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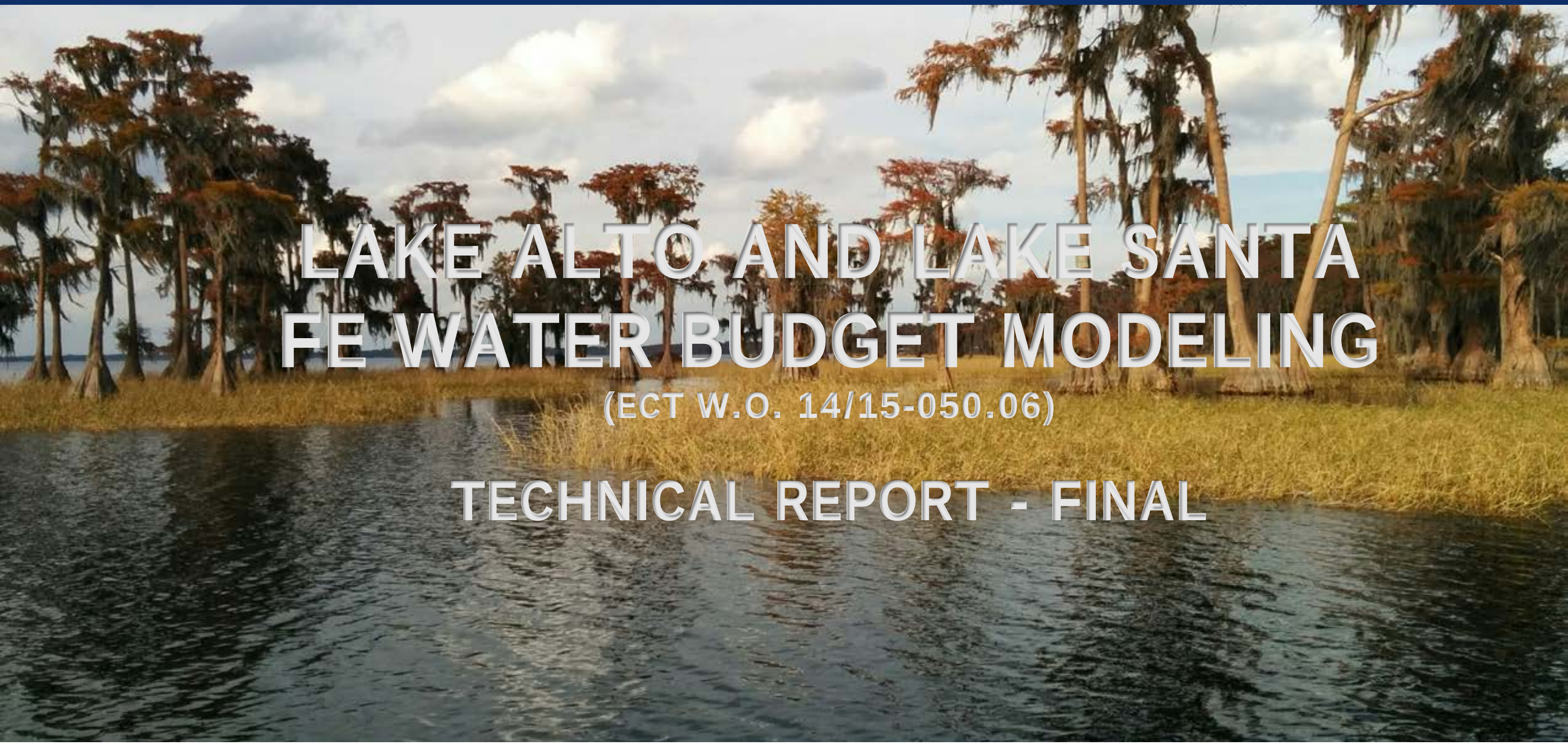

LAKE ALTO AND LAKE SANTA FE WATER BUDGET MODELING

(ECT W.O. 14/15-050.06)

TECHNICAL REPORT - FINAL

Suwannee River Water Management District
9225 CR 49
Live Oak, FL 32060

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COMPLEX CHALLENGES . . . PRACTICAL SOLUTIONS

Document Review

The technical contents of the Lake Alto and Lake Santa Fe Water Budget Modeling Technical Report represent our professional interpretations and are arrived at in accordance with generally accepted hydrologic, hydrogeologic, hydraulic, and engineering practices. The findings and results of this report are for the sole use and benefit of Suwannee River Water Management District. Utilization of this report by other parties is at their risk, and Environmental Consulting & Technology, Inc. is not liable for consequences or damages extending therefrom.

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List of Acronyms and Abbreviations

°F	degree Fahrenheit
cfs	cubic feet per second
CMP	corrugated metal pipe
DEM	digital elevation model
ECT	Environmental Consulting & Technology, Inc.
EPA	U.S. Environmental Protection Agency
ET	Evapotranspiration
FAS	Floridan Aquifer System
FDOT	Florida Department of Transportation
FFWCC	Florida Fish and Wildlife Conservation Commission
FH	minimum frequent high
FL	minimum frequent low
ft	foot
GFY	George F. Young, Inc.
GPI	Greenmen-Pedersen, Inc.
in	inch
LiDAR	Light Detection and Ranging
LOC	Line of Organic Correlation
MA	minimum average
MFLs	minimum flows and levels
NAVD	North American Vertical Datum
NEXRAD	Next-Generation Radar
NFSEG	North Florida Southeast Georgia
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
ORNL	Oak Ridge National Laboratory
PET	potential evapotranspiration
RET	reference evapotranspiration
RCP	reinforced concrete pipe
RMSE	root mean square error
SJRWMD	St. Johns River Water Management District
SRWMD	Suwannee River Water Management District
SWMM	Storm Water Management Model
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
yr	year

1.0 Executive Summary

In support of the establishment of Minimum Flows and Levels (MFLs) at Lake Alto and Lake Santa Fe, a water budget model is desired by the Suwannee River Water Management District (SRWMD or District) to assess hydrologic changes in these two lake systems. The complexity of the lake hydrologic system, especially as it relates to the upper Floridan aquifer system (FAS) and surface water connection between these two lake systems, requires a predictive computer model to adequately examine the effects of hydrologic changes. The selected modeling tool, Storm Water Management Model (SWMM) Version 5.1, has been successfully employed as a useful tool for the water budget modeling of Lake Butler and Lake Hampton by the District and Environmental Consulting & Technology, Inc. (ECT) in 2016. The SWMM model is capable of performing long-term continuous simulation that involves a full hydrologic cycle, such as rainfall, evapotranspiration (ET), surface runoff, infiltration/percolation, and surface water/groundwater flow exchange.

The District has authorized ECT to undertake the water budget modeling project. Based on results of data collection/review and site visits, a lake water budget model was developed and calibrated to be used to predict hydrologic changes in various water resources development scenarios. The major modeling tasks include: 1) Task 3 - Model Development; 2) Task 4 - Model Calibration; 3) Task 5 - Long-term Model Simulation, and associated document preparation and project meetings, as briefly described below.

<u>Task 3. Model Development</u>

The SWMM Version 5.1 developed by the U.S. Environmental Protection Agency (EPA) was selected by the District and ECT staff to assess long-term hydrologic changes at Lake Alto and Lake Santa Fe.

The Light Detection and Ranging (LiDAR) topographic data in the digital elevation model (DEM) format was provided by the District and used to develop the required model parameters, with the supplementation of the topographic survey at various cross-sections and drainage structures. The model was geo-referenced to the projection coordinate system "NAD_1983_ HARN_StatePlane_Florida_North_FIPS_0903_Feet", as specified in the project scope of work.

Task 4. Model Calibration

The water budget model was calibrated by comparing the model simulated lake stage against the known gage data. Multiple model parameters were adjusted within reasonable ranges to achieve the best overall fit of the model estimate with the observed data at Lake Alto and Lake Santa Fe.

The lake stage gage data from 2006 through 2015 was used in the model calibration task. Based on the comparison of simulated and observed lake stage hydrographs, the model calibration was successfully executed. The primary criterion for acceptable model calibration is 0.5 foot or less root mean square error.

Task 5. Long-term Model Simulation and "Hybrid" Data Method

Once the District accepted the model calibration of the water budget model, the model was used to perform a long-term simulation of a total of 32.7 years from May 1, 1983 through Dec 31, 2015. It was assumed the current groundwater withdrawals from the upper FAS and the existing land use were the same throughout the entire simulation span. The historical groundwater well records were evaluated through a double-mass curve analysis to study historical ground water level fluctuations.

The 32.7-year model period includes three significant droughts, including the 2000-2002, 2006-2008, and 2011-2012 drought periods. The lake stage data during that period do not adequately represent the longer lake stage data record. To include a more representative record, a "hybrid" lake stage data set was used that combined the 32.7-year model period with the historical lake stage data prior to May 1, 1983, for Lake Alto and Lake Santa Fe.

Based on the St. Johns River Water Management District (SJRWMD) MFLs method, frequency analysis of the "hybrid" lake stage data sets, i.e., a combination of the 32.7-year long-term model results and historical observed/calculated gage data prior to May 1, 1983, was conducted to determine whether or not the draft Lake MFLs recommended by the District are being met. All the recommended minimum frequent high, minimum average, and minimum frequent low levels are being met under 2006 hydrologic conditions for Lake Alto and Lake Santa Fe. The 2006 hydrologic conditions refer to a hypothetical case where the long-term model simulation assumes land use and average groundwater withdrawals at 2006 levels. The main reasons for selecting the 2006 hydrologic conditions are: 1) the 2006 land use data was utilized in development of the water budget model; and 2) no significant land use changes and/or water resource development occurred in the Lake Alto and Lake Santa Fe watershed since 2006.

The Lake Alto and Lake Santa Fe water budget model as well as the historical gage data were used to determine the limit of the upper FAS potentiometric elevation at which the recommended MFLs will no longer be complied for Lake Alto and Lake Santa Fe. For this determination, model simulations were performed assuming the upper FAS potentiometric elevation to be lower than the 2006 hydrologic conditions. Model simulations were continued by gradually lowering the upper FAS potentiometric elevation value, the historical lake stage data prior to May 1, 1983 was also adjusted accordingly, until the recommended MFLs were tripped (i.e., exceeded). Based on the analysis results, the recommended MFLs would be met with a maximum potentiometric elevation decline of 7.0 feet for Lake Alto and 16.0 feet for Lake Santa Fe in the upper FAS beyond 2006 hydrologic conditions.

Task 6. Draft Report

The draft project report presents all model assumptions, parameterizations, and model inputs utilized in the model development, model calibration, and long-term model simulations performed during the previous tasks. The model input/output data and associated supporting data and documents are being submitted to the District along with the draft report.

Task 7. Final Report

The final project report was prepared by addressing the District's review comments on the draft project report and any model updates performed during this task. The final model input/output data and associated supporting data and documents are being submitted to the District along with the final report.

2.0 Watershed Description

2.1 General Description

Lake Alto and Lake Santa Fe are located in northeastern Alachua County, Florida (Figure 2-1). Lake Alto, also known as Lake Altho, has an area of approximately 573 acres at typical water level elevations (Alachua County, 2014). Lake Alto is bounded by Lake Alto Swamp to the north. The eastern part of Lake Alto Swamp, named as Lake Alto Preserve, is currently co-owned by SRWMD and Alachua County. A county-owned park, Lake Alto Park, is located at the east lake bank, just south of Lake Alto Preserve. A boat ramp in this park can provide access to the lake for boats. Another public access point is the boat ramp located in Waldo Canal Park through the Waldo Canal that was originally dredged in the 1880s. Another man-made canal, the Santa Fe Canal, was dredged in the 1870s and 1880s to connect Lake Alto into Lake Santa Fe to the east (Figure 2-1). The Waldo Canal and Santa Fe Canal were primarily used to connect Waldo, the railroad terminal, and Melrose (at the time the center of a thriving citrus and tourist industry).

Lake Santa Fe is the headwater of the Santa Fe River and is designated as an Outstanding Florida Water. It has an area of approximately 5,200 acres at a water elevation of 139.47 ft-NAVD 1988, according to the bathymetric map created by SRWMD in 1976. The “little” northern area of Lake Santa Fe is also referred to as Little Lake Santa Fe, which is separated from its “big” southern arm by a pass that is just 1,000 feet in width and approximately 10 feet in depth. Little Lake Santa Fe has an area of approximately 1,135 acres or 22% of the overall lake surface of Lake Santa Fe. Little Lake Santa Fe is bounded by Santa Fe Swamp to the north. A majority of Santa Fe Swamp, also known as Santa Fe Swamp Conservation Area, is managed by SRWMD in cooperation with the Florida Fish and Wildlife Conservation Commission (FFWCC). The SRWMD management activities include small scale prescribed burning in the growing seasons on the west and east sides of the Santa Fe Swamp tract, as well as timber harvesting during most months of the year.

Several small lakes and wetland areas, such as Hickory Pond, Bonnet Lake, and Black Lake, discharge to Lake Santa Fe through streams, culverts, and/or overland flows (Figure 2-1). Santa Fe Lake Park, managed by Alachua County, is located at the south lake bank near Melrose, Florida. A boat ramp at the north side of the park can be used to launch boats.

To avoid further confusion, Lake Santa Fe at this point and thereafter refers to the "big" southern portion of the lake system, unless otherwise specified.

The Lake Alto and Lake Santa Fe watershed (the lake watershed), including the three major lakes and their contributing drainage areas, encompasses a total area of approximately 37,484 acres. Note that the lake watershed is primarily located in Alachua and Bradford counties and only the very small eastern portion is within Clay and Putnam counties (Figure 2-1).

The Santa Fe River, originating from Lake Santa Fe and Little Lake Santa Fe, is the surface water outfall of the lake watershed. Near its headwaters, the river has not developed a well-integrated surface water drainage system. Instead, the upper most reaches of the river and its tributaries are characterized by broad shallow lakes (i.e., Lake Alto, Lake Santa Fe, and Little Lake Santa Fe) and swamps (i.e., Lake Alto Swamp and Santa Fe Swamp). The Santa Fe River empties into the Suwannee River near Branford, Florida.

2.2 Climate

The climate in the lake watershed can be characterized by long, warm summers and relatively mild winters. In summer, the temperature is fairly uniform, in the upper 80s and lower 90s in the afternoon, and in the upper 60s to upper 70s late at night and early in the morning. In winter the temperature varies considerably. When cold fronts pass, the temperature often drops to 32 degrees or less late at night and early in the morning. Warm air from the south can raise the temperature to 80 ºF or more for several days (USDA, 1991).

The average annual rainfall in Bradford County is approximately 54.2 inches with a large part of this rainfall occurring in summer as locally heavy afternoon thundershowers. As much as 2 to 3 inches of rain can fall in an hour. Daylong rains in the summer are rare but occasionally occur when accompanying tropical depressions. These rains can be heavy and of long duration. As much as several inches of rain can fall in a 24-hour period. The annual frequency of tropical depressions ranges from none to several. Rainfall during the winter generally is more moderate. This precipitation usually occurs as cold fronts pass and can last from a few hours to a few days (USDA, 1991).

2.3 Topography

Topography in the lake watershed can be characterized as mildly sloping and poorly drained, as graphically presented in the topographic DEM and contour maps (Figures 2-2A and 2-2B). The topographic DEM and contours were developed based on the Light Detection And Ranging (LiDAR) topographic survey data provided by U.S. Geographical Survey (USGS) (NGC, 2011), St. Johns River Water Management District (SJRWMD), and SRWMD.

The highest land surface elevation of approximately 233 ft-NAVD is observed at northeast corner of the watershed. Isolated high land elevations of 170 ft-NAVD or greater are observed in the areas located south of the Santa Fe Canal and west of Lake Santa Fe (Figures 2-2A and 2-2B).

The bathymetric map of Lake Alto was provided in triangulated irregular network (TIN) format by SRWMD (Figure 2-2C). The bathymetric TIN data at Lake Alto was originally developed by Greenmen-Pedersen, Inc. (GPI) in 2014, based on their interior lake survey points and other related topographic data. The lake shoreline was estimated at 137.0 ft-NAVD and the lowest point is approximately 122.0 ft-NAVD at the south center of Lake Alto (Figure 2-2C).

The bathymetric maps of Lake Santa Fe and Little Lake Santa Fe were originally provided in scanned .TIFF format by SRWMD, on the basis of the survey data collected in 1976. Unfortunately, there is no recent bathymetric data available at these two lakes. The maps were georeferenced and digitized to ESRI shapefile format by ECT (Figure 2-2D). The shoreline of these two lakes was set at 140.32 ft-NGVD 1929 or 139.47 ft-NAVD. The lowest point at Lake Santa Fe is below 113.0 ft-NGVD or 112.15 ft-NAVD at the lake center and the lowest point at Little Lake Santa Fe is below 116.0 ft-NGVD or 118.15 ft-NAVD. The deepest point at the pass separating these two lakes was estimated at 131 ft-NGVD or 130.15 ft-NAVD, i.e., the water depth at this location is approximately 10 feet.

2.4 Soils

The most current soils data of Alachua, Bradford, Clay, and Putnam counties was directly downloaded from the Natural Resource Conservation Service (NRCS). The soils map for the lake watershed was created by assembling the soils data in these four counties (Figure 2-3). The various types of soils have been grouped into three soil texture classes, including Sand, Loamy Sand, and Sandy Loam. These soil texture classes are used in the hydrologic modeling analysis to estimate infiltration from rainfall, see Section 3.2.5 for details.

The Lake Alto and Lake Santa Fe watershed is classified as 49.4% for Sand, 15.5% for Loamy Sand, 18.2% for Sandy Loam, and the remaining 16.9% for water. A majority of the watershed is classified as Sand, most of which is located to the north, east, and west of the Lake (Table 2-1 and Figure 2-3).

Table 2-1. Statistical Summary of Soil Texture Classes in Lake Alto and Lake Santa Fe Watershed

Soil Texture Class	Area (acre)	Percentage
Sand	18,511.0	49.4%
Loamy Sand	5,813.5	15.5%
Sandy Loam	6,818.5	18.2%
Water	6,340.9	16.9%
Total	**37,483.8**	**100.0%**

Source: NRCS, 2016.

2.5 Land Use/Land Cover

The SRWMD 2006 land use coverage and SJRWMD 2004 land use coverage are both based on the Florida Land Use and Cover Classification System (FLUCCS, Florida Department of Transportation [FDOT], 1999). The 2004/2006 land use map for the lake watershed was created by merging these land use coverages in the SRWMD and SJRWMD jurisdictional limits, as presented in Figure 2-4.

The lake watershed is generally rural with limited developed land (residential, transportation, etc.), most of which is located surrounding the lakes and along the U.S. Hwy 301 corridor. As summarized in Table 2-2, the top three land uses in the lake watershed are upland forests (31.1%), wetlands (25.7%), and waters (15.6%).

Table 2-2. Statistical Summary of Land Use in Lake Alto and Lake Santa Fe Watershed

FLUCCS	Description	Area (acre)	Percentage
1000	Urban & Built-up	3,138.0	8.4%
2000	Agriculture	3,025.7	8.1%
3000	Rangeland	783.2	2.1%
4000	Upland Forests	11,668.8	31.1%
5000	Waters	5,849.2	15.6%
6000	Wetlands	9,651.9	25.7%
7000	Barren Lands	3,029.4	8.1%
8000	Transportation, Communication & Utilization	337.5	0.9%
	Total	**37,483.8**	**100.0%**

Source: SRWMD, 2006; SJRWMD, 2004.

2.6 Major Conveyance System

Lake Alto, Lake Santa Fe, and Little Lake Santa Fe receive surface flows from a watershed covering approximately 37,484 acres or 58.6 square miles, by means of flows emerging from the extensive forested wetlands that fringe the lakes, by direct precipitation and stormwater runoff from surrounding developed/undeveloped lands (Figure 2-4). The lake watershed can be further subdivided into five subwatersheds (Figure 2-5) including:

- Lake Alto Swamp
- Lake Alto
- Santa Fe Swamp
- Little Lake Santa Fe
- Lake Santa Fe

The major conveyance system for each of these five subwatersheds is briefly described in the subsequent sections.

2.6.1 Subwatershed: Lake Alto Swamp

The Lake Alto Swamp subwatershed is located in the northeast portion of Alachua County between Lake Alto and the Santa Fe River (Figure 2-5). This subwatershed encompasses a total area of approximately 4,905 acres or 7.7 square miles.

Inflow to the west side of the swamp is contributed by several major drainage systems that discharge the developed/undeveloped areas within the City of Waldo and unincorporated Alachua County. These drainage systems consist of dredged ditches and canals through the wetland areas between U.S. Hwy 301 and the railroad, as well as the roadway drainage systems of U.S. Hwy 301 and the railroad. The developed areas in the southern portion of the subwatershed, mostly located in the City, are discharged through a dredged canal between the railroad and Doan Road. Selected culverts along the major conveyance systems were inspected by ECT and the District staff and surveyed by George F. Young, Inc. (GFY) in the spring of 2017.

On the east side of the swamp, the contributing areas are mostly classified as undeveloped lands, including agriculture lands and upland forests that are drained through sheet flow, ditches, and/or the cross drains under State Road (S.R.) 325. Selected culverts across S.R. 325 were also surveyed by GFY.

The swamp primarily discharges to the Santa Fe River to the north by means of an outfall canal dredged through its lower northern portion. The southern portion of the swamp may also drain to Lake Alto directly through sheet flow and/or small defined flow paths during a major storm event (Figure 2-2A).

2.6.2 Subwatershed: Lake Alto

The Lake Alto subwatershed is located south of Lake Alto Swamp and west of Lake Santa Fe/Little Lake Santa Fe (Figure 2-5). This subwatershed encompasses a total area of approximately 2,184 acres or 3.4 square miles.

The southeast portion of the City of Waldo and Waldo Canal Park drains to the wetland areas adjacent to the west lake bank. The Waldo Canal, primarily used for navigation purpose, conveys stormwater runoff from the wetland area to the north into the lake.

Inflows to the south and east sides of the lake are contributed primarily by means of sheet flow, except for the low-density residential area to the east of the lake, where the stormwater runoff discharges through a secondary roadway drainage system and empties into a wetland area adjacent to the lake.

As described previously, the Santa Fe Canal was dredged to link Lake Alto to Little Lake Santa Fe. Depending on the lake levels in these two lakes, Lake Alto may discharge into or receive surface water from Little Lake Santa Fe. As this canal is not currently used for navigation purposes, vegetation overgrowth and siltation were observed at some shallow canal segments during a field trip conducted by ECT and SRWMD in December 2016. Upon evaluation of the cross-section and bridge survey data collected at this canal, the highest point of the canal is likely located east of the S.R. 325 bridge.

During extreme high water conditions, the lake may discharge to Lake Alto Swamp to the north, by means of sheet flow over the north lake bank.

2.6.3 Subwatershed: Santa Fe Swamp

The Santa Fe Swamp subwatershed is located north of Little Lake Santa Fe and east of Lake Alto Swamp. The subwatershed is mostly located in the southeast portion of Bradford County, with small portions in Alachua County and Clay County (Figure 2-5). This subwatershed encompasses a total area of approximately 17,590 acres (27.5 square miles), or 47% of the entire lake watershed.

Inflow to the north and northeast side of the swamp is contributed by Double Run Creek, an unnamed creek, and several small drainage systems that discharge mostly undeveloped contributing areas. These drainage systems consist of natural creeks and dredged ditches through the wetland areas north of County Road (C.R.) 18 and east of S.R. 100. Selected culverts along the major conveyance systems were surveyed by GFY.

On the east side of the swamp, the contributing areas are mostly undeveloped lands, including agriculture lands and upland forests, that are drained through sheet flow, ditches, and/or the roadway drainage system of S.R. 100 and C.R. 21B. Selected culverts along the drainage systems were surveyed by GFY.

On the west side of the swamp, the contributing areas are mostly agriculture lands and upland forests that are drained through sheet flow and ditches. Hickory Pond empties into the swamp through an outfall ditch and various culverts. One culvert in the outfall ditch was surveyed by GFY.

The swamp primarily discharges to the Santa Fe River to the northwest by means of sheet flow through forested wetland areas. No well-defined flow paths were identified near the outfall location. The southern portion of the swamp may drain into Little Lake Santa Fe through an unnamed stream and sheet flow during a major storm event, per the topographic map (Figure 2-2A).

2.6.4 Subwatershed: Little Lake Santa Fe

The Little Lake Santa Fe subwatershed is located between Santa Fe Swamp and Lake Santa Fe. Most of the subwatershed is located in the northeast portion of Alachua County, with a small portion in Bradford County (Figure 2-5). This subwatershed encompasses a total area of approximately 3,291 acres or 5.1 square miles.

Inflow to the east side of the lake is contributed by several roadway drainage systems that discharge to the wetland areas on the east side of C.R. 21B. One culvert under C.R. 21B was surveyed by GFY.

Inflow to the west side of the lake is contributed primarily by the Santa Fe Canal that discharges mostly undeveloped areas. A local drainage system is used to drain a small residential area on the southwest lake bank. A cross drain under S.R. 200A was surveyed by GFY.

As mentioned above, Little Lake Santa Fe exchanges surface water with Santa Fe Swamp to the north, Lake Alto to the west through the Santa Fe Canal, and Lake Santa Fe through the pass.

2.6.5 Subwatershed: Lake Santa Fe

The Lake Santa Fe subwatershed is located south of Little Lake Santa Fe. A majority of the subwatershed, including Lake Santa Fe itself, is located in the northeast portion of Alachua County, with the remaining portions located in Bradford, Clay, and Putnam counties (Figure 2-5). This subwatershed encompasses a total area of approximately 9,513 acres or 14.9 square miles.

Inflow to the east side of the lake is contributed by multiple local drainage systems that discharge the undeveloped areas on the east side of S.R. 21 and C.R. 21B and the residential communities adjacent to the lakeshore. Selected culverts under S.R. 21 and C.R. 21B were surveyed by GFY.

Inflow to the west and south sides of the lake is contributed primarily by sheet flow and several small unnamed streams that discharge lakes (Bonnet Lake and Black Lake), wetlands, agriculture land, and upland forests. One cross drain under S.R. 26 and two channel cross sections at the outfall canals of Bonnet Lake and Black Lake were surveyed by GFY.

Lake Santa Fe and Little Lake Santa Fe to the north are separated by the pass, a 1,000-foot long, 10-foot deep opening that was submerged throughout the entire stage recording period (1957 to present) at USGS gauge station 02320601 Santa Fe near Earleton, FL.

Several closed drainage basins, encompassing Indian Lake and several wetlands to the south, are located on the northeast portion of the subwatershed between C.R. 21B and the watershed boundary. Another closed drainage basin with an unnamed lake is located near Melrose Bay (a round-shaped bay at southeast corner of the lake). Indian Lake, the unnamed lake, and Melrose Bay are likely created by collapse sinkholes. In general, stormwater runoff in these closed drainage basins is mainly discharged through underground conduits and evaporation/evapotranspiration.

3.0 Water Budget Model Development

3.1 Model Selection

To support the establishment of MFLs in Lake Alto and Lake Santa Fe (including Little Lake Santa Fe), a water budget model is required to be developed and calibrated in order to assess the Lake's hydrologic changes over a long-term time period and under various water resources development scenarios.

It is important that the water budget model is able to perform long-term continuous simulation of a full hydrologic cycle, including rainfall, evapotranspiration, surface runoff, infiltration/percolation, and surface water/groundwater flow exchange. The complexity of the Lake hydrologic system, especially as it relates to the upper FAS and surface water connection between the two lake systems, requires a predictive computer model to adequately examine the effects of hydrologic changes. The model should be capable of performing long-term continuous simulation, coupling groundwater and surface water, and be widely and successfully applied in other similar projects.

The EPA SWMM 5.1 was selected for the water budget modeling of Lake Alto and Lake Santa Fe. Much of the information presented herein is directly extracted from the SWMM User's Manual (Rossman, 2015) and User's Guide to SWMM 5, 13th Edition (James *et al.*, 2010). SWMM, a public domain software developed by EPA, is a physically based, discrete-time simulation model on the basis of rainfall hyetographs, land use, topography and system characterization to predict outcomes in the form of quality and quantity values. It employs principles of conservation of mass, energy, and momentum wherever appropriate. SWMM is widely used in Florida as well as nationwide. The detailed features of hydrology and hydraulic components are addressed in the following sections.

3.2 Hydrologic Modeling in SWMM

SWMM accounts for various hydrologic processes that produce runoff from the basins. These processes include:

- time-varying rainfall;
- evaporation of standing surface water;
- snow accumulation and melting;
- rainfall interception from depression storage;
- infiltration of rainfall into unsaturated soil layers;
- evapotranspiration from groundwater layers;
- percolation of infiltrated water into groundwater layers;
- interflow between groundwater and the drainage system; and
- nonlinear reservoir routing of overland flow.

Note that not all the hydrologic processes were considered equally important in modeling of a single storm event, for example, the evaporation and groundwater components may be considered insignificant for a short duration and hence excluded. However, for a long-term simulation, the evaporation and groundwater components play very important roles and are necessary to be simulated along with other components.

3.2.1 Subbasin Delineations

Spatial variability in all of these processes is achieved by dividing a study area into a collection of smaller, homogeneous subbasins, each containing its own fraction of pervious and impervious sub-areas. The determination of the subbasin boundaries within the model domain was made on the basis of the data availability of the existing physical features in the watershed, such as the drainage basin areas by topography, depression areas (wetlands, ponds, reservoirs etc.) and structures (pipes, control structures etc.), which constitute the conveyance system (Figure 3-1).

3.2.2 Surface Runoff

The Nonlinear Reservoir Runoff method is used by SWMM, as illustrated in the graph below. Each subbasin surface is treated as a nonlinear reservoir. Inflow comes from precipitation and any designated upstream subbasin. There are several outflows, including infiltration, evaporation, and surface runoff. The capacity of this "reservoir" is the maximum depression storage, which is the maximum surface storage provided by ponding, surface wetting, and interception. Surface runoff per unit area, Q, occurs only when the depth of water in the "reservoir" exceeds the maximum depression storage, d_p, in which case the outflow is given by Manning's equation.

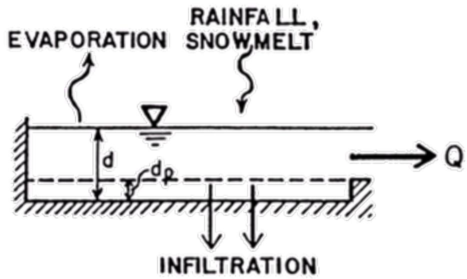


Table 3-1 is the lookup table of the hydrologic parameters for different land use categories. It allows the user to assign percentage of average impervious areas, overland Manning's n coefficients and depression storage (abstraction) to various land use categories, which were then applied on an area-weighted basis to each subbasin based on land use coverage. Note that some of the land use categories listed in Table 3-1 may not be present in the Lake Alto and Lake Santa Fe watershed. Other parameters for surface non-linear reservoir method, such as average ground slope and watershed width, were derived from the LiDAR-based DEM and subbasin coverage in ArcGIS.

3.2.3 Rainfall

Rain gages in SWMM supply precipitation data for one or more subcatchments in a study area. Long-term rainfall data was collected from various agencies during Phase A of the overall water budget modeling project, including:

- Hourly daily Next-Generation Radar (NEXRAD) rainfall data by SRWMD (10/1/2007 through current);
- Daily NEXRAD rainfall data by SRWMD (2/1/2001 through current);
- Daily rainfall data (Daymet) by Oak Ridge National Laboratory (ORNL) (1/1/1980 to 12/31/2014) (Thornton *et al*., 2012); and
- Daily rainfall data at Rainfall Station - Starke by SJRWMD (1/1/1941 to 12/31/2012).

Depending on the simulation duration, one or multiple abovementioned data sources may be utilized in the SWMM model.

Table 3-1. Lookup Table of Hydrologic Parameters for Surface Runoff Calculation - Preliminary

FLUCCS	Description	% of Imperv. Area	% of Zero Storage Imperv.	Manning n Imperv.	Manning n Perv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)
1100	Residential Low Density <2 Dwelling Units	15	25	0.012	0.1	0.05	0.15
1200	Residential Med Density 2->5 Dwelling Units	30	25	0.012	0.1	0.05	0.15
1300	Residential High Density	50	25	0.012	0.1	0.05	0.15
1400	Commercial and Services	85	25	0.012	0.1	0.05	0.15
1500	Industrial	72	25	0.012	0.1	0.05	0.15
1600	Extractive	65	25	0.012	0.1	0.1	0.15
1650	Reclaimed Land	65	25	0.012	0.1	0.05	0.15
1700	Institutional	60	25	0.012	0.1	0.05	0.15
1800	Recreational	60	25	0.012	0.1	0.05	0.15
1820	Golf Courses	5	25	0.012	0.1	0.05	0.15
1900	Open Land	0	25	0.012	0.15	0.1	0.1
2100	Cropland and Pastureland	0	25	0.012	0.1	0.05	0.2
2140	Row Crops	0	25	0.012	0.17	0.05	0.2
2200	Tree Crops	0	25	0.012	0.4	0.05	0.2
2300	Feeding Operations	0	25	0.012	0.1	0.05	0.2
2400	Nurseries and Vineyards	0	25	0.012	0.1	0.05	0.2
2500	Specialty Farms	0	25	0.012	0.1	0.05	0.2
2550	Tropical Fish Farms	0	25	0.012	0.1	0.05	0.2
2600	Other Open Lands (Rural)	0	25	0.012	0.13	0.05	0.2
3100	Herbaceous	0	25	0.012	0.24	0.05	0.2
3200	Shrub and Brushland	0	25	0.012	0.4	0.05	0.25
3300	Mixed Rangeland	0	25	0.012	0.13	0.05	0.25
4100	Upland Coniferous Forest	0	25	0.012	0.5	0.05	0.3
4110	Pine Flatwoods	0	25	0.012	0.5	0.05	0.3
4120	Longleaf Pine - Xeric Oak	0	25	0.012	0.5	0.05	0.3
4200	Upland Hardwood Forests	0	25	0.012	0.5	0.05	0.3
4340	Hardwood Conifer Mixed	0	25	0.012	0.5	0.05	0.3
4400	Tree Plantations	0	25	0.012	0.5	0.05	0.3
5100	Streams and Waterways	100	100	0.01	0.1	0	0
5200	Lakes	100	100	0.01	0.1	0	0
5300	Reservoirs	100	100	0.01	0.1	0	0
5400	Bays and Estuaries	100	100	0.01	0.1	0	0
6100	Wetland Hardwood Forests	98	75	0.4	0.4	0.1	0.25
6110	Bay Swamps	98	75	0.4	0.4	0.1	0.25
6120	Mangrove Swamps	98	75	0.4	0.4	0.1	0.25

Table 3-1. Lookup Table of Hydrologic Parameters for Surface Runoff Calculation - Preliminary (Cont.)

FLUCCS	Description	% of Imperv. Area	% of Zero Storage Imperv.	Manning n Imperv.	Manning n Perv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)
6150	Stream and Lake Swamps (Bottomland)	98	75	0.4	0.4	0.1	0.25
6200	Wetland Coniferous Forests	98	75	0.4	0.4	0.1	0.25
6210	Cypress	98	75	0.4	0.4	0.1	0.25
6300	Wetland Forests Mixed	98	75	0.4	0.4	0.1	0.25
6400	Vegetated Non-Forested Wetlands	98	75	0.24	0.24	0.1	0.25
6410	Freshwater Marshes	98	75	0.24	0.24	0.1	0.25
6420	Saltwater Marshes	98	75	0.24	0.24	0.1	0.25
6430	Wet Prairies	98	75	0.24	0.24	0.1	0.25
6440	Emergent Aquatic Vegetation	98	75	0.24	0.24	0.1	0.25
6500	Non - Vegetated	98	75	0.24	0.24	0.1	0.25
6510	Tidal Flats / Submerged Shallow Platform	98	75	0.24	0.24	0.1	0.25
6520	Shorelines	98	75	0.24	0.24	0.1	0.25
6530	Intermittent Ponds	98	75	0.24	0.24	0.1	0.25
6600	Salt Flats	98	75	0.24	0.24	0.1	0.25
7100	Beaches Other Than Swimming Beaches	0	25	0.012	0.1	0.05	0.1
7400	Disturbed Land	0	25	0.012	0.1	0.05	0.1
8100	Transportation	50	75	0.012	0.1	0.05	0.15
8200	Communications	85	25	0.012	0.1	0.05	0.15
8300	Utilities	72	25	0.012	0.1	0.05	0.15

Sources: TR-55 (USDA, 1986); Drainage Handbook Hydrology (FDOT, 2012); ECT 2017a & 2017b.

3.2.4 Evapotranspiration

Evapotranspiration (ET) can occur from standing water on the subcatchment surface, subsurface water in groundwater aquifers, water traveling through open channels, and water held in storage units. In this project, the following two main data sources were considered in the subsequent modeling efforts:

- Daily potential and reference evapotranspiration (PET and RET) data by USGS (6/1/1995 to 12/31/2015); and
- Daily Pan Evaporation data by NOAA at three climate stations:
  - USC00084731 – Lake City 2 E FL US (5/1/1965 to 2/26/2011),
  - USC00083322 – Gainesville 11 WNW FL US (2/1/1989 to 12/31/2000), and

- USC00083321 – Gainesville 3 WSW FL US (10/6/1953 to 12/31/1988).

Single or combination of the abovementioned ET data sources may be utilized in model simulation.

For the ET occurring in the upper zone of groundwater aquifers, a monthly ET pattern was created for each aquifer. Monthly ET coefficients for different land use categories have been developed based on two similar modeling projects, both located in southwest Florida (Table 3-2). The watersheds studied in these projects have a very high similarity in climate, topography, soils, and land use/land cover characteristics with the Lake Alto and Lake Santa Fe watershed.

Using an area-weighted method, a monthly ET pattern can be developed for each aquifer in the Lake Alto and Lake Santa Fe watershed. A total of eight lakes, including Lake Alto, Lake Santa Fe, Little Lake Santa Fe, Hickory Pond, Bonnet Lake, Black Lake, Indian Lake, and an unnamed lake near Melrose, were excluded from the estimation of the monthly ET pattern for their corresponding aquifers, since the lakes were treated as storage units in SWMM and the direct evaporation from these lakes was calculated separately in the hydraulic modeling.

Table 3-2. Lookup Table of Monthly ET Coefficients - Preliminary

Land Use/Cover	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Urban - Low Density	0.40	0.40	0.60	0.80	0.90	0.84	0.72	0.65	0.65	0.65	0.65	0.50
Urban - Medium Density	0.30	0.30	0.50	0.60	0.60	0.60	0.60	0.50	0.50	0.50	0.50	0.50
Urban - High Density	0.25	0.25	0.30	0.35	0.50	0.50	0.50	0.50	0.35	0.30	0.30	0.30
Pasture / Open Lands	0.60	0.65	0.70	0.85	0.85	0.85	0.85	0.85	0.85	0.75	0.65	0.60
Range Land	0.55	0.60	0.75	0.85	0.85	0.85	0.85	0.85	0.75	0.65	0.60	0.55
Upland Forest	0.55	0.60	0.75	0.85	0.90	0.90	0.85	0.85	0.75	0.65	0.60	0.55
Pine Flatwoods	0.70	0.70	0.85	0.90	0.90	1.00	1.00	1.00	1.00	0.90	0.80	0.70
Open Water	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Forested Wetland	1.00	1.00	1.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.00	1.00
Non-Forested Wetland	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Burned Areas*	0.78	0.80	0.88	0.98	0.98	0.98	0.98	0.98	0.93	0.88	0.80	0.78

* Coefficients of Burned Areas (Santa Fe Swamp in this project) were estimated by averaging the values for Upland Forest and Forested Wetland.

Sources: Peace River integrated modeling (HGL, 2008) and Myakka River Watershed Initiative (Interflow, 2008).

3.2.5 Infiltration

Infiltration is the process of rainfall penetrating the ground surface into the unsaturated soil zone of pervious subbasin areas. SWMM offers three choices for modeling infiltration: 1) Horton's Equation, 2) Green-Ampt method, and 3) Curve Number method.

In this project, the Green-Ampt method was selected for modeling infiltration, as it accounts for more variables than the other two methods. It assumes that a sharp wetting front exists in the soil column, separating soil with some initial moisture content below from the saturated soil above. The two governing equations are Equations A and B. The input parameters required are the initial moisture deficit of the soil, the soil's saturated hydraulic conductivity, and the suction head at the wetting front.

$$F(t) - \psi\Delta\theta ln\left(1 + \frac{F(t)}{\psi\Delta\theta}\right) = K_t \qquad \text{(A)}$$

Where F is cumulative infiltration, ψ is wetting front soil suction head.

$$f(t) = K\left(\frac{\psi\Delta\theta}{F(t)}\right) + 1 \qquad \text{(B)}$$

Where *f* is incremental infiltration.

As there is no site-specific geotechnical investigation available in the study area, the soil parameters were directly derived from the literature, specifically the soil characteristics provided in the SWMM User's Manual (Table 3-3).

Table 3-3. Summary of Soil Characteristics

Soil Texture Class	K	Ψ	ϕ	FC	WP
Sand	4.74	1.93	0.437	0.062	0.024
Loamy Sand	1.18	2.40	0.437	0.105	0.047
Sandy Loam	0.43	4.33	0.453	0.190	0.085
Loam	0.13	3.50	0.463	0.232	0.116
Silt Loam	0.26	6.69	0.501	0.284	0.135
Sandy Clay Loam	0.06	8.66	0.398	0.244	0.136
Clay Loam	0.04	8.27	0.464	0.310	0.187
Silty Clay Loam	0.04	10.63	0.471	0.342	0.210
Sandy Clay	0.02	9.45	0.430	0.321	0.221
Silty Clay	0.02	11.42	0.479	0.371	0.251
Clay	0.01	12.60	0.475	0.378	0.265

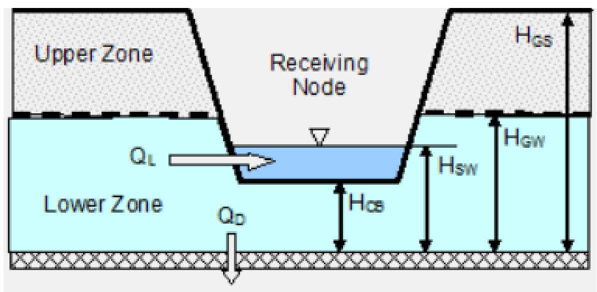
K = hydraulic conductivity, in/hr
Ψ = suction head, in.
ϕ = porosity, fraction
FC = field capacity, fraction
WP = wilting point, fraction

Source: Rawls, W.J. *et al*., (1983). J. Hyd. Engr., 109:1316.

3.2.6 Groundwater & Aquifers

Aquifers are sub-surface groundwater areas used to model the vertical movement of water infiltrating from the subcatchments that lie above them. They also permit the infiltration of groundwater into the drainage system, or exfiltration of surface water from the drainage system, depending on the hydraulic gradient that exists. Aquifers are only required in the long-term model simulations that need to explicitly account for the exchange of groundwater with the drainage system or to establish baseflow and recession curves in natural channels and non-urban systems.

Aquifers are represented using two zones - an un-saturated zone and a saturated zone, as illustrated in the graph below. Their behavior is characterized using such parameters as soil porosity, hydraulic conductivity, ET depth, aquifer bottom elevation, and a constant groundwater loss rate to deep aquifer. Some of



the required hydrologic parameters were derived from the soil characteristics table discussed in Section 3.2.5 above. The saturated hydraulic conductivity, ET depth, aquifer bottom elevation, and lower groundwater loss rate were developed on the basis of the most current North Florida Southeast Georgia (NFSEG) Groundwater Flow Model data developed by SJRWMD (Durden *et al*., 2013; SJRWMD, 2016).

3.3 Hydraulic Modeling in SWMM

SWMM contains a flexible set of hydraulic modeling capabilities used to route runoff and external inflows through the conveyance system of pipes, channels, storage/treatment units and diversion structures. These include the ability to:

- handle networks of unlimited size;
- use a wide variety of standard closed and open conduit shapes and natural channels;
- model special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices;
- apply external flows and water quality inputs from surface runoff, groundwater interflow, rainfall-dependent infiltration/inflow, dry weather sanitary flow, and user-defined inflows;
- utilize either kinematic wave or full dynamic wave flow routing methods;
- model various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding; and
- apply user-defined dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels.

Flow routing within a conduit/link network is governed by the conservation of mass and momentum equations for gradually varied, unsteady flow. Dynamic wave routing was selected for the flow routing computation. Dynamic wave routing can account for channel storage, backwater, entrance/exit losses, flow reversal, and pressurized flow. It is the most accurate solution, but comes with a price of having to use a smaller time step to overcome the numerical instability.

3.3.1 Channels/Ditches

In SWMM, a channel/ditch is modeled as open geometry conduit with regular or irregular cross section. The data for the irregular channel geometry was derived mostly from the survey data by GPI and GFY as well as the LiDAR-based DEM data. The upstream and downstream elevations were mostly taken from the LiDAR-based DEM when land survey data was not available.

Natural channel reaches were evaluated for out of bank conveyance capability based on LiDAR-based DEM data, aerial photographs, as well as field evaluations. Channel roughness (Manning's coefficients) values were derived from the SWMM User's Manual and other literature.

3.3.2 Pipes/Culverts

SWMM offers a variety of standard closed geometries for pipes/culverts. The parameters of the pipes, such as length, type, material, and geometry, were either field surveyed or derived from the aerial photographs and LiDAR-based DEM data, at various major crossings within the lake watershed. For the un-surveyed culverts, the parameters were estimated by the modeler based on the aerial photos, LiDAR-based DEM, Google Streetview, and other surveyed culverts.

The friction loss calculation for the pipes accounts toward the total head loss, as do the minor losses such as entry, exit, and culvert transitions. The Manning's n values or the roughness of the pipes were obtained from the SWMM User's Manual. The entry and exit loss coefficients for each pipe were evaluated by the survey data and aerial photos. In addition, if a conduit experienced instability during a simulation, an equivalent conduit (elongated) would be automatically used in SWMM.

3.3.3 Outlet

Outlets are flow control devices that are typically used to control outflows from storage units. They are used to model special head-discharge relationships that cannot be characterized by pumps, orifices, or weirs. Outlets are internally represented in SWMM as a link connecting two nodes.

Because SWMM is incapable of simulating time-variant lower groundwater loss rate, an “outlet” link was used to calculate the lower groundwater loss rates at the surficial aquifer beneath various lakes and sinkholes. In SWMM, a user-defined rating curve determines an outlet’s discharge flow as a function of the head difference across it (i.e., the difference between the water table elevations in the lakes/sinkholes and potentiometric surface elevations in the upper FAS were used in this model).

3.3.4 Weirs

The overtopping of roadways at channel crossings was simulated as broad crested weirs. The weir invert elevations were derived from the topographic survey and/or LiDAR-based DEM data. The width of the weir was scaled from the aerial photographic maps, as well as the LiDAR-based DEM data. After preliminary simulations were made, the weir widths were evaluated and modified as necessary. Weir coefficients of 2.6, 2.2, and 2.0 were assigned to the paved and unpaved roads, respectively.

Broad crested weirs were also used to simulate flow that may occur in an overland fashion from subbasin to subbasin. Modeling overland flow as a one-dimensional broad crested weir has been widely applied in many similar stormwater models (e.g., EPA SWMM, HEC-RAS, and ICPR), at subbasin scales in urban and rural areas. Also note that there has been a trend to use weir coefficients much lower than published values for broad crested weirs. The weir invert elevations were estimated from the LiDAR-based DEM data. Weir coefficients of 1.6, 1.0, and 0.6 were assigned to all the overland flow weirs with land cover of grass, upland wood, and wetland swamp, respectively.

3.3.5 Storage Calculations

In SWMM, a depth-area relationship is assigned to a specific node/storage within the model schematic. In this project, the depth-area relationships were established by primarily using the LiDAR-based DEM data.

In addition, the depth-area relationships were modified in the storage nodes for the lakes and several large wetland areas. The LiDAR-based DEM data does not offer a reliable estimate of the wetland or lake bottom elevation due to intense vegetation cover and/or standing water. For example, the bathymetry survey data collected by GPI was used to modify the depth-area relationship representing the storage at Lake Alto in the SWMM model.

3.3.6 Initial Conditions

The node initial elevations in the lakes and their adjacent lakes/wetland areas were adjusted to match stage data measured at the three major lakes (Lake Alto, Lake Santa Fe, and Little Lake Santa Fe). Three lake stations (USGS 02320601 Santa Fe Lake near Earleton, USGS 02320610 Little Santa Fe Lake, and USGS 02320630 Lake Alto at Waldo) currently operated by the District, were used to establish the initial stage at these lakes. The initial stage values in other storage area, junction nodes, and groundwater tables in aquifers were adjusted accordingly.

3.3.7 Boundary Conditions

In SWMM, outfalls are terminal nodes of the drainage system used to define most downstream boundary under dynamic wave flow routing. The outfall for surface water was defined as the Santa Fe River, located north of Santa Fe Swamp and Alto Swamp. As no stage data is available at this location, the outfall stage was determined by the minimum of the critical flow depth and normal flow depth in the connecting canal/conduit.

To simulate time-variant lower groundwater loss of the surficial aquifer directly beneath the lakes and sinkholes, various outfalls were added to represent the groundwater level in the upper FAS. A long-term USGS groundwater well station (USGS ID: 294313082024601 / SRWMD ID: S092307001), located approximately 2,000 feet east of Lake Santa Fe near Melrose, provides daily average groundwater level data measured in the upper FAS. The data gaps in the groundwater database were filled by using a linear interpolation method, prior to being utilized in the SWMM model.

3.3.8 Numerical Instability

SWMM is based on the solution of the Saint-Venant equations for unsteady state flow in conveyance system. Due to the explicit nature of the numerical methods used for Dynamic Wave routing, the flows in some links or water depths at some nodes may fluctuate or oscillate significantly at certain periods of time as a result of numerical instabilities.

Adjustments of model parameters might include but are not limited to:

- Use of equivalent conduits;
- Adjusting storage values;
- Lengthening pipe lengths;
- Adjusting weir lengths;
- Reducing routing time steps; and
- Selecting to ignore the inertial terms of the momentum equation.

In this project, combinations of techniques were employed to achieve the model stability.

3.3.9 Model Schematic

The hydraulic model consists of all of the components that make up the primary conveyance system. These may include lakes, ponds, wetlands, pipes, natural channels, weirs, pumps, and control structures. SWMM uses a node/reach concept to idealize the hydraulics of the system. The nodes within the model are the discrete locations within the watershed boundary where the conservation of mass is maintained. These represent the storage and stage related elements of the model. The reaches are the connections between the junctions. These represent the flow and conveyance related elements of the model.

3.4 Preliminary Model Development and Simulation

The water budget model of Lake Alto and Lake Santa Fe was developed based on the 2004/2006 land use and land cover data, existing topographic data, and other available information that is considered appropriate to characterize the existing conditions in the lake watershed.

3.4.1 Hydrologic Model Parameterization

On the basis of the latest LiDAR-based DEM and contour maps (Figures 2-2A and 2-2B) and the major conveyance system map (Figure 2-5), the lake watershed was subdivided into a total of 157 subbasins (Figure 3-1).

Table 3-4 summarizes the hydrologic parameters for each subbasin or subcatchment for the existing conditions. The Green-Ampt method was used in the hydrologic modeling and the values of Capillary Suction Head, Saturated Hydraulic Conductivity, and Initial Moisture Deficit are also listed in Table 3-4.

Based on the similarity of the topographic and subsurface characters in the 157 subbasins, the subbasin features were further grouped to create a total of 123 aquifers (Figure 3-2). Hydrologic parameters for each aquifer are summarized in Table 3-5.

3.4.2 Hydraulic Model Parameterization

There is a total of 166 nodes in the conveyance system, including:

- 118 “storage nodes” representing wetlands, lakes and ponds;
- 36 “junction nodes” with a minimum surface area of 2,500 square feet; and
- 12 “outfall nodes” representing the model boundaries at the Santa Fe River, a roadside ditch draining to the Santa Fe River, and the upper FAS.

There is a total of 268 reaches including:

- 51 open channels;
- 95 pipes or culverts;
- 113 weirs, representing the road overtopping or the sheet flow between subbasins; and
- nine outlets, representing lower groundwater loss at various lakes and sinkholes.

The model schematic map with nodes and reaches is graphically presented in Figure 3-3.

3.4.3 Subbasin, Aquifer, Node, and Reach Naming Convention

A total of 5 characters have been dedicated for naming the subbasins. For example, a subbasin name can be designated as “B0100.” The first left character “B” indicates one of the five sub-watershed areas, i.e., “Lake Alto” (Figure 3-1). The remaining four character fields are reserved for numbering of the subbasins within the major sub-watershed.

A total of 6 characters have been dedicated for naming the aquifers. The character “A” is used to represent the aquifers. For an aquifer beneath a subbasin, it will use the subbasin name with the character “A” placed at the first left character position. For example, the designated aquifer name

"AB0100" would be used for the aquifer that exchanges flow with subbasin "B0100" (Figure 3-2).

A total of 6 characters have been dedicated for naming the nodes and up to 8 characters have been dedicated for naming the reaches in the hydraulic network being modeled. The character "N" is used for the nodes and the character "R" is used for the reaches. For a node receiving runoff directly from a subbasin, it will use the subbasin name with the character "N" placed at the first left character position. For example, the designated node name "NB0410" would be used at the loading node of subbasin "B0410" and its downstream connecting reach would have the name "RB0410XX." Other nodes and reaches not directly associated with a subbasin will follow in a sequential manner. For example, the next downstream connecting node may be named "NB0400" while the next reach will be named "RB0400XX" due its association. The first character "X" in a reach name is reserved to represent reach type. The character "P" is for pipes or culverts, "C" for channels or ditches, "W" for weirs, and "T" for outlets. The second "X" is used only when there are more than one same type reaches discharging from a node. For example, "RD0200P2" would be used for naming the second culvert that discharge node "ND0200" (Figures 3-3 and 3-4).

3.4.4 Preliminary Model Simulation

Model parameterization was mostly conducted in ArcGIS, and the resultant parameters for hydrologic and hydraulic features were converted into the input file of the SWMM model (Figure 3-4). A randomly picked time period, from 1/1/2014 through 12/31/2015, was simulated to identify any potential issues in this preliminary model.

The preliminary model results were briefly checked by plotting and comparing the simulated and observed node depth hydrographs at Node NB0100 (Lake Alto, Figure 3-5A) and Node NE0100 (Lake Santa Fe, Figure 3-5B). As observed in these comparison plots, the preliminary model appears to be able to capture the hydrologic response to rainfall and ET during the two-year simulation period.

In summary, the preliminary water budget model of Lake Alto and Lake Santa Fe has been developed to simulate the major hydrologic and hydraulic features in the lake watershed. The simulation results for the two-year test run was considered reasonable and adequate.

The same model developed for the existing conditions will be calibrated in the subsequent task, by adjusting model parameters in order to have a good overall fit with the observed lake stage data collected in the past decade.

