CHERRY LAKE WATER BUDGET MODELING – UPDATED TO INCLUDE REFERENCE TIMEFRAME ANALYSIS

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Prepared for:

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Document Review

The technical contents of the Cherry Lake Water Budget Modeling – Updated to Include Reference Timeframe Analysis 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
CR	County Road
DEM	digital elevation model
ECT	Environmental Consulting & Technology, Inc.
EPA	U.S. Environmental Protection Agency
ET	Evapotranspiration
FAS	Floridan Aquifer System
FDEP	Florida Department of Environmental Protection
FDOT	Florida Department of Transportation
FFWCC	Florida Fish and Wildlife Conservation Commission
ft	Foot
GPI	Greenman-Pedersen, Inc
HMLL	high minimum lake level
hr	Hour
HSG	hydrologic soil group
in	Inch
LiDAR	Light Detection and Ranging
MFLs	minimum flows and levels
MLL	minimum lake level
NAVD88	North American Vertical Datum of 1988
NEXRAD	Next-Generation Radar
NFSEG	North Florida Southeast Georgia Groundwater Model
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
ORNL	Oak Ridge National Laboratory
PET	potential evapotranspiration
RCP	reinforced concrete pipe
RET	reference evapotranspiration
RMSE	root mean square error
RTF	reference timeframe (for level/flow)
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 evaluation of Minimum Flows and Levels (MFLs) at Cherry Lake, a water budget model is desired by the Suwannee River Water Management District (SRWMD or District) to assess hydrologic changes in this lake system. The complexity of the lake hydrologic system, especially as it relates to the upper Floridan aquifer system (FAS), 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, Lake Hampton, Lake Alto, and Lake Santa Fe by the District and Environmental Consulting & Technology, Inc. (ECT). 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 efforts include model development, calibration, and long-term model simulation.

Groundwater level data sets were developed for the measured and no-pumping scenarios based on the reference timeframe (RTF) analysis methodology and results provided by the District. An RTF of groundwater levels includes an addition to the water levels to adjust for the effect of groundwater pumping over time, creating an estimated “pumps off” or natural condition with respect to withdrawals. The existing water budget model, previously developed under Work Order 14/15-050.08 in 2017, was updated and used to simulate the measured, no-pumping, and predicted pumping scenarios. The updated model results were used for assessment of hypothetical allowable FAS drawdown in the context of MFLs for Cherry Lake, where minimum lake levels were developed for various lake Control Point (CP) scenarios by the District in 2023.

The Cherry Lake Water Budget Modeling Technical Report – Draft, previously developed in 2017, was updated to include the RTF analysis results and modeling update efforts for the measured and no-pumping scenarios.

A brief description of the major modeling tasks performed is provided below.

<u>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 Cherry Lake.

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.

<u>Model Calibration</u>

The water budget model was calibrated by comparing the model simulated lake stage against the known gauge data. The calibration model was developed based on 2006 land use and it runs from 2006 through 2015 on a sub-minute timestep. Multiple model parameters were adjusted within reasonable ranges to achieve the best overall fit of the model estimate with the observed data at Cherry Lake.

The lake stage gauge 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 (RMSE).

<u>Long-term Model Simulation and Assessment of Predicted Pumping Scenarios</u>

Following model calibration of the water budget model, the model was then updated to 2016 land use to perform a long-term simulation of an extended period of approximately 55.7 years from 4/29/1960 through 12/31/2015. It was assumed the 2016 land use has stayed the same throughout the entire simulation span.

Two long-term groundwater well stations: USGS Blackwater Plantation station near Ashville, FL (USGS 303812083362401 / SRWMD ID: N030727001) and USGS Valdosta station near Valdosta, GA (USGS 304949083165301), were used to estimate the historic groundwater level data (4/29/1960 through 6/13/1989) at the USGS Lovette Tower groundwater well station near Hamburg, FL (USGS 303400083305301 / SRWMD ID: N020822002), which is located approximately 6.3 miles southwest of Cherry Lake and provides monthly or daily groundwater level data in the upper FAS since 6/14/1989. The groundwater level time series data beneath Cherry Lake was developed by using the estimated long-term groundwater dataset at the USGS Lovette Tower station and a regression curve developed between the USGS Lovette Tower and Cherry Lake 4H Camp stations. Cherry Lake 4H Camp groundwater well station (SRWMD ID: N030933004), a short-term station operated by the District since August 2018, is located within the lake watershed. The estimated groundwater level data set extends the simulation period of the water budget model and allows for a more robust and defensible MFLs analysis.

Based on the recent RTF analysis results provided by the District, the groundwater level data sets for the “no-pumping” scenario were created using the “measured” groundwater data set estimated for Cherry Lake.

The Cherry Lake water budget model was used to determine the limit of the upper FAS drawdowns at which the minimum lake levels for each CP scenario will no longer be achieved for Cherry Lake. For this determination, model simulations were performed assuming the upper FAS potentiometric elevation to be lower than that under the no-pumping scenario. Model simulations were made by gradually lowering the upper FAS potentiometric elevation value until each of the minimum levels was no longer exceeded, i.e., not met.

Based on the stage duration analysis results, the minimum levels for Cherry Lake could still be met with a drawdown of 75 ft in the upper FAS beyond the no-pumping scenario, for the high and medium CP scenarios. For the low CP scenario, the minimum levels needed to protect cypress wetlands around the lake could be exceeded by a drawdown of 12 ft in the upper FAS beyond the no-pumping scenario. The drawdown analysis results for the high and medium CP scenarios indicate that Cherry Lake is well buffered from upper FAS drawdowns due to a thick clay confining unit underlying the lake. The low CP scenario represents a condition in which the outfall canal that drains Cherry Lake has eroded to the extent that the culvert under NE Cherry Lake Circle becomes the lake control point. The drawdown analysis results for the low CP scenario reflect that a relatively small change in lake levels over time (0.08 ft, or the difference between the Historic P50 elevation and minimum lake level for this scenario) could impact lake-fringing cypress wetlands if this condition were to occur.

This drawdown analysis results are also consistent with the water budget results for the 10-year model calibration, i.e., the groundwater loss to upper FAS through deep percolation in surficial aquifers and the lake is a relatively small value compared to the loss through evaporation and surface water discharge (through the outlet canal) such that the lake levels are primarily controlled by rainfall, evaporation, and the outlet canal.

2.0 Watershed Description

2.1 General Description

Cherry Lake (the lake) is located in northern Madison County, Florida, approximately 1.3 miles south of the Florida/Georgia state line (Figure 2-1). Cherry Lake has an area of approximately 479 acres at a water level elevation of 152.54 ft NAVD88, according to the bathymetric map created by SRWMD in 1976 (Figure 2-2).

Cherry Lake Beach Boat Ramp, located at the northwest corner of the lake, was constructed by Madison County (the County) in July 1994 and is currently operated by the County. This boat ramp can provide access to the lake for boats.

The Garden Pond, a 4.2-acre lake located 1,500 feet west of Cherry Lake, is surrounded by non-forested wetlands. There are two small wetland areas draining to the lake through ditches, culverts, and/or overland flows (Figure 2-1).

The Cherry Lake watershed (the lake watershed), including Cherry Lake, the Garden Pond, and their contributing drainage areas, encompasses a total area of approximately 965 acres.

An outfall canal, located on the east lakeshore, is the major conveyance way that discharges flows to the downstream wetland areas located east of the lake (Figure 2-1).

2.2 Climate

The climate in the lake watershed can be characterized by long, hot, and humid summers and relatively mild winters. In summer, the average temperature is 81 degrees F, and the average daily maximum temperature is 92 degrees. In winter, the average temperature is 54 degrees, and the average daily minimum temperature is 42 degrees. The lowest temperature on record, which occurred at Madison on December 13, 1962, is 7 degrees (USDA, 1990).

The average annual rainfall in Madison County is approximately 52 inches. Of this, 30 inches, or 58 percent, usually falls in April through September. The growing season for most crops falls within this period. The heaviest 1-day rainfall during the period of record was 8.9 inches at Madison on March 31, 1962. Thunderstorms occur on about 40 days each year, and most occur in July (USDA, 1990).

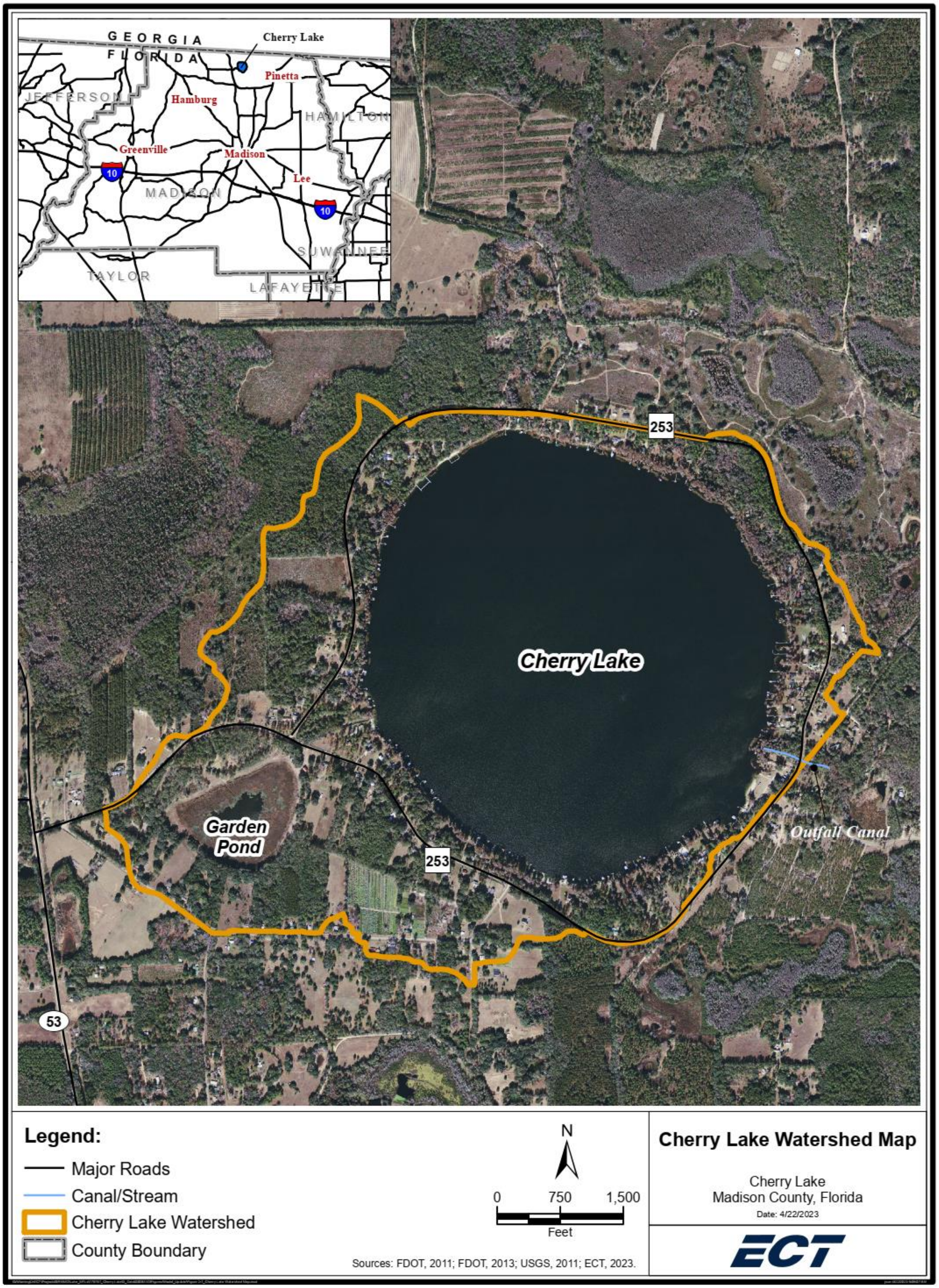


Figure 2-1. Cherry Lake Watershed Map.

2.3 Topography

Topography in the lake watershed can be characterized as mildly sloping, as graphically presented in the digital elevation model (DEM) and contour maps (Figures 2-2A and 2-2B), which were developed based on the 2011 Light Detection And Ranging (LiDAR) topographic survey (NGC, 2011) and the National Elevation Dataset (NED), both from U.S. Geographical Survey (USGS).

Cherry Lake and most of its contributing areas have an average land surface elevation of 164 ft NAVD88. The highest land surface elevation of approximately 220 ft NAVD88 is observed at southwest corner of the lake watershed (Figures 2-2A and 2-2B).

A bathymetric map was provided in triangulated irregular network (TIN) format by SRWMD (Figure 2-2C). The bathymetric TIN data was originally developed by Greenmen-Pedersen, Inc. (GPI) in 2017, based on their interior lake survey points and other related topographic data. The lowest point is approximately 137.5 ft NAVD88 at the lake center (Figure 2-2C).

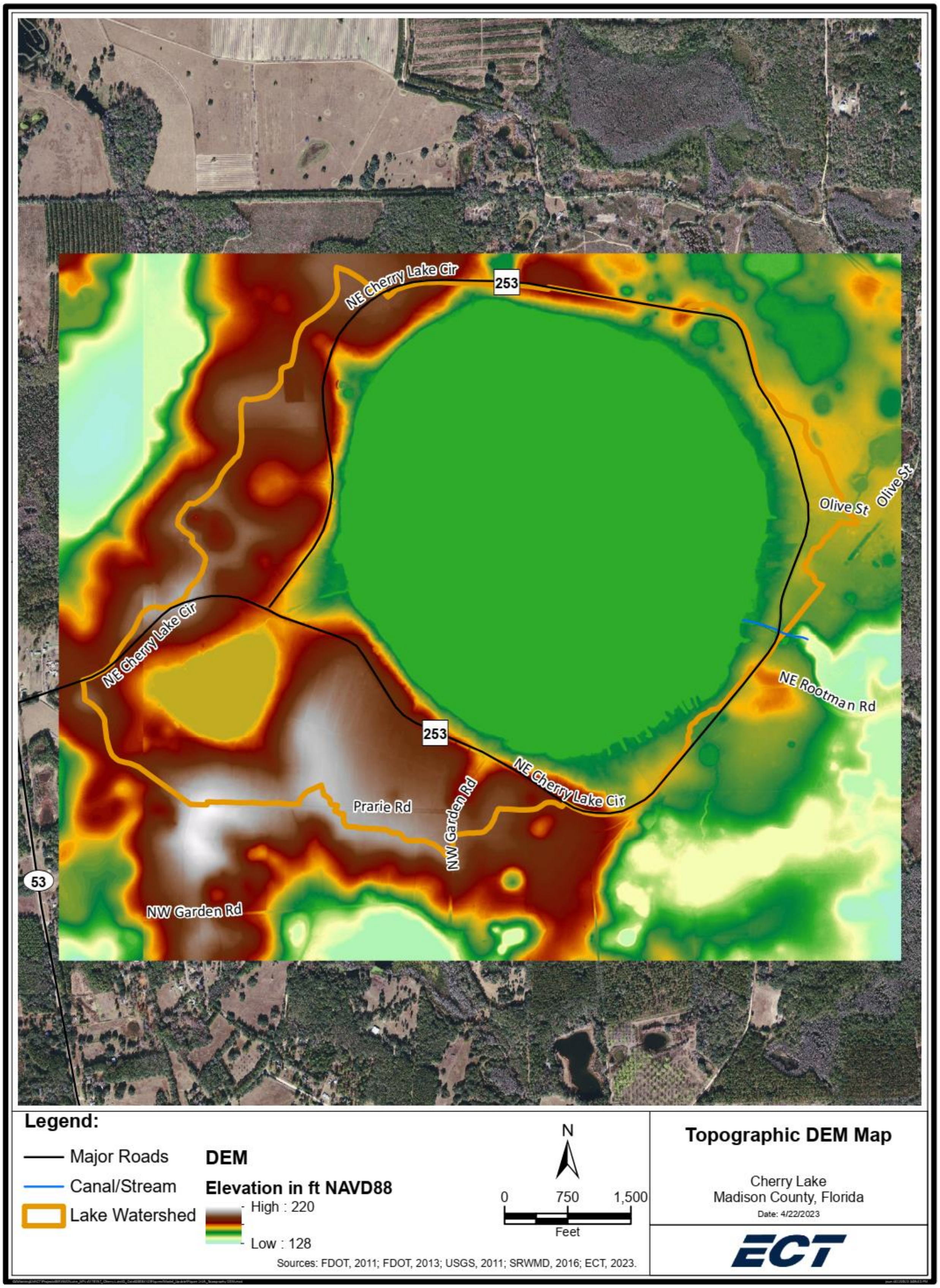


Figure 2-2A. Topographic DEM Map.

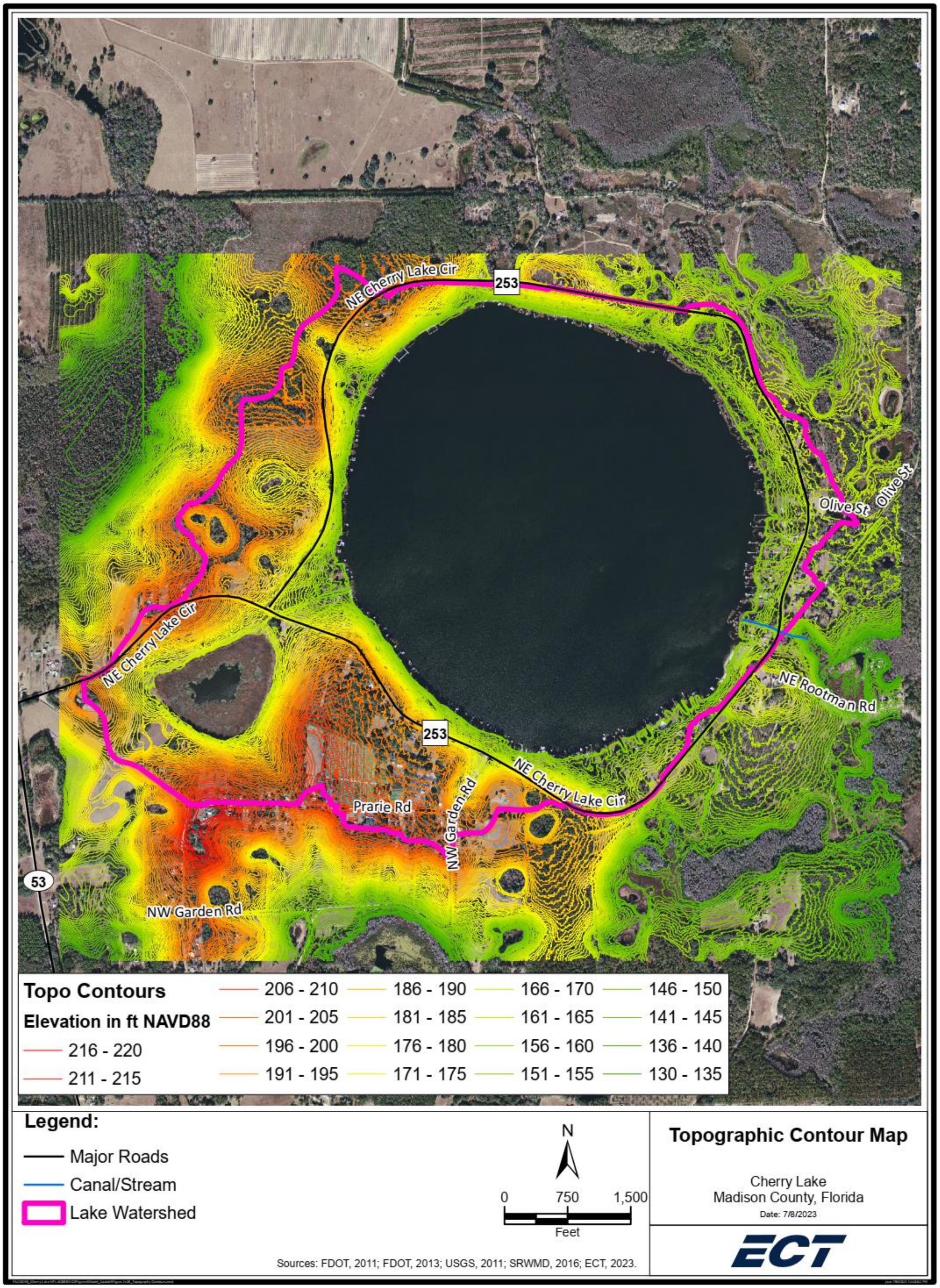


Figure 2-2B. Topographic Contours Map.

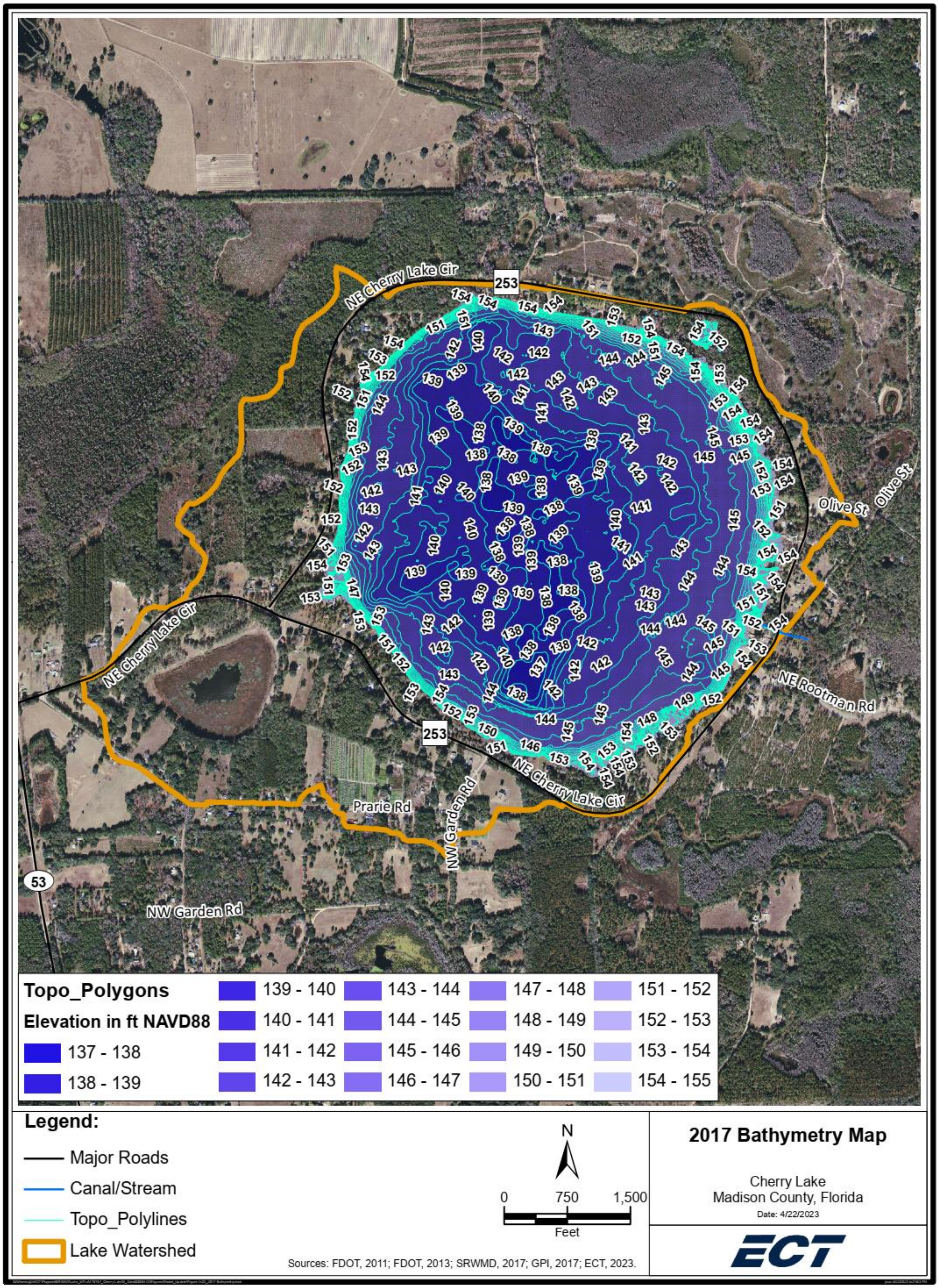


Figure 2-2C. 2017 Bathymetry Map.

2.4 Geology and Groundwater

2.4.1 Geology

Located in the eastern part of the Florida panhandle, Madison County encompasses a transitional geologic area that separates the thick Tertiary carbonate sediments characteristic of the Florida peninsula from the predominant age equivalent clastic sediments of western Florida. This area is underlain by thick limestone deposits of the Oligocene and Eocene age which in turn are covered by younger limestones, dolomites, sands and clays in the northern half of the county (Hoenstine and Spencer, 1986).

Two major physiographic divisions occur within Madison County. As proposed by Puri and Vernon (1964), these divisions include the Northern Highlands and the Coastal Lowlands (Figure 2-3A). The Northern Highlands extend over the northern two-thirds of the county while the Coastal Lowlands occupy the remaining third of Madison County.

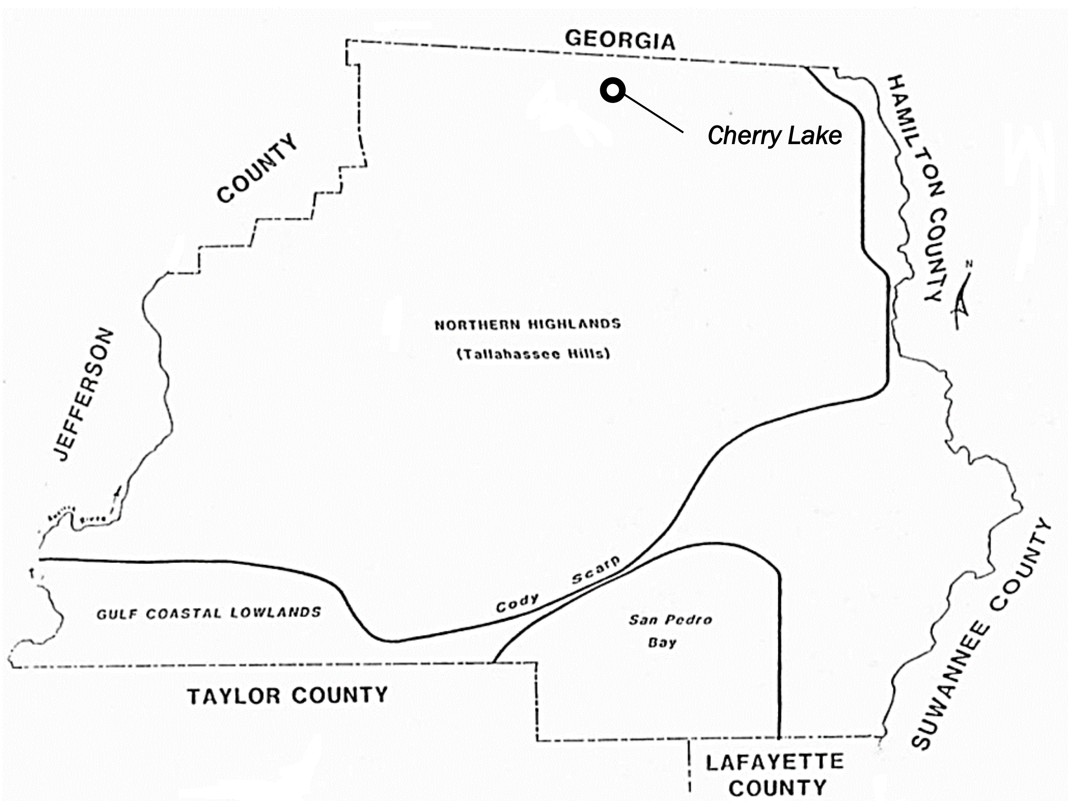


Figure 2-3A. Physiographic Divisions within Madison County (Hoenstine and Spencer, 1986).

Extending over parts of several counties in Florida and Georgia, the Northern Highlands in Madison County includes all of the area north of the Cody Scarp (Figure 2-3A). This physiographic region includes a prominent physiographic feature known as the Tallahassee Hills.

The sediments that occur in Madison County range in age from Paleozoic to Recent. To date, the deepest penetration of subsurface sediments occurred at a depth of 10,150 feet below mean sea level. These sediments obtained from an oil test well (P-1033) were identified as Paleozoic quartzitic sandstones deposited hundreds of millions of years ago. In contrast, surface and near-surface occurrences include unconsolidated sands, limestone and highly indurated dolomites ranging in age from the Eocene Epoch (36 to 58 million years ago) to the Recent. The oldest surface outcrops are dolomite and limestone belonging to the Eocene Epoch (40 to 38 million years ago).

Hoenstine and Spencer (1986) provided a geologic discussion of the near-surface and surface sediments at the county. Cherry Lake is located near Cross Section A-A’ that lies in the Northern Highlands region and south of the Florida-Geogia state line (Figure 2-3B).

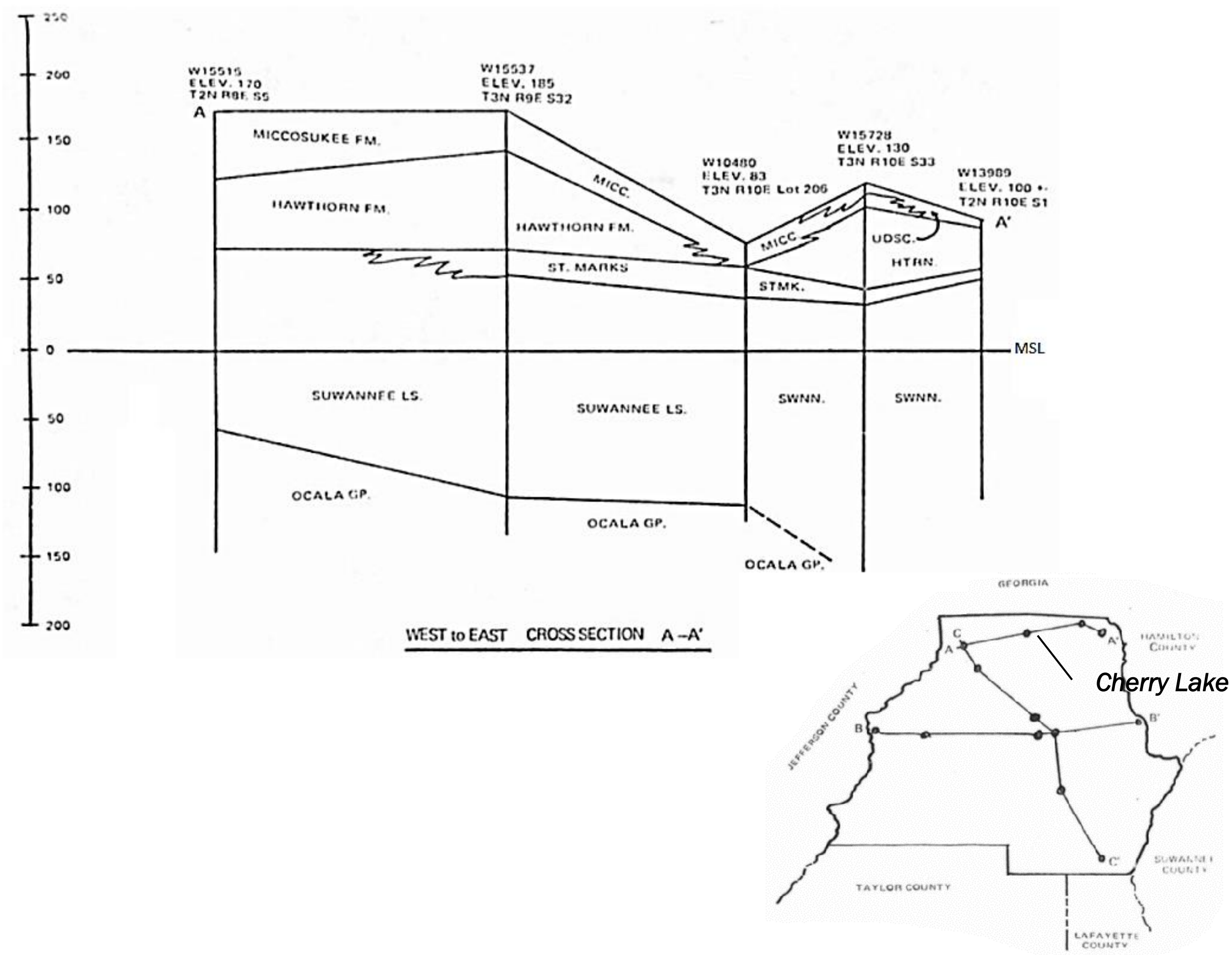


Figure 2-3B. Geologic Cross Section A-A’ (Hoenstine and Spencer, 1986).

