	3,215.37	3,215.40
123.5	145,745,229.81	145,746,946.48	899,067,241.37	3,345.85	3,345.89

Elevation (ft NAVD88)	Area_2D (ft^2)	Area_3D (ft^2)	Volume (ft^3)	Area_2D (acres)	Area_3D (acres)
124.0	151,673,870.65	151,675,788.61	973,410,058.05	3,481.95	3,482.00
124.5	156,963,856.44	156,965,991.79	1,050,672,470.74	3,603.39	3,603.44
125.0	161,603,982.83	161,606,357.41	1,130,310,819.63	3,709.92	3,709.97
125.5	166,347,971.01	166,350,587.21	1,212,293,655.03	3,818.82	3,818.88
126.0	171,256,561.42	171,259,420.73	1,296,685,229.49	3,931.51	3,931.58
126.5	176,438,645.41	176,441,791.57	1,383,788,171.63	4,050.47	4,050.55
127.0	180,131,661.11	180,135,135.54	1,472,926,876.40	4,135.25	4,135.33
127.5	183,938,792.35	183,942,597.59	1,563,938,702.27	4,222.65	4,222.74
128.0	187,937,894.19	187,942,031.38	1,656,896,526.60	4,314.46	4,314.56
128.5	191,899,202.78	191,903,769.20	1,751,978,867.44	4,405.40	4,405.50
129.0	194,891,592.10	194,896,669.11	1,848,674,091.34	4,474.10	4,474.21
129.5	197,960,040.62	197,965,631.35	1,946,883,105.98	4,544.54	4,544.67
130.0	201,157,976.49	201,164,080.39	2,046,654,726.65	4,617.95	4,618.09
130.5	204,056,100.96	204,062,901.43	2,148,099,670.53	4,684.48	4,684.64
131.0	205,786,400.43	205,794,069.12	2,250,561,343.98	4,724.21	4,724.38
131.5	207,500,956.72	207,509,510.02	2,353,883,248.36	4,763.57	4,763.76
132.0	209,224,199.80	209,233,636.49	2,458,062,841.75	4,803.13	4,803.34
132.5	210,877,777.38	210,888,152.64	2,563,120,953.85	4,841.09	4,841.33
133.0	212,247,905.97	212,259,321.11	2,668,902,435.90	4,872.54	4,872.80
133.5	213,616,827.40	213,629,272.23	2,775,368,254.64	4,903.97	4,904.25
134.0	214,999,967.83	215,013,418.88	2,882,520,991.23	4,935.72	4,936.03
134.5	216,324,637.45	216,339,213.33	2,990,380,308.12	4,966.13	4,966.46
135.0	217,404,444.90	217,420,303.14	3,098,812,125.65	4,990.92	4,991.28
135.5	218,486,308.25	218,503,444.97	3,207,784,423.03	5,015.76	5,016.15
136.0	219,587,153.80	219,605,554.30	3,317,300,895.73	5,041.03	5,041.45
136.5	220,747,347.85	220,767,553.88	3,427,421,689.37	5,067.66	5,068.13
137.0	221,553,501.70	221,575,934.50	3,537,994,241.59	5,086.17	5,086.68
137.5	222,359,389.87	222,384,069.92	3,648,972,235.89	5,104.67	5,105.24
138.0	223,183,924.60	223,210,813.07	3,760,353,772.08	5,123.60	5,124.22
138.5	224,314,775.94	224,343,606.84	3,872,229,265.03	5,149.56	5,150.22
139.0	225,401,407.26	225,432,024.67	3,984,657,329.07	5,174.50	5,175.21
139.2	225,830,662.83	225,861,852.39	4,029,780,746.84	5,184.36	5,185.07
139.47	226,796,689.69	226,829,969.23	4,090,885,439.43	5,206.54	5,207.30
140.0	241,286,311.83	241,324,594.82	4,214,927,434.83	5,539.17	5,540.05
140.5	243,292,621.32	243,334,137.78	4,336,072,168.12	5,585.23	5,586.18
141.0	245,145,825.56	245,190,777.75	4,458,181,779.84	5,627.77	5,628.81

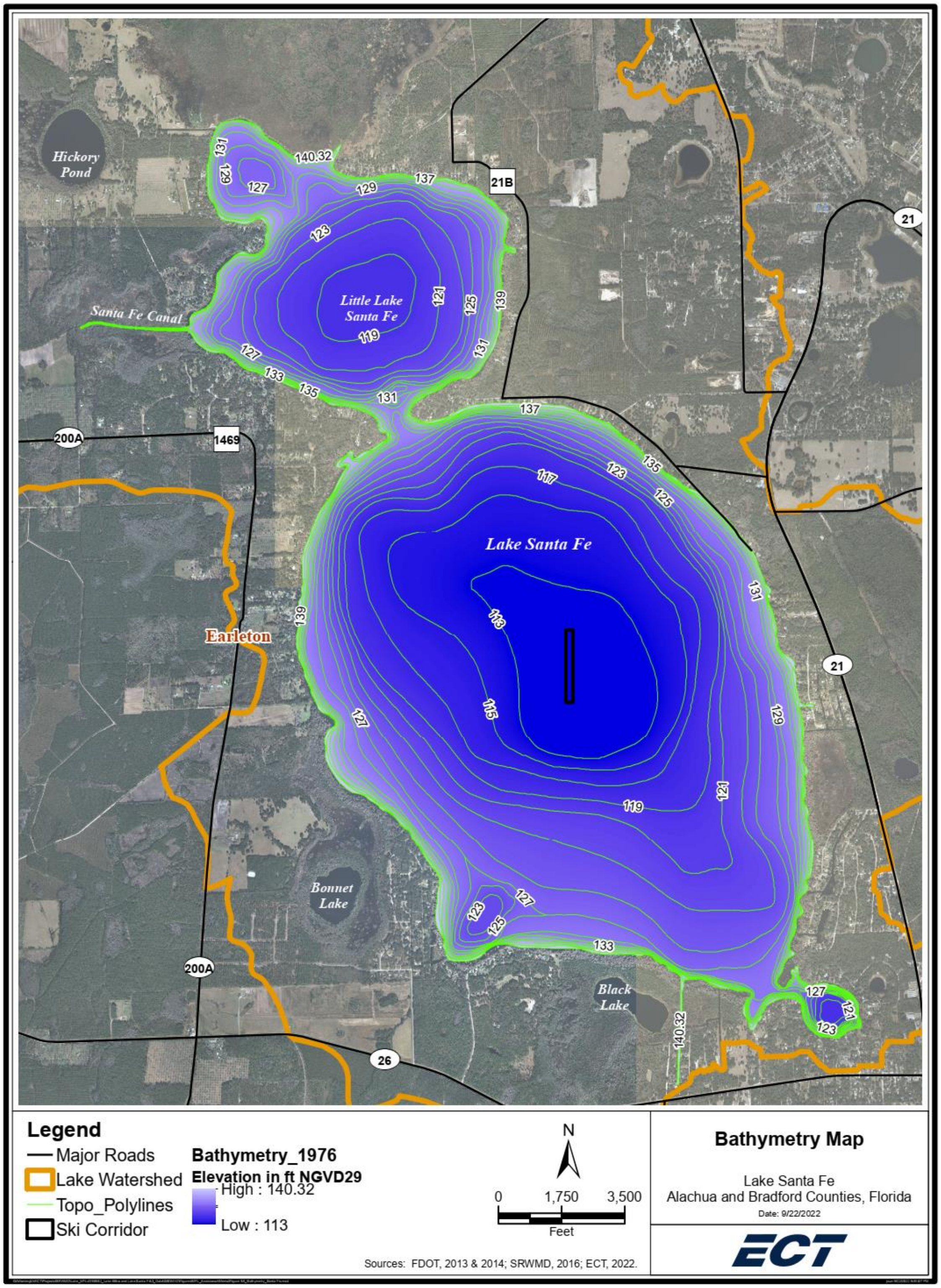

Figure 5A. Bathymetry map for Lake Santa Fe.