Table 3-4. Summary Table of Hydrologic Parameters in Subbasins - Preliminary

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
A0100	318.63	3812	1.60	73.69	62.52	0.088	0.258	0.300	0.406	2.1	3.2045	0.363
A0110	78.98	1611	1.70	38.79	43.74	0.069	0.239	0.155	0.334	2.1	3.5499	0.366
A0120	57.04	1550	1.90	25.88	37.47	0.062	0.243	0.098	0.331	2.0	4.1364	0.371
A0200	239.74	5636	2.50	61.48	55.92	0.081	0.251	0.252	0.385	2.1	3.7545	0.368
A0210	96.33	2118	1.60	4.88	25.61	0.051	0.219	0.017	0.230	1.9	4.6378	0.375
A0220	25.79	1182	2.40	4.59	26.85	0.052	0.256	0.026	0.345	2.0	4.1193	0.371
A0300	177.98	5764	2.80	80.22	65.86	0.091	0.252	0.291	0.353	1.9	4.6292	0.375
A0310	61.53	1612	1.90	12.65	31.25	0.056	0.288	0.049	0.458	1.9	4.6378	0.375
A0320	126.09	2786	1.80	17.30	33.68	0.059	0.249	0.079	0.317	2.0	4.3068	0.372
A0330	73.41	1263	1.70	1.28	25.00	0.050	0.235	0.012	0.259	1.9	4.6378	0.375
A0400	581.87	7933	2.70	92.01	72.18	0.097	0.252	0.369	0.397	2.1	3.4348	0.365
A0405	33.60	2197	2.00	59.99	58.44	0.078	0.232	0.227	0.367	1.9	4.6378	0.375
A0410	65.73	2153	2.10	13.13	32.78	0.056	0.260	0.043	0.307	1.9	4.6378	0.375
A0412	68.06	1404	1.60	18.31	34.33	0.059	0.276	0.073	0.413	2.0	4.1600	0.371
A0414	44.20	991	1.70	11.51	30.49	0.055	0.242	0.055	0.304	1.9	4.6378	0.375
A0420	19.40	866	2.30	6.34	31.34	0.050	0.279	0.012	0.441	1.9	4.6378	0.375
A0422	19.90	1336	1.80	7.32	28.73	0.054	0.272	0.041	0.371	2.0	4.0432	0.37
A0430	38.70	1082	1.90	13.10	33.04	0.055	0.286	0.053	0.462	2.0	4.0803	0.37
A0500	308.05	3923	2.90	90.45	71.80	0.095	0.251	0.348	0.381	2.1	3.2376	0.364
A0505	45.87	851	1.80	24.39	38.67	0.061	0.260	0.092	0.357	1.9	4.6378	0.375
A0510	43.28	1767	1.80	14.14	32.08	0.057	0.289	0.067	0.476	2.1	3.7286	0.368

Table 3-4. Summary Table of Hydrologic Parameters in Subbasins - Preliminary (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
A0512	24.31	1221	1.50	16.39	33.36	0.058	0.274	0.077	0.430	1.9	4.6378	0.375
A0514	7.59	748	1.40	26.21	38.37	0.063	0.260	0.116	0.404	2.1	3.7444	0.368
A0516	51.01	1241	1.60	47.17	33.08	0.054	0.208	0.041	0.247	2.0	4.5597	0.374
A0518	37.53	1228	1.80	16.62	31.39	0.054	0.243	0.044	0.337	2.0	4.2237	0.372
A0520	23.50	1376	2.30	54.36	48.13	0.055	0.173	0.050	0.166	2.0	4.3190	0.372
A0522	89.61	1102	2.00	25.65	32.11	0.056	0.209	0.056	0.255	2.0	4.2096	0.372
A0530	131.87	2008	2.10	22.04	36.91	0.060	0.248	0.079	0.354	2.0	4.1780	0.371
A0540	144.23	2291	2.40	18.49	30.79	0.049	0.206	0.013	0.220	1.9	4.6378	0.375
A0542	82.52	2491	2.30	37.48	31.82	0.053	0.207	0.038	0.243	2.0	4.6253	0.375
A0544	64.43	1823	2.90	16.67	33.71	0.058	0.290	0.059	0.463	2.0	4.2953	0.372
A0550	196.40	2566	2.60	38.17	40.75	0.062	0.230	0.085	0.298	1.9	4.6378	0.375
A0560	88.87	2147	2.20	20.67	29.66	0.050	0.228	0.013	0.290	1.9	4.6378	0.375
A0570	78.82	1737	2.00	37.04	27.56	0.050	0.175	0.012	0.178	2.0	4.5278	0.374
A0580	153.79	1732	1.80	25.48	33.77	0.059	0.239	0.080	0.329	1.9	4.6378	0.375
A0582	47.16	1486	1.30	7.74	26.34	0.051	0.247	0.022	0.303	1.9	4.6378	0.375
A0584	44.00	875	2.10	18.67	34.37	0.058	0.261	0.068	0.347	2.0	4.0252	0.37
A0586	67.68	1423	1.90	10.95	28.12	0.053	0.232	0.032	0.264	1.9	4.6378	0.375
A0588	56.24	1548	1.70	15.38	32.02	0.057	0.266	0.065	0.403	2.0	4.4979	0.374
A0590	46.41	1775	2.70	18.48	35.72	0.056	0.223	0.059	0.331	2.0	4.5893	0.375
A0592	84.34	1024	2.70	28.67	34.98	0.049	0.178	0.012	0.172	1.9	4.6378	0.375
A0600	546.57	9938	2.80	87.01	69.39	0.094	0.253	0.343	0.387	2.0	4.0456	0.37

Table 3-4. Summary Table of Hydrologic Parameters in Subbasins - Preliminary (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
A0610	75.83	1376	3.20	22.65	36.56	0.062	0.285	0.085	0.431	1.9	4.6378	0.375
A0620	155.69	1708	2.60	12.15	31.20	0.056	0.266	0.052	0.327	1.9	4.6378	0.375
A0630	54.02	1015	3.90	67.53	59.45	0.084	0.266	0.279	0.431	1.9	4.6378	0.375
A0640	28.78	977	2.10	0.00	25.00	0.050	0.299	0.012	0.493	1.9	4.6378	0.375
B0100	627.14	98284	0.40	98.25	96.82	0.008	0.023	0.039	0.125	2.0	4.0332	0.370
B0110	121.43	3431	2.40	3.66	25.97	0.051	0.253	0.019	0.319	1.9	4.6378	0.375
B0112	93.09	1186	2.40	0.20	25.00	0.050	0.287	0.012	0.443	1.9	4.6378	0.375
B0120	215.95	3053	2.50	12.41	30.98	0.054	0.263	0.045	0.367	1.9	4.6378	0.375
B0130	103.57	1364	3.40	26.46	38.50	0.063	0.287	0.107	0.463	2.0	4.5700	0.374
B0140	14.35	9975	7.70	61.61	65.94	0.040	0.164	0.092	0.307	1.9	4.6348	0.375
B0150	58.85	2852	2.00	1.45	25.01	0.050	0.282	0.012	0.431	1.9	4.6378	0.375
B0160	82.30	2381	1.50	6.58	27.24	0.052	0.229	0.029	0.386	1.9	4.6378	0.375
B0200	184.79	3697	2.70	42.61	41.26	0.066	0.230	0.138	0.324	1.9	4.6378	0.375
B0300	118.84	3068	2.80	64.30	57.23	0.082	0.257	0.262	0.406	2.0	4.5372	0.374
B0400	538.11	5309	2.70	65.95	57.12	0.081	0.236	0.190	0.291	2.0	4.3011	0.372
B0410	25.98	1104	2.00	25.40	32.75	0.058	0.226	0.072	0.315	2.0	3.9943	0.370
C0100	3282.25	20036	1.50	61.70	56.13	0.098	0.250	0.276	0.286	4.2	0.6285	0.306
C0110	286.32	3197	1.70	17.43	33.79	0.064	0.224	0.085	0.211	1.9	4.6336	0.375
C0120	304.79	3765	1.90	5.23	27.59	0.053	0.280	0.029	0.404	2.0	3.9130	0.369
C0200	303.41	4240	3.00	73.90	62.70	0.088	0.261	0.275	0.391	3.8	1.0073	0.317
C0201	247.97	2984	1.60	3.62	26.33	0.051	0.244	0.020	0.301	2.2	3.1028	0.363

Table 3-4. Summary Table of Hydrologic Parameters in Subbasins - Preliminary (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
C0202	45.77	1201	1.90	15.21	32.72	0.058	0.277	0.069	0.403	2.0	4.0478	0.370
C0203	86.49	1604	2.10	4.24	27.11	0.052	0.263	0.028	0.336	2.2	3.0854	0.362
C0204	123.80	2062	2.20	18.71	34.55	0.060	0.280	0.085	0.458	2.1	3.6599	0.367
C0210	539.07	2767	2.20	12.80	30.88	0.056	0.286	0.053	0.459	2.1	3.3150	0.364
C0212	313.58	1856	1.90	10.96	30.24	0.054	0.253	0.048	0.357	2.2	2.8304	0.360
C0220	459.79	3156	2.00	14.90	30.77	0.056	0.286	0.054	0.463	2.3	2.2328	0.356
C0230	171.71	2356	2.30	16.11	30.20	0.055	0.282	0.052	0.456	2.3	1.9945	0.354
C0240	202.32	2205	2.10	10.31	29.61	0.055	0.293	0.045	0.481	2.3	1.8948	0.353
C0244	218.63	2186	2.00	14.28	31.03	0.056	0.256	0.058	0.380	2.3	1.7515	0.352
C0250	773.85	4065	1.90	27.82	39.06	0.064	0.282	0.120	0.458	2.3	2.2511	0.356
C0254	32.65	1244	1.70	8.88	29.53	0.055	0.295	0.047	0.491	2.0	4.3354	0.373
C0260	263.04	2027	2.30	42.05	46.44	0.071	0.278	0.150	0.428	2.1	3.3036	0.364
C0270	176.00	3466	3.80	54.52	33.71	0.065	0.195	0.049	0.223	1.9	4.6378	0.375
C0280	1175.20	4055	2.40	31.89	40.44	0.065	0.280	0.117	0.442	2.4	3.6807	0.361
C0282	243.25	3088	2.50	28.01	33.70	0.058	0.262	0.074	0.404	2.0	4.5743	0.374
C0300	443.32	5361	2.90	83.21	67.13	0.095	0.250	0.329	0.359	4.0	0.9642	0.311
C0301	45.77	1961	1.80	2.72	25.01	0.050	0.254	0.012	0.340	2.0	4.3418	0.372
C0303	17.43	811	2.20	19.54	34.97	0.060	0.290	0.089	0.480	1.9	4.6378	0.375
C0304	143.90	1659	2.50	12.65	30.77	0.056	0.271	0.057	0.402	2.0	4.5550	0.374
C0306	19.75	645	1.70	13.58	25.00	0.050	0.222	0.012	0.257	1.9	4.6378	0.375
C0308	88.40	2328	2.90	35.69	41.15	0.066	0.238	0.126	0.309	2.0	4.5688	0.374

Table 3-4. Summary Table of Hydrologic Parameters in Subbasins - Preliminary (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
C0310	253.38	3511	1.80	17.78	30.91	0.055	0.204	0.051	0.189	2.2	4.0189	0.366
C0311	95.54	1529	1.40	11.25	27.21	0.052	0.209	0.027	0.178	2.0	4.5701	0.374
C0314	158.85	1939	2.10	10.11	27.11	0.052	0.233	0.028	0.278	2.0	4.3669	0.373
C0316	112.09	877	2.40	9.45	27.55	0.053	0.265	0.032	0.358	2.0	4.4610	0.374
C0320	154.52	1942	2.10	2.01	25.31	0.050	0.226	0.012	0.209	2.0	4.0101	0.370
C0322	115.61	1313	2.10	3.08	25.26	0.050	0.275	0.014	0.407	2.0	4.5619	0.374
C0330	170.25	2295	2.00	10.74	29.05	0.053	0.241	0.032	0.327	2.1	3.7872	0.368
C0340	483.91	2612	1.90	14.03	30.11	0.055	0.251	0.046	0.328	2.0	3.8925	0.369
C0342	36.50	1333	1.80	41.78	45.94	0.071	0.227	0.175	0.259	2.1	3.6633	0.367
C0344	48.87	2478	2.10	20.72	35.57	0.061	0.247	0.094	0.302	2.1	3.2240	0.364
C0350	789.53	4176	2.30	11.09	30.73	0.053	0.284	0.037	0.452	2.0	4.4657	0.374
C0360	223.65	2041	1.80	12.64	31.45	0.056	0.293	0.062	0.487	2.1	3.8679	0.369
C0370	312.88	2223	2.20	10.10	30.15	0.055	0.295	0.050	0.487	2.0	4.4686	0.374
C0400	969.54	10498	1.50	64.24	57.54	0.094	0.255	0.279	0.335	3.9	1.1289	0.314
C0410	296.39	3274	2.70	34.76	40.42	0.064	0.258	0.124	0.365	2.7	3.2627	0.352
C0420	117.48	2211	2.70	8.95	29.57	0.055	0.282	0.047	0.440	2.0	4.4394	0.373
C0430	161.95	2817	2.00	8.35	29.23	0.056	0.291	0.044	0.464	2.2	4.1585	0.367
C0500	1445.33	8622	1.30	91.53	71.67	0.098	0.249	0.361	0.365	4.2	0.6535	0.306
C0505	49.15	1906	1.90	0.87	25.00	0.050	0.204	0.012	0.132	1.9	4.6378	0.375
C0507	120.82	3680	2.30	3.33	26.34	0.051	0.291	0.020	0.473	2.0	4.5737	0.374
C0508	59.41	995	1.70	28.62	39.60	0.065	0.285	0.116	0.462	2.4	3.8150	0.361

Table 3-4. Summary Table of Hydrologic Parameters in Subbasins - Preliminary (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
C0510	117.73	2426	2.10	28.82	39.48	0.064	0.271	0.124	0.435	2.7	3.3673	0.353
C0520	83.05	1386	2.90	32.85	42.00	0.064	0.261	0.114	0.392	2.6	3.4143	0.355
C0522	69.54	1259	2.40	21.50	35.97	0.061	0.270	0.091	0.428	2.1	3.7447	0.368
C0530	312.99	3146	2.00	13.86	32.03	0.057	0.281	0.063	0.431	2.1	4.1152	0.370
C0540	195.52	2789	2.40	9.64	29.92	0.055	0.211	0.044	0.191	2.0	4.3321	0.372
C0550	552.81	5036	1.80	40.53	48.26	0.058	0.221	0.107	0.342	2.1	3.5917	0.367
C0552	74.52	2189	2.30	22.00	36.19	0.061	0.229	0.099	0.268	2.0	4.4880	0.374
D0040	489.56	3901	1.80	10.37	30.02	0.055	0.252	0.048	0.372	2.0	4.4251	0.373
D0045	62.60	1586	1.80	27.11	38.22	0.063	0.269	0.115	0.431	2.0	4.1066	0.371
D0050	581.97	6326	1.80	33.57	41.61	0.067	0.261	0.120	0.390	2.1	3.6985	0.367
D0055	207.44	2915	1.90	9.97	28.86	0.054	0.267	0.042	0.416	2.0	4.2417	0.372
D0100	1224.32	172321	0.30	96.95	95.89	0.008	0.023	0.031	0.119	3.0	2.7165	0.343
D0110	28.94	1212	3.30	75.07	61.95	0.087	0.237	0.299	0.355	3.7	1.4780	0.320
D0120	72.94	1568	2.70	44.35	47.27	0.071	0.265	0.162	0.406	2.9	3.0049	0.347
D0130	33.23	2989	2.20	11.58	28.05	0.053	0.241	0.036	0.342	2.1	4.3188	0.369
D0140	64.23	1345	2.50	2.10	25.00	0.050	0.259	0.012	0.312	2.0	4.1265	0.371
D0150	131.26	2623	2.20	10.97	29.13	0.052	0.211	0.032	0.305	2.0	4.3516	0.373
D0160	9.53	1335	2.10	33.11	32.90	0.058	0.198	0.067	0.227	1.9	4.6378	0.375
D0170	109.94	1582	1.60	31.52	39.08	0.064	0.256	0.093	0.379	2.0	3.9315	0.369
D0180	134.04	3340	1.90	8.13	25.24	0.050	0.223	0.014	0.295	2.0	4.5348	0.374
D0200	140.81	2821	2.00	16.20	33.19	0.058	0.268	0.076	0.386	2.3	4.0754	0.365

Table 3-4. Summary Table of Hydrologic Parameters in Subbasins - Preliminary (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
E0100	4289.98	424660	0.20	97.52	96.56	0.007	0.018	0.028	0.115	2.5	3.2595	0.355
E0110	192.56	3772	2.60	15.08	29.48	0.051	0.216	0.025	0.285	2.1	4.3746	0.370
E0120	103.92	2326	2.80	89.39	70.27	0.095	0.248	0.271	0.300	3.5	1.6125	0.327
E0130	42.25	2054	2.40	30.64	28.62	0.054	0.179	0.040	0.179	2.0	4.5375	0.373
E0140	23.23	541	3.50	94.67	73.13	0.098	0.249	0.385	0.395	3.2	2.4212	0.337
E0150	279.61	6121	1.90	9.50	27.57	0.053	0.222	0.029	0.318	2.0	4.4847	0.374
E0160	301.91	2791	1.60	11.30	30.71	0.055	0.245	0.042	0.317	1.9	4.6372	0.375
E0162	47.66	1281	1.70	23.61	37.04	0.062	0.285	0.105	0.466	2.0	3.9897	0.370
E0170	306.22	2447	2.00	16.88	29.85	0.055	0.212	0.047	0.209	2.0	4.5942	0.375
E0172	47.90	1508	1.40	20.42	35.42	0.060	0.290	0.093	0.479	1.9	4.6378	0.375
E0180	87.91	1559	3.40	48.52	50.62	0.065	0.225	0.138	0.310	2.1	3.4496	0.365
E0190	87.43	3738	2.00	14.98	25.00	0.050	0.199	0.012	0.231	1.9	4.6378	0.375
E0200	76.44	1118	2.80	33.49	27.65	0.053	0.156	0.033	0.117	2.6	3.4517	0.355
E0210	100.14	1473	3.30	22.87	36.40	0.061	0.286	0.100	0.470	2.1	3.7011	0.367
E0220	792.63	8823	1.90	37.23	43.04	0.068	0.255	0.129	0.340	2.6	3.2698	0.354
E0230	86.51	3475	3.00	36.20	45.88	0.058	0.256	0.095	0.413	2.3	3.9847	0.365
E0300	169.49	1998	2.40	34.53	39.91	0.065	0.262	0.126	0.405	2.3	3.8535	0.364
E0400	94.62	2721	2.60	34.10	42.31	0.067	0.281	0.132	0.446	2.4	3.4807	0.360
E0410	134.78	2660	3.20	29.60	40.10	0.065	0.268	0.113	0.420	2.5	3.5793	0.359
E0420	40.78	1226	1.90	25.11	37.23	0.062	0.276	0.107	0.445	2.5	3.6728	0.358
E0422	26.15	1767	2.30	13.24	31.24	0.056	0.272	0.060	0.412	2.1	3.8703	0.369

Table 3-4. Summary Table of Hydrologic Parameters in Subbasins - Preliminary (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
E0425	36.59	1210	1.80	7.61	28.73	0.054	0.293	0.029	0.472	1.9	4.6378	0.375
E0430	165.62	3884	3.20	17.42	26.89	0.060	0.224	0.023	0.285	2.1	4.4412	0.372
E0440	170.18	2894	2.30	5.27	25.00	0.050	0.231	0.012	0.324	2.0	4.2684	0.372
E0450	261.88	3980	1.60	20.64	36.81	0.054	0.245	0.057	0.339	2.1	4.2736	0.369
E0452	78.61	1651	1.80	19.14	34.77	0.060	0.276	0.081	0.424	2.3	3.9096	0.364
E0460	89.23	2369	2.50	0.09	25.00	0.050	0.255	0.012	0.354	1.9	4.6378	0.375
E0462	45.26	1656	1.80	13.23	33.47	0.047	0.206	0.025	0.218	2.2	4.1775	0.367
E0500	523.39	5458	1.50	44.00	47.33	0.063	0.227	0.115	0.298	2.0	4.4685	0.374
E0600	676.82	4326	2.00	46.31	49.76	0.068	0.253	0.151	0.388	2.1	3.6416	0.367
E0700	133.47	2334	2.50	12.49	27.17	0.049	0.236	0.012	0.341	1.9	4.6378	0.375

Table 3-5. Summary Table of Hydrologic Parameters in Aquifers - Preliminary

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AA0100	0.4104	0.0541	0.1366	18.442	5.2899	15	1	8.42	0.000002	108.93	136.45	0.15
AA0110	0.4131	0.0524	0.1297	17.221	5.1703	15	1	11.36	0.000002	112.44	142.73	0.15
AA0200	0.4128	0.0526	0.1304	17.530	5.1820	15	1	7.54	0.000002	110.08	137.44	0.15
AA0210	0.4165	0.0503	0.1213	15.902	5.0221	15	1	10.89	0.000001	114.46	143.89	0.15
AA0310	0.4170	0.0500	0.1200	14.635	5.0000	15	1	11.71	0.000002	124.03	155.97	0.15
AA0320	0.4155	0.0510	0.1238	15.656	5.0669	15	1	10.93	0.000001	116.47	145.26	0.15
AA0330	0.4170	0.0500	0.1200	15.034	5.0000	15	1	12.02	0.000002	122.14	150.92	0.15
AA0405	0.4170	0.0500	0.1200	19.818	5.0000	15	1	11.34	0.000002	112.36	145.55	0.15
AA0410	0.4170	0.0500	0.1200	20.824	5.0000	15	1	13.75	0.000002	113.72	141.89	0.15
AA0412	0.4148	0.0514	0.1255	21.165	5.0966	15	1	14.27	0.000003	116.07	143.15	0.15
AA0414	0.4170	0.0500	0.1200	21.261	5.0000	15	1	14.44	0.000003	117.32	145.14	0.15
AA0420	0.4156	0.0509	0.1235	19.949	5.0609	15	1	11.92	0.000002	113.05	144.08	0.15
AA0430	0.4144	0.0516	0.1264	19.993	5.1128	15	1	12.39	0.000003	115.41	142.56	0.15
AA0505	0.4170	0.0500	0.1200	19.443	5.0000	15	1	11.14	0.000002	113.36	142.89	0.15
AA0510	0.4128	0.0526	0.1305	20.075	5.1839	15	1	12.57	0.000003	116.09	143.17	0.15
AA0512	0.4160	0.0506	0.1225	20.367	5.0430	15	1	13.02	0.000003	116.45	146.13	0.15
AA0516	0.4163	0.0504	0.1218	21.070	5.0311	15	1	13.70	0.000003	118.81	147.17	0.15
AA0518	0.4151	0.0512	0.1248	20.563	5.0838	15	1	13.34	0.000003	121.33	147.76	0.15
AA0522	0.4150	0.0512	0.1250	21.833	5.0866	15	1	13.41	0.000003	121.16	155.67	0.15
AA0530	0.4149	0.0513	0.1253	19.581	5.0930	15	1	13.78	0.000003	115.56	143.33	0.15
AA0540	0.4170	0.0500	0.1200	20.736	5.0000	15	1	13.59	0.000003	122.23	152.50	0.15

Table 3-5. Summary Table of Hydrologic Parameters in Aquifers – Preliminary (Cont.)

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AA0542	0.4169	0.0500	0.1201	20.883	5.0025	15	1	14.56	0.000003	124.57	155.12	0.15
AA0544	0.4154	0.0510	0.1240	21.873	5.0693	15	1	15.49	0.000004	122.15	157.10	0.15
AA0550	0.4170	0.0500	0.1200	18.918	5.0000	15	1	13.43	0.000003	116.09	142.40	0.15
AA0560	0.4170	0.0500	0.1200	19.744	5.0000	15	1	14.16	0.000003	123.14	151.28	0.15
AA0570	0.4165	0.0503	0.1213	18.799	5.0222	15	1	14.32	0.000003	120.75	152.09	0.15
AA0580	0.4170	0.0500	0.1200	19.801	5.0000	15	1	13.52	0.000004	125.51	153.62	0.15
AA0582	0.4156	0.0509	0.1234	20.619	5.0598	15	1	14.40	0.000004	126.16	156.74	0.15
AA0586	0.4167	0.0502	0.1207	19.959	5.0128	15	1	12.63	0.000005	125.97	154.92	0.15
AA0590	0.4168	0.0501	0.1206	17.983	5.0098	15	1	13.44	0.000003	114.92	142.91	0.15
AA0592	0.4170	0.0500	0.1200	18.180	5.0000	15	1	13.53	0.000004	122.36	152.96	0.15
AA0610	0.4170	0.0500	0.1200	14.102	5.0000	15	1	11.25	0.000003	122.10	155.73	0.15
AA0620	0.4170	0.0500	0.1200	14.257	5.0000	15	1	11.22	0.000002	124.43	155.38	0.15
AA0630	0.4170	0.0500	0.1200	17.734	5.0000	15	1	12.48	0.000003	112.44	140.93	0.15
AA0640	0.4170	0.0500	0.1200	15.169	5.0000	15	1	12.83	0.000002	120.75	151.76	0.15
AB0100	0.4142	0.0517	0.1270	14.727	5.1223	15	1	8.37	0*	108.44	134.30	0.15
AB0110	0.4170	0.0500	0.1200	13.093	5.0000	15	1	14.43	0.000004	120.95	161.89	0.15
AB0120	0.4170	0.0500	0.1200	12.481	5.0000	15	1	13.54	0.000004	121.42	151.42	0.15
AB0130	0.4167	0.0502	0.1208	13.847	5.0137	15	1	10.64	0.000002	120.14	149.31	0.15
AB0150	0.4170	0.0500	0.1200	14.972	5.0000	15	1	13.83	0.000002	109.85	142.68	0.15
AB0160	0.4170	0.0500	0.1200	14.392	5.0000	15	1	12.22	0.000002	118.60	148.47	0.15
AB0200	0.4170	0.0500	0.1200	13.187	5.0000	15	1	10.26	0.000002	119.46	148.98	0.15

Table 3-5. Summary Table of Hydrologic Parameters in Aquifers – Preliminary (Cont.)

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AB0300	0.4157	0.0508	0.1234	16.873	5.0587	15	1	9.62	0.000003	112.20	140.47	0.15
AB0410	0.4140	0.0519	0.1274	18.011	5.1302	15	1	14.48	0.000003	118.13	144.47	0.15
AC0100	0.4122	0.0684	0.2027	11.638	7.2901	15	1	9.92	0.00005	110.30	138.24	0.15
AC0110	0.4170	0.0500	0.1200	13.658	5.0008	15	1	9.51	0.000002	121.30	151.54	0.15
AC0120	0.4136	0.0521	0.1284	18.065	5.1466	15	1	12.32	0.000016	112.45	155.10	0.15
AC0201	0.4099	0.0544	0.1377	13.964	5.3105	15	1	11.41	0.000044	108.43	155.79	0.15
AC0202	0.4143	0.0517	0.1268	13.699	5.1194	15	1	12.58	0.000049	107.14	164.27	0.15
AC0203	0.4098	0.0545	0.1379	18.174	5.3140	15	1	13.37	0.000028	110.91	152.79	0.15
AC0204	0.4125	0.0528	0.1313	19.804	5.1978	15	1	13.58	0.000026	111.33	162.67	0.15
AC0210	0.4109	0.0538	0.1353	21.744	5.2676	15	1	13.69	0.000044	110.69	160.22	0.15
AC0212	0.4086	0.0552	0.1409	16.986	5.3656	15	1	14.00	0.000046	109.45	156.89	0.15
AC0220	0.4059	0.0570	0.1478	20.034	5.4865	15	1	15.20	0.000079	112.11	164.19	0.15
AC0230	0.4048	0.0576	0.1506	14.787	5.5347	15	1	15.54	0.000069	112.24	167.62	0.15
AC0240	0.4043	0.0579	0.1517	15.032	5.5548	15	1	15.81	0.000097	114.93	168.09	0.15
AC0244	0.4037	0.0583	0.1534	18.117	5.5838	15	1	13.79	0.00014	114.48	171.75	0.15
AC0250	0.4064	0.0567	0.1466	13.471	5.4657	15	1	14.41	0.000199	117.16	173.82	0.15
AC0260	0.4108	0.0539	0.1354	7.578	5.2699	15	1	10.92	0.00025	118.21	189.48	0.15
AC0270	0.4170	0.0500	0.1200	5.883	5.0000	15	1	8.47	0.000423	106.88	206.02	0.15
AC0280	0.4150	0.0541	0.1380	8.512	5.4705	15	1	12.46	0.000133	122.24	181.32	0.15
AC0282	0.4167	0.0502	0.1207	5.812	5.0129	15	1	11.22	0.000178	117.56	193.27	0.15
AC0301	0.4157	0.0509	0.1238	11.995	5.0731	15	1	10.89	0.000053	107.18	151.41	0.15

Table 3-5. Summary Table of Hydrologic Parameters in Aquifers – Preliminary (Cont.)

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AC0303	0.4170	0.0500	0.1200	9.596	5.0000	15	1	12.02	0.000093	110.55	148.67	0.15
AC0304	0.4167	0.0502	0.1208	8.271	5.0147	15	1	12.37	0.000215	106.94	158.40	0.15
AC0308	0.4167	0.0502	0.1208	6.914	5.0140	15	1	10.80	0.00038	100.73	168.02	0.15
AC0310	0.4157	0.0526	0.1316	10.621	5.3020	15	1	10.39	0.000069	103.86	161.33	0.15
AC0311	0.4169	0.0503	0.1214	8.855	5.0402	15	1	10.66	0.00013	104.84	153.45	0.15
AC0314	0.4159	0.0507	0.1227	8.373	5.0469	15	1	10.76	0.00014	100.31	165.48	0.15
AC0320	0.4141	0.0518	0.1274	12.222	5.1318	15	1	12.02	0.000052	105.45	161.01	0.15
AC0330	0.4145	0.0516	0.1262	10.095	5.1087	15	1	12.00	0.000057	102.34	171.48	0.15
AC0340	0.4136	0.0522	0.1286	11.311	5.1508	15	1	12.77	0.00005	107.64	168.18	0.15
AC0342	0.4113	0.0535	0.1342	14.438	5.2480	15	1	12.95	0.00005	107.79	163.06	0.15
AC0350	0.4162	0.0505	0.1220	6.827	5.0348	15	1	13.41	0.000059	96.07	186.47	0.15
AC0360	0.4134	0.0522	0.1289	10.491	5.1557	15	1	14.76	0.000066	113.14	174.30	0.15
AC0370	0.4162	0.0505	0.1220	6.963	5.0342	15	1	13.36	0.000078	108.05	186.74	0.15
AC0410	0.4150	0.0563	0.1483	6.870	5.7735	15	1	12.50	0.000523	110.61	152.65	0.15
AC0420	0.4161	0.0506	0.1223	8.549	5.0401	15	1	13.28	0.000179	111.08	152.93	0.15
AC0430	0.4161	0.0521	0.1294	6.451	5.2524	15	1	12.09	0.000722	113.91	144.80	0.15
AC0505	0.4170	0.0500	0.1200	10.375	5.0000	15	1	9.45	0.000009	116.43	148.52	0.15
AC0507	0.4169	0.0503	0.1214	6.794	5.0381	15	1	11.57	0.00022	114.09	147.28	0.15
AC0508	0.4157	0.0553	0.1440	6.177	5.6655	15	1	10.12	0.000832	113.98	142.40	0.15
AC0520	0.4141	0.0542	0.1381	5.741	5.4442	15	1	12.98	0.001539	114.62	147.57	0.15
AC0530	0.4149	0.0517	0.1270	5.614	5.1427	15	1	11.35	0.001118	114.72	148.09	0.15

Table 3-5. Summary Table of Hydrologic Parameters in Aquifers – Preliminary (Cont.)

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AC0540	0.4160	0.0511	0.1246	11.808	5.1037	15	1	8.84	0.000006	119.61	151.92	0.15
AC0550	0.4122	0.0530	0.1321	11.478	5.2116	15	1	10.66	0*	124.10	154.42	0.15
AC0552	0.4163	0.0504	0.1217	12.684	5.0303	15	1	11.02	0.000005	126.44	163.98	0.15
AD0040	0.4160	0.0506	0.1225	11.464	5.0430	15	1	12.13	0.000007	123.62	158.71	0.15
AD0045	0.4145	0.0515	0.1261	10.283	5.1075	15	1	12.47	0.000015	124.67	169.07	0.15
AD0050	0.4127	0.0527	0.1309	9.910	5.1900	15	1	11.95	0.00001	123.56	148.56	0.15
AD0055	0.4152	0.0511	0.1246	8.720	5.0801	15	1	13.86	0.000033	123.37	162.15	0.15
AD0100	0.4143	0.0589	0.1599	7.041	6.0929	15	1	10.93	0*	107.15	133.19	0.15
AD0110	0.4145	0.0598	0.1642	5.324	6.2276	15	1	10.52	0.000019	110.04	141.14	0.15
AD0130	0.4153	0.0515	0.1262	6.341	5.1328	15	1	12.42	0.000128	114.10	146.73	0.15
AD0150	0.4157	0.0508	0.1233	9.471	5.0579	15	1	11.37	0.000001	119.72	151.90	0.15
AD0160	0.4140	0.0519	0.1275	8.908	5.1315	15	1	11.70	0.000002	114.32	142.63	0.15
AD0180	0.4165	0.0503	0.1212	7.703	5.0208	15	1	13.28	0.000007	116.33	151.70	0.15
AD0200	0.4163	0.0527	0.1320	5.323	5.3331	15	1	11.15	0.000602	111.20	147.51	0.15
AE0100	0.4139	0.0557	0.1453	4.340	5.6504	15	1	7.62	0*	104.69	133.45	0.15
AE0110	0.4167	0.0513	0.1256	2.188	5.1563	15	1	11.73	0.000316	89.70	153.94	0.15
AE0120	0.4141	0.0545	0.1397	2.429	5.4951	15	1	11.86	0.000271	95.42	144.38	0.15
AE0140	0.4144	0.0605	0.1674	5.079	6.3167	15	1	10.24	0.000002	108.42	139.91	0.15
AE0150	0.4163	0.0504	0.1218	7.313	5.0310	15	1	13.31	0.000011	121.01	163.83	0.15
AE0160	0.4170	0.0500	0.1200	7.575	5.0001	15	1	12.30	0.000065	125.21	160.03	0.15
AE0162	0.4140	0.0519	0.1275	8.641	5.1311	15	1	14.52	0.000058	129.72	162.29	0.15

Table 3-5. Summary Table of Hydrologic Parameters in Aquifers – Preliminary (Cont.)

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AE0170	0.4168	0.0501	0.1205	5.463	5.0088	15	1	13.32	0.000119	113.03	158.26	0.15
AE0172	0.4170	0.0500	0.1200	5.914	5.0000	15	1	13.16	0.000372	112.68	171.76	0.15
AE0180	0.4115	0.0534	0.1337	2.880	5.2403	15	1	10.00	0.00021	94.20	140.47	0.15
AE0190	0.4170	0.0500	0.1200	2.210	5.0000	15	1	12.06	0.00006	84.40	154.39	0.15
AE0220	0.4144	0.0560	0.1465	2.059	5.7014	15	1	10.37	0.00146	89.24	150.34	0.15
AE0230	0.4158	0.0529	0.1328	2.029	5.3431	15	1	11.85	0.001018	88.57	156.71	0.15
AE0300	0.4150	0.0532	0.1338	3.129	5.3470	15	1	12.72	0.000136	101.60	146.73	0.15
AE0410	0.4147	0.0546	0.1401	4.619	5.5247	15	1	12.69	0.000352	107.65	142.84	0.15
AE0422	0.4135	0.0522	0.1289	3.942	5.1553	15	1	12.38	0.000532	104.44	147.35	0.15
AE0425	0.4170	0.0500	0.1200	3.897	5.0000	15	1	12.39	0*	103.21	142.19	0.15
AE0430	0.4168	0.0509	0.1242	3.538	5.1168	15	1	11.85	0*	97.44	141.52	0.15
AE0440	0.4153	0.0511	0.1243	3.988	5.0747	15	1	12.71	0*	101.13	146.71	0.15
AE0450	0.4165	0.0517	0.1275	4.373	5.2046	15	1	12.28	0*	106.57	148.40	0.15
AE0452	0.4156	0.0532	0.1341	4.551	5.3738	15	1	12.45	0.001114	106.63	148.36	0.15
AE0460	0.4168	0.0507	0.1231	3.600	5.0873	15	1	11.74	0.000794	101.38	148.78	0.15
AE0500	0.4162	0.0505	0.1220	6.734	5.0343	15	1	12.05	0.000106	119.69	152.11	0.15
AE0600	0.4124	0.0529	0.1315	3.951	5.2015	15	1	10.77	0.000288	102.97	143.26	0.15
AE0700	0.4170	0.0500	0.1200	1.884	5.0000	15	1	11.88	0*	80.01	160.47	0.15

* Lower groundwater loss in Aquifers AB0100, AC0550, AD0100, AE0100, AE0425, AE0430, AE0440, AE0450, and AE0700, beneath lakes and sinkholes, was simulated via an outlet link in the SWMM model, see Section 3.3.3.

4.0 Water Budget Model Calibration

4.1 Model Calibration Period

The water budget model for Lake Alto and Lake Santa Fe was calibrated with data in a 10-year simulation span from 1/1/2006 through 12/31/2015. This simulation span includes a variety of hydrologic conditions, including two high water (2009-2010 and 2013-2015) and two low water periods (2006-2008 and 2011-2012), from the long-term historical stage records collected at Lake Alto and Lake Santa Fe. The supporting data sources, such as NEXRAD daily rainfall, groundwater well levels, and ET data, were also available in the calibration simulation span.

In addition, the changes in land use/land cover and withdrawals of water during this simulation period are minimal; therefore, the water budget model developed using the 2006 land use/land cover data and other best available data sources is suitable for model calibration for the selected simulation period.

4.2 Model Calibration Criteria

It is a standard procedure in which observed and simulated values are compared for calibration of a water budget model. The water budget model will ultimately be used to determine the effects of consumptive use withdrawals on lake stages. Therefore, the model's capability to predict or simulate lake stages will be tested by calibration against known gage data.

The primary criterion or goal for model calibration has been established by the District, as stated in the project scope of work, i.e., acceptable model calibration is 0.5 foot or less root mean square error (RMSE) of the difference between simulated and observed stage values. This primary goal is to maximize the number of simulated stage values within ±0.5 foot of the corresponding observed stage values at the lakes.

The secondary criteria or goals include: 1) to have at least two thirds or 67% of residuals within ±0.5 foot; 2) to have at least 90% of residuals within ±1.0 foot; and 3) to meet these criteria over a wide range of stages. The size of these ranges was set based on a hypothetical lake with a 10-ft range of fluctuation. For a lake with 10 ft of total fluctuation, 0.5 foot corresponds to 5% and 1.0 foot corresponds to 10%. These secondary criteria or goals have been employed previously in the Indian Lake System Minimum Flows and Levels Hydrologic Methods Report (Robison, 2014).

4.3 Model Calibration Approach

4.3.1 Time Series Data

A number of different types of time series data are used as input in the SWMM model. In this project, rainfall, ET, potentiometric surface levels of the upper FAS, as well as lake stage values, were used in the model calibration task.

4.3.1.1 Rainfall

Upon review of the long-term rainfall data collected, the NEXRAD rainfall data provided by the District was considered the best available data and hence used for model calibration (Figure 4-1). Weather radar, when combined with rain gauge records, provides detailed information concerning rainfall densities over specified areas. The entire District is divided into individual 2 km x 2 km pixels, each of which has daily rainfall estimates.

In the SWMM model, a series of rain gages were used to represent the selected NEXRAD pixels and to supply daily rainfall data for one or more subcatchments in the model domain.

4.3.1.2 Evapotranspiration

Daily PET data has been developed by USGS for a time period from 6/1/1995 through 12/31/2015, from 15 data collection sites that represent various land cover types in Florida (Jacobs *et al.*, 2008). The long-term, accurate, and unbiased PET information meets all the needs for model calibration of the SWMM model. Similar to the NEXRAD rainfall data, the entire State of Florida is divided into individual 2 km x 2 km pixels, each of which has daily PET estimates. The USGS data uses the same pixel polygon features that the NEXRAD rainfall data uses to store and manage the PET data (Figure 4-1).

Because SWMM can only model one ET time series data source, daily PET data was estimated for the entire lake watershed, by using the area-weighted daily PET data at each of the pixels intersected with the watershed. The estimated daily PET data for the lake watershed (Figure 4-2) was utilized in the SWMM model in two ways: 1) to calculate direct lake evaporation; and 2) to estimate ET occurring in the upper and lower zones of the groundwater aquifers.

Direct evaporation from the lakes can be estimated using PET data multiplied by a coefficient. The average monthly and annual PET values were estimated for the entire lake watershed, based on the area-weighted daily PET data from 1996 through 2014 (Table 4-1). As indicated in the Indian Lake System Minimum Flows and Levels Hydrologic Methods Report (Robison, 2014), the average annual evaporation for shallow lakes in the SJRWMD vary from 45 to 48 inches. Since the average annual PET value of 48.29 inches is close to the upper limit of the annual evaporation range for the SJRWMD lakes, the daily PET data was used to calculate the direct evaporation with a coefficient of 1.0.

The methodology for estimation of ET occurring in the upper zone of groundwater aquifers has been previously described in Section 3.2.4.

Table 4-1. Summary Table of Average Monthly and Annual PET Data for Lake Alto and Lake Santa Fe Watershed (1996-2015)

Month	PET Value (inch/month)
January	1.46
February	2.04
March	3.63
April	5.05
May	6.38
June	6.15
July	6.46
August	5.94
September	4.59
October	3.36
November	1.93
December	1.29
Total	**48.29 inch/year**

Sources: USGS, 2016.

4.3.1.3 FAS Potentiometric Surface Levels

A long-term USGS groundwater well station near Melrose, FL (USGS ID: 294313082024601 / SRWMD ID: S092307001) is located approximately 0.5 miles east of Lake Santa Fe (Figure 4-3). This well station provides daily potentiometric surface levels in the upper FAS since 4/28/1983. The data gaps in the raw data from 1/1/2006 to 1/31/2015 were filled using a linear interpolation method.

Shift factors were estimated for the major lakes and sinkholes, by approximating the groundwater level differences between the USGS Melrose station and these lakes/sinkholes based on the May 2005 potentiometric contour map (Figure 4-3). The estimated shift factors varied from -2.5 feet to -10 feet (Table 4-2). Upon applying the estimated shift factors to the observed/filled daily groundwater well levels at the Melrose station, the new shifted daily well level data would be more representative of the groundwater conditions beneath Lake Alto, Lake Santa Fe, and other lakes and sinkholes.

The observed/filled well level hydrograph at the Melrose station as well as the shifted well level hydrographs at the lakes and sinkholes are plotted in Figure 4-4.

Table 4-2. Summary Table of Shift Factors to Estimate Well Levels beneath Lakes and Sinkholes

ID	Location	Shift Factor (ft)
1	USGS Melrose	0
2	Lake Santa Fe	-2.5
3	Sinkhole S. of Indian Lake	-4
4	Indian Lake	-4.5
5	Little Lake Santa Fe	-6
6	Hickory Pond	-8
7	**Lake Alto**	**-10**

Sources: SRWMD, 2016.

4.3.1.4 Lake Stages

USGS 02320630 Lake Alto at Waldo, FL is a long-term stage gage located at the west end of the Waldo Canal (Figure 4-5). This District-operated lake stage station provides the long-term historical lake stage values in a variety of frequencies from 1976 to current (Figure 4-6A). The lake stage records were used to establish the initial stage value at Lake Alto in the model as well as to compare with the simulated stage values for model calibration. Since the majority of the stage values at this station were provided on a weekly basis, the recently-collected daily stage records (3/17/2013 to current) were resampled to weekly stage values (Figure 4-6B). The data resampling was done to eliminate the bias due to the different frequencies in the raw data. The resampled lake stage data was used to compare with the simulated stage values in the model calibration.

A USGS long-term stage station 02320600 Santa Fe Lake near Keystone HTS, FL is located at the northeast corner of Lake Santa Fe, and a District-operated long-term stage station USGS 02320601 Santa Fe Lake near Earleton, FL is located on the west lakeshore of Lake Santa Fe (Figure 4-5). This USGS/District-operated lake stage stations provides the long-term historical lake stage values in a variety of frequencies from 7/11/1957 to 11/29/ 1993 (USGS 02320600) and from 4/27/2006 to current (USGS 02320601) (Figure 4-6A). The lake stage records were used to establish the initial stage value at Lake Santa Fe in the model as well as to compare with the simulated stage values for model calibration. Since the lake stage values from 4/27/2006 to current were provided on a daily basis at USGS 02320601, no data resampling was required at this station (Figure 4-6C).

For Little Lake Santa Fe, a USGS long-term stage station 02320610 Little Santa Fe Lake near Waldo, FL is located at the north lake shore, and a District-operated long-term stage station USGS 02320611 was located on the west lake shore of Little Lake Santa Fe (Figure 4-5). Weekly stage data was manually measured from 2/15/1989 to 11/26/1993 by USGS at USGS 02320610 and from 8/28/2000 to current by the District at USGS 02320611 (Figure 4-6A). The lake stage data provided at this short-term gage station could be used to validate the stage data measured at USGS stations 02320600 and 02320601; however, it will not be used for model calibration purposes due to its shorter data history compared to the USGS stations located at the "Big" Lake Santa Fe.

4.3.2 Adjustment of Hydrologic Model Parameters

Various hydrologic model parameters were adjusted during the model calibration process, including impervious percentage, lower groundwater loss rate, and other parameters used in groundwater and aquifer components in the SWMM model, as discussed in detail below. Other hydrologic model parameters were held constant in the model calibration process.

4.3.2.1 Impervious Percentages

It is common to model wetland areas (FLUCCS 6000) as impervious areas for design storm event simulations; however, for long-term simulations of a water budget model, wetland areas may not even hold standing water during dry conditions and infiltration may occur where the soils underneath are unsaturated and the groundwater table is low. The impervious percentage value of 98%, as originally defined in the model development task, seems inappropriate particularly for the shallow forested wetland areas, e.g., Lake Alto Swamp and Santa Fe Swamp, which dominate the central lake watershed. High impervious percentage results in high surface water runoff volumes and underestimates infiltration and percolation to the surficial aquifer, particularly for the 2006-2008 and 2011-2012 drought periods (Figures 4-6B and 4-6C).

Therefore, impervious percentage values for wetland areas were reduced to 50% to account for low rainfall periods, as highlighted in Table 4-3, the updated lookup table of the hydrologic parameters for the surface runoff calculation. The impervious percentage value for each subbasin was recalculated and updated in the SWMM model as well (Table 4-4). The revised impervious percentage and other hydrologic parameters for the subbasins (Table 4-4) were then held constant in the model calibration.

Table 4-3. Lookup Table of Hydrologic Parameters for Surface Runoff Calculation - Final

FLUCCS	Description	% of Imperv. Area	% of Zero Storage Imperv.	Manning n Imperv.	Manning n Perv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)
1100	Residential Low Density <2 Dwelling Units	15	25	0.012	0.1	0.05	0.15
1200	Residential Med Density 2->5 Dwelling Units	30	25	0.012	0.1	0.05	0.15
1300	Residential High Density	50	25	0.012	0.1	0.05	0.15
1400	Commercial and Services	85	25	0.012	0.1	0.05	0.15
1500	Industrial	72	25	0.012	0.1	0.05	0.15
1600	Extractive	65	25	0.012	0.1	0.1	0.15
1650	Reclaimed Land	65	25	0.012	0.1	0.05	0.15
1700	Institutional	60	25	0.012	0.1	0.05	0.15
1800	Recreational	60	25	0.012	0.1	0.05	0.15
1820	Golf Courses	5	25	0.012	0.1	0.05	0.15
1900	Open Land	0	25	0.012	0.15	0.1	0.1
2100	Cropland and Pastureland	0	25	0.012	0.1	0.05	0.2
2140	Row Crops	0	25	0.012	0.17	0.05	0.2
2200	Tree Crops	0	25	0.012	0.4	0.05	0.2
2300	Feeding Operations	0	25	0.012	0.1	0.05	0.2
2400	Nurseries and Vineyards	0	25	0.012	0.1	0.05	0.2
2500	Specialty Farms	0	25	0.012	0.1	0.05	0.2
2550	Tropical Fish Farms	0	25	0.012	0.1	0.05	0.2
2600	Other Open Lands (Rural)	0	25	0.012	0.13	0.05	0.2
3100	Herbaceous	0	25	0.012	0.24	0.05	0.2
3200	Shrub and Brushland	0	25	0.012	0.4	0.05	0.25
3300	Mixed Rangeland	0	25	0.012	0.13	0.05	0.25
4100	Upland Coniferous Forest	0	25	0.012	0.5	0.05	0.3
4110	Pine Flatwoods	0	25	0.012	0.5	0.05	0.3
4120	Longleaf Pine - Xeric Oak	0	25	0.012	0.5	0.05	0.3
4200	Upland Hardwood Forests	0	25	0.012	0.5	0.05	0.3
4340	Hardwood Conifer Mixed	0	25	0.012	0.5	0.05	0.3
4400	Tree Plantations	0	25	0.012	0.5	0.05	0.3
5100	Streams and Waterways	100	100	0.01	0.1	0	0
5200	Lakes	100	100	0.01	0.1	0	0
5300	Reservoirs	100	100	0.01	0.1	0	0
5400	Bays and Estuaries	100	100	0.01	0.1	0	0

Table 4-3. Lookup Table of Hydrologic Parameters for Surface Runoff Calculation - Final (Cont.)

FLUCCS	Description	% of Imperv. Area	% of Zero Storage Imperv.	Manning n Imperv.	Manning n Perv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)
6100	Wetland Hardwood Forests	50	75	0.4	0.4	0.1	0.25
6110	Bay Swamps	50	75	0.4	0.4	0.1	0.25
6120	Mangrove Swamps	50	75	0.4	0.4	0.1	0.25
6150	Stream and Lake Swamps (Bottomland)	50	75	0.4	0.4	0.1	0.25
6200	Wetland Coniferous Forests	50	75	0.4	0.4	0.1	0.25
6210	Cypress	50	75	0.4	0.4	0.1	0.25
6300	Wetland Forests Mixed	50	75	0.4	0.4	0.1	0.25
6400	Vegetated Non-Forested Wetlands	50	75	0.24	0.24	0.1	0.25
6410	Freshwater Marshes	50	75	0.24	0.24	0.1	0.25
6420	Saltwater Marshes	50	75	0.24	0.24	0.1	0.25
6430	Wet Prairies	50	75	0.24	0.24	0.1	0.25
6440	Emergent Aquatic Vegetation	50	75	0.24	0.24	0.1	0.25
6500	Non - Vegetated	50	75	0.24	0.24	0.1	0.25
6510	Tidal Flats / Submerged Shallow Platform	50	75	0.24	0.24	0.1	0.25
6520	Shorelines	50	75	0.24	0.24	0.1	0.25
6530	Intermittent Ponds	50	75	0.24	0.24	0.1	0.25
6600	Salt Flats	50	75	0.24	0.24	0.1	0.25
7100	Beaches Other Than Swimming Beaches	0	25	0.012	0.1	0.05	0.1
7400	Disturbed Land	0	25	0.012	0.1	0.05	0.1
8100	Transportation	50	75	0.012	0.1	0.05	0.15
8200	Communications	85	25	0.012	0.1	0.05	0.15
8300	Utilities	72	25	0.012	0.1	0.05	0.15

Sources: TR-55 (USDA, 1986); Drainage Handbook Hydrology (FDOT, 2012); ECT, 2017a & 2017b.