2.4.1.1 Ocala Group

The Ocala Group Limestones, which were deposited during the Eocene Epoch (40 to 38 million years ago), represent the oldest sediments exposed in Madison County. These limestones, which form an integral part of the Floridan Aquifer, occur at varying depths throughout the county. The Ocala Group Limestone is generally a pale orange, poor to moderately indurated, moderately to high porous, microfossiliferous, partially dolomitized, partially recrystallized limestone (calcarenite). The occurrence of the distinctive foraminifera genera Lepidocyclina is common to abundant and often used as a guide in distinguishing this formation from the overlying younger Suwannee Formation.

2.4.1.2 Suwannee Limestone

Exposures of limestone and dolomites belonging to the Suwannee Limestone Formation, which was deposited during the Oligocene Epoch, occur along the Suwannee River at Ellaville. The Suwannee Limestone lies unconformably upon the Ocala group limestone and unconformably underlies the St. Marks or Hawthorn Formation.

The Suwannee Formation is a marine limestone consisting of a partially recrystallized limestone (calcarenite). It is very pale orange, finely crystalline, moderate to well indurated, with moderate to good porosity and very fossiliferous. Chemical tests indicate a composition that is nearly 97% $CaCO_3$.

2.4.1.3 St. Marks Formation

Early Miocene sediments unconformably overlie the Suwannee Limestone in many parts of Madison County. These sediments, which form the St. Marks Formation, are white to very pale orange, finely crystalline, sandy, silty, clayey limestone (calcilutite). The St. Marks is poor to well indurated, has low to medium porosity, contains molluscan casts and a few species of foraminifera (Sorites sp., Archaias florldanus). The calcilutite has been partially dolomitized and silicified in the subsurface.

2.4.1.4 Hawthorn Formation

The Hawthorn Formation consists of pale olive to moderate yellow, sandy, waxy, phosphatic clays and sands. The clay contains phosphorite grains and is interbedded with very fine to medium, clayey quartz sands that also contain phosphorite. The clays and sands are frequently cherty and often associated with stringers of sandy calcilutites.

2.4.1.5 Miccosukee Formation

A prominent feature throughout the county is the varicolored, heterogeneous complex of sediments referred to as the Miccosukee Formation. The Miccosukee is an aggregate of lenticular clayey sands and clay beds which individually can be traced laterally for only short distances. These sediments are moderately sorted to poorly sorted, coarse to fine-grained, varicolored, clayey, quartz sand and montmorillonitic, kaolinitic, varicolored, sandy clays. The frequently crossbedded sands contained crossbedded thin laminae of white to light gray clay. X-ray diffraction patterns indicate that the laminae associated with both quartz sands is kaolinite.

2.4.2 Groundwater

As stated by Hoenstine and Spencer (1986), the Floridan Aquifer is the principal water-bearing unit in Madison County. It includes all of the Middle Eocene to Early Miocene formations (Ocala Group, Suwannee Limestone, and St. Marks Formation).

Intermediate aquifers are present in northern Madison County. These aquifers occur within discontinuous units of limestone, dolomite and sand that form the Hawthorn Formation. Although the amount of water obtained from the intermediate aquifers are minimal compared to the underlying Floridan Aquifer, it may be sufficient for small domestic supplies. In addition, the quality of water in the intermediate aquifer is diminished relative to the Floridan by the presence of more dissolved solids.

Other sources of water include water table aquifers that occur within the surficial sand deposits at higher elevations. These aquifers receive recharge primarily from rainfall or through upward percolation of underlying aquifers when their potentiometric surfaces are higher than that of the water table. Water quality in these aquifers is diminished due to the high concentration of iron.

2.5 Soils

According to the Natural Resource Conservation Service (NRCS), there are a total of 15 different types of soils that occur within the lake watershed that are mapped in the Soil Survey of Madison County (USDA, 1990). The various types of soils have been grouped into four soil texture classes, including Sand, Loamy Sand, Sandy Loam, and Sandy Clay. These soil texture classes are used in the hydrologic modeling analysis to estimate infiltration from rainfall, see Section 3.2.5 for details. The Cherry Lake watershed is classified as 40.7% for Sand, 7.0% for Loamy Sand, 3.1% for Sandy Loam, 0.2% for Sandy Clay, and the remaining 49.0% for water. Most of the watershed land is classified as Sand (Table 2-1 and Figure 2-4).

Table 2-1. Statistical summary of soil texture classes in Cherry Lake watershed.

Soil Texture Class	Area (acre)	Percentage
Sand	392.7	40.7%
Loamy Sand	67.1	7.0%
Sandy Loam	29.8	3.1%
Sandy Clay	1.9	0.2%
Water	473.1	49.0%
Total	**964.6**	**100.0%**

Source: NRCS, 2016.

2.6 Land Use/Land Cover

The SRWMD 2006 land use coverage is based on the Florida Land Use and Cover Classification System (FLUCCS, Florida Department of Transportation [FDOT]). The 2006 land use map for the lake watershed is graphically presented in Figure 2-5.

Most of the upland areas next to the lake have been developed into residential areas, and agriculture lands and upland forests were observed at the west and south of the lake, including the areas surrounding the Garden Pond. As summarized in Table 2-2, the top three land uses in the lake watershed are waters (50.4%), urban & built-up (23.8%), and upland forests (17.2%). Cherry Lake and the Garden Pond together occupies over 50% of the lake watershed area. Note that the waters area listed in the land use summary table is different from the value in Table 2-1, mostly due to different source data and methods used in developing the land use and soils data.

Table 2-2. Statistical summary of 2006 land use in Cherry Lake watershed.

FLUCCS	Description	Area (acre)	Percentage
1000	Urban & Built-up	229.4	23.8%
2000	Agriculture	40.2	4.2%
3000	Rangeland	2.7	0.3%
4000	Upland Forests	166.3	17.2%
5000	Waters	486.5	50.4%
6000	Wetlands	39.5	4.1%
	Total	**964.6**	**100.0%**

Source: SRWMD, 2006.

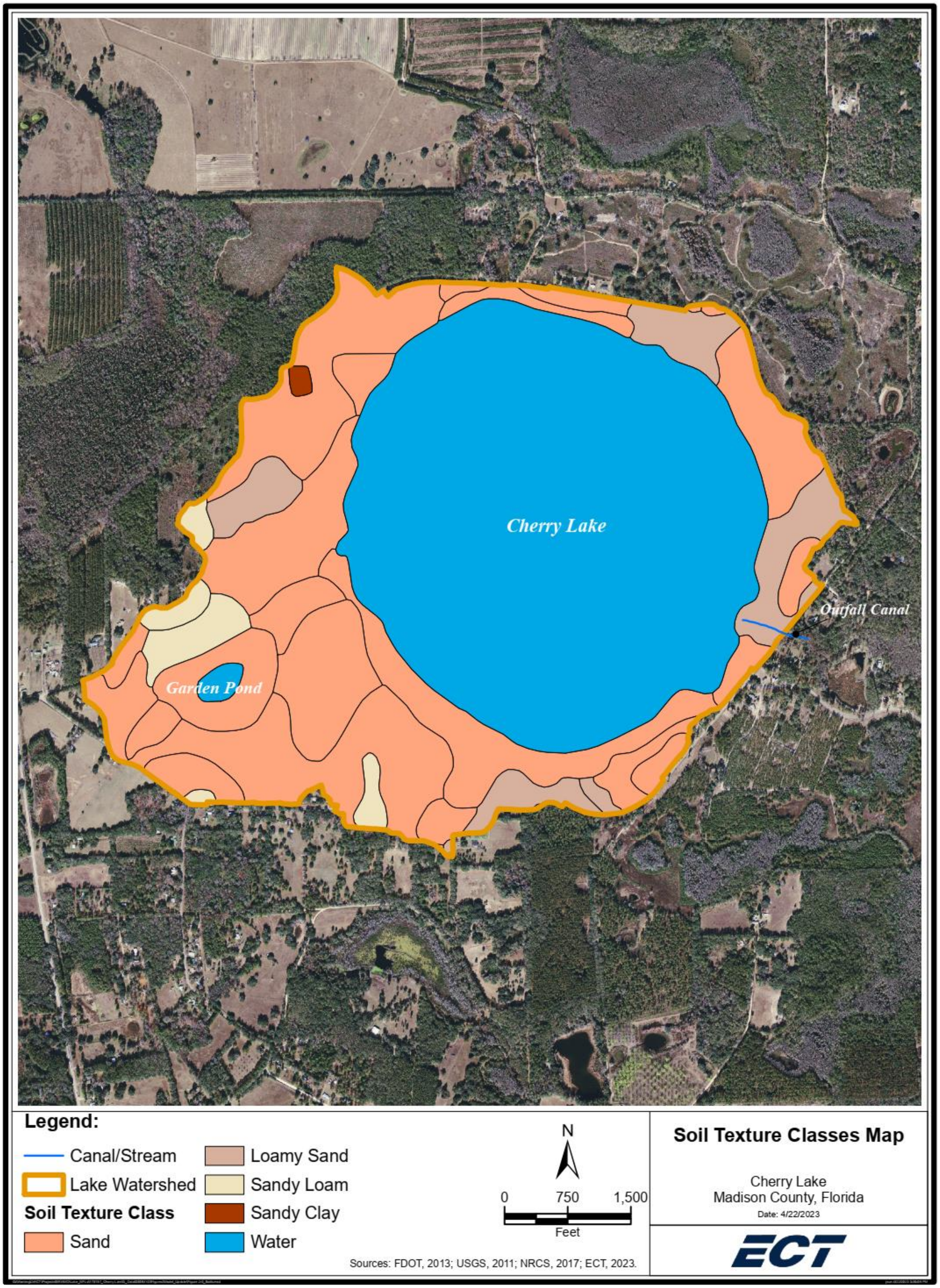


Figure 2-4. Soil Texture Classes Map.

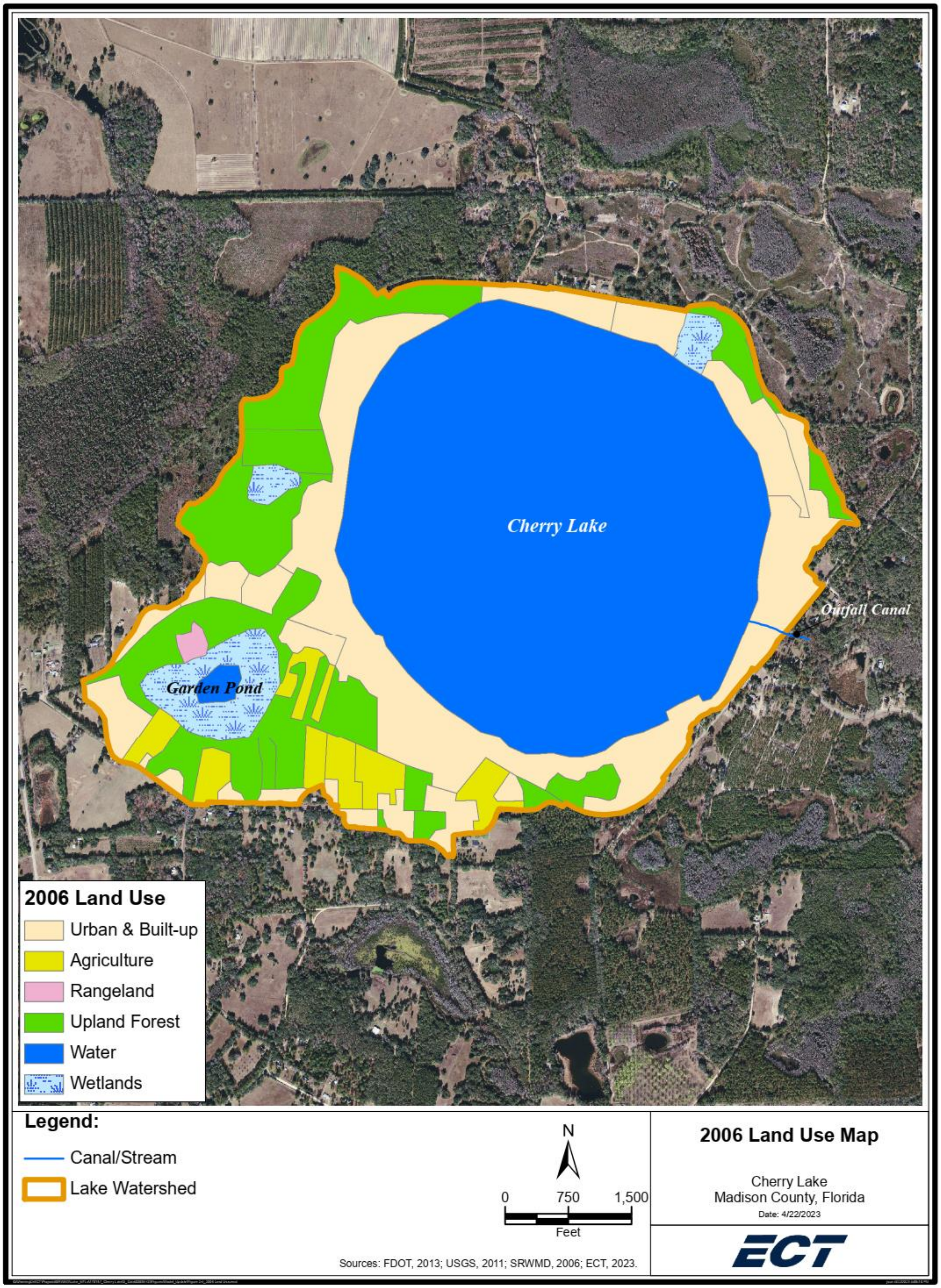


Figure 2-5. 2006 Land Use Map.

2.7 Major Conveyance System

Cherry Lake receives surface flows from a watershed covering approximately 965 acres or 1.5 square miles, by means of flows emerging from the residential areas and upland forests that fringe the lake, by direct precipitation, and by stormwater runoff from surrounding developed lands (Figure 2-6).

Inflow to the west side of the lake is contributed by six defined inflows:

1. Inflow from west to east through Pipe # 1 – an un-surveyed 24” reinforced concrete pipe (RCP) on NE Cherry Lake Cir., approximately 3,800 feet north of the Garden Pond;
2. Inflow from west to east through Pipe # 2 – an un-surveyed 30” RCP on NE Cherry Lake Cir., approximately 2,300 feet north of the Garden Pond;
3. Inflow from west to east through Pipe # 3 – an un-surveyed 24” RCP on NE Cherry Lake Cir., approximately 1,500 feet north of the Garden Pond;
4. Inflow from west to east through Pipe # 4 – an un-surveyed 24” RCP on NE Cherry Lake Cir., north of a roadway intersection, draining to the ditch to the east that empties into the lake;
5. Inflow from south to north through Pipe # 5 – a 24” RCP on NE Cherry Lake Cir., east of the roadway intersection mentioned above, draining to the ditch that empties to the lake; and
6. Inflow from north to south through Pipe # 6 – an un-surveyed 19” x 30” elliptical corrugated metal pipe (ECMP) on NE Cherry Lake Cir., approximately 1,000 feet northwest of the Garden Pond.

On the south side of the lake, three 30” RCPs (Pipes # 7 – 9) on NE Cherry Lake Cir., approximately 3,000 feet east of the Garden Pond, convey flows from the upland areas northward to the lake.

On the northeast side of the lake, an un-surveyed 24” RCP (Pipe # 10) on Olive St., conveys flows southward to the wetland next to the northeast lakeshore.

Cherry Lake discharges by means of the outfall canal located on the east lakeshore. The canal and two culverts (Pipes # 11 & 12 – 42” RCP on NE Cherry Lake Cir. and 42” CMP on CR 253) convey flows eastward to the downstream wetland areas.

Local resident, Mr. Mike Holton, provided useful information about the history of the lake during a meeting on March 23, 2017, including a discussion of the outfall canal. He explained that the outfall canal was constructed to provide power for a grist mill, which was known to be in operation as early as 1936 (ECT, 2023).

Upon evaluation of the topographic survey data and field observations by the District and ECT staff on March 2, 2017, the highest point of the outfall canal appeared to be a beaver dam located approximately 100 feet upstream of NE Cherry Lake Cir. and had a top elevation of 150.80 ft NAVD88, approximately 1 foot above the normal canal bottom near the dam. At the time of the survey, the 42” RCP beneath NE Cherry Lake Cir. seems to have been blocked by debris (likely due to beaver activities). The beaver dam and culvert blockage together seemed to control the outfall flow discharge from the lake during years preceding the survey but are no longer present.

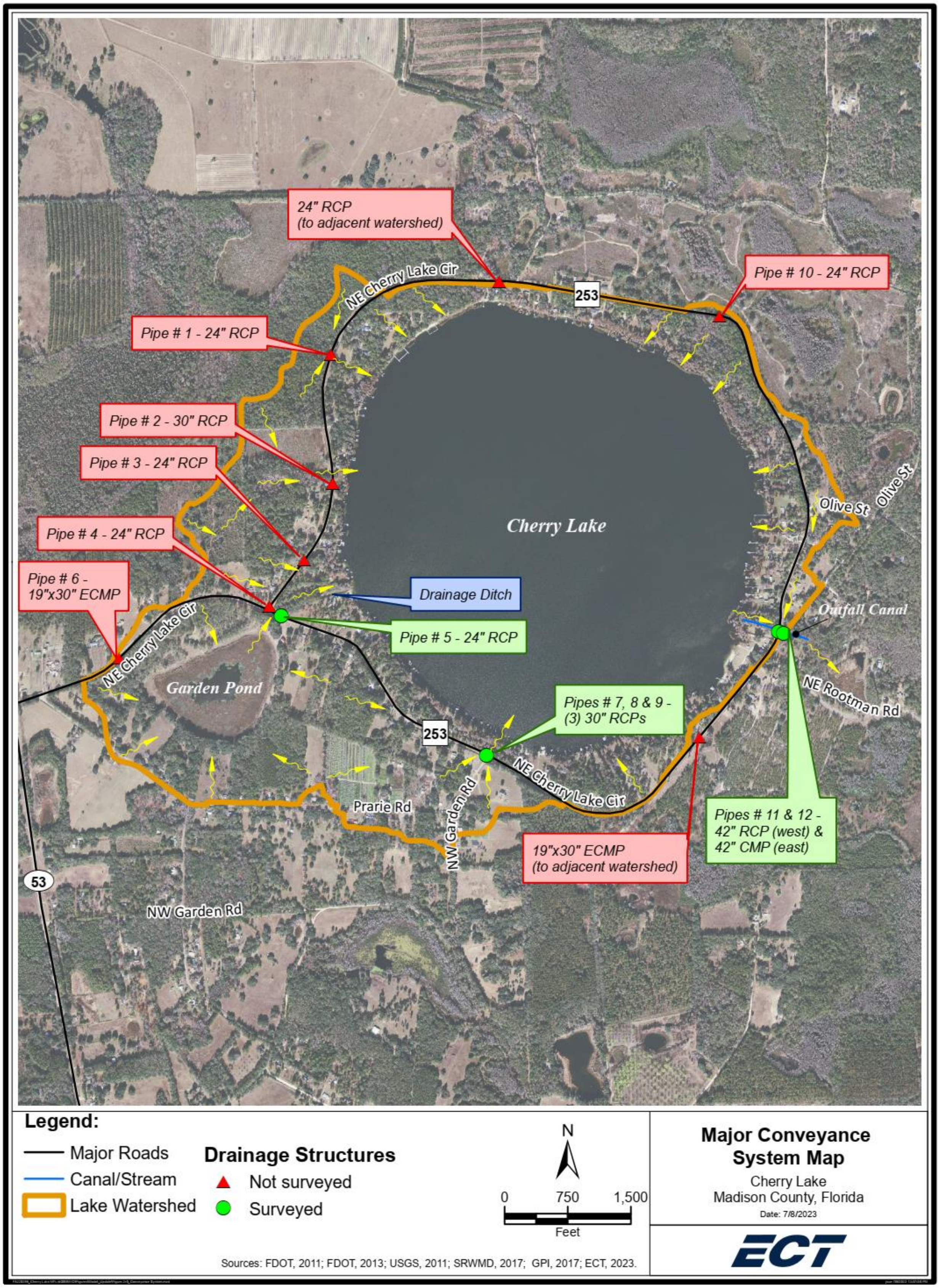


Figure 2-6. Major Conveyance System Map.

3.0 Water Budget Model Development

3.1 Model Selection

To support the development of MFLs in Cherry Lake, a water budget model was required to be developed and calibrated in order to assess the lake's hydrologic changes over a long-term duration 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, requires a predictive computer model to adequately examine the effects of hydrologic changes. The candidate 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 Cherry Lake. 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 based on 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
- 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 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 subbasin boundaries within the model domain were determined by the data available for the existing physical features in the watershed, such as the drainage basin areas by topography, depression areas (e.g., wetlands, ponds, and reservoirs), and structures (e.g., pipes and control structures), which constitute the conveyance system (Figure 3-1).

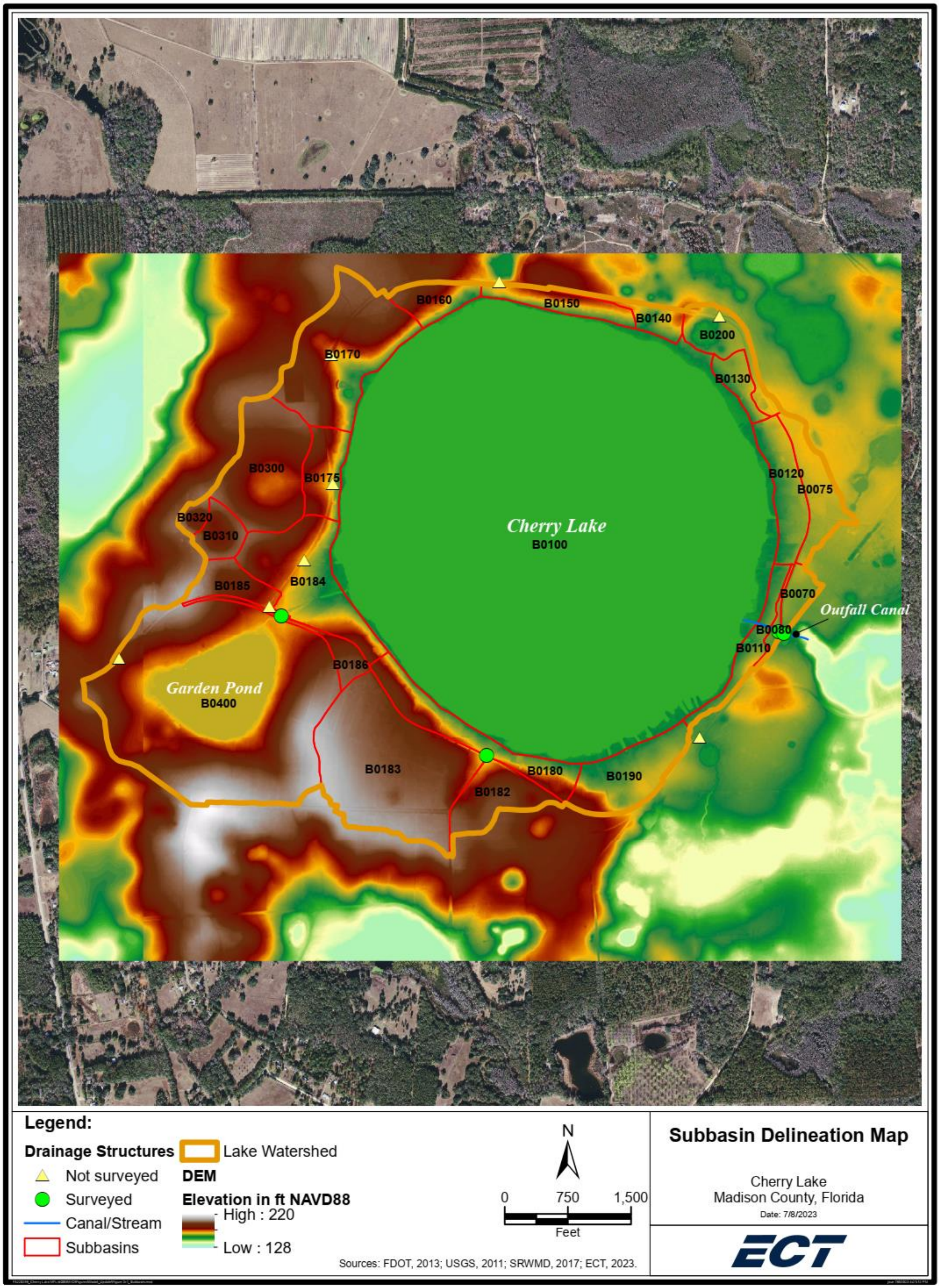
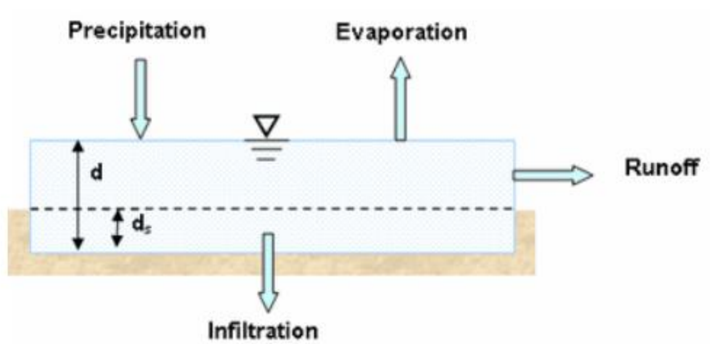


Figure 3-1. Subbasin Delineation Map.

3.2.2 Surface Runoff

The Nonlinear Reservoir Runoff method is used by SWMM, as illustrated in Figure 3-2. 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_s, in which case the outflow is given by Manning’s equation.



Source: EPA SWMM Help File (V5.1.015)

Figure 3-2. Conceptual View of Surface Runoff Used in SWMM.

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 presented in the Cherry Lake watershed. Other parameters used in the 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.

Table 3-1. Lookup table of hydrologic parameters for surface runoff calculation – pre-calibration.

FLUCCS	Description	% Imperv. Area	% 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

Table 3-1. Lookup table of hydrologic parameters for surface runoff calculation – pre-calibration (cont.).

FLUCCS	Description	% Imperv. Area	% Zero Storage Imperv.	Manning n Imperv.	Manning n Perv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)
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
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

Table 3-1. Lookup table of hydrologic parameters for surface runoff calculation – pre-calibration (cont.).

FLUCCS	Description	% Imperv. Area	% Zero Storage Imperv.	Manning n Imperv.	Manning n Perv.	Storage on Imperv. Area Depth (in)	Storage on Perv. Area Depth (in)
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, 2021.

3.2.3 Rainfall

Rain gauges in SWMM supply precipitation data for one or more subcatchments in a study area. Long-term rainfall data was collected from various agencies, including:

- Hourly Next-Generation Radar (NEXRAD) rainfall data by SRWMD (10/1/2007 through 12/31/2015)
- Daily NEXRAD rainfall data by SRWMD (2/1/2001 through 12/31/2015)
- Daily rainfall data (Daymet) by Oak Ridge National Laboratory (ORNL) (1/1/1980 to 12/31/2014) (Thornton *et al.*, 2012)
- Daily rainfall data at various NOAA stations (1/1/1892 to 12/31/2015)

Depending on the simulation duration, one or multiple of the abovementioned data sources may be utilized in the SWMM models. For the 10-year model calibration from 1/1/2006 through 12/31/2015, only the daily NEXRAD rainfall data from SRWMD was utilized as described in Section 4.3.1.1; while for the long-term model simulation from 4/29/1960 through 12/31/2015, the daily rainfall data from SRWMD, ORNL, and NOAA was assembled and used in the model as described in Section 5.2.1.

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

Single or multiple of the abovementioned ET data sources may be utilized in the 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 compared with the Cherry Lake watershed (HGL, 2008; Interflow, 2008).

Using an area-weighted method, a monthly ET pattern can be developed for each aquifer in the Cherry Lake watershed. Cherry Lake was excluded from the estimation of the monthly ET pattern for their corresponding aquifers since the lake surface was treated as a storage unit in SWMM and the direct evaporation from the lake was calculated separately in the hydraulic modeling.

Table 3-2. Lookup table of monthly ET coefficients – pre-calibration.

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

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 method, 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 ($\Delta\theta$), the soil's saturated hydraulic conductivity, and the suction head at the wetting front.

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

Where F is cumulative infiltration, ψ is wetting front soil suction head, and K_t is hydraulic conductivity in in/hr.

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

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.

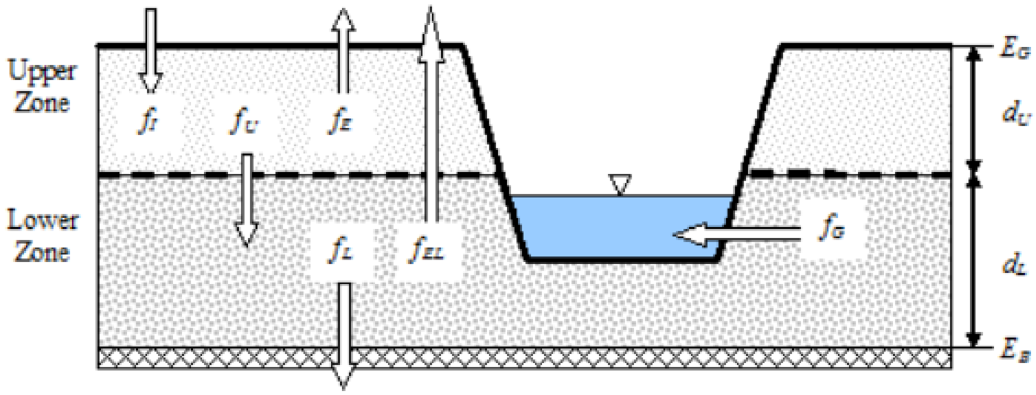
Soil Texture Class	K	Ψ	φ	FC	WP
Sand	4.74	1.93	0.437	0.062	0.024
Loamy Sand	1.18	2.40	0.437	0.105	0.047
Sandy Loam	0.43	4.33	0.453	0.190	0.085
Loam	0.13	3.50	0.463	0.232	0.116
Silt Loam	0.26	6.69	0.501	0.284	0.135
Sandy Clay Loam	0.06	8.66	0.398	0.244	0.136
Clay Loam	0.04	8.27	0.464	0.310	0.187
Silty 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 and Aquifers

As represented in SWMM, aquifers are sub-surface groundwater features used to simulate the downward movement of water from the subcatchments that lie above them. Aquifers also allow flow exchange of groundwater with the drainage system, depending on the hydraulic gradient that exists. Aquifers are only required in 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 Figure 3-3. 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 groundwater loss rate to deep aquifer were developed based on the 2016 North Florida Southeast Georgia (NFSEG) Groundwater Flow Model data developed by SJRWMD (Durden *et al*., 2013; SJRWMD, 2016).