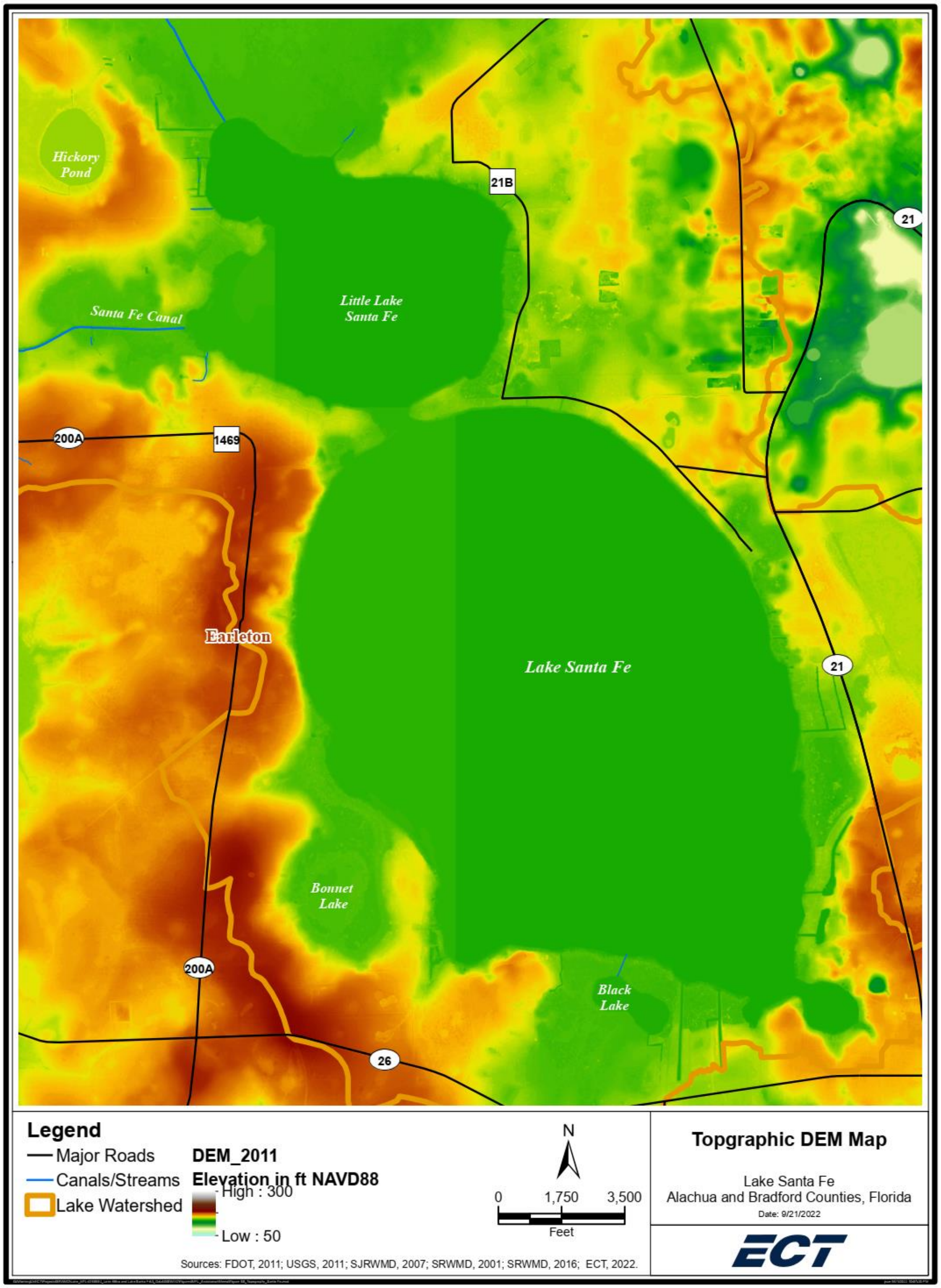

Figure 5B. Topography DEM map for Lake Santa Fe.

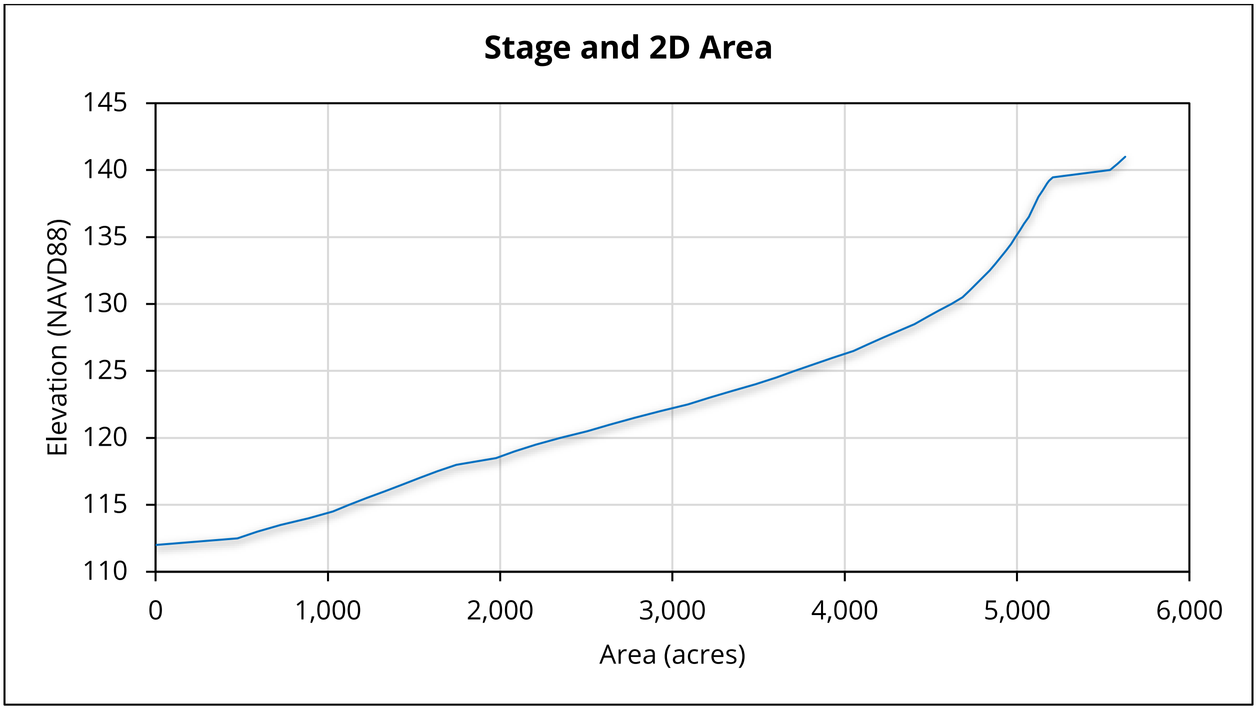

Figure 6. Lake stage to surface area (2D area) for Lake Santa Fe.

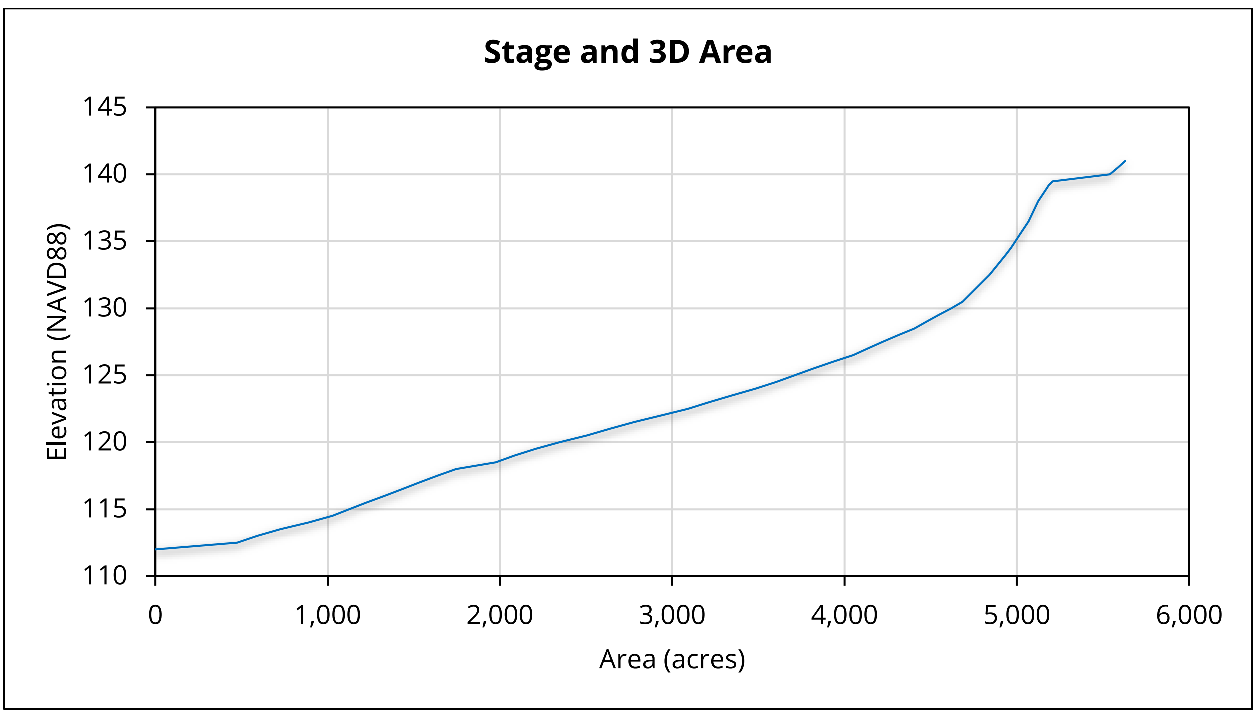

Figure 7. Lake stage to bottom area (3D area) for Lake Santa Fe.