Table 4-4. Summary Table of Hydrologic Parameters in Subbasins - Final

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
A0100	318.63	3812	1.60	37.67	62.52	0.088	0.258	0.300	0.406	2.1	3.2045	0.363
A0110	78.98	1611	1.70	20.85	43.74	0.069	0.239	0.155	0.334	2.1	3.5499	0.366
A0120	57.04	1550	1.90	13.90	37.47	0.062	0.243	0.098	0.331	2.0	4.1364	0.371
A0200	239.74	5636	2.50	31.80	55.92	0.081	0.251	0.252	0.385	2.1	3.7545	0.368
A0210	96.33	2118	1.60	4.29	25.61	0.051	0.219	0.017	0.230	1.9	4.6378	0.375
A0220	25.79	1182	2.40	2.82	26.85	0.052	0.256	0.026	0.345	2.0	4.1193	0.371
A0300	177.98	5764	2.80	40.99	65.86	0.091	0.252	0.291	0.353	1.9	4.6292	0.375
A0310	61.53	1612	1.90	6.65	31.25	0.056	0.288	0.049	0.458	1.9	4.6378	0.375
A0320	126.09	2786	1.80	8.97	33.68	0.059	0.249	0.079	0.317	2.0	4.3068	0.372
A0330	73.41	1263	1.70	1.28	25.00	0.050	0.235	0.012	0.259	1.9	4.6378	0.375
A0400	581.87	7933	2.70	47.18	72.18	0.097	0.252	0.369	0.397	2.1	3.4348	0.365
A0405	33.60	2197	2.00	33.44	58.44	0.078	0.232	0.227	0.367	1.9	4.6378	0.375
A0410	65.73	2153	2.10	7.78	32.78	0.056	0.260	0.043	0.307	1.9	4.6378	0.375
A0412	68.06	1404	1.60	9.34	34.33	0.059	0.276	0.073	0.413	2.0	4.1600	0.371
A0414	44.20	991	1.70	6.24	30.49	0.055	0.242	0.055	0.304	1.9	4.6378	0.375
A0420	19.40	866	2.30	6.34	31.34	0.050	0.279	0.012	0.441	1.9	4.6378	0.375
A0422	19.90	1336	1.80	3.73	28.73	0.054	0.272	0.041	0.371	2.0	4.0432	0.37
A0430	38.70	1082	1.90	8.04	33.04	0.055	0.286	0.053	0.462	2.0	4.0803	0.37
A0500	308.05	3923	2.90	46.80	71.80	0.095	0.251	0.348	0.381	2.1	3.2376	0.364
A0505	45.87	851	1.80	13.74	38.67	0.061	0.260	0.092	0.357	1.9	4.6378	0.375
A0510	43.28	1767	1.80	7.35	32.08	0.057	0.289	0.067	0.476	2.1	3.7286	0.368

Table 4-4. Summary Table of Hydrologic Parameters in Subbasins – Final (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
A0512	24.31	1221	1.50	8.36	33.36	0.058	0.274	0.077	0.430	1.9	4.6378	0.375
A0514	7.59	748	1.40	13.37	38.37	0.063	0.260	0.116	0.404	2.1	3.7444	0.368
A0516	51.01	1241	1.60	43.59	33.08	0.054	0.208	0.041	0.247	2.0	4.5597	0.374
A0518	37.53	1228	1.80	12.64	31.39	0.054	0.243	0.044	0.337	2.0	4.2237	0.372
A0520	23.50	1376	2.30	49.71	48.13	0.055	0.173	0.050	0.166	2.0	4.3190	0.372
A0522	89.61	1102	2.00	20.18	32.11	0.056	0.209	0.056	0.255	2.0	4.2096	0.372
A0530	131.87	2008	2.10	12.70	36.91	0.060	0.248	0.079	0.354	2.0	4.1780	0.371
A0540	144.23	2291	2.40	18.31	30.79	0.049	0.206	0.013	0.220	1.9	4.6378	0.375
A0542	82.52	2491	2.30	34.25	31.82	0.053	0.207	0.038	0.243	2.0	4.6253	0.375
A0544	64.43	1823	2.90	8.83	33.71	0.058	0.290	0.059	0.463	2.0	4.2953	0.372
A0550	196.40	2566	2.60	27.01	40.75	0.062	0.230	0.085	0.298	1.9	4.6378	0.375
A0560	88.87	2147	2.20	20.39	29.66	0.050	0.228	0.013	0.290	1.9	4.6378	0.375
A0570	78.82	1737	2.00	37.04	27.56	0.050	0.175	0.012	0.178	2.0	4.5278	0.374
A0580	153.79	1732	1.80	17.06	33.77	0.059	0.239	0.080	0.329	1.9	4.6378	0.375
A0582	47.16	1486	1.30	6.45	26.34	0.051	0.247	0.022	0.303	1.9	4.6378	0.375
A0584	44.00	875	2.10	10.50	34.37	0.058	0.261	0.068	0.347	2.0	4.0252	0.37
A0586	67.68	1423	1.90	7.95	28.12	0.053	0.232	0.032	0.264	1.9	4.6378	0.375
A0588	56.24	1548	1.70	8.64	32.02	0.057	0.266	0.065	0.403	2.0	4.4979	0.374
A0590	46.41	1775	2.70	12.63	35.72	0.056	0.223	0.059	0.331	2.0	4.5893	0.375
A0592	84.34	1024	2.70	28.67	34.98	0.049	0.178	0.012	0.172	1.9	4.6378	0.375
A0600	546.57	9938	2.80	44.39	69.39	0.094	0.253	0.343	0.387	2.0	4.0456	0.37

Table 4-4. Summary Table of Hydrologic Parameters in Subbasins – Final (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
A0610	75.83	1376	3.20	11.56	36.56	0.062	0.285	0.085	0.431	1.9	4.6378	0.375
A0620	155.69	1708	2.60	6.20	31.20	0.056	0.266	0.052	0.327	1.9	4.6378	0.375
A0630	54.02	1015	3.90	34.45	59.45	0.084	0.266	0.279	0.431	1.9	4.6378	0.375
A0640	28.78	977	2.10	0.00	25.00	0.050	0.299	0.012	0.493	1.9	4.6378	0.375
B0100	627.14	98284	0.40	94.66	96.82	0.008	0.023	0.039	0.125	2.0	4.0332	0.370
B0110	121.43	3431	2.40	2.74	25.97	0.051	0.253	0.019	0.319	1.9	4.6378	0.375
B0112	93.09	1186	2.40	0.20	25.00	0.050	0.287	0.012	0.443	1.9	4.6378	0.375
B0120	215.95	3053	2.50	8.18	30.98	0.054	0.263	0.045	0.367	1.9	4.6378	0.375
B0130	103.57	1364	3.40	13.50	38.50	0.063	0.287	0.107	0.463	2.0	4.5700	0.374
B0140	14.35	9975	7.70	51.60	65.94	0.040	0.164	0.092	0.307	1.9	4.6348	0.375
B0150	58.85	2852	2.00	1.44	25.01	0.050	0.282	0.012	0.431	1.9	4.6378	0.375
B0160	82.30	2381	1.50	4.43	27.24	0.052	0.229	0.029	0.386	1.9	4.6378	0.375
B0200	184.79	3697	2.70	27.08	41.26	0.066	0.230	0.138	0.324	1.9	4.6378	0.375
B0300	118.84	3068	2.80	33.36	57.23	0.082	0.257	0.262	0.406	2.0	4.5372	0.374
B0400	538.11	5309	2.70	36.58	57.12	0.081	0.236	0.190	0.291	2.0	4.3011	0.372
B0410	25.98	1104	2.00	17.96	32.75	0.058	0.226	0.072	0.315	2.0	3.9943	0.370
C0100	3282.25	20036	1.50	48.04	56.13	0.098	0.250	0.276	0.286	4.2	0.6285	0.306
C0110	286.32	3197	1.70	14.03	33.79	0.064	0.224	0.085	0.211	1.9	4.6336	0.375
C0120	304.79	3765	1.90	2.74	27.59	0.053	0.280	0.029	0.404	2.0	3.9130	0.369
C0200	303.41	4240	3.00	37.71	62.70	0.088	0.261	0.275	0.391	3.8	1.0073	0.317
C0201	247.97	2984	1.60	2.65	26.33	0.051	0.244	0.020	0.301	2.2	3.1028	0.363

Table 4-4. Summary Table of Hydrologic Parameters in Subbasins – Final (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
C0202	45.77	1201	1.90	7.80	32.72	0.058	0.277	0.069	0.403	2.0	4.0478	0.370
C0203	86.49	1604	2.10	2.22	27.11	0.052	0.263	0.028	0.336	2.2	3.0854	0.362
C0204	123.80	2062	2.20	9.55	34.55	0.060	0.280	0.085	0.458	2.1	3.6599	0.367
C0210	539.07	2767	2.20	7.26	30.88	0.056	0.286	0.053	0.459	2.1	3.3150	0.364
C0212	313.58	1856	1.90	6.42	30.24	0.054	0.253	0.048	0.357	2.2	2.8304	0.360
C0220	459.79	3156	2.00	9.36	30.77	0.056	0.286	0.054	0.463	2.3	2.2328	0.356
C0230	171.71	2356	2.30	11.12	30.20	0.055	0.282	0.052	0.456	2.3	1.9945	0.354
C0240	202.32	2205	2.10	5.88	29.61	0.055	0.293	0.045	0.481	2.3	1.8948	0.353
C0244	218.63	2186	2.00	8.49	31.03	0.056	0.256	0.058	0.380	2.3	1.7515	0.352
C0250	773.85	4065	1.90	14.32	39.06	0.064	0.282	0.120	0.458	2.3	2.2511	0.356
C0254	32.65	1244	1.70	4.53	29.53	0.055	0.295	0.047	0.491	2.0	4.3354	0.373
C0260	263.04	2027	2.30	21.47	46.44	0.071	0.278	0.150	0.428	2.1	3.3036	0.364
C0270	176.00	3466	3.80	48.38	33.71	0.065	0.195	0.049	0.223	1.9	4.6378	0.375
C0280	1175.20	4055	2.40	17.12	40.44	0.065	0.280	0.117	0.442	2.4	3.6807	0.361
C0282	243.25	3088	2.50	20.07	33.70	0.058	0.262	0.074	0.404	2.0	4.5743	0.374
C0300	443.32	5361	2.90	45.70	67.13	0.095	0.250	0.329	0.359	4.0	0.9642	0.311
C0301	45.77	1961	1.80	2.72	25.01	0.050	0.254	0.012	0.340	2.0	4.3418	0.372
C0303	17.43	811	2.20	9.97	34.97	0.060	0.290	0.089	0.480	1.9	4.6378	0.375
C0304	143.90	1659	2.50	7.11	30.77	0.056	0.271	0.057	0.402	2.0	4.5550	0.374
C0306	19.75	645	1.70	13.58	25.00	0.050	0.222	0.012	0.257	1.9	4.6378	0.375
C0308	88.40	2328	2.90	20.19	41.15	0.066	0.238	0.126	0.309	2.0	4.5688	0.374

Table 4-4. Summary Table of Hydrologic Parameters in Subbasins – Final (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
C0310	253.38	3511	1.80	12.82	30.91	0.055	0.204	0.051	0.189	2.2	4.0189	0.366
C0311	95.54	1529	1.40	9.13	27.21	0.052	0.209	0.027	0.178	2.0	4.5701	0.374
C0314	158.85	1939	2.10	8.08	27.11	0.052	0.233	0.028	0.278	2.0	4.3669	0.373
C0316	112.09	877	2.40	7.00	27.55	0.053	0.265	0.032	0.358	2.0	4.4610	0.374
C0320	154.52	1942	2.10	2.01	25.31	0.050	0.226	0.012	0.209	2.0	4.0101	0.370
C0322	115.61	1313	2.10	2.82	25.26	0.050	0.275	0.014	0.407	2.0	4.5619	0.374
C0330	170.25	2295	2.00	8.25	29.05	0.053	0.241	0.032	0.327	2.1	3.7872	0.368
C0340	483.91	2612	1.90	9.12	30.11	0.055	0.251	0.046	0.328	2.0	3.8925	0.369
C0342	36.50	1333	1.80	21.68	45.94	0.071	0.227	0.175	0.259	2.1	3.6633	0.367
C0344	48.87	2478	2.10	10.57	35.57	0.061	0.247	0.094	0.302	2.1	3.2240	0.364
C0350	789.53	4176	2.30	7.77	30.73	0.053	0.284	0.037	0.452	2.0	4.4657	0.374
C0360	223.65	2041	1.80	6.45	31.45	0.056	0.293	0.062	0.487	2.1	3.8679	0.369
C0370	312.88	2223	2.20	5.15	30.15	0.055	0.295	0.050	0.487	2.0	4.4686	0.374
C0400	969.54	10498	1.50	44.17	57.54	0.094	0.255	0.279	0.335	3.9	1.1289	0.314
C0410	296.39	3274	2.70	20.86	40.42	0.064	0.258	0.124	0.365	2.7	3.2627	0.352
C0420	117.48	2211	2.70	4.57	29.57	0.055	0.282	0.047	0.440	2.0	4.4394	0.373
C0430	161.95	2817	2.00	5.87	29.23	0.056	0.291	0.044	0.464	2.2	4.1585	0.367
C0500	1445.33	8622	1.30	48.47	71.67	0.098	0.249	0.361	0.365	4.2	0.6535	0.306
C0505	49.15	1906	1.90	0.87	25.00	0.050	0.204	0.012	0.132	1.9	4.6378	0.375
C0507	120.82	3680	2.30	2.05	26.34	0.051	0.291	0.020	0.473	2.0	4.5737	0.374
C0508	59.41	995	1.70	14.60	39.60	0.065	0.285	0.116	0.462	2.4	3.8150	0.361

Table 4-4. Summary Table of Hydrologic Parameters in Subbasins – Final (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
C0510	117.73	2426	2.10	14.93	39.48	0.064	0.271	0.124	0.435	2.7	3.3673	0.353
C0520	83.05	1386	2.90	18.45	42.00	0.064	0.261	0.114	0.392	2.6	3.4143	0.355
C0522	69.54	1259	2.40	10.97	35.97	0.061	0.270	0.091	0.428	2.1	3.7447	0.368
C0530	312.99	3146	2.00	7.11	32.03	0.057	0.281	0.063	0.431	2.1	4.1152	0.370
C0540	195.52	2789	2.40	4.92	29.92	0.055	0.211	0.044	0.191	2.0	4.3321	0.372
C0550	552.81	5036	1.80	27.08	48.26	0.058	0.221	0.107	0.342	2.1	3.5917	0.367
C0552	74.52	2189	2.30	11.26	36.19	0.061	0.229	0.099	0.268	2.0	4.4880	0.374
D0040	489.56	3901	1.80	5.81	30.02	0.055	0.252	0.048	0.372	2.0	4.4251	0.373
D0045	62.60	1586	1.80	14.42	38.22	0.063	0.269	0.115	0.431	2.0	4.1066	0.371
D0050	581.97	6326	1.80	17.63	41.61	0.067	0.261	0.120	0.390	2.1	3.6985	0.367
D0055	207.44	2915	1.90	6.27	28.86	0.054	0.267	0.042	0.416	2.0	4.2417	0.372
D0100	1224.32	172321	0.30	93.82	95.89	0.008	0.023	0.031	0.119	3.0	2.7165	0.343
D0110	28.94	1212	3.30	39.60	61.95	0.087	0.237	0.299	0.355	3.7	1.4780	0.320
D0120	72.94	1568	2.70	23.59	47.27	0.071	0.265	0.162	0.406	2.9	3.0049	0.347
D0130	33.23	2989	2.20	8.64	28.05	0.053	0.241	0.036	0.342	2.1	4.3188	0.369
D0140	64.23	1345	2.50	2.10	25.00	0.050	0.259	0.012	0.312	2.0	4.1265	0.371
D0150	131.26	2623	2.20	8.48	29.13	0.052	0.211	0.032	0.305	2.0	4.3516	0.373
D0160	9.53	1335	2.10	25.52	32.90	0.058	0.198	0.067	0.227	1.9	4.6378	0.375
D0170	109.94	1582	1.60	18.03	39.08	0.064	0.256	0.093	0.379	2.0	3.9315	0.369
D0180	134.04	3340	1.90	7.90	25.24	0.050	0.223	0.014	0.295	2.0	4.5348	0.374
D0200	140.81	2821	2.00	8.34	33.19	0.058	0.268	0.076	0.386	2.3	4.0754	0.365

Table 4-4. Summary Table of Hydrologic Parameters in Subbasins – Final (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
E0100	4289.98	424660	0.20	94.99	96.56	0.007	0.018	0.028	0.115	2.5	3.2595	0.355
E0110	192.56	3772	2.60	12.98	29.48	0.051	0.216	0.025	0.285	2.1	4.3746	0.370
E0120	103.92	2326	2.80	45.93	70.27	0.095	0.248	0.271	0.300	3.5	1.6125	0.327
E0130	42.25	2054	2.40	27.17	28.62	0.054	0.179	0.040	0.179	2.0	4.5375	0.373
E0140	23.23	541	3.50	48.46	73.13	0.098	0.249	0.385	0.395	3.2	2.4212	0.337
E0150	279.61	6121	1.90	7.04	27.57	0.053	0.222	0.029	0.318	2.0	4.4847	0.374
E0160	301.91	2791	1.60	6.12	30.71	0.055	0.245	0.042	0.317	1.9	4.6372	0.375
E0162	47.66	1281	1.70	12.04	37.04	0.062	0.285	0.105	0.466	2.0	3.9897	0.370
E0170	306.22	2447	2.00	12.37	29.85	0.055	0.212	0.047	0.209	2.0	4.5942	0.375
E0172	47.90	1508	1.40	10.42	35.42	0.060	0.290	0.093	0.479	1.9	4.6378	0.375
E0180	87.91	1559	3.40	29.83	50.62	0.065	0.225	0.138	0.310	2.1	3.4496	0.365
E0190	87.43	3738	2.00	14.98	25.00	0.050	0.199	0.012	0.231	1.9	4.6378	0.375
E0200	76.44	1118	2.80	30.95	27.65	0.053	0.156	0.033	0.117	2.6	3.4517	0.355
E0210	100.14	1473	3.30	11.93	36.40	0.061	0.286	0.100	0.470	2.1	3.7011	0.367
E0220	792.63	8823	1.90	19.91	43.04	0.068	0.255	0.129	0.340	2.6	3.2698	0.354
E0230	86.51	3475	3.00	23.40	45.88	0.058	0.256	0.095	0.413	2.3	3.9847	0.365
E0300	169.49	1998	2.40	20.22	39.91	0.065	0.262	0.126	0.405	2.3	3.8535	0.364
E0400	94.62	2721	2.60	17.48	42.31	0.067	0.281	0.132	0.446	2.4	3.4807	0.360
E0410	134.78	2660	3.20	15.10	40.10	0.065	0.268	0.113	0.420	2.5	3.5793	0.359
E0420	40.78	1226	1.90	13.37	37.23	0.062	0.276	0.107	0.445	2.5	3.6728	0.358
E0422	26.15	1767	2.30	7.25	31.24	0.056	0.272	0.060	0.412	2.1	3.8703	0.369

Table 4-4. Summary Table of Hydrologic Parameters in Subbasins – Final (Cont.)

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% of Imperv. Area	% of Zero Storage Imperv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)	Manning n Imperv.	Manning n Perv.	Suction Head (in)	Conductivity (in/hr)	Initial Moisture Deficit
E0425	36.59	1210	1.80	4.03	28.73	0.054	0.293	0.029	0.472	1.9	4.6378	0.375
E0430	165.62	3884	3.20	15.61	26.89	0.060	0.224	0.023	0.285	2.1	4.4412	0.372
E0440	170.18	2894	2.30	5.27	25.00	0.050	0.231	0.012	0.324	2.0	4.2684	0.372
E0450	261.88	3980	1.60	13.71	36.81	0.054	0.245	0.057	0.339	2.1	4.2736	0.369
E0452	78.61	1651	1.80	9.77	34.77	0.060	0.276	0.081	0.424	2.3	3.9096	0.364
E0460	89.23	2369	2.50	0.09	25.00	0.050	0.255	0.012	0.354	1.9	4.6378	0.375
E0462	45.26	1656	1.80	11.65	33.47	0.047	0.206	0.025	0.218	2.2	4.1775	0.367
E0500	523.39	5458	1.50	27.75	47.33	0.063	0.227	0.115	0.298	2.0	4.4685	0.374
E0600	676.82	4326	2.00	26.42	49.76	0.068	0.253	0.151	0.388	2.1	3.6416	0.367
E0700	133.47	2334	2.50	12.49	27.17	0.049	0.236	0.012	0.341	1.9	4.6378	0.375

4.3.2.2 Groundwater & Aquifers

The majority of the parameters associated with groundwater and aquifers were kept constant in the model calibration, e.g., the parameters for soil characteristics (Table 4-5).

The lower groundwater loss rate in aquifers controls deep seepage flow into the upper FAS and is an important part of a water budget model. It is one of the few primary parameters that were adjusted in a series of trial and error runs during model calibration. The final calibrated lower groundwater loss rate values are highlighted in Table 4-5.

Also note that the lower groundwater loss in the aquifer beneath lakes and sinkholes was modeled via an "outlet" link in the SWMM model, as discussed in Section 4.3.3.2. A constant lower groundwater loss rate was used for other aquifers upon review of the simulated flow results at the modeled outlet links (Figures 4-7A through 4-7C).

Based on the initial calibration model run results, monthly ET coefficients were adjusted for Upland Forests (FLUCCS 4000), as highlighted in Table 4-6, which dominates the upland areas of the lake watershed. The ET coefficients were kept constant for the subsequent model calibration runs.

The coefficients (A1, A2, B1, B2, and A3), used in the equation that computes lateral groundwater flow, were adjusted through the first few model calibration runs, as highlighted in Table 4-7, to obtain reasonable groundwater levels in the aquifers and flows between the aquifers and the receiving storage nodes. These coefficients were kept constant for the subsequent model calibration runs.

Table 4-5. Summary Table of Hydrologic Parameters in Aquifers - Final

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AA0100	0.4104	0.0541	0.1366	18.442	5.2899	15	1	8.42	0.000900	108.93	136.45	0.15
AA0110	0.4131	0.0524	0.1297	17.221	5.1703	15	1	11.36	0.000960	112.44	142.73	0.15
AA0200	0.4128	0.0526	0.1304	17.530	5.1820	15	1	7.54	0.000900	110.08	137.44	0.15
AA0210	0.4165	0.0503	0.1213	15.902	5.0221	15	1	10.89	0.001100	114.46	143.89	0.15
AA0310	0.4170	0.0500	0.1200	14.635	5.0000	15	1	11.71	0.001440	124.03	155.97	0.15
AA0320	0.4155	0.0510	0.1238	15.656	5.0669	15	1	10.93	0.000660	116.47	145.26	0.15
AA0330	0.4170	0.0500	0.1200	15.034	5.0000	15	1	12.02	0.001020	122.14	150.92	0.15
AA0405	0.4170	0.0500	0.1200	19.818	5.0000	15	1	11.34	0.001320	112.36	145.55	0.15
AA0410	0.4170	0.0500	0.1200	20.824	5.0000	15	1	13.75	0.001200	113.72	141.89	0.15
AA0412	0.4148	0.0514	0.1255	21.165	5.0966	15	1	14.27	0.001500	116.07	143.15	0.15
AA0414	0.4170	0.0500	0.1200	21.261	5.0000	15	1	14.44	0.001500	117.32	145.14	0.15
AA0420	0.4156	0.0509	0.1235	19.949	5.0609	15	1	11.92	0.001260	113.05	144.08	0.15
AA0430	0.4144	0.0516	0.1264	19.993	5.1128	15	1	12.39	0.001500	115.41	142.56	0.15
AA0505	0.4170	0.0500	0.1200	19.443	5.0000	15	1	11.14	0.001260	113.36	142.89	0.15
AA0510	0.4128	0.0526	0.1305	20.075	5.1839	15	1	12.57	0.001500	116.09	143.17	0.15
AA0512	0.4160	0.0506	0.1225	20.367	5.0430	15	1	13.02	0.001560	116.45	146.13	0.15
AA0516	0.4163	0.0504	0.1218	21.070	5.0311	15	1	13.70	0.001560	118.81	147.17	0.15
AA0518	0.4151	0.0512	0.1248	20.563	5.0838	15	1	13.34	0.001560	121.33	147.76	0.15
AA0522	0.4150	0.0512	0.1250	21.833	5.0866	15	1	13.41	0.002040	121.16	155.67	0.15
AA0530	0.4149	0.0513	0.1253	19.581	5.0930	15	1	13.78	0.001500	115.56	143.33	0.15
AA0540	0.4170	0.0500	0.1200	20.736	5.0000	15	1	13.59	0.001980	122.23	152.50	0.15

Table 4-5. Summary Table of Hydrologic Parameters in Aquifers - Final (Cont.)

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AA0542	0.4169	0.0500	0.1201	20.883	5.0025	15	1	14.56	0.001980	124.57	155.12	0.15
AA0544	0.4154	0.0510	0.1240	21.873	5.0693	15	1	15.49	0.002400	122.15	157.10	0.15
AA0550	0.4170	0.0500	0.1200	18.918	5.0000	15	1	13.43	0.001800	116.09	142.40	0.15
AA0560	0.4170	0.0500	0.1200	19.744	5.0000	15	1	14.16	0.001920	123.14	151.28	0.15
AA0570	0.4165	0.0503	0.1213	18.799	5.0222	15	1	14.32	0.001980	120.75	152.09	0.15
AA0580	0.4170	0.0500	0.1200	19.801	5.0000	15	1	13.52	0.002220	125.51	153.62	0.15
AA0582	0.4156	0.0509	0.1234	20.619	5.0598	15	1	14.40	0.002340	126.16	156.74	0.15
AA0586	0.4167	0.0502	0.1207	19.959	5.0128	15	1	12.63	0.002880	125.97	154.92	0.15
AA0590	0.4168	0.0501	0.1206	17.983	5.0098	15	1	13.44	0.001860	114.92	142.91	0.15
AA0592	0.4170	0.0500	0.1200	18.180	5.0000	15	1	13.53	0.002580	122.36	152.96	0.15
AA0610	0.4170	0.0500	0.1200	14.102	5.0000	15	1	11.25	0.001500	122.10	155.73	0.15
AA0620	0.4170	0.0500	0.1200	14.257	5.0000	15	1	11.22	0.001440	124.43	155.38	0.15
AA0630	0.4170	0.0500	0.1200	17.734	5.0000	15	1	12.48	0.001560	112.44	140.93	0.15
AA0640	0.4170	0.0500	0.1200	15.169	5.0000	15	1	12.83	0.001080	120.75	151.76	0.15
AB0100	0.4142	0.0517	0.1270	14.727	5.1223	15	1	8.37	0*	108.44	134.30	0.15
AB0110	0.4170	0.0500	0.1200	13.093	5.0000	15	1	14.43	0.002280	120.95	161.89	0.15
AB0120	0.4170	0.0500	0.1200	12.481	5.0000	15	1	13.54	0.002640	121.42	151.42	0.15
AB0130	0.4167	0.0502	0.1208	13.847	5.0137	15	1	10.64	0.001440	120.14	149.31	0.15
AB0150	0.4170	0.0500	0.1200	14.972	5.0000	15	1	13.83	0.001080	109.85	142.68	0.15
AB0160	0.4170	0.0500	0.1200	14.392	5.0000	15	1	12.22	0.001140	118.60	148.47	0.15
AB0200	0.4170	0.0500	0.1200	13.187	5.0000	15	1	10.26	0.001920	119.46	148.98	0.15

Table 4-5. Summary Table of Hydrologic Parameters in Aquifers – Final (Cont.)

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AB0300	0.4157	0.0508	0.1234	16.873	5.0587	15	1	9.62	0.001560	112.20	140.47	0.15
AB0410	0.4140	0.0519	0.1274	18.011	5.1302	15	1	14.48	0.001800	118.13	144.47	0.15
AC0100	0.4122	0.0684	0.2027	11.638	7.2901	15	1	9.92	0.001004	110.30	138.24	0.15
AC0110	0.4170	0.0500	0.1200	13.658	5.0008	15	1	9.51	0.000046	121.30	151.54	0.15
AC0120	0.4136	0.0521	0.1284	18.065	5.1466	15	1	12.32	0.000310	112.45	155.10	0.15
AC0201	0.4099	0.0544	0.1377	13.964	5.3105	15	1	11.41	0.000880	108.43	155.79	0.15
AC0202	0.4143	0.0517	0.1268	13.699	5.1194	15	1	12.58	0.001230	107.14	164.27	0.15
AC0203	0.4098	0.0545	0.1379	18.174	5.3140	15	1	13.37	0.000550	110.91	152.79	0.15
AC0204	0.4125	0.0528	0.1313	19.804	5.1978	15	1	13.58	0.000522	111.33	162.67	0.15
AC0210	0.4109	0.0538	0.1353	21.744	5.2676	15	1	13.69	0.001100	110.69	160.22	0.15
AC0212	0.4086	0.0552	0.1409	16.986	5.3656	15	1	14.00	0.001374	109.45	156.89	0.15
AC0220	0.4059	0.0570	0.1478	20.034	5.4865	15	1	15.20	0.001574	112.11	164.19	0.15
AC0230	0.4048	0.0576	0.1506	14.787	5.5347	15	1	15.54	0.001382	112.24	167.62	0.15
AC0240	0.4043	0.0579	0.1517	15.032	5.5548	15	1	15.81	0.001461	114.93	168.09	0.15
AC0244	0.4037	0.0583	0.1534	18.117	5.5838	15	1	13.79	0.001402	114.48	171.75	0.15
AC0250	0.4064	0.0567	0.1466	13.471	5.4657	15	1	14.41	0.001391	117.16	173.82	0.15
AC0260	0.4108	0.0539	0.1354	7.578	5.2699	15	1	10.92	0.001250	118.21	189.48	0.15
AC0270	0.4170	0.0500	0.1200	5.883	5.0000	15	1	8.47	0.001269	106.88	206.02	0.15
AC0280	0.4150	0.0541	0.1380	8.512	5.4705	15	1	12.46	0.001332	122.24	181.32	0.15
AC0282	0.4167	0.0502	0.1207	5.812	5.0129	15	1	11.22	0.001782	117.56	193.27	0.15
AC0301	0.4157	0.0509	0.1238	11.995	5.0731	15	1	10.89	0.001066	107.18	151.41	0.15

Table 4-5. Summary Table of Hydrologic Parameters in Aquifers - Final (Cont.)

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AC0303	0.4170	0.0500	0.1200	9.596	5.0000	15	1	12.02	0.001862	110.55	148.67	0.15
AC0304	0.4167	0.0502	0.1208	8.271	5.0147	15	1	12.37	0.002147	106.94	158.40	0.15
AC0308	0.4167	0.0502	0.1208	6.914	5.0140	15	1	10.80	0.001902	100.73	168.02	0.15
AC0310	0.4157	0.0526	0.1316	10.621	5.3020	15	1	10.39	0.001374	103.86	161.33	0.15
AC0311	0.4169	0.0503	0.1214	8.855	5.0402	15	1	10.66	0.002594	104.84	153.45	0.15
AC0314	0.4159	0.0507	0.1227	8.373	5.0469	15	1	10.76	0.002802	100.31	165.48	0.15
AC0320	0.4141	0.0518	0.1274	12.222	5.1318	15	1	12.02	0.001042	105.45	161.01	0.15
AC0330	0.4145	0.0516	0.1262	10.095	5.1087	15	1	12.00	0.001136	102.34	171.48	0.15
AC0340	0.4136	0.0522	0.1286	11.311	5.1508	15	1	12.77	0.001008	107.64	168.18	0.15
AC0342	0.4113	0.0535	0.1342	14.438	5.2480	15	1	12.95	0.000996	107.79	163.06	0.15
AC0350	0.4162	0.0505	0.1220	6.827	5.0348	15	1	13.41	0.001176	96.07	186.47	0.15
AC0360	0.4134	0.0522	0.1289	10.491	5.1557	15	1	14.76	0.001322	113.14	174.30	0.15
AC0370	0.4162	0.0505	0.1220	6.963	5.0342	15	1	13.36	0.001550	108.05	186.74	0.15
AC0410	0.4150	0.0563	0.1483	6.870	5.7735	15	1	12.50	0.002614	110.61	152.65	0.15
AC0420	0.4161	0.0506	0.1223	8.549	5.0401	15	1	13.28	0.003570	111.08	152.93	0.15
AC0430	0.4161	0.0521	0.1294	6.451	5.2524	15	1	12.09	0.002166	113.91	144.80	0.15
AC0505	0.4170	0.0500	0.1200	10.375	5.0000	15	1	9.45	0.000900	116.43	148.52	0.15
AC0507	0.4169	0.0503	0.1214	6.794	5.0381	15	1	11.57	0.003293	114.09	147.28	0.15
AC0508	0.4157	0.0553	0.1440	6.177	5.6655	15	1	10.12	0.001664	113.98	142.40	0.15
AC0520	0.4141	0.0542	0.1381	5.741	5.4442	15	1	12.98	0.002308	114.62	147.57	0.15
AC0530	0.4149	0.0517	0.1270	5.614	5.1427	15	1	11.35	0.001676	114.72	148.09	0.15

Table 4-5. Summary Table of Hydrologic Parameters in Aquifers - Final (Cont.)

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AC0540	0.4160	0.0511	0.1246	11.808	5.1037	15	1	8.84	0.002440	119.61	151.92	0.15
AC0550	0.4122	0.0530	0.1321	11.478	5.2116	15	1	10.66	0*	124.10	154.42	0.15
AC0552	0.4163	0.0504	0.1217	12.684	5.0303	15	1	11.02	0.000235	126.44	163.98	0.15
AD0040	0.4160	0.0506	0.1225	11.464	5.0430	15	1	12.13	0.000296	123.62	158.71	0.15
AD0045	0.4145	0.0515	0.1261	10.283	5.1075	15	1	12.47	0.000612	124.67	169.07	0.15
AD0050	0.4127	0.0527	0.1309	9.910	5.1900	15	1	11.95	0.000396	123.56	148.56	0.15
AD0055	0.4152	0.0511	0.1246	8.720	5.0801	15	1	13.86	0.001336	123.37	162.15	0.15
AD0100	0.4143	0.0589	0.1599	7.041	6.0929	15	1	10.93	0*	107.15	133.19	0.15
AD0110	0.4145	0.0598	0.1642	5.324	6.2276	15	1	10.52	0.000386	110.04	141.14	0.15
AD0130	0.4153	0.0515	0.1262	6.341	5.1328	15	1	12.42	0.002566	114.10	146.73	0.15
AD0150	0.4157	0.0508	0.1233	9.471	5.0579	15	1	11.37	0.000060	119.72	151.90	0.15
AD0160	0.4140	0.0519	0.1275	8.908	5.1315	15	1	11.70	0.000115	114.32	142.63	0.15
AD0180	0.4165	0.0503	0.1212	7.703	5.0208	15	1	13.28	0.000138	116.33	151.70	0.15
AD0200	0.4163	0.0527	0.1320	5.323	5.3331	15	1	11.15	0.003010	111.20	147.51	0.15
AE0100	0.4139	0.0557	0.1453	4.340	5.6504	15	1	7.62	0*	104.69	133.45	0.15
AE0110	0.4167	0.0513	0.1256	2.188	5.1563	15	1	11.73	0.003160	89.70	153.94	0.15
AE0120	0.4141	0.0545	0.1397	2.429	5.4951	15	1	11.86	0.001353	95.42	144.38	0.15
AE0140	0.4144	0.0605	0.1674	5.079	6.3167	15	1	10.24	0.000240	108.42	139.91	0.15
AE0150	0.4163	0.0504	0.1218	7.313	5.0310	15	1	13.31	0.000222	121.01	163.83	0.15
AE0160	0.4170	0.0500	0.1200	7.575	5.0001	15	1	12.30	0.001300	125.21	160.03	0.15
AE0162	0.4140	0.0519	0.1275	8.641	5.1311	15	1	14.52	0.001168	129.72	162.29	0.15

Table 4-5. Summary Table of Hydrologic Parameters in Aquifers - Final (Cont.)

Aquifer	Porosity	Wilting Point	Field Capacity	Conduct-ivity (in/hr)	Conduct-ivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	Lower GW Loss Rate (in/hr)	Bottom Elev. (ft NAVD)	Water Table Elev. (ft NAVD)	Unsat. Zone Moisture
AE0170	0.4168	0.0501	0.1205	5.463	5.0088	15	1	13.32	0.002382	113.03	158.26	0.15
AE0172	0.4170	0.0500	0.1200	5.914	5.0000	15	1	13.16	0.001859	112.68	171.76	0.15
AE0180	0.4115	0.0534	0.1337	2.880	5.2403	15	1	10.00	0.002101	94.20	140.47	0.15
AE0190	0.4170	0.0500	0.1200	2.210	5.0000	15	1	12.06	0.001202	84.40	154.39	0.15
AE0220	0.4144	0.0560	0.1465	2.059	5.7014	15	1	10.37	0.002189	89.24	150.34	0.15
AE0230	0.4158	0.0529	0.1328	2.029	5.3431	15	1	11.85	0.002036	88.57	156.71	0.15
AE0300	0.4150	0.0532	0.1338	3.129	5.3470	15	1	12.72	0.002036	101.60	146.73	0.15
AE0410	0.4147	0.0546	0.1401	4.619	5.5247	15	1	12.69	0.001762	107.65	142.84	0.15
AE0422	0.4135	0.0522	0.1289	3.942	5.1553	15	1	12.38	0.001597	104.44	147.35	0.15
AE0425	0.4170	0.0500	0.1200	3.897	5.0000	15	1	12.39	0*	103.21	142.19	0.15
AE0430	0.4168	0.0509	0.1242	3.538	5.1168	15	1	11.85	0*	97.44	141.52	0.15
AE0440	0.4153	0.0511	0.1243	3.988	5.0747	15	1	12.71	0*	101.13	146.71	0.15
AE0450	0.4165	0.0517	0.1275	4.373	5.2046	15	1	12.28	0*	106.57	148.40	0.15
AE0452	0.4156	0.0532	0.1341	4.551	5.3738	15	1	12.45	0.003343	106.63	148.36	0.15
AE0460	0.4168	0.0507	0.1231	3.600	5.0873	15	1	11.74	0.003573	101.38	148.78	0.15
AE0500	0.4162	0.0505	0.1220	6.734	5.0343	15	1	12.05	0.001059	119.69	152.11	0.15
AE0600	0.4124	0.0529	0.1315	3.951	5.2015	15	1	10.77	0.002884	102.97	143.26	0.15
AE0700	0.4170	0.0500	0.1200	1.884	5.0000	15	1	11.88	0*	80.01	160.47	0.15

* Lower groundwater loss in Aquifers AB0100, AC0550, AD0100, AE0100, AE0425, AE0430, AE0440, AE0450, and AE0700, beneath lakes and sinkholes, was simulated via an outlet link in the SWMM model, see Section 4.3.3.3.

Table 4-6. Lookup Table of Monthly ET Coefficients - Final

Land Use/Cover	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Urban - Low Density	0.40	0.40	0.60	0.80	0.90	0.84	0.72	0.65	0.65	0.65	0.65	0.50
Urban - Medium Density	0.30	0.30	0.50	0.60	0.60	0.60	0.60	0.50	0.50	0.50	0.50	0.50
Urban - High Density	0.25	0.25	0.30	0.35	0.50	0.50	0.50	0.50	0.35	0.30	0.30	0.30
Pasture / Open Lands	0.60	0.65	0.70	0.85	0.85	0.85	0.85	0.85	0.85	0.75	0.65	0.60
Range Land	0.55	0.60	0.75	0.85	0.85	0.85	0.85	0.85	0.75	0.65	0.60	0.55
Upland Forest	0.65	0.70	0.80	0.90	0.90	0.90	0.90	0.90	0.85	0.75	0.70	0.65
Pine Flatwoods	0.70	0.70	0.85	0.90	0.90	1.00	1.00	1.00	1.00	0.90	0.80	0.70
Open Water	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Forested Wetland	1.00	1.00	1.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.00	1.00
Non-Forested Wetland	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Burned Areas*	0.78	0.80	0.88	0.98	0.98	0.98	0.98	0.98	0.93	0.88	0.80	0.78

* Coefficients of Burned Areas (Santa Fe Swamp in this project) were estimated by averaging the values for Upland Forest and Forested Wetland.

Sources: Peace River integrated modeling (HGL, 2008); Myakka River Watershed Initiative (Interflow, 2008); ECT, 2017a & 2017b.

Table 4-7. Summary Table of Hydrologic Parameters in Groundwater - Final

Subbasin Name	Aquifer	Node	Surface Elevation (ft NAVD)	A1	B1	A2	B2	A3	Threshold Water Table Elev. (ft NAVD)	Ini. Water Table Elev. (ft NAVD)
A0100	AA0100	NA0100	138.45	0.02	0.7	0.02	0.7	0	100	138.0
A0110	AA0110	NA0110	143.99	0.02	0.7	0.02	0.7	0	100	140.0
A0120	AA0110	NA0120	145.76	0.02	0.7	0.02	0.7	0	100	141.0
A0200	AA0200	NA0200	140.19	0.02	0.7	0.02	0.7	0	100	139.5
A0210	AA0210	NA0210	145.74	0.02	0.7	0.02	0.7	0	100	139.5
A0220	AA0210	NA0220	146.45	0.02	0.7	0.02	0.7	0	100	139.8
A0300	AA0200	NA0300	139.77	0.02	0.7	0.02	0.7	0	100	139.5
A0310	AA0310	NA0310	157.97	0.02	0.7	0.02	0.7	0	100	153.8
A0320	AA0320	NA0320	147.26	0.02	0.7	0.02	0.7	0	100	139.8
A0330	AA0330	NA0300	152.92	0.02	0.7	0.02	0.7	0	100	139.8
A0400	AA0200	NA0400	138.96	0.02	0.7	0.02	0.7	0	100	138.9
A0405	AA0405	NA0400	147.55	0.02	0.7	0.02	0.7	0	100	139.5
A0410	AA0410	NA0410	143.89	0.02	0.7	0.02	0.7	0	100	139.5
A0412	AA0412	NA0412	145.15	0.02	0.7	0.02	0.7	0	100	141.0
A0414	AA0414	NA0414	147.14	0.02	0.7	0.02	0.7	0	100	140.0
A0420	AA0420	NA0420	145.55	0.02	0.7	0.02	0.7	0	100	139.5
A0422	AA0420	NA0422	146.6	0.02	0.7	0.02	0.7	0	100	140.0
A0430	AA0430	NA0430	144.56	0.02	0.7	0.02	0.7	0	100	139.5
A0500	AA0200	NA0500	139.13	0.02	0.7	0.02	0.7	0	100	139.1
A0505	AA0505	NA0505	144.89	0.02	0.7	0.02	0.7	0	100	139.5
A0510	AA0510	NA0510	145.17	0.02	0.7	0.02	0.7	0	100	140.2

Table 4-7. Summary Table of Hydrologic Parameters in Groundwater - Final (Cont.)

Subbasin Name	Aquifer	Node	Surface Elevation (ft NAVD)	A1	B1	A2	B2	A3	Threshold Water Table Elev. (ft NAVD)	Ini. Water Table Elev. (ft NAVD)
A0512	AA0512	NA0512	147.97	0.02	0.7	0.02	0.7	0	100	144.1
A0514	AA0512	NA0514	148.64	0.02	0.7	0.02	0.7	0	100	147.3
A0516	AA0516	NA0516	148.88	0.02	0.7	0.02	0.7	0	100	143.7
A0518	AA0518	NA0518	149.76	0.02	0.7	0.02	0.7	0	100	145.4
A0520	AA0516	NA0520	149.79	0.02	0.7	0.02	0.7	0	100	143.3
A0522	AA0522	NA0522	157.67	0.02	0.7	0.02	0.7	0	100	147.55
A0530	AA0530	NA0530	145.33	0.02	0.7	0.02	0.7	0	100	139.5
A0540	AA0540	NA0540	154.5	0.02	0.7	0.02	0.7	0	100	146.5
A0542	AA0542	NA0542	157.12	0.02	0.7	0.02	0.7	0	100	152.5
A0544	AA0544	NA0544	159.1	0.02	0.7	0.02	0.7	0	100	154.6
A0550	AA0550	NA0550	144.4	0.02	0.7	0.02	0.7	0	100	139.5
A0560	AA0560	NA0560	153.28	0.02	0.7	0.02	0.7	0	100	142.0
A0570	AA0570	NA0570	154.09	0.02	0.7	0.02	0.7	0	100	143.7
A0580	AA0580	NA0580	155.62	0.02	0.7	0.02	0.7	0	100	147.63
A0582	AA0582	NA0582	158.51	0.02	0.7	0.02	0.7	0	100	155.2
A0584	AA0582	NA0584	158.99	0.02	0.7	0.02	0.7	0	100	156.5
A0586	AA0586	NA0586	156.34	0.02	0.7	0.02	0.7	0	100	151.2
A0588	AA0586	NA0588	157.62	0.02	0.7	0.02	0.7	0	100	154.6
A0590	AA0590	NA0590	144.91	0.02	0.7	0.02	0.7	0	100	140.0
A0592	AA0592	NA0592	154.96	0.02	0.7	0.02	0.7	0	100	146.1
A0600	AA0200	NA0600	139.68	0.02	0.7	0.02	0.7	0	100	139.5

Table 4-7. Summary Table of Hydrologic Parameters in Groundwater - Final (Cont.)

Subbasin Name	Aquifer	Node	Surface Elevation (ft NAVD)	A1	B1	A2	B2	A3	Threshold Water Table Elev. (ft NAVD)	Ini. Water Table Elev. (ft NAVD)
A0610	AA0610	NA0610	157.73	0.02	0.7	0.02	0.7	0	100	148.5
A0620	AA0620	NA0620	157.38	0.02	0.7	0.02	0.7	0	100	142.0
A0630	AA0630	NA0630	142.93	0.02	0.7	0.02	0.7	0	100	139.5
A0640	AA0640	NA0600	153.76	0.02	0.7	0.02	0.7	0	100	139.8
B0100	AB0100	NB0100	142	0.02	0.7	0.02	0.7	0	100	139.5
B0110	AB0110	NB0100	160.18	0.02	0.7	0.02	0.7	0	100	139.5
B0112	AB0110	NB0100	168.74	0.02	0.7	0.02	0.7	0	100	139.5
B0120	AB0120	NB0100	153.42	0.02	0.7	0.02	0.7	0	100	139.5
B0130	AB0130	NB0100	151.31	0.02	0.7	0.02	0.7	0	100	139.5
B0140	AB0300	NB0100	139.01	0.02	0.7	0.02	0.7	0	100	139.0
B0150	AB0150	NB0100	144.68	0.02	0.7	0.02	0.7	0	100	139.5
B0160	AB0160	NB0100	150.47	0.02	0.7	0.02	0.7	0	100	139.5
B0200	AB0200	NB0200	150.98	0.02	0.7	0.02	0.7	0	100	139.5
B0300	AB0300	NB0300	142.1	0.02	0.7	0.02	0.7	0	100	139.5
B0400	AB0300	NB0400	142.65	0.02	0.7	0.02	0.7	0	100	139.5
B0410	AB0410	NB0410	146.47	0.02	0.7	0.02	0.7	0	100	142.0
C0100	AC0100	NC0100	140.31	0.02	0.7	0.02	0.7	0	100	139.7
C0110	AC0110	NC0100	153.54	0.02	0.7	0.02	0.7	0	100	140.0
C0120	AC0120	NC0100	157.1	0.02	0.7	0.02	0.7	0	100	140.0
C0200	AC0100	NC0200	142.05	0.02	0.7	0.02	0.7	0	100	139.7
C0201	AC0201	NC0200	157.79	0.02	0.7	0.02	0.7	0	100	140.0

Table 4-7. Summary Table of Hydrologic Parameters in Groundwater – Final (Cont.)

Subbasin Name	Aquifer	Node	Surface Elevation (ft NAVD)	A1	B1	A2	B2	A3	Threshold Water Table Elev. (ft NAVD)	Ini. Water Table Elev. (ft NAVD)
C0202	AC0202	NC0202	166.27	0.02	0.7	0.02	0.7	0	100	163.5
C0203	AC0203	NC0200	154.79	0.02	0.7	0.02	0.7	0	100	140.0
C0204	AC0204	NC0204	164.67	0.02	0.7	0.02	0.7	0	100	155.3
C0210	AC0210	NC0210	162.22	0.02	0.7	0.02	0.7	0	100	142.0
C0212	AC0212	NC0212	158.89	0.02	0.7	0.02	0.7	0	100	145.5
C0220	AC0220	NC0220	166.19	0.02	0.7	0.02	0.7	0	100	153.1
C0230	AC0230	NC0230	169.62	0.02	0.7	0.02	0.7	0	100	158.6
C0240	AC0240	NC0240	170.09	0.02	0.7	0.02	0.7	0	100	163.8
C0244	AC0244	NC0244	173.75	0.02	0.7	0.02	0.7	0	100	167.1
C0250	AC0250	NC0250	175.89	0.02	0.7	0.02	0.7	0	100	166.7
C0254	AC0250	NC0254	174.22	0.02	0.7	0.02	0.7	0	100	171.8
C0260	AC0260	NC0260	191.48	0.02	0.7	0.02	0.7	0	100	183.9
C0270	AC0270	NC0270	208.02	0.02	0.7	0.02	0.7	0	100	194.9
C0280	AC0280	NC0280	183.32	0.02	0.7	0.02	0.7	0	100	167.7
C0282	AC0282	NC0282	195.27	0.02	0.7	0.02	0.7	0	100	186.0
C0300	AC0100	NC0300	141.09	0.02	0.7	0.02	0.7	0	100	139.7
C0301	AC0301	NC0300	153.41	0.02	0.7	0.02	0.7	0	100	140.0
C0303	AC0303	NC0300	150.67	0.02	0.7	0.02	0.7	0	100	140.0
C0304	AC0304	NC0304	159.09	0.02	0.7	0.02	0.7	0	100	143.2
C0306	AC0304	NC0306	169.92	0.02	0.7	0.02	0.7	0	100	162.0
C0308	AC0308	NC0308	170.02	0.02	0.7	0.02	0.7	0	100	163.6

Table 4-7. Summary Table of Hydrologic Parameters in Groundwater - Final (Cont.)

Subbasin Name	Aquifer	Node	Surface Elevation (ft NAVD)	A1	B1	A2	B2	A3	Threshold Water Table Elev. (ft NAVD)	Ini. Water Table Elev. (ft NAVD)
C0310	AC0310	NC0310	163.33	0.02	0.7	0.02	0.7	0	100	142.5
C0311	AC0311	NC0300	155.45	0.02	0.7	0.02	0.7	0	100	140.0
C0314	AC0314	NC0314	163.16	0.02	0.7	0.02	0.7	0	100	148.0
C0316	AC0314	NC0316	173.61	0.02	0.7	0.02	0.7	0	100	162.2
C0320	AC0320	NC0320	163.01	0.02	0.7	0.02	0.7	0	100	149.9
C0322	AC0330	NC0320	178.51	0.02	0.7	0.02	0.7	0	100	149.9
C0330	AC0330	NC0330	170.06	0.02	0.7	0.02	0.7	0	100	152.5
C0340	AC0340	NC0340	170.18	0.02	0.7	0.02	0.7	0	100	156.3
C0342	AC0342	NC0342	163.76	0.02	0.7	0.02	0.7	0	100	158.0
C0344	AC0342	NC0344	166.03	0.02	0.7	0.02	0.7	0	100	162.6
C0350	AC0350	NC0350	188.47	0.02	0.7	0.02	0.7	0	100	172.0
C0360	AC0360	NC0360	176.3	0.02	0.7	0.02	0.7	0	100	170.0
C0370	AC0370	NC0370	188.74	0.02	0.7	0.02	0.7	0	100	177.5
C0400	AC0100	NC0400	140.58	0.02	0.7	0.02	0.7	0	100	139.7
C0410	AC0410	NC0410	154.65	0.02	0.7	0.02	0.7	0	100	142.5
C0420	AC0420	NC0400	154.93	0.02	0.7	0.02	0.7	0	100	140.0
C0430	AC0430	NC0400	146.8	0.02	0.7	0.02	0.7	0	100	140.0
C0500	AC0100	NC0500	140	0.02	0.7	0.02	0.7	0	100	139.7
C0505	AC0505	NC0500	150.52	0.02	0.7	0.02	0.7	0	100	139.7
C0507	AC0507	NC0500	149.28	0.02	0.7	0.02	0.7	0	100	139.7
C0508	AC0508	NC0508	144.55	0.02	0.7	0.02	0.7	0	100	139.7

Table 4-7. Summary Table of Hydrologic Parameters in Groundwater - Final (Cont.)

Subbasin Name	Aquifer	Node	Surface Elevation (ft NAVD)	A1	B1	A2	B2	A3	Threshold Water Table Elev. (ft NAVD)	Ini. Water Table Elev. (ft NAVD)
C0510	AC0508	NC0510	144.33	0.02	0.7	0.02	0.7	0	100	140.0
C0520	AC0520	NC0520	148.68	0.02	0.7	0.02	0.7	0	100	142.0
C0522	AC0520	NC0522	150.64	0.02	0.7	0.02	0.7	0	100	144.5
C0530	AC0530	NC0530	150.09	0.02	0.7	0.02	0.7	0	100	140.5
C0540	AC0540	NC0540	153.92	0.02	0.7	0.02	0.7	0	100	140.0
C0550	AC0550	NC0550	156.42	0.02	0.7	0.02	0.7	0	100	147.0
C0552	AC0552	NC0552	165.98	0.02	0.7	0.02	0.7	0	100	163.1
D0040	AD0040	ND0040	160.71	0.02	0.7	0.02	0.7	0	100	139.7
D0045	AD0045	ND0045	171.07	0.02	0.7	0.02	0.7	0	100	165.6
D0050	AD0050	ND0050	150.56	0.02	0.7	0.02	0.7	0	100	139.7
D0055	AD0055	ND0055	164.15	0.02	0.7	0.02	0.7	0	100	149.7
D0100	AD0100	ND0100	142.00	0.02	0.7	0.02	0.7	0	100	139.7
D0110	AD0110	ND0100	140.65	0.02	0.7	0.02	0.7	0	100	139.7
D0120	AD0110	ND0100	144.13	0.02	0.7	0.02	0.7	0	100	139.7
D0130	AD0130	ND0100	144.99	0.02	0.7	0.02	0.7	0	100	139.7
D0140	AD0130	ND0100	150.66	0.02	0.7	0.02	0.7	0	100	139.7
D0150	AD0150	ND0100	153.9	0.02	0.7	0.02	0.7	0	100	139.7
D0160	AD0160	ND0100	142.24	0.02	0.7	0.02	0.7	0	100	140.0
D0170	AD0160	ND0100	144.83	0.02	0.7	0.02	0.7	0	100	139.7
D0180	AD0180	ND0100	153.7	0.02	0.7	0.02	0.7	0	100	139.7
D0200	AD0200	ND0200	149.51	0.02	0.7	0.02	0.7	0	100	140.46

Table 4-7. Summary Table of Hydrologic Parameters in Groundwater - Final (Cont.)

Subbasin Name	Aquifer	Node	Surface Elevation (ft NAVD)	A1	B1	A2	B2	A3	Threshold Water Table Elev. (ft NAVD)	Ini. Water Table Elev. (ft NAVD)
E0100	AE0100	NE0100	142.00	0.02	0.7	0.02	0.7	0	100	139.7
E0110	AE0110	NE0100	155.94	0.02	0.7	0.02	0.7	0	100	139.7
E0120	AE0120	NE0100	141.27	0.02	0.7	0.02	0.7	0	100	139.7
E0130	AE0120	NE0100	148.87	0.02	0.7	0.02	0.7	0	100	139.7
E0140	AE0140	NE0140	141.91	0.02	0.7	0.02	0.7	0	100	139.7
E0150	AE0150	NE0100	165.83	0.02	0.7	0.02	0.7	0	100	139.7
E0160	AE0160	NE0100	162.03	0.02	0.7	0.02	0.7	0	100	139.7
E0162	AE0162	NE0162	164.29	0.02	0.7	0.02	0.7	0	100	160.7
E0170	AE0170	NE0100	160.26	0.02	0.7	0.02	0.7	0	100	139.7
E0172	AE0172	NE0172	173.76	0.02	0.7	0.02	0.7	0	100	168.6
E0180	AE0180	NE0100	142.47	0.02	0.7	0.02	0.7	0	100	139.7
E0190	AE0190	NE0100	156.39	0.02	0.7	0.02	0.7	0	100	139.7
E0200	AE0120	NE0100	145.54	0.02	0.7	0.02	0.7	0	100	139.7
E0210	AE0120	NE0210	151.28	0.02	0.7	0.02	0.7	0	100	141.0
E0220	AE0220	NE0220	152.34	0.02	0.7	0.02	0.7	0	100	141.0
E0230	AE0230	NE0230	158.71	0.02	0.7	0.02	0.7	0	100	150.0
E0300	AE0300	NE0300	148.73	0.02	0.7	0.02	0.7	0	100	139.7
E0400	AE0410	NE0400	143.61	0.02	0.7	0.02	0.7	0	100	139.7
E0410	AE0410	NE0410	146.17	0.02	0.7	0.02	0.7	0	100	139.5
E0420	AE0410	NE0420	143.32	0.02	0.7	0.02	0.7	0	100	139.8
E0422	AE0422	NE0422	149.35	0.02	0.7	0.02	0.7	0	100	143.4

Table 4-7. Summary Table of Hydrologic Parameters in Groundwater - Final (Cont.)

Subbasin Name	Aquifer	Node	Surface Elevation (ft NAVD)	A1	B1	A2	B2	A3	Threshold Water Table Elev. (ft NAVD)	Ini. Water Table Elev. (ft NAVD)
E0425	AE0425	NE0425	144.19	0.02	0.7	0.02	0.7	0	100	136.5
E0430	AE0430	NE0430	143.52	0.02	0.7	0.02	0.7	0	100	125.0
E0440	AE0440	NE0440	148.71	0.02	0.7	0.02	0.7	0	100	123.0
E0450	AE0450	NE0450	150.40	0.02	0.7	0.02	0.7	0	100	131.5
E0452	AE0452	NE0452	150.36	0.02	0.7	0.02	0.7	0	100	139.8
E0460	AE0460	NE0460	150.34	0.02	0.7	0.02	0.7	0	100	135.5
E0462	AE0460	NE0462	151.64	0.02	0.7	0.02	0.7	0	100	142.0
E0500	AE0500	NE0500	154.11	0.02	0.7	0.02	0.7	0	100	139.7
E0600	AE0600	NE0600	145.26	0.02	0.7	0.02	0.7	0	100	139.7
E0700	AE0700	NE0700	162.47	0.02	0.7	0.02	0.7	0	100	136.5

4.3.3 Adjustment of Hydraulic Model Parameters

Various hydraulic model parameters were adjusted during model calibration, including channel invert elevations, weir crest elevations, outlet rating curves, and initial conditions, as discussed in detail below. Other hydraulic model parameters were held constant in the model calibration process.

4.3.3.1 Channel Invert Elevations

Surface water flow exchange between Lake Alto and Lake Santa Fe is controlled by the Santa Fe Canal. Based on the ground survey data and LiDAR-based DEM data, the highest point of the Santa Fe Canal is likely located east of the S.R. 325 bridge, which was modeled as Channel RD0038C in the SWMM model.

The upstream invert of Channel RD0038C was adjusted based on the observed lake stage values (Figures 4-6B and 4-6C) during periods of high lake levels in 2009-2010 and 2013-2015 when the lake levels exceeded the control elevation in the Santa Fe Canal. The final upstream invert of RD0038C was set at 136.0 ft-NAVD from 1/1/2006 through 12/31/2008, and 138.0 ft-NAVD from 1/1/2009 through 12/31/2015. The Canal may be silted due to poor maintenance conditions or partially blocked by debris, upon evaluation of the lake stage data collected at these two lakes.

Other coefficients (e.g., Manning's n roughness values in channel transects), were adjusted during the initial calibration model runs and held constant in the subsequent model calibration runs.

4.3.3.2 Weir Crest Elevations

As illustrated in Figure 3-3, the flow paths in Lake Alto Swamp and Santa Fe Swamp were modeled as series of overland flow weirs. The crest elevations of the overland flow weirs also control the outfall flow discharge from Lake Alto and Lake Santa Fe to the Santa Fe River to the north.

The weir crest elevations were adjusted based on the observed lake stage values (Figures 4-6B and 4-6C), particularly during the two high water periods of 2009-2010 and 2013-2015 when the lakes may possibly exceed the weir crest elevations and discharge north to the Santa Fe River.

The following factors may potentially result in different weir crest or control elevations in the swamp areas: 1) changes in vegetation cover caused by wild fires, e.g., the wild fires occurred in 2004, 2007, and 2010; 2) changes in water flow paths due to sediment deposit/erosion and vegetation growth; and 3) impacts of cyclic wetting and drying on soils and vegetation cover. The weir crest elevations were finalized after a series of trial and error runs.

Other parameters for these overland flow weirs, e.g., weir discharge coefficient, were held constant in the model calibration.

4.3.3.3 Outlet Functional Rating Curves

To simulate the time-variant lower groundwater loss rate, a total of nine “outlet” links were used to calculate the lower groundwater loss rates from various lakes and sinkholes into the upper FAS.

A user-defined functional rating curve determines an outlet’s discharge flow as a power function of the head difference across it, i.e., the head difference between the water table elevations in a given lake and groundwater table elevations in the upper FAS (Equation C).

$$Q = A * \Delta H^B \qquad \text{(C)}$$

where,
- Q = flow (cfs)
- A = coefficient A (ft^2/s)
- B = coefficient B (set at 1.0, per Darcy’s equation)
- ΔH = head difference (ft)

As listed in Table 4-8, the initial coefficient A in this equation was first estimated for each outlet link using Darcy’s equation with the aquifer’s saturated hydraulic conductivity values of Intermediate Aquifer System/Intermediate Confining Unit in the latest NFSEG model. Seismic profiling of numerous northeast Florida lakes shows a variety of collapse structures providing preferred paths toward the aquifer (Kindinger et al. 2000), which may potentially increase lower groundwater loss rate. Based on the initial model calibration run results, the initial estimation of coefficient A was not high enough to account for these collapse structures, and needs to be further adjusted in the model calibration process.

Coefficient A is one of the few parameters that were adjusted in a series of model calibration runs to match the observed lake stage data and historical aerial imagery, if lake gage data is not available. The final coefficient A was estimated for each of the nine outlet links by multiplying a factor (Table 4-8).

Table 4-8. Summary Table of Initial and Final Coefficient A Values for Outlet Functional Curves

Outlet Name	Location	Initial Coefficient A (ft^2/s)	Factor	Final Coefficient A (ft^2/s)
RB0100T	Lake Alto	0.000014	1,400	0.019600
RC0550T	Hickory Pond	0.000005	4,250	0.021250
RD0100T	Little Lake Santa Fe	0.000018	1,250	0.022500
RE0100T	Lake Santa Fe	0.000161	1,280	0.206080
RE0425T	Sinkhole at NE0425	0.000026	85	0.002210
RE0430T	Sinkhole at NE0430	0.000101	120	0.012120
RE0440T	Sinkhole S. of Indian Lake	0.000079	145	0.011455
RE0450T	Indian Lake	0.000399	35	0.013965
RE0700T	Sinkhole near Melrose	0.000016	500	0.008000

4.3.3.4 Initial Conditions

The node initial elevations in Lake Alto, Lake Santa Fe, and their adjacent wetland areas were adjusted to match stage data measured at USGS 02320630 Lake Alto at Waldo, FL and USGS 02320601 Lake Santa Fe near Earleton, FL (Figure 4-5). The node initial elevations were set at 139.41 ft-NAVD and 139.72 ft-NAVD for Lake Alto and Lake Santa Fe, respectively, by interpolating the observed lake stage values.