Source: EPA SWMM Help File (V5.1.015)

Figure 3-3. Conceptual View of Two-Zone Groundwater Model Used in SWMM.

Groundwater discharge, f_G, (lateral flow per horizontal area of the groundwater region or cfs/ft^2) represents lateral flow from the saturated zone to elements in the conveyance system. The flux equation for groundwater discharge takes on the following equation:

$$f_G = A1(d_L - h^*)^{B1} - A2(h_{SW} - h^*)^{B2} + A3 d_L I \qquad \text{(E)}$$

where: f_G= groundwater flow rate (cfs/ft^2),
d_L = depth of the lower saturated groundwater zone (ft),
h_{SW}= height of surface water above the bottom of the groundwater zone (ft),
h^*= reference height above the bottom of the groundwater zone (ft),
A1, B1 = groundwater flow coefficient and exponent,
A2, B2 = surface water flow coefficient and exponent,
A3 = surface-groundwater interaction coefficient.

The lower groundwater loss rate parameter (DP) and the depth of the lower saturated groundwater zone (d_L) used in the following equation (Equation D) control deep seepage flow into the upper FAS that is an important part of a lake water budget model.

$$f_L = DP \frac{d_L}{E_G - E_B} \qquad \text{(D)}$$

where: f_L= deep percolation (in/hr),
E_G = ground surface elevation (ft),
E_B = elevation of bottom of lower groundwater zone (ft),
DP = lower groundwater loss rate parameter for percolation to deep groundwater (in/hr).

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
- 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 an open geometry conduit with regular or irregular cross sections. The data for the irregular channel geometry was derived mostly from the survey data by GPI as well as the LiDAR-based DEM data (Figures 2-2A and 2-2B). 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 using LiDAR-based DEM data, aerial photographs, and field evaluations. Channel roughness (Manning's coefficients) values were derived from the SWMM User's Manual and the Hydraulic Reference Manual for HEC-RAS (Brunner, 2010).

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 field surveyed by GPI (Figure 2-6).

The friction loss calculation for the pipes is part of the total head loss, as are 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 using survey data and aerial photos. In addition, if a conduit experienced instability during a simulation, an equivalent conduit (elongated) was automatically generated 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 groundwater loss rates to deep aquifers that account for the upper FAS potentiometric surface level fluctuation, an “outlet” link was used to calculate the groundwater loss rates from the lake into the upper FAS. In SWMM, a user-defined rating curve determines an outlet’s discharge flow as a power function of the head difference across it, i.e., the difference between the water table elevations at the lake and potentiometric surface elevations in the upper FAS (Equation E).

$$Q = A * \Delta H^{B} \quad \text{(E)}$$

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).

The initial coefficient “A” of 0.00027 ft^2/s in this equation was estimated using the following equation (Equation F):

$$A = A_L * K / b \quad \text{(F)}$$

where, A_L = lake surface area at historic normal pool elevation of 151.48 ft NAVD88, which is 21,076,848.8 ft^2,
K = saturated vertical hydraulic conductivity of Intermediate Aquifer System/Intermediate Confining Unit (IAS/ICU), which is 0.00014 ft/day or 1.62E-09 ft/s,
b = distance from the lake bottom to the IAS/ICU bottom, which is 126.48 ft.

The saturated vertical hydraulic conductivity values and the IAS/ICU bottom elevations were derived from the 2016 NFSEG model. The distance from the lake bottom to the IAS/ICU bottom was estimated by calculating the difference between the average lake bottom elevation of 142.30 ft NAVD88 and the IAS/ICU bottom elevation of 15.82 ft NAVD88.

3.3.4 Orifice

Orifices are typically used to model outlet and diversion structures in drainage systems which are typically openings in the wall of a manhole (sewer hole), storage facilities, or control gate. Orifices are internally represented in SWMM as a link connecting two nodes.

In this project, two orifices were used to simulate the small seepage flow through the culvert blockage at the 42” RCP beneath NE Cherry Lake Cir. and the earth berm between a wetland area and the lake.

3.3.5 Weirs

The overtopping of roadways at channel crossings was simulated as broad crested weirs. The weir invert elevations were derived from the ground survey and/or LiDAR-based DEM. 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 and 2.0 were assigned to the paved roads and unpaved roads, respectively, based on our past modeling experience in the District (ECT, 2021).

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 similar stormwater models (e.g., EPA SWMM, HEC-RAS, and ICPR), at subbasin scales in urban and rural areas. Also note that there have been similar recent studies in Florida to use weir coefficients much lower than published values for broad crested weirs (CH2M, 2016). The weir invert elevations were estimated from the LiDAR-based DEM data. Weir coefficients of 1.6 and 1.0 were initially assigned to all the overland flow weirs with land cover of pasture/open land and forest, respectively.

The top of the beaver dam located in the outfall canal and culvert blockage at the 42" RCP beneath NE Cherry Lake Cir. were also modeled as a broad crested weir, with a weir coefficient of 2.0.

3.3.6 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 primarily by using the LiDAR-based DEM data and the bathymetric map provided by GPI (Figures 2-2A and 2-2C).

In addition, the depth-area relationships were modified in the storage nodes for the Garden Pond and the wetland areas. The LiDAR-based DEM data does not offer a reliable estimate of the wetland or lake bottom elevations due to dense vegetation cover and/or standing water. The storage areas at wetland/pond bottom were manually increased to approximate the bare ground surface without vegetation cover or standing water based on review of the LiDAR-based DEM data and aerial photographs.

3.3.7 Initial Conditions

The node initial elevations of the lake and its adjacent wetland areas were adjusted to match stage data measured at the lake. A lake station (USGS 02319150 Cherry Lake) currently operated by the District was used to establish the initial stage at the lake. The initial stage values in other storage areas, junction nodes, and groundwater tables in aquifers were adjusted accordingly.

3.3.8 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 in the outfall canal, located east of CR 253. 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 groundwater loss rates to deep aquifer of the surficial aquifer directly beneath the lake, a second outfall was added to represent the groundwater level in the upper FAS. A long-term USGS groundwater well station "Lovette Tower" (USGS 303400083305385 / SRWMD ID: N020822002), located approximately 6.3 miles southwest of the lake, provides monthly or daily groundwater level data measured in the upper FAS since 6/14/1989. The data gaps in the groundwater database were filled using a linear interpolation method, prior to being utilized in the SWMM model.

3.3.9 Numerical Instability

SWMM is based on the solution of the Saint-Venant equations for unsteady state flow in a 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 include the use of equivalent pipes, adjusting storage junction values, adjusting pipe lengths, adjusting weir lengths, adjusting routing time steps, and selecting to ignore the inertial terms of the momentum equation. In this project, combinations of techniques were employed to achieve model stability.

3.3.10 Model Schematic

The hydraulic model consists of all 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 nodes. These represent the flow and conveyance related elements of the model.

3.4 Preliminary Model Development and Simulation

The Cherry Lake water budget model was developed based on the 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 and hence was also used in the model parameterization in this task.

3.4.1 Hydrologic Model Parameterization

Based on the 2011 LiDAR-based DEM and contour maps (Figures 2-2A and 2-2B) and the major conveyance system map (Figure 2-6), the lake watershed was subdivided into a total of 24 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 this table.

Based on the similarities of the topographic and subsurface character of the 24 subbasins, the subbasin features were further grouped to create a total of 17 aquifers (Figure 3-4). Hydrologic parameters for each aquifer are summarized in Table 3-5.

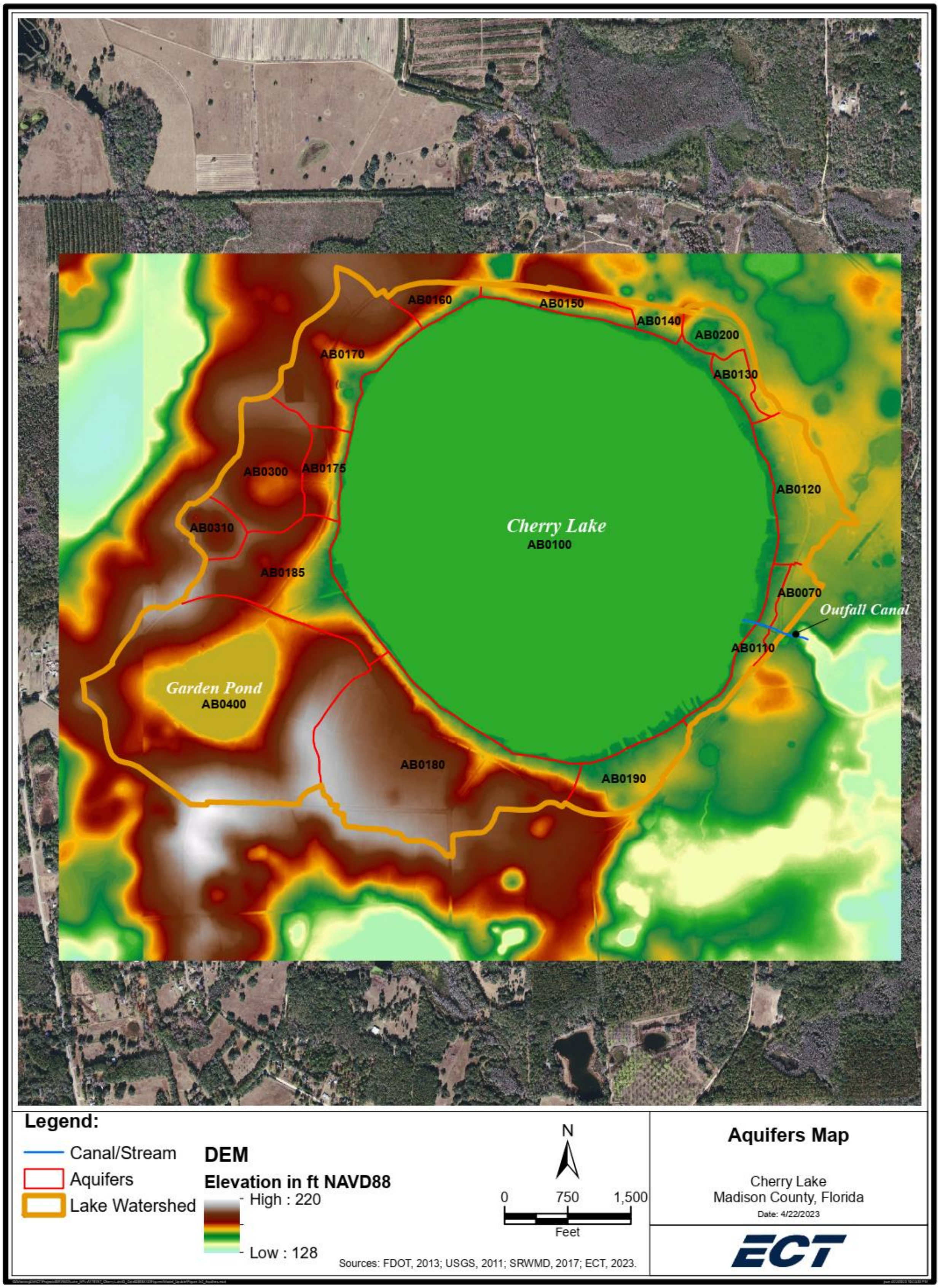


Figure 3-4. Aquifers Map.

Table 3-4. Summary table of hydrologic parameters in subbasins – pre-calibration.

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% Imperv. Area	% 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
B0070	4.88	256	2.21	9.00	25.00	0.050	0.170	0.012	0.100	2.1	3.3493	0.365
B0075	12.62	359	1.77	6.05	25.00	0.050	0.213	0.012	0.231	2.2	2.8171	0.360
B0080	1.89	158	3.77	9.00	25.00	0.050	0.170	0.012	0.100	2.2	2.5883	0.358
B0100	511.89	135046	1.50	94.98	95.90	0.003	0.011	0.012	0.104	2.1	3.7755	0.368
B0110	8.66	1442	2.77	9.00	25.00	0.050	0.170	0.012	0.100	2.1	3.2453	0.364
B0120	13.95	1731	2.29	9.00	25.00	0.050	0.192	0.012	0.188	2.1	3.4506	0.365
B0130	5.52	765	2.70	5.22	25.00	0.050	0.248	0.012	0.361	2.0	4.3803	0.373
B0140	5.77	424	3.70	11.54	25.93	0.051	0.210	0.019	0.261	2.3	1.8083	0.352
B0150	9.12	1654	5.36	26.77	25.00	0.050	0.160	0.012	0.126	2.0	4.5402	0.374
B0160	8.23	769	4.58	1.00	25.00	0.050	0.286	0.012	0.455	1.9	4.6378	0.375
B0170	39.25	1744	3.80	4.24	25.00	0.050	0.239	0.012	0.312	2.3	4.4125	0.364
B0175	10.84	857	4.89	5.69	25.00	0.050	0.218	0.012	0.247	1.9	4.6353	0.375
B0180	19.00	2589	5.40	8.20	25.00	0.050	0.182	0.012	0.135	2.0	4.3715	0.373
B0182	14.32	672	3.26	3.47	25.00	0.050	0.205	0.012	0.165	2.2	2.6127	0.359
B0183	57.39	1234	2.01	5.48	25.00	0.050	0.210	0.012	0.203	2.2	4.2439	0.368
B0184	30.50	1328	3.77	7.29	25.00	0.050	0.212	0.012	0.233	1.9	4.6378	0.375
B0185	8.65	331	2.92	14.86	25.00	0.050	0.174	0.012	0.130	2.3	4.0165	0.364
B0186	6.05	250	3.56	14.83	25.00	0.050	0.178	0.012	0.146	2.2	4.2375	0.368
B0190	18.85	1569	2.66	6.96	25.00	0.050	0.199	0.012	0.191	2.0	3.8910	0.369
B0200	11.19	991	3.70	18.08	42.52	0.068	0.277	0.148	0.450	2.2	2.8853	0.361
B0300	29.89	1700	2.35	8.33	33.18	0.058	0.290	0.075	0.477	2.1	3.4281	0.365

Table 3-4. Summary table of hydrologic parameters in subbasins – pre-calibration (cont.).

Subbasin Name	Area (Acre)	Width (feet)	% Slope	% Imperv. Area	% 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
B0310	6.74	819	3.31	0.00	25.00	0.050	0.300	0.012	0.500	2.6	2.4056	0.349
B0320	2.57	494	4.46	0.00	25.00	0.050	0.300	0.012	0.500	4.2	0.5078	0.304
B0400	126.85	4780	2.42	16.88	38.63	0.059	0.239	0.063	0.299	2.3	3.9844	0.364

Table 3-5. Summary table of hydrologic parameters in aquifers – pre-calibration.

Aquifer	Porosity	Wilting Point	Field Capacity	Conductivity (in/hr)	Conductivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	DP (GW Loss to Deep Aquifer)* (in/hr)	Bottom Elev. (ft NAVD88)	Water Table Elev. (ft NAVD88)	Unsat. Zone Moisture
AB0070	0.4101	0.0543	0.1374	3.0609	5.3036	15	1.0	12.06	0.000126	121.77	158.23	0.15
AB0100	0.4130	0.0525	0.1300	3.1482	5.1744	15	1.0	13.23	0.000000	122.38	151.50	0.15
AB0110	0.4106	0.0540	0.1361	3.0505	5.2817	15	1.0	10.77	0.000063	121.78	155.81	0.15
AB0120	0.4101	0.0543	0.1372	3.0836	5.3010	15	1.0	13.74	0.000064	123.98	159.67	0.15
AB0130	0.4158	0.0507	0.1230	3.1524	5.0521	15	1.0	12.67	0.000059	125.24	157.97	0.15
AB0140	0.4039	0.0582	0.1527	3.1875	5.5723	15	1.0	12.82	0.000059	124.92	162.95	0.15
AB0150	0.4165	0.0503	0.1211	3.2033	5.0197	15	1.0	13.35	0.000060	124.14	164.87	0.15
AB0160	0.4170	0.0500	0.1200	3.2750	5.0000	15	1.0	13.05	0.000452	123.08	174.61	0.15
AB0170	0.4123	0.0573	0.1327	3.2649	5.1953	15	1.0	13.25	0.000340	116.47	181.64	0.15
AB0175	0.4170	0.0500	0.1200	3.2202	5.0005	15	1.0	12.94	0.000060	122.92	173.55	0.15
AB0180	0.4149	0.0523	0.1296	3.1137	5.2200	15	1.0	13.70	0.000258	122.48	189.47	0.15
AB0185	0.4168	0.0507	0.1229	3.2098	5.0816	15	1.0	15.23	0.000333	116.93	174.78	0.15
AB0190	0.4135	0.0522	0.1286	3.0499	5.1511	15	1.0	12.65	0.000064	121.81	160.44	0.15
AB0200	0.4089	0.0551	0.1403	3.1611	5.3545	15	1.0	12.54	0.000058	125.40	158.50	0.15
AB0300	0.4114	0.0535	0.1340	3.2260	5.2451	15	1.0	14.38	0.000240	118.83	186.12	0.15
AB0310	0.4101	0.0611	0.1687	3.2365	6.2276	15	1.0	17.02	0.000625	111.36	191.56	0.15
AB0400	0.4162	0.0530	0.1337	3.1762	5.3801	15	1.0	13.27	0.000528	121.04	181.27	0.15

** Groundwater loss to deep aquifer in Aquifer AB0100, beneath Cherry Lake, was simulated via an outlet link in the SWMM model, see Section 3.3.3.*

3.4.2 Hydraulic Model Parameterization

There is a total of 18 nodes in the conveyance system, including 12 "storage nodes" representing wetlands, lakes, and ponds, four "junction nodes" representing the confluence of natural channels, manholes in a drainage system, or pipe connection fittings, and two "outfall nodes" representing the model boundaries at the outfall canal and the upper FAS (Figure 3-5).

There is a total of 26 reaches, including four open channels, six pipes or culverts, two orifices, 13 weirs representing the road overtopping, beaver dam and culvert blockage in the outfall canal, and the sheet flow between subbasins, and one outlet representing groundwater loss to deep aquifer at the lake (Figure 3-5).

3.4.3 Subbasin, Aquifer, Node, and Reach Naming Convention

A total of 5 characters were used to name the subbasins. For example, a subbasin name can be designated as "B0100." The first left character "B" indicates one of the subwatershed areas (tributary). For the Cherry Lake watershed, there is only one subwatershed area. The remaining four-character fields are reserved for numbering of the subbasins within the subwatershed (Figure 3-1).

A total of 6 characters were used to name 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 3-4).

A total of 6 characters were used to name 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 "NB0100" would be used at the loading node of subbasin "B0100" and its downstream connecting reach would have the name "RB0100XX." 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 "NB0090" while the next reach will be named "RB0090XX" due to 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, "O" for orifices, and "T" for outlets. The second "X" is used only when there are more than one of the same type of reaches discharging from a node. For example, "RB0183P2" would be used for naming the second culvert that discharge node "NB0183" (Figure 3-5).

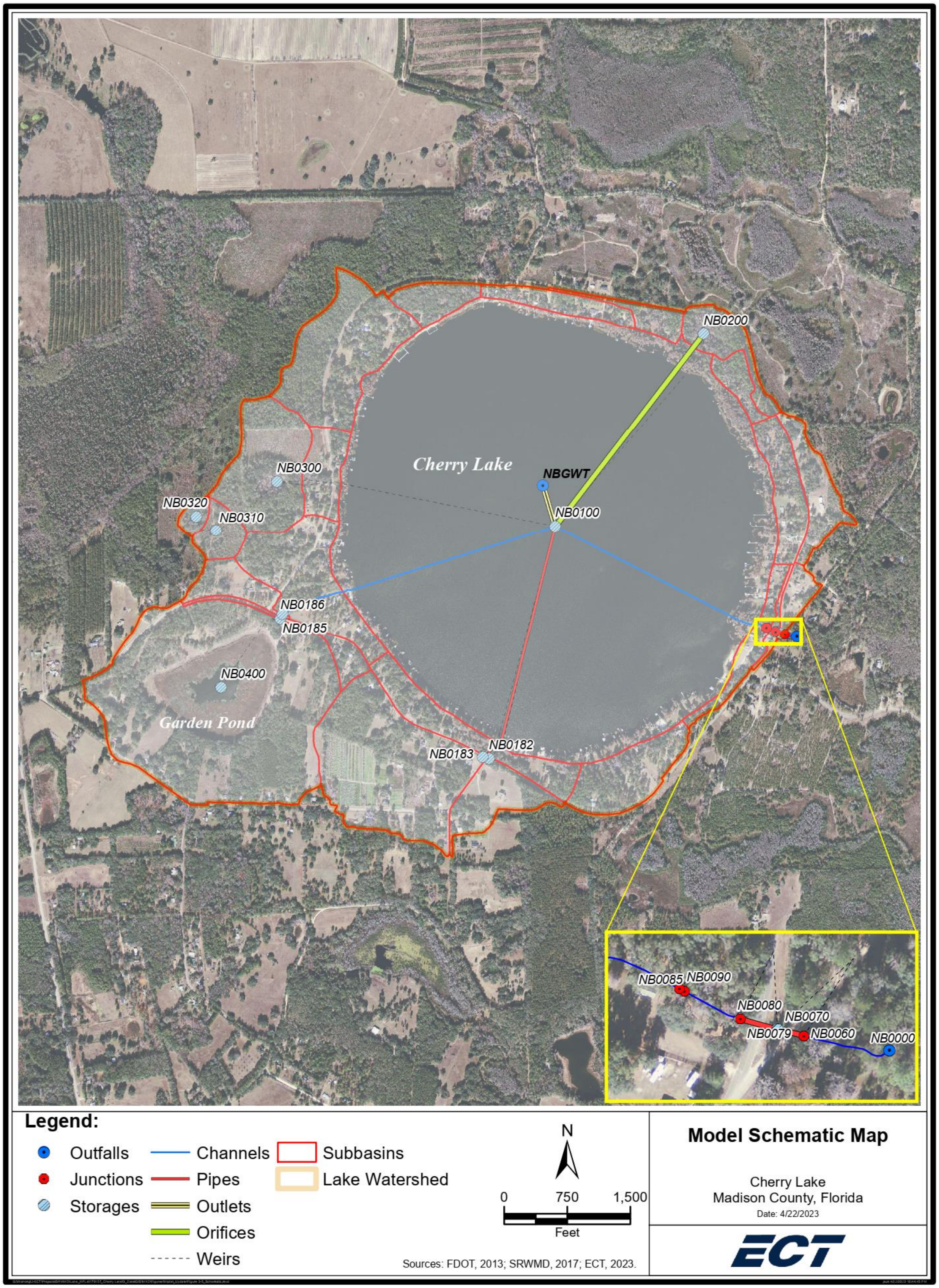


Figure 3-5. Model Schematic Map.

3.4.4 Preliminary Model Simulation

Model parameterization was conducted primarily in ArcGIS, and the resultant parameters for hydrologic and hydraulic features were converted into the input file of the SWMM model. A randomly picked period, from 1/1/2014 through 12/31/2015 in this case, was simulated to identify any potential errors or omissions in this preliminary model.

The preliminary model results were briefly checked by plotting and comparing the simulated and observed node stage hydrographs at Node NB0100 or Cherry Lake (Figure 3-6). As observed in this comparison plot, 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 Cherry Lake was developed to simulate the major hydrologic and hydraulic features in the lake watershed. The simulation results for the two-year test run were considered reasonable and adequate.

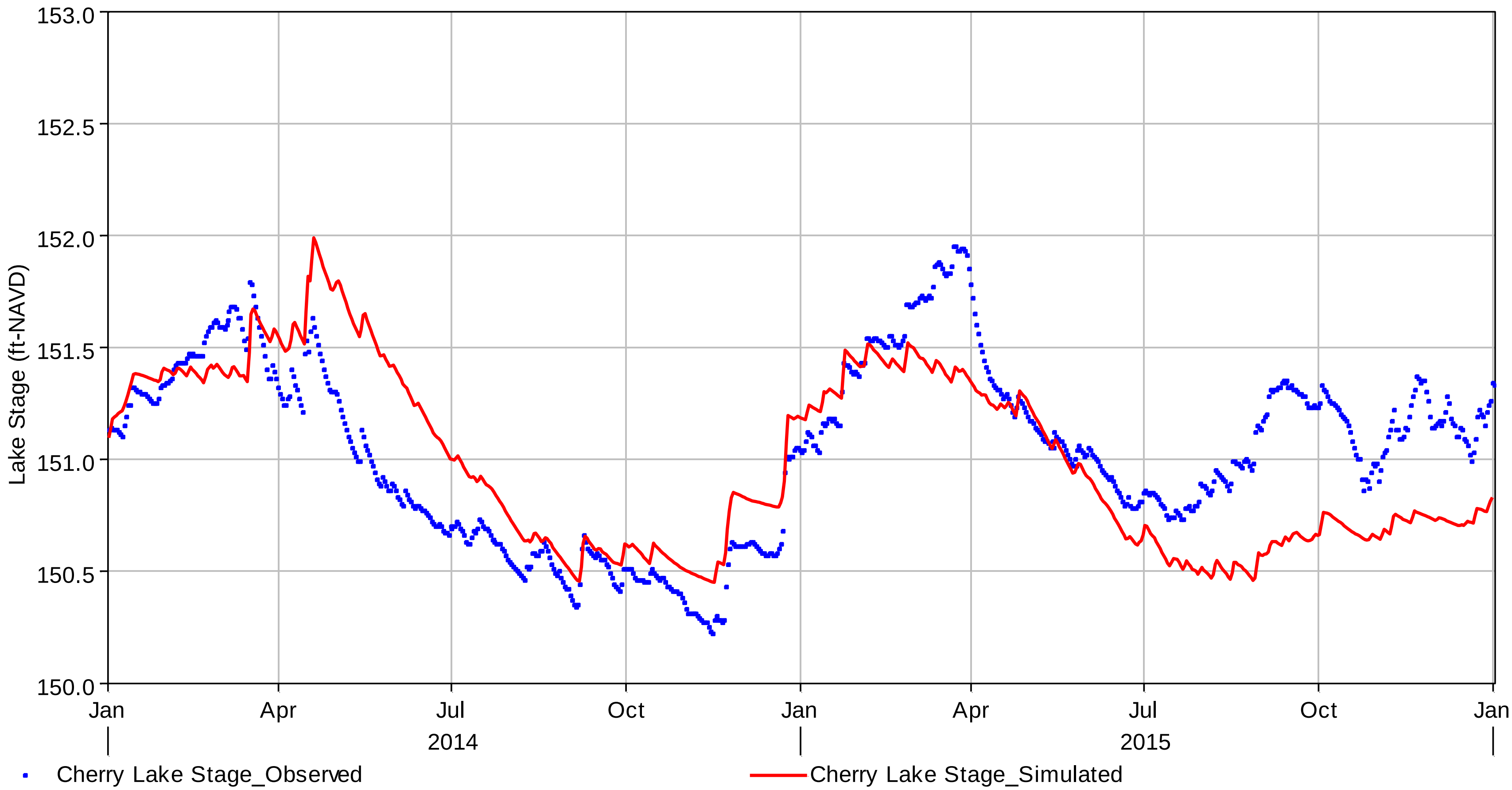


Figure 3-6. Comparison of Observed and Simulated Lake Stage Hydrographs at Cherry Lake (2014-2015).

4.0 Water Budget Model Calibration

4.1 Model Calibration Period

The water budget model for Cherry Lake 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 Cherry Lake. 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 to compare observed and simulated values for calibration of a water budget model. The water budget model was to be used for determining the effects of consumptive use withdrawals on lake stages. Therefore, the model's capability to predict or simulate lake stages was assessed by calibration against known gauge data. Flow data for lake inflows and outflows could have been used to improve the calibration results and verify water balance; however, there was no such flow data available for calibration.

The primary criterion or goal for model calibration was 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 secondary criteria were developed 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

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, provided 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 gauges were used to represent the selected NEXRAD pixels that supply daily rainfall data. The rain gauge specific to each subcatchment is the pixel that contains the centroid point of the subcatchment.

4.3.1.2 Evapotranspiration

Daily PET data used for model calibration was developed by USGS for a period from 6/1/1995 through 12/31/2015, based on 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 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 2015 (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 47.57 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.

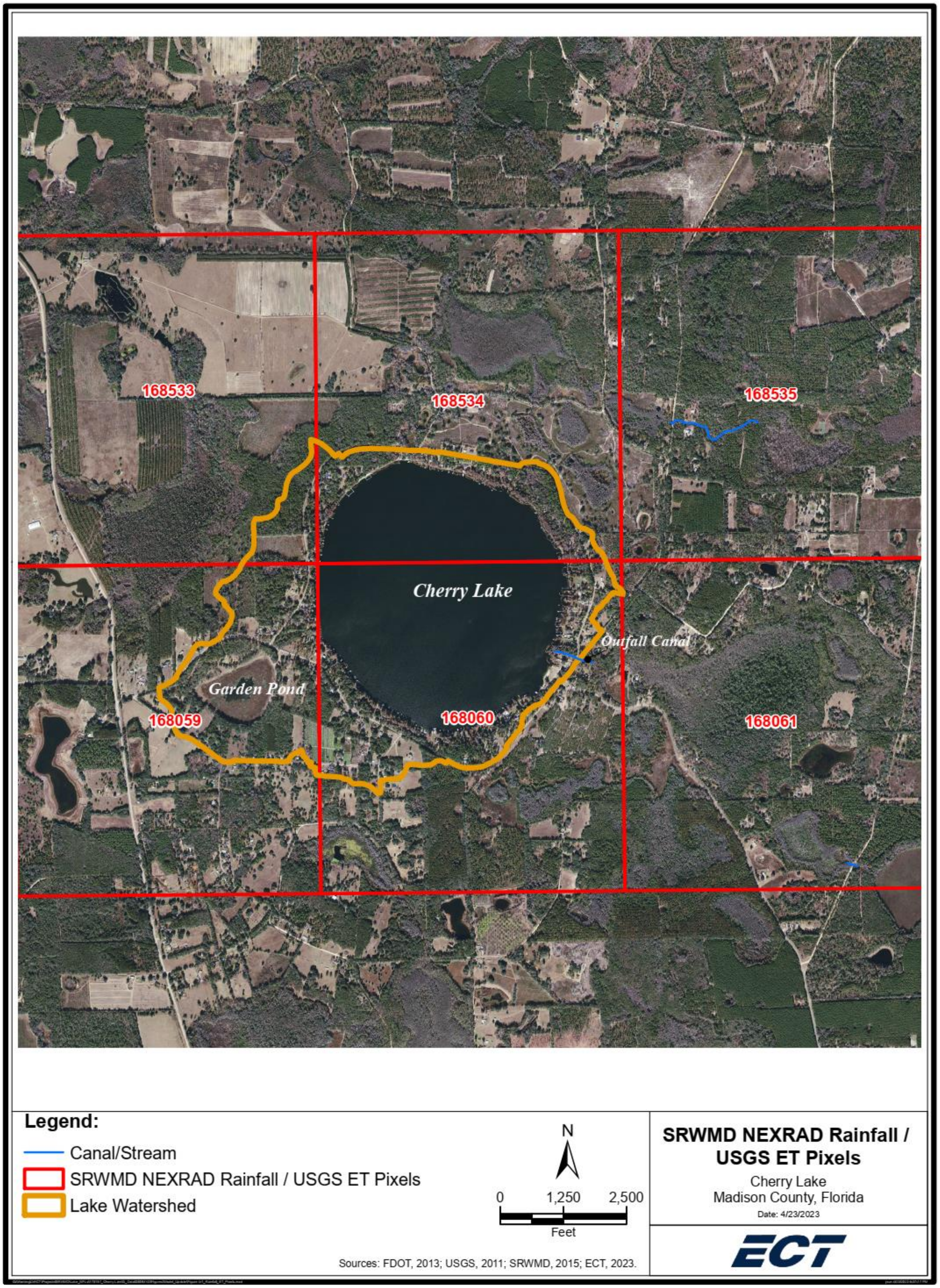


Figure 4-1. SRWMD NEXRAD Rainfall / USGS ET Pixels.