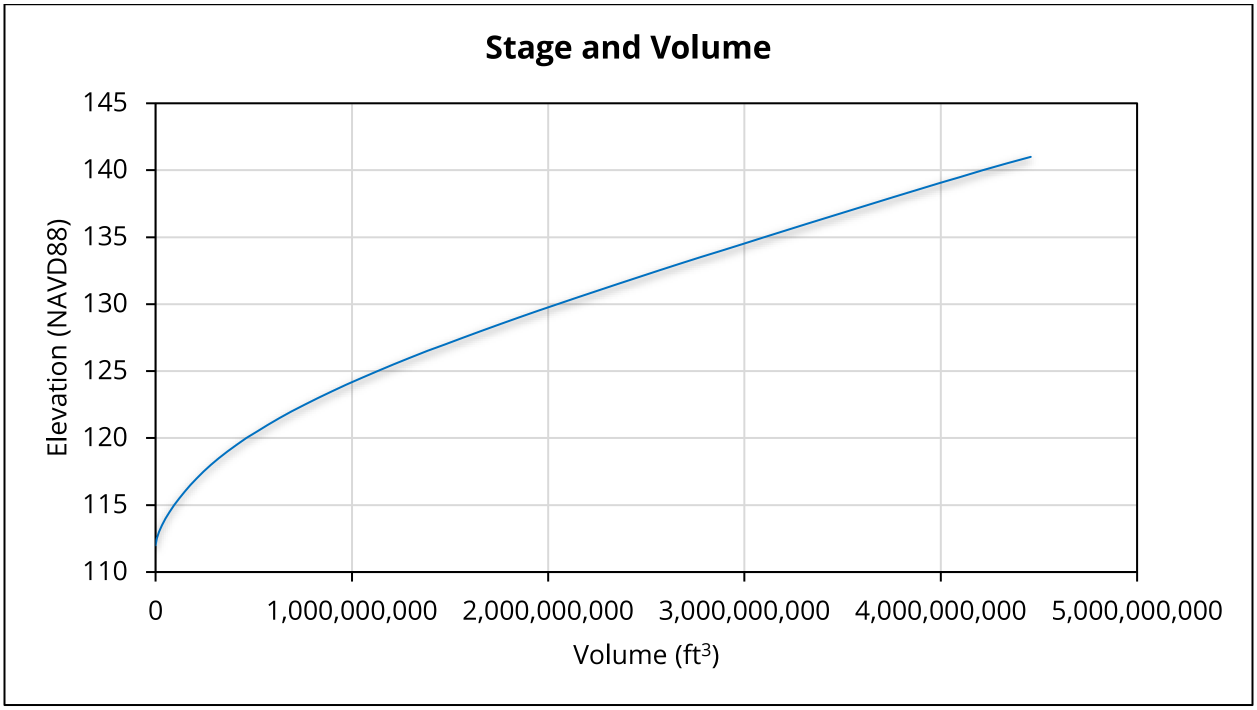

Figure 8. Lake stage to volume for Lake Santa Fe.

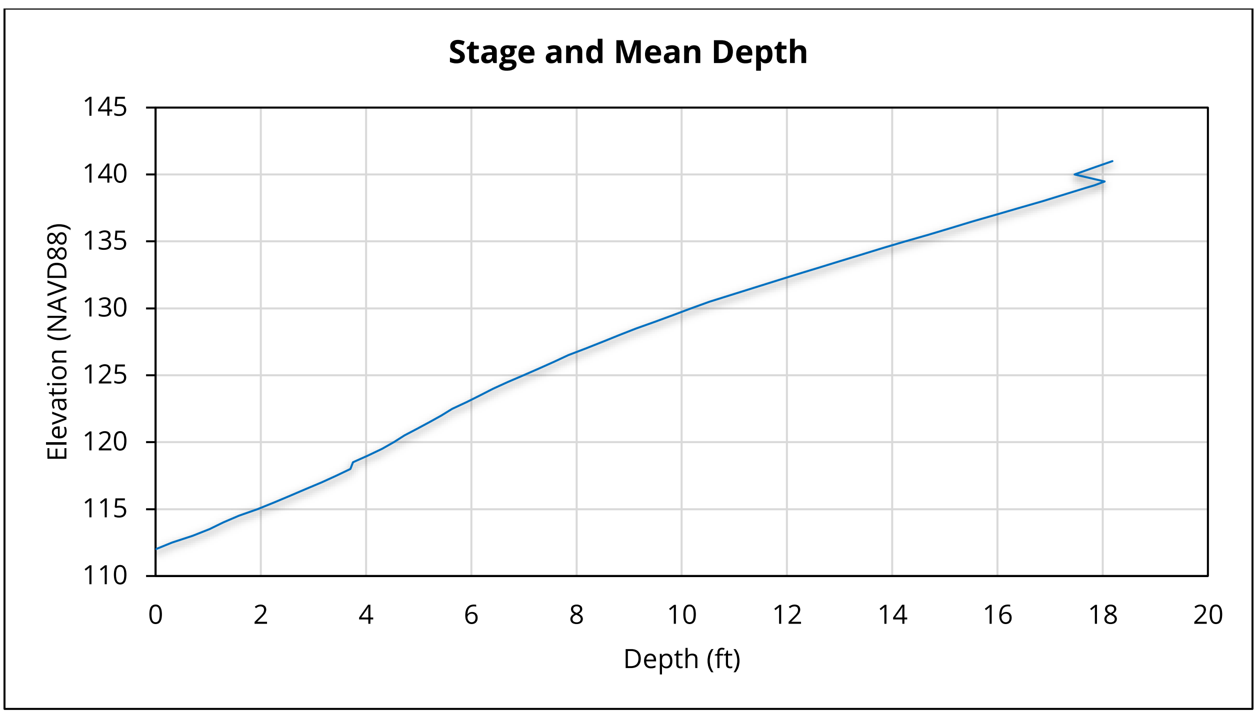

Figure 9. Lake stage to mean depth for Lake Santa Fe.

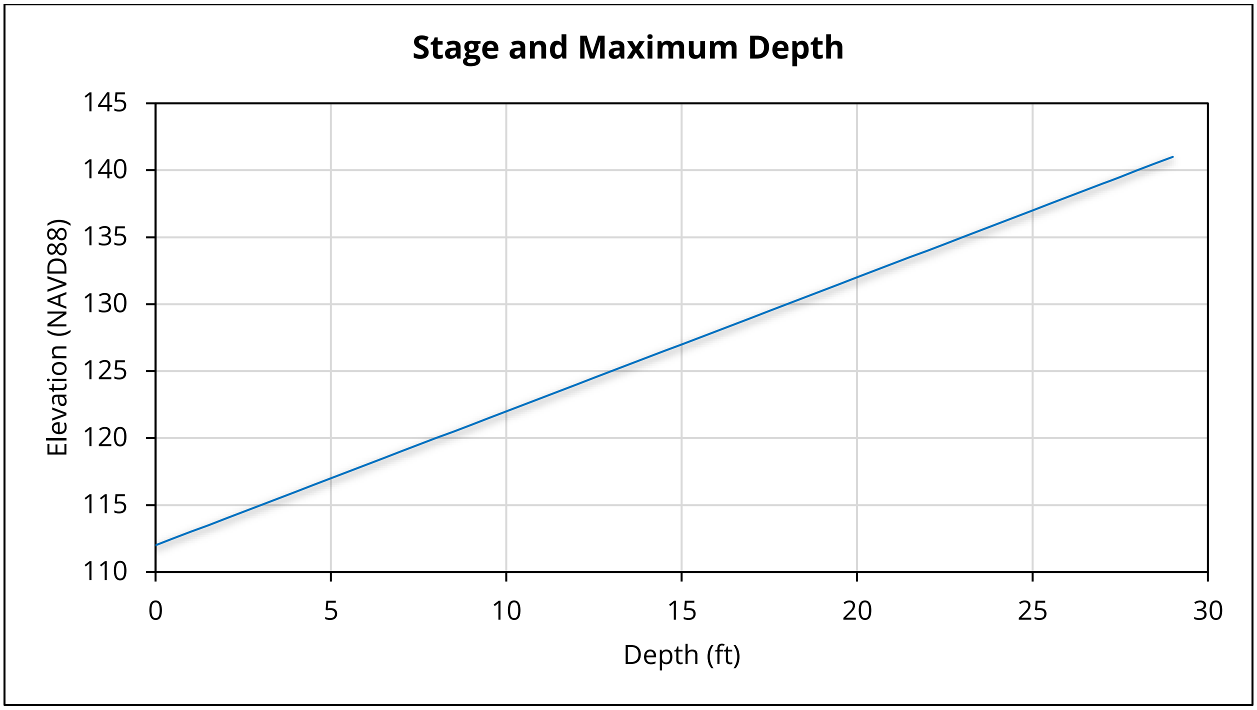

Figure 10. Lake stage to maximum depth for Lake Santa Fe.