The initial stage values in the adjacent storage areas, junction nodes, as well as the water elevations in groundwater and aquifers (Tables 4-5 and 4-7) were also adjusted to avoid unreasonable initial flows.

4.4 Model Calibration Results

4.4.1 Model Simulation and Calibration

The water budget model of Lake Alto and Lake Santa Fe was calibrated with data from 2006 through 2015, by comparing observed lake stage values with simulated stages. A series of trial and error model runs were simulated to obtain the closest overall fit to measured values, by adjusting certain model parameters while leaving other parameters constant, as discussed in Section 4.3.

The following model parameters were adjusted initially to make the model ready for calibration, and were held constant thereafter:

- Impervious percentages;
- The coefficients used for computing of lateral groundwater flow;
- Shift factors used to adjust potentiometric surface levels beneath lakes/sinkholes; and
- Initial conditions at nodes (lakes, wetlands, and channels) and water tables in aquifers.

The following model parameters were adjusted during the model calibration process:

- Channel invert elevations (control elevation at Santa Fe Canal);
- Weir crest elevations (control elevations at Lake Alto Swamp and Santa Fe Swamp);
- Lower groundwater loss rates between the surficial aquifers and upper FAS; and
- Outlet functional curves for flow exchange between the lakes/sinkholes and FAS.

4.4.2 Model Calibration Results

The simulated and observed lake stage hydrographs are graphically presented in Figures 4-8A and 4-8B for Lake Alto and Lake Santa Fe, respectively. The final calibration model simulated stage values that replicate the trends of the historical data for both lakes.

Two scatter plots comparing individual simulated lake stages with corresponding observed values are provided in Figures 4-9A and 4-9B to assist in the model assessment for Lake Alto and Lake Santa Fe, respectively. The statistical analysis results are summarized in these two plots as well.

For Lake Alto, the RMSE of the lake stage residuals was 0.19 (Figure 4-9A), which is less than the 0.5 foot primary goal. 99.8% of the residuals were within ±0.5 foot of the observed values meeting the second goal of 67%. 100.0% of the residuals were within ±1.0 foot of the observed values meeting the third goal of 90%. The agreement between simulated and observed values covers approximately 4 feet, so the final goal of meeting these abovementioned criteria over a wide range of stages, is also being met.

For Lake Santa Fe, the RMSE of the residuals was 0.31 (Figure 4-9B), which is less than 0.5 foot as the primary goal. 89.5% of the residuals were within ±0.5 foot of the observed values meeting the second goal of 67%. 100.0% of the residuals were within ±1.0 foot of the observed values meeting the third goal of 90%. The agreement between simulated and observed values covers approximately 6 feet, so the final goal of meeting these abovementioned criteria over a wide range of stages, is also met.

4.4.3 Water Budget Results

The water budgets of the Lake Alto and Lake Santa Fe watershed, as simulated in the SWMM model, can be grouped into three categories: runoff quantity in subcatchments, groundwater in aquifers, and flow routing in conveyance systems. Each category consists of multiple components, as summarized below:

- Runoff Quantity
  - Precipitation
  - Evaporation
  - Infiltration
  - Surface Runoff
- Groundwater
  - Infiltration
  - Upper Zone ET
  - Lower Zone ET
  - Deep Percolation to FAS
  - Groundwater Flow
  - Storage Change in Aquifers
- Flow Routing
  - Surface Runoff
  - Groundwater Flow
  - Evaporation
  - External Outflow, to Downstream Canal and FAS
  - Storage Change in Conveyance System

The water budget results of the 10-year calibration simulation were provided in the model output report file. The results of the model calibration simulation indicate that the lake watershed has, on average, precipitation of 47.7 in/yr, evaporation (from land surface and conveyance system) and ET of 33.1 in/yr, deep percolation of 12.1 in/yr, outflow to the downstream canal of 2.6 in/yr, and storage change in aquifers and conveyance system of -0.1 in/yr in the 10-year simulation period from 2006 through 2015 (Table 4-9).

Note that the values of “Total Depth” and “Average Depth” (Columns 3 and 4 in Table 4-9) were derived from the “Total Volume” values (Column 2 in Table 4-9) that apply to the entire lake watershed. The “Total Depth” values were calculated by dividing the “Total Volume” in acre-ft by the watershed area of 37,484 acres and then multiplying 12 in/ft. The “Average Depth” values over the 10-year simulation period can then be estimated by dividing the “Total Depth” values by 10. For example, the “Evaporation” value of 381,676.20 acre-ft or 12.2 in/yr listed in the flow routing category (Table 4-9), apply to the entire lake watershed, not just the lake surface area (5,778 acres for a total of eight lakes included in the SWMM model). The evaporation value at these lakes would be 79.3 in/year (12.2 in/yr x 37,484 acres / 5,778 acres), if these eight lakes are the only water bodies in the watershed. Provided that the evaporation could occur at all water bodies, including lakes, wetlands (e.g., Alto Swamp and Santa Fe Swamp, approximately 8,600 acres), channels, and ditches, as long as standing water exists, the true evaporation value from these lakes would be much lower. Unfortunately, the evaporation value at an individual water body was not provided explicitly in the SWMM output.

Again, the “Total Depth” and “Average Depth” values in the model water budget results should always apply to the entire lake watershed, not just the lake surface.

In the SWMM model, it is assumed that the lake watershed or model domain boundary is a no-flow boundary that has a flux of zero for both surface water and groundwater flow simulation. The simulated deep percolation to the upper FAS of 12.1 in/yr may consist of three possible components that were not distinguished in the model, including 1) the lateral groundwater flow away from the surficial aquifer to its surrounding areas; 2) the lateral groundwater flow away from the intermediate aquifer system; and 3) the deep recharge from the intermediate aquifer system to the upper FAS. In addition, the high deep percolation rates simulated may also be attributed to various collapse structures providing preferred flow paths toward the intermediate aquifer system and/or the upper FAS (Kindinger *et al.*, 2000).

Table 4-9. Summary Table of Water Budget Results in Lake Alto and Lake Santa Fe Watershed (2006-2015)

Runoff Quantity

Items	Total Volume (acre-ft)	Total Depth (in)	Average Depth (in/yr)
Precipitation	1,489,629.08	476.88	47.7
Evaporation	163,200.01	52.25	5.2
Infiltration	930,704.44	297.95	29.8
Surface Runoff	395,809.80	126.71	12.7
Final Storage	5.77	0.00	0.0

Groundwater

Items	Total Volume (acre-ft)	Total Depth (in)	Average Depth (in/yr)
Initial Storage	576,500.62	184.56	18.5
Infiltration	930,704.44	297.95	29.8
Upper Zone ET	476,090.77	152.41	15.2
Lower Zone ET	12,641.85	4.05	0.4
Deep Percolation	239,141.22	76.56	7.7
Groundwater Flow	207,021.81	66.28	6.6
Final Storage	572,019.47	183.12	18.3
Storage Change	-4,481.15	-1.44	-0.1

Flow Routing

Items	Total Volume (acre-ft)	Total Volume (10^6 Gal)	Average Depth (in/yr)
Initial Storage	107,133.24	34,910.97	3.4
Surface Runoff	395,796.00	128,976.04	12.7
Groundwater Inflow	207,022.12	67,461.25	6.6
External Outflow*	221,757.59	72,263.02	7.1
Evaporation	381,676.20	124,374.89	12.2
Final Storage	106,695.64	34,768.37	3.4
Storage Change	-437.60	-142.60	0.0

*** External Outflow includes:**

To Santa Fe River	82,167.19	26,774.30	2.6
To Upper FAS	139,583.13	45,483.36	4.5

4.4.4 Summary of Model Calibration

Based on the model calibration results for the 10-year simulation span, the Lake Alto and Lake Santa Fe water budget model has been successfully calibrated and meet both the primary and secondary goals and criteria as discussed previously. Thus, the approach and assumptions utilized in the model development and calibration tasks appear to be appropriate.

In summary, the calibrated Lake Alto and Lake Santa Fe water budget model should provide a useful tool for comparing water management alternatives in the context of MFLs.

5.0 Assessment of Existing Hydrologic Conditions

5.1 Introduction

The purpose of long-term continuous simulations is to assess the characteristics of a water body over a wide variety of hydrologic conditions. The MFLs establishment also relies on the results of the long-term continuous simulations as well as the historical lake stage data to determine if MFLs are being met.

The calibrated Lake Alto and Lake Santa Fe water budget model was used to run long-term simulations for a total of 32.7 years from 5/1/1983 through 12/31/2015, which was limited by the available groundwater well data records since 4/28/1983. The 32.7-year model period includes the three lowest lake stage periods since lake stage data collection began in 1957 (Figure 4-6A). All the lowest lake stage periods occur between 2000 and 2010 and coincide with decreased rainfall (Figures 5-1A and 5-1B). The lake stages have since rebounded to pre-drought levels. The lake stage data during the 32.7-year model period do not adequately represent the longer lake stage data history.

Based on the observed lake stage data at Lake Alto and Lake Santa Fe (Figure 4-6A), a historical daily lake stage data set (7/11/1957-4/30/1983) was developed by the District for each lake system, by using a linear interpolation method for Lake Santa Fe or a Line of Organic Correlation (LOC) analysis for Lake Alto. The historical daily lake data sets were then combined with the 32.7-year model simulation results to develop “hybrid” lake stage data sets for both Lake Alto and Lake Santa Fe. It was assumed that the hybrid lake stage data sets (7/11/1957-12/31/2015), are statistically realistic representations of the lake hydrology, absent significant anthropogenic or climatological changes, over the next 59 years for Lake Alto and Lake Santa Fe.

In the subsequent sections, the 2006 hydrologic conditions assessed in the context of MFLs refers to a hypothetical case where the hybrid lake stage data set assume land use and average groundwater withdrawals at 2006 levels.

5.2 Long-term Model Data Assembling and Evaluation

Expansion of the model simulations from the 10-year calibration period to a long-term simulation requires assembling and evaluation of additional time series data, including rainfall, ET, and potentiometric surface levels of the upper FAS (Table 5-1). The data used for the model calibration, as discussed in Section 4.3.1, were retained for use in the long-term simulations.

Table 5-1. Time Series Data Used in Model Calibration and Long-term Simulations

Simulation	Rainfall	Evapotranspiration	FAS Well Level
Calibration (2006-2015)	NEXRAD (1/1/2006 - 12/31/2015)	USGS PET (1/1/2006-12/31/2015)	SRWMD S051933001 (1/1/2006 – 12/31/2015)
Long-term Simulations (1983-2015)	Oak Ridge National Laboratory (ORNL) Daymet (5/1/1983 - 1/31/2001) NEXRAD (2/1/2001 - 12/31/2015)	NOAA Pan Evaporation at Gainesville stations (5/1/1983 – 5/31/1995) USGS PET (6/1/1995-12/31/2015)	SRWMD S051933001 (5/1/1983 – 12/31/2015)

Source: ORNL, 2016; NOAA, 2016; USGS, 2016; SRWMD, 2016.

5.2.1 Rainfall

As NEXRAD rainfall data previously used for the model calibration is only available after February 2001, the Daymet daily rainfall data developed by ORNL was employed to extend the rainfall records used in the model calibration. Similar to the NEXRAD rainfall data, the Daymet rainfall data was also organized in individual 1 km x 1 km pixels, each of which has daily rainfall estimates (Figure 5-2).

The Daymet rainfall data from 5/1/1983 to 1/31/2001 and the NEXRAD rainfall data from 2/1/2001 to 12/31/2015 (Table 5-1), were assembled to be used in the long-term model simulations.

The rainfall data collected at various NOAA and SRWMD weather stations were not selected, mostly due to their long distance to the lake watershed and/or lengthy data gaps.

5.2.2 Evapotranspiration

The daily PET data developed by USGS in individual 2 km x 2 km pixels (Figure 4-1) has a period of record from 6/1/1995 to 12/31/2015.

The daily pan evaporation data collected at three NOAA weather stations, including two at Gainesville, FL and one at Lake City, FL, was used to extend the PET record by USGS. Upon review of the pan evaporation data at these three stations, the two stations at Gainesville, FL (USC00083321 and USC00083322) were selected to estimate the PET value prior to 6/1/1995. Based on a regression analysis between the USGS PET and NOAA pan evaporation data at these two NOAA stations, a coefficient of 0.78 was estimated and then used to convert pan evaporation data to PET.

In summary, the daily PET data required for the long-term model simulation with a span of 32.7-years (Table 5-1 and Figure 5-3) were developed by combining the USGS PET data as well as the PET values estimated from the NOAA pan evaporation data.

5.2.3 FAS Potentiometric Surface Levels

The data record collected at the USGS well station near Melrose, FL (USGS ID: 294313082024601 / SRWMD ID: S092307001, data record starting from 4/28/1983) was used to estimate the groundwater conditions beneath the major lakes and sinkholes (Table 5-1), by applying the method discussed in Section 4.3.1.3. The estimated shift factors, as listed in Table 4-2, were applied to the daily well records at the USGS Melrose station. Note that the period of record for this well limited the long-term simulation period to 32.7 years (5/1/1983-12/31/2015).

To determine if significant historical drawdowns might be detected, double-mass analysis of groundwater well data was conducted using the USGS Melrose well data and the NOAA Starke rainfall data (Figure 4-3) composited by SJRWMD. The slope of the trend line is fairly constant with no noticeable changes that might indicate outstanding historical groundwater withdrawals in the time period from 1983 through 2015 (Figure 5-4). This observation is also consistent with the fact that the lake watershed is dominated by undeveloped lands (Table 2-2) and no major land development occurred in the vicinity of Lake Alto and Lake Santa Fe during the same time span.

The population of Bradford County increased from 20,023 in 1980 to 28,520 in 2010 (increased by 8,497 or 42%), and among which the populations in the cities of Hampton and Starke increased from 466 in 1980 to 500 in 2010 and from 5,306 in 1980 to 5,449 in 2010, respectively. The population of Alachua County increased from 151,348 in 1980 to 247,336 in 2010 (increased by 95,988 or 63%), and among which the populations in the cities of Waldo and Gainesville increased from 993 in 1980 to 1,015 in 2010 and from 81,371 in 1980 to 124,354 in 2010, respectively (U.S. Census Bureau, 1982 & 2012). It is unlikely the population growth near the lakes (cities of Hampton, Starke, and Waldo) would demand expansion of the public water supply systems or indicate any significant historical groundwater withdrawals in the upper FAS beneath the lake watershed.

Therefore, no adjustment was deemed necessary prior to utilizing the shifted well hydrographs for the long-term simulations. The observed and filled well hydrographs as well as the shifted well hydrographs are illustrated in Figure 5-5.

5.3 Draft Recommended MFLs

Draft MFLs, including a minimum frequent high (FH) level, a minimum average (MA) level, and a minimum frequent low (FL) level, have been recommended by SRWMD for Lake Alto and Lake Santa Fe (Tables 5-2 and 5-3). The SJRWMD MFLs method (SJRWMD, 2006; Neubauer *et al*., 2008) was utilized to determine the minimum lake levels for Lake Alto and Lake Santa Fe. MFLs determination is based on the evaluation of topography, vegetation, soils, and hydrologic indicator data collected from plant communities associated with the water body (SRWMD, 2016). The MFLs levels relate to hydroperiod categories and definitions adapted from water regime modifiers developed by Cowardin *et al*., (1979).

Table 5-2. Summary of Draft Recommended MFLs for Lake Alto

Designated Level	Minimum Level Criterion	Elevation (ft NAVD)	Defining event of hydrologic criteria
Minimum Frequent High (FH)	Max elevation of hardwood swamp and cypress samples	**140.20**	14-day maximum, continuously exceeded/ 2.5-year return interval/ Water Year (Jun 1 – May 31)
Minimum Average (MA)	Mean elevation of thick organic soils sampled in Bayhead, Cypress, and Hardwood Swamp (i.e., excluding Lakeshore Emergents/ Deep Marsh) minus 0.3 feet	**138.89**	180-day minimum mean/ 1.7-year return interval / Water Year (Oct 1 – Sep 30)
Minimum Frequent Low (FL)	Mean elevation of thick organic soils sampled in Bayhead, Cypress, and Hardwood Swamp (i.e., excluding Lakeshore Emergents/ Deep Marsh) minus 20 inches	**137.52**	120-day minimum, continuously not exceeded/ 5-year return interval/ Water Year (Oct 1- Sep 30)

Source: GPI, 2017a.

Table 5-3. Summary of Draft Recommended MFLs for Lake Santa Fe

Designated Level	Minimum Level Criterion	Elevation (ft NAVD)	Defining event of hydrologic criteria
Minimum Frequent High (FH)	Max elevation of hardwood swamp and cypress samples	**140.06**	14-day maximum, continuously exceeded/ 2.5-year return interval/ Water Year (Jun 1 – May 31)
Minimum Average (MA)	Mean elevation of thick organic soils sampled in Bayhead, Cypress, and Hardwood Swamp (i.e., excluding Lakeshore Emergents/ Deep Marsh) minus 0.3 feet	**137.89**	180-day minimum mean/ 1.7-year return interval / Water Year (Oct 1 – Sep 30)
Minimum Frequent Low (FL)	Mean elevation of thick organic soils sampled in Bayhead, Cypress, and Hardwood Swamp (i.e., excluding Lakeshore Emergents/ Deep Marsh) minus 20 inches	**136.52**	120-day minimum, continuously not exceeded/ 5-year return interval/ Water Year (Oct 1- Sep 30)

Source: GPI, 2017b.

5.4 Long-term Simulations and "Hybrid" Data Method

5.4.1 Long-term Model Simulations

The calibrated water budget model was used to perform long-term simulations for a total of 32.7 years from 5/1/1983 through 12/31/2015, by implementing the time series data described in Section 5.2 above. The simulated lake stage hydrographs and the corresponding gage records are graphically presented in Figures 5-6A and 5-6B, for Lake Alto and Lake Santa Fe, respectively. The simulated stage hydrographs generally replicate the trends of the historical data in the 32.7-year time period.

5.4.2 Development of "Hybrid" Lake Stage Data Sets

As discussed in Section 5.1, the 32.7-year model period includes three severe drought periods. The period of record (1957-2015) shows the stage exceeded 75% of the time is 139.00 ft NAVD at Lake Alto (Figure 5-8) and 138.87 ft NAVD at Lake Santa Fe (Figure 5-11), meaning that stages below those levels are the lowest quartile of the data. Stages exceeding those levels in the 32.7-year model period account for 61.3% and 65.1% of the period from 5/1/1983 through 12/31/2015, for Lake Alto and Lake Santa Fe, respectively. This does not adequately represent the longer period of record at these two lake systems. Since the model simulation is necessary for use in testing hypothetical allowable FAS drawdowns, ideally the model would be extended back to capture the full period of record. However, the groundwater well data needed for the model only extends back until 4/28/1983 and the ORNL Daymet rainfall data only extends back until 1/1/1980. Using alternative data, such as relationships with other wells and rainfall stations, to drive the model would introduce greater error into the modeling analysis. To incorporate the modeled data for further analysis, and yet include the measured data to extend the period of record further back, two hybrid lake stage data sets were used by combining the long-term model results and the historical lake stage data prior to May 1, 1983.

Because the simulated stage hydrograph of the 32.7-year model run approximates the stage hydrograph for that period well (Figures 5-6A and 5-6B), the analysis for the MFLs will include both the simulated data (5/1/1983-12/31/2015) and the historical lake stage data prior to May 1, 1983 for both Lake Alto and Lake Santa Fe (Figure 4-6A).

To take advantage of the longer historical stage records back to 7/11/1957 at the USGS station (02320600 Santa Fe Lake near Keystone HTS, FL) and also due to the fact that Lake Alto and Lake Santa Fe are hydraulically connected through Santa Fe Canal, during average or high water periods if not all the time, a new lake stage data set was developed by the District for Lake Alto for a time duration from 7/11/1957 to 11/22/1993. A Line of Organic Correlation (LOC) analysis was performed by using the measured lake stage values at both lakes, i.e., USGS stations 02320630 and 02320600. A total of 310 stage data pairs between 4/21/1976 and 11/22/1993 was involved in the LOC analysis and the R^2 value is 0.82 for the resultant LOC regression curve (Figure 5-7A). The comparison plot of the observed and calculated lake stage values is graphically presented in Figure 5-7B, showing that the calculated lake stage values do replicate the overall trend of the measured data and are appropriate to be used to substitute and extend the current observed lake stage records at Lake Alto since 4/21/1976. The daily lake stage values from 7/11/1957 to 4/30/1983 were then estimated for Lake Alto, by implementing the resultant LOC regression curve and the linear interpolated daily lake stage data at Lake Santa Fe. Finally, the calculated daily stage data set was combined with the simulated lake stage values to develop a hybrid lake stage data set, which will be used for the subsequent MFLs analysis at Lake Alto.

Figures 5-7C and 5-10 show the hybrid stage hydrographs, while Figures 5-8 and 5-11 show the hybrid lake stage duration curves for the two lake systems. The use of the hybrid lake stage data sets also allows for analysis over a greater portion of the Atlantic Multidecadal Oscillation than the long-term model simulation alone (Enfield *et al.*, 2001).

5.4.3 MFLs Analysis - Lake Alto

The recommended FH level for Lake Alto is 140.20 ft NAVD. Based on the SJRWMD guidance (Table 5-2), this elevation should remain continuously wet for at least 14 days and occur at least once every 2.5 years on average (at least 40% of the years).

The recommended MA level for Lake Alto is 138.89 ft NAVD. Based on the SJRWMD guidance, the lake should maintain this average low level at most 180 days no more often than once every 1.7 years on average (at most 59% of the years).

The recommended FL level for Lake Alto is 137.52 ft NAVD. Based on the SJRWMD guidance, this elevation should remain continuously dry for at most 120 days and no more often than once every 5 years on average (at most 20% of the years).

To obtain a better understanding of the relationship between MFLs and the hydrology of a lake, MFLs can be examined in three different ways: 1) in the context of the long-term hydrograph of a lake; 2) in the context of the stage-duration curve of a lake; and 3) in the context of the frequency of events pertinent to each minimum level (Robison, 2014).

Figure 5-7C illustrates the recommended lake MFLs superimposed on the 59-year hybrid daily lake stage hydrograph. The stage of a lake can remain above or below each of the MFLs for extended periods. Note that the daily lake stage data from 7/11/1957 to 4/30/1983 was estimated based on the LOC analysis results of the observed lake stage data of both Lake Alto and Lake Santa Fe, as described above.

Figure 5-8 illustrates the recommended lake MFLs superimposed on the stage-duration curve of the hybrid lake stage data set. In this context, the FH, MA, and FL levels anchor the hydrology of Lake Alto.

Based on the SJRWMD MFLs method (Robison, 2014), the ultimate determination of whether or not MFLs are being met is made through a frequency analysis. The frequency analysis results of the hybrid lake stage data set are illustrated in Figures 5-9A through 5-9C for the draft recommended FH, MA, and FL levels, respectively. A best-fit line was developed based on the frequency analysis results by using a polynomial regression. Based on the SJRWMD MFLs procedures, the minimum level is being met if any pertinent event or the best-fit line lies within/crosses the shaded box shown in the figures.

In summary, all three of the draft recommended MFLs are being met at Lake Alto under the 2006 hydrologic conditions.

5.4.4 MFLs Analysis - Lake Santa Fe

The recommended FH level for Lake Santa Fe is 140.06 ft NAVD. Based on the SJRWMD guidance (Table 5-3), this elevation should remain continuously wet for at least 14 days and occur at least once every 2.5 years on average (at least 40% of the years).

The recommended MA level for Lake Santa Fe is 137.89 ft NAVD. Based on the SJRWMD guidance, the lake should maintain this average low level at most 180 days no more often than once every 1.7 years on average (at most 59% of the years).

The recommended FL level for Lake Santa Fe is 136.52 ft NAVD. Based on the SJRWMD guidance, this elevation should remain continuously dry for at most 120 days and no more often than once every 5 years on average (at most 20% of the years).

To obtain a better understanding of the relationship between MFLs and the hydrology of a lake, MFLs can be examined in three different ways: 1) in the context of the long-term hydrograph of a lake; 2) in the context of the stage-duration curve of a lake; and 3) in the context of the frequency of events pertinent to each minimum level (Robison, 2014).

Figure 5-10 illustrates the recommended lake MFLs superimposed on the 59-year hybrid daily lake stage hydrograph. The stage of a lake can remain above or below each of the MFLs for extended periods. Note that the daily lake stage data prior to May 1, 1983 was developed based on the historical observed gage data and the data gaps were filled in using a linear interpolation method.

Figure 5-11 illustrates the recommended lake MFLs superimposed on the stage-duration curve of the hybrid lake stage data set. In this context, the FH, MA, and FL levels anchor the hydrology of Lake Santa Fe.

Based on the SJRWMD MFLs method (Robison, 2014), the ultimate determination of whether or not MFLs are being met is made through a frequency analysis. The frequency analysis results of the hybrid lake stage data set are illustrated in Figures 5-12A through 5-12C for the draft recommended FH, MA, and FL levels, respectively. A best-fit line was developed based on the frequency analysis results by using a polynomial regression. Based on the SJRWMD MFLs procedures, the minimum level is being met if any pertinent event or the best-fit line lies within/crosses the shaded box shown in the figures.

In summary, all three of the draft recommended MFLs are being met at Lake Santa Fe under the 2006 hydrologic conditions.

6.0 Assessment of Hypothetical Water Resource Development at Lake Santa Fe

6.1 Introduction

The Lake Alto and Lake Santa Fe water budget model as well as the historical lake stage data prior to May 1, 1983 were used to assess the hydrologic effects of FAS drawdowns in the context of MFLs. This section documents the determination of allowable FAS declines beyond 2006 hydrologic conditions for Lake Santa Fe.

A series of trial and error runs of the 32.7-year long-term model simulations were performed with different aquifer declines. The simulation results were carried over to the entire hybrid data set for Lake Santa Fe, using transfer functions. The updated hybrid lake stage data set was developed and used to assess each aquifer decline scenario until one of the recommended MFLs for Lake Santa Fe is no longer being met.

The following two assumptions were applied in developing the hybrid lake stage data sets for each scenario:

1. the 59-year (1957-2015) hybrid lake stage data set is a statistically realistic representation of the hydrology, absent significant anthropogenic or climatological changes, over the next 59 years for Lake Alto and Lake Santa Fe; and
2. any potential water resource developments under consideration would essentially continue indefinitely.

6.2 Assessment of Hypothetical Allowable Florida Aquifer Drawdowns

Based on the frequency analysis results as noted in Section 5.4, the recommended MFLs for Lake Alto and Lake Santa Fe are being met under the 2006 hydrologic conditions. Therefore, further drawdowns in the upper FAS may be allowable at the lakes. As the most probable water resource development in this area would be manifested in drawdowns in the upper FAS by groundwater withdrawals, as opposed to direct surface water withdrawals, this analysis will include only upper FAS drawdowns.

Based on the model methodology described in Section 3.3.3, the FAS potentiometric surface levels at USGS Melrose station were used in modeling the groundwater loss from the lakes and sinkholes through various “outlet” links in the model. The FAS drawdowns were simulated by subtracting a set amount from the USGS Melrose station shifted well hydrographs used in the model (Figure 5-5). In addition, the lower groundwater loss rate values for the Aquifers in the model (Section 3.2.6) were adjusted for different FAS drawdowns. The remainder of the model parameters were not changed.

To determine the maximum allowable amount of FAS drawdown in the area beyond 2006 hydrologic conditions, a series of trial and error runs were performed. Drawdowns were gradually increased, the long-term models re-run, the historical data adjusted, and the generated hybrid lake stage data sets were assessed with respect to MFLs of Lake Alto and Lake Santa Fe.

In order to adjust the historical observed/calculated lake stage data prior to May 1, 1983, a transfer function is needed. For the FH level at Lake Alto and Lake Santa Fe, the maximum elevations remaining wet for 14 days for each water year were used (Figures 6-1A and 6-5A); for the MA level, the minimum average elevations for 180 days for each water year were used (Figures 6-1B and 6-5B); and for the FL level, the minimum elevations remaining dry for 120 days for each water year were used (Figures 6-1C and 6-5C). The modeled results for the 2006 hydrologic conditions or baseline conditions were plotted on the x-axis and the modeled results with the proposed FAS drawdown were plotted on the y-axis. A regression relationship was developed and then used as a transfer function to adjust the observed data prior to May 1, 1983 for the different FAS drawdown scenarios.

The transfer functions for the FH, MA, and FL levels at Lake Alto are presented in Figures 6-1A through 6-1C, based on a FAS drawdown of 7.0 ft beyond 2006 hydrologic conditions. The transfer functions for the FH, MA, and FL levels at Lake Santa Fe are presented in Figures 6-5A through 6-5C, based on a FAS drawdown of 16.0 ft beyond 2006 hydrologic conditions.

Based on the analysis results, all three recommended MFLs for Lake Alto would be met with a maximum drawdown of 7.0 ft beyond 2006 hydrologic conditions (Figures 6-2A through 6-2C). Based on the SJRWMD MFLs procedures, the minimum level is being met if any pertinent event or a best-fit line lies within/crosses the shaded box shown in these figures. With FAS drawdowns greater than 7.0 ft, the recommended FL level would no longer be met for Lake Alto.

Based on the analysis results, all three recommended MFLs for Lake Santa Fe would be met with a maximum drawdown of 16.0 ft beyond 2006 hydrologic conditions (Figures 6-6A through 6-6C). With FAS drawdowns greater than 16.0 ft, the recommended FH level would no longer be met for Lake Santa Fe.

Hybrid lake stage hydrographs and stage duration curves for each scenario can be used to evaluate the time extent and magnitude of the hydrologic changes involved at Lake Alto (Figures 6-3 and 6-4) and Lake Santa Fe (Figures 6-7 and 6-8).

It appears that when the lakes are in high level conditions, the FAS drawdown has minimal impact to the lake stages as compared to low stage conditions. This is particularly true for this lake system, where rainfall is the only input to the hydrologic cycle and when the lakes and the aquifer underneath have no chance to recover to their normal water levels after prolonged drought conditions, such as the 2000-2002 and 2006-2008 drought periods.

7.0 Conclusions and Limitations

EPA SWMM Version 5.1 was selected in development of a water budget model, to assist in establishment of MFLs at Lake Alto and Lake Santa Fe located in northeastern Alachua County, Florida.

The best available data sources, including the topographic survey, USGS LiDAR-based DEM data, NFSEG groundwater flow model data, and other pertinent data, have been reviewed and implemented in the model development.

The Lake Alto and Lake Santa Fe water budget model was well calibrated using a 10-year lake gage data record from 2006 through 2015. Model parameters were adjusted during the model calibration process to achieve the best overall fit of the model estimate with the observed data. The model calibration criteria or goals were met based on the statistical analysis results. The model calibration of the water budget model has been successfully executed.

The calibrated Lake Alto and Lake Santa Fe water budget model was employed in a long-term simulation for a 32.7-year time period from 5/1/1983 through 12/31/2015. The 32.7-year long-term simulation results were combined with the historical observed/calculated lake stage data prior to May 1, 1983 to develop two hybrid lake stage data sets to assess the existing hydrologic conditions of the two lake systems. Evaluation of the hybrid lake stage data sets indicates the recommended MFLs at Lake Alto and Lake Santa Fe are met under the 2006 hydrologic conditions.

The Lake Alto and Lake Santa Fe water budget model and the historical data prior to May 1, 1983 was also utilized in assessment of hypothetical allowable FAS drawdowns in the context of MFLs. The draft Lake Alto MFLs, including FH level of 140.20 ft NAVD, MA level of 138.89 ft NAVD, and FL level of 137.52 ft NAVD, would be met with a maximum drawdown of 7.0 ft beyond 2006 hydrologic conditions. The draft Lake Santa Fe MFLs, including FH level of

140.06 ft NAVD, MA level of 137.89 ft NAVD, and FL level of 136.52 ft NAVD, would be met with a maximum drawdown of 16.0 ft beyond 2006 hydrologic conditions.

Nevertheless, no model can possibly simulate all factors that could affect the hydrologic cycle. Prior to analyzing the final product of the model in context of MFLs, a judgment should be made as to the appropriateness of the model assumptions and/or limitations. Several principal modeling assumptions were made in developing the water budget model, as follows:

1. In the SWMM model, a constant lower groundwater loss rate is the only model parameter that is used to estimate groundwater loss to the upper FAS. The assumption is made that influence on water budget model results by the FAS potentiometric surface level fluctuation is considered insignificant in the lake watershed, except for the area immediately beneath the major lakes and sinkholes where collapse structures might provide preferred paths toward the upper FAS. Various "outlet" links were employed in the SWMM model with a functional rating curve developed to calculate the time-variant discharge from the lakes/sinkholes to the upper FAS.
2. Topographic surveys at Santa Fe Canal and major drainage structures and bathymetry survey at Lake Alto were provided by the District. However, the topographic and bathymetric survey data may not be sufficient to determine the location and elevation of the highest point of the Santa Fe Canal and outflow control points of the lakes. It was assumed that the LiDAR-based DEM data could be used to assist in locating the control points of the lakes, and the invert elevation at the control point could be further determined during model calibration.
3. The 10-year calibration period from 2006 through 2015 covers a wide range of hydrologic conditions. It was assumed that the calibrated model will provide a realistic simulation over a much longer period of record (i.e., 32.7 years).
4. Various data sources with different techniques and levels of accuracy (e.g., NEXRAD vs. ORNL Daymet daily rainfall data and NOAA pan evaporation vs. USGS PET data), were utilized in developing the time series data required for long-term model simulation.
5. It was assumed that the developed hybrid lake stage data set for each lake system is a statistically realistic representation of the hydrology, absent significant anthropogenic or climatological changes, over the next 59 years, for Lake Alto and Lake Santa Fe.

6. It was also assumed that any hypothetical water resource developments under consideration would essentially continue indefinitely in assessing allowable FAS drawdowns in context of MFLs.

The limitation in the water budget modeling efforts could be further improved with a more comprehensive integrated surface water and groundwater model and/or by recalibrating the model when additional data becomes available.

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Figures

G:\Working\2-ECT\Projects\SRWMD\Lake_MFLs\160682_Lake Altho and Lake Santa Fe\3_Data\GIS\MXD\Figures\Task 6\Figure 2-1 Lake Watershed.mxd By: jsun Date: 8/8/2017

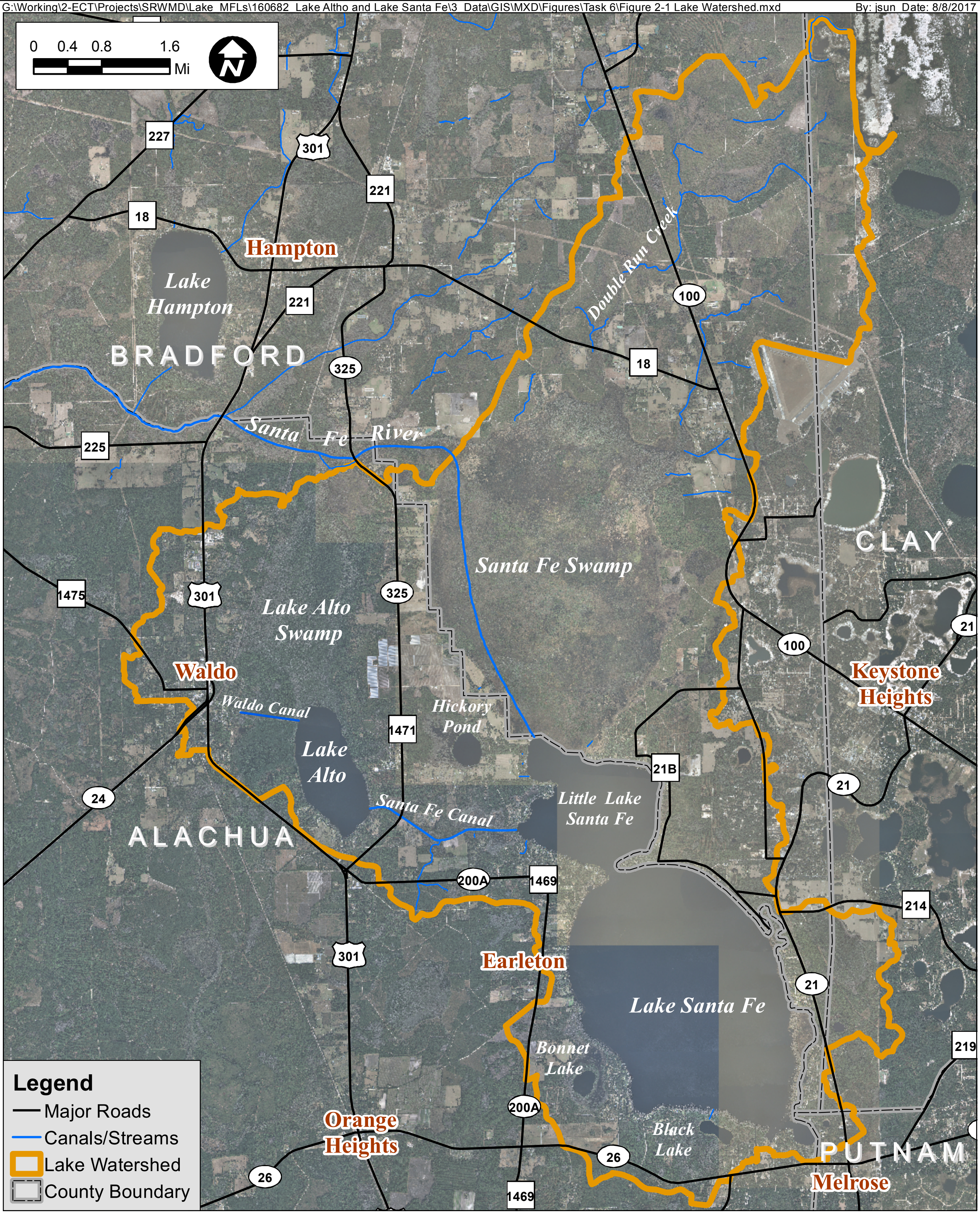

Figure 2-1
Lake Alto and Lake Santa Fe Watershed
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2011; FDOT, 2013 & 2014; USGS, 2011; ECT, 2016.

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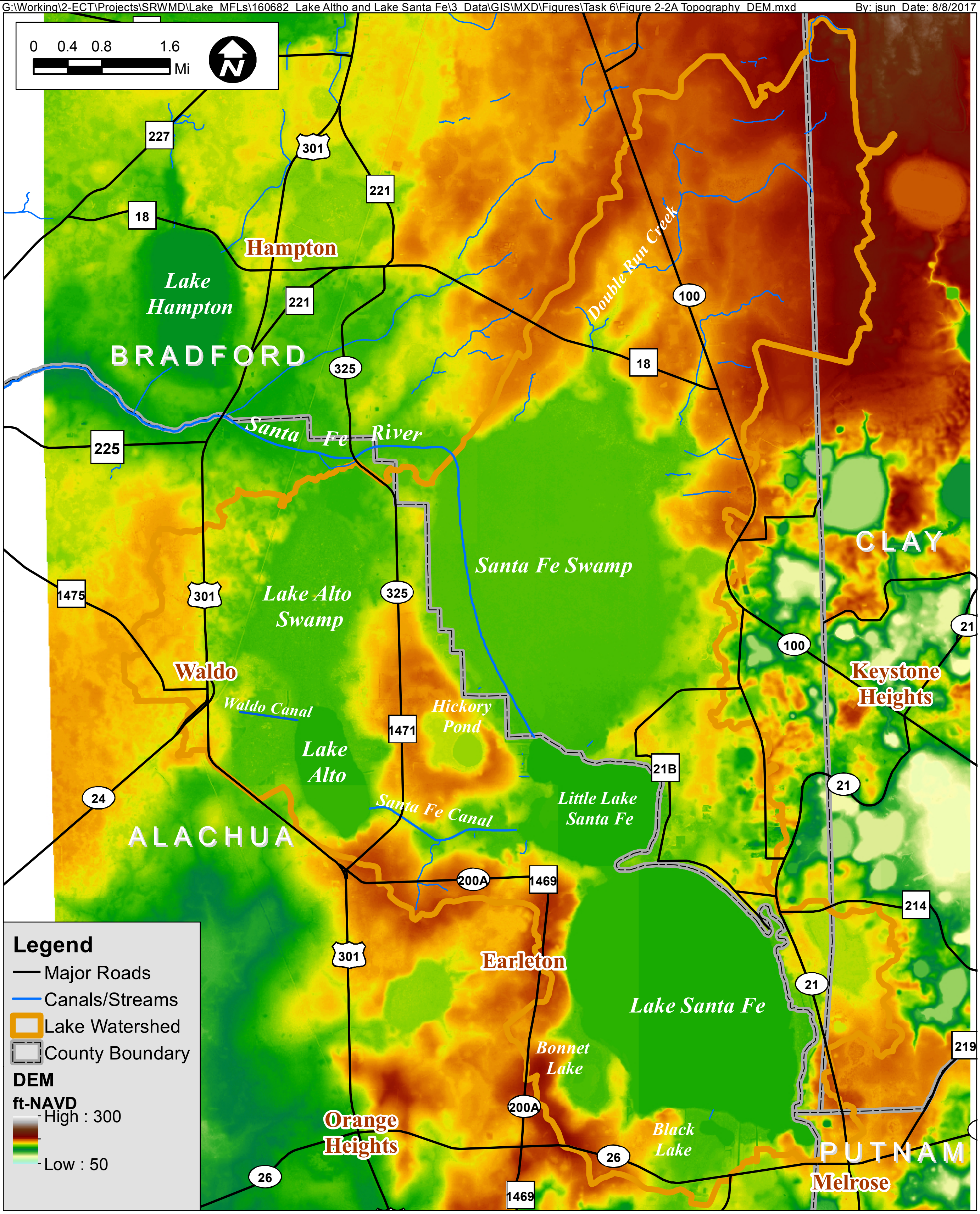

Figure 2-2A
Topographic DEM Map
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2011; USGS, 2011; SJRWMD, 2007; SRWMD, 2001; SRWMD, 2016; ECT, 2016.

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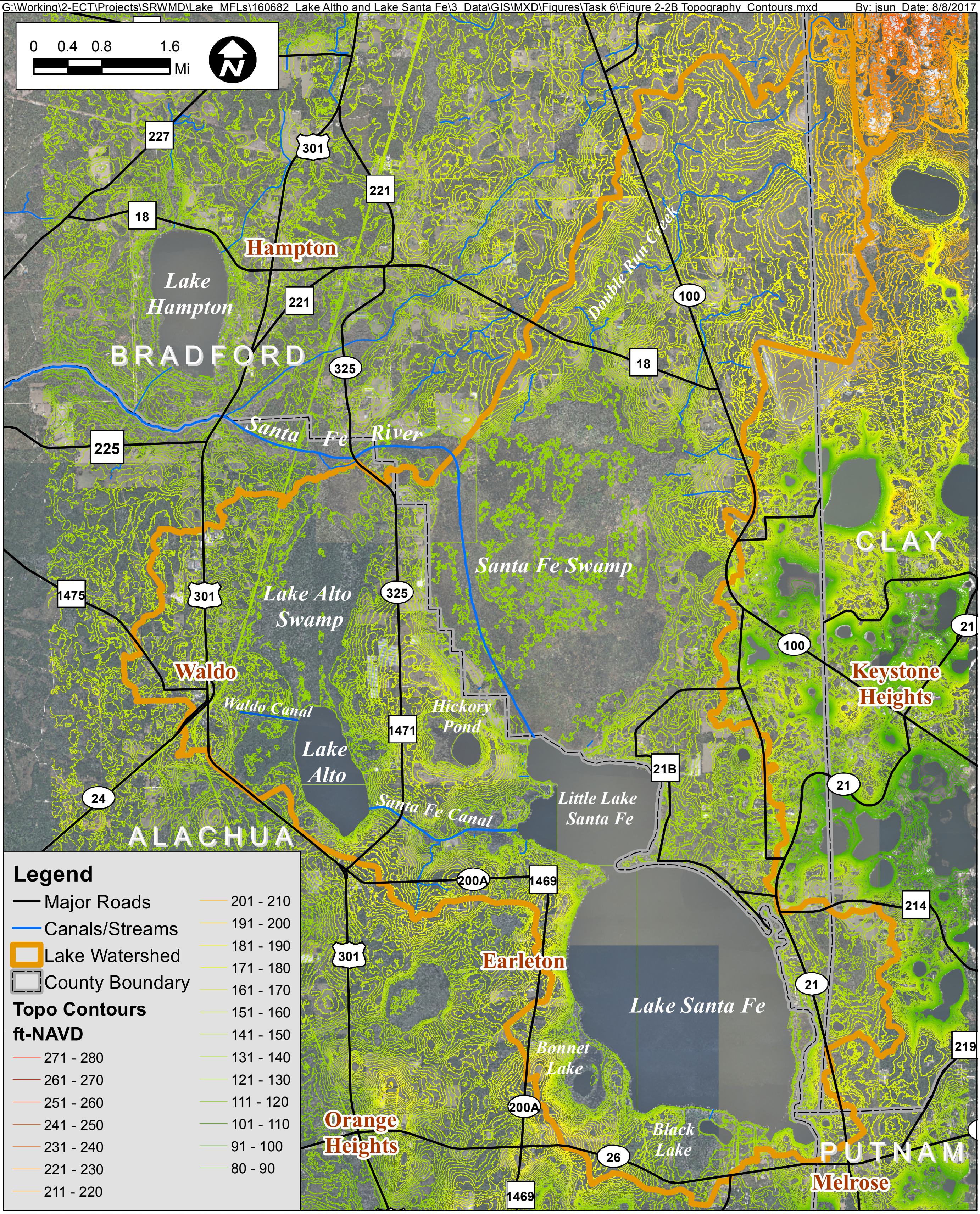

Figure 2-2B
Topographic Contour Map
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2011; USGS, 2011; SJRWMD, 2007; SRWMD, 2001; SRWMD, 2016; ECT, 2016.

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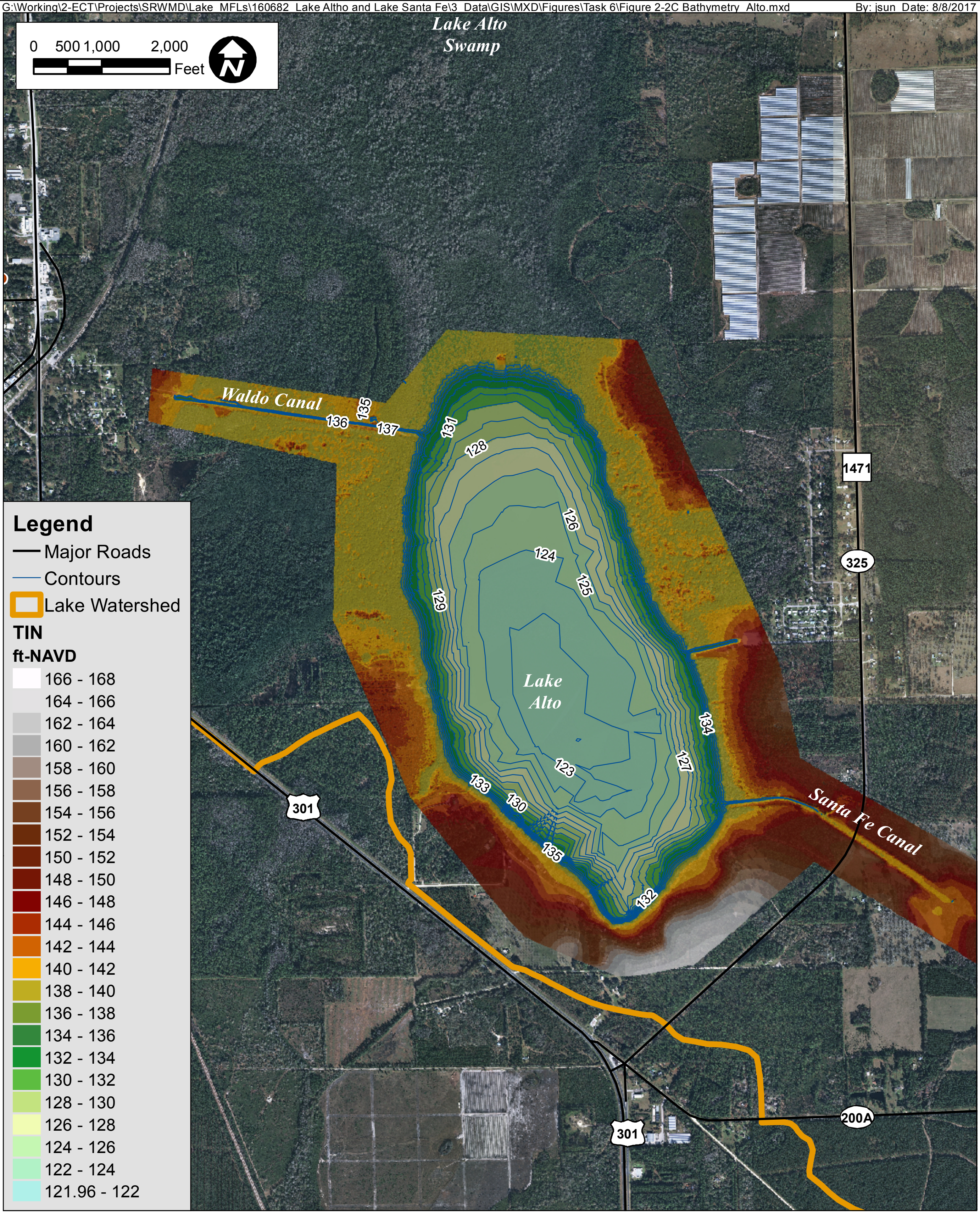

Figure 2-2C
Bathymetric Map - Lake Alto
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2013 & 2014; SRWMD, 2016; ECT, 2016.

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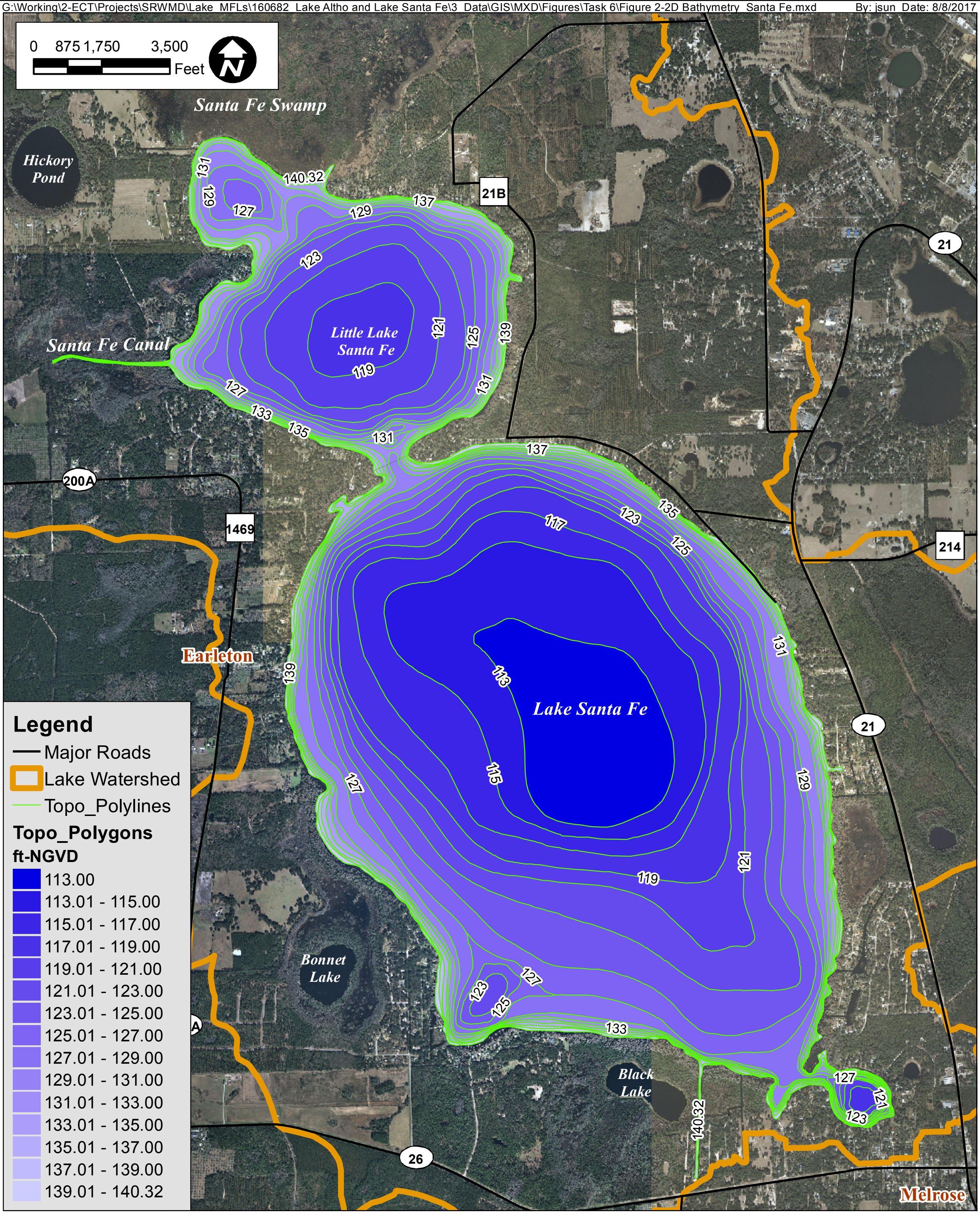

Figure 2-2D
Bathymetric Map - Lake Santa Fe and Little Lake Santa Fe
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2013 & 2014; SRWMD, 2016; ECT, 2016.

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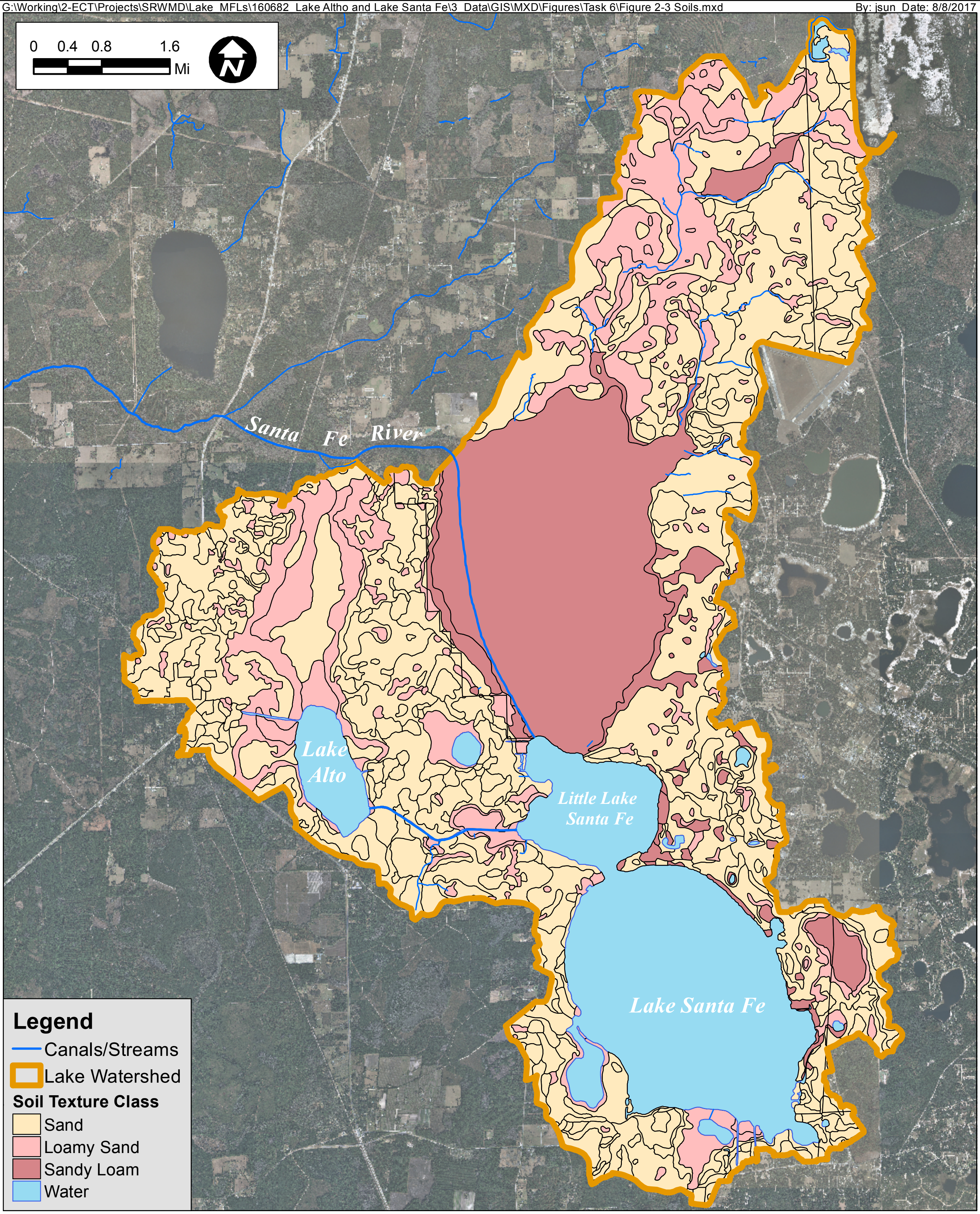

Figure 2-3
Soil Texture Classes Map
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2013 & 2014; USGS, 2011; NRCS, 2016; ECT, 2017.