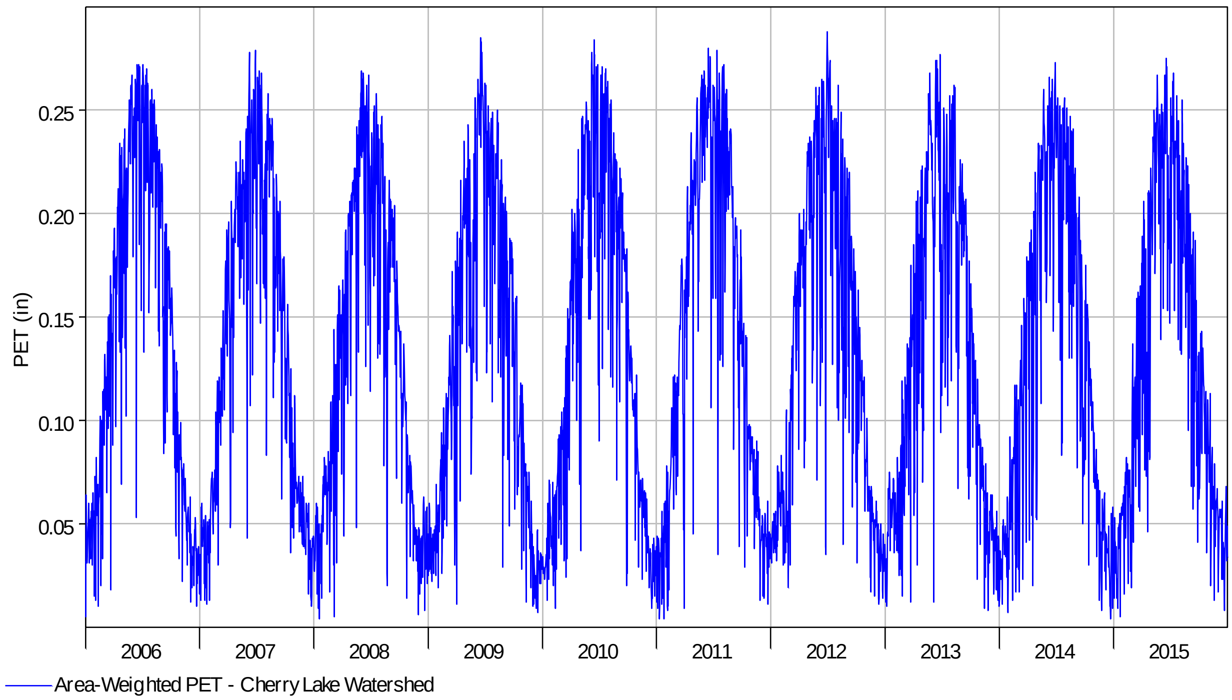


Figure 4-2. Area-Weighted Daily Potential Evapotranspiration (2006-2015).

Table 4-1. Summary table of average monthly PET data for Cherry Lake watershed (1996-2015).

Month	PET Value (inch/month)
January	1.28
February	1.86
March	3.44
April	4.83
May	6.43
June	6.33
July	6.67
August	6.07
September	4.59
October	3.22
November	1.74
December	1.10
Total	**47.57**

Sources: USGS, 2016.

4.3.1.3 Upper FAS Potentiometric Surface Levels

A long-term USGS groundwater well station “Lovette Tower” (USGS 303400083305301 / SRWMD ID: N020822002) is located approximately 6.3 miles southwest of Cherry Lake (Figure 4-3). The USGS Lovette Tower station provides monthly or daily potentiometric surface levels in the upper FAS since 6/14/1989. The data gaps in the raw data were filled using a linear interpolation method. Cherry Lake 4H Camp station (SRWMD ID: N030933004), located at the 4H Camp near the west lakeshore, is a short-term groundwater well station operated by the District since August 2018 (Figure 4-3).

The groundwater levels at the Cherry Lake 4H Camp station were developed by using the long-term groundwater dataset at the USGS Lovette Tower station and a regression curve developed between the USGS Lovette Tower and Cherry Lake 4H Camp stations. A total of 1,295 groundwater level data pairs between 8/1/2018 and 2/15/2021 were used in the regression analysis. The R^2 value is 0.70 for the resultant non-linear regression curve (Figure 4-4).

Upon applying the regression curve to the observed/filled daily groundwater well levels at the Lovette Tower station, the estimated daily groundwater level data at the Cherry Lake 4H Camp station would be more representative of the groundwater conditions beneath Cherry Lake. The observed/filled groundwater level hydrograph at the USGS Lovette Tower station as well as the estimated groundwater level hydrograph at the Cherry Lake 4H Camp station are plotted in Figure 4-5.

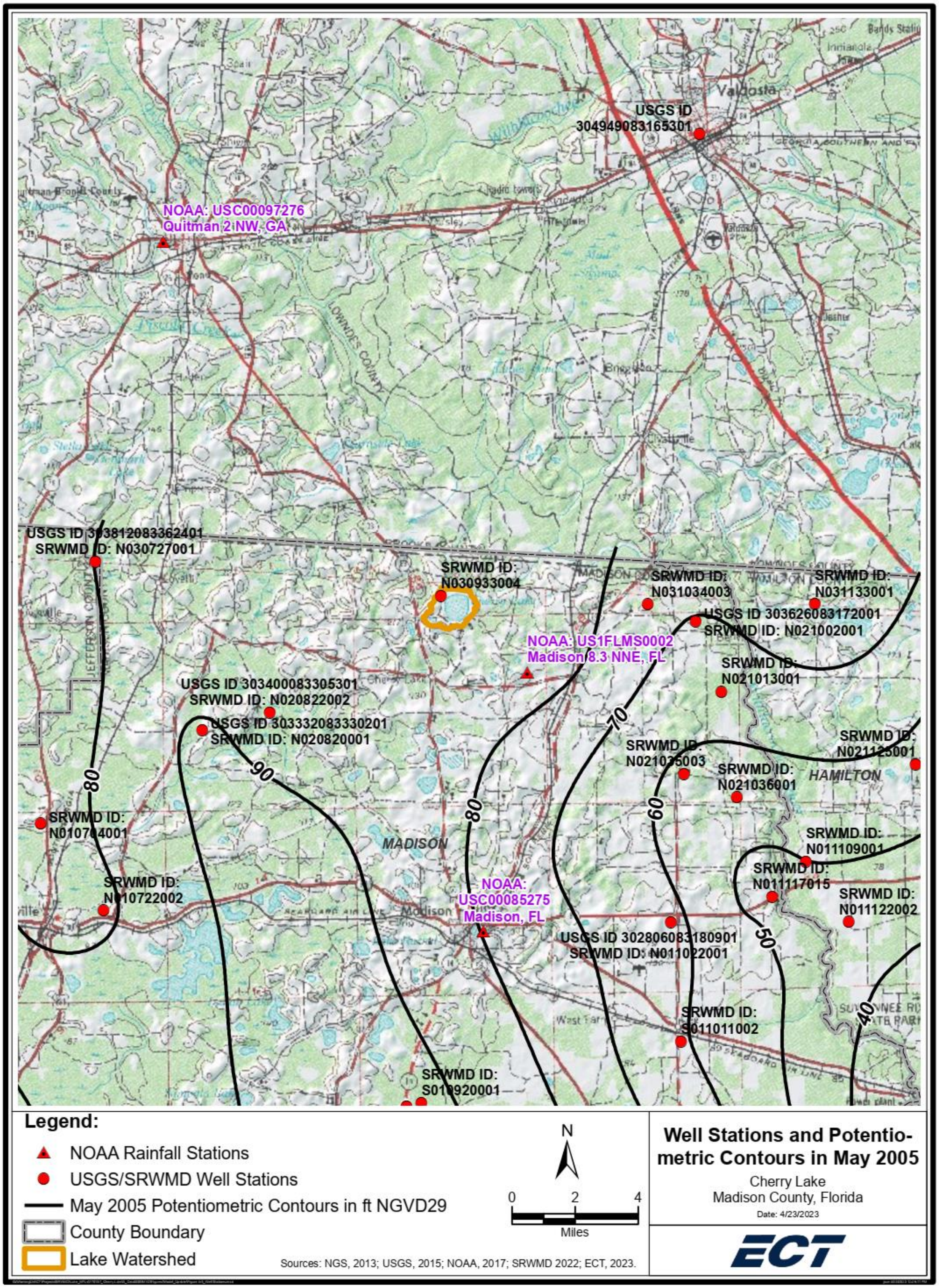


Figure 4-3. Well Stations and Potentiometric Contours in May 2005.

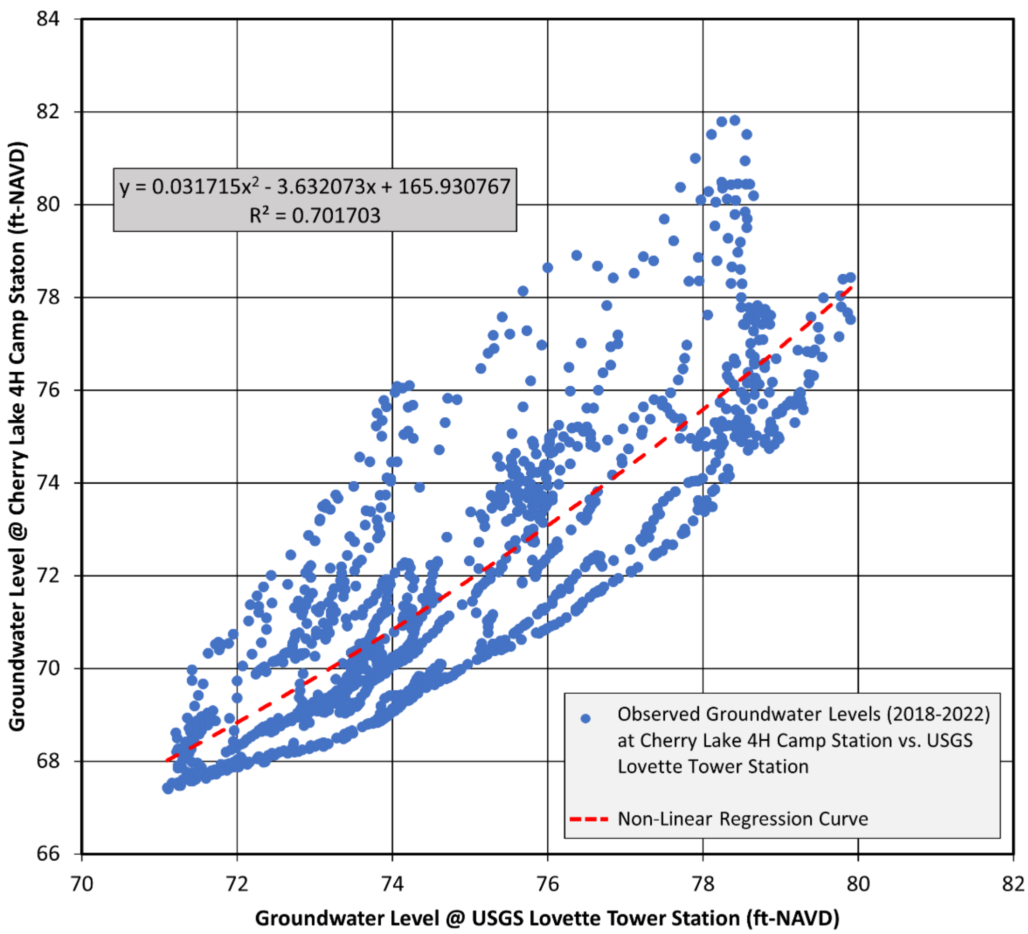


Figure 4-4. Correlation Analysis of Groundwater Levels – USGS Lovette Tower Station vs. Cherry Lake 4H Camp Station (2018-2022).

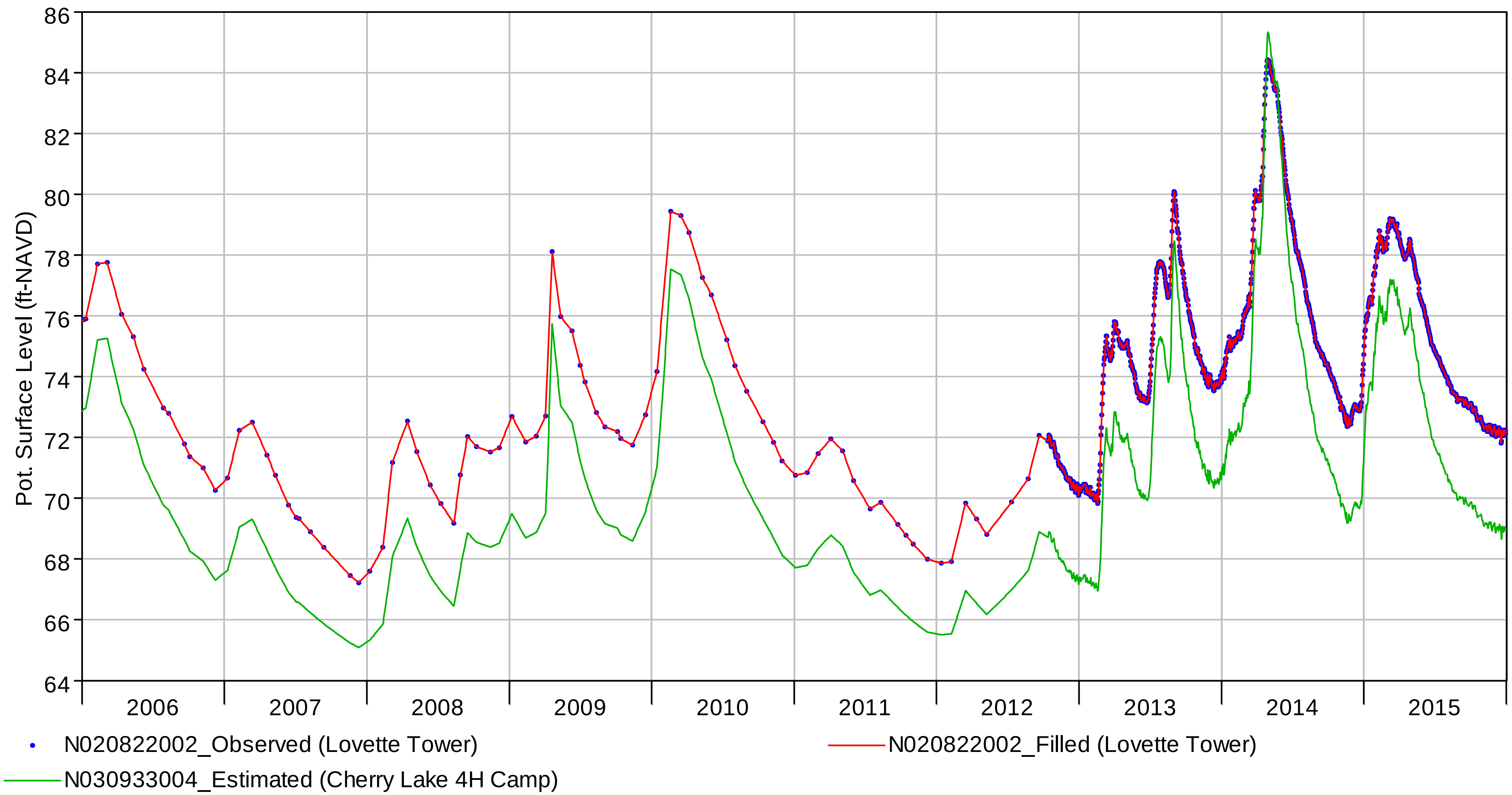


Figure 4-5. Observed/Filled Groundwater Level Hydrographs at USGS Lovette Tower Station and Estimated Groundwater Level Hydrograph at Cherry Lake 4H Camp Station (2006-2015).

4.3.1.4 Lake Stages

USGS 02319150 Cherry Lake is a long-term stage gauge located at a wood dock on the west lakeshore (Figure 4-6). This District-operated lake stage station provides the long-term historical lake stage values in a variety of frequencies from 1974 to the present (Figure 4-7A). The lake stage records were used to establish the initial stage value at the lake 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 recent daily stage records (3/29/2013 to 12/31/2015) were resampled to weekly stage values (Figure 4-7B). 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.

Figure 4-6. USGS/SRWMD Lake Stations.

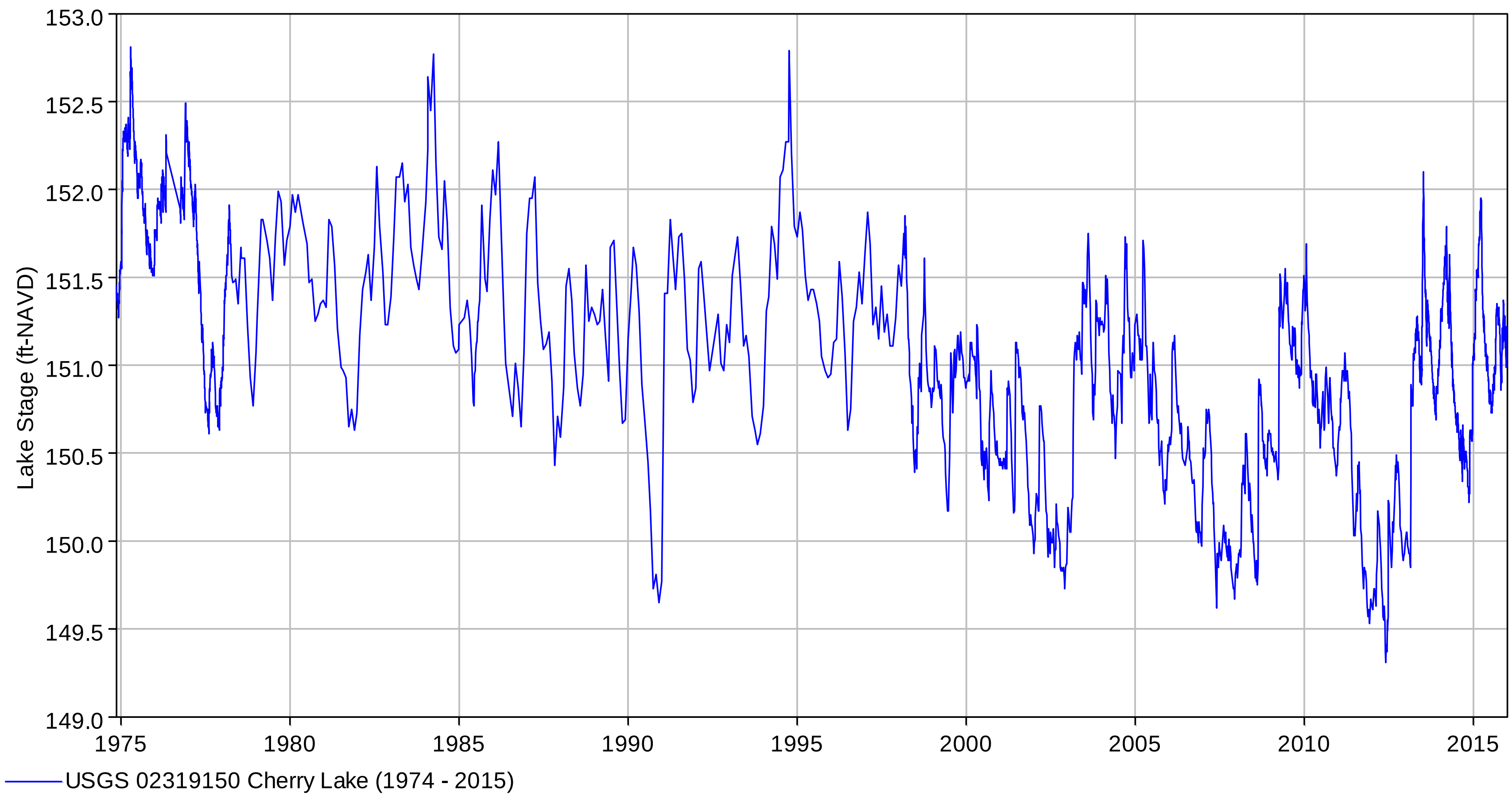


Figure 4-7A. Observed Lake Stage Hydrograph at Cherry Lake (1974-2015).

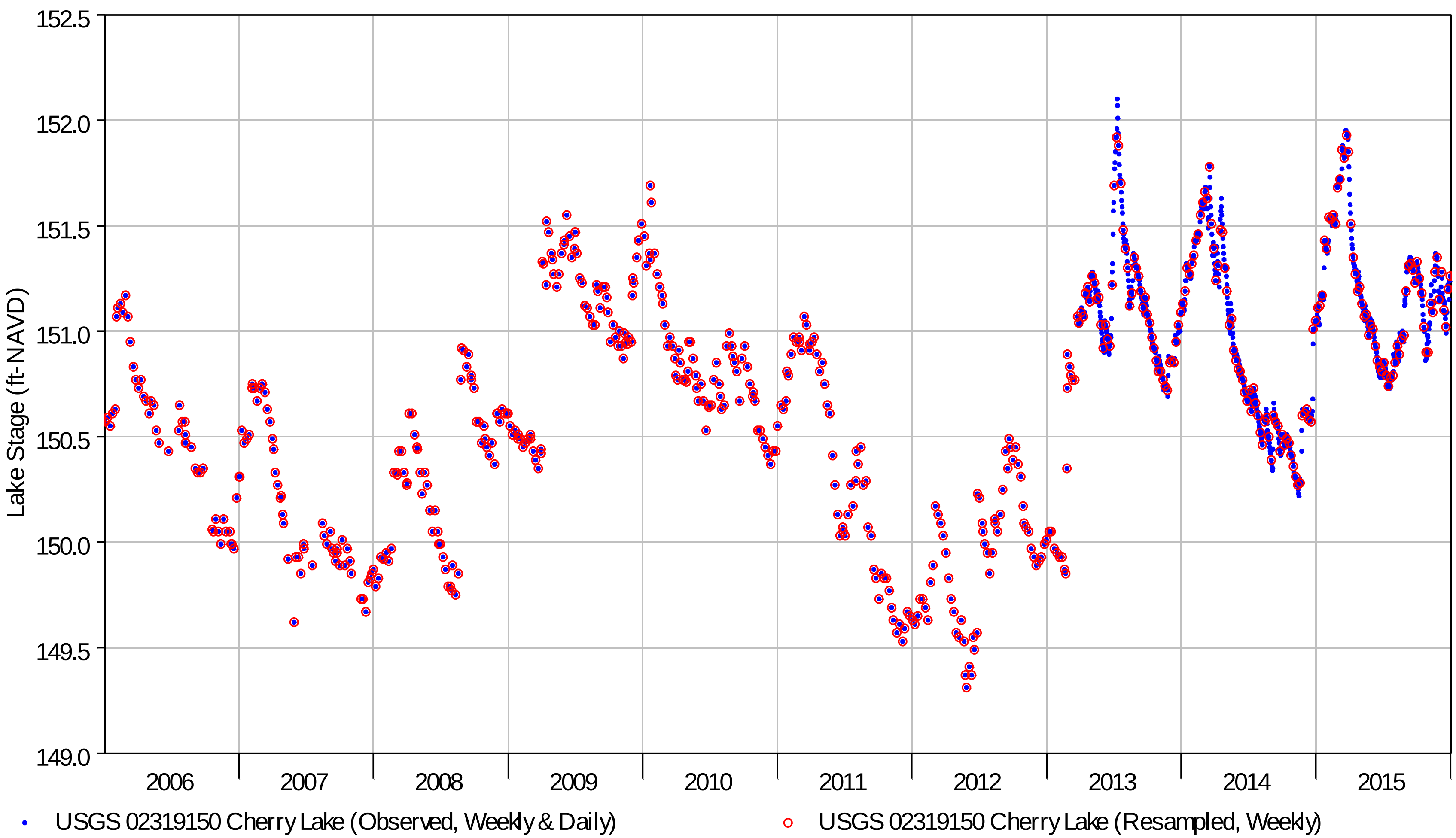


Figure 4-7B. Observed and Resampled Lake Stage Hydrographs at Cherry Lake (2006-2015).

4.3.2 Adjustment of Hydrologic Model Parameters

Various hydrologic model parameters were adjusted during the model calibration process, including impervious percentage, groundwater loss rate to deep aquifer, 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 Land Use/Land Cover

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 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 herbaceous wetland area surrounding the Garden Pond. 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 (Figure 4-7B).

Therefore, impervious percentage values for wetland areas were reduced to 50% to account for low rainfall periods, as highlighted in yellow color in the updated lookup table (Table 4-2).

Also note that at developed lands, in addition to a land use code (e.g., FLUCCS 1100-Residential Low Density), a separate land cover code (e.g., FLUCCS 4340-Hardwood Conifer Mixed) was provided in the land use data to describe the vegetative community type of the pervious area (Figure 2-5). For these instances, the hydrologic parameters related to pervious area (e.g., Manning's n for pervious area) were assigned based on their land cover codes when calculating the hydrologic parameters for subbasins.

Based on the updated lookup table (Table 4-2) as well as the improved approach of applying both land use and land cover codes, the hydrologic parameters for each subbasin were recalculated, as highlighted in yellow color in Table 4-3, and updated in the SWMM model. The revised hydrologic parameters for the subbasins were then held constant in the model calibration.

Table 4-2. Lookup table of hydrologic parameters for surface runoff calculation – final.

FLUCCS	Description	% Imperv. Area	% 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	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

Table 4-2. Lookup table of hydrologic parameters for surface runoff calculation-final (cont.)

FLUCCS	Description	% Imperv. Area	% 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)	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, 2022.

Table 4-3. 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
B0070	4.88	256	2.21	15.00	25.00	0.050	0.200	0.012	0.100	2.1	3.3493	0.365
B0075	12.62	359	1.77	10.08	25.00	0.050	0.233	0.012	0.231	2.2	2.8171	0.360
B0080	1.89	158	3.77	15.00	25.00	0.050	0.200	0.012	0.100	2.2	2.5883	0.358
B0100	511.89	135046	1.50	95.27	95.90	0.003	0.013	0.012	0.108	2.1	3.7755	0.368
B0110	8.66	1442	2.77	15.00	25.00	0.050	0.200	0.012	0.100	2.1	3.2453	0.364
B0120	13.95	1731	2.29	15.00	25.00	0.050	0.255	0.012	0.320	2.1	3.4506	0.365
B0130	5.52	765	2.70	8.70	25.00	0.050	0.300	0.012	0.500	2.0	4.3803	0.373
B0140	5.77	424	3.70	16.31	25.93	0.051	0.282	0.019	0.452	2.3	1.8083	0.352
B0150	9.12	1654	5.36	27.61	25.00	0.050	0.172	0.012	0.160	2.0	4.5402	0.374
B0160	8.23	769	4.58	1.67	25.00	0.050	0.289	0.012	0.455	1.9	4.6378	0.375
B0170	39.25	1744	3.80	7.06	25.00	0.050	0.253	0.012	0.312	2.3	4.4125	0.364
B0175	10.84	857	4.89	9.48	25.00	0.050	0.237	0.012	0.247	1.9	4.6353	0.375
B0180	19.00	2589	5.40	13.67	25.00	0.050	0.209	0.012	0.135	2.0	4.3715	0.373
B0182	14.32	672	3.26	5.79	25.00	0.050	0.216	0.012	0.165	2.2	2.6127	0.359
B0183	57.39	1234	2.01	8.04	25.00	0.050	0.223	0.012	0.203	2.2	4.2439	0.368
B0184	30.50	1328	3.77	10.93	25.00	0.050	0.230	0.012	0.233	1.9	4.6378	0.375
B0185	8.65	331	2.92	18.54	25.00	0.050	0.192	0.012	0.130	2.3	4.0165	0.364
B0186	6.05	250	3.56	18.18	25.00	0.050	0.195	0.012	0.146	2.2	4.2375	0.368
B0190	18.85	1569	2.66	11.60	25.00	0.050	0.223	0.012	0.191	2.0	3.8910	0.369
B0200	11.19	991	3.70	18.45	42.52	0.068	0.282	0.148	0.465	2.2	2.8853	0.361
B0300	29.89	1700	2.35	8.44	33.18	0.058	0.290	0.075	0.477	2.1	3.4281	0.365

Table 4-3. 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
B0310	6.74	819	3.31	0.00	25.00	0.050	0.300	0.012	0.500	2.6	2.4056	0.349
B0320	2.57	494	4.46	0.00	25.00	0.050	0.300	0.012	0.500	4.2	0.5078	0.304
B0400	126.85	4780	2.42	17.62	38.63	0.059	0.243	0.063	0.301	2.3	3.9844	0.364

4.3.2.2 Groundwater and Aquifers

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

Monthly ET coefficients were adjusted for Urban-Low Density and Upland Forests (the dominant land uses in the upland areas of the lake watershed), based on the initial calibration model run results. The ET coefficients were kept constant for the subsequent model calibration runs (Table 4-5).

The coefficients (A1, A2, B1, B2, and A3) used in Equation C that computes lateral groundwater flow were adjusted during the initial model runs to obtain reasonable groundwater levels in the aquifers and flows between the aquifers and the receiving storage nodes. The historic aerial photographs from Google Earth were also visually checked to ensure that the simulated water levels at Garden Pond and various isolated wetlands were not overestimated or underestimated due to inadequate coefficients applied in this equation. These coefficients were kept constant for the subsequent model calibration runs (Table 4-6).

DP used in Equation D that computers deep seepage flow into the upper FAS is one of the few primary parameters that were adjusted in a series of runs during model calibration. The final calibrated DP are highlighted in yellow color in Table 4-4.

Note that the groundwater loss to deep aquifer in Aquifer AB0100 was modeled as an “outlet” link in the SWMM model, as discussed in Section 3.3.3. Using a constant DP for other aquifers seems reasonable, based on the simulated flows at Outlet RB0100T, which vary from 0.241 cfs to 0.309 cfs with an average value of 0.293 cfs (Figure 4-8).

Table 4-4. Summary table of hydrologic parameters in aquifers – final.