2.3 HISTORIC NORMAL POOL ELEVATION, CONTROL POINT ELEVATION, AND STRUCTURAL ALTERATION STATUS

The Historic Normal Pool (HNP) elevation, a reference elevation used for development of minimum lake levels, is established based on the elevations of hydrologic indicators of sustained inundation. The indicators selected change slowly with changing hydrology, so they are considered useful for defining the Historic water level regime. The buttress inflection points on the trunks of *Taxodium spp.* are known to be reliable biologic indicators of historical hydrology (Carr *et al.* 2006). A total of 41 cypress buttress inflection points were surveyed and the average elevation of 140.74 ft NAVD88 represents the HNP elevation on Lake Santa Fe (Table 1).

For modeling purposes, the outfall for surface water for the system including Lake Santa Fe was defined as the Upper Santa Fe River, located north of Santa Fe Swamp. The "Control Point" elevation of 140.20 ft NAVD88 provided in Table 1 is an approximate elevation derived from the 2011 USGS topographic DEM data and adjusted through the model calibration process (ECT 2022a). The "Control Point" represents a natural overflow weir associated with the connection between the lake and the contiguous Santa Fe Swamp.

Structural alteration status is determined to support development of minimum and guidance levels and for the modeling of historic lake stage records. In addition to identification of outlet conveyance characteristics, comparison of the Control Point elevation and HNP elevation is typically used to determine if a lake has been structurally altered. If the Control Point elevation is below the HNP, the lake is classified as a structurally altered system. If the Control Point elevation is above the HNP and the lake has no outlet, the lake is not considered to be structurally altered. Based on the existence of the Santa Fe Canal that links Little Lake Santa Fe and Lake Alto (Figure 1) and given that the HNP of 140.74 ft NAVD88 is considerably higher than the Control Point elevation of 140.20 ft NAVD88 (Table 1), Lake Santa Fe was classified as structurally altered.

2.4 GUIDANCE LEVELS

2.4.1 HIGH GUIDANCE LEVEL

The High Guidance Level (HGL) is provided as an advisory guideline for construction of lakeshore development, water dependent structures, and operation of water management structures. The High Guidance Level is the expected Historic P10 of the lake and is established using historic data if it is available, or is estimated using the Current P10, the Control Point elevation and the Historic Normal Pool elevation. Based on the availability of historic lake stage data developed for Lake Santa Fe, the High Guidance Level was established at the Historic P10 elevation, 140.23 ft NAVD88. The recorded data at USGS 02320611 indicates that the highest level was 142.52 ft NAVD88 collected on September 14, 2017 (Figure 2).

2.4.2 LOW GUIDANCE LEVEL

The Low Guidance Level (LGL) is provided as an advisory guideline for water dependent structures, and as information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis. The level is established using Historic or Current lake stage data and, in some cases, Reference Lake Water Regime (RLWR) statistics. Based on the availability of Historic data for Lake Santa Fe, the Low Guidance Level was established at the Historic P90 elevation, 137.88 ft NAVD88. The recorded data at USGS 02320611 indicates the lowest lake level elevation was 134.86 ft NAVD88, in October 2002. The most recent record of the water level dropping below the Low Guidance Level was in May 2012, with a recorded level of 135.0 ft NAVD88 recorded at USGS 02320601 (Figure 2).

2.5 LAKE CLASSIFICATION

Lakes are classified as Category 1, 2 or 3 for the purpose of minimum lake levels development. Those with fringing cypress wetlands greater than 0.5 acres in size where water levels currently rise to an elevation expected to fully maintain the integrity of the wetlands (i.e., the Historic P50 is equal to or higher than the elevation 1.8 ft below the HNP elevation) are classified as Category 1 Lakes. Lakes with fringing cypress wetlands greater than 0.5 acres in size that have been structurally altered such that the Historic P50 elevation is more than 1.8 ft below the HNP elevation are classified as Category 2 Lakes. Lakes without fringing cypress wetlands or with cypress wetlands less than 0.5 acres in size are classified as Category 3 Lakes.

Lake Santa Fe meets the classification as a Category 1 lake, based on the presence of the lake-fringing cypress wetlands of 0.5 acre or more in size, and because the Historic P50 elevation of 139.43 ft NAVD88 is higher than the elevation 1.8 ft below the HNP elevation of 140.74 ft NAVD88.

2.6 SIGNIFICANT CHANGE STANDARDS

Category 3 lake standards (Leeper *et al.* 2001) were developed for comparative purposes but were not used for minimum levels development. The following sections summarize the supporting data and methodology utilized in the development of the seven significant change standards for Category 3 Lakes, including a Dock-Use Standard, a Wetland Offset Standard, an Aesthetics Standard, a Basin Connectivity Standard, a Species Richness Standard, a Recreation/Ski Standard, and a Lake Mixing Standard (Table 1). Potential changes in the coverage of herbaceous wetland vegetation and submersed aquatic plants are also discussed below.

2.6.1 DOCK-USE STANDARD

The Dock-Use Standard was estimated by calculating the P10 of dock sediment elevations, then adding 2 feet to that and adding the absolute difference between the HP90 and HP50 (i.e., 139.43 – 137.88 = 1.55 ft) to get the final standard.

The P10 of the 9 surveyed dock sediment elevations was 135.34 ft NAVD88 (Figure 11). Using the Dock-Use Standard formula, it gives a final Dock-Use Standard of 138.89 ft NAVD88.

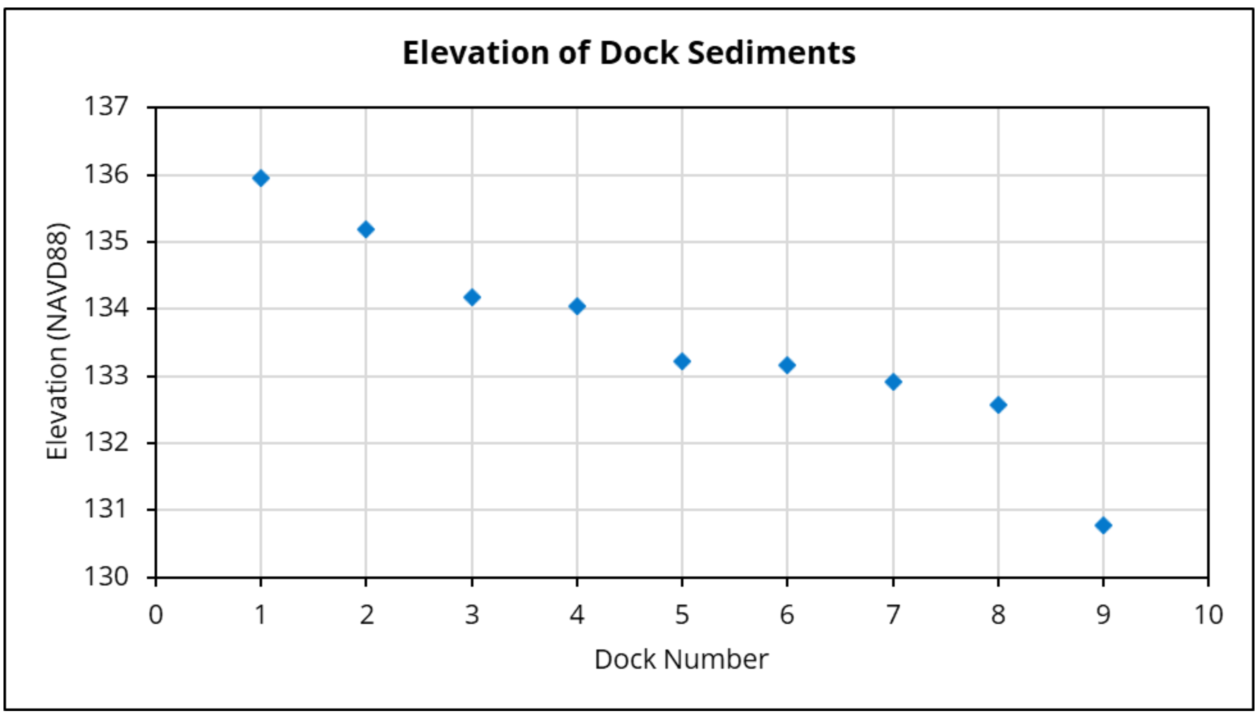

Figure 11. Elevation of dock sediments surveyed for Lake Santa Fe.