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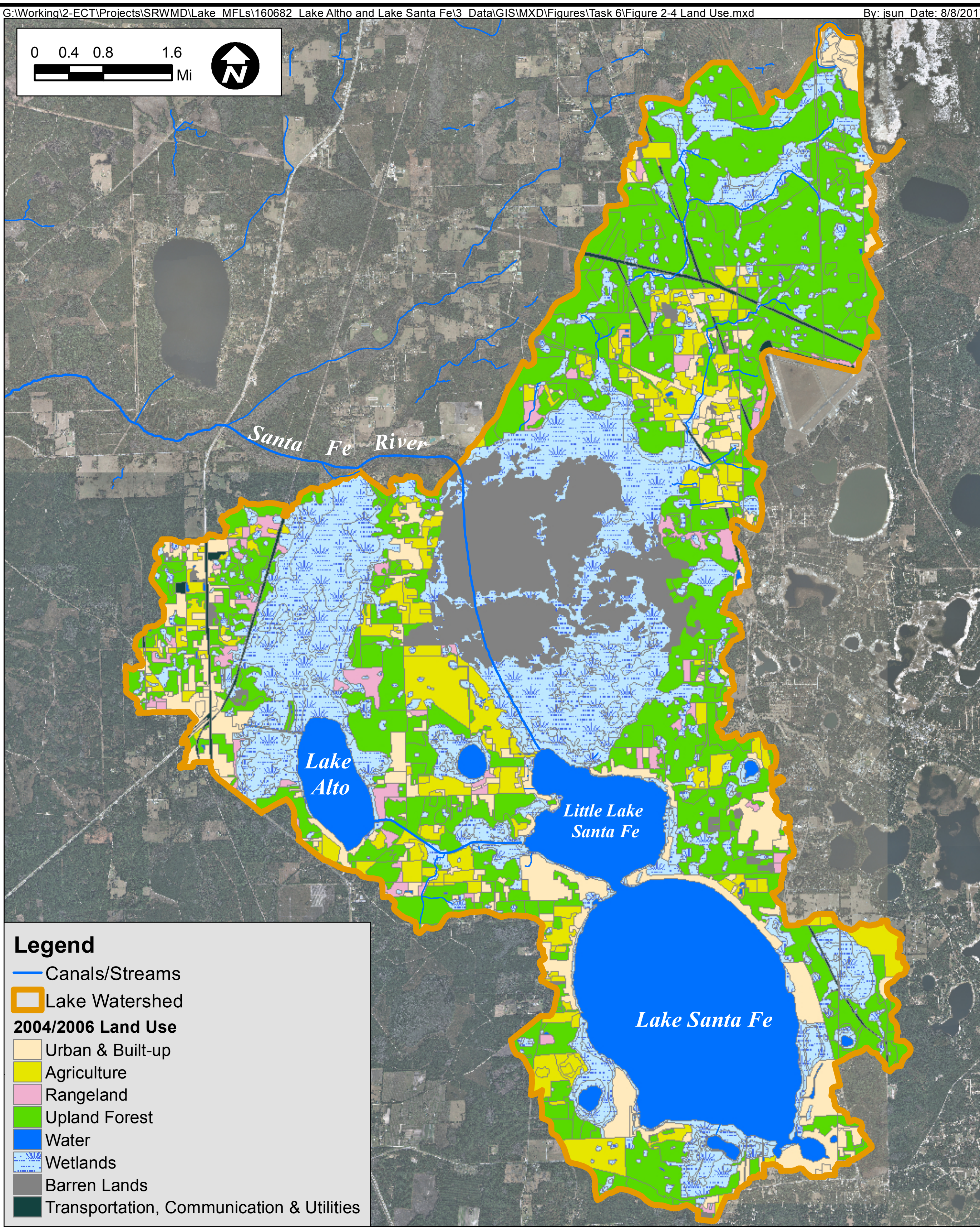

Figure 2-4
2004/2006 Land Use Map
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2013 & 2014; USGS, 2011; SRWMD, 2006; SJRWMD, 2004; ECT, 2016.

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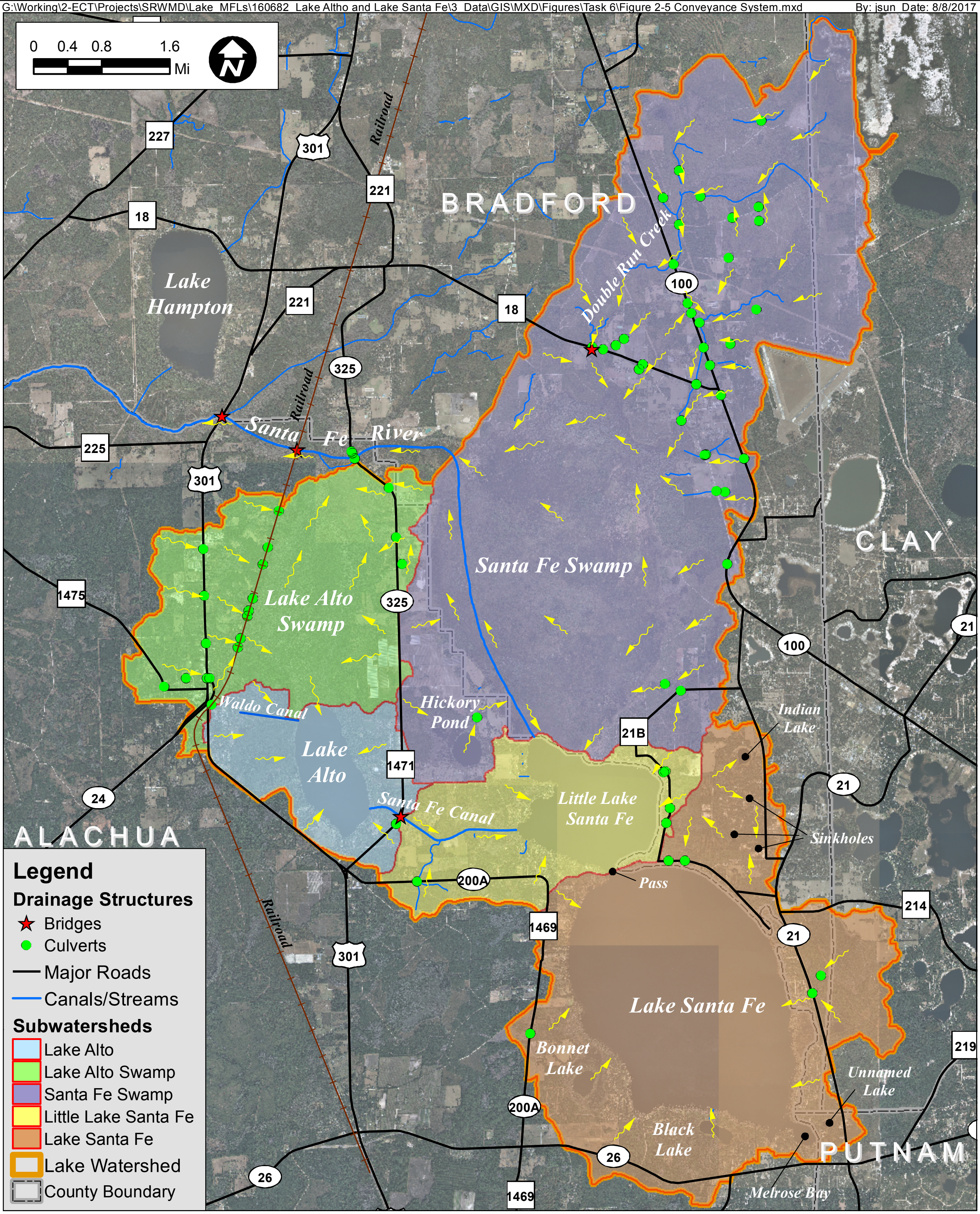

Figure 2-5
Subwatersheds and Major Conveyance System Map
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2011; FDOT 2013 & 2014; USGS, 2011; SRWMD, 2016; GFY, 2017; ECT, 2017.

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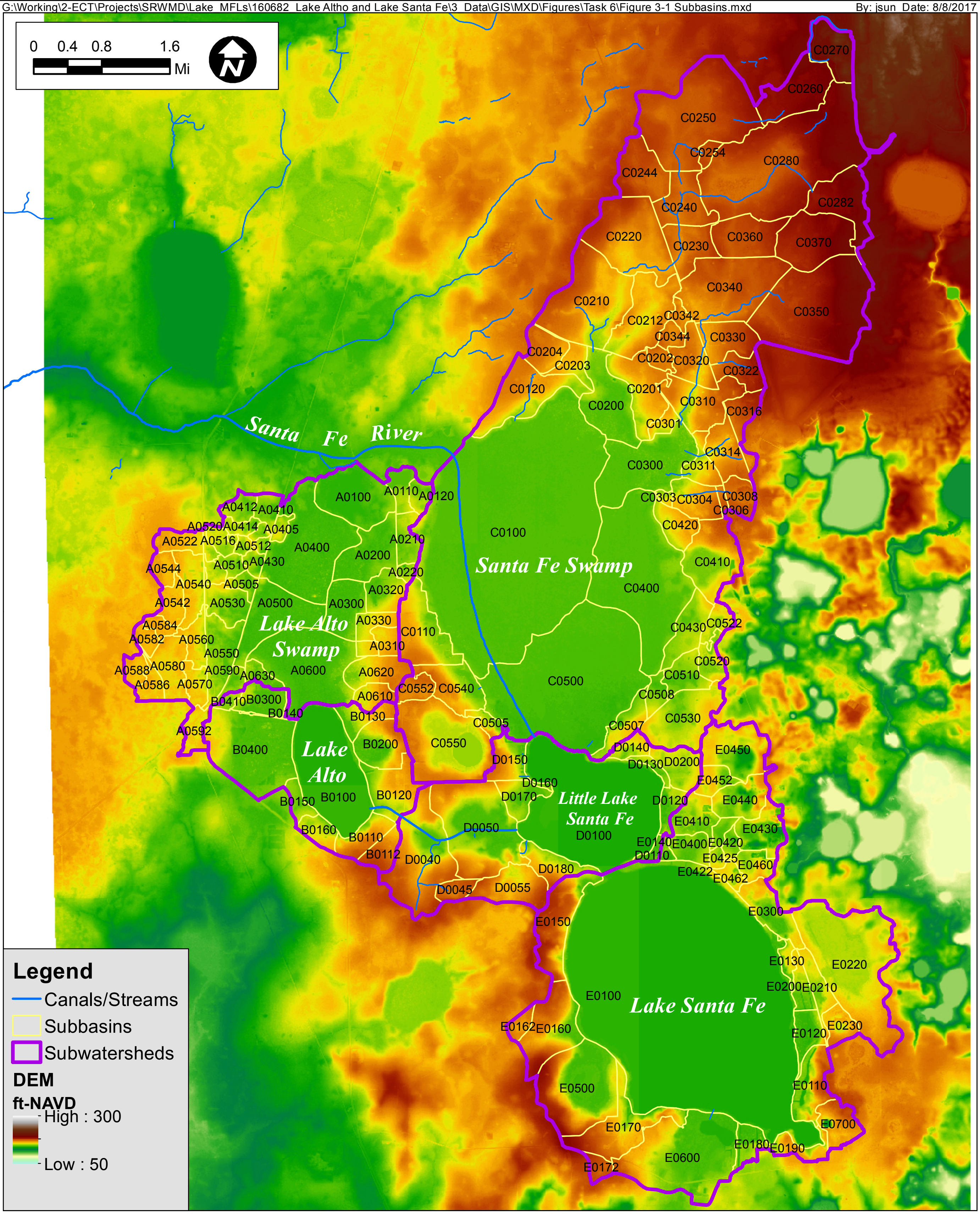

Figure 3-1
Subbasin Delineation Map
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: USGS, 2011; SJRWMD, 2007; SRWMD, 2001; SRWMD, 2016; ECT, 2016.

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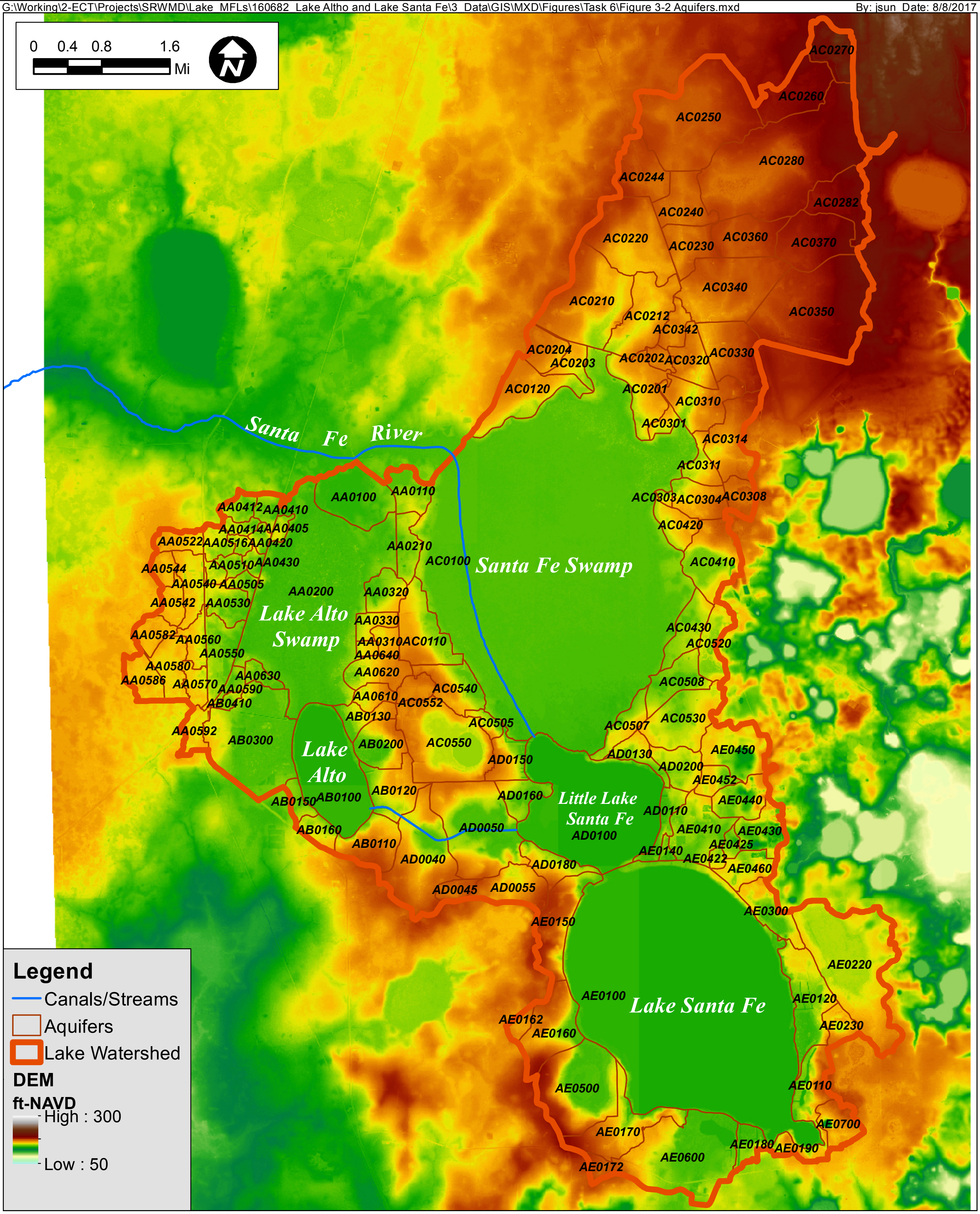

Figure 3-2
Aquifers Map
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: USGS, 2011; SJRWMD, 2007; SRWMD, 2001; SRWMD, 2016; ECT, 2016.

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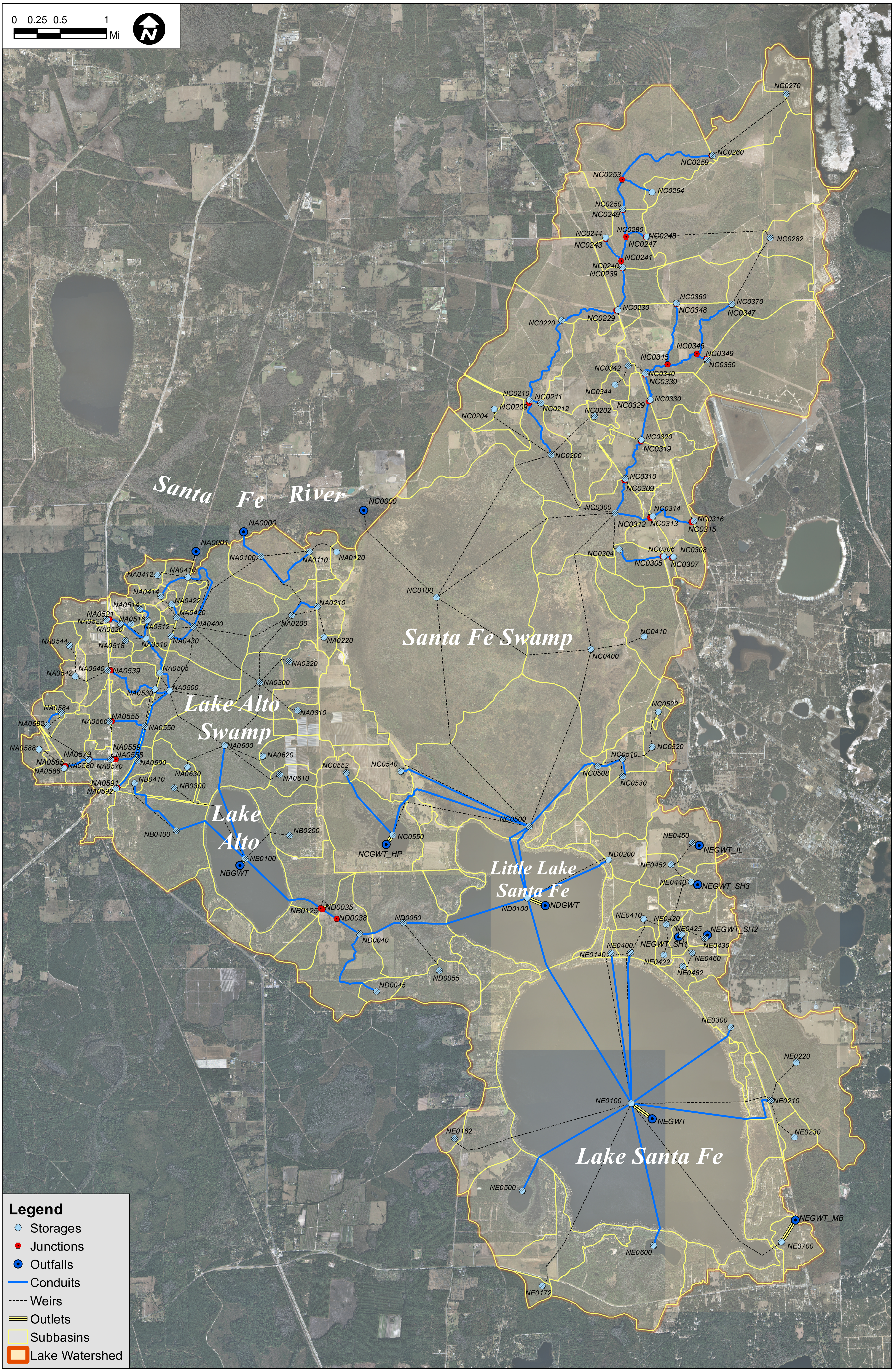

Figure 3-3
Model Schematic Map
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2013 & 2014; SRWMD, 2016; ECT, 2017.

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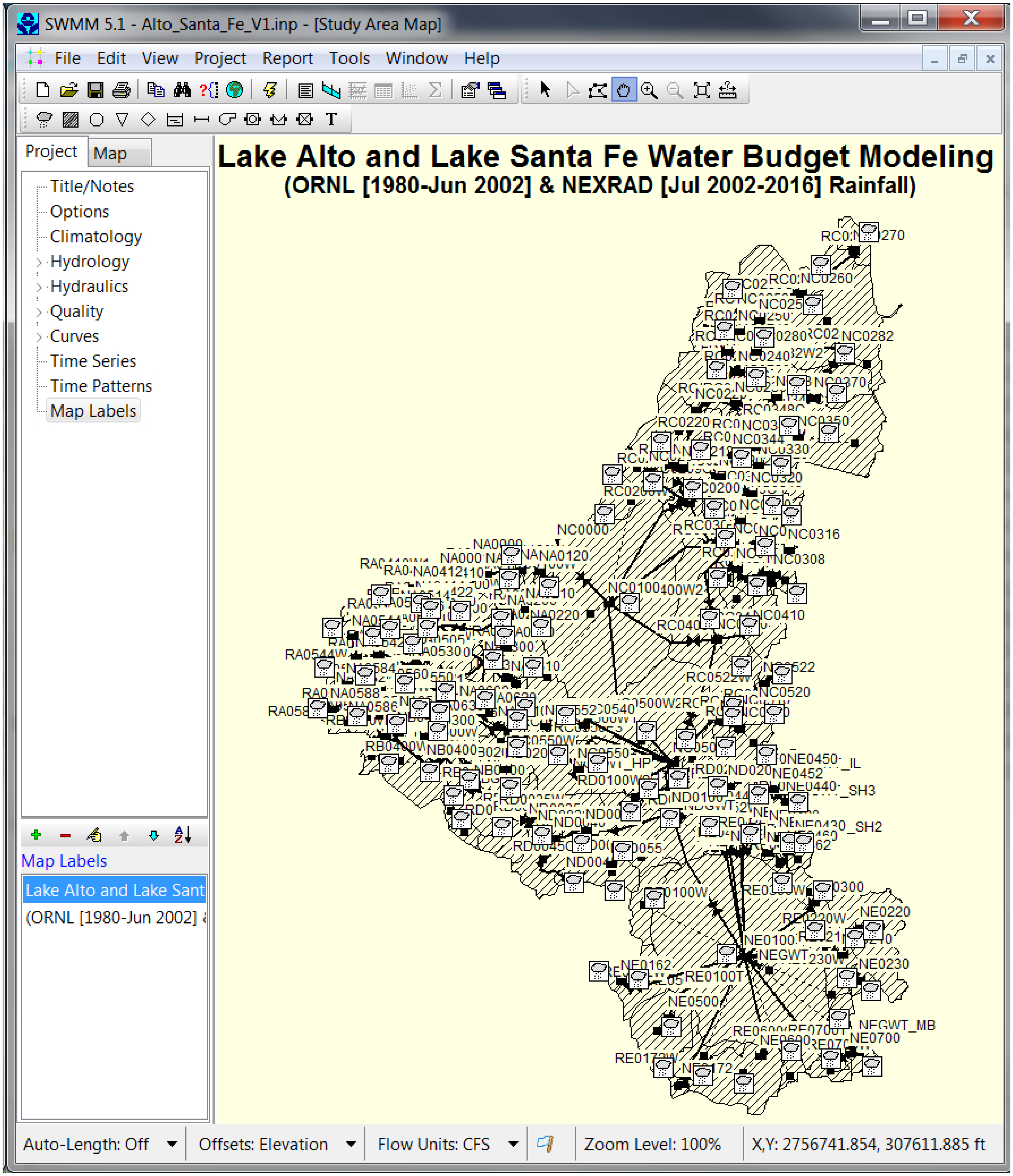

Figure 3-4
Subbasins and Model Schematic in SWMM's Main Window
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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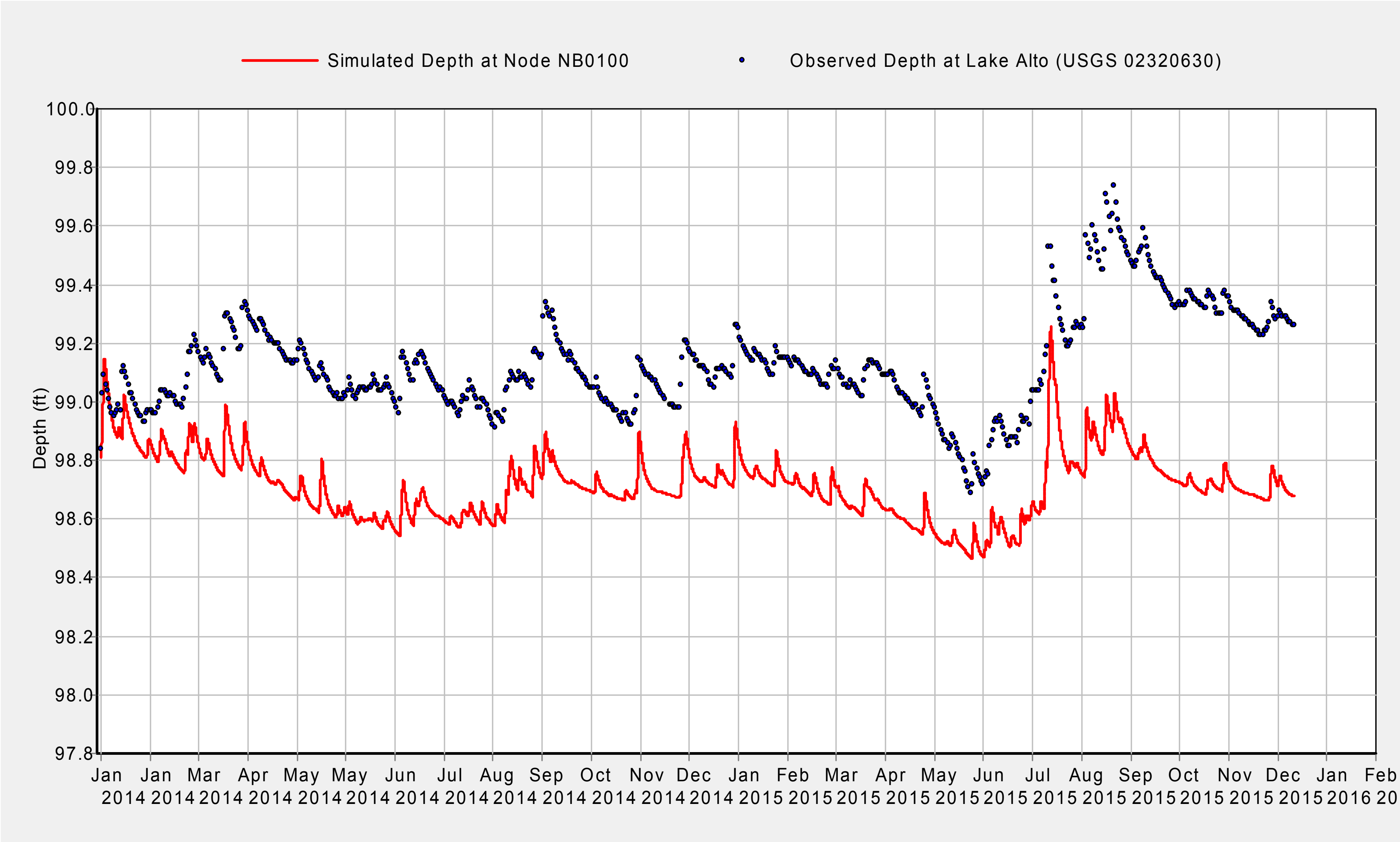

Figure 3-5A
Node Depth Hydrographs Comparison at Lake Alto (2014-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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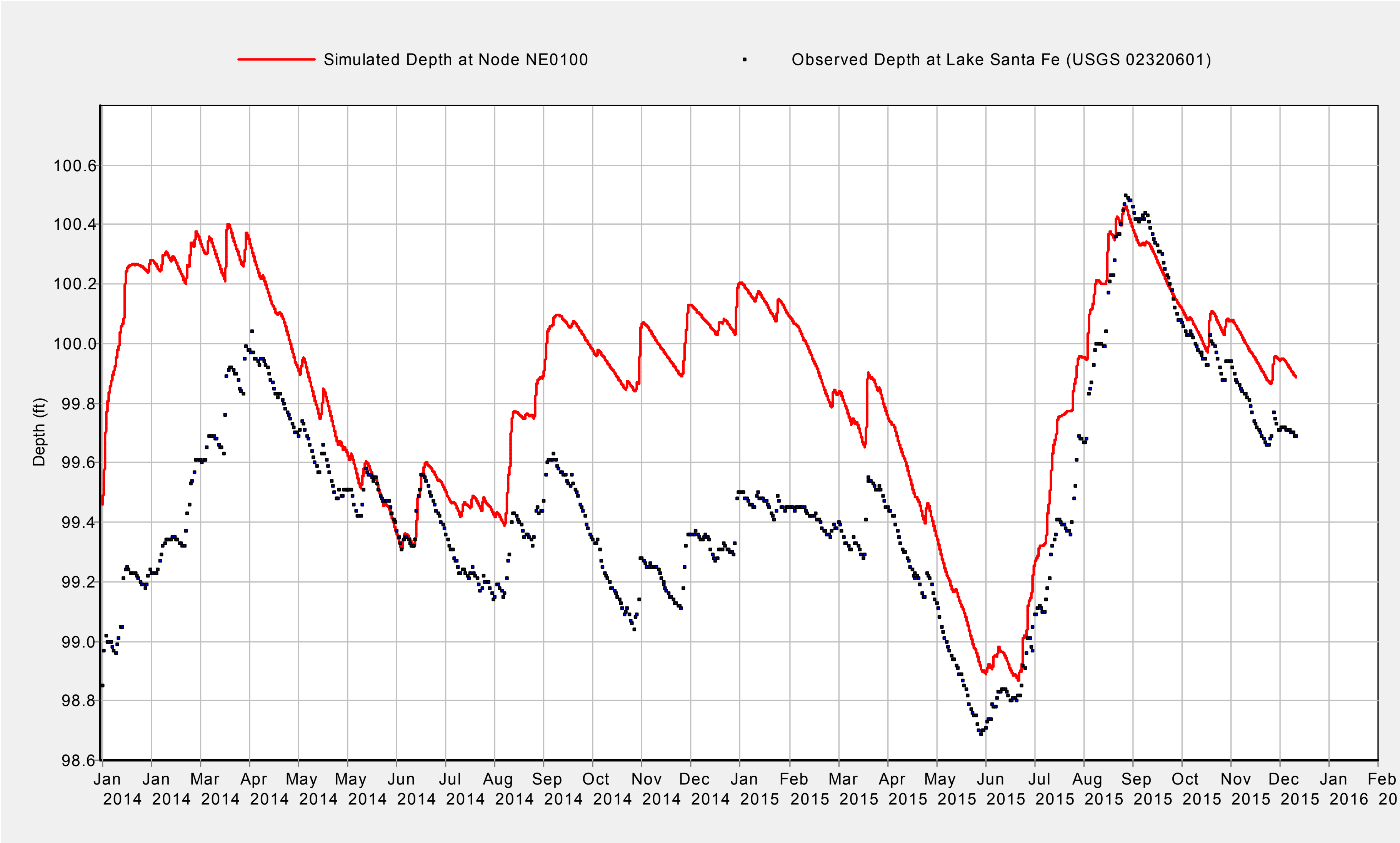

Figure 3-5B
Node Depth Hydrographs Comparison at Lake Santa Fe (2014-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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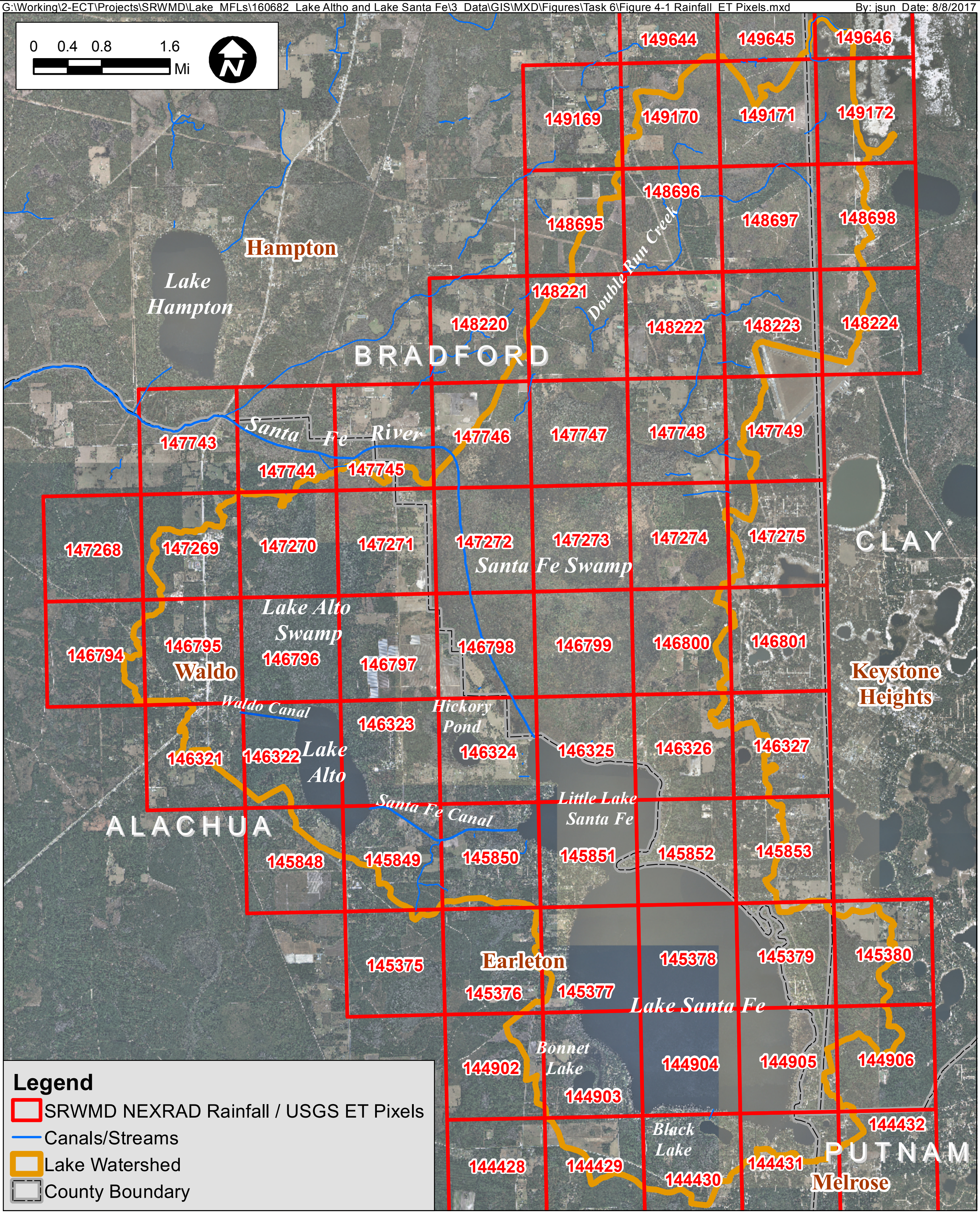

Figure 4-1
SRWMD NEXRAD Rainfall / USGS ET Pixels
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2011; FDOT, 2013 & 2014; USGS, 2011; SRWMD, 2015; ECT, 2016.

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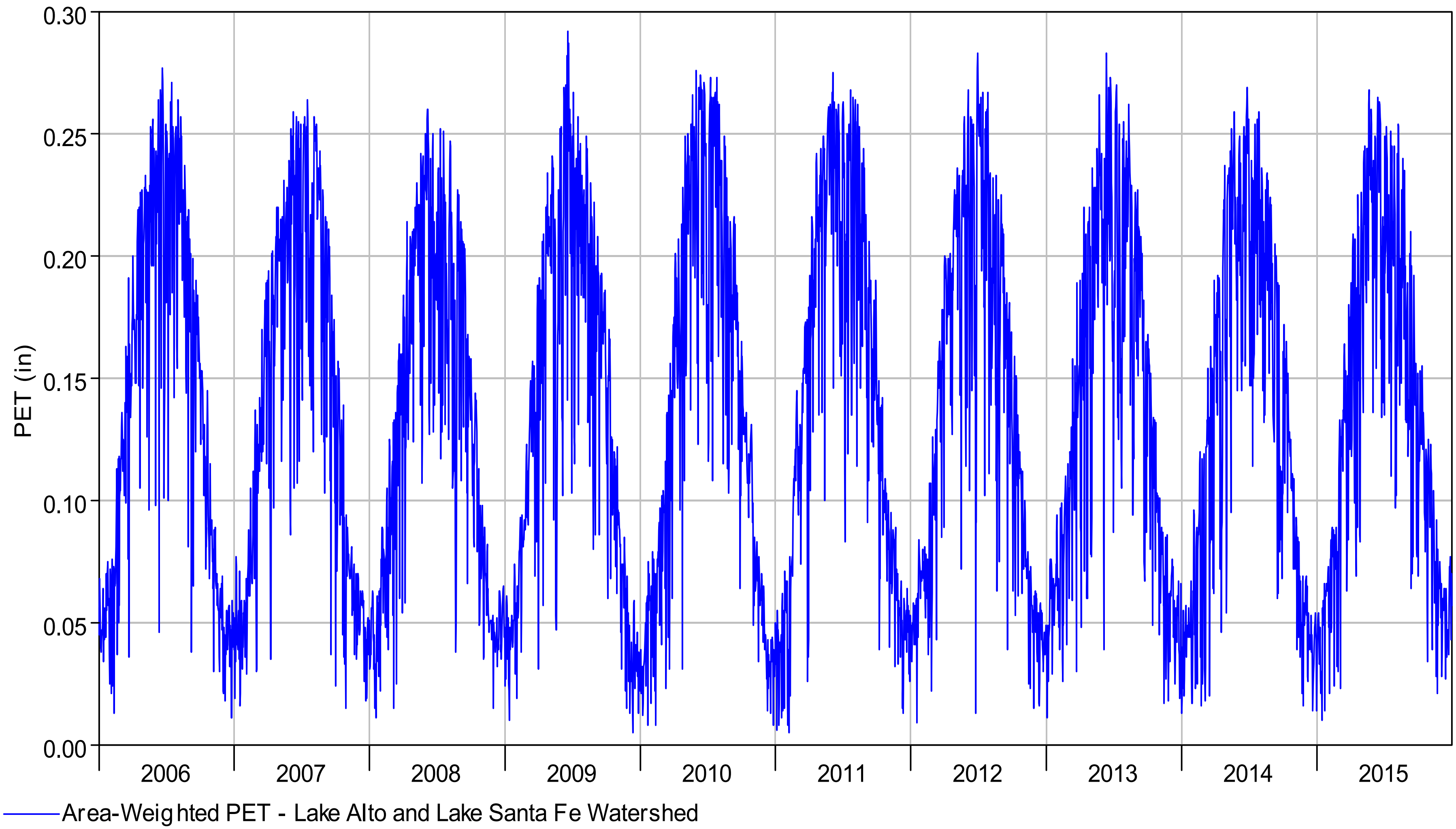

Figure 4-2
Area-Weighted Daily Potential Evapotranspiration (2006-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: USGS, 2016; ECT, 2017.

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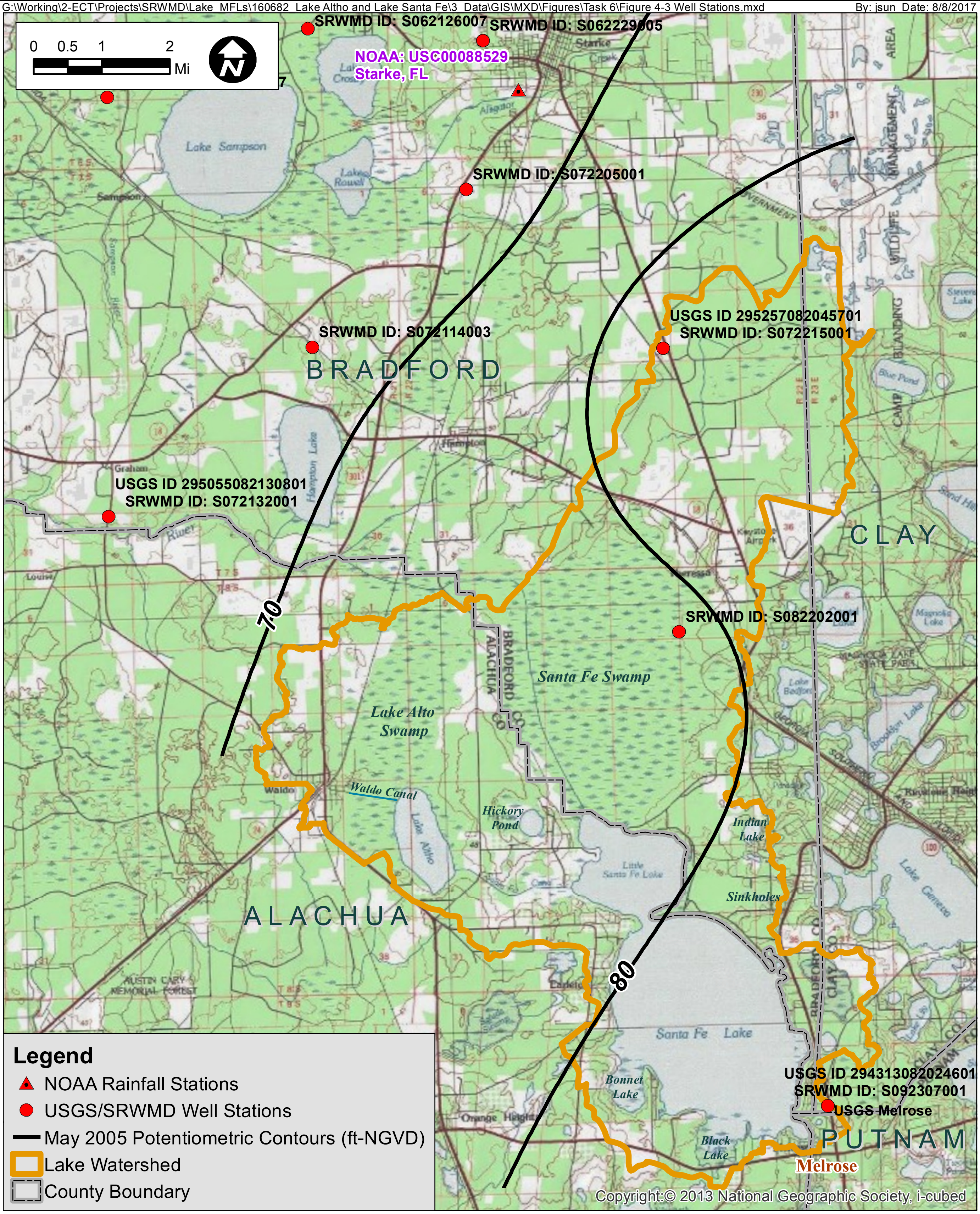

Figure 4-3
USGS Well Stations and Potentiometric Contours in May 2005
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: NGS, 2013; USGS, 2015; SRWMD 2016; ECT, 2016.

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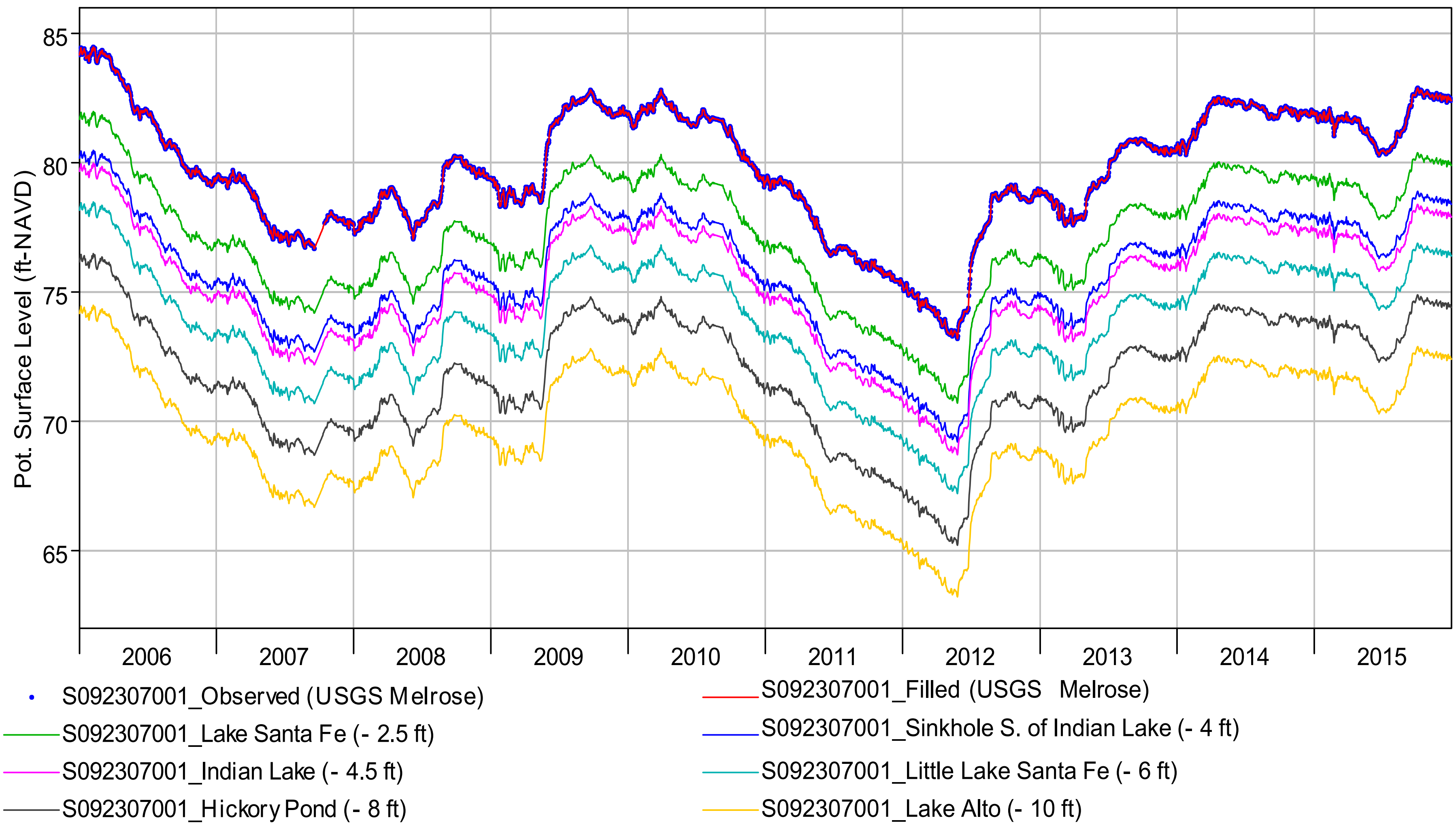

Figure 4-4
Observed/Filled/Shifted Well Level Hydrographs at USGS Melrose Station (SRWMD ID S092307001)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: USGS, 2016; SRWMD, 2016; ECT, 2017.

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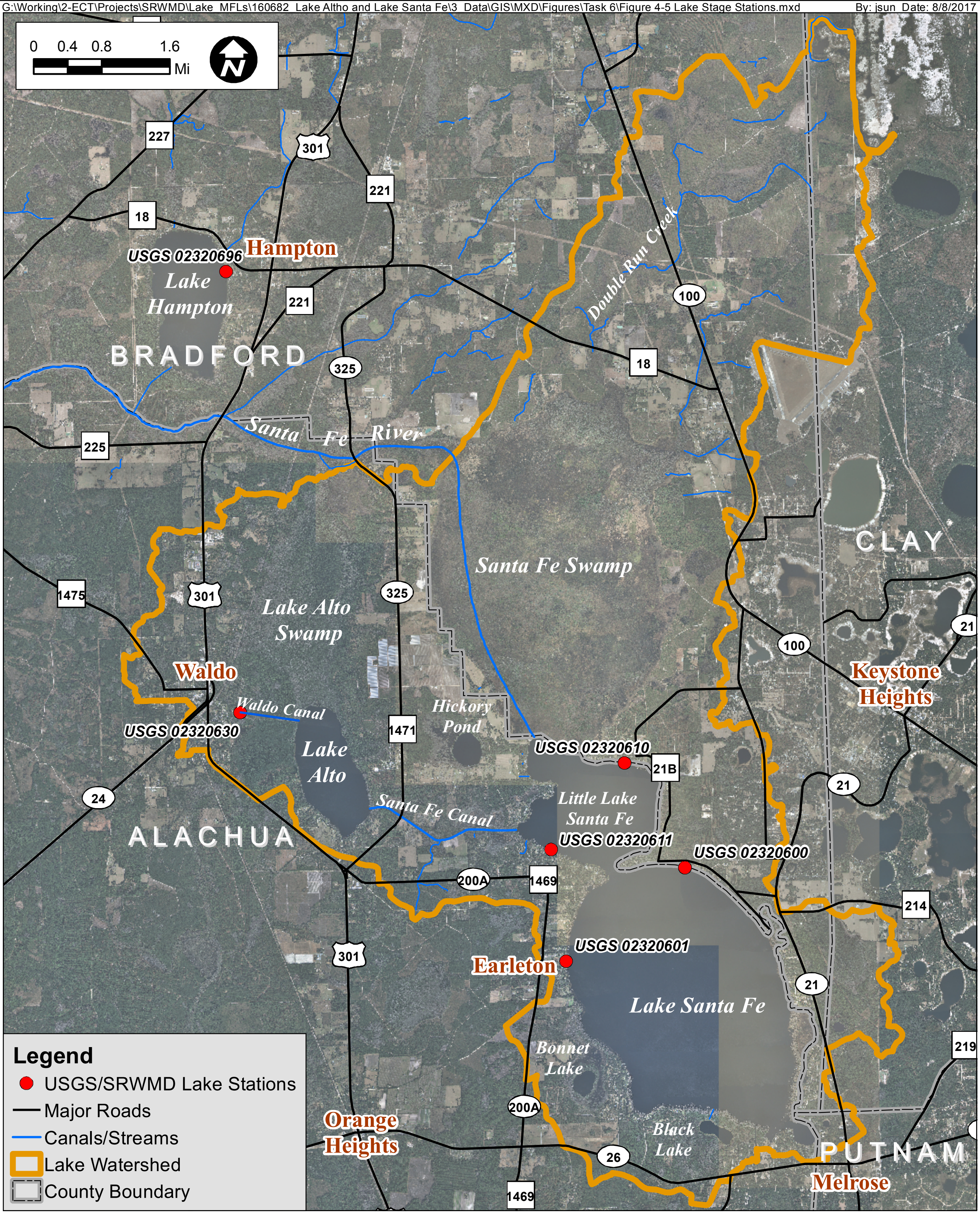

Figure 4-5
USGS/SRWMD Lake Stations
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2011; FDOT, 2013 & 2014; USGS, 2011; SRWMD, 2016; ECT, 2016.