Aquifer	Porosity	Wilting Point	Field Capacity	Conductivity (in/hr)	Conductivity Slope	Tension Slope	Upper Evap. Fraction	Lower Eva. Depth (ft)	DP (GW Loss to Deep Aquifer)* (in/hr)	Bottom Elev. (ft NAVD88)	Water Table Elev. (ft NAVD88)	Unsat. Zone Moisture
AB0070	0.4101	0.0543	0.1374	3.0609	5.3036	15	1.0	12.06	0.000126	121.77	158.23	0.140
AB0100	0.4130	0.0525	0.1300	3.1482	5.1744	15	1.0	13.23	0.000000	122.38	151.50	0.130
AB0110	0.4106	0.0540	0.1361	3.0505	5.2817	15	1.0	10.77	0.000063	121.78	155.81	0.140
AB0120	0.4101	0.0543	0.1372	3.0836	5.3010	15	1.0	13.74	0.000064	123.98	159.67	0.140
AB0130	0.4158	0.0507	0.1230	3.1524	5.0521	15	1.0	12.67	0.000059	125.24	157.97	0.125
AB0140	0.4039	0.0582	0.1527	3.1875	5.5723	15	1.0	12.82	0.000059	124.92	162.95	0.153
AB0150	0.4165	0.0503	0.1211	3.2033	5.0197	15	1.0	13.35	0.000060	124.14	164.87	0.125
AB0160	0.4170	0.0500	0.1200	3.2750	5.0000	15	1.0	13.05	0.000452	123.08	174.61	0.125
AB0170	0.4123	0.0573	0.1327	3.2649	5.1953	15	1.0	13.25	0.000340	116.47	181.64	0.138
AB0175	0.4170	0.0500	0.1200	3.2202	5.0005	15	1.0	12.94	0.000060	122.92	173.55	0.125
AB0180	0.4149	0.0523	0.1296	3.1137	5.2200	15	1.0	13.70	0.000258	122.48	189.47	0.130
AB0185	0.4168	0.0507	0.1229	3.2098	5.0816	15	1.0	15.23	0.000333	116.93	174.78	0.125
AB0190	0.4135	0.0522	0.1286	3.0499	5.1511	15	1.0	12.65	0.000064	121.81	160.44	0.133
AB0200	0.4089	0.0551	0.1403	3.1611	5.3545	15	1.0	12.54	0.000580	125.40	158.50	0.145
AB0300	0.4114	0.0535	0.1340	3.2260	5.2451	15	1.0	14.38	0.002400	118.83	186.12	0.138
AB0310	0.4101	0.0611	0.1687	3.2365	6.2276	15	1.0	17.02	0.003125	111.36	191.56	0.160
AB0400	0.4162	0.0530	0.1337	3.1762	5.3801	15	1.0	13.27	0.004224	121.04	181.27	0.138

* Groundwater loss to deep aquifer in Aquifer AB0100, beneath Cherry Lake, was simulated via an outlet link in the SWMM model, see Section 4.3.3.2.

Table 4-5. 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	0.80	0.80	0.70	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

Sources: Peace River integrated modeling (HGL, 2008); Myakka River Watershed Initiative (Interflow, 2008). ECT, 2021.

Table 4-6. Summary table of hydrologic parameters in groundwater – final.

Subbasin Name	Aquifer	Node	Surface Elevation (ft NAVD88)	A1	B1	A2	B2	A3	Threshold Water Table Elev. (ft NAVD88)	Ini. Water Table Elev. (ft NAVD88)
B0070	AB0070	NB0070	160.25	0.02	0.7	0.02	0.7	0	100	150.0
B0075	AB0120	NB0100	164.35	0.02	0.7	0.02	0.7	0	100	151.1
B0080	AB0070	NB0080	160.17	0.02	0.7	0.02	0.7	0	100	151.1
B0100	AB0100	NB0100	153.50	0.02	0.7	0.02	0.7	0	100	150.6
B0110	AB0110	NB0100	157.81	0.02	0.7	0.02	0.7	0	100	151.1
B0120	AB0120	NB0100	159.23	0.02	0.7	0.02	0.7	0	100	151.1
B0130	AB0130	NB0100	159.97	0.02	0.7	0.02	0.7	0	100	151.1
B0140	AB0140	NB0100	164.95	0.02	0.7	0.02	0.7	0	100	151.1
B0150	AB0150	NB0100	166.87	0.02	0.7	0.02	0.7	0	100	151.1

Table 4-6. Summary table of hydrologic parameters in groundwater – final (cont.).

Subbasin Name	Aquifer	Node	Surface Elevation (ft NAVD88)	A1	B1	A2	B2	A3	Threshold Water Table Elev. (ft NAVD88)	Ini. Water Table Elev. (ft NAVD88)
B0160	AB0160	NB0100	176.61	0.02	0.7	0.02	0.7	0	100	151.1
B0170	AB0170	NB0100	183.64	0.02	0.7	0.02	0.7	0	100	151.1
B0175	AB0175	NB0100	175.55	0.02	0.7	0.02	0.7	0	100	151.1
B0180	AB0180	NB0100	170.79	0.02	0.7	0.02	0.7	0	100	151.1
B0182	AB0180	NB0100	189.22	0.02	0.7	0.02	0.7	0	100	151.1
B0183	AB0180	NB0100	198.88	0.02	0.7	0.02	0.7	0	100	151.1
B0184	AB0185	NB0100	172.82	0.02	0.7	0.02	0.7	0	100	151.1
B0185	AB0185	NB0100	190.74	0.02	0.7	0.02	0.7	0	100	151.1
B0186	AB0400	NB0400	189.87	0.02	0.7	0.02	0.7	0	100	161.0
B0190	AB0190	NB0100	162.44	0.02	0.7	0.02	0.7	0	100	151.1
B0200	AB0200	NB0200	160.50	0.02	0.7	0.02	0.7	0	100	151.1
B0300	AB0300	NB0300	188.12	0.02	0.7	0.02	0.7	0	100	174.1
B0310	AB0310	NB0310	193.16	0.02	0.7	0.02	0.7	0	100	183.0
B0320	AB0310	NB0320	194.60	0.02	0.7	0.02	0.7	0	100	183.0
B0400	AB0400	NB0400	182.96	0.02	0.7	0.02	0.7	0	100	161.1

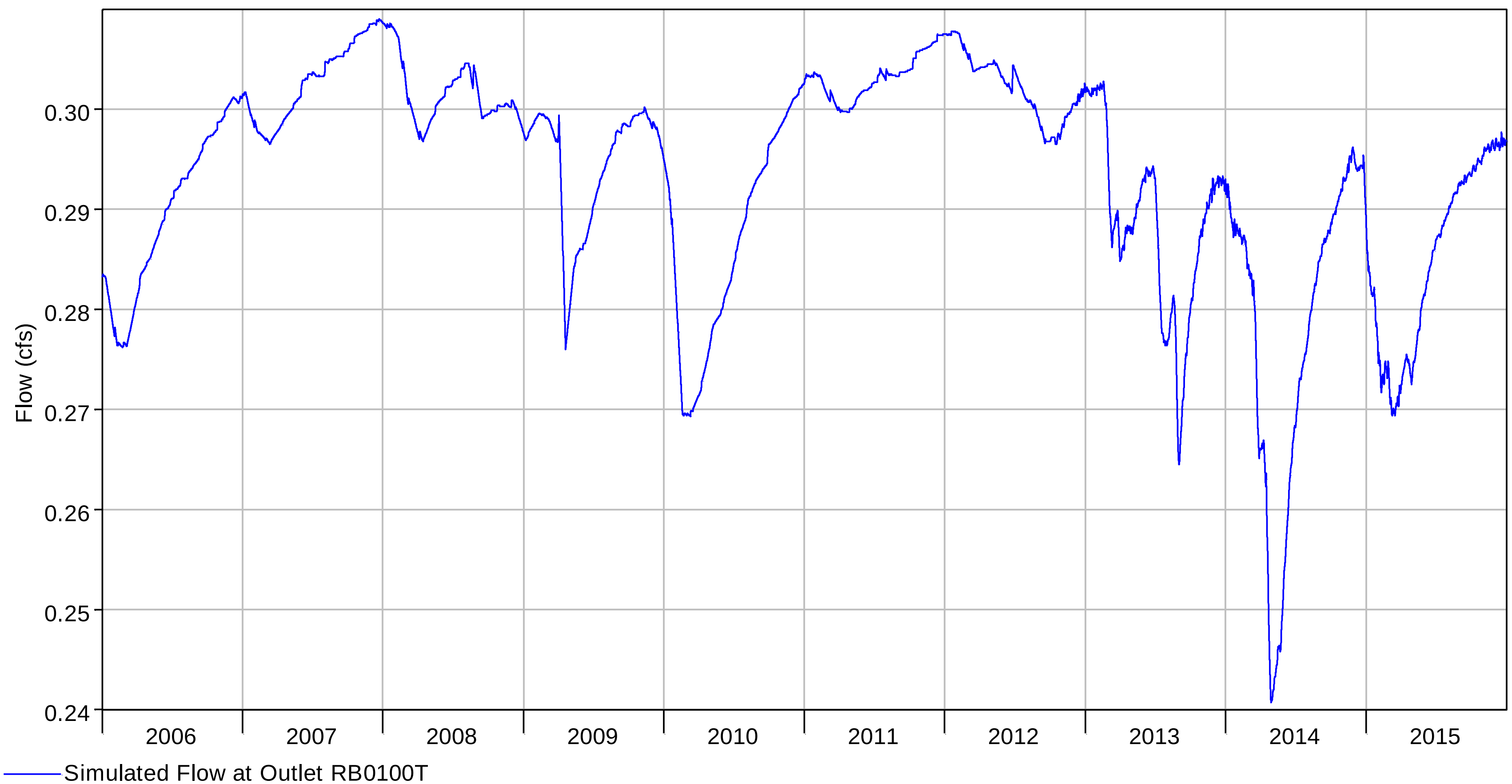


Figure 4-8. Simulated Groundwater Loss Rates from Cherry Lake to Deep Aquifer (2006-2015).

4.3.3 Adjustment of Hydraulic Model Parameters

Various hydraulic model parameters were adjusted during model calibration, including 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 Weir Crest Elevations and Discharge Coefficients

Based on the ground survey data and field observations by the District and ECT staff on March 2, 2017, the highest point of the outfall canal appears to be the beaver dam located approximately 100 feet upstream of NE Cherry Lake Cir., which has a top elevation of 150.80 ft NAVD88. At the time of the survey, the 42" RCP beneath NE Cherry Lake Cir. seems to have been blocked by debris (likely due to beaver activities). The beaver dam and culvert blockage together seem to control the outfall flow discharge from the lake and were modeled as Weirs RB0090W and RB0080W2, respectively.

The crest elevation of Weir RB0090W was estimated at the top of the beaver dam or 150.80 ft NAVD88. The crest elevation of Weir RB0080W2 was set to match the upstream invert elevation of the 42" RCP beneath NE Cherry Lake Cir. or 149.52 ft NAVD88, assuming the culvert is fully open throughout the model calibration period. These weir crest elevations seem reasonable in representing the lake control point elevation at the outfall canal, after comparing the initial model simulated lake levels with the observed lake stage values (Figure 4-7B). While it is possible that the beaver dam (Weir RB0090W) did not exist throughout the calibration period, and its removal could significantly decrease lake levels, there was not sufficient information to determine at which times the beaver dam was present or removed. Also, the increase in lake levels caused by the presence of Weir RB0090W are countered by an increase in lake leakage into the upper FAS (controlled by coefficient "A" in Equation E) in the model calibration process. Thus, the calibrated model is representative of the maximum amount of leakage that could likely be occurring in the lake. This is expected to result in a conservative assessment of the effects of groundwater withdrawals on Cherry Lake water levels.

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

4.3.3.2 Outlet Functional Rating Curve

Based on the initial model run results, the initial estimation of coefficient "A" in Equation E needed 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 runs to match the observed lake stage data. The optimal coefficient "A" was 0.003645 ft^2/s.

4.3.3.3 Initial Conditions

The node initial elevations in the lake and its adjacent wetlands/ditches were adjusted to match stage data measured at USGS 02319150 Cherry Lake (Figure 4-6). The node initial elevations were set at 150.56 ft NAVD88. The initial stage values in other adjacent storage areas, junctions, as well as the water elevations in groundwater and aquifers (Tables 4-4 and 4-6) were adjusted accordingly to avoid unreasonable initial flows.

4.4 Model Calibration Results

4.4.1 Model Simulation and Calibration

The Cherry Lake water budget model was calibrated with data from 2006 through 2015, by comparing the observed lake stage values with the simulated stages. A series of 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 lateral groundwater flow
- Weir crest elevations (control point elevation of the lake)
- Initial conditions at nodes (lakes, wetlands, and channels) and water tables in aquifers

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

- Lower groundwater loss rate parameter (DP) (Table 4-4)
- Outlet functional curve for flow exchange between the lake and FAS (Section 4.3.3.2)

4.4.2 Model Calibration Results

The simulated and observed lake stage hydrographs are graphically presented in Figure 4-9 for Cherry Lake. This figure demonstrates that the final calibration model simulated stage values replicate the trends of the historical data for the lake. In the latter years of the calibration period, there are times when the modeled stages are up to approximately 1 foot lower than observed stages. This is likely due to debris blockages in the outfall canal which were known to have occurred during this time. However, there is insufficient information available to account for these blockages in the model calibration.

A scatter plot comparing individual simulated lake stages with corresponding observed values is provided in Figure 4-10 to assist in the model assessment. The statistical analysis results are summarized in this plot as well.

The RMSE of the lake stage residuals was 0.30 (Figure 4-10), which is less than the primary goal of 0.5 ft. 91.9% of the residuals were within ±0.5 ft of the observed values, meeting the second goal of 67%. 99.7% of the residuals were within ±1.0 ft of the observed values, meeting the third goal of 90%. The agreement between simulated and observed values covers approximately 3 vertical feet, so the final goal of meeting these criteria over a wide range of stages is also being met.

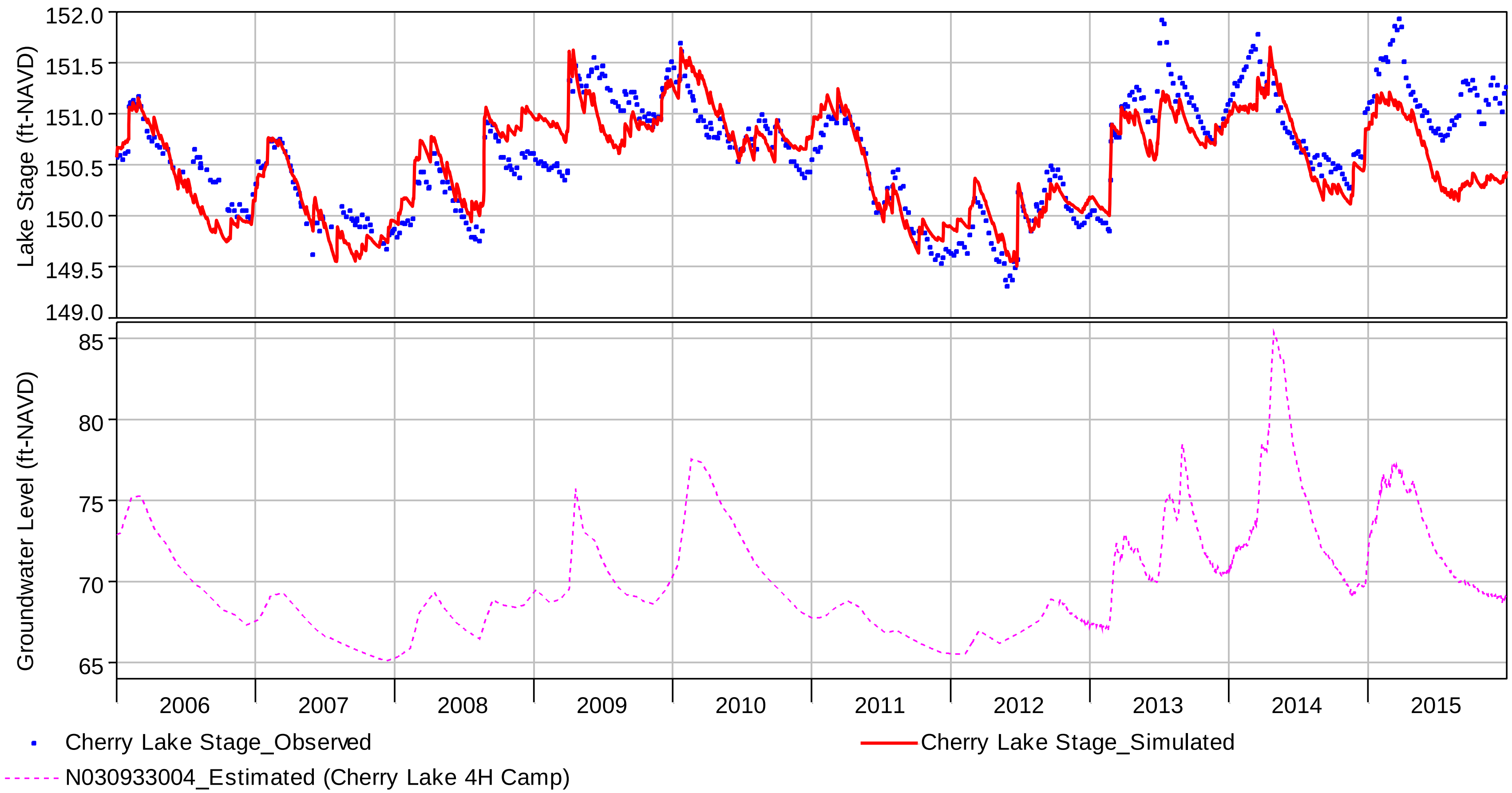


Figure 4-9. Comparison of Observed and Simulated Lake Stage Hydrographs at Cherry Lake (2006-2015).

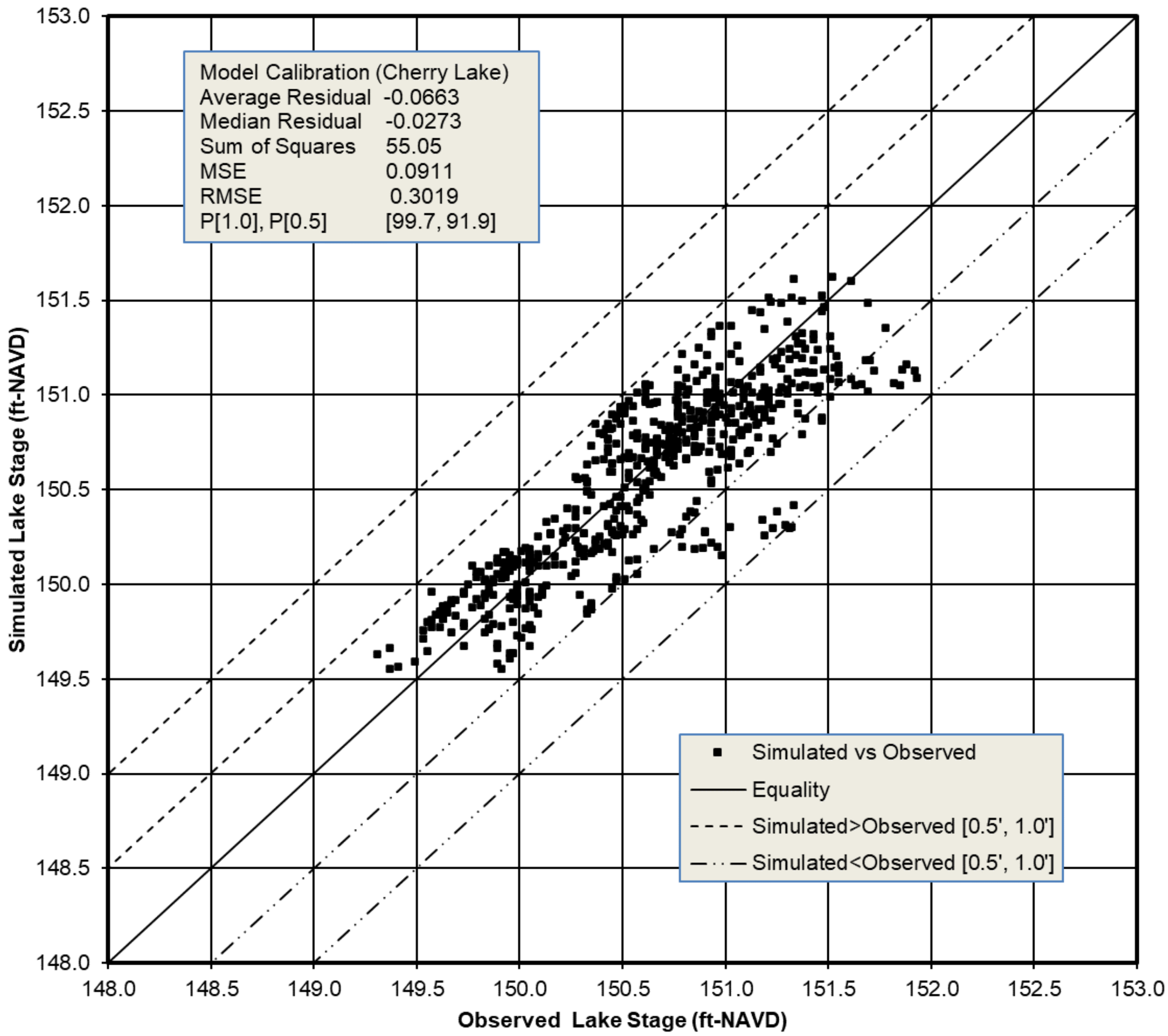


Figure 4-10. Scatter Plot Comparing Simulated and Observed Stages at Cherry Lake (2006-2015).

4.4.3 Water Budget Results

The water budgets of the Cherry Lake 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 Upper FAS
    - Groundwater Flow
    - Storage Change in Aquifers
- Flow Routing
    - Surface Runoff
    - Groundwater Flow
    - Evaporation
    - External Outflow (to Downstream Canal and Upper 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 52.38 in/yr, evaporation (from land surface and conveyance system) and ET of 41.10 in/yr, deep percolation (from the surficial aquifers and the lake) of 7.07 in/yr, outflow to the downstream wetland of 4.37 in/yr, and storage change in aquifers and conveyance system of -0.10 in/yr in the 10-year simulation period from 2006 through 2015 (Table 4-7).

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 from the surficial aquifer to the upper FAS of 4.43 in/yr may include three components that were not distinguished in the model: 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.

Table 4-7. Summary table of water budget results in Cherry Lake watershed (2006-2015).

Runoff Quantity

Items	Total Volume (acre-ft)	Total Depth (in)	Average Depth (in/yr)
Precipitation	42,143.8	524.3	52.38
Evaporation	4,314.6	53.7	5.36
Infiltration	19,845.1	246.9	24.67
Surface Runoff	18,002.6	224.0	22.38
Final Storage	0.5	0.0	0.00

Groundwater

Items	Total Volume (acre-ft)	Total Depth (in)	Average Depth (in/yr)
Initial Storage	14,248.8	177.3	17.71
Infiltration	19,845.1	246.9	24.67
Upper Zone ET	8,564.7	106.5	10.64
Lower Zone ET	256.4	3.2	0.32
Deep Percolation	3,565.3	44.4	4.43
Groundwater Flow	7,495.2	93.2	9.32
Final Storage	14,209.5	176.8	17.66
Storage Change	-39.3	-0.5	-0.05

Flow Routing

Items	Volume (acre-ft)	Volume (10^6 Gal)	Average Depth (in/yr)
Initial Storage	4,021.5	1,310.5	5.00
Surface Runoff	18,002.5	5,866.4	22.38
Groundwater Inflow	7,495.2	2,442.4	9.32
External Outflow*	5,639.1	1,837.6	7.01
Evaporation	19,901.4	6,485.2	24.74
Final Storage	3,979.4	1,296.7	4.95
Storage Change	-42.1	-13.7	-0.05
* External Outflow includes:			
To Downstream Wetland	3,514.6	1,145.2	4.37
To Upper Floridan Aquifer	2,124.3	692.2	2.64

4.4.4 Summary of Model Calibration

Based on the model calibration results for the 10-year simulation span, the Cherry Lake water budget model has been successfully calibrated and meets 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 Cherry Lake water budget model will provide a useful tool for comparing water management alternatives in the context of MFLs.

5.0 Development of Measured and No-pumping Scenarios

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 and assessment also rely on results of the long-term continuous simulations. For the purpose of minimum levels determination, lake stage data are classified as "Historic" for periods when there are no measurable impacts due to water withdrawals, and the impacts due to structural alterations are similar to existing conditions. "Structural alterations," in this context, means physical alteration of the control point, or highest stable point along the outlet conveyance system of a lake, to the degree that water level fluctuations are affected (ECT, 2023).

As stated in Section 4.3.1.4, USGS 02319150 Cherry Lake provides the long-term historical lake stage values at various reporting frequencies from 1974 to the present (Figure 4-7A). The period of record (POR) at this station appears to show a downtrend in water levels or possibly a downshift of about one foot occurring around April 1998. The date of April 1998 was derived by performing a changepoint analysis in R using the changepoint package considering both changes in mean and variance of the time series (Killick and Eckley, 2014). As observed by Mr. Holton and others, the outfall canal had been lowered over time, eroding down into a clay layer in the bottom of the canal. The downward trend in lake levels did not continue after April 1998 and this might indicate the canal bottom had been stabilized. In addition, the beaver dam and culvert blockage observed in the canal need to be considered when evaluating the historic lake stage data. In summary, the "measured" lake stage data during the POR does not adequately represent the Historic conditions at Cherry Lake, since a stable highest point in the outlet conveyance system did not exist throughout the entire POR.

To better represent the Historic conditions and the impacts due to structural alterations in the existing outfall canal and in the absence of groundwater withdrawals, the calibrated Cherry Lake water budget model was used, with necessary adjustments, to run long-term simulations for a total of 55.7 years from 4/29/1960 through 12/31/2015, which is limited by the available groundwater well data at the USGS Lovette Tower station (USGS 303400083305301 / SRWMD ID: N020822002) and the USGS Blackwater Plantation station (USGS 303812083362401 / SRWMD ID: N030727001) (Figure 4-3) as well as the recent reference timeframe (RTF) analysis results provided by the District (Section 5.2.4).

Based on the RTF analysis results, the groundwater level data set for the no-pumping scenario was created using the "measured" groundwater data set estimated for Cherry Lake, which is described in Section 5.2.3. In this report, the term RTF data set is referred to as the "no-pumping" groundwater levels, which was created by adding the RTF adjustment factors to the measured groundwater level data set.

The 55.7-year model duration includes the entire POR at USGS 02319150 Cherry Lake that indicates four low lake stage events and over ten high periods (Figure 4-7A). The four recorded low lake stage periods occur between 1990 and 2012. The lake stages have since rebounded to pre-drought levels. It was assumed that the 55.7-year model duration is a reasonable representation of the long-term lake hydrology for use in MFLs development. The use of the simulated lake stage data sets also allows for analysis over a greater portion of the Atlantic Multidecadal Oscillation (Enfield *et al.*, 2001).

In subsequent sections, the calibrated model was updated to 2016 land use conditions for MFLs evaluation as it is the most recent land use data at the time this modeling analysis was set up.

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. The data used for the model calibration, as discussed in Section 4.3.1, were retained and extended for use in the long-term simulations (Table 5-1).

In addition, the 2016 land use map was collected and utilized in the subsequent long-term modeling analysis to be consistent with the current pumping conditions to be assessed in the future.

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 N020822002 (1/1/2006 – 12/31/2015) SRWMD N030933004 (8/1/2018 – 2/15/2022)
Long-term Simulations (1960-2015)	NOAA rainfall stations at Madison and Monticello, FL, and Quitman, GA (1/1/1960 – 12/31/1979) Oak Ridge National Laboratory (ORNL) Daymet (1/1/1980-6/30/2002) NEXRAD (7/1/2002-12/31/2015)	NOAA Pan Evaporation at Gainesville and Lake City stations (10/1/1953 – 8/24/2015) USGS PET (6/1/1995-12/31/2015)	SRWMD N020822002 (6/14/1989 – 12/31/2015) SRWMD N030933004 (8/1/2018 – 2/15/2022) SRWMD N030727001 (4/29/1960 – 7/10/2021) USGS 304949083165301 (2/25/1957 – 9/28/2016)

Source: ORNL, 2016; NOAA, 2016; USGS, 2016; SRWMD, 2016 & 2022.

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 and NOAA rainfall gauge data were employed to extend the rainfall records used in the model calibration.

Similar to the NEXRAD rainfall data, the Daymet rainfall data was organized in individual 1 km x 1 km pixels, each of which has daily rainfall estimates after 1/1/1980 (Figure 5-1). A total of three NOAA weather stations, located near Madison, FL, Monticello, FL, and Quitman, GA, were utilized to assemble the rainfall data prior to January 1, 1980 (Figure 5-2). The NOAA Madison station is the primary data source used in assembling the rainfall data. When the Madison station data was missing, the Quitman station in Georgia was used to fill the data gaps. When both the Madison and Quitman stations have no available data, the Monticello station data was used as it is the farthest station from the lake.

The NOAA rainfall data from 4/29/1960 to 12/31/1979, the Daymet rainfall data from 1/1/1980 to 6/30/2002, and the NEXRAD rainfall data from 7/1/2002 to 12/31/2015 (Table 5-1), were assembled to be used in the long-term model simulations. Note that the NEXRAD rainfall data from 2/1/2001 to 6/60/2002 was excluded from the long-term model simulations. The Daymet rainfall data seems to have a better performance than the NEXRAD rainfall data in terms of matching the model simulated lake stage data with the observed lake stage data in this time period.

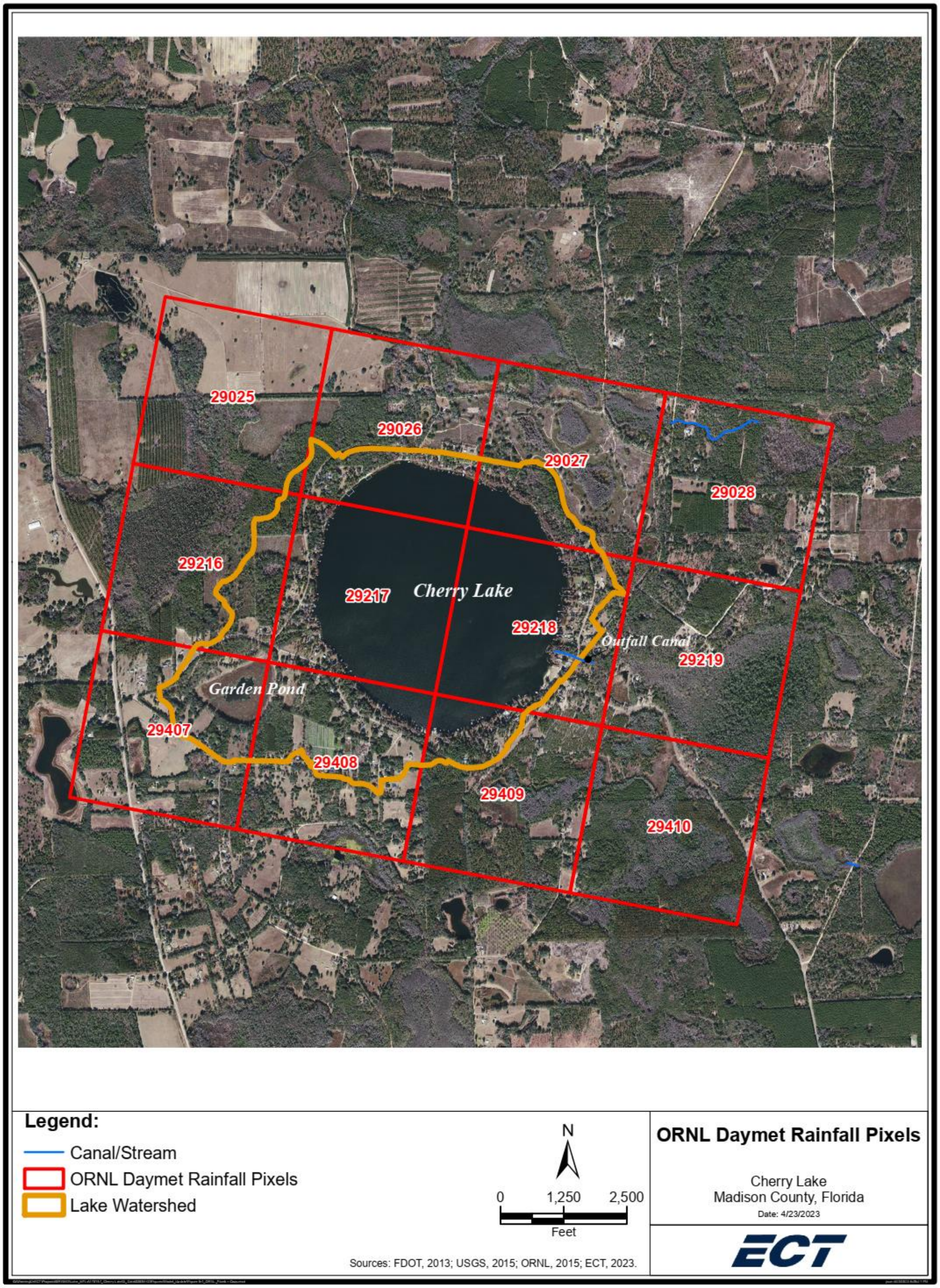


Figure 5-1. ORNL Daymet Rainfall Pixels.