2.6.2 WETLAND OFFSET STANDARD

Based on an evaluation of the relationship of the Cypress Standard with the HP50 for hydrologically unimpacted cypress wetlands, the Wetland Offset Standard for Category 3 Lakes is established at an elevation 0.8 ft below the HP50 elevation (Hancock 2007).

The HP50 elevation was 139.43 ft NAVD88 for Lake Santa Fe. So, the Wetland Offset Standard was established at 138.63 ft NAVD88.

2.6.3 AESTHETICS STANDARD

The Aesthetic Standard was established at the Low Guidance Level, which was 137.88 ft NAVD88 for Lake Santa Fe.

2.6.4 BASIN CONNECTIVITY STANDARD

Using a depth profile in ArcGIS, we identified the saddle point between "Big" Lake Santa Fe and Little Lake Santa Fe as a basin connectivity critical elevation of 131.00 ft NGVD29 or 130.15 ft NAVD88 (Figure 12), and after adding in the HP90-HP50 difference and 2 feet, the final change standard was 133.70 ft NAVD88.

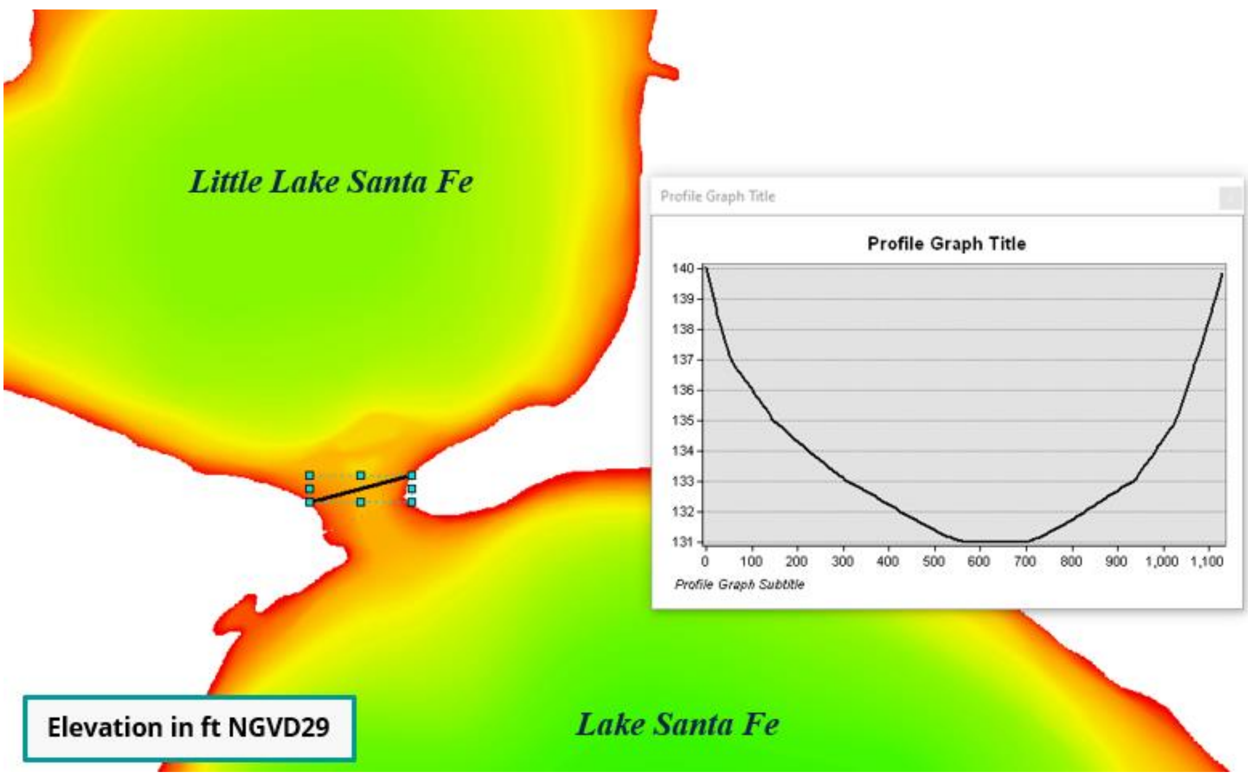

Figure 12. Identifying Saddle Area between Lake Santa Fe and Little Lake Santa Fe

2.6.5 SPECIES RICHNESS STANDARD

The Species Richness Standard was estimated by identifying what drop in elevation from the HP50 water elevation will result in a 15% change in lake area. Preventing a loss of 15% of the area is expected to preserve the species richness (i.e., number) of birds utilizing the lake based on previous empirical research (Bachmann and Hoyer 1999, Emery *et al.* 2009). Based on the stage-area relationship (Table 3 and Figure 6), the lake area at the HP50 elevation of 139.43 ft NAVD88 was estimated at 5,203.25 acres; and a 15% reduction in this area results in an area of 4,422.76 acres. By using linear interpolation method, the Species Richness Standard was established at an elevation of 128.63 ft NAVD88.

2.6.6 RECREATION/SKI STANDARD

The Recreation/Ski Standard was estimated using a rectangular corridor that was 2,000 feet x 200 feet in size aligned with the deepest part of the lake (Figure 5A). Using the Zonal Statistics tool in the Zonal toolset of the ArcGIS Spatial Analyst toolbox, the maximum elevation within the corridor was estimated at 113.00 ft NGVD29 or 112.15 ft NAVD88. Then, 5 feet and the difference of the HP90 and HP50 (1.55 ft) were added to establish the Recreation/Ski Standard at 118.70 ft NAVD88.

2.6.7 LAKE MIXING STANDARD

We calculated the Lake Mixing Standard by calculating the dynamic ratio (Bachmann *et al.* 2000) at the maximum elevation listed in Table 3, then gradually lowering it to see when the ratio changes from either above 0.8 to below 0.8, or from below 0.8 to above 0.8. More detailed methods included the following:

1. Converted lake surface area (2D area in Table 3) from ft^2 to km^2.
2. Mean depth in feet calculated as volume in ft^3/2D area in ft^2.
3. Converted mean depth in feet to meters.
4. Dynamic Ratio calculated as (sqrt(lake 2D area in km^2))/(mean depth in meters).
5. Repeated steps 1 through 4 for each elevation listed in Table 3 and any new elevations to have a Dynamic Ratio of 0.8, if needed.

The dynamic ratio calculation results for selected lake stages are listed in Table 4. Figure 13 illustrates the relationship of lake stage versus dynamic ratio for Lake Santa Fe. We concluded that all dynamic ratio values were greater than 0.8 for the available elevation data for Lake Santa Fe. So, no Lake Mixing Standard was developed.

The implication of ratio values above 0.8 is that all areas of the lakebed are subject to disturbance by wind-driven waves at least some of the time due to the large surface area relative to depth (Bachmann *et al.* 2000). Lower water surface elevations would not be predicted to change this situation.

Table 4. Lake Stage and Dynamic Ratio for Lake Santa Fe.