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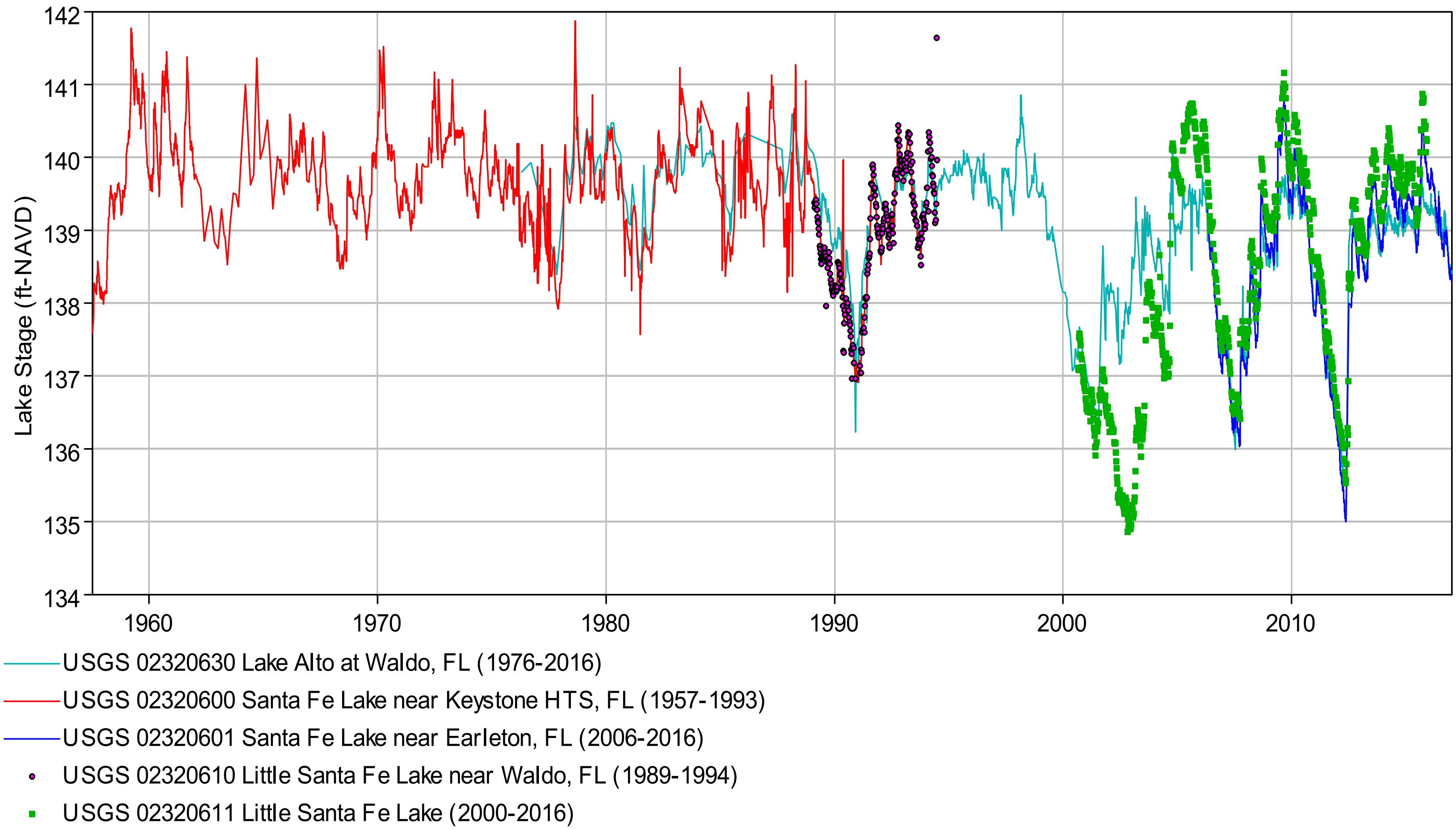

Figure 4-6A
Observed Lake Stage Hydrographs at Lake Alto and Lake Santa Fe (1957-2016)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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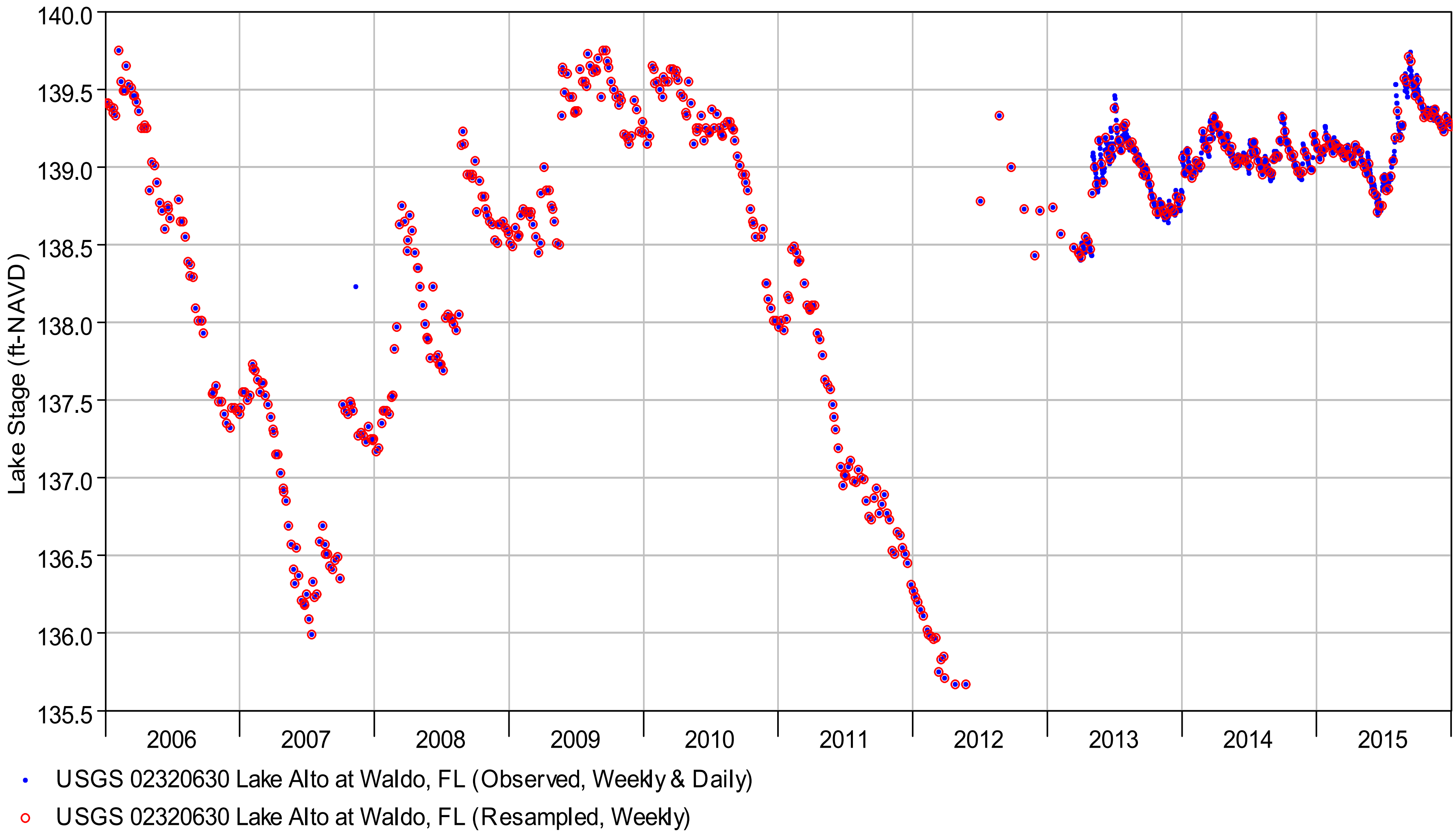

Figure 4-6B
Observed and Resampled Lake Stage Hydrographs at Lake Alto (2006-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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Figure 4-6C
Observed Lake Stage Hydrograph at Lake Santa Fe (2006-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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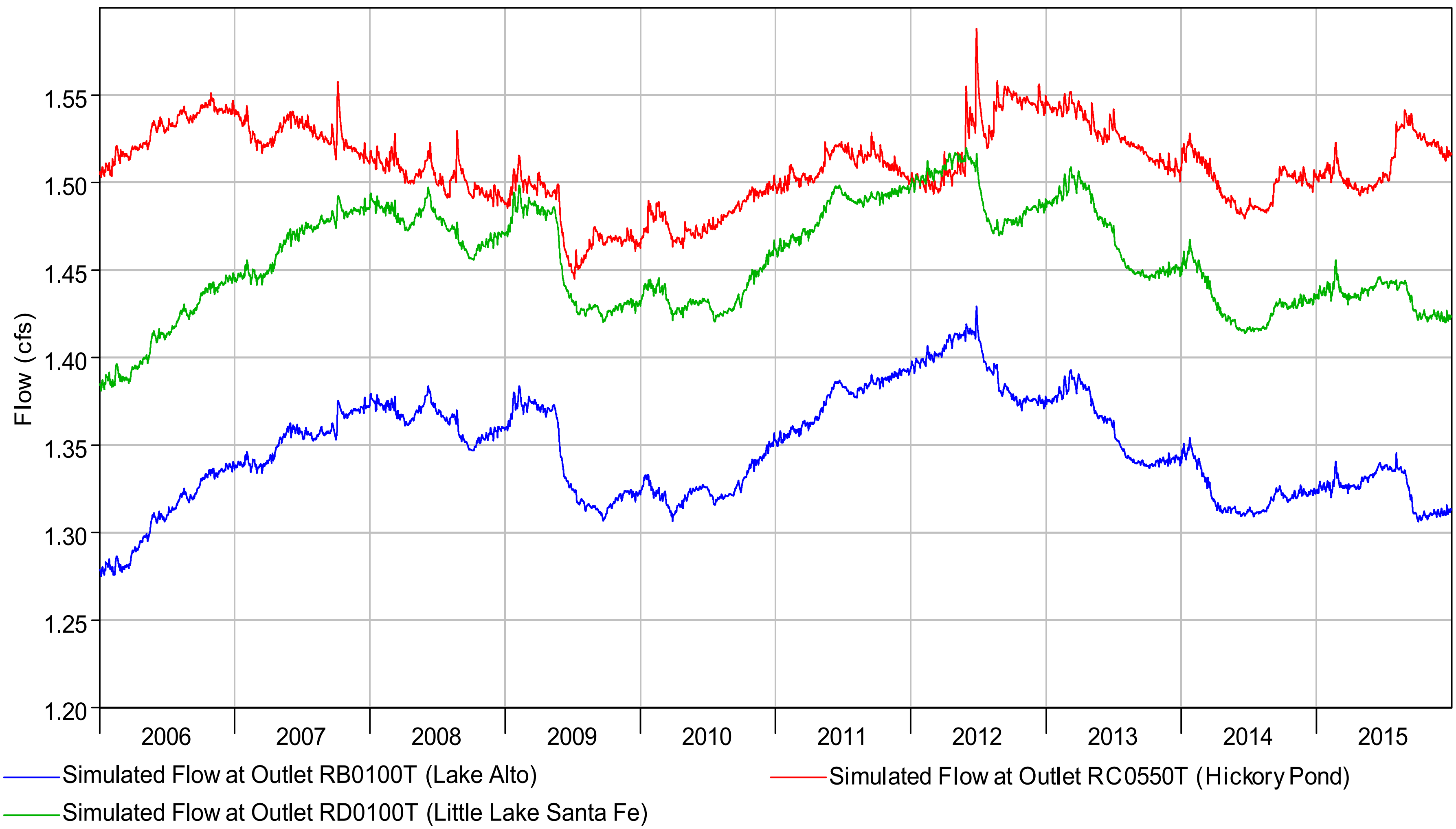

Figure 4-7A
Simulated Groundwater Flow Hydrographs (2006-2015) - 1 of 3
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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Figure 4-7B
Simulated Groundwater Flow Hydrographs (2006-2015) - 2 of 3
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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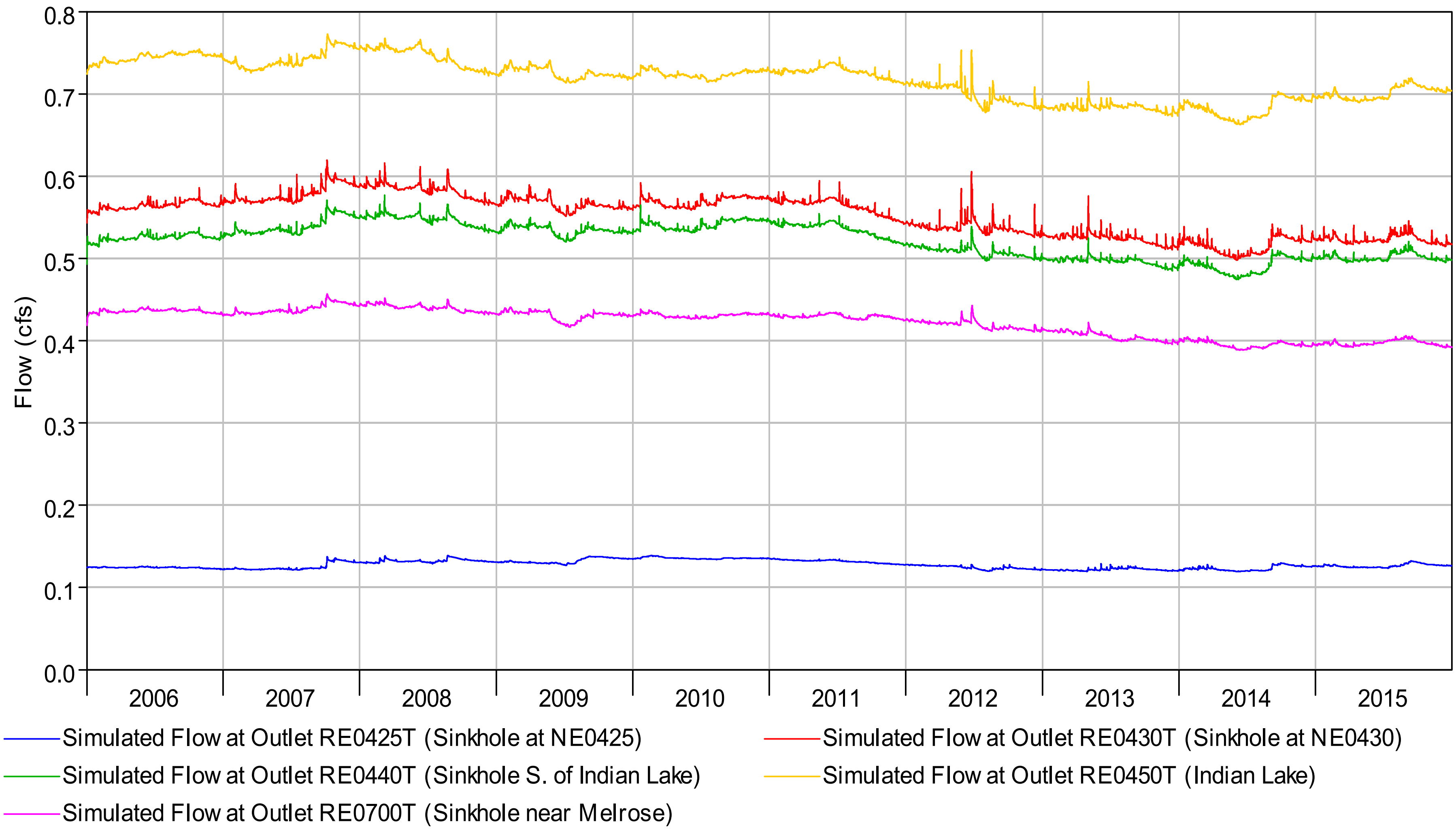

Figure 4-7C
Simulated Groundwater Flow Hydrographs (2006-2015) - 3 of 3
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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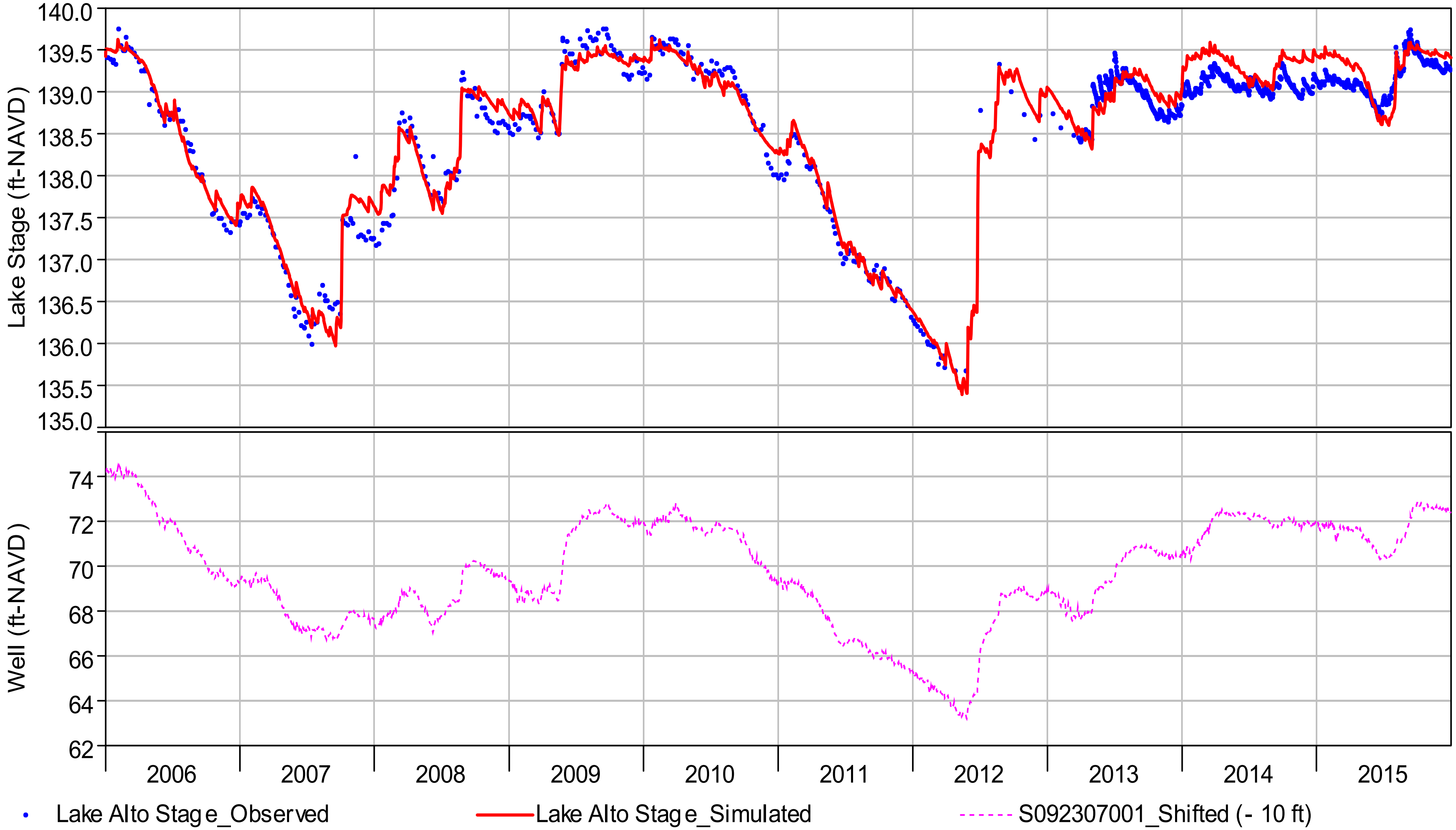

Figure 4-8A
Comparison of Observed and Simulated Lake Stage Hydrographs at Lake Alto (2006-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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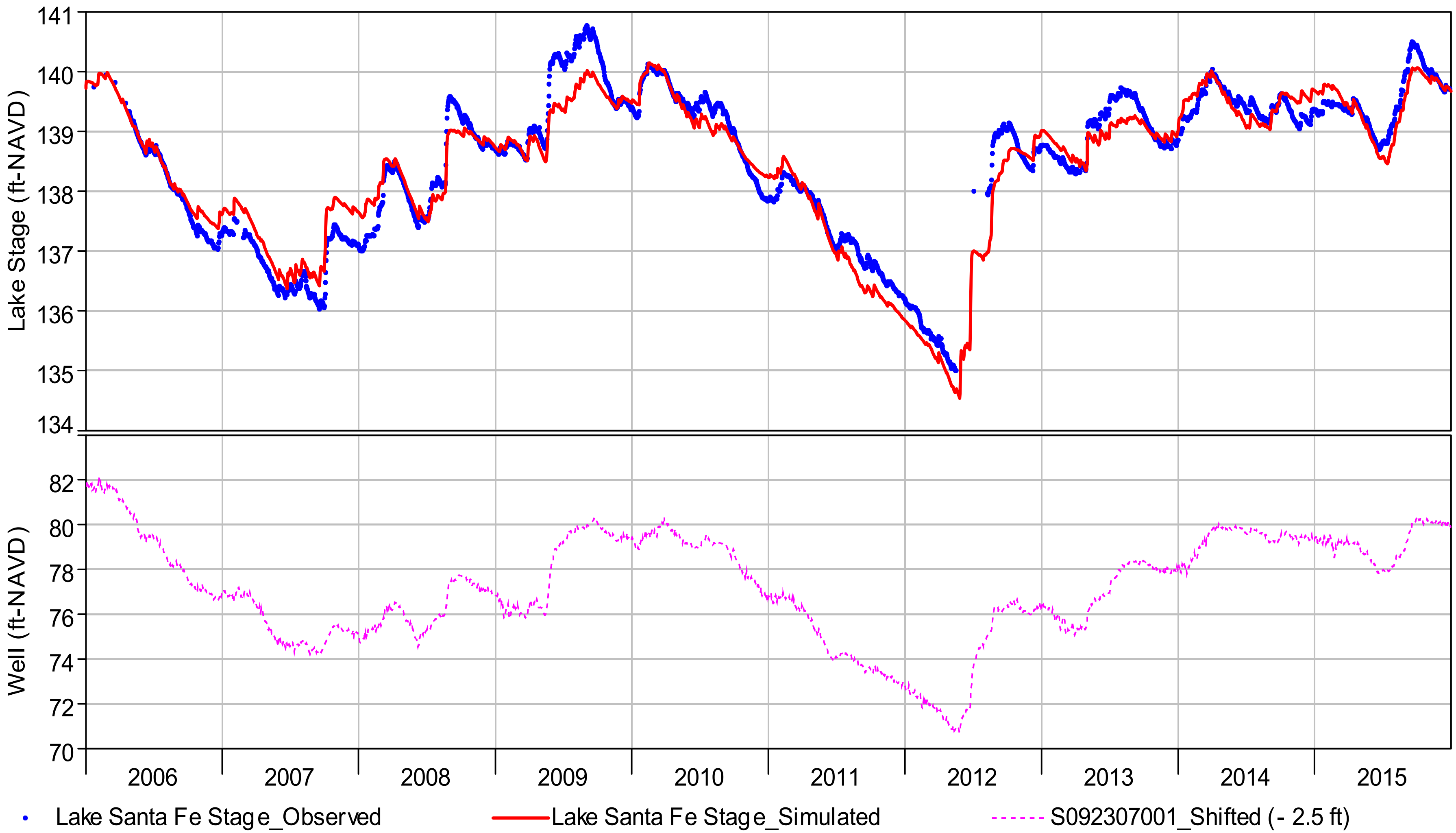

Figure 4-8B
Comparison of Observed and Simulated Lake Stage Hydrographs at Lake Santa Fe (2006-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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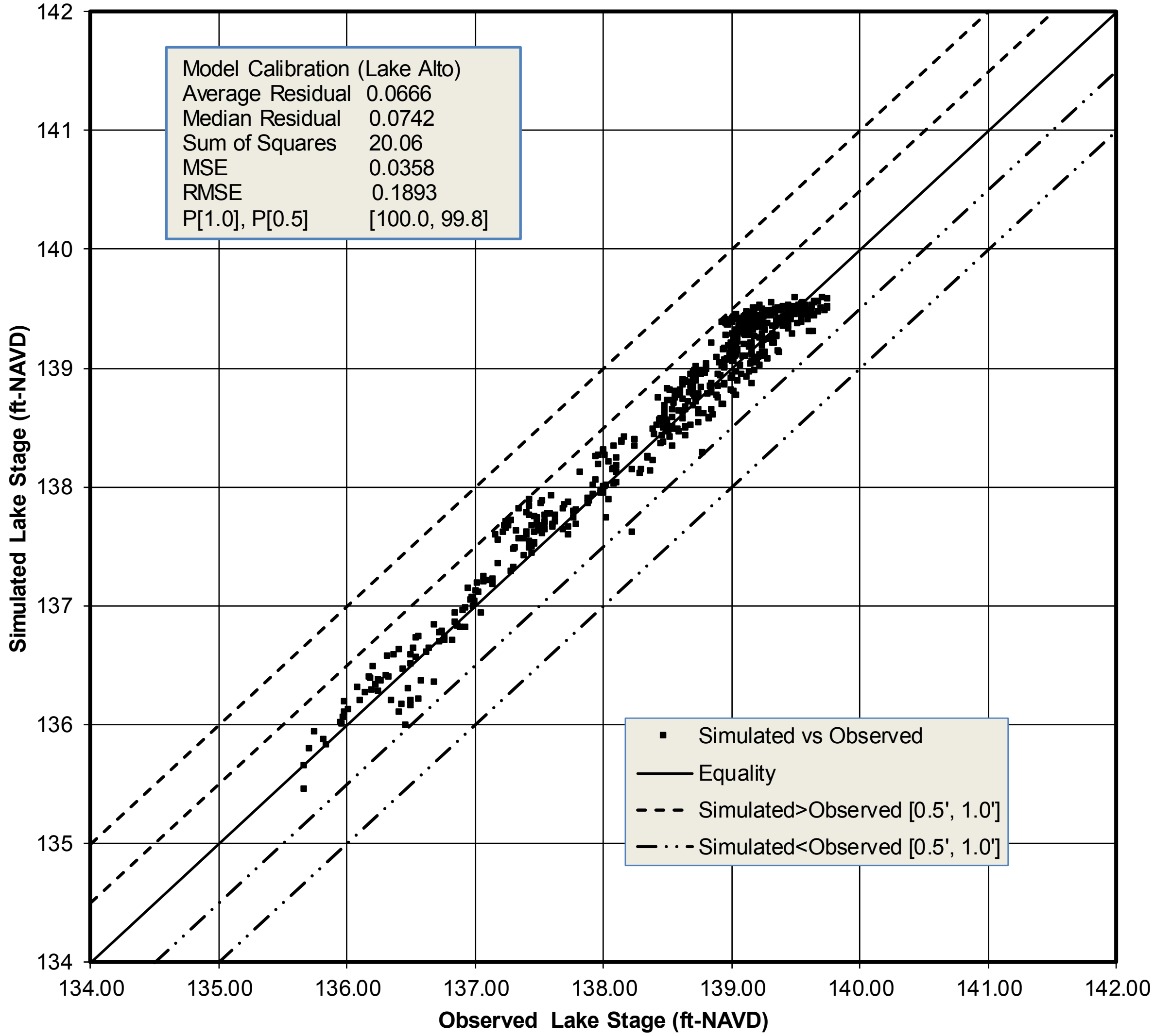

Figure 4-9A
Scatter Plot Comparing Simulated and Observed Stages at Lake Alto (2006-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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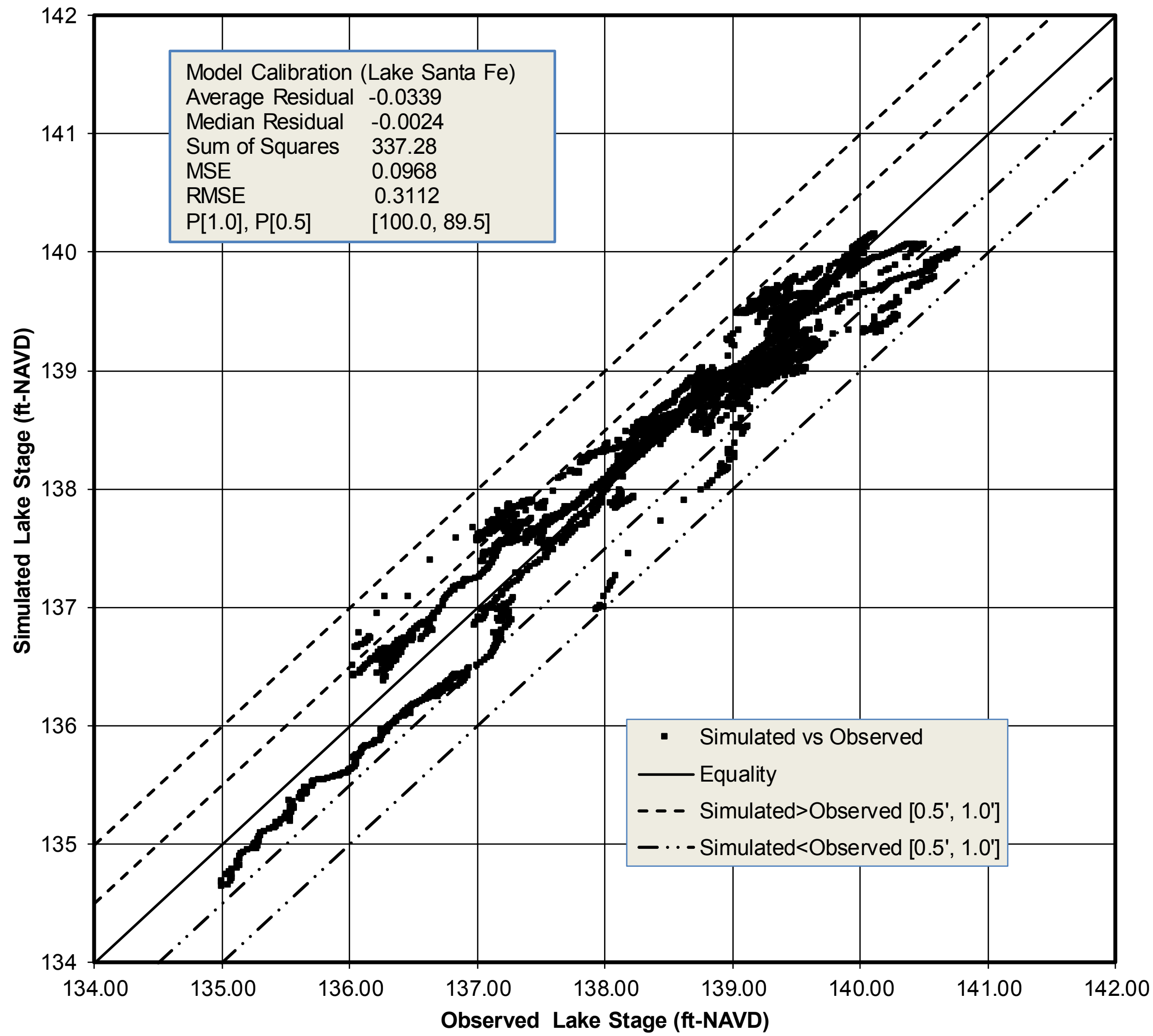

Figure 4-9B
Scatter Plot Comparing Simulated and Observed Stages at Lake Santa Fe (2006-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: ECT, 2017.

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G:\Working\2-ECT\Projects\SRWMD\Lake_MFLs\160682_Lake Altho and Lake Santa Fe\3_Data\GIS\MXD\Figures\Task 6\Figure 5-1A Rainfall vs Lake Stage_Alto.mxd

By: jsun Date: 8/30/2017

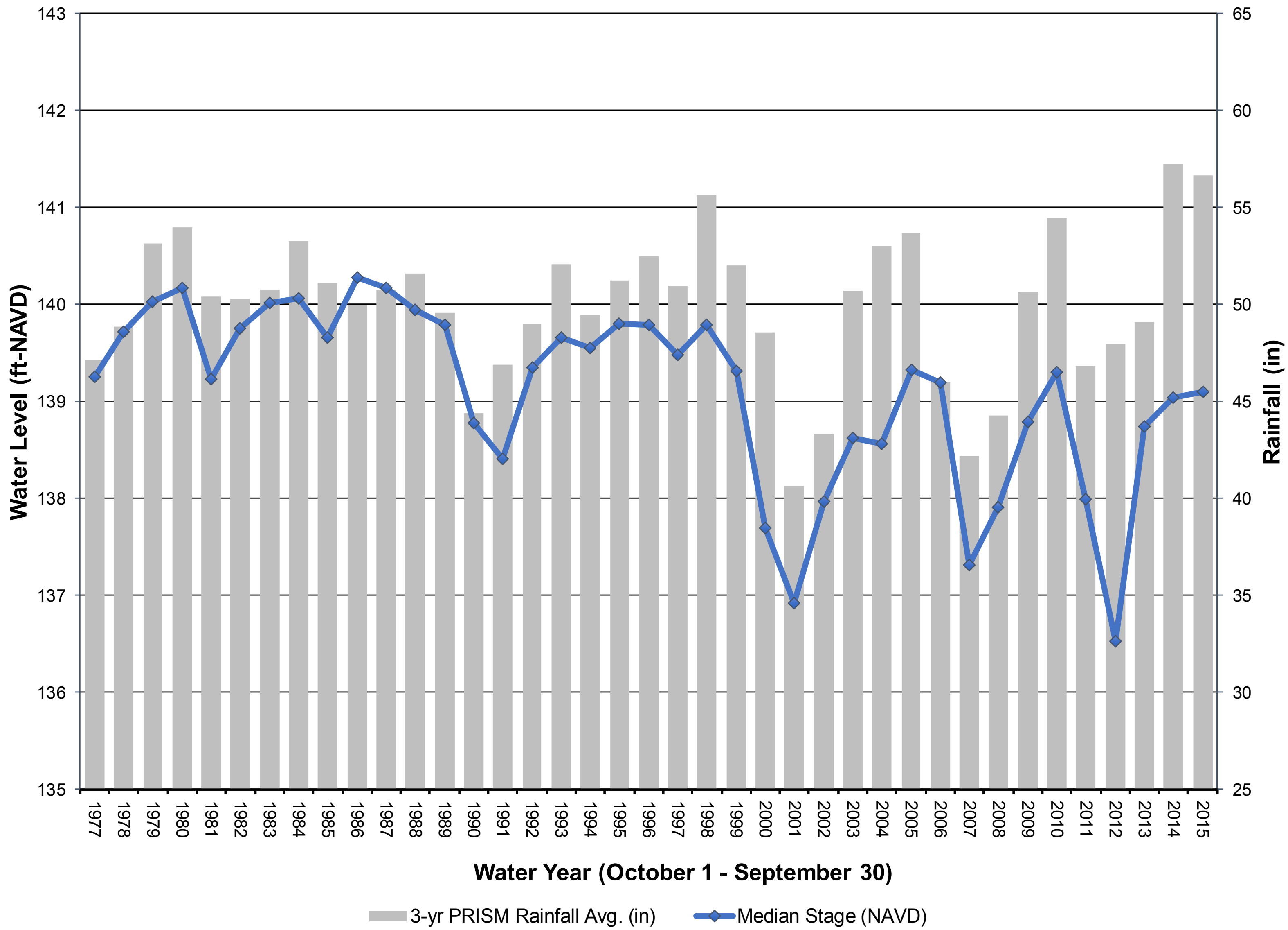

Figure 5-1A
Annual Median Lake Stage Data vs. PRISM Rainfall Data (3-Yr Average) (WY 1977-2015) at Lake Alto
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: PRISM, 2017; SRWMD, 2017; ECT, 2017.

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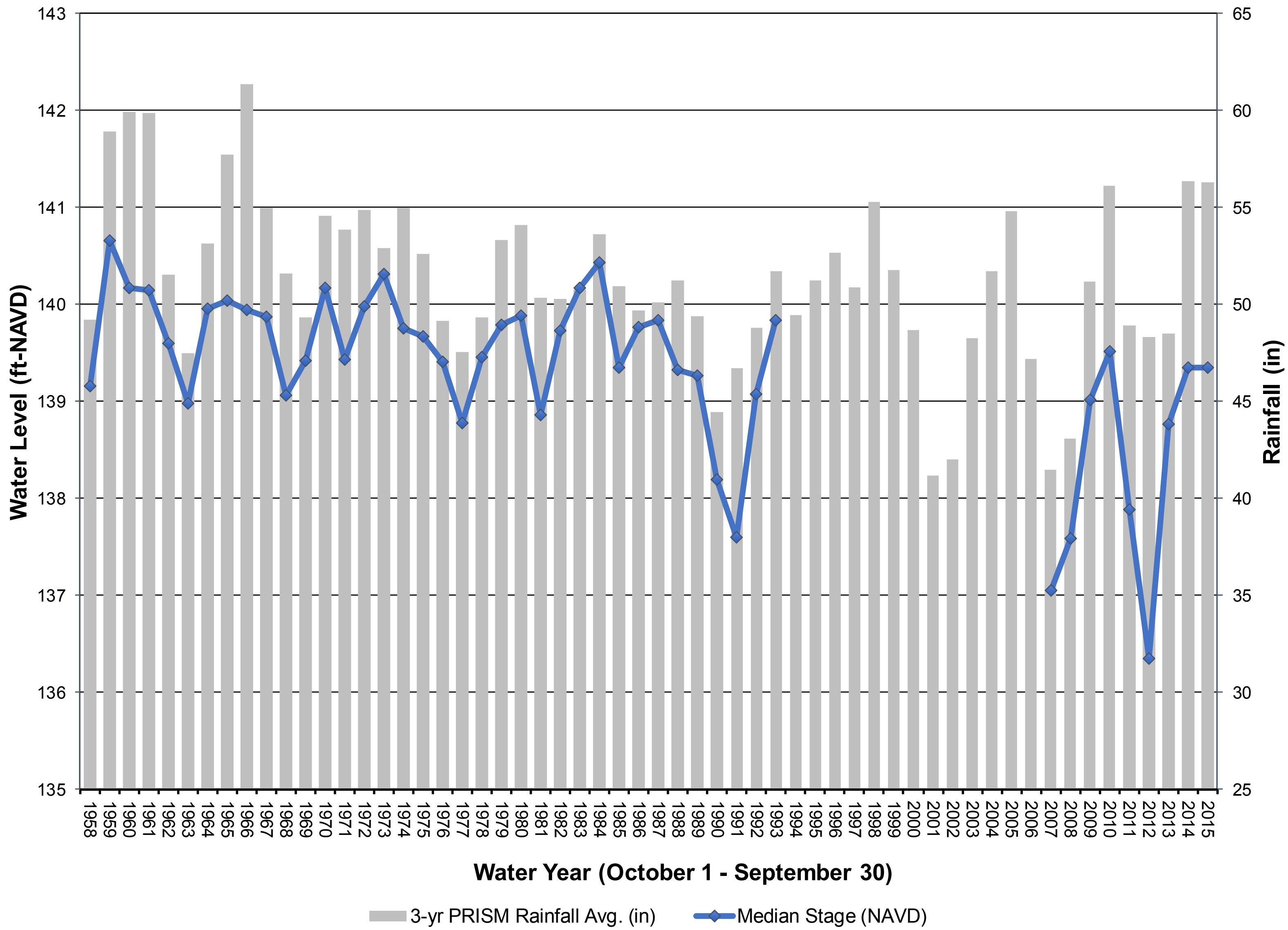

Figure 5-1B
Annual Median Lake Stage Data vs. PRISM Rainfall Data (3-Yr Average) (WY 1958-2015)
at Lake Santa Fe
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District
Sources: PRISM, 2017; SRWMD, 2017; ECT, 2017.

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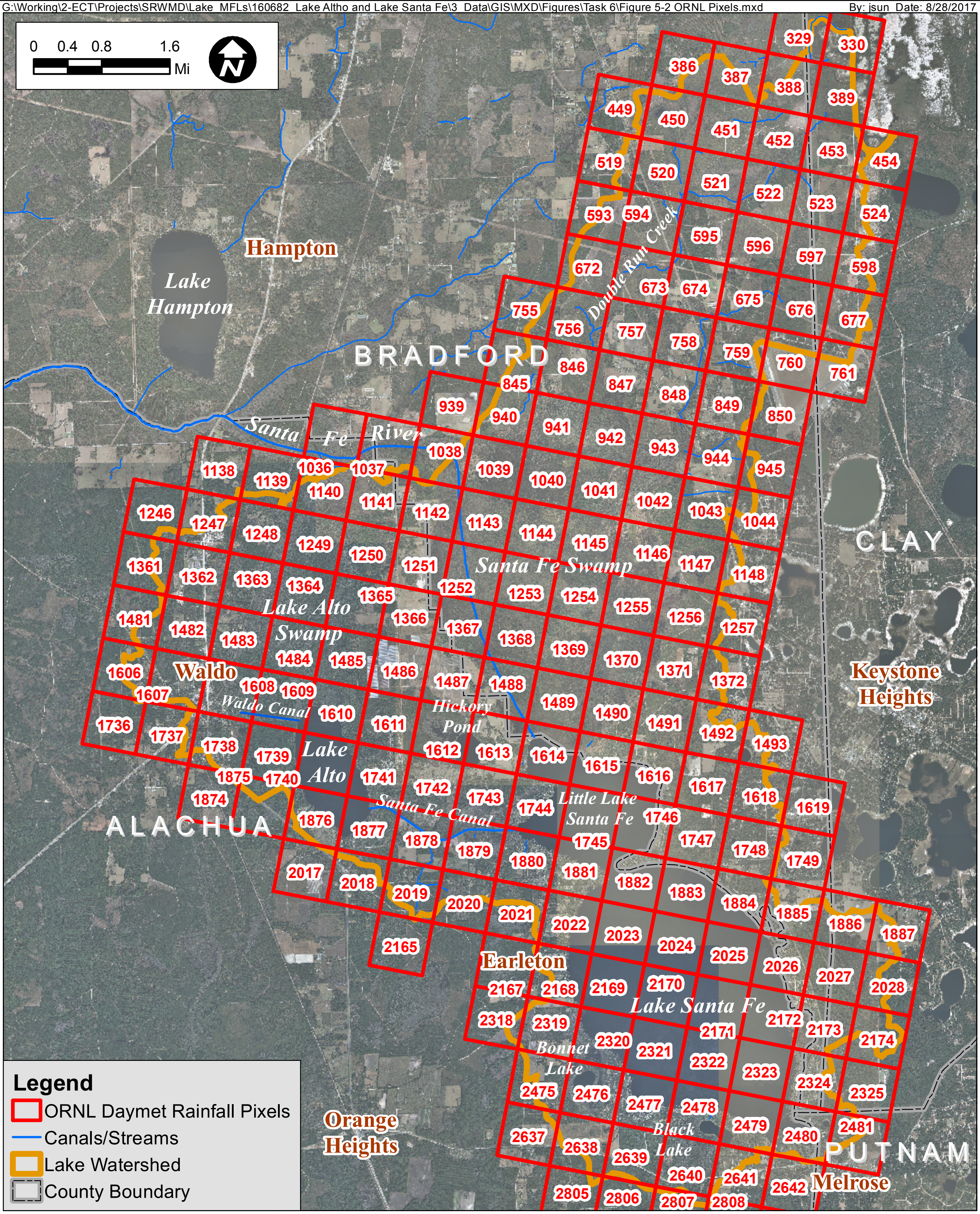

Figure 5-2
ORNL Daymet Rainfall Pixels
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: FDOT, 2013 & 2014; ORNL, 2016; USGS, 2011; ECT, 2016.

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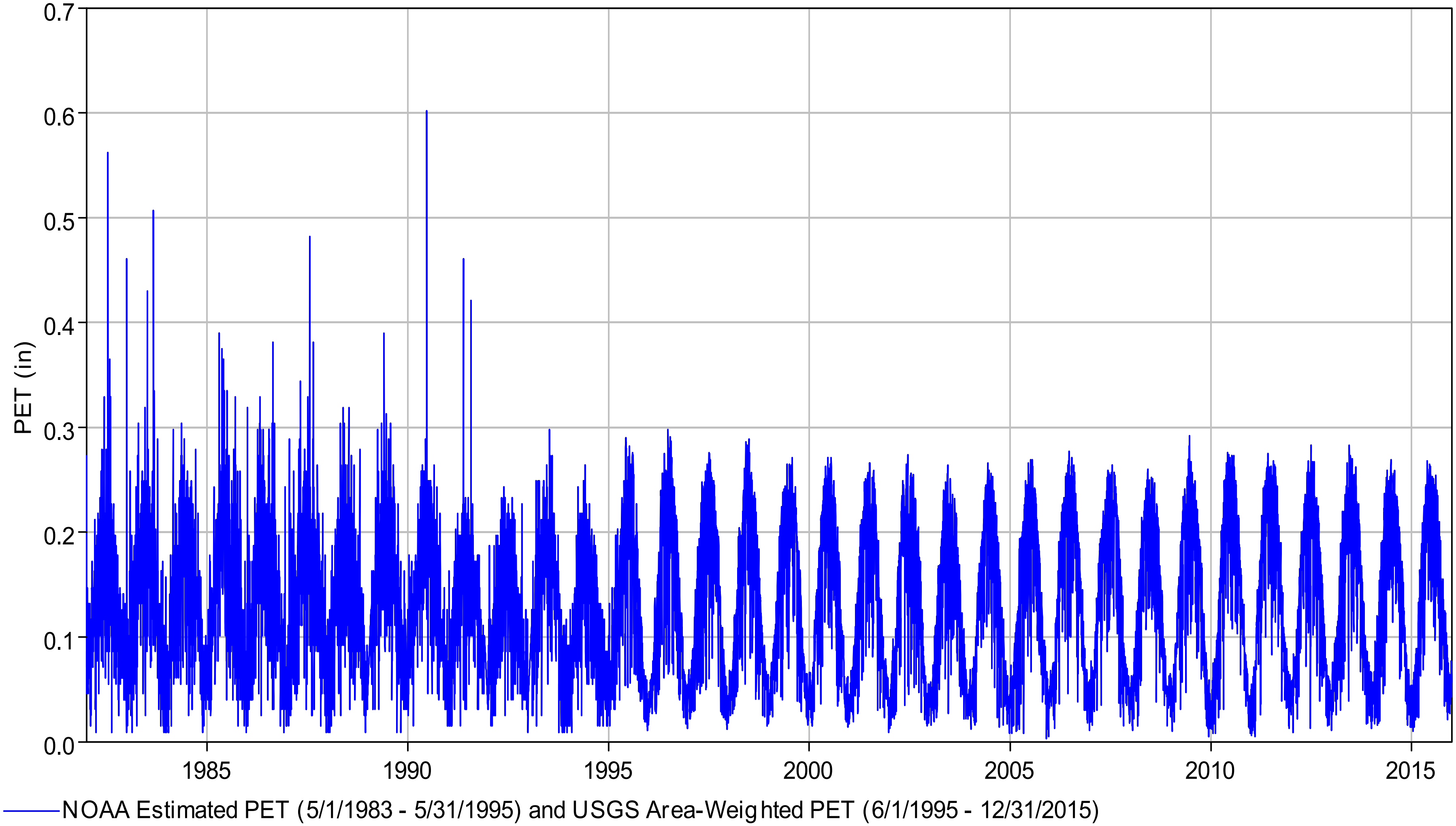

Figure 5-3
NOAA & USGS Potential Evapotranspiration Data (1983-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: USGS, 2016; NOAA, 2016; ECT, 2017.

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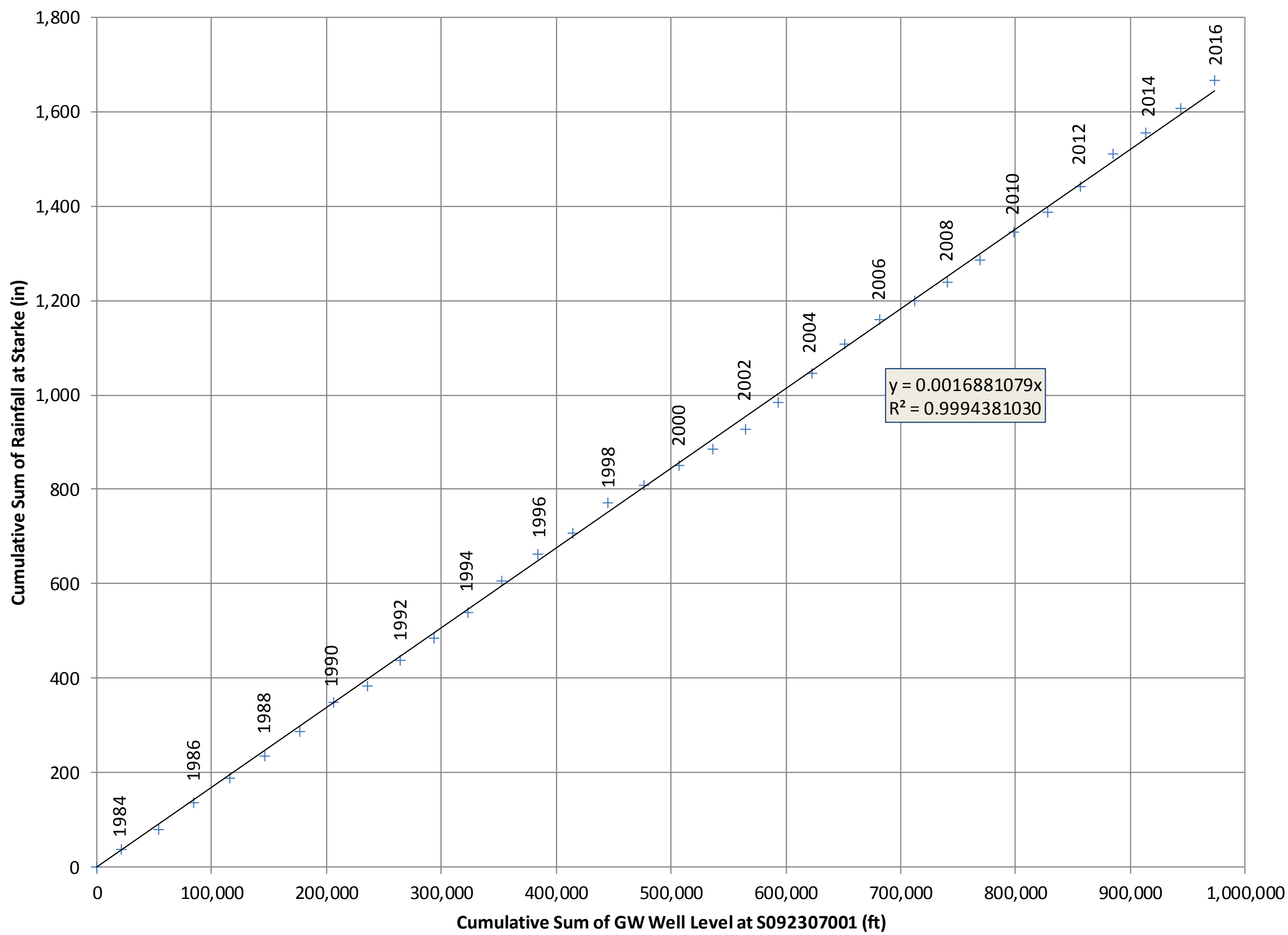

Figure 5-4
Double Mass Curve Analysis for S092307001 Well Level vs. Rainfall at Starke
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: NOAA, 2016; USGS, 2016; SJRWMD, 2015; SRWMD, 2016; ECT, 2017.

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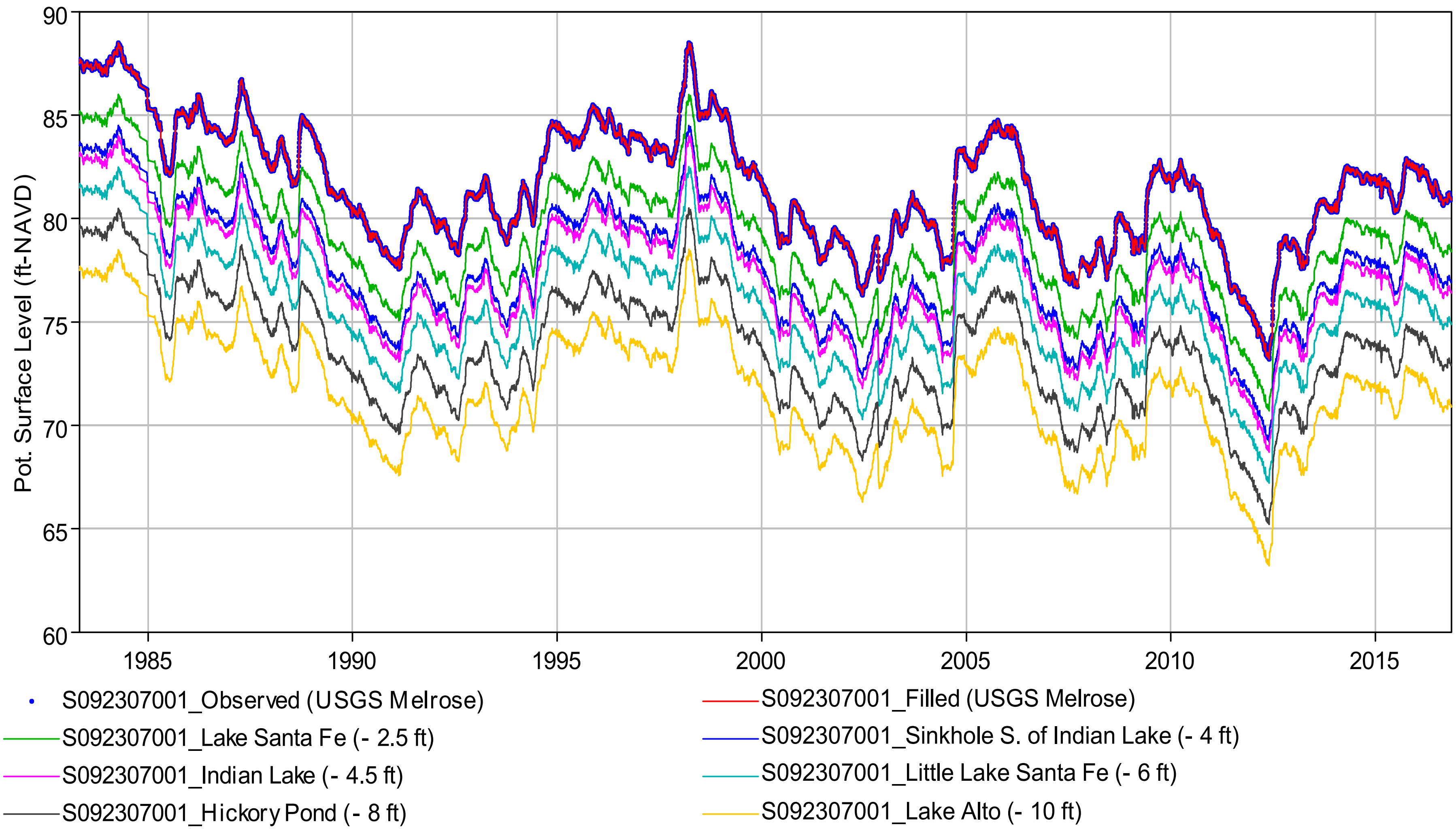

Figure 5-5
Observed/Filled/Shifted Well Level Hydrographs at USGS Melrose Station (1983-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: USGS, 2016; SRWMD, 2016; ECT, 2017.