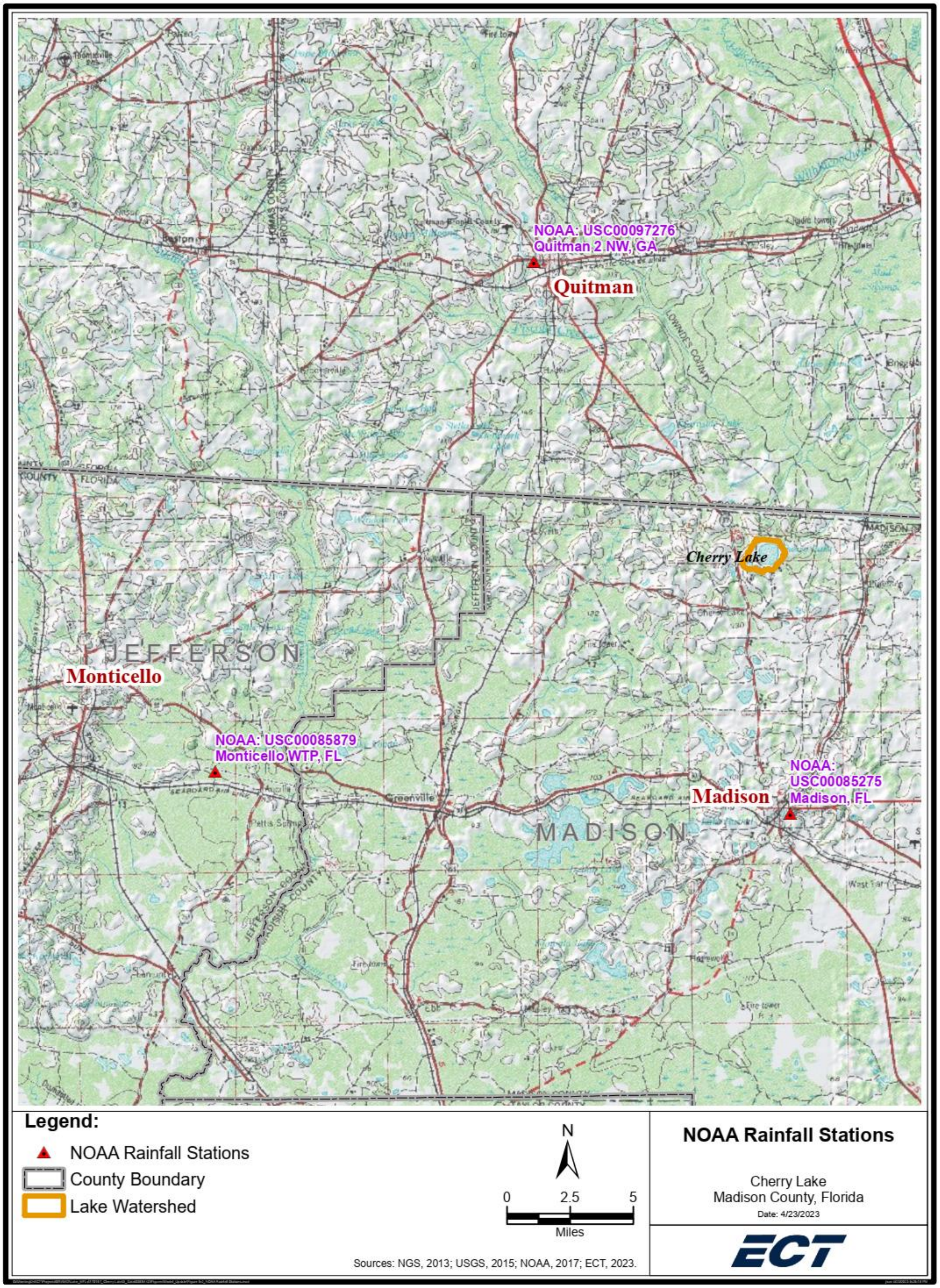


Figure 5-2. NOAA Rainfall Stations.

5.2.2 Evapotranspiration

The daily PET data developed by the USGS in individual 2 km x 2 km pixels (Figure 4-1) has a POR 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 considered the best available data prior to 6/1/1995 and hence used to extend the PET record back to 1960. Upon review of the pan evaporation data at these three stations, the two Gainesville stations (USC00083321 and USC00083322) and the Lake City station (USC00084731) were used to estimate the PET data prior to 6/1/1995. The following data processing steps were involved to accomplish this task:

1. The daily pan evaporation data at the two Gainesville stations were first combined as one Gainesville station with a POR from 1960 through 2000. The missing data at the Gainesville (combined) station and Lake City station (with a POR from 1965 through 2011) were filled using a linear interpolation method;
2. The annual pan evaporation values for Years 1982 through 2000 were calculated for the Gainesville (combined) station and Lake City station. This time period was selected due to the poor quality of data observed prior to 1982 at the Lake City station (i.e., more missing data). The average ratio of the Lake City / Gainesville (combined) annual pan evaporation data was estimated at 1.095;
3. The annual pan evaporation values for Years 1996 through 2008 were generated for the Lake City station. This time period was selected due to the availability of the USGS PET data and the poor quality of data collected after 2008 at the Lake City station. The annual PET values for the same period were created at Cherry Lake based on the USGS area-weighted daily PET Data (Figure 4-2). The average ratio of the USGS PET / Lake City annual pan evaporation data was estimated at 0.707; and
4. A transfer factor of 0.774 (1.095 x 0.707) was calculated and used to convert pan evaporation data at the Gainesville (combined) station to PET at Cherry Lake for a POR from 1/1/1960 to 5/31/1995.

In summary, the daily PET data required for the long-term model simulation with a span of 55.7 years (Table 5-1 and Figure 5-3A) were developed by combining the USGS PET data with the PET values estimated from the NOAA pan evaporation data. The annual PET data for Years 1960 through 2015, as illustrated in Figure 5-3B, were created based on the abovementioned daily PET data.

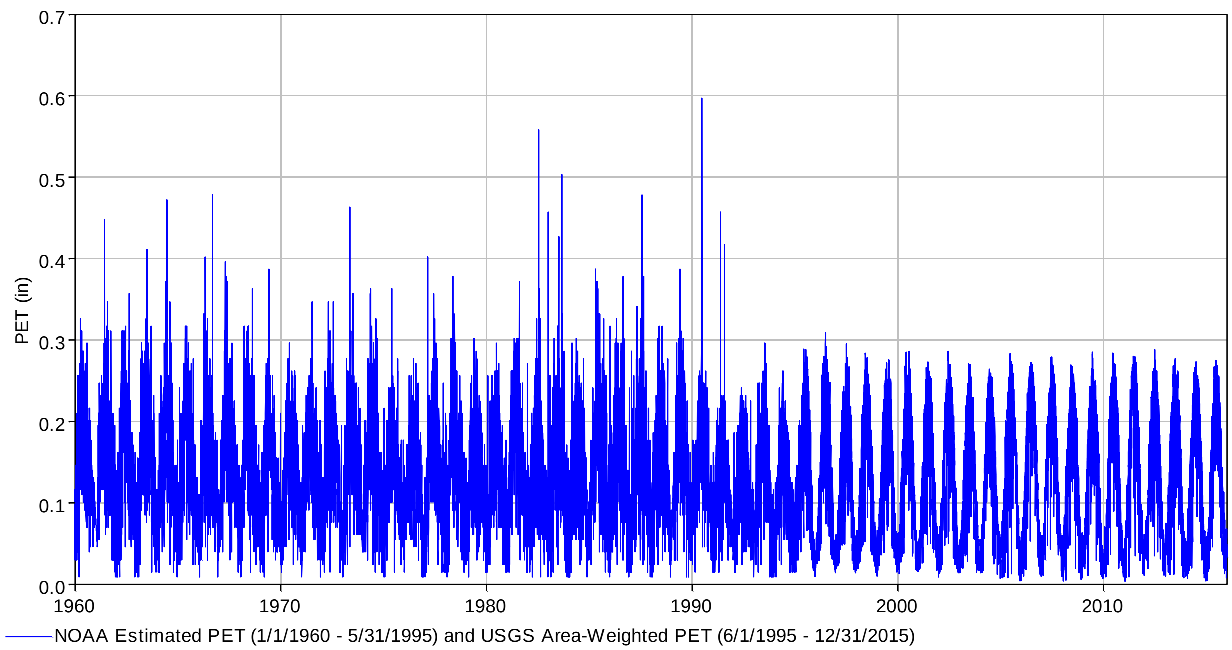


Figure 5-3A. Daily NOAA and USGS Potential Evapotranspiration Data (1960-2015).

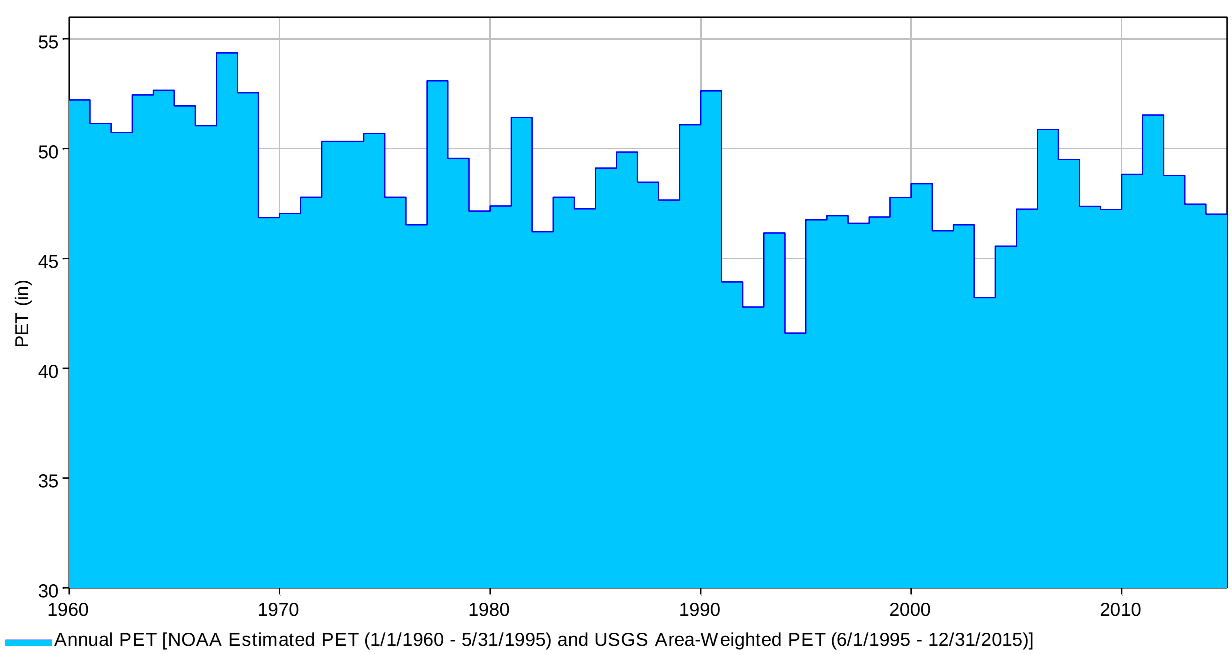


Figure 5-3B. Annual NOAA and USGS Potential Evapotranspiration Data (1960-2015).

5.2.3 Upper FAS Potentiometric Surface Levels

The groundwater level data collected at the USGS Lovette Tower station near Hamburg, FL (USGS 303400083305301 / SRWMD ID: N020822002, data record starting on 6/14/1989), the USGS Blackwater Plantation station near Ashville, FL (USGS 303812083362401 / SRWMD ID: N030727001, data record starting 4/29/1960), and the USGS Valdosta station near Valdosta, GA (USGS 304949083165301, data record starting on 2/25/1957) was used to estimate the long-term groundwater dataset at the USGS Lovette Tower station (Table 5-1, Figures 4-3 and 5-4), as described below. Note that the POR for the USGS Lovette Tower and Blackwater Plantation stations limited the long-term simulation period to 55.7 years (4/29/1960-12/31/2015).

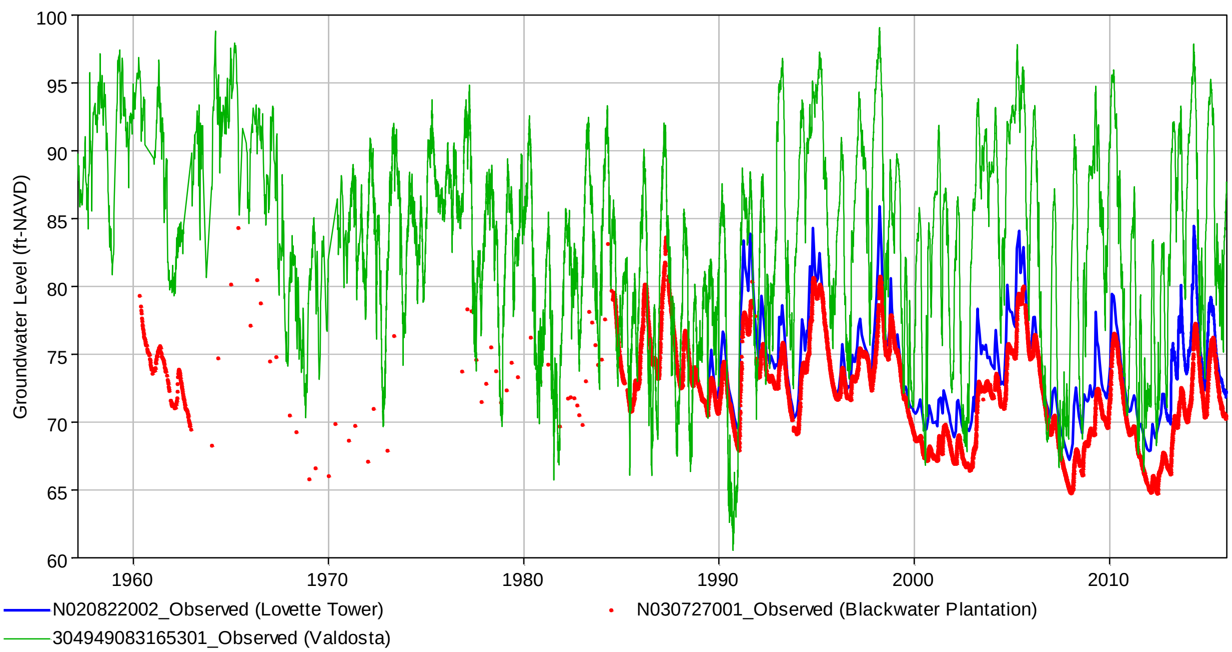


Figure 5-4. Observed Groundwater Levels at USGS Lovette Tower, Blackwater Plantation, and Valdosta Stations (1957-2015).

First, a linear regression analysis was performed by using the observed data collected at the USGS Lovette Tower and Blackwater Plantation stations. A total of 127 groundwater level data pairs between 6/14/1989 and 12/20/1999 were used in the regression analysis, based on the following two reasons: 1) to have improved regression results (higher R^2 value) as compared to utilizing all the available data (1989 through 2021); and 2) this 10-year period was closer to the time period to be filled (1960 through 1989) than the remaining data after 1999. The R^2 value is 0.89 for the resultant linear regression curve (Figure 5-5A). The groundwater level values from 4/29/1960 to 6/14/1989 were then estimated at the USGS Lovette Tower station, based on the observed data at the USGS Blackwater Plantation station and the resultant linear regression curve. However, there is a 3.5-year data gap (5/10/1973 – 11/1/1976) in the observed groundwater level data at the USGS Blackwater Plantation station (Figure 5-4).

To fill in this data gap at the USGS Blackwater Plantation station, the groundwater well data at the USGS Valdosta station was used to develop a non-linear regression curve between the observed data at the USGS Lovette Tower station and 50-day moving average value of the daily groundwater level data at the USGS Valdosta station. A total of 1,744 groundwater level data pairs between 6/14/1989 and 9/28/2016 were used in the regression analysis. The R^2 value is 0.68 for the resultant non-linear regression curve (Figure 5-5B). The daily groundwater level values from 5/25/1973 to 10/17/1976 were then estimated at the USGS Lovette Tower station, based on the observed daily groundwater level data at the USGS Valdosta station and the resultant non-linear regression curve.

Finally, the estimated irregular interval groundwater level data set (4/29/1960–6/13/1989) at the USGS Lovette Tower station was combined with the observed groundwater level data collected after 6/14/1989 to develop a longer daily groundwater level data set at the USGS Lovette Tower station by applying a linear interpolation method. The estimated groundwater level data set significantly extended the simulation period of the water budget model by over two decades.

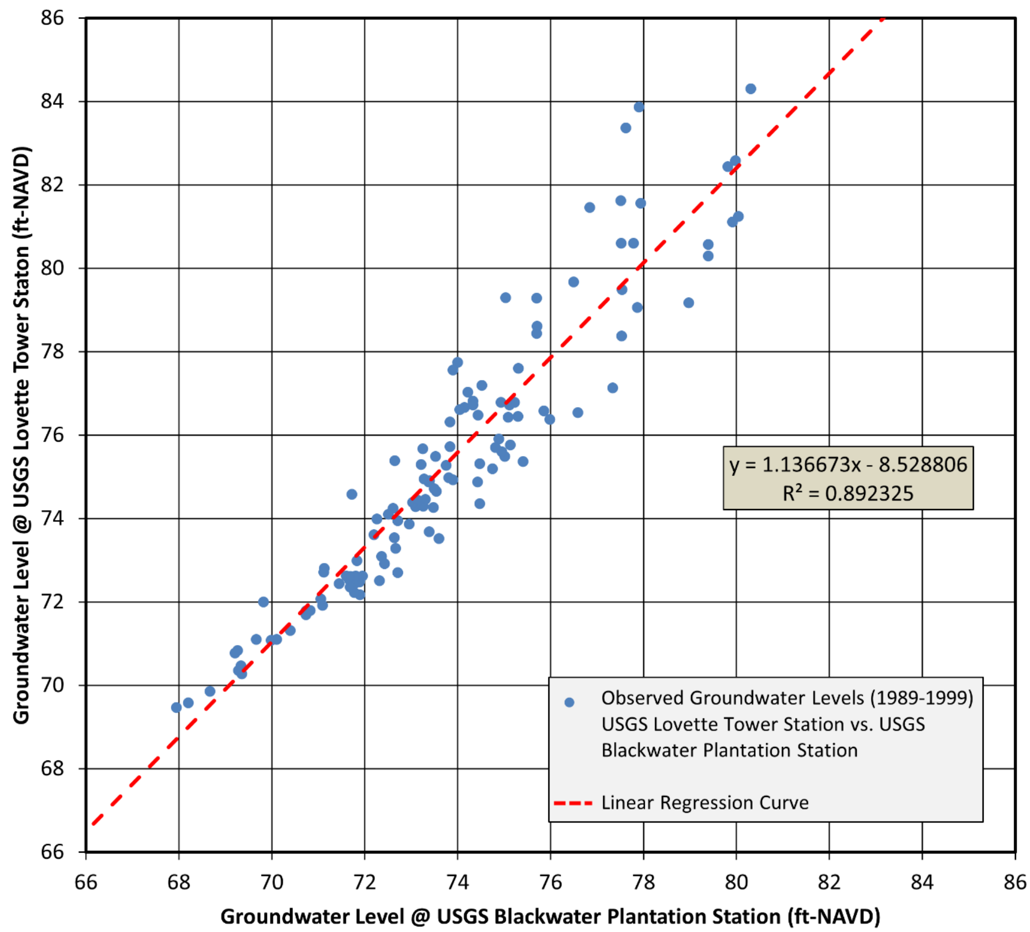


Figure 5-5A. Correlation Analysis of Groundwater Levels – USGS Blackwater Plantation Station vs. USGS Lovette Tower Station (1989-1999).

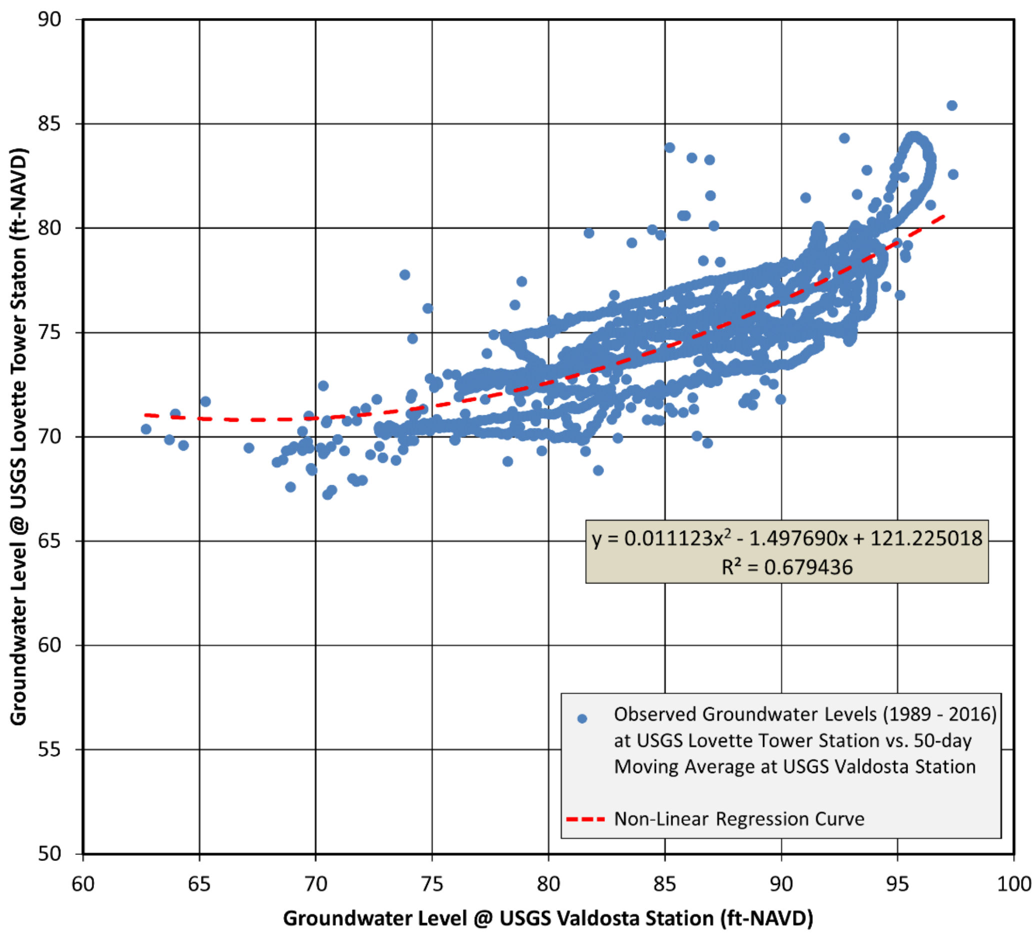


Figure 5-5B. Correlation Analysis of Groundwater Levels – USGS Valdosta Station vs. USGS Lovette Tower Station (1989-2016).

By applying the same non-linear regression curve developed in Section 4.3.1.3 (Figure 4-4) to the observed/ estimated long-term daily groundwater well levels at the USGS Lovette Tower station, the estimated long-term daily groundwater level data at the Cherry Lake 4H Camp station was generated. The observed and estimated groundwater well hydrographs at the USGS Lovette Tower station, as well as the estimated groundwater well hydrograph at the Cherry Lake 4H Camp station, are illustrated in Figure 5-6. The estimated groundwater well hydrograph at the Cherry Lake 4H Camp station was used to represent the groundwater conditions beneath the lake and this data set is referred to as the “measured” data sets.

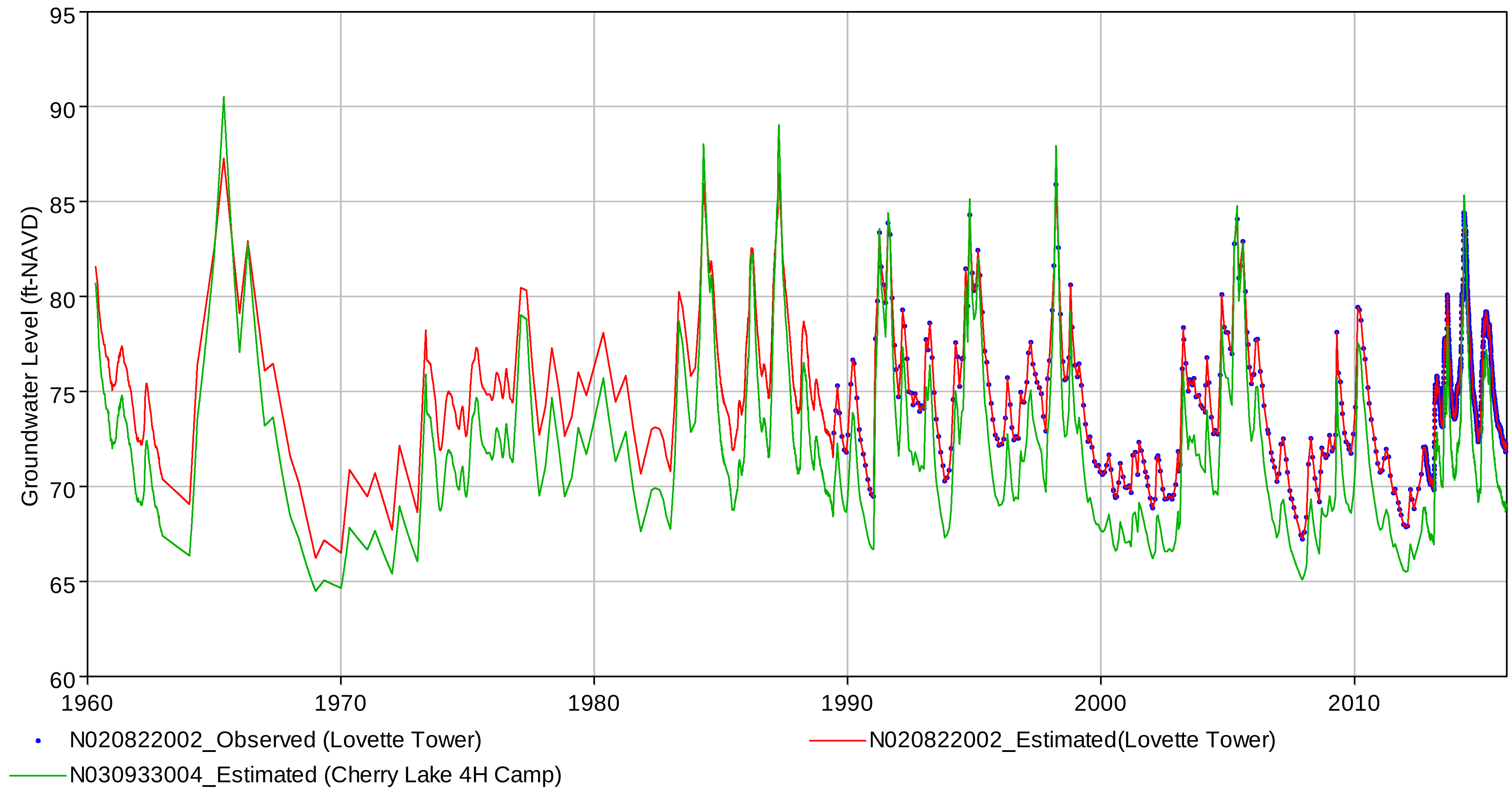


Figure 5-6. Observed/Estimated Groundwater Level Hydrographs at USGS Lovette Tower Station and Estimated Groundwater Level Hydrograph at Cherry Lake 4H Campa Station (1960-2015).

5.2.4 Reference Timeframe Analysis

Evaluating the historic influence of water use on flows and levels in regional rivers, springs, lakes, and estuaries is a component of the MFL process in the District. Groundwater is the source of most potable water used in northeastern Florida and southeastern Georgia (SJRWMD & SRWMD, 2017). To evaluate the historic influence of groundwater withdrawals, estimates of groundwater use over time were prepared by the District for the area encompassed by the NFSEG model domain.

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

The District estimated the RTF adjustment factors for groundwater levels at Cherry Lake for a period of 1948 through 2015, as illustrated in Figure 5-7.

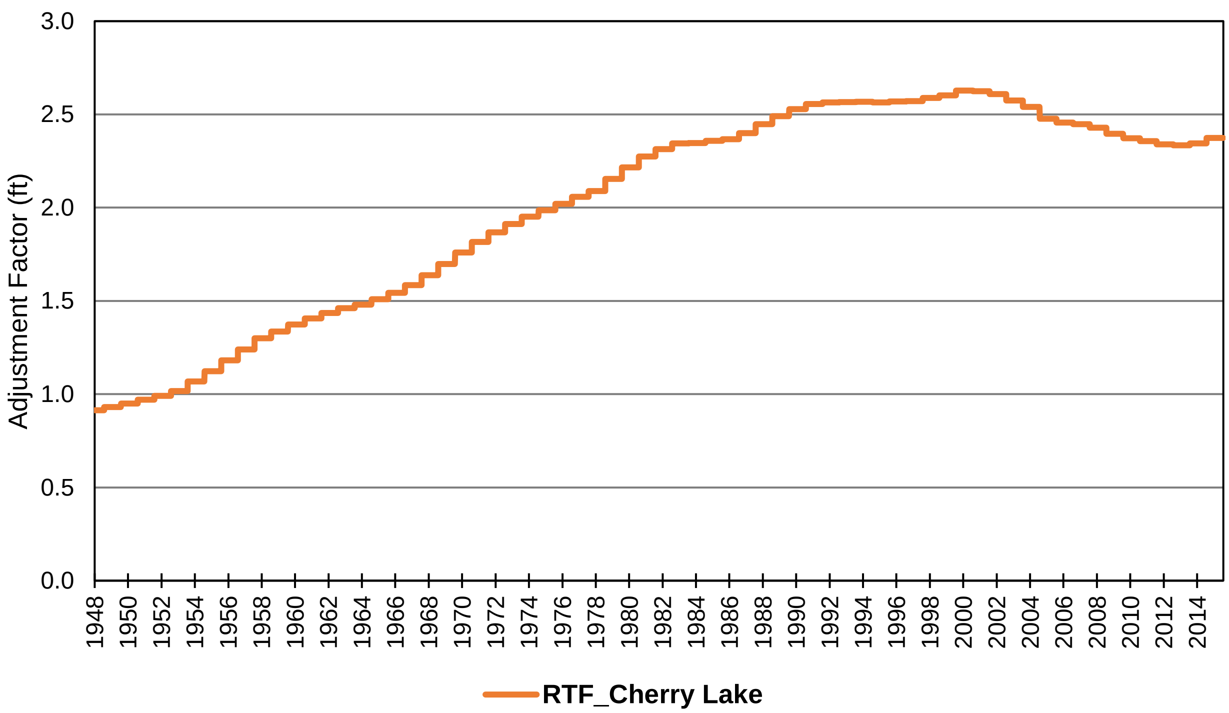


Figure 5-7. RTF Adjustment Factors at Cherry Lake (1948-2015).