Elevation (ft NAVD88)	2D Area (ft^2)	Volume (ft^3)	Mean Depth (meter)	2D Area (km^2)	Dynamic Ratio
113	25,743,881.12	18,156,677.01	0.21	2.39	7.19
115	48,973,092.33	94,545,066.86	0.59	4.55	3.62
120	102,254,234.58	463,054,872.78	1.38	9.50	2.23
125	161,603,982.83	1,130,310,819.63	2.13	15.01	1.82
130	201,157,976.49	2,046,654,726.65	3.10	18.69	1.39
135	217,404,444.90	3,098,812,125.65	4.34	20.20	1.03
136	219,587,153.80	3,317,300,895.73	4.60	20.40	0.98
137	221,553,501.70	3,537,994,241.59	4.87	20.58	0.93
138	223,183,924.60	3,760,353,772.08	5.14	20.73	0.89
139	225,401,407.26	3,984,657,329.07	5.39	20.94	0.85
140	241,286,311.83	4,214,927,434.83	5.32	22.42	0.89
141	245,145,825.56	4,458,181,779.84	5.54	22.77	0.86

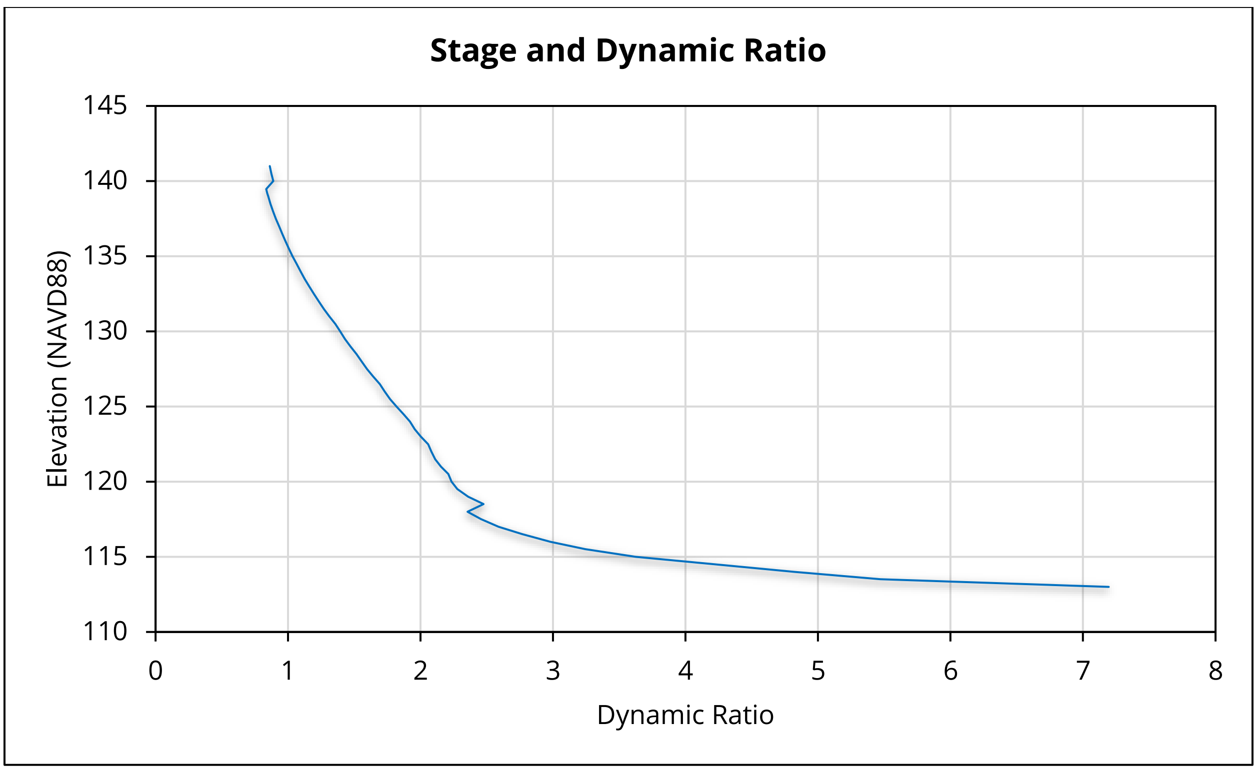

Figure 13. Lake stage to dynamic ratio for Lake Santa Fe.

2.6.8 HERBACEOUS WETLANDS INFORMATION FOR CONSIDERATION

The herbaceous wetland information was evaluated by identifying the lake bottom area (3D area) less than 4 feet deep at the median water level (HP50), then plotting how that area changes with lowered depth.

As shown in Figure 14, a change in the median water level from the HP50 (139.43 ft NAVD88) to a lower level proposed here as the Minimum Lake Level (138.89 ft NAVD88) would be expected to result in a 22.45-acre decrease in the potential herbaceous coverage, from 206.34 to 183.89 acres, which is 0.4% of the total lake bottom area at the HP50 of 5,219.00 acres. At lake levels below 137.0 ft NAVD88, we found increasing area available for herbaceous wetland. Based on the gradual slope of the function on the graph, lower water levels below 135.0 ft NAVD88 would result in relatively large potential increases of herbaceous coverage relative to changing lake stage.

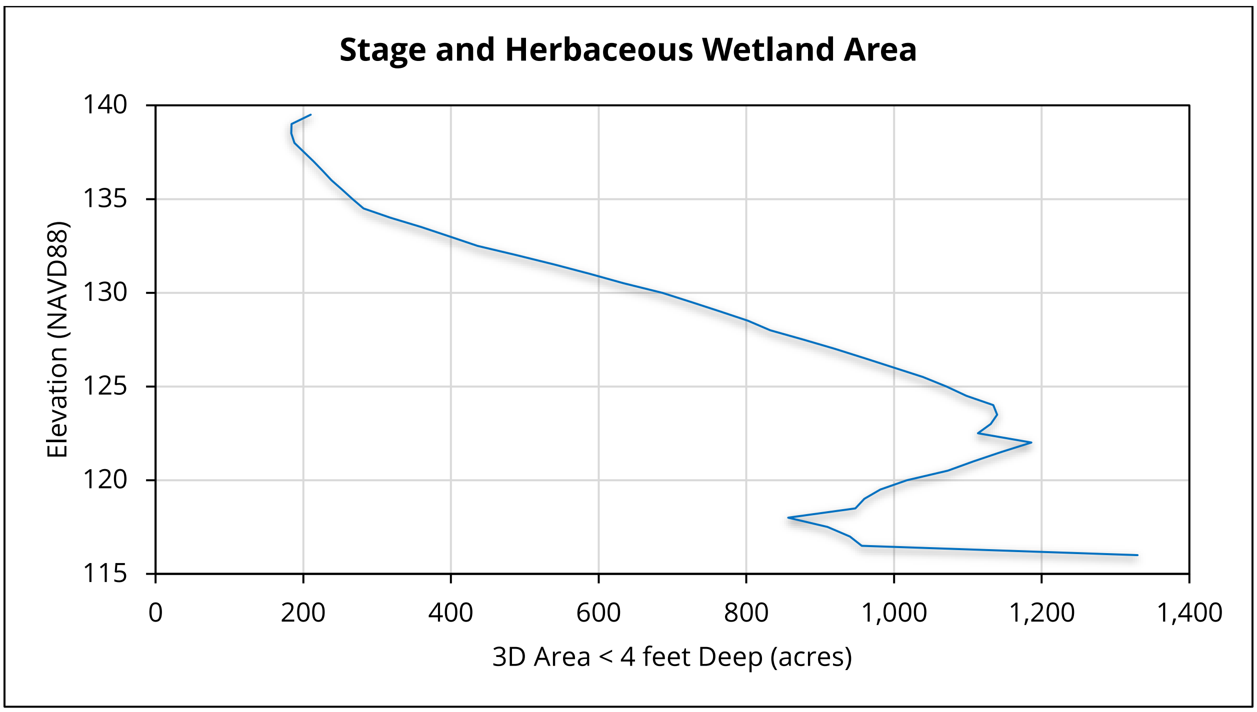

Figure 14. Lake stage to herbaceous wetland area for Lake Santa Fe.

2.6.9 SUBMERSED AQUATIC MACROPHYTE INFORMATION FOR CONSIDERATION

Changes in lake stage associated with changes in area available for colonization by rooted submersed macrophytes are evaluated, based on water transparency values.

Secchi disk data for Lake Santa Fe and Little Lake Santa Fe was assembled by the District and provided to ECT, including the water quality data retrieved from the U.S. Environmental Protection Agency (USEPA) Water Quality Portal (WQP) and Florida Department of Environmental Protection (FDEP) Watershed Information Network (WIN) and STORET Public Access (SPA) databases (USEPA

2022, FDEP 2022a & 2022b). Since sample sites were georeferenced, Secchi disk data from the two lake lobes were separated using ArcGIS, eliminating any measurements made in the saddle between the lakes and the Melrose Bay (Figure 15).