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G:\Working\2-ECT\Projects\SRWMD\Lake_MFLs\160682_Lake Altho and Lake Santa Fe\3_Data\GIS\MXD\Figures\Task 6\Figure 5-6A Obs vs Sim Stages_Long-term_Alto.mxd

By: jsun Date: 9/27/2017

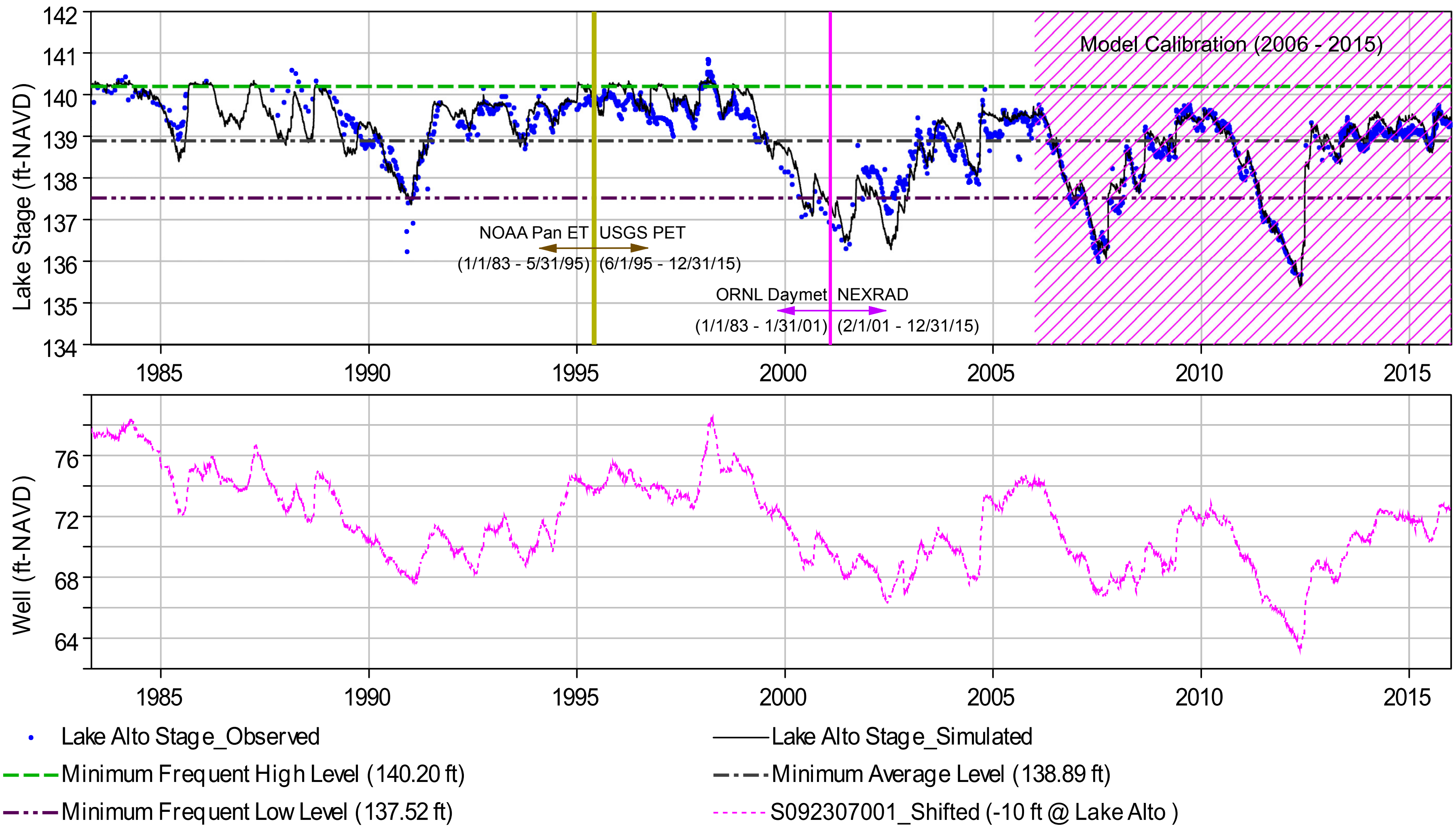

Figure 5-6A
Comparison of Observed and Simulated Lake Stage Hydrographs at Lake Alto (1983-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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G:\Working\2-ECT\Projects\SRWMD\Lake_MFLs\160682_Lake Altho and Lake Santa Fe\3_Data\GIS\MXD\Figures\Task 6\Figure 5-6B Obs vs Sim Stages_Long-term_Santa Fe.mxd By: jsun Date: 9/24/2017

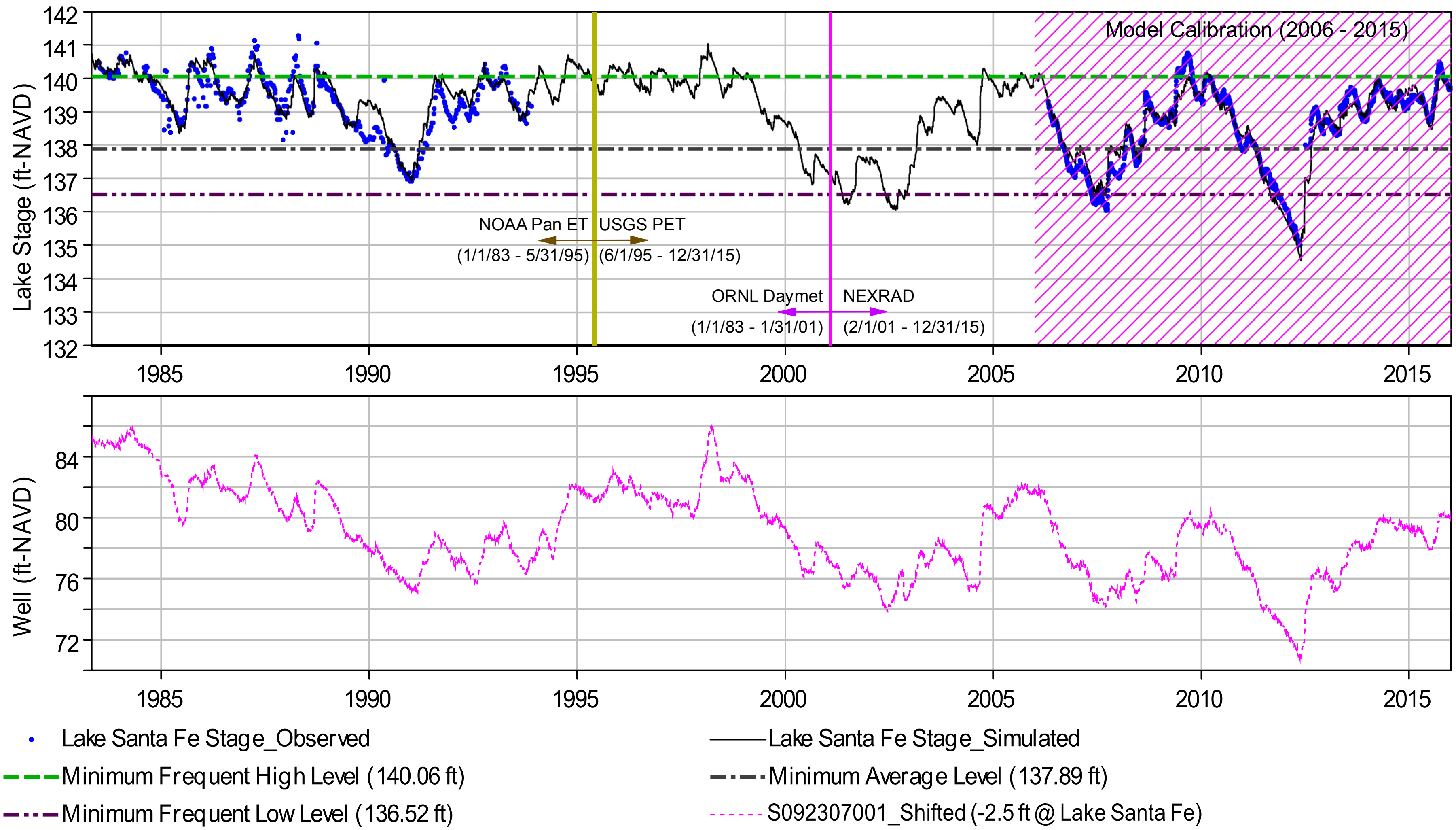

Figure 5-6B
Comparison of Observed and Simulated Lake Stage Hydrographs at Lake Santa Fe (1983-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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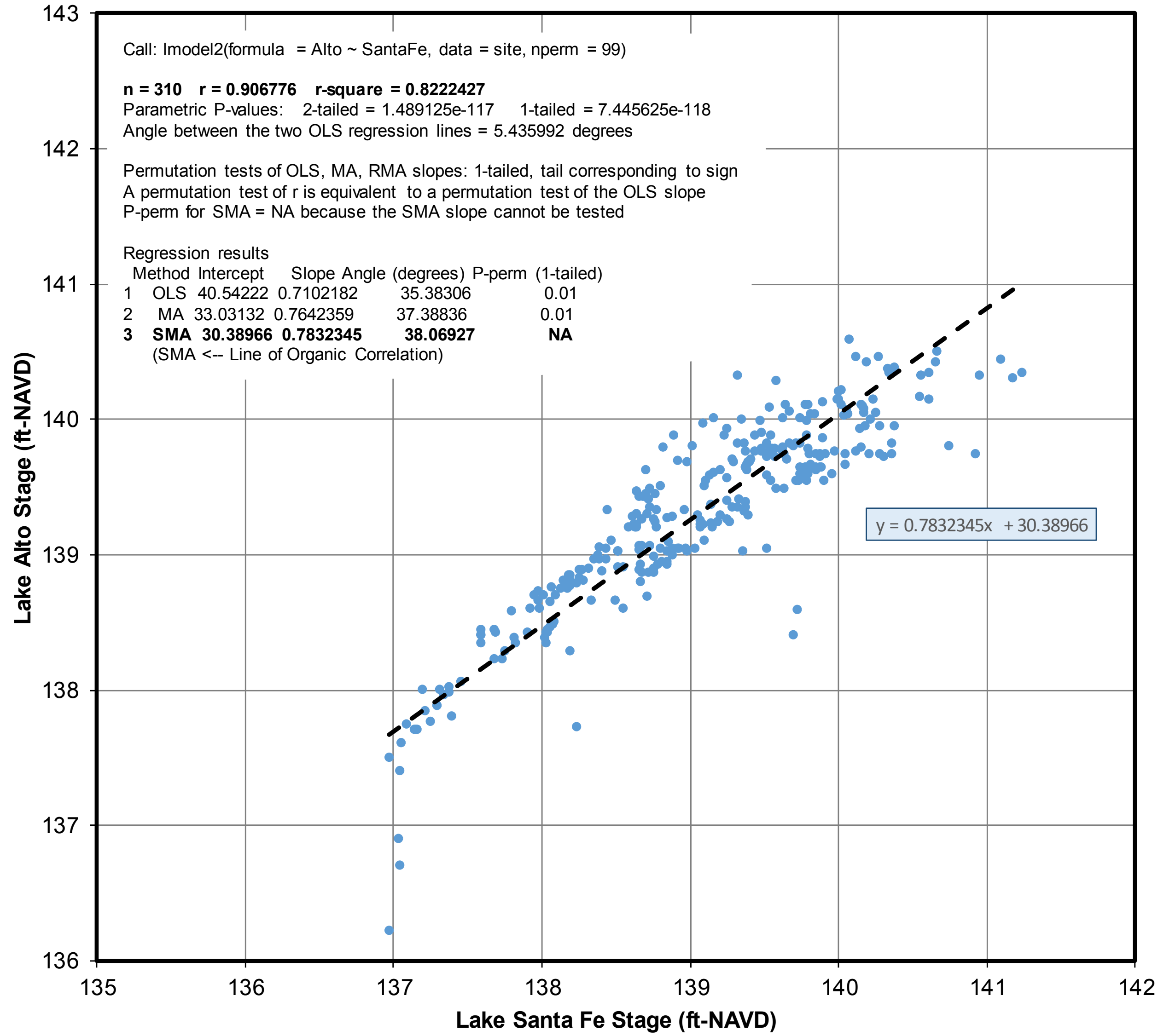

Figure 5-7A
Line of Organic Correlation Analysis – Observed Stage Data of Lake Alto and Lake Santa Fe (1976-1993)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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By: jsun Date: 10/27/2017

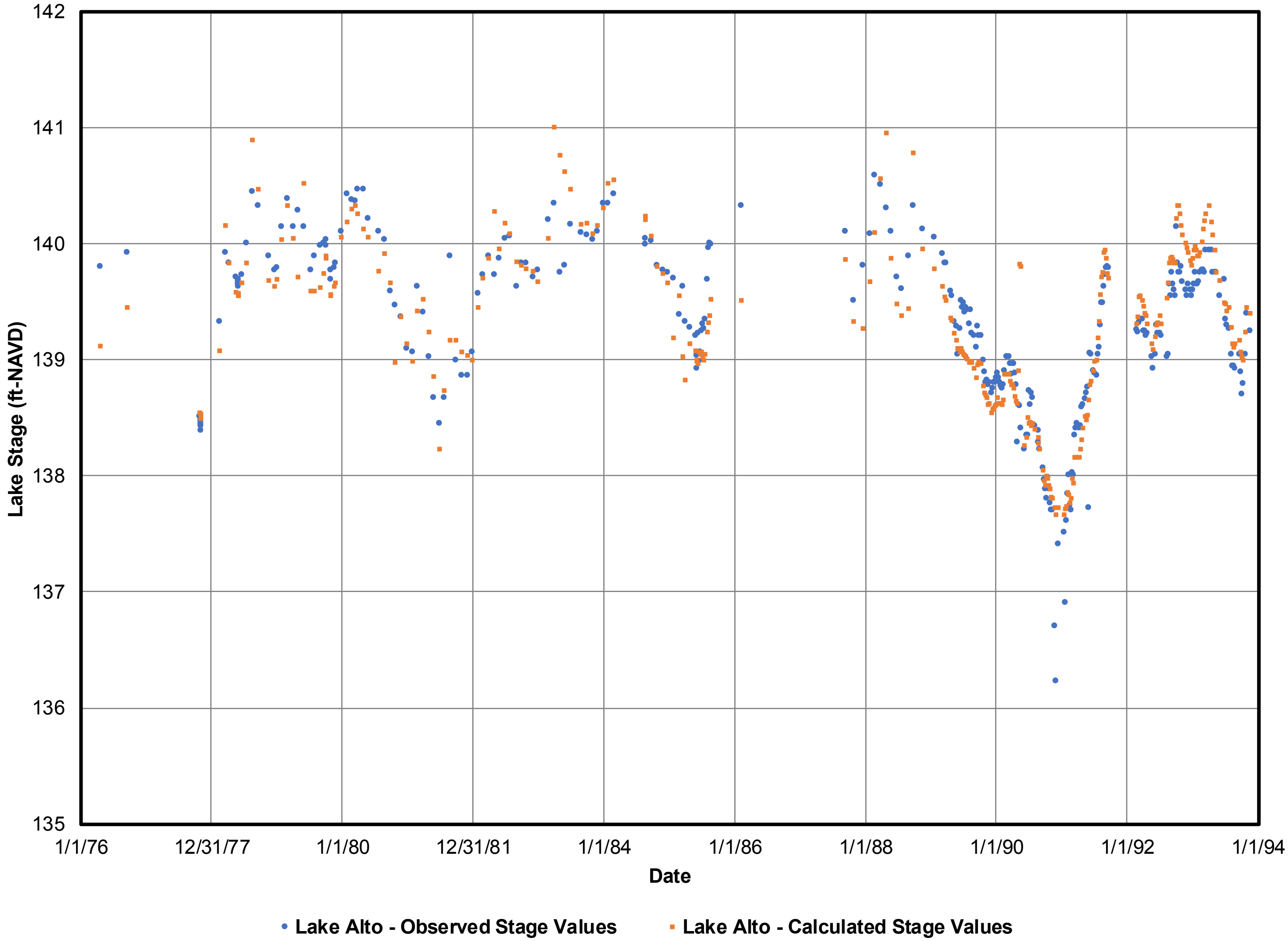

Figure 5-7B
Comparison of Observed and Calculated Stage Data at Lake Alto (1976-1993)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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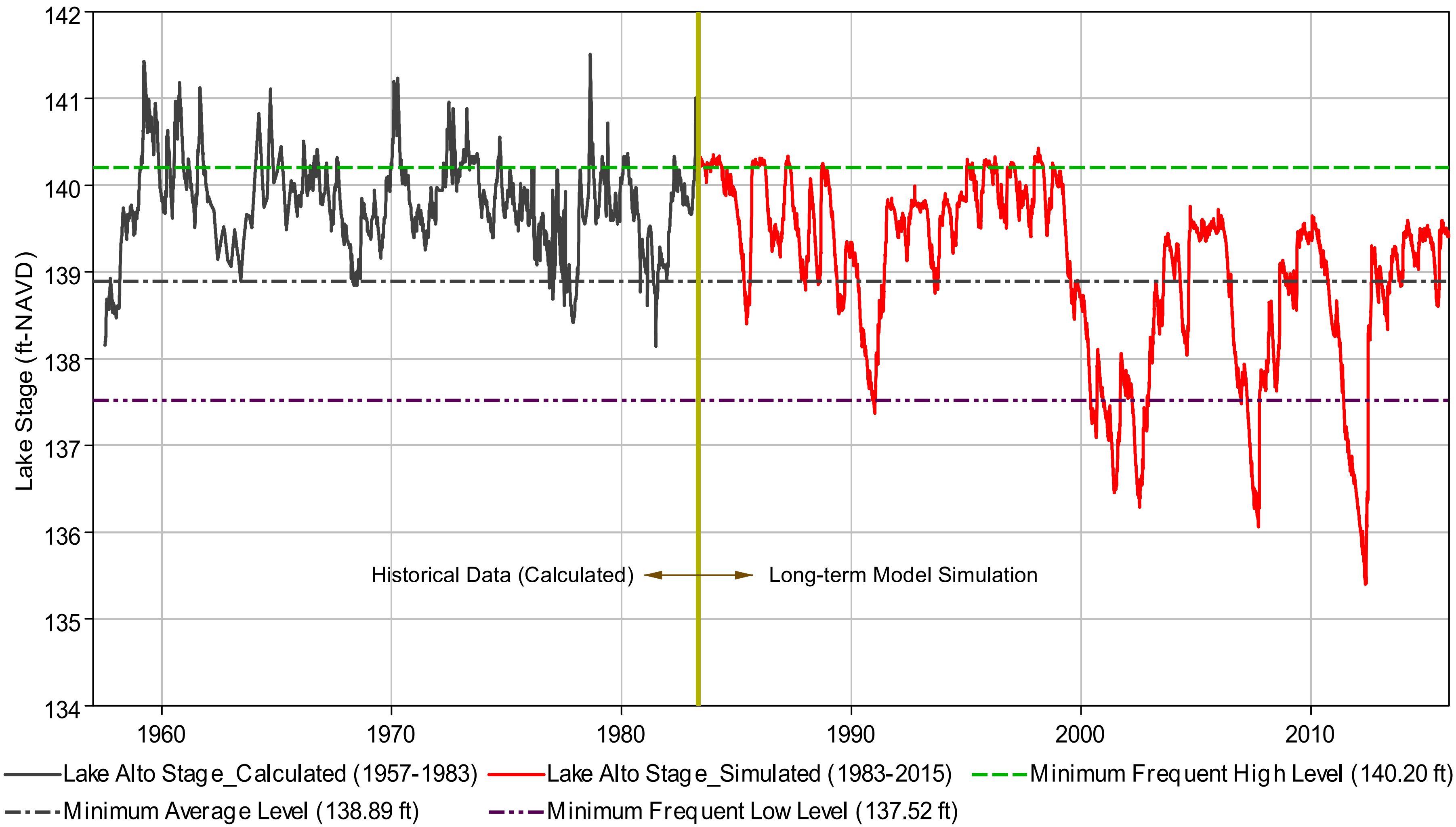

Figure 5-7C
Hybrid Lake Stage Hydrographs at Lake Alto (1957-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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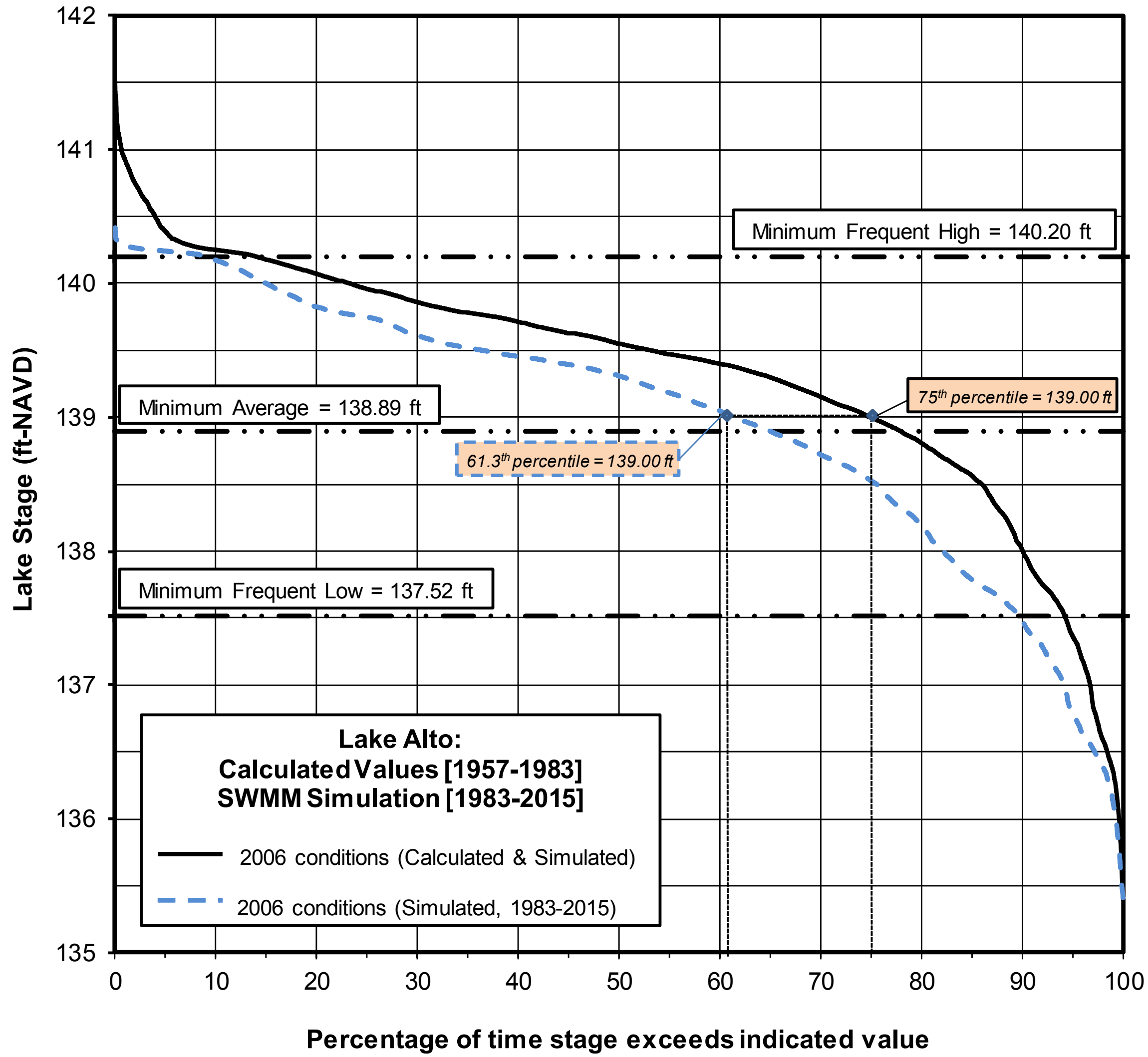

Figure 5-8
Stage Duration Curve - SWMM Simulation (1983-2015) and Hybrid Lake Stage Data Set (1957-2015) at Lake Alto in 2006 Conditions
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District
Sources: SRWMD, 2017; ECT, 2017.

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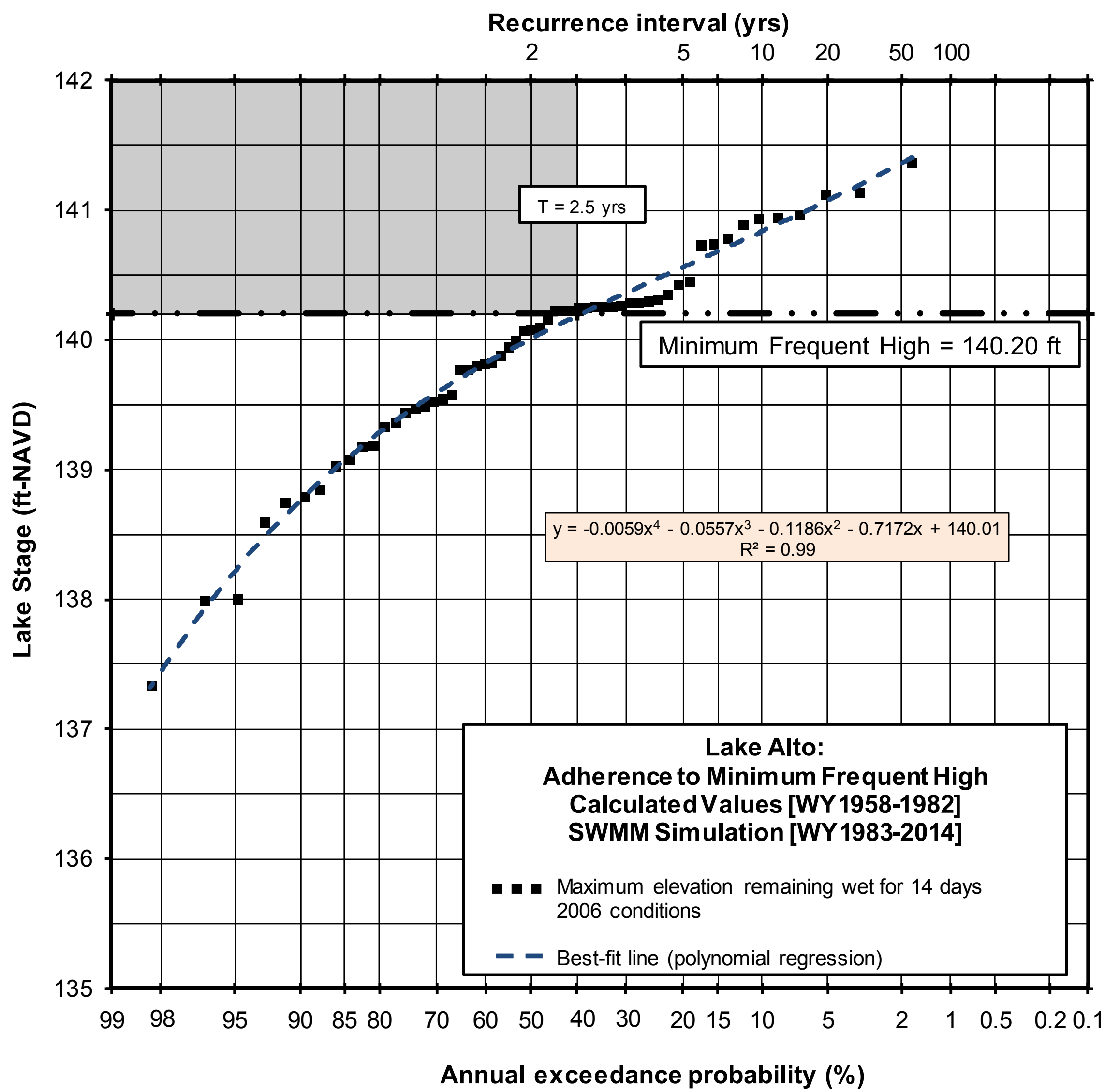

Figure 5-9A
Minimum Frequent High Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Alto in 2006 Conditions
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District
Sources: SRWMD, 2017; ECT, 2017.

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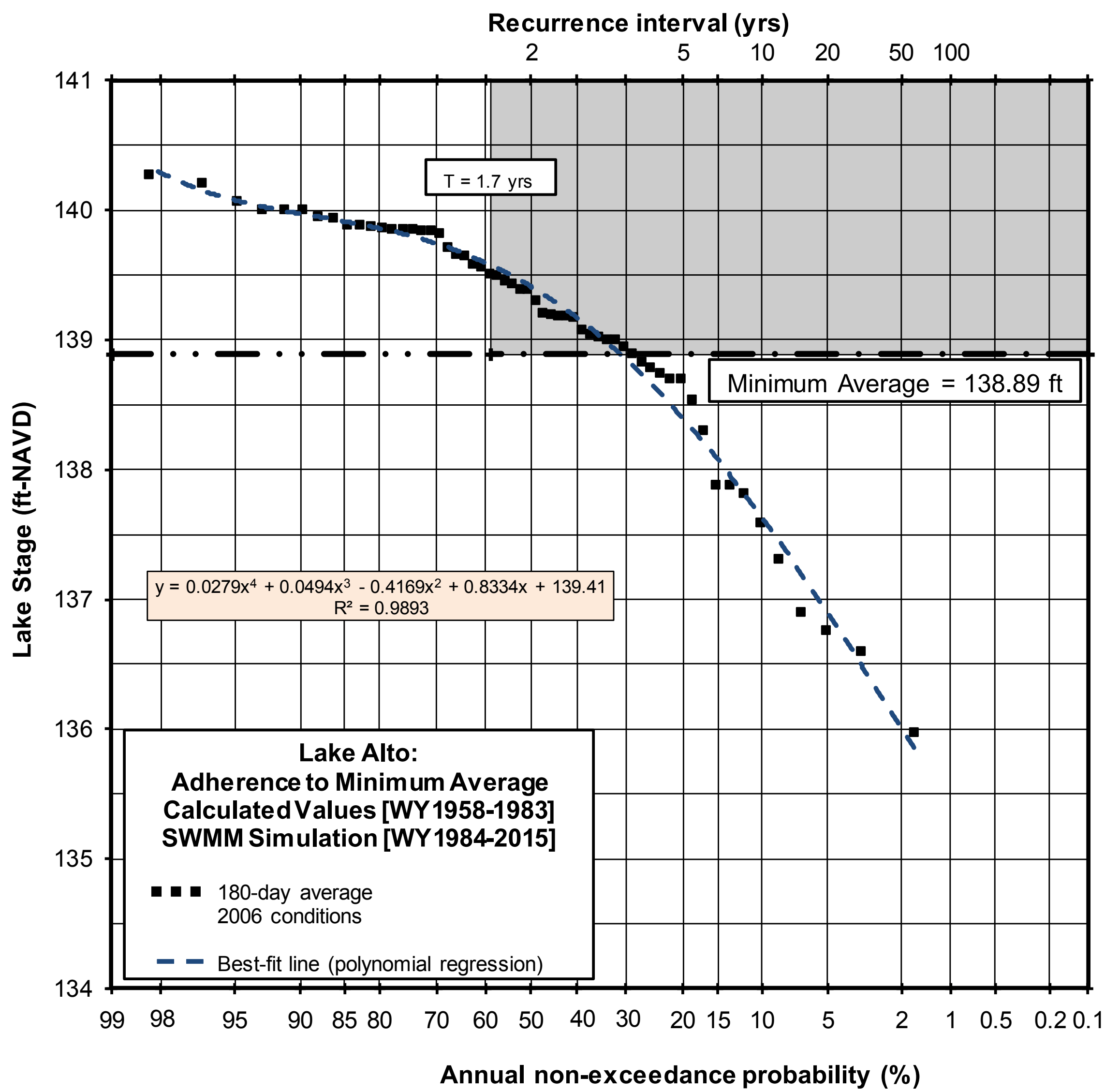

Figure 5-9B
Minimum Average Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Alto in 2006 Conditions
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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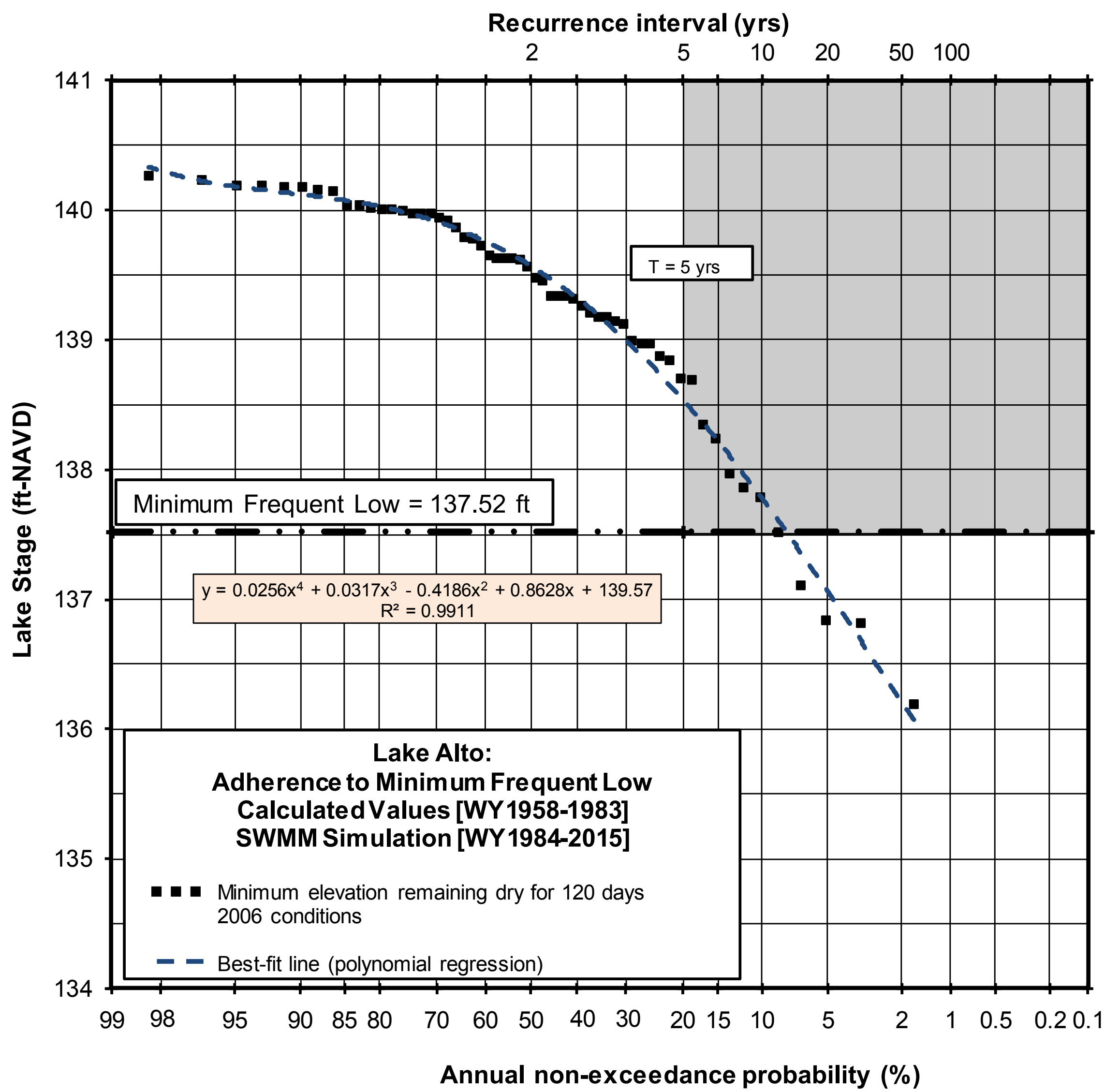

Figure 5-9C
Minimum Frequent Low Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Alto in 2006 Conditions
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District
Sources: SRWMD, 2017; ECT, 2017.

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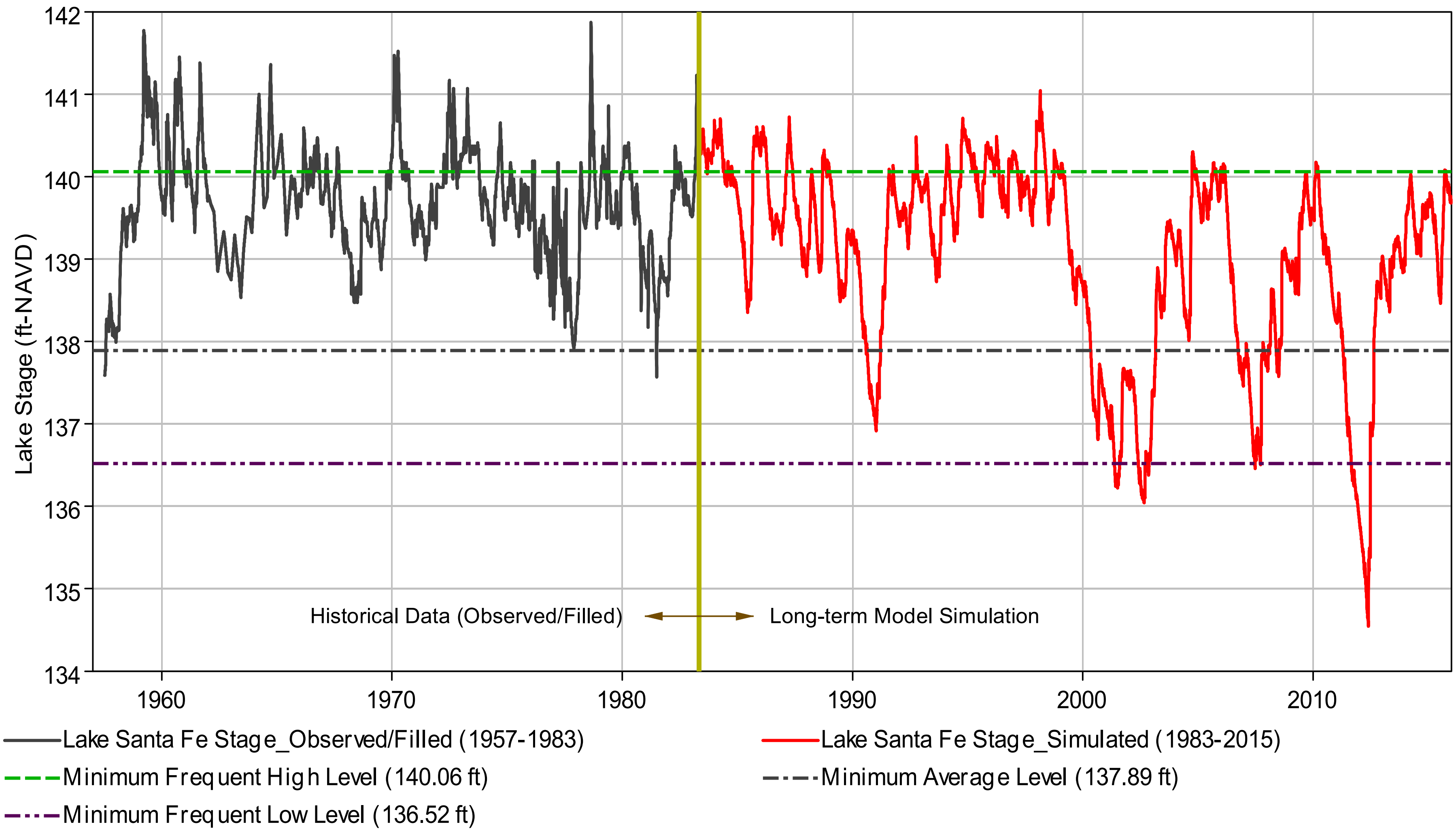

Figure 5-10
Hybrid Lake Stage Hydrographs at Lake Santa Fe (1957-2015)
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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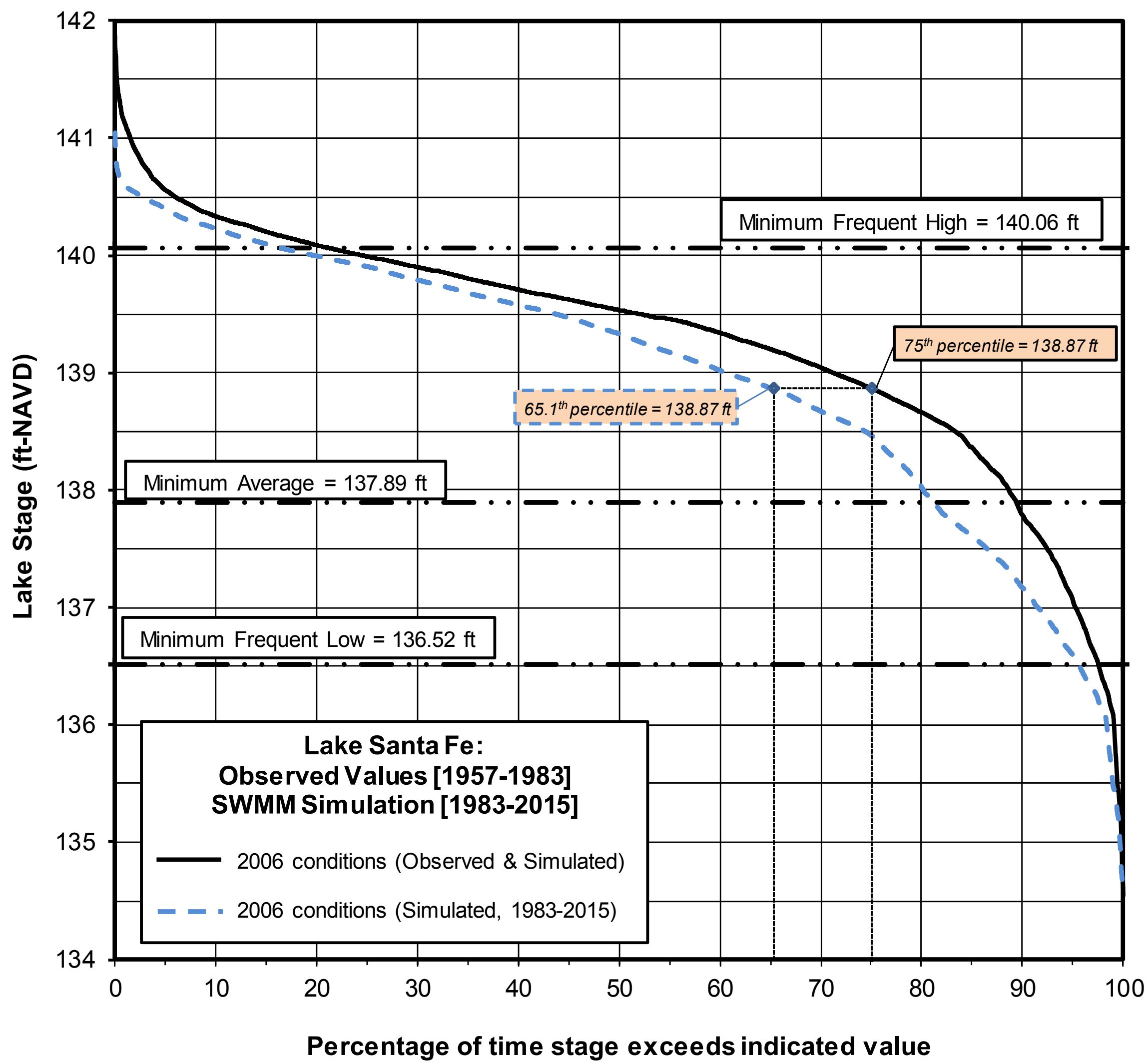

Figure 5-11
Stage Duration Curve - SWMM Simulation (1983-2015) and Hybrid Lake Stage Data Set (1957-2015) at Lake Santa Fe in 2006 Conditions
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District
Sources: SRWMD, 2017; ECT, 2017.

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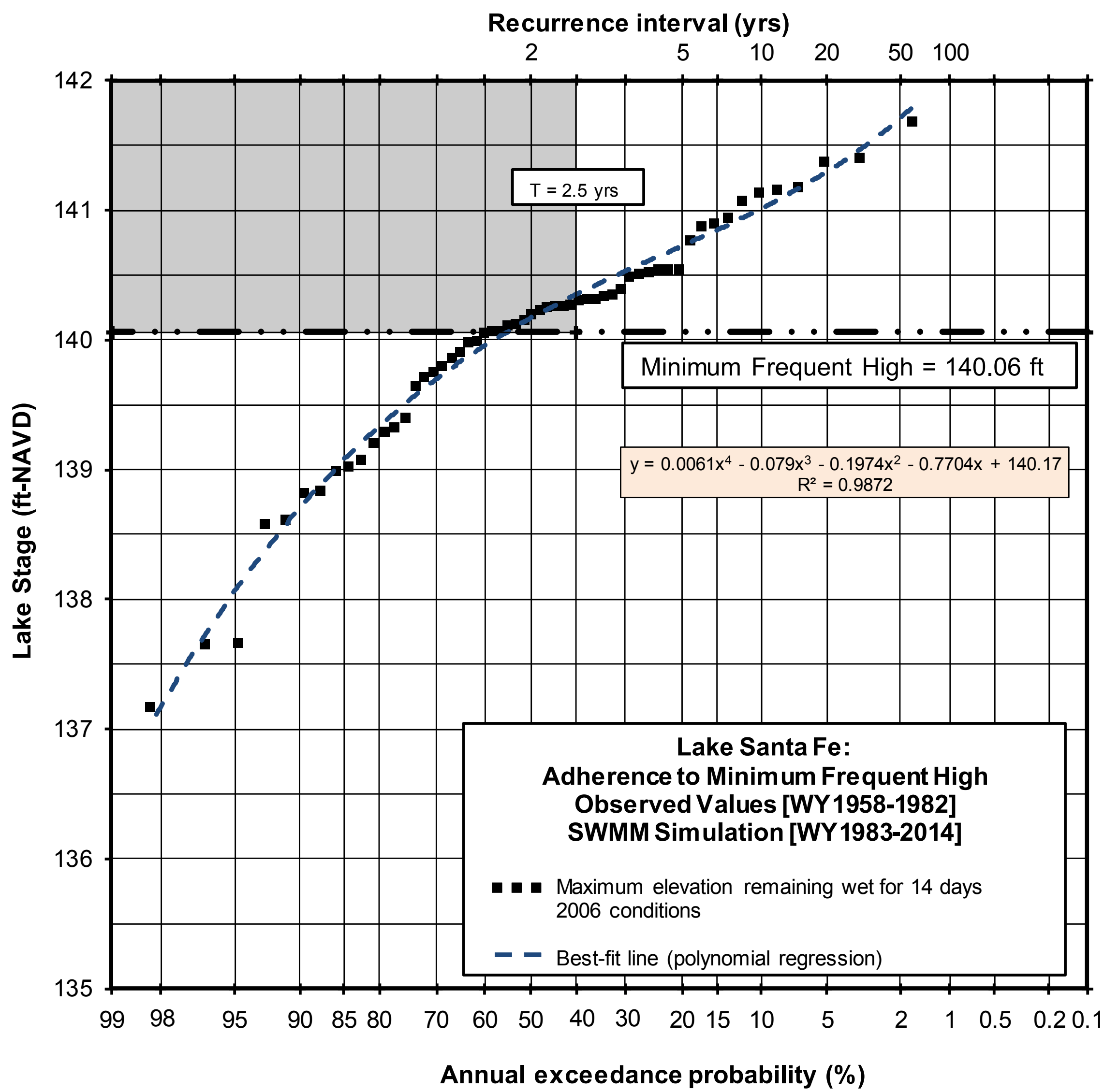

Figure 5-12A
Minimum Frequent High Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Santa Fe in 2006 Conditions
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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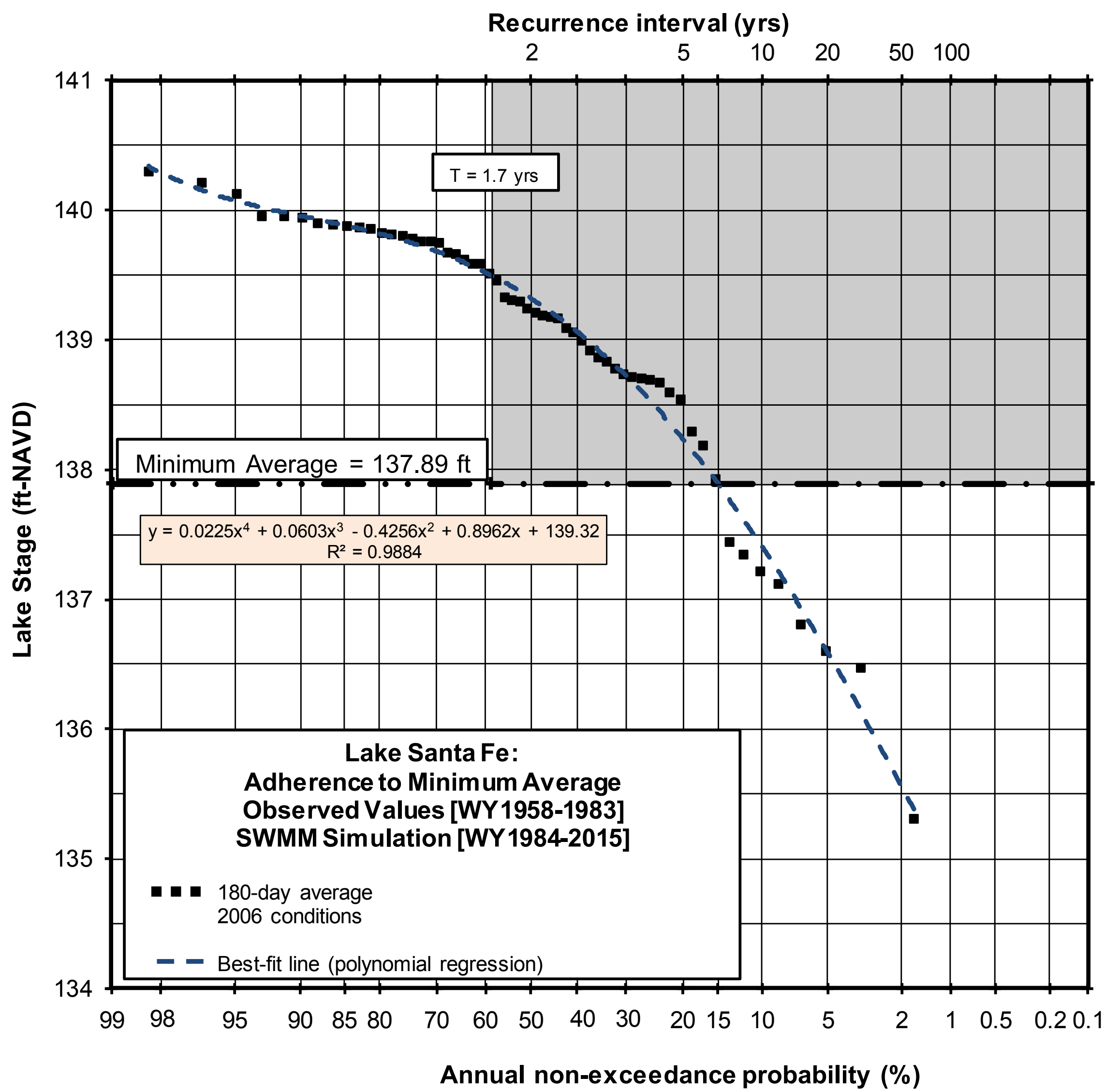

Figure 5-12B
Minimum Average Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Santa Fe in 2006 Conditions
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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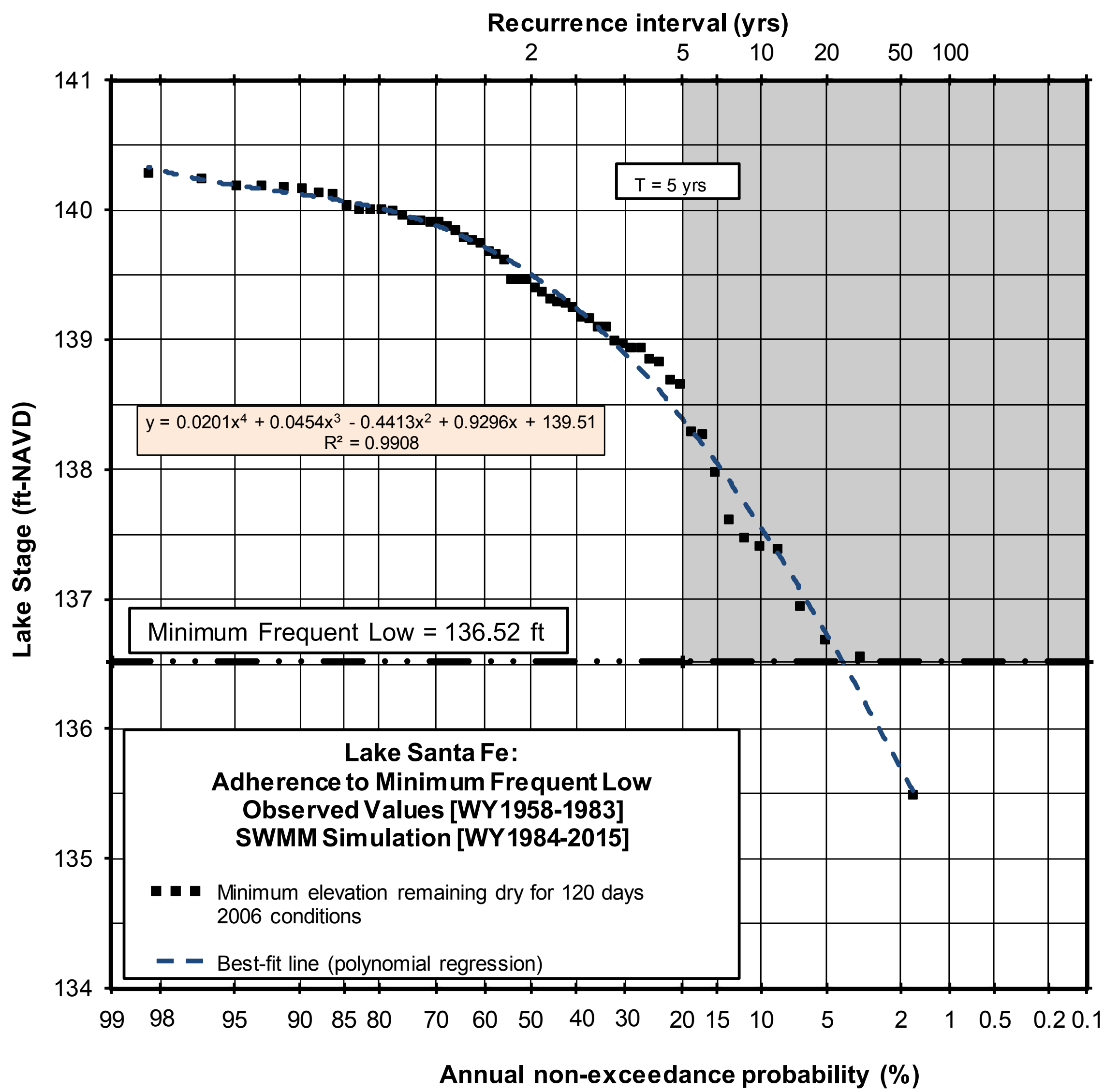

Figure 5-12C
Minimum Frequent Low Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Santa Fe in 2006 Conditions
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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G:\Working\2-ECT\Projects\SRWMD\Lake_MFLs\160682_Lake Altho and Lake Santa Fe\3_Data\GIS\MXD\Figures\Task 7\Figure 6-1A FH_Long-term_Transfer_Alto.mxd By: jsun Date: 10/27/2017

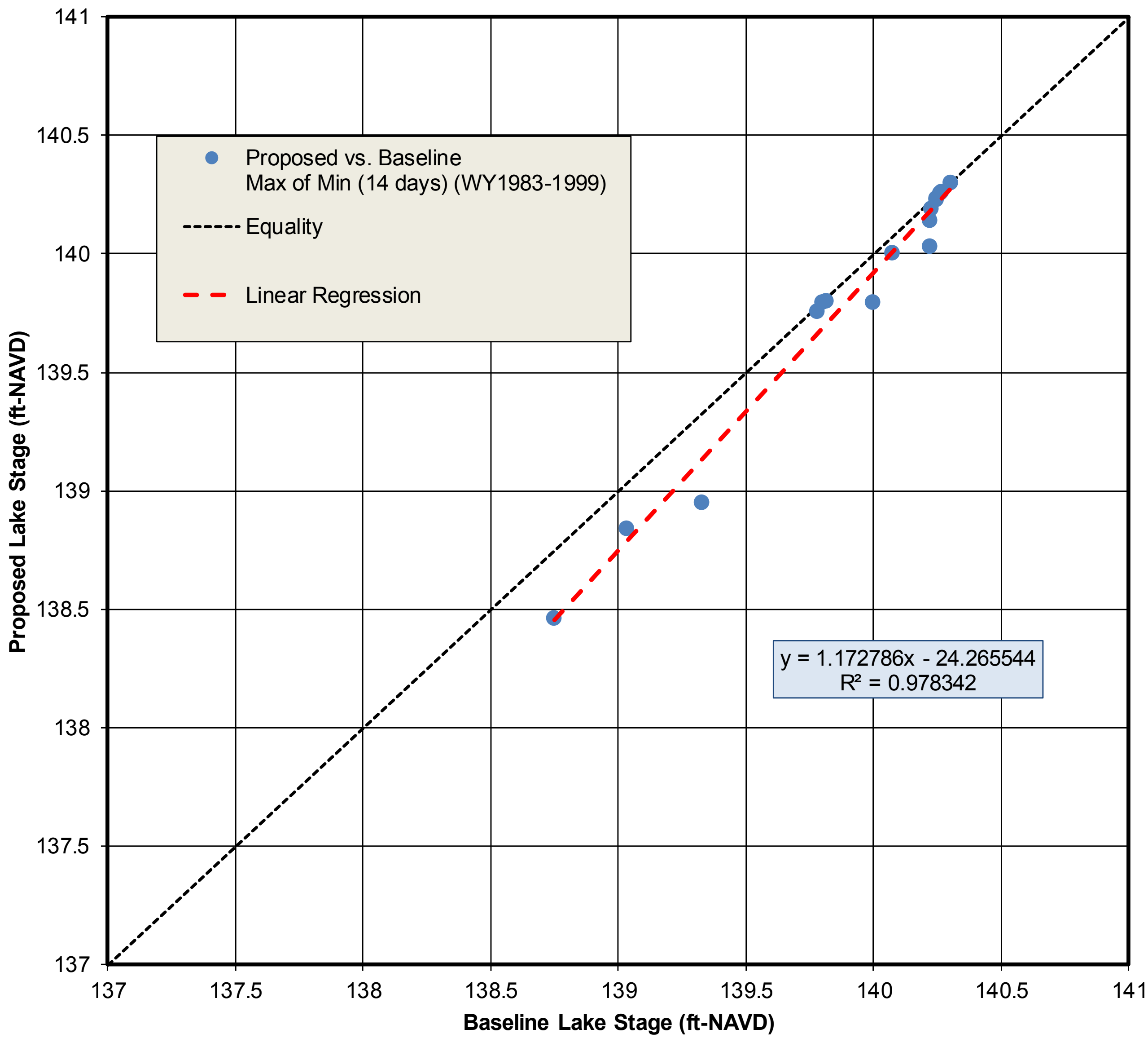

Figure 6-1A
Transfer Function for Minimum Frequent High Level at Lake Alto in 2006 Conditions vs.
2006 Conditions + 7.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District
Sources: SRWMD, 2017; ECT, 2017.