In this report, the term RTF data set is referred to as the no-pumping groundwater levels, which was created by adding the RTF adjustment factors to the measured groundwater level data set. The measured and no-pumping groundwater level data sets at Cherry Lake for a period of 1960 through 2015 are illustrated in Figure 5-8.

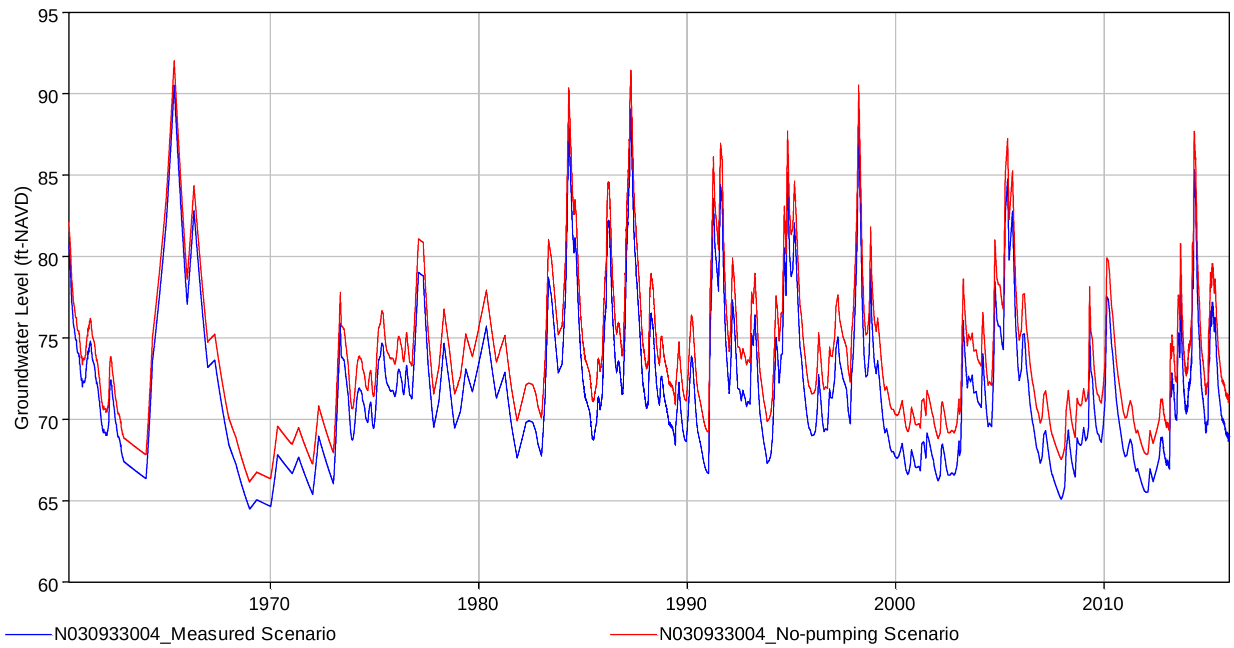


Figure 5-8. Groundwater Level Hydrographs at Cherry Lake – Measured and No-pumping Scenarios (1960-2015).

5.2.5 2016 Land Use/Land Cover

As described in Sections 3 and 4, the 2006 land use data was used in the model development and calibration. However, for the purpose of minimum lake levels determination, the 2016 state-wide land use map assembled by the Florida Department of Environmental Protection (FDEP) from all WMD's land use databases was downloaded and utilized in model parameterization for the subsequent long-term modeling simulations (Figure 5-9).

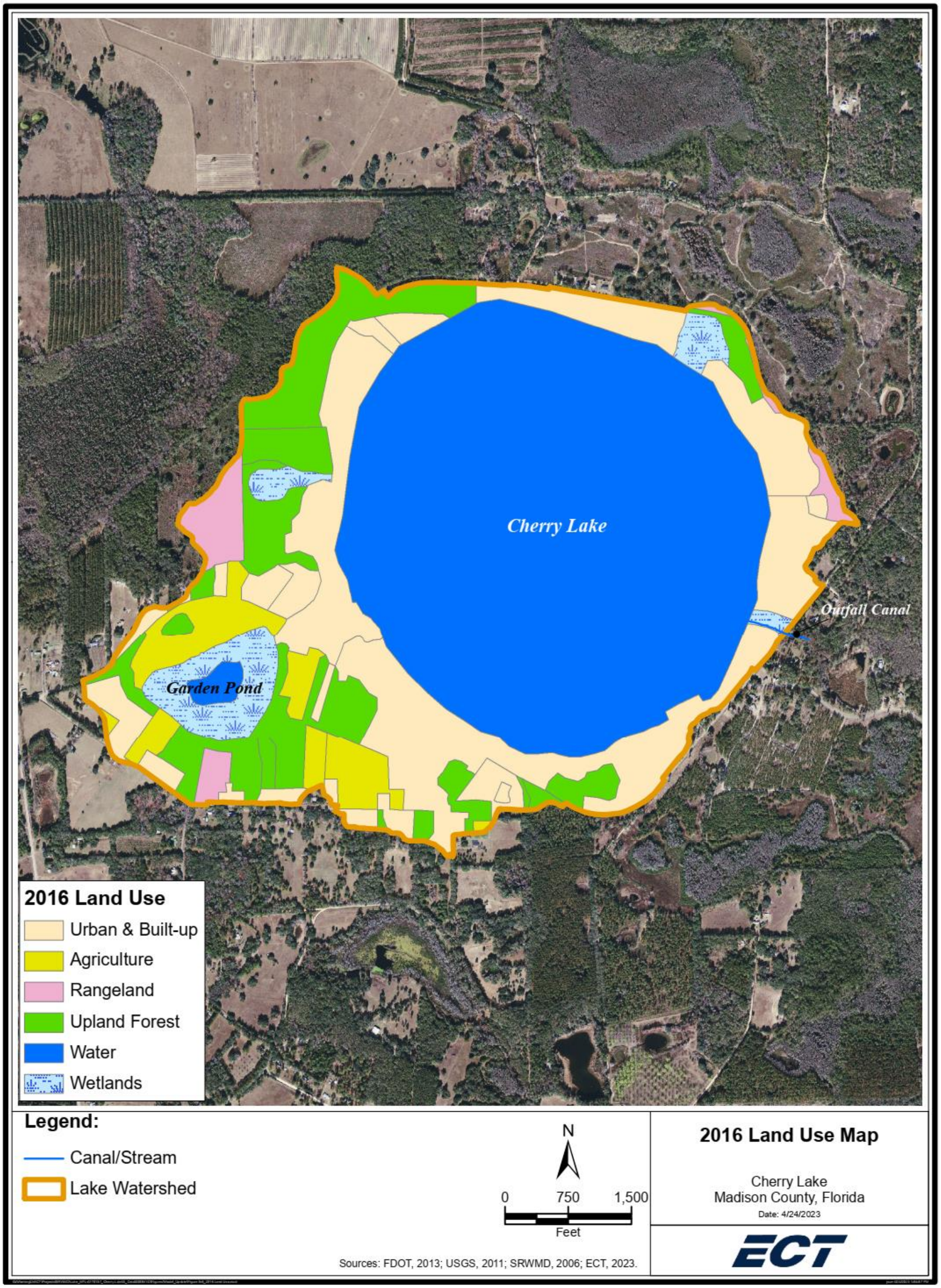


Figure 5-9. 2016 Land Use Map.

Comparison results of the 2006 and 2016 land use data in the lake watershed are summarized in Table 5-2. As shown in this table, the most significant land use change occurred at upland forests (FLUCCS 4000), with an approximately 39.9-acre decrease, which is approximately 4.1% of the total lake watershed area. The second largest change occurred at rangeland (FLUCCS 3000), with an approximately 22.2-acre increase. One of the major acreage increases in rangeland was found at the west portion of the lake watershed where an upland forests area was reclassified as rangeland (Figures 2-4 and 5-9).

Table 5-2. Comparison of 2006 and 2016 land use data in Cherry Lake watershed.

FLUCCS	Description	2006 Area (acre)	2016 Area (acre)	Difference (acre)	2016 Area / 2006 Area (%)
1000	Urban & Built-up	229.4	235.1	5.7	102.5%
2000	Agriculture	40.2	49.5	9.3	123.1%
3000	Rangeland	2.7	24.9	22.2	923.2%
4000	Upland Forests	166.3	126.4	-39.9	76.0%
5000	Waters	486.5	487.1	0.6	100.1%
6000	Wetlands	39.5	41.6	2.1	105.3%
	Total	**964.6**	**964.6**	**0.0**	**100.0%**

Source: SRWMD, 2006; FDEP, 2022.

Based on the 2016 land use data, the lookup table of hydrologic parameters for surface runoff calculation (Table 4-2), and the approach described in Section 4.3.2.1 for model calibration, the hydrologic parameters for each subbasin were recalculated, as listed in Table 5-3, and utilized in the long-term model simulations.

Table 5-3. Summary table of revised hydrologic parameters in subbasins – 2016 land use.

Subbasin Name	% 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.
B0070	18.97	30.67	0.056	0.117	0.056	0.178
B0075	14.88	25.00	0.050	0.151	0.012	0.139
B0080	22.49	35.70	0.061	0.132	0.095	0.203
B0100	95.17	95.85	0.003	0.008	0.012	0.107
B0110	17.92	29.17	0.054	0.112	0.044	0.171
B0120	15.15	25.00	0.050	0.100	0.012	0.150
B0130	10.75	27.02	0.052	0.182	0.028	0.292
B0140	15.41	26.00	0.051	0.299	0.020	0.498
B0150	15.00	25.00	0.050	0.300	0.012	0.500

Table 5-3. Summary table of revised hydrologic parameters in subbasins – 2016 land use (cont.).

Subbasin Name	% 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.
B0160	2.13	25.00	0.050	0.277	0.012	0.460
B0170	10.10	25.01	0.050	0.209	0.012	0.331
B0175	13.38	29.22	0.054	0.174	0.045	0.278
B0180	13.66	25.00	0.050	0.118	0.012	0.181
B0182	3.01	25.00	0.071	0.213	0.012	0.302
B0183	8.08	25.00	0.050	0.168	0.012	0.215
B0184	9.21	25.00	0.058	0.144	0.012	0.226
B0185	7.04	25.00	0.052	0.172	0.012	0.227
B0186	11.21	25.00	0.050	0.130	0.012	0.157
B0190	11.46	25.00	0.050	0.147	0.012	0.233
B0200	21.94	46.00	0.071	0.250	0.175	0.393
B0300	7.79	32.52	0.058	0.282	0.070	0.464
B0310	0.00	25.00	0.050	0.251	0.012	0.402
B0320	0.00	25.00	0.050	0.251	0.012	0.401
B0400	17.19	38.67	0.059	0.234	0.060	0.293

5.3 Long-term Model Simulations

The calibrated water budget model described in Section 4.0 was used to perform long-term simulations for a total of 55.7 years from 4/29/1960 through 12/31/2015, by implementing the time series data and 2016 land use data described in Section 5.2 above, for the measured and no-pumping scenarios.

Based on the model methodology described in Section 3.3.3, the upper FAS potentiometric surface levels were used in estimating the groundwater loss from the lake through an “outlet” link in the model. The groundwater level data sets developed for the measured and no-pumping scenarios (Figure 5-8) were implemented in the long-term model simulations to estimate the groundwater loss from the lake for each of these two scenarios.

In the SWMM model, a groundwater loss rate to deep aquifer for the Aquifers in the model (f_L in Figure 3-3 and Equation D) is used to estimate groundwater loss to the upper FAS. The assumption is made that influence on water budget model results by the upper FAS potentiometric surface level fluctuation is considered insignificant, except for the area immediately beneath the lake where potential collapse structures might exist and provide preferred paths toward the upper FAS. The calibrated groundwater loss rates to deep aquifer, as listed in Table 4-4, were used for the long-term model simulation of the measured scenario. The lower groundwater loss rate parameter (DP in Equation D) for the no-pumping scenario were estimated based on the following equation (Equation

G), as summarized in Table 5-4, to account for the impacts caused by higher no-pumping groundwater levels than the measured scenario. The remainder of the model parameters were not changed.

$$DP' = DP * \frac{\Delta H + B}{\Delta H} \qquad \text{(G)}$$

where, *DP'* = proposed lower groundwater loss rate parameter (in/hr), i.e., the no-pumping scenario,

DP = base lower groundwater loss rate parameter (in/hr), i.e., the measured scenario,

B = upper FAS drawdown (ft), average difference between the no-pumping and measured scenarios, which is –2.21 ft,

Δ*H* = head difference (ft), between the average water elevation of 150.35 ft NAVD88 at Cherry Lake and average groundwater table elevation of 71.81 ft NAVD88 in the upper FAS (1960-2015), which is approximately 78.5 ft for the measured scenario.

Table 5-4. Summary table of lower groundwater loss rate parameter (DP) for measured and no-pumping scenarios.

Aquifer	DP (Measured Scenario)* (in/hr)	DP' (No-pumping Scenario)* (in/hr)
AB0070	0.000126	0.000122
AB0100	0.000000	0.000000
AB0110	0.000063	0.000061
AB0120	0.000064	0.000062
AB0130	0.000059	0.000057
AB0140	0.000059	0.000057
AB0150	0.000060	0.000058
AB0160	0.000452	0.000439
AB0170	0.000340	0.000330
AB0175	0.000060	0.000058
AB0180	0.000258	0.000251
AB0185	0.000333	0.000324
AB0190	0.000064	0.000062
AB0200	0.000580	0.000564
AB0300	0.002400	0.002332
AB0310	0.003125	0.003037
AB0400	0.004224	0.004105

* Groundwater loss to deep aquifer in Aquifer AB0100, beneath Cherry Lake, was simulated via an outlet link in the SWMM model, see Section 4.3.3.2.

5.3.1 Measured Scenario vs. No-pumping Scenario

The simulated lake stage hydrographs for the measured and no-pumping scenarios, both with the constant lake Control Point elevation of 150.8 ft NAVD88 at the outfall canal, as well as the corresponding groundwater level records are graphically presented in Figure 5-10 for Cherry Lake.

Scatter plots comparing simulated lake stages for the measured and no-pumping scenarios are provided in Figure 5-11 for Cherry Lake. The statistical analysis results are summarized in this scatter plot as well. The average residual of -0.0143 ft indicates the difference between the simulated lake stages for these two scenarios is very small, i.e., the lake levels are not sensitive to the upper FAS drawdowns (Figure 5-10).

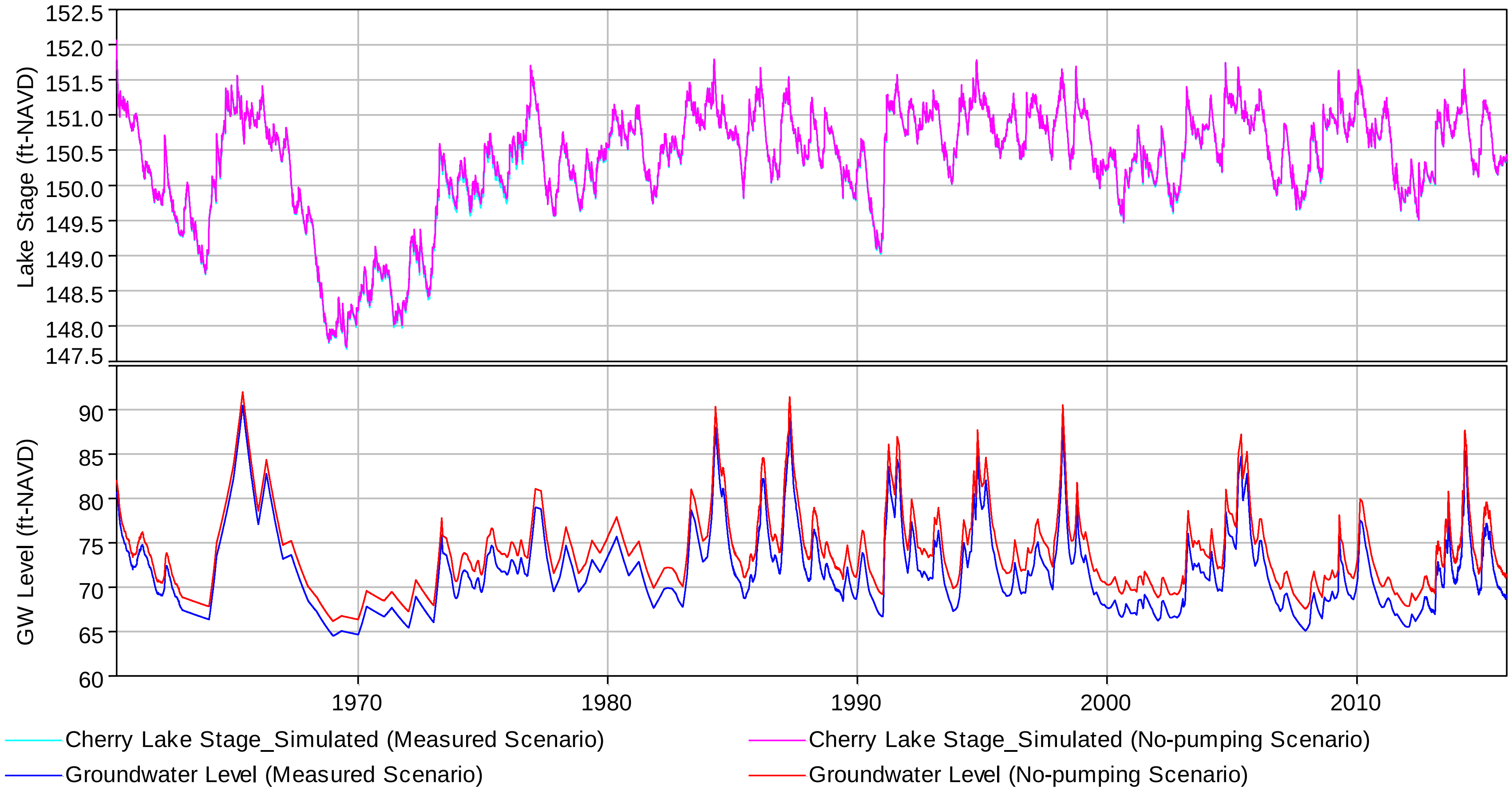


Figure 5-10. Simulated Lake Stage Hydrographs at Cherry Lake – Measured and No-pumping Scenarios (1960-2015).

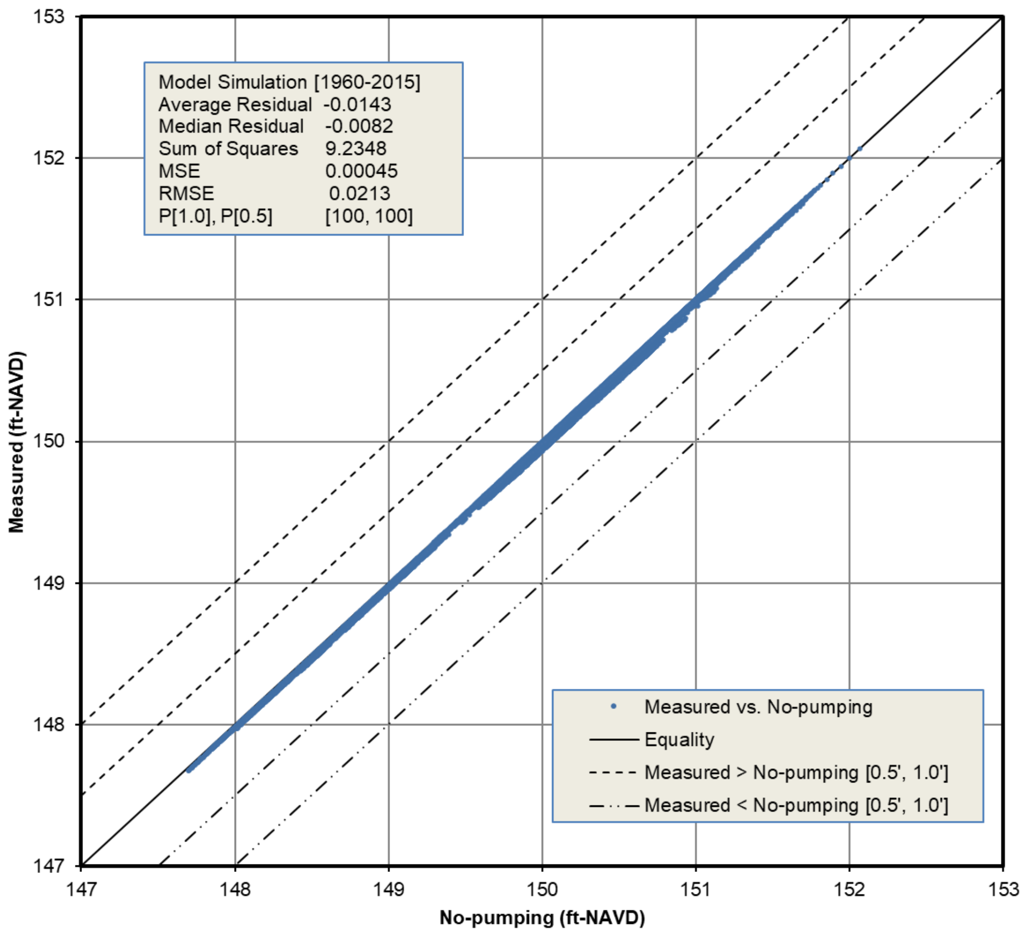


Figure 5-11. Scatter Plot Comparing Simulated Lake Stages at Cherry Lake – No-pumping vs. Measured Scenarios (1960-2015).

5.3.2 High, Medium, and Low Control Point Elevations

To support development of minimum levels for Cherry Lake, a total of three Control Point (CP) scenarios, as listed below, were selected by the District to represent the existing and predicted structural alterations in the outfall canal (ECT, 2023).

- High CP Scenario: 150.80 ft NAVD88 at the top of the beaver dam in the outfall canal
- Medium CP Scenario: 150.20 ft NAVD88 at the highest point along the outfall canal
- Low CP Scenario: 149.52 ft NAVD88 at the invert of the culvert beneath NE Cherry Lake Cir.

The high and medium CP scenarios are based on elevations in the outfall canal that were surveyed in 2017. These two scenarios represent conditions that have occurred in recent decades, during which beaver dams have been periodically removed and then reconstructed. The low CP scenario represents a predicted future condition in which the canal continues to erode down to the culvert invert elevation at NE Cherry Lake Cir.

In the long-term models for the no-pumping scenario, the invert elevations of the weir and channel links along the outfall canal, assumed constant throughout the entire model duration, were defined for each CP scenario to evaluate the impacts on lake levels due to the structural alterations in the outfall canal.

The simulated lake stage hydrographs for the no-pumping scenario for the high, medium, and low CP scenarios are graphically presented in Figure 5-12.

Based on the daily model simulated lake stage data sets for the no-pumping scenario for the high, medium, and low CP scenarios (Figure 5-12), the stage duration curves were developed for the high, medium, and low CP scenarios (Figure 5-13) and utilized in estimating the Historic P10, P50, and P90 elevations that are commonly used in establishing minimum levels for lakes per the SWFWMD MFLs methodology.

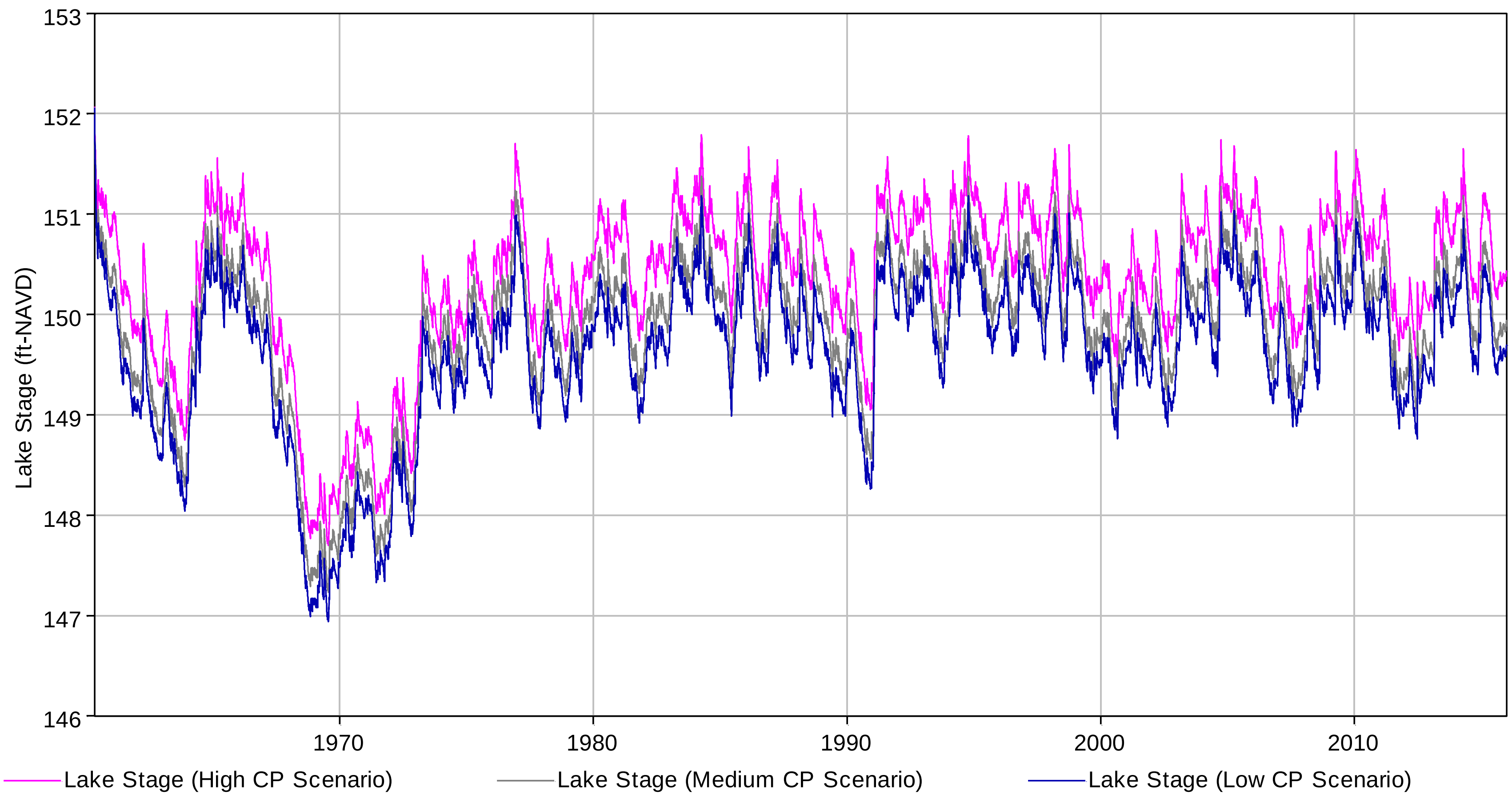


Figure 5-12. Simulated Lake Stage Hydrographs at Cherry Lake for No-pumping Scenario for High, Medium, and Low Control Point Scenarios (1960-2015).

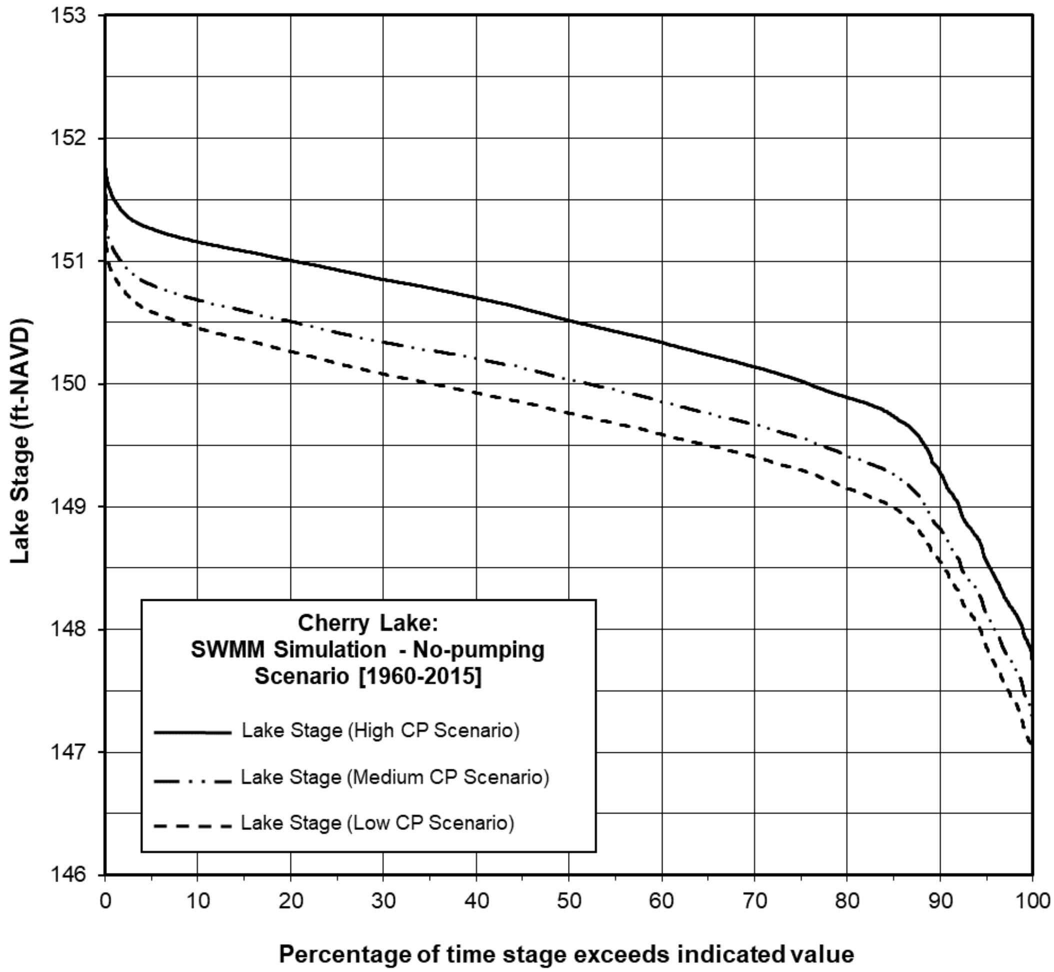


Figure 5-13. Exceedance Probability Chart for Simulated Lake Stage Data at Cherry Lake for No-pumping Scenario for High, Medium, and Low Control Point Scenarios (1960-2015).

5.4 Potential MFLs for Cherry Lake

The SWFWMD methodology (SWFWMD, 1999a, 1999b, and 2021; Leeper *et al.,* 2001; Hancock, 2007) was utilized to develop potential minimum lake levels for Cherry Lake. Minimum levels determination is based on the evaluation of observed and model simulated stage data, vegetation sampling, hydrologic indicators of sustained inundation, control point elevation, bathymetry, water quality, and elevations of anthropogenic features such as docks, as documented in detail at *Technical Support Document for Minimum Lake Levels: Cherry Lake, Florida* (ECT, 2023). Potential minimum levels for Cherry Lake, including High Minimum Lake Levels (HMLLs) and Minimum Lake Level (MLLs), have been determined by the District for the high, medium, and low CP scenarios (Table 5-5).

Table 5-5. Summary of minimum levels for Cherry Lake (elevations in ft NAVD88).