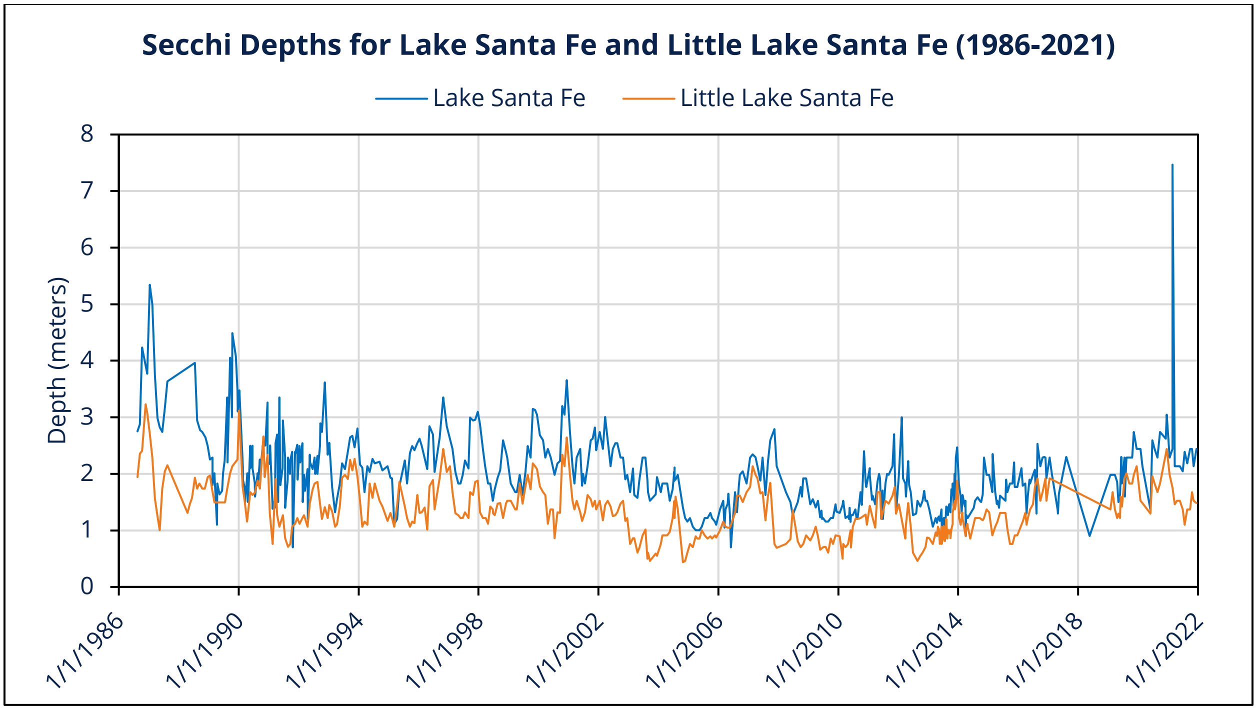

Figure 15. Secchi disk depths for Lake Santa Fe and Little Lake Santa Fe.

As shown in Figure 15, Lake Santa Fe has experienced consistently better visibility over the period of record than Little Lake Santa Fe, based on a total of 1,329 records for Lake Santa Fe and 1,162 records for Little Lake Santa Fe that were retrieved for the period of record (POR) of 8/16/1986 through 12/31/2021. The data were collected by Lakewatch volunteers, FDEP, SRWMD, and North American Lake Management Society (NALMS) personnel. Daily means were determined for those records occurring on the same date for both lake lobes, thus paring the data to 512 records (an outlier of 7.47 meters occurred on 2/24/2021 was removed, Figure 16). All Secchi depth data were converted to metric equivalents (Figures 15 & 16).

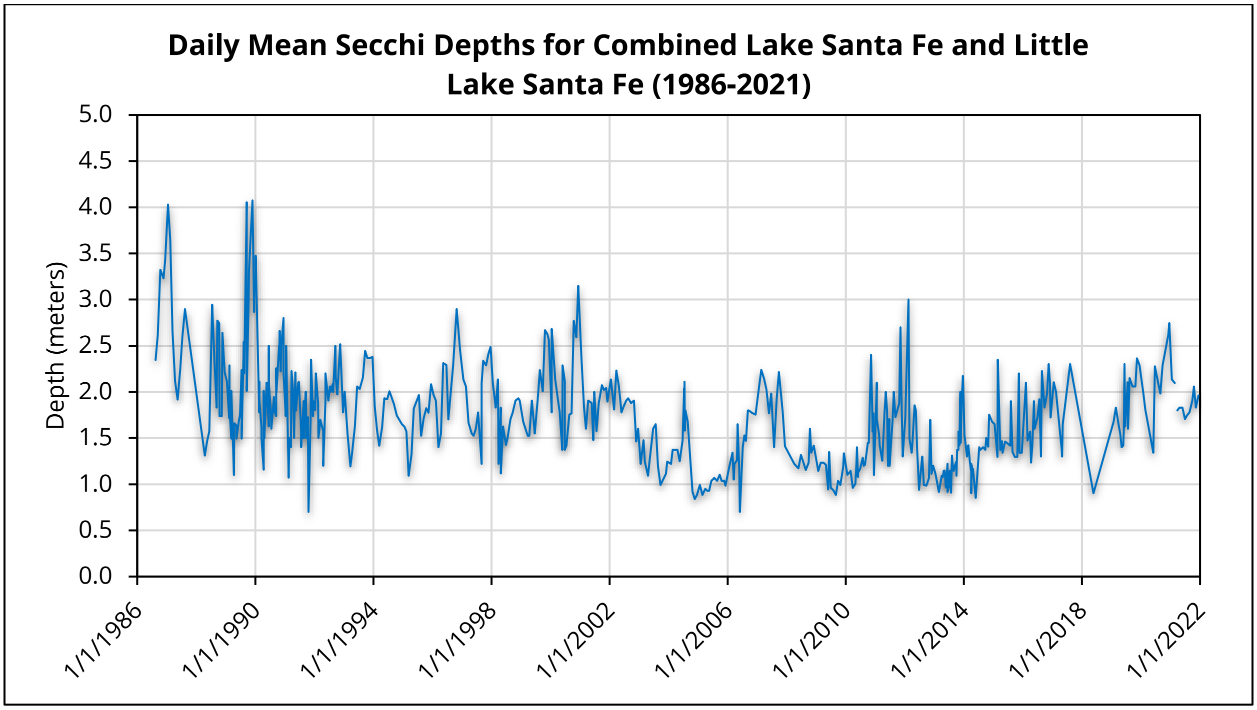

Figure 16. Mean daily Secchi disk depths for Combined Lake Santa Fe and Little Lake Santa Fe.

Based on an apparent downward trend in Secchi disk depths, the data prior to 1/1/2002 has relatively higher transparency than the later records and hence been eliminated from the data set for the subsequent analysis. The daily mean for each unique date during a 20-yr period of 1/1/2002 through 12/31/2021 (n=280) was used to estimate an overall mean Secchi disk depth of 1.51 meters (Figure 16). This value was used as a variable in the maximum depth of colonization (MDC) equation provided below (Caffrey 2006).

Log10(MDC) = 0.66 * log10(1.51) + 0.30 = 0.418125-> 10^X = 2.62 meters or 8.59 feet

For the lake bathymetry (Table 3 and Figure 10), we concluded that the estimated MDC value of 8.59 ft, say 8.5 ft, was not deep enough to support submersed aquatic vegetation (SAV) colonization for the entire lake bottom. As a result of SAV having the potential to grow within an MDC of 8.5 ft, the change in area that is available for SAV colonization is a function of lake stage versus lake bottom area (i.e., 3D area) less than 8.5 ft deep (Figure 17). A change from the HP50 elevation (139.43 ft NAV88) to a lower level proposed as the Minimum Lake Level (138.89 ft NAVD88) would essentially have no change in the coverage of SAV with approximately 0.48 acres decrease from 500.19 to 499.71 acres. At lower lake levels, we found increasing area available for SAV colonization, but no abrupt change occurred in the area available for SAV colonization when lake level is above 126.0 ft NAVD88.