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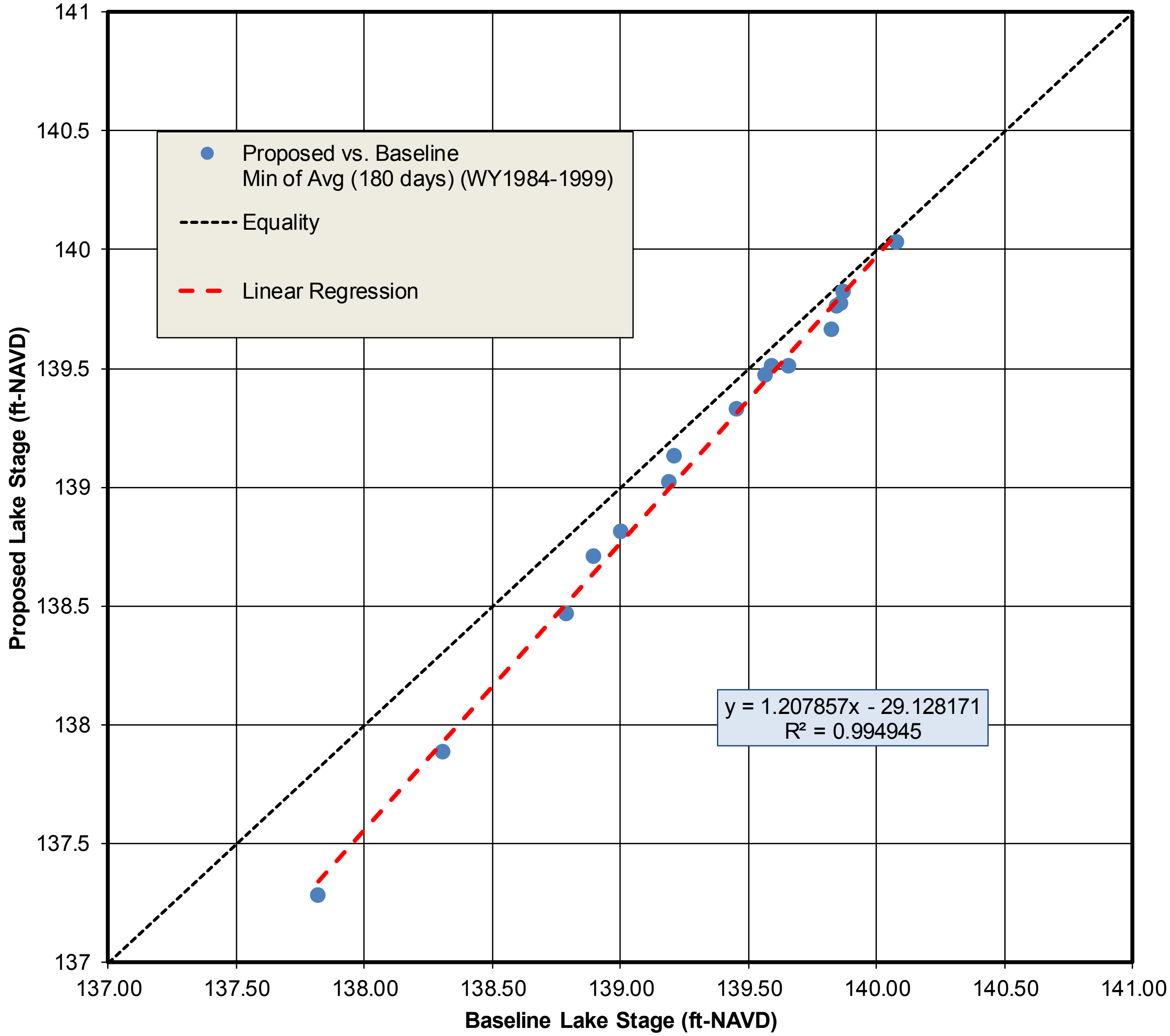

Figure 6-1B
Transfer Function for Minimum Average Level at Lake Alto in 2006 Conditions vs.
2006 Conditions + 7.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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G:\Working\2-ECT\Projects\SRWMD\Lake_MFLs\160682_Lake Altho and Lake Santa Fe\3_Data\GIS\MXD\Figures\Task 7\Figure 6-1C FL_Long-term_Transfer_Alto.mxd

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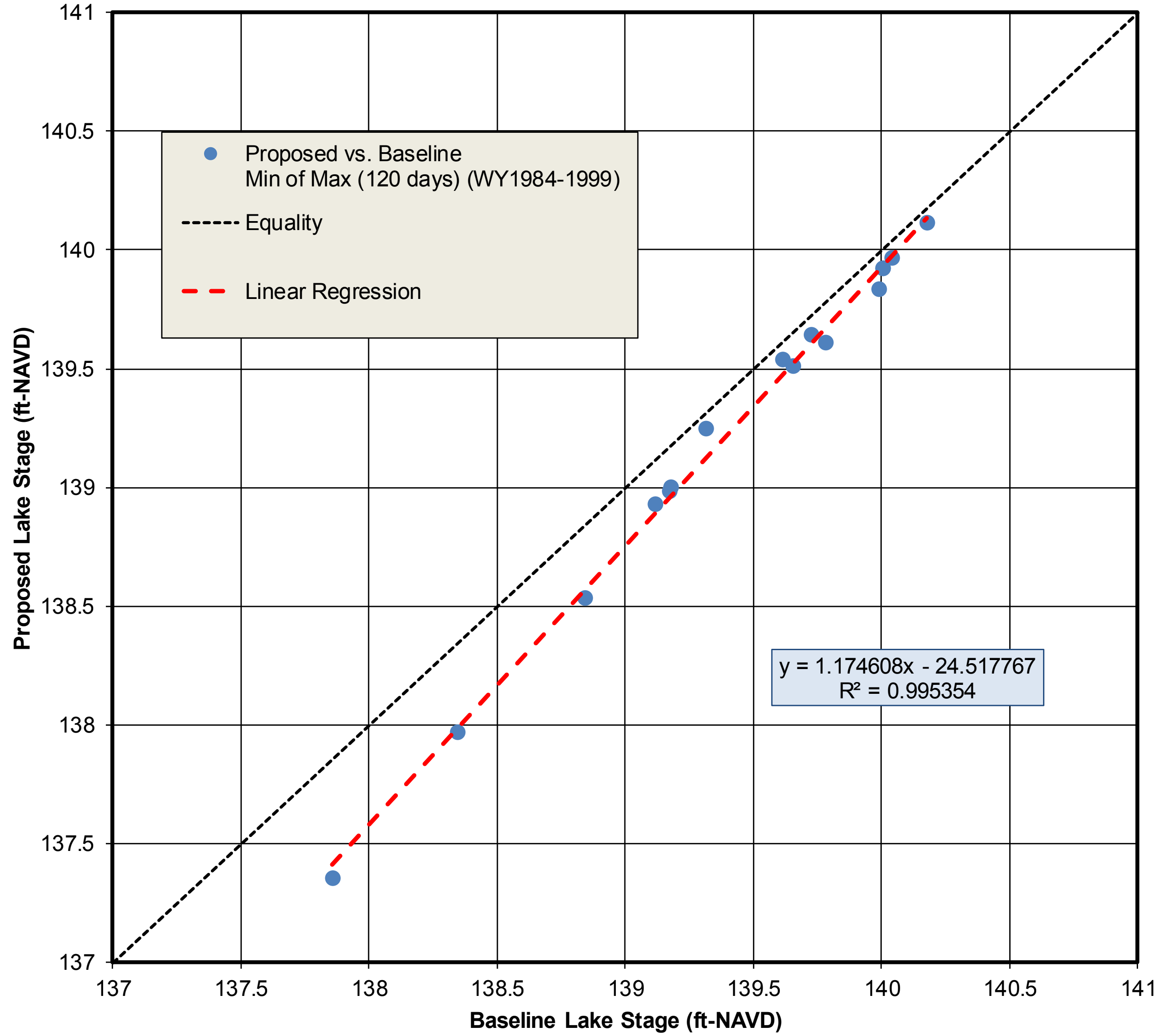

Figure 6-1C
Transfer Function for Minimum Frequent Low Level at Lake Alto in 2006 Conditions vs.
2006 Conditions + 7.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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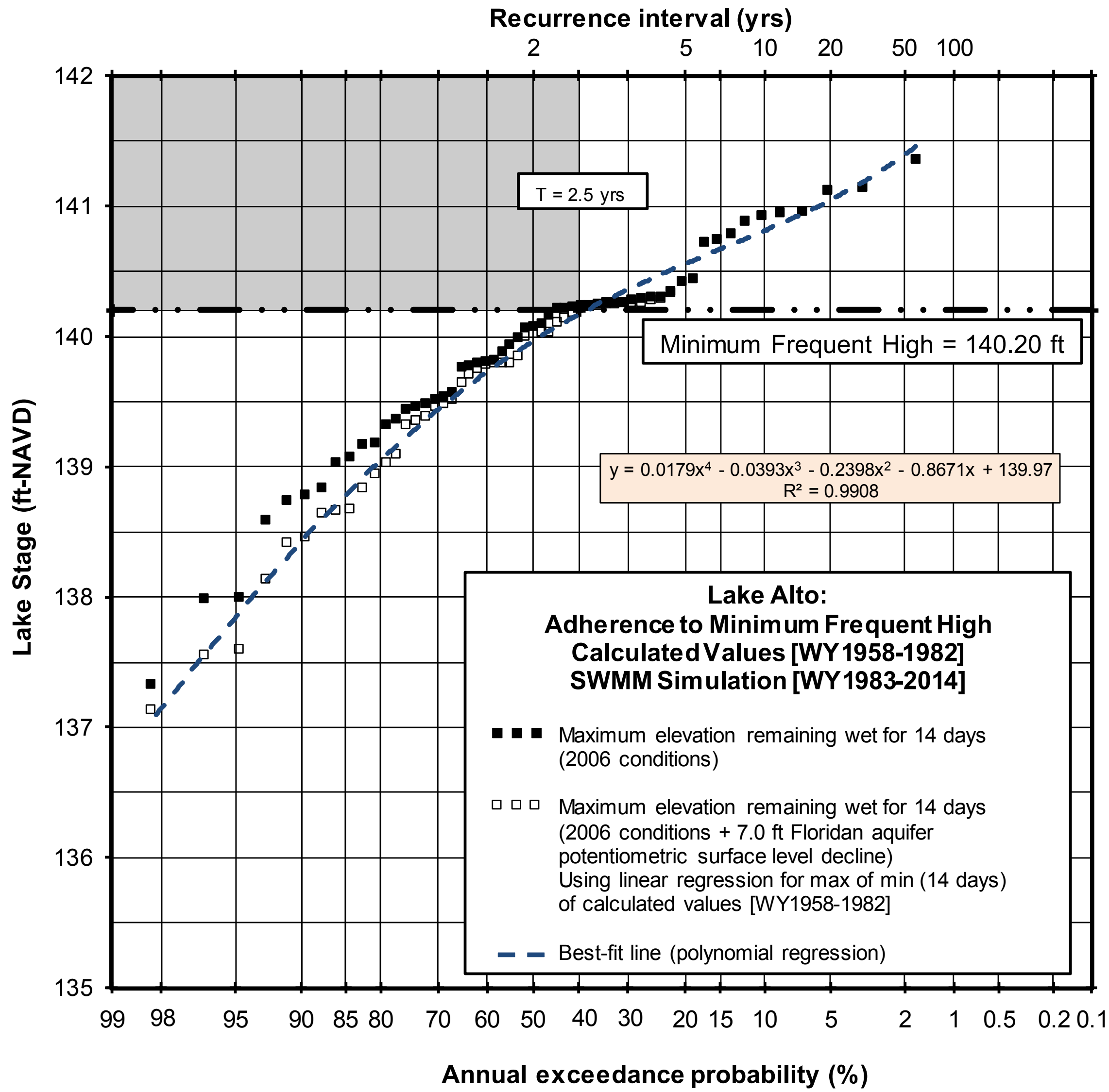

Figure 6-2A
Minimum Frequent High Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Alto
in 2006 Conditions vs. 2006 Conditions + 7.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District
Sources: SRWMD, 2017; ECT, 2017.

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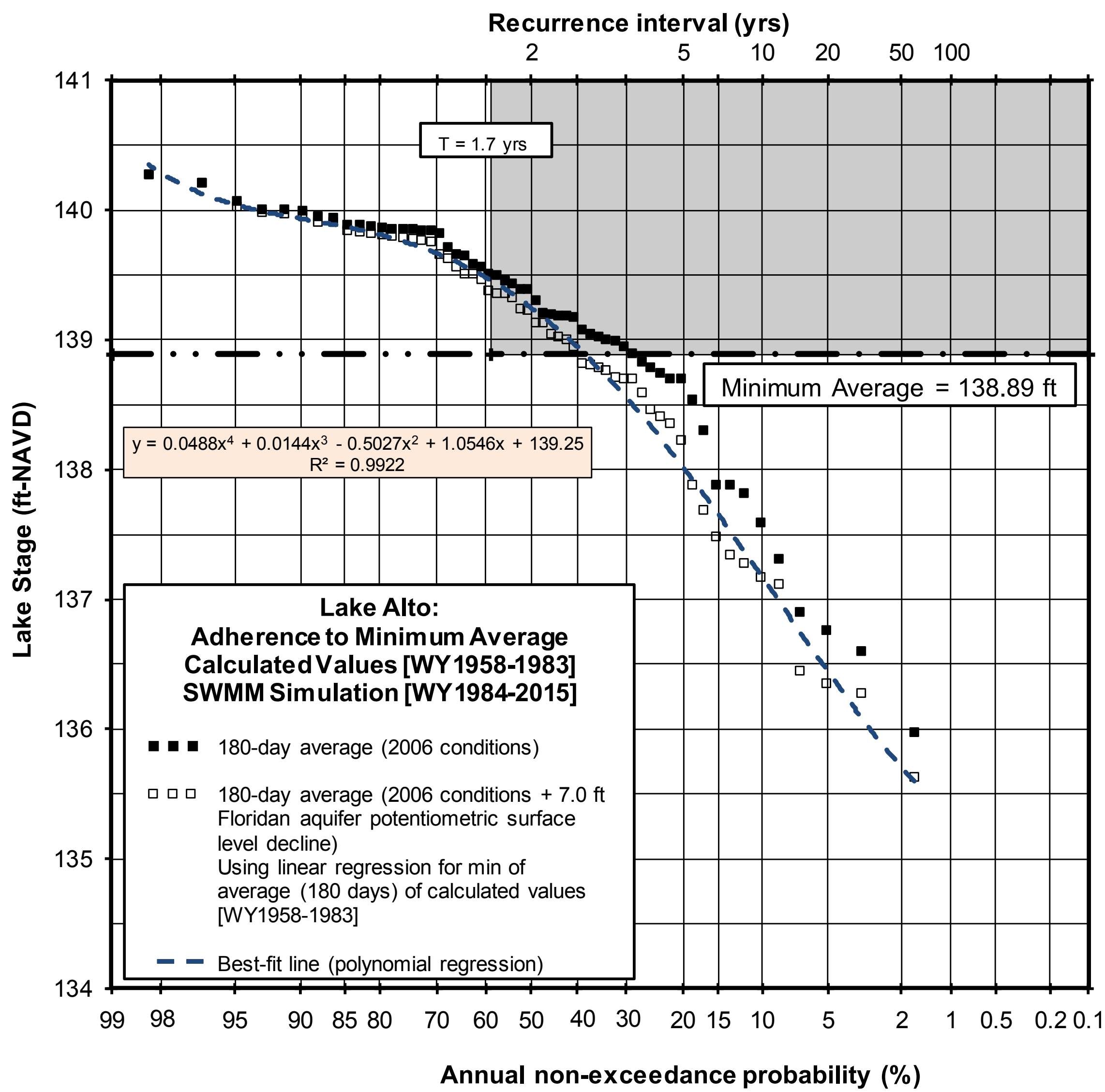

Figure 6-2B
Minimum Average Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Alto
in 2006 Conditions vs. 2006 Conditions + 7.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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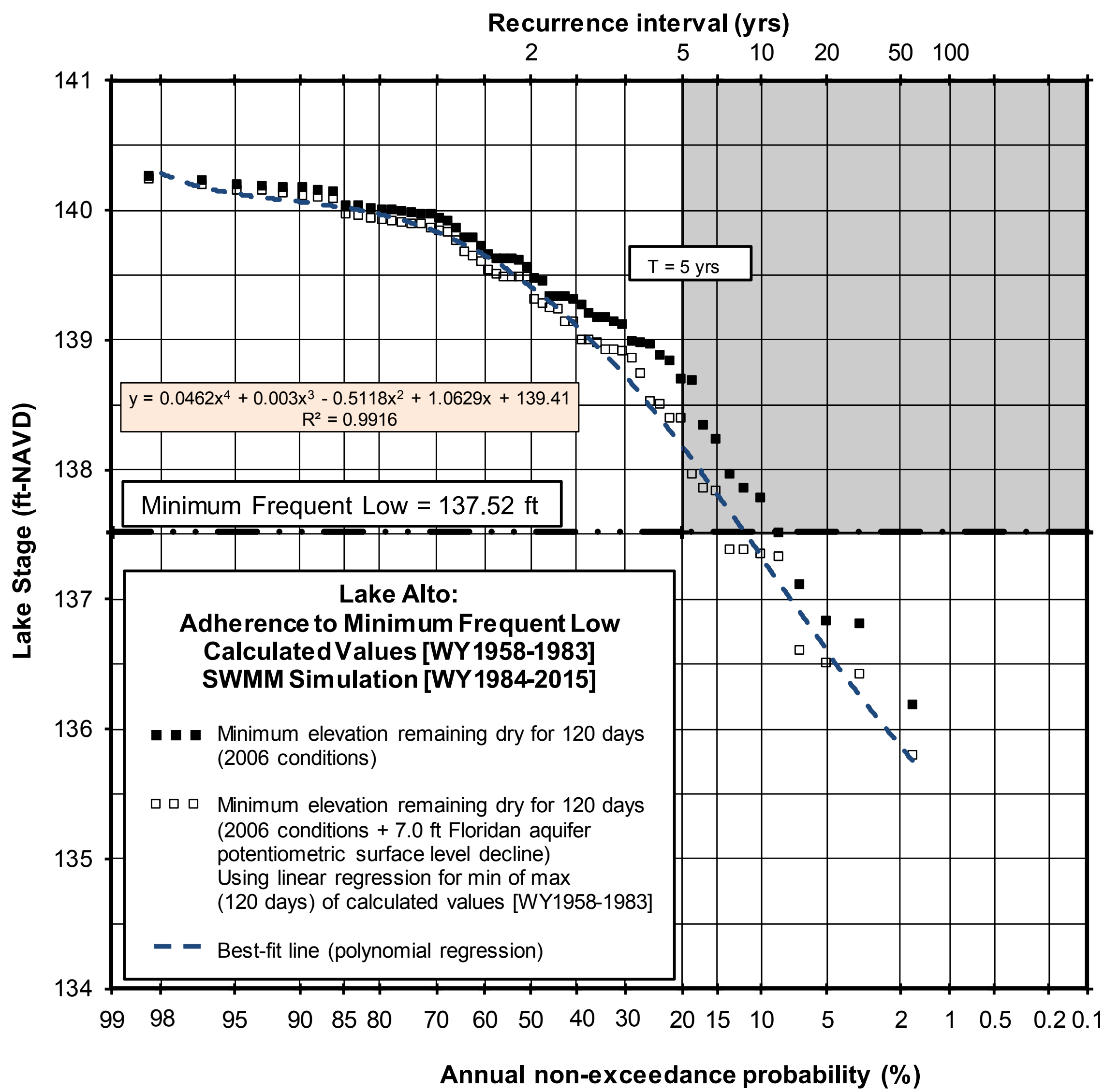

Figure 6-2C
Minimum Frequent Low Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Alto
in 2006 Conditions vs. 2006 Conditions + 7.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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G:\Working\2-ECT\Projects\SRWMD\Lake_MFLs\160682_Lake Altho and Lake Santa Fe\3_Data\GIS\MXD\Figures\Task 7\Figure 6-3 Hybrid Stage Hydrograph_Drawdown_Alto.mxd By: jsun Date: 10/27/2017

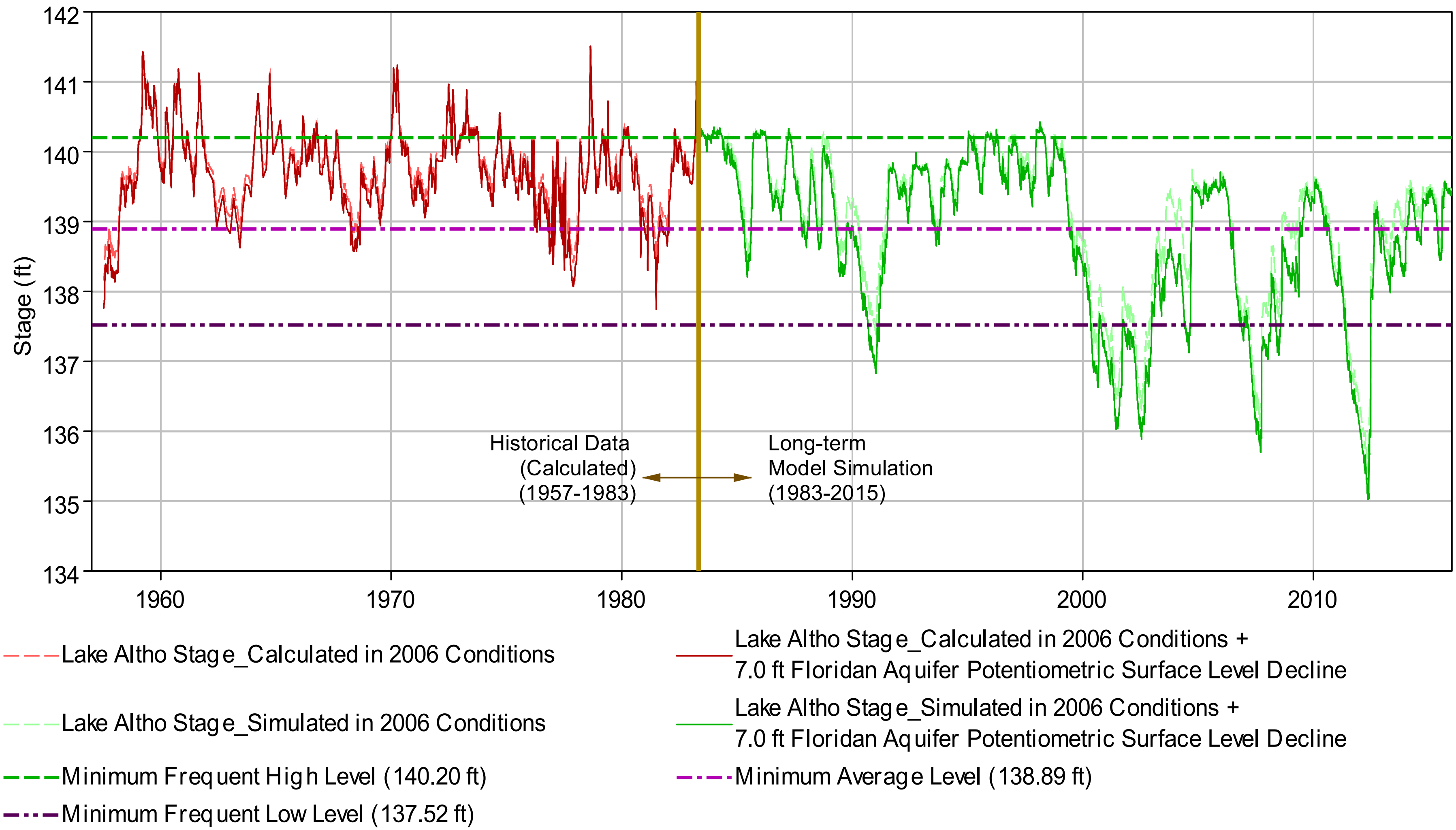

Figure 6-3
Hydrographs Comparison - Hybrid Lake Stage Data set (1957-2015) at Lake Alto
in 2006 Conditions vs. 2006 Conditions + 7.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

G:\Working\2-ECT\Projects\SRWMD\Lake_MFLs\160682_Lake Altho and Lake Santa Fe\3_Data\GIS\MXD\Figures\Task 7\Figure 6-4 SDC_Long-term_Drawdown_Alto.mxd By: jsun Date: 10/27/2017

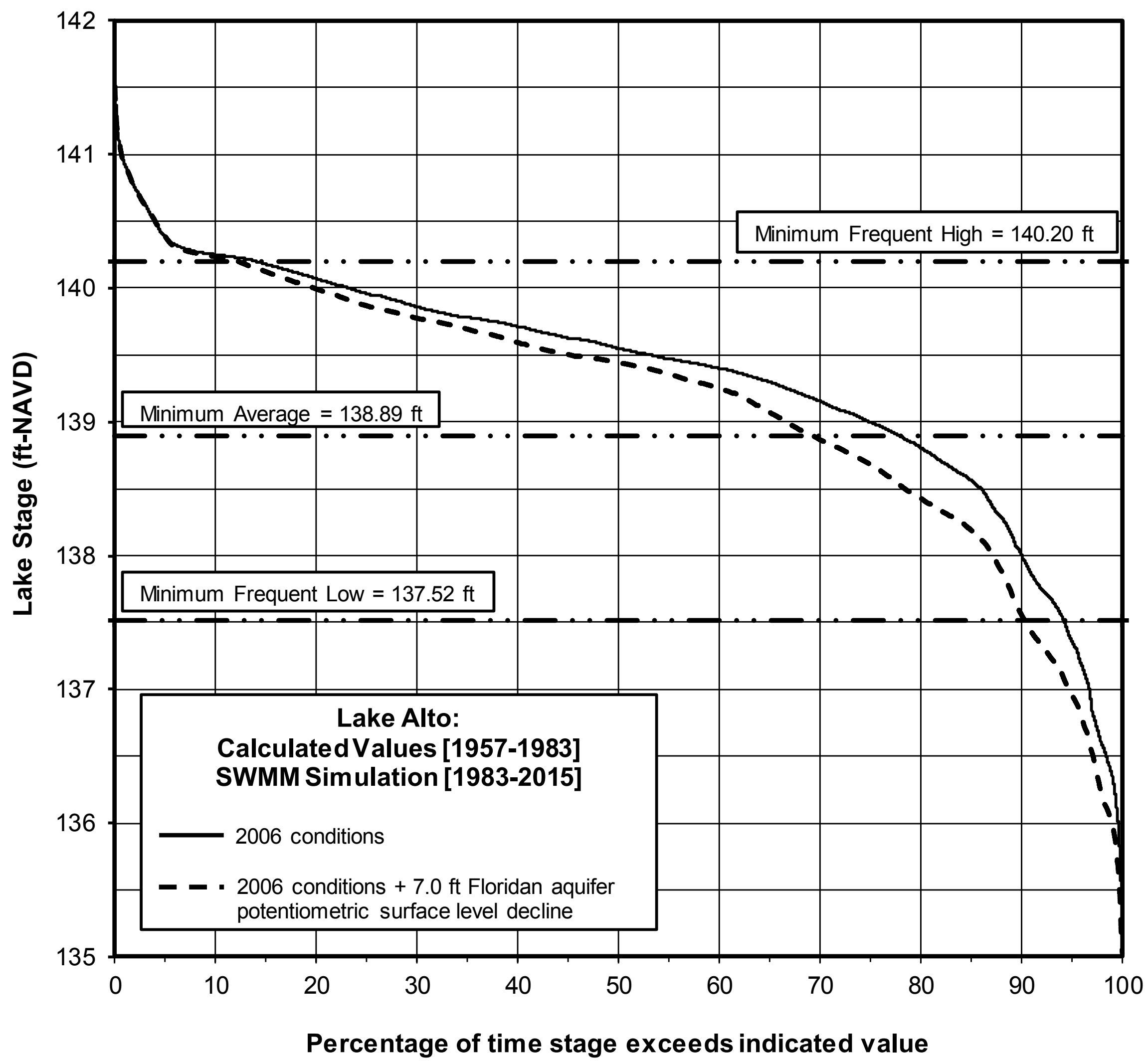

Figure 6-4
Stage Duration Curve - Hybrid Lake Stage Data Set (1957-2015) at Lake Alto
in 2006 Conditions vs. 2006 Conditions + 7.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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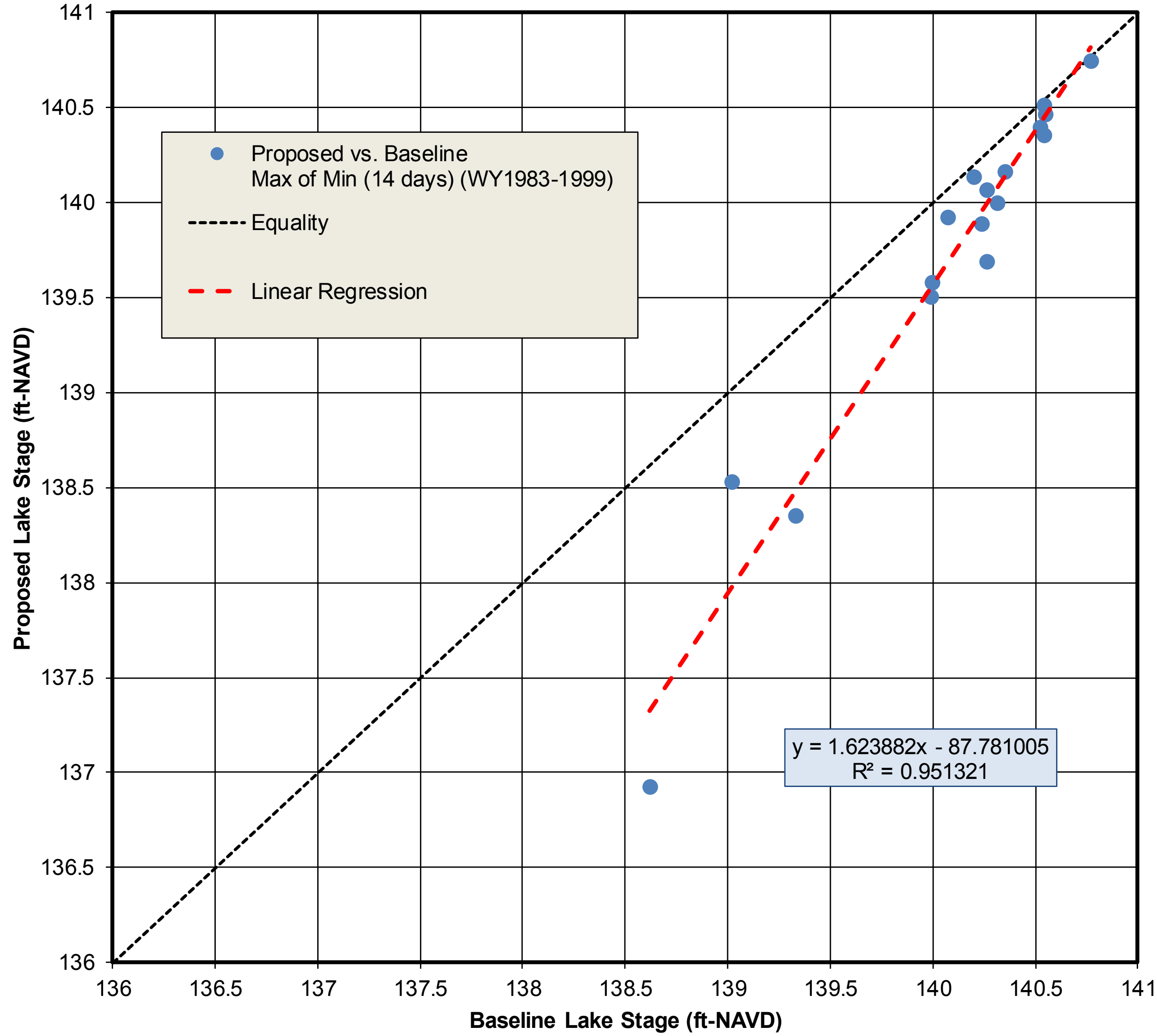

Figure 6-5A
Transfer Function for Minimum Frequent High Level at Lake Santa Fe in 2006 Conditions vs.
2006 Conditions + 16.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District
Sources: SRWMD, 2017; ECT, 2017.

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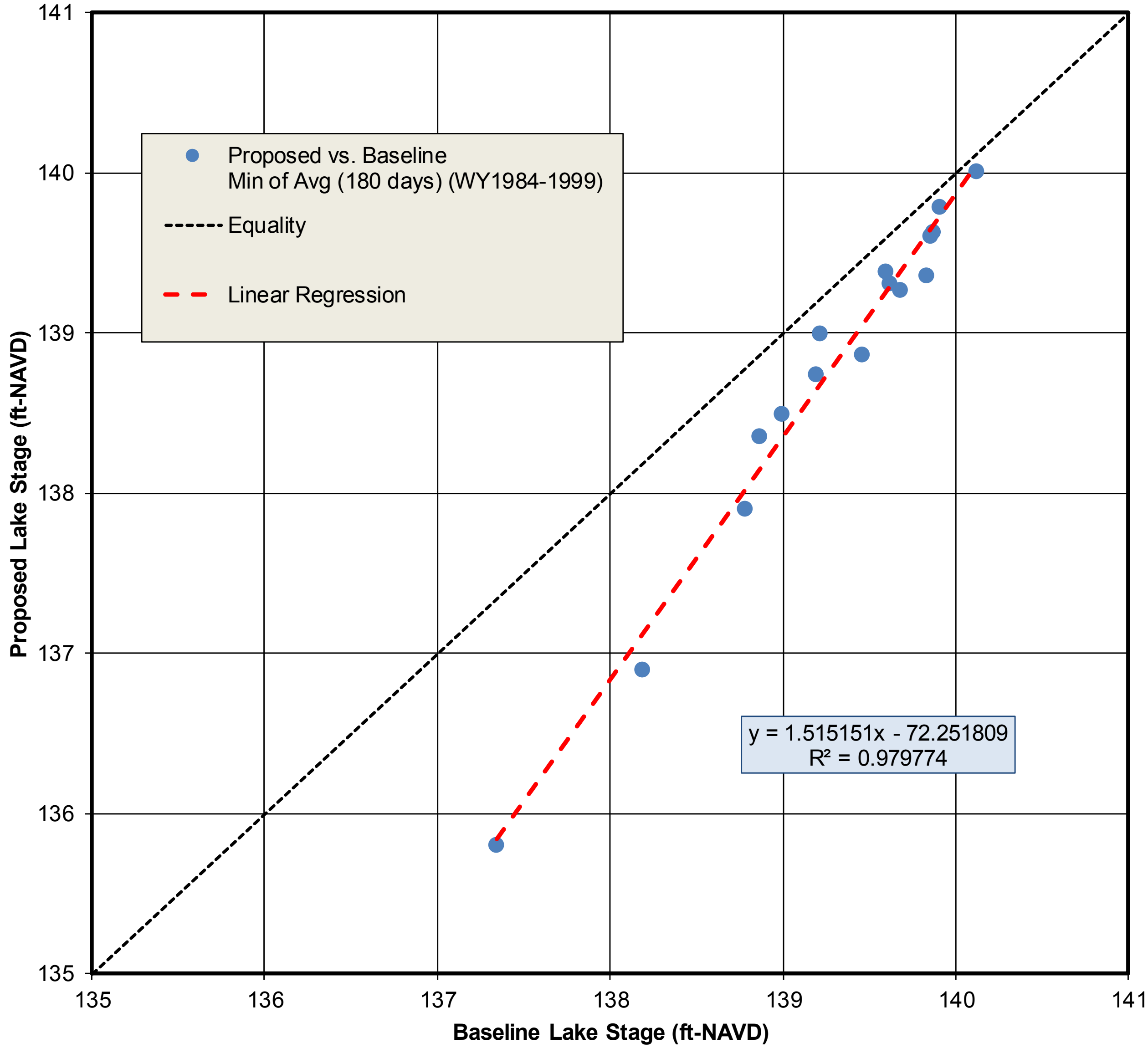

Figure 6-5B
Transfer Function for Minimum Average Level at Lake Santa Fe in 2006 Conditions vs.
2006 Conditions + 16.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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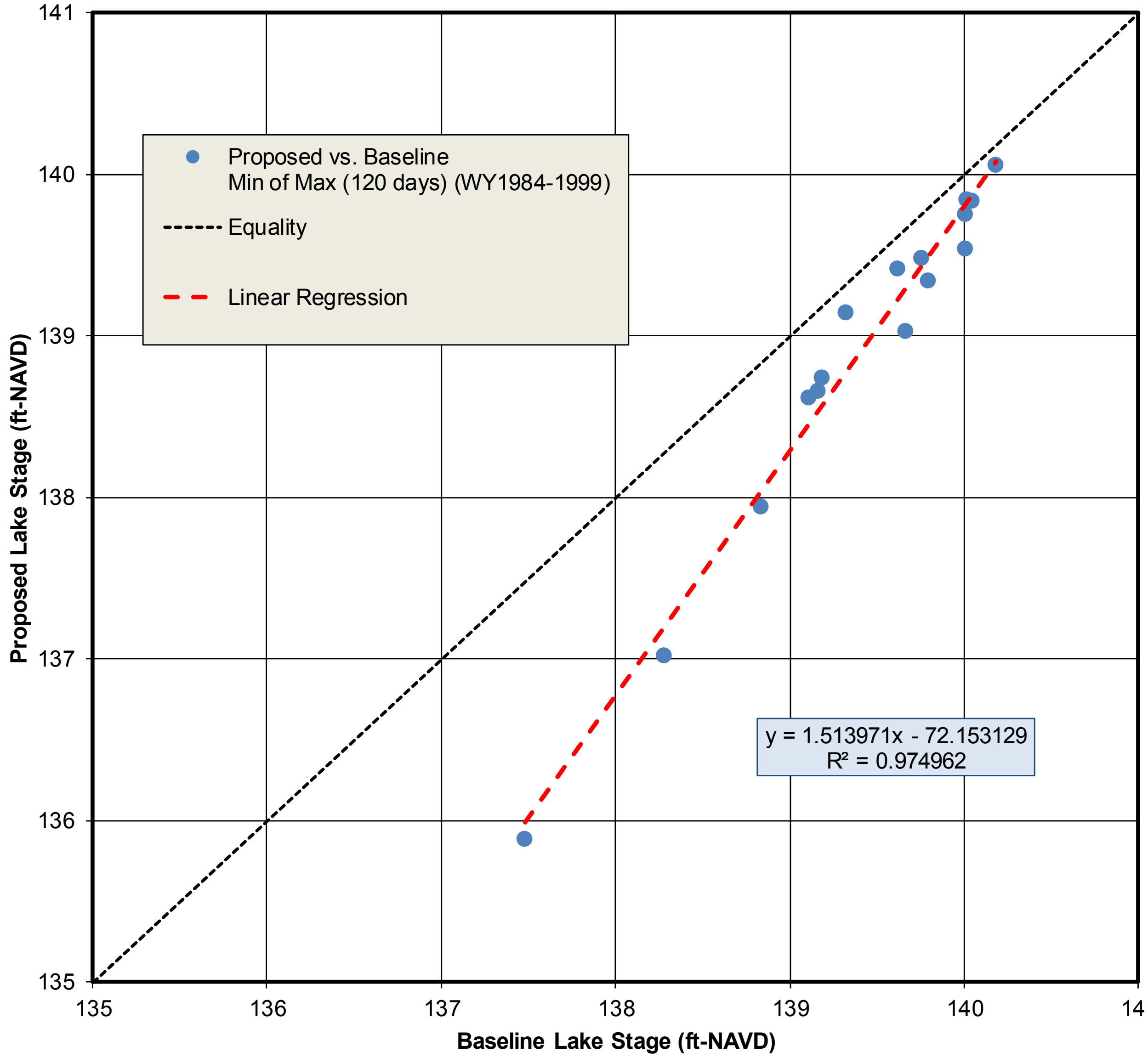

Figure 6-5C
Transfer Function for Minimum Frequent Low Level at Lake Santa Fe in 2006 Conditions vs.
2006 Conditions + 16.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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By: jsun Date: 10/27/2017

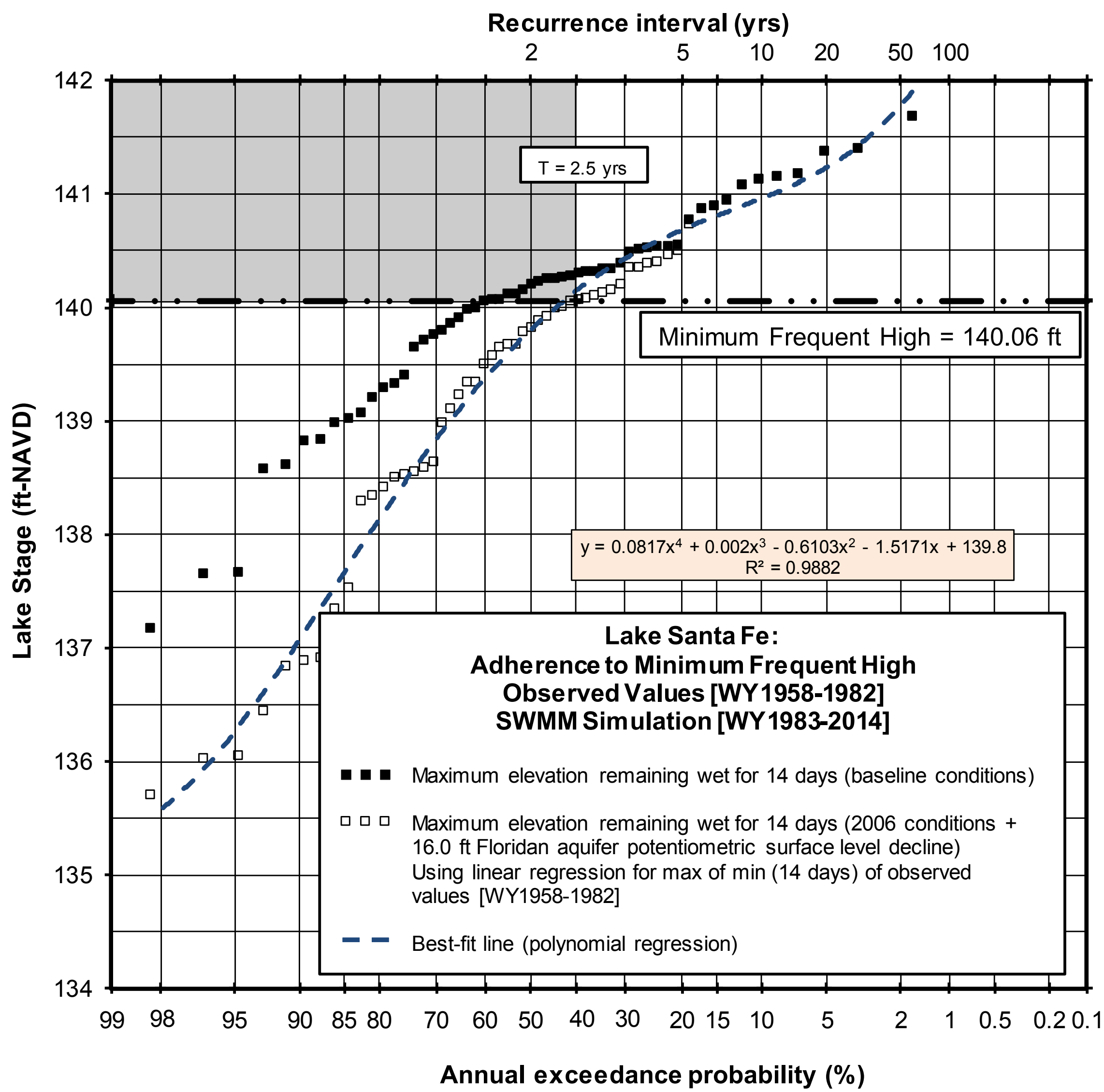

Figure 6-6A
Minimum Frequent High Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Santa Fe in 2006 Conditions vs. 2006 Conditions + 16.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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By: jsun Date: 10/27/2017

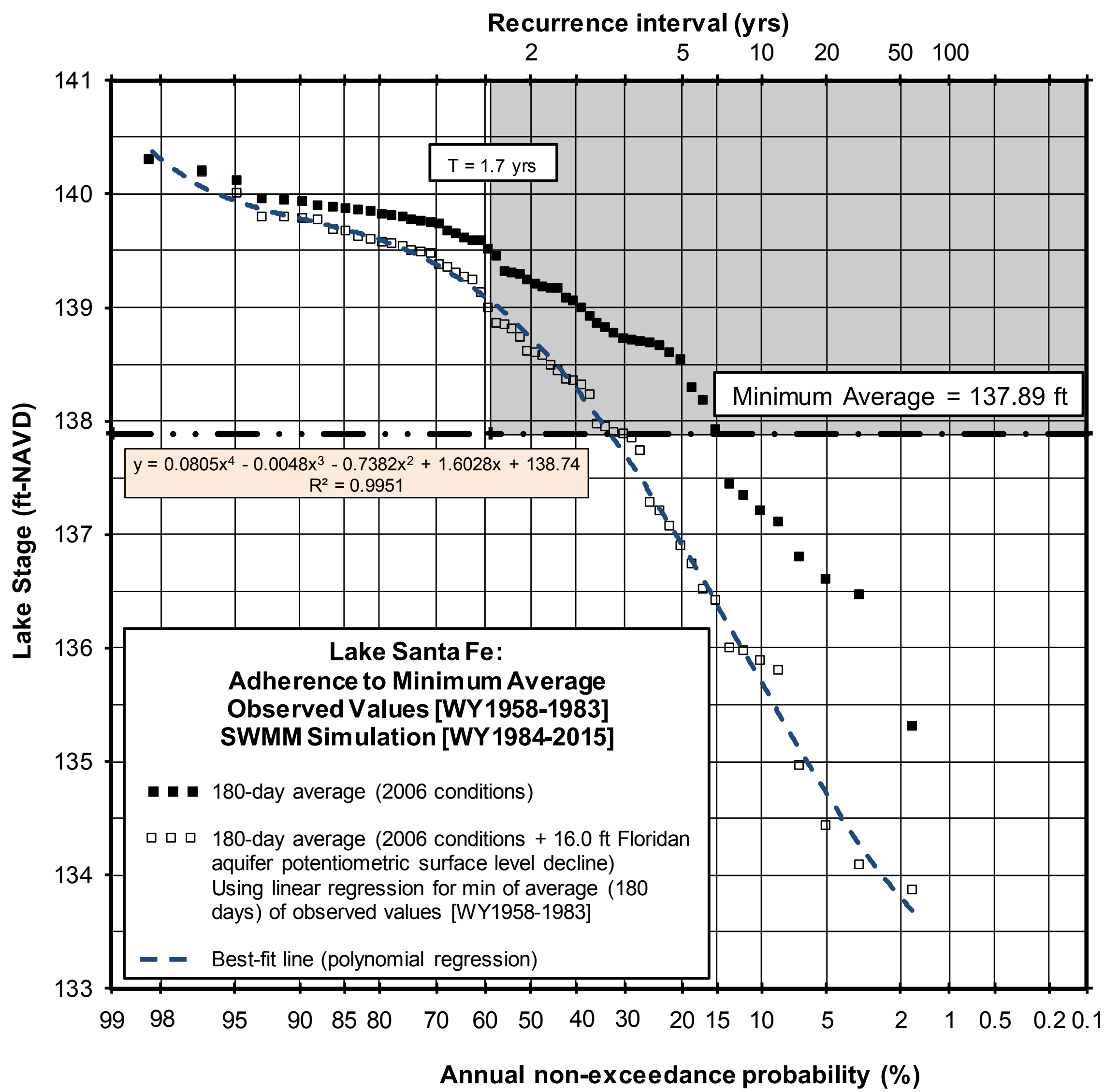

Figure 6-6B
Minimum Average Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Santa Fe
in 2006 Conditions vs. 2006 Conditions + 16.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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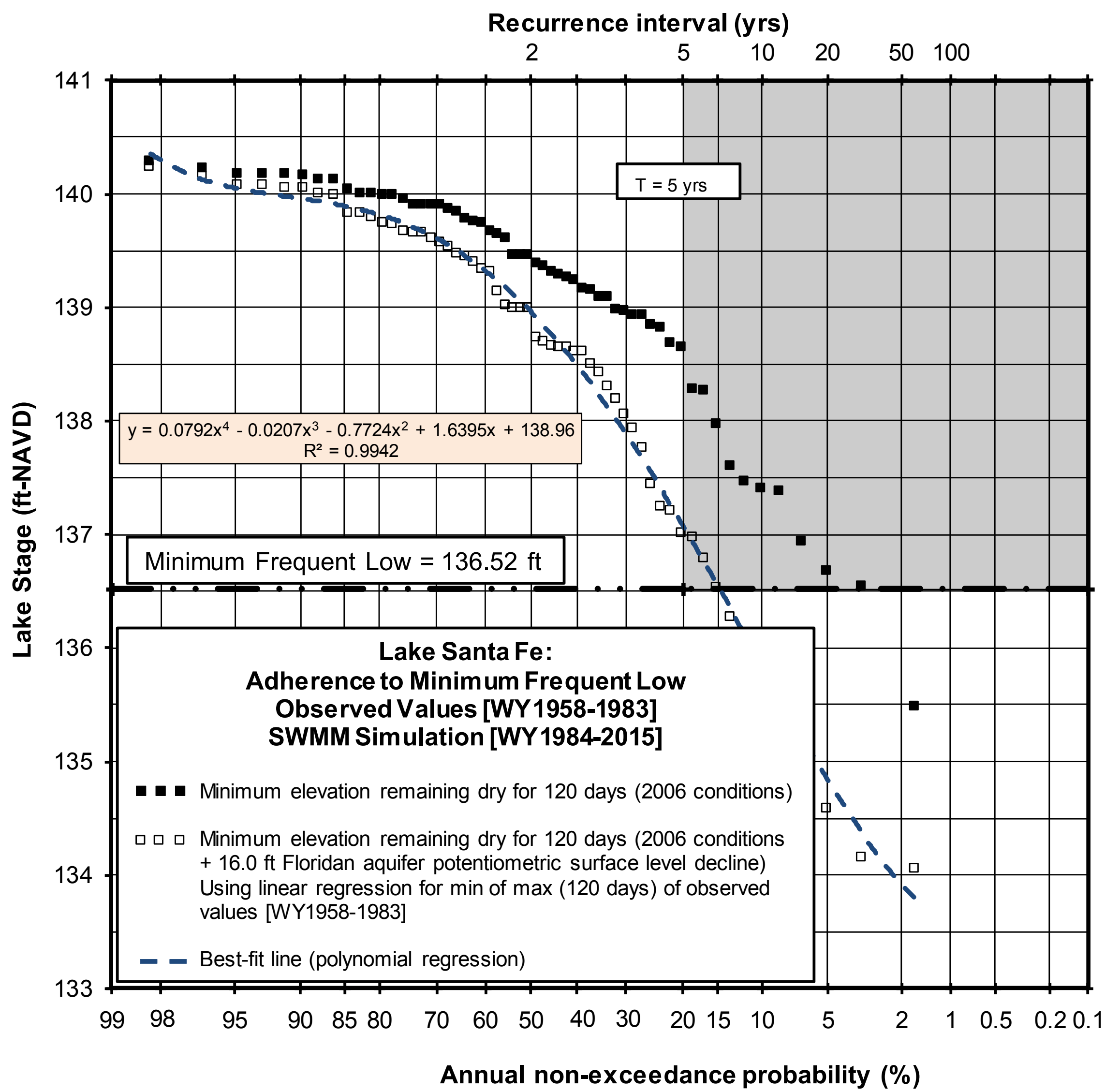

Figure 6-6C
Minimum Frequent Low Level and Hybrid Lake Stage Data Set (1957-2015) at Lake Santa Fe in 2006 Conditions vs. 2006 Conditions + 16.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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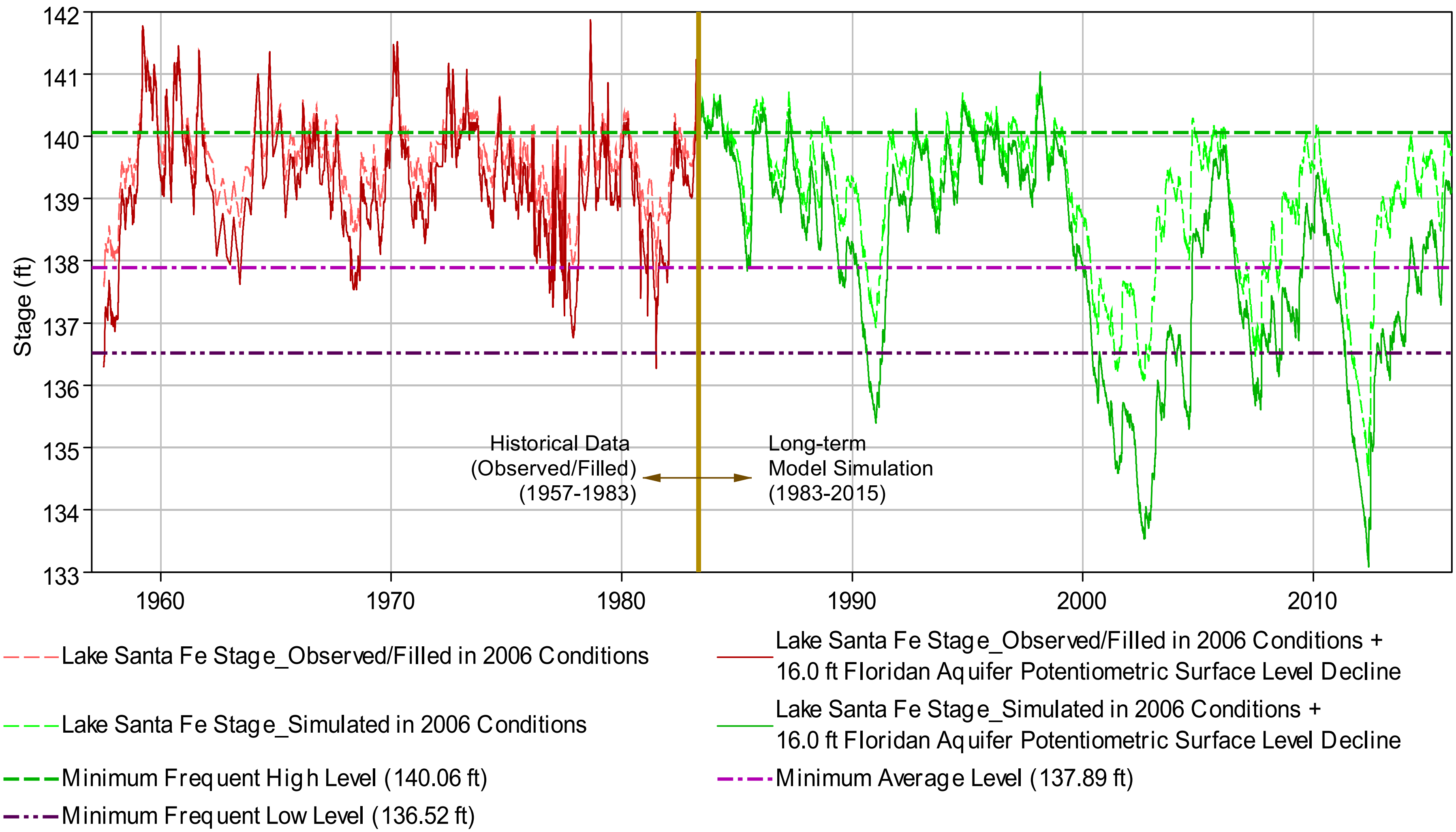

Figure 6-7
Hydrographs Comparison - Hybrid Lake Stage Data set (1957-2015) at Lake Santa Fe
in 2006 Conditions vs. 2006 Conditions + 16.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District

Sources: SRWMD, 2017; ECT, 2017.

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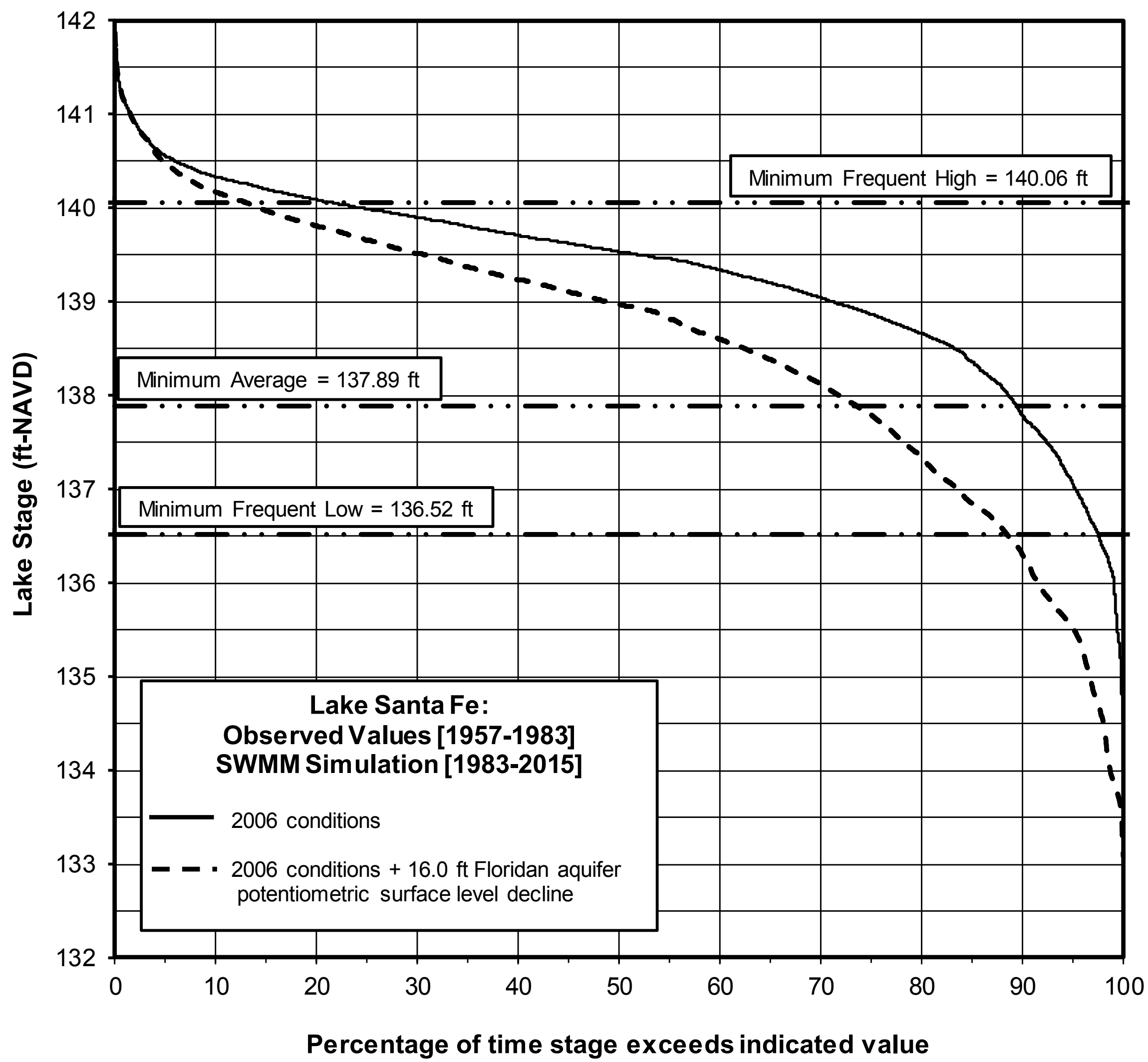

Figure 6-8
Stage Duration Curve - Hybrid Lake Stage Data Set (1957-2015) at Lake Santa Fe
in 2006 Conditions vs. 2006 Conditions + 16.0-ft Florida Aquifer Potentiometric Surface Level Decline
Lake Alto and Lake Santa Fe Water Budget Modeling
Suwannee River Water Management District
Sources: SRWMD, 2017; ECT, 2017.

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APPENDIX A

SWMM MODEL INPUT AND OUTPUT DATA
(located on DVDs)