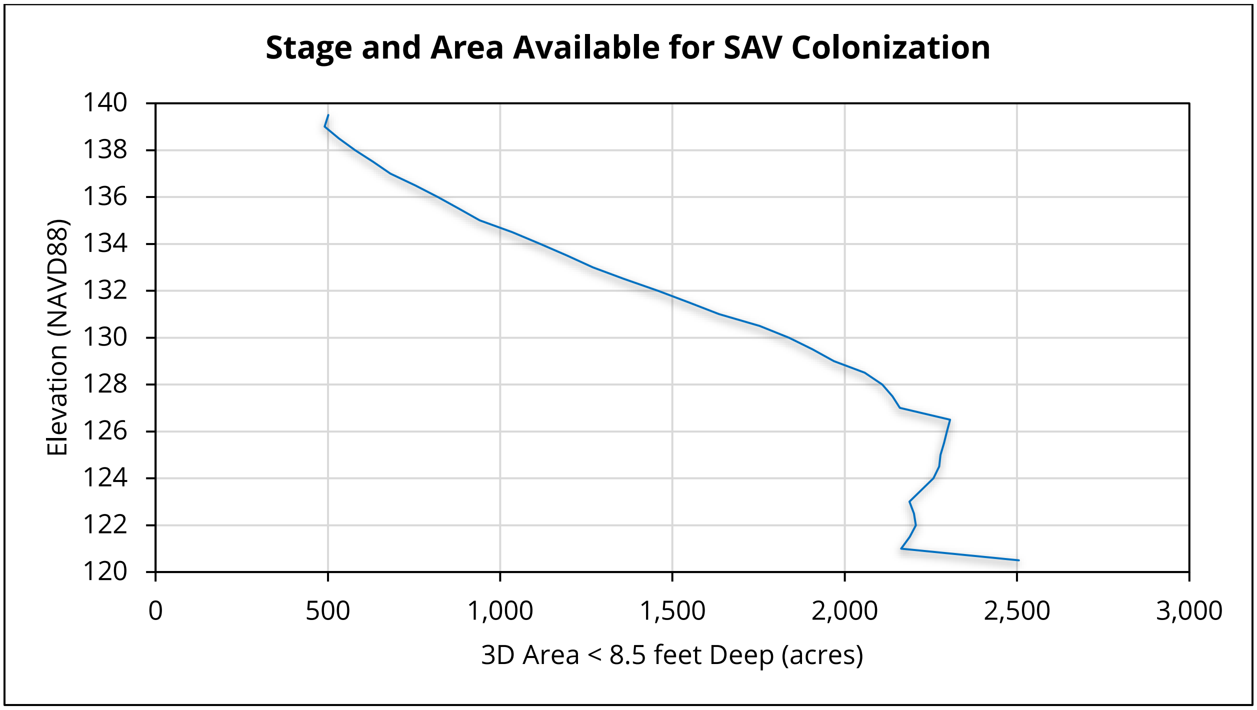

Figure 17. Lake stage to area available for SAV colonization for Lake Santa Fe.

2.7 MINIMUM LEVELS

The minimum levels based on Category 3 Lake standards described above were developed for Lake Santa Fe for comparative purposes. Note that an event-based MFL approach developed by SJRWMD had been used to establish the MFLs for Lake Santa Fe (ECT 2022b).

2.7.1 MINIMUM LAKE LEVEL

Based on the SWFWMD methods, 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 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 MLL is established at the Historic P50 elevation (SWFWMD 2006). The MLL would be established at the Dock-Use Standard of 138.89 ft NAVD88, which is lower than the Historic P50, but higher than other significant change standards for Category 3 Lakes.

Based on the model simulated stage data set for the duration of 4/25/1960 through 12/31/2015, there is approximately 0.54 feet of “freeboard” above the MLL based on the median water level (HP50) of 139.43 ft NAVD88.

2.7.2 HIGH MINIMUM LAKE LEVEL

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 a Category 3 lake, the HMLL may be established using one of two methods. The High Minimum Lake Level is established at the elevation corresponding to the Minimum Lake Level plus the difference between the Historic P10 and the Historic P50, or alternatively, the HMLL is established at the elevation corresponding to the MLL plus the RLWR value. Due to the availability of Historic percentiles (Tables 1 and 2), the HMLL would be established using the first method, resulting in a HMLL of 139.69 ft NAVD88. This elevation accounts for a natural fluctuation of lake levels.

The proposed minimum lake levels are shown with the model simulated lake stage hydrograph for the duration of 4/25/1960 through 12/31/2015 in Figure 18.

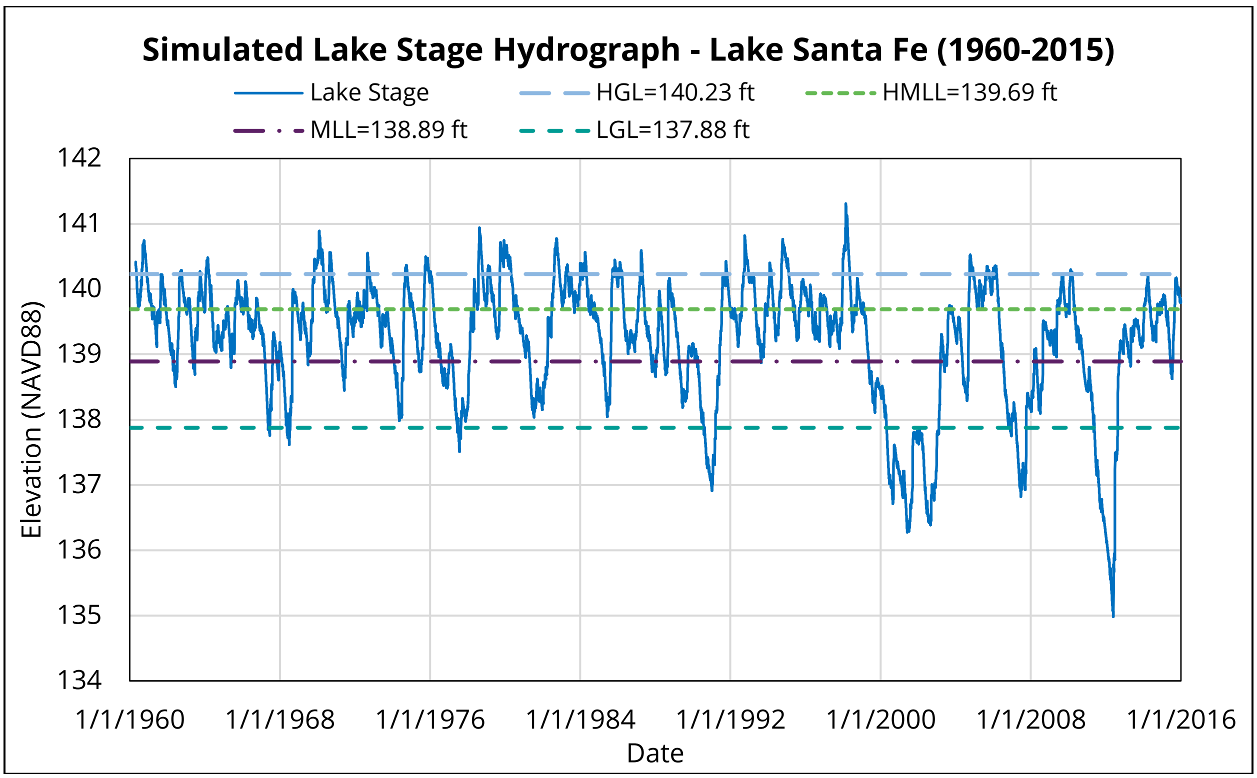

Figure 18. Hydrograph for simulated stage data from 4/25/1960 to 12/31/2015 with guidance and minimum lake levels for Lake Santa Fe.

3.0 SUMMARY

Following the SWFWMD methodology for Category 3 Lakes, the Minimum and Guidance Levels have been evaluated for Lake Santa Fe, as summarized in Table 5.

The HMLL of 139.69 ft NAVD88 is recommended to be achieved at least 10% of the time to ensure that the lake reaches higher levels on a periodic basis. The minimum level of 138.89 ft NAVD88 is recommended to be achieved at least 50% of the time to prevent significant deleterious ecological changes from occurring in the lake system. Based on the time period analyzed (4/25/1960 through 12/31/2015), both the MLL and HMLL are being met.

Additional elevations presented in Table 5 represent guidance levels (Leeper *et al.* 2001, Rule 40D-8.021, F.A.C.). Specifically, the High Guidance Level (HGL) represents a high water elevation only exceeded 10% of the time based on historic data, and the Low Guidance Level (LGL) is a low water level achieved 90% of the time over the historic period of record. These guidance levels do not represent regulatory elevations, but they may be useful for planning purposes such as dock construction.

Table 5. Minimum and guidance levels for Lake Santa Fe.

Level	Recommended Elevation (ft NAVD88)	Level Description
High Guidance Level (HGL)	140.23	Advisory guideline for construction of lake shore development, water dependent structures, and operation of water management structures. The HGL is the elevation that lake stage is expected to equal or exceed 10% of the time on a long-term basis.
High Minimum Lake Level (HMLL)	139.69	Elevation that lake stage is required to equal or exceed 10% of the time on a long-term basis.
Minimum Lake Level (MLL)	138.89	Elevation that lake stage is required to equal or exceed 50% of the time on a long-term basis.
Low Guidance Level (LGL)	137.88	Advisory guideline for water dependent structures, information for lakeshore residents, and operation of water management structures. The LGL is the elevation that lake stage is expected to equal or exceed 90% of the time on a long-term basis.

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