Level	High CP Scenario	Medium CP Scenario	Low CP Scenario	Level Description
High Minimum Lake Level (HMLL)	150.35	150.33	150.37	Elevation that lake stage is required to equal or exceed 10% of the time on a long-term basis.
Minimum Lake Level (MLL)	149.72	149.68	149.68	Elevation that lake stage is required to equal or exceed 50% of the time on a long-term basis.

Source: Technical Support Document for Minimum Lake Levels: Cherry Lake, Florida (ECT, 2023).

The HMLLs for Cherry Lake are 150.35, 150.33, and 150.37 ft NAVD88, and the MLLs are 149.72, 149.68, and 149.68 ft NAVD88, for the high, medium, and low CP scenarios, respectively (Table 5-5).

For the purpose of allowing the lake to continue to periodically achieve historic high water levels, the HMLLs are required to be reached or exceeded 10% of the time over a long-term record. The MLL for the high CP scenario should be reached or exceeded at least 50% of the time for the purpose of preserving the ecological integrity of the non-cypress fringing wetlands and meeting other environmental values outlined in Rule 62-40.473, F.A.C., including: fish and wildlife habitats and the passage of fish, transfer of detrital material, and filtration and absorption of nutrients and other pollutants. The MLLs for the medium and low CP scenarios should be reached or exceeded at least 50% of the time for the purpose of preserving the ecological integrity of the cypress fringing wetlands and meeting other environmental values outlined in Rule 62-40.473, F.A.C., including: fish and wildlife habitats and the passage of fish, transfer of detrital material, and filtration and absorption of nutrients and other pollutants. However, the environmental values, recreation in and on the water, aesthetic and scenic attributes, and water quality are not fully met, because the proposed MLLs are lower than the Dock-Use Standard for the high, medium, and low CP scenarios.

6.0 Assessment of Hypothetical Water Resource Development

6.1 Introduction

The Cherry Lake water budget model was used to assess the hydrologic effects of upper FAS drawdowns in the context of MFLs. This section documents the determination of freeboard or maximum allowable upper FAS declines beyond the no-pumping scenario for the high, medium, and low CP scenarios at Cherry Lake.

A series of runs of the 55.7-year long-term model simulations were performed with different aquifer declines. The updated lake stage data set was developed and used to assess each aquifer decline scenario for each minimum level until it is no longer being met.

The following two assumptions were applied in developing the model simulated lake stage data set for each scenario:

1. The 55.7-year (4/29/1960 through 12/31/2015) rainfall, ET, and groundwater data sets are reasonable representation of the long-term climate in the watershed, absent significant anthropogenic or climatological changes.
2. To assess future water resource developments, a constant upper FAS drawdown value beyond the no-pumping scenario was assumed throughout the entire model simulation.

6.2 Assessment of Hypothetical Allowable Floridan Aquifer Drawdowns

Based on the initial stage duration analysis results, the MFLs for Cherry Lake would be met under the measured scenario. Therefore, further drawdowns in the upper FAS might be allowable at the lake. 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 upper FAS potentiometric surface levels were used in modeling the groundwater loss from the lake through an "outlet" link in the model. The upper FAS drawdowns were simulated by subtracting a set amount from the groundwater level data set for the no-pumping scenario (Figure 5-7). Based on the methodology described in Section 5.3 (Equation G), the lower groundwater loss rate parameter for each Aquifer in the model, as the single most important factor to evaluate the freeboard or maximum allowable amount of upper FAS drawdown, was adjusted for different upper FAS drawdowns. The remainder of the model parameters were not changed.

To determine the freeboard in the area beyond the no-pumping scenario, a series of runs were performed. Drawdowns were gradually increased, the long-term models re-run, and the resulting model simulated lake stage data set was assessed with respect to each minimum level to be no longer met. Based on the MFLs procedures used by SWFWMD, the HMLL is required to be reached or exceeded 10% of the time over a long-term record and the MLL is required to be reached or exceeded 50% of the time.

Based on the stage duration analysis results, the HMLL and MLL levels at Cherry Lake would still be met with a drawdown of 75 ft beyond the no-pumping scenario for the high and medium CP scenarios (Figures 6-1 and 6-2). Since the mean upper FAS groundwater level from 1960 through 2015 for the no-pumping scenario is approximately 75 ft NAVD88 (Figure 5-6), a drawdown value greater than 75 ft will reduce the upper FAS groundwater levels to be lower than mean sea level, which is unrealistic given that the distance between the lake and the Gulf of Mexico (over 50 miles) and other constraints for protections of MFLs established at various springs and Withlacoochee and Suwannee rivers in the vicinity. Therefore, the upper FAS drawdowns greater than 75 ft beyond the no-pumping scenario were not involved in the maximum drawdown analysis for the high and medium CP scenarios at Cherry Lake.

For the low CP scenario, the HMLL and MLL levels at Cherry Lake would be met with maximum drawdowns of 41 and 12 ft beyond the no-pumping scenario, respectively (Figures 6-3A and 6-3B).

The freeboard or maximum allowable upper FAS drawdowns for the HMLL and MLL levels for the high, medium, and low CP scenarios at Cherry Lake are presented in Table 6-1. The MLL level is the constraining level for Cherry Lake for the low CP scenario since it allows the smallest upper FAS drawdown.

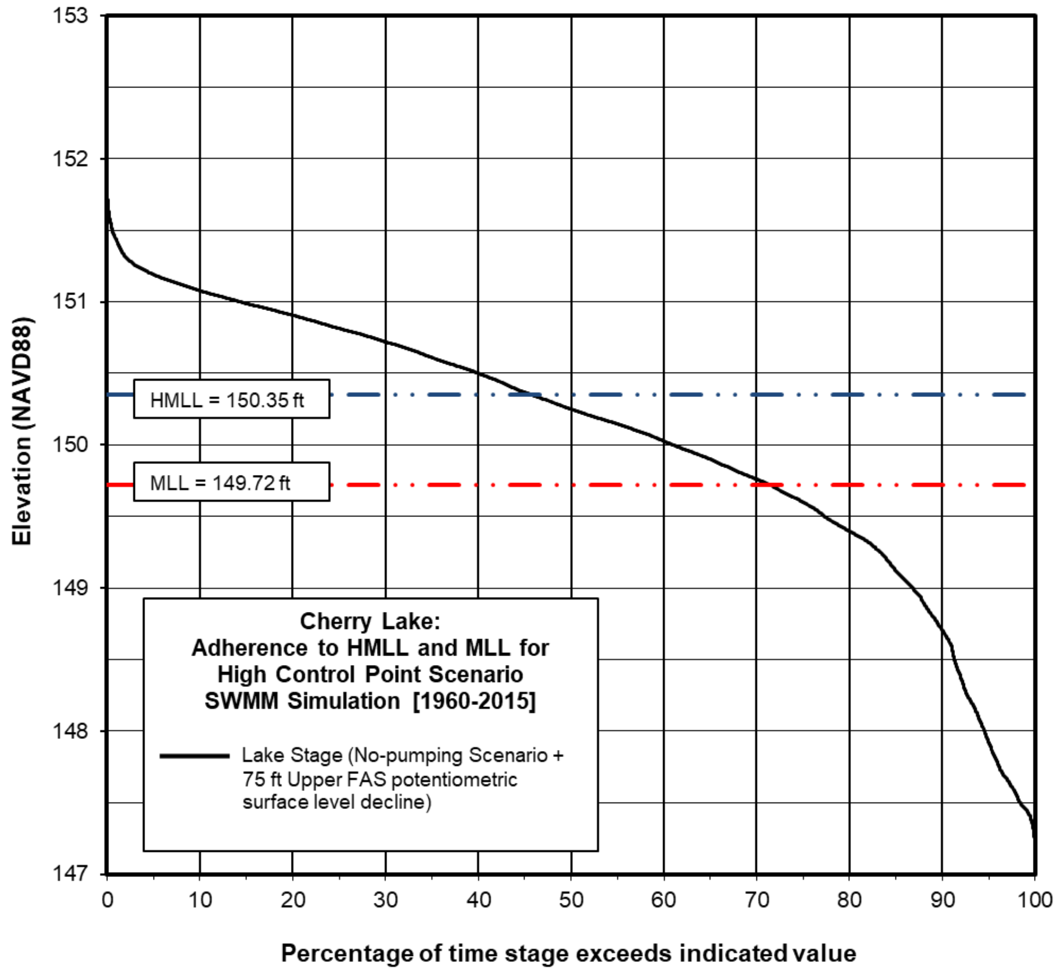


Figure 6-1. Stage Duration Curve – High Minimum Lake Level, Minimum Lake Level, and SWMM Simulation (1960-2015) for the High Control Point Scenario at Cherry Lake – No-pumping Scenario + 75 ft Upper FAS Potentiometric Surface Level Decline.

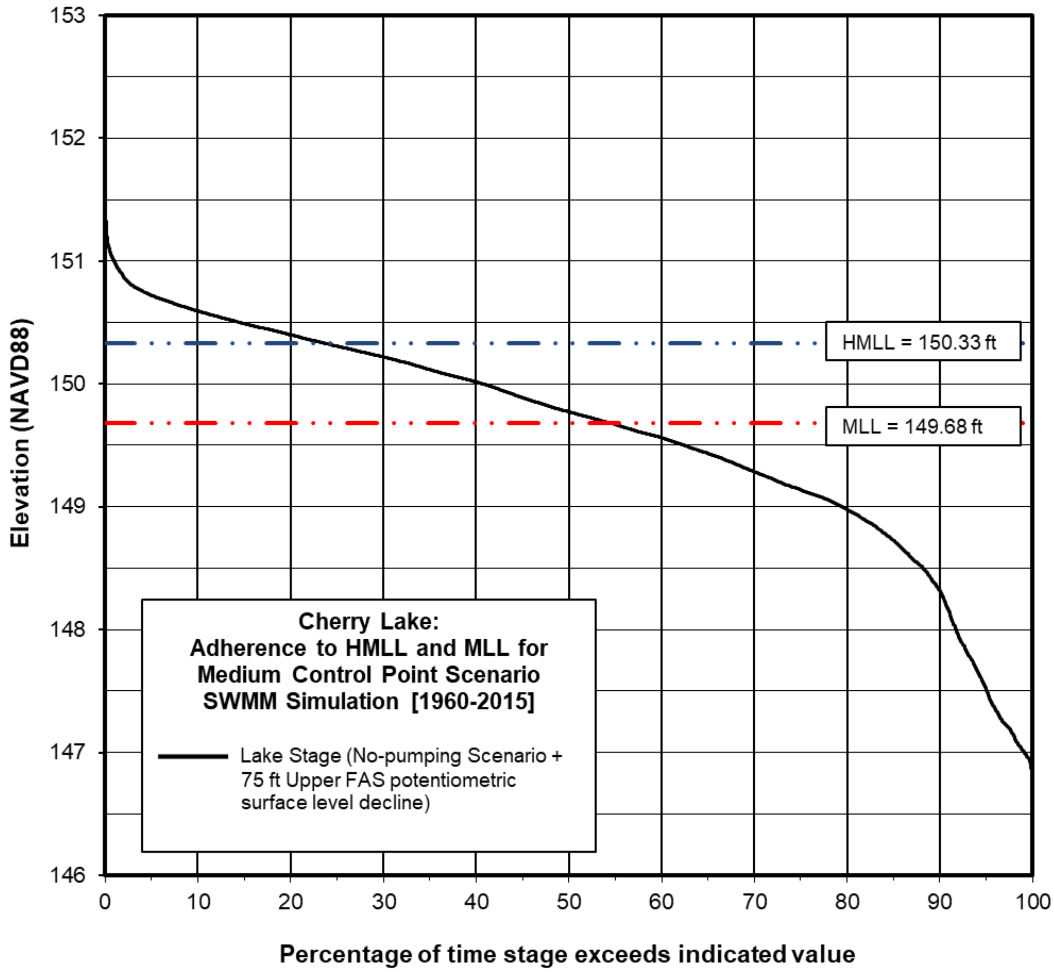


Figure 6-2. Stage Duration Curve – High Minimum Lake Level, Minimum Lake Level, and SWMM Simulation (1960-2015) for the Medium Control Point Scenario at Cherry Lake – No-pumping Scenario + 75 ft Upper FAS Potentiometric Surface Level Decline.

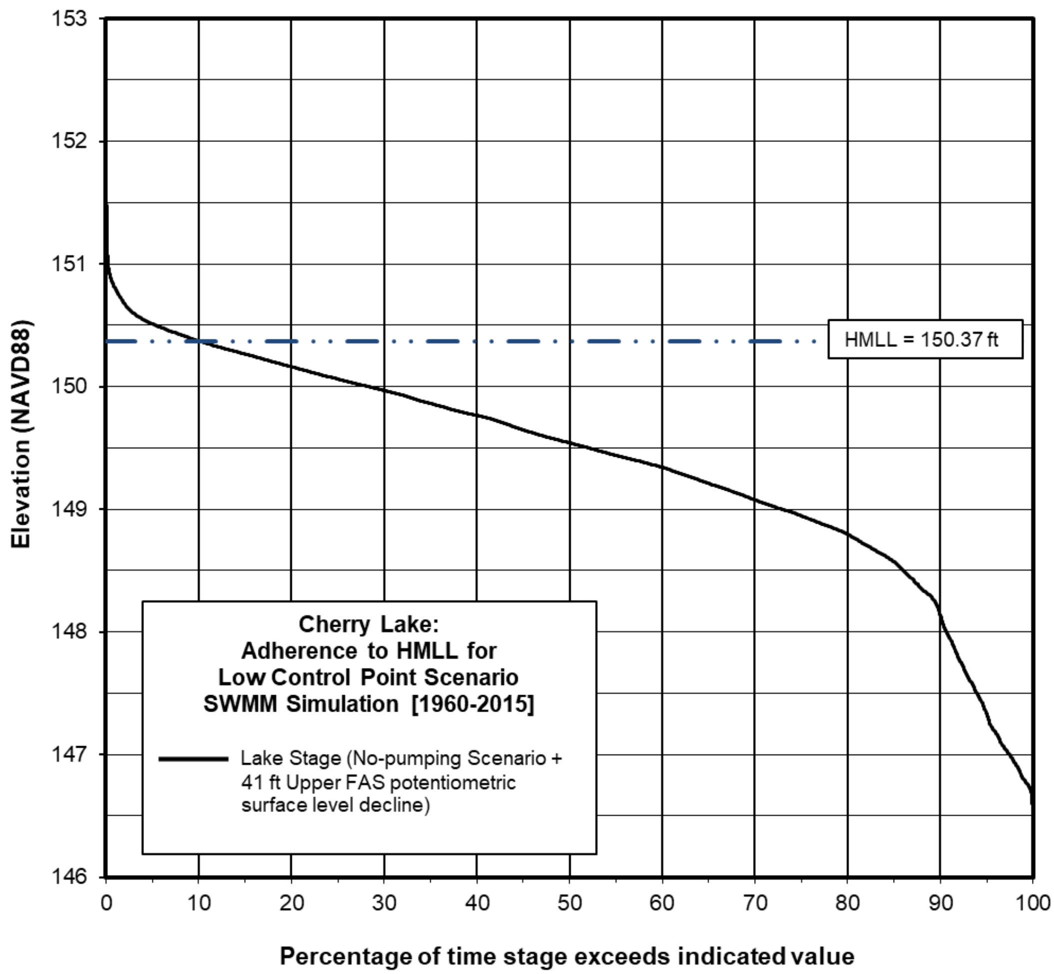


Figure 6-3A. Stage Duration Curve – High Minimum Lake Level and SWMM Simulation (1960-2015) for the Low Control Point Scenario at Cherry Lake - No-pumping Scenario + 41 ft Upper FAS Potentiometric Surface Level Decline.

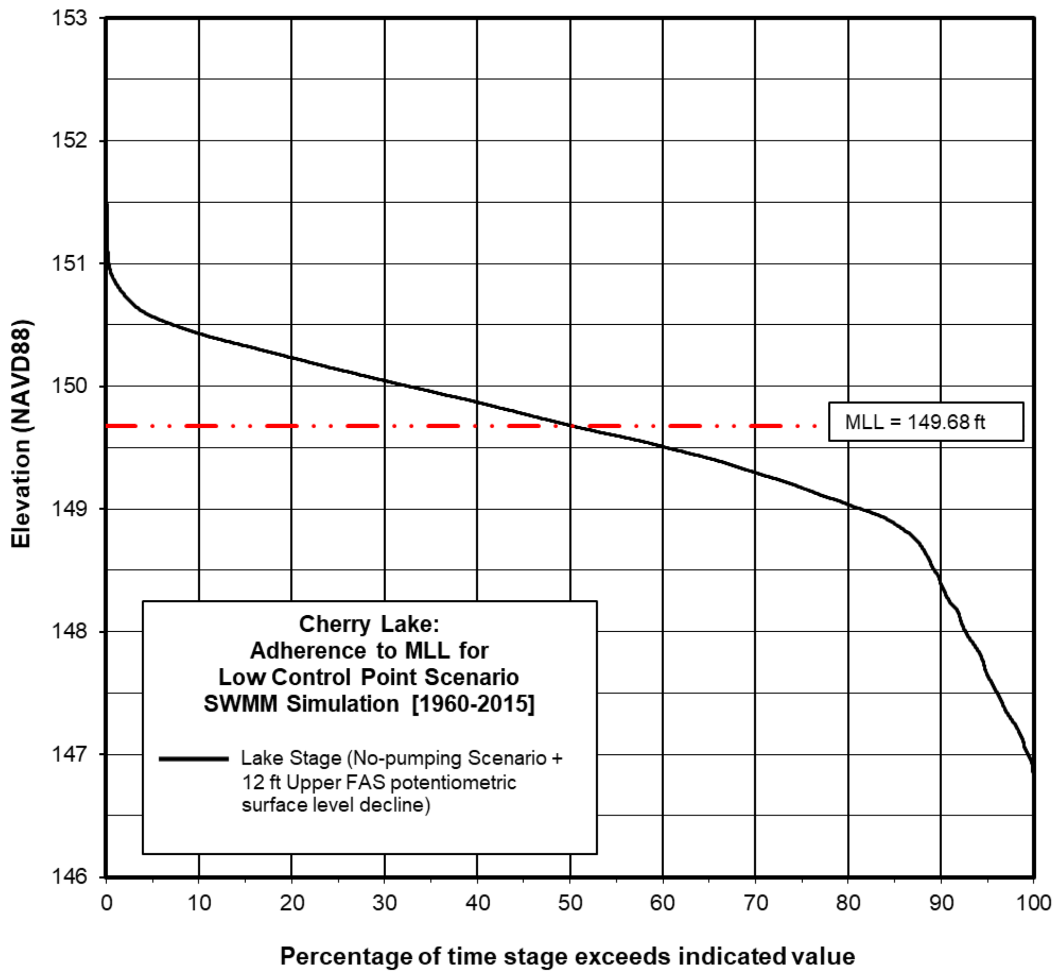


Figure 6-3B. Stage Duration Curve – Minimum Lake Level and SWMM Simulation (1960-2015) for the Low Control Point Scenario at Cherry Lake - No-pumping Scenario + 12 ft Upper FAS Potentiometric Surface Level Decline.

Table 6-1. Summary of upper FAS freeboard for the minimum levels for Cherry Lake.

Designated Level	High CP Scenario	Medium CP Scenario	Low CP Scenario
High Minimum Lake Level (HMLL)	>75	>75	41
Minimum Lake Level (MLL)	>75	>75	12

This drawdown analysis results are also consistent with the water budget results for the 10-year model calibration (Table 4-7), i.e., the groundwater loss to upper FAS through deep percolation in Aquifers and the outlet link at the lake is a relatively small value compared to the loss through evaporation and surface water discharge (through the outlet canal) such that the lake levels are primarily controlled by rainfall, evaporation, and the outlet canal.

Long-term lake stage hydrographs and stage duration curves can be used to evaluate the time extent and magnitude of the hydrologic changes involved at Cherry Lake between the no-pumping scenario and the maximum drawdowns of 75 ft beyond the no-pumping scenario for the HMLL and MLL levels for the high and medium CP scenarios and the maximum drawdowns of 41 and 12 ft beyond the no-pumping scenario for the HMLL and MLL levels, respectively, for the low CP scenario (Figures 6-4 through 6-9B).

It appears that when the lake is high, the upper FAS drawdown has less impact on the lake stages 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 both the lake and the aquifer underneath have minimal chance to recover to their normal water levels after prolonged drought conditions, such as the 1968-1971 drought period (Figures 6-4 through 6-6B).

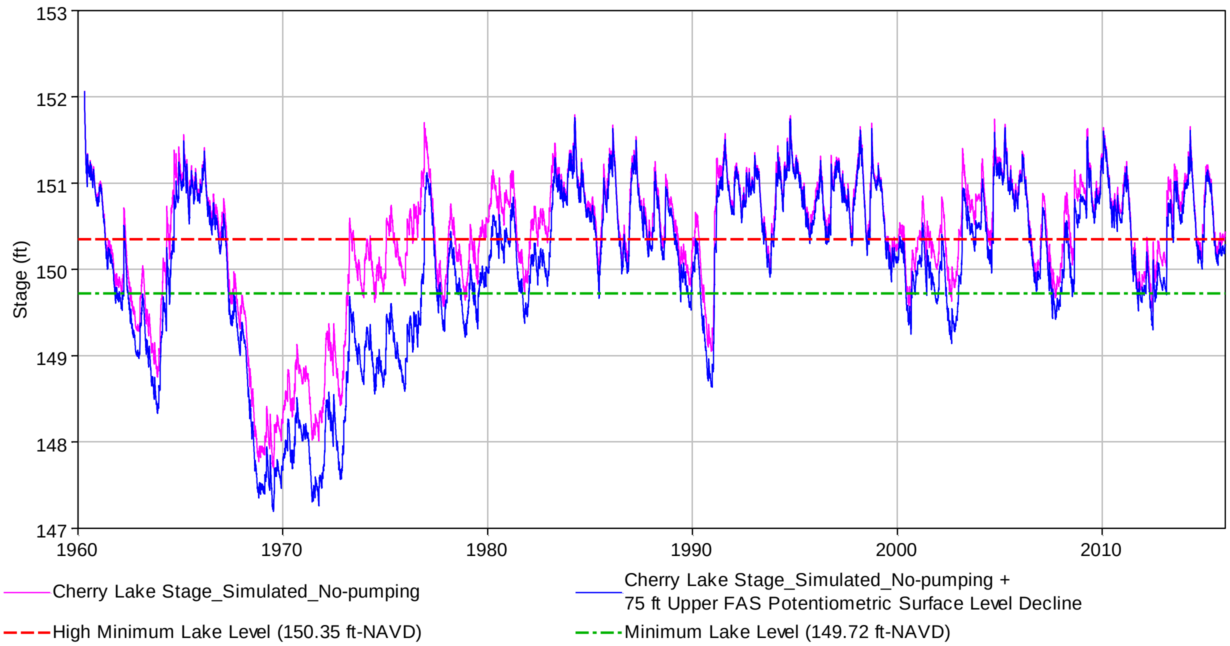


Figure 6-4. Hydrographs Comparison - SWMM Simulation (1960-2015) for the High Control Point Scenario at Cherry Lake – No-pumping vs. No-pumping + 75 ft Upper FAS Potentiometric Surface Level Decline.

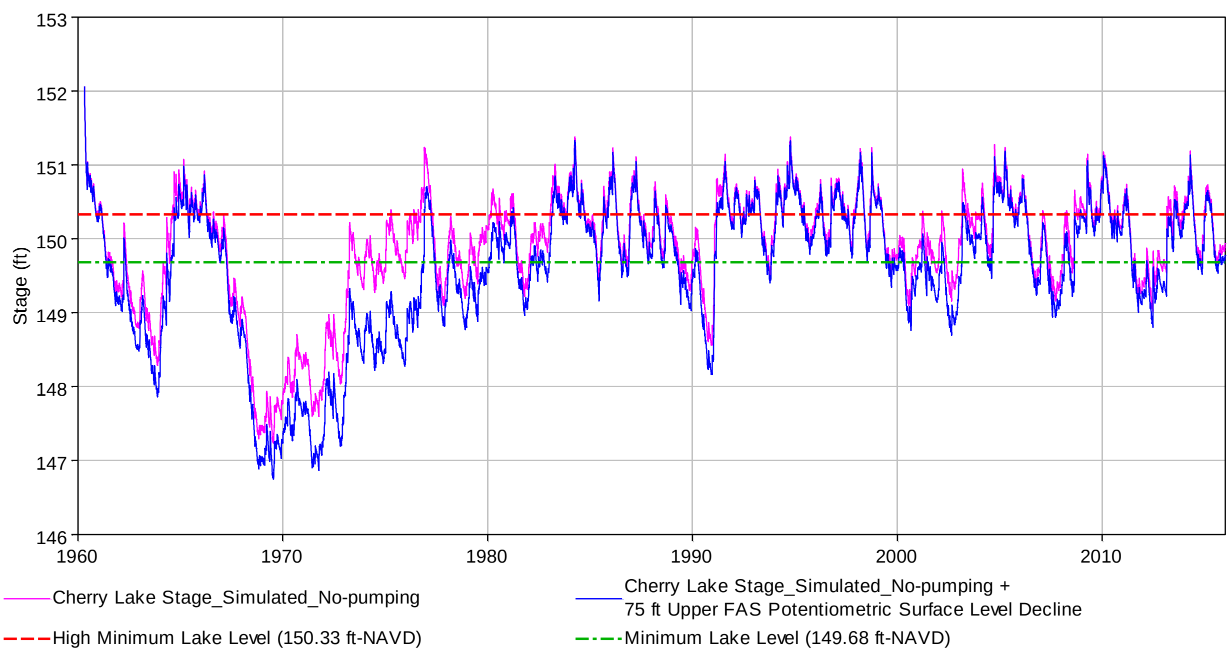


Figure 6-5. Hydrographs Comparison - SWMM Simulation (1960-2015) for the Medium Control Point Scenario at Cherry Lake – No-pumping vs. No-pumping + 75 ft Upper FAS Potentiometric Surface Level Decline.

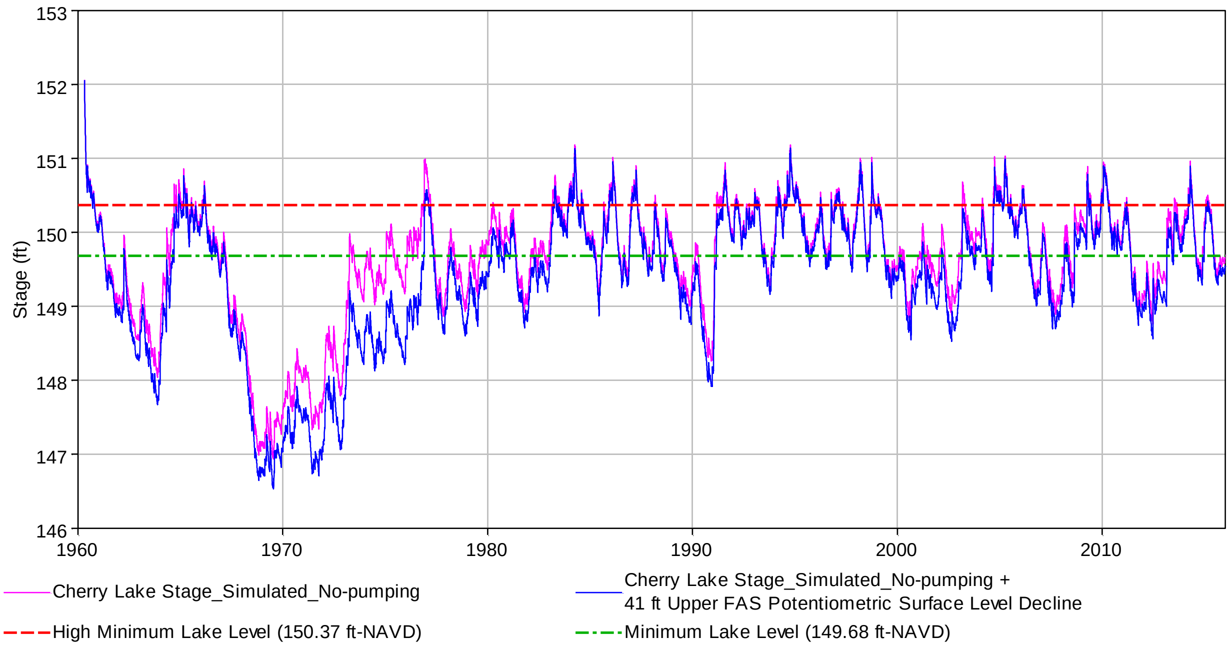


Figure 6-6A. Hydrographs Comparison - SWMM Simulation (1960-2015) for the Low Control Point Scenario at Cherry Lake – No-pumping vs. No-pumping + 41 ft Upper FAS Potentiometric Surface Level Decline.

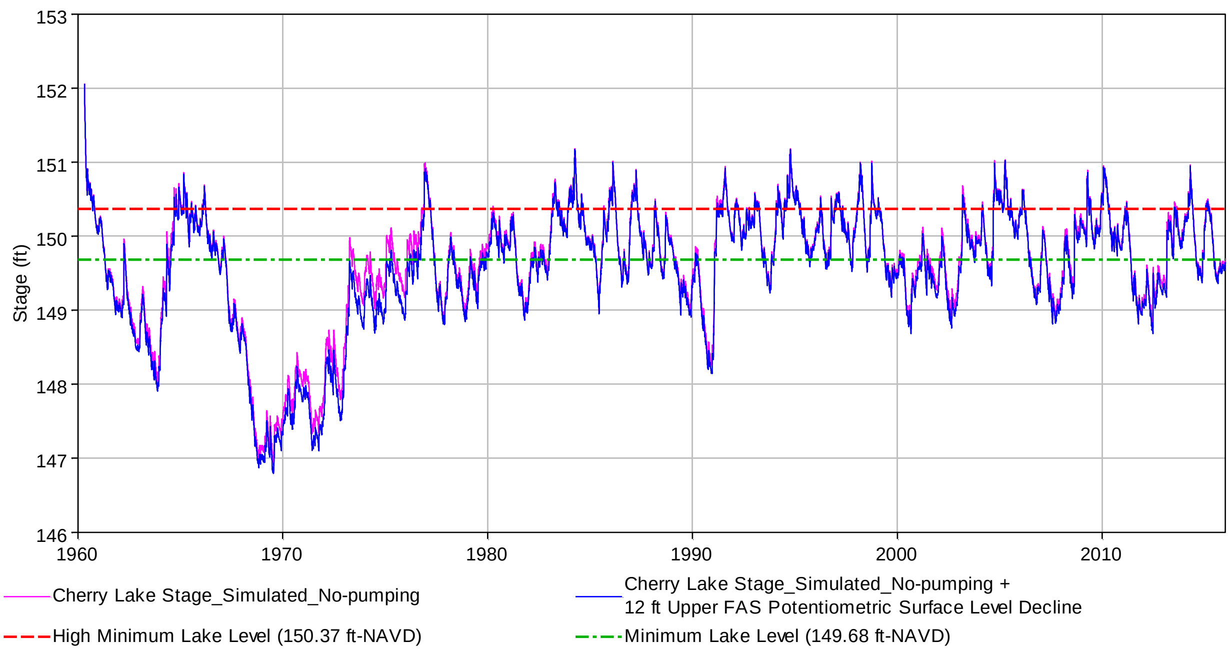


Figure 6-6B. Hydrographs Comparison - SWMM Simulation (1960-2015) for the Low Control Point Scenario at Cherry Lake – No-pumping vs. No-pumping + 12 ft Upper FAS Potentiometric Surface Level Decline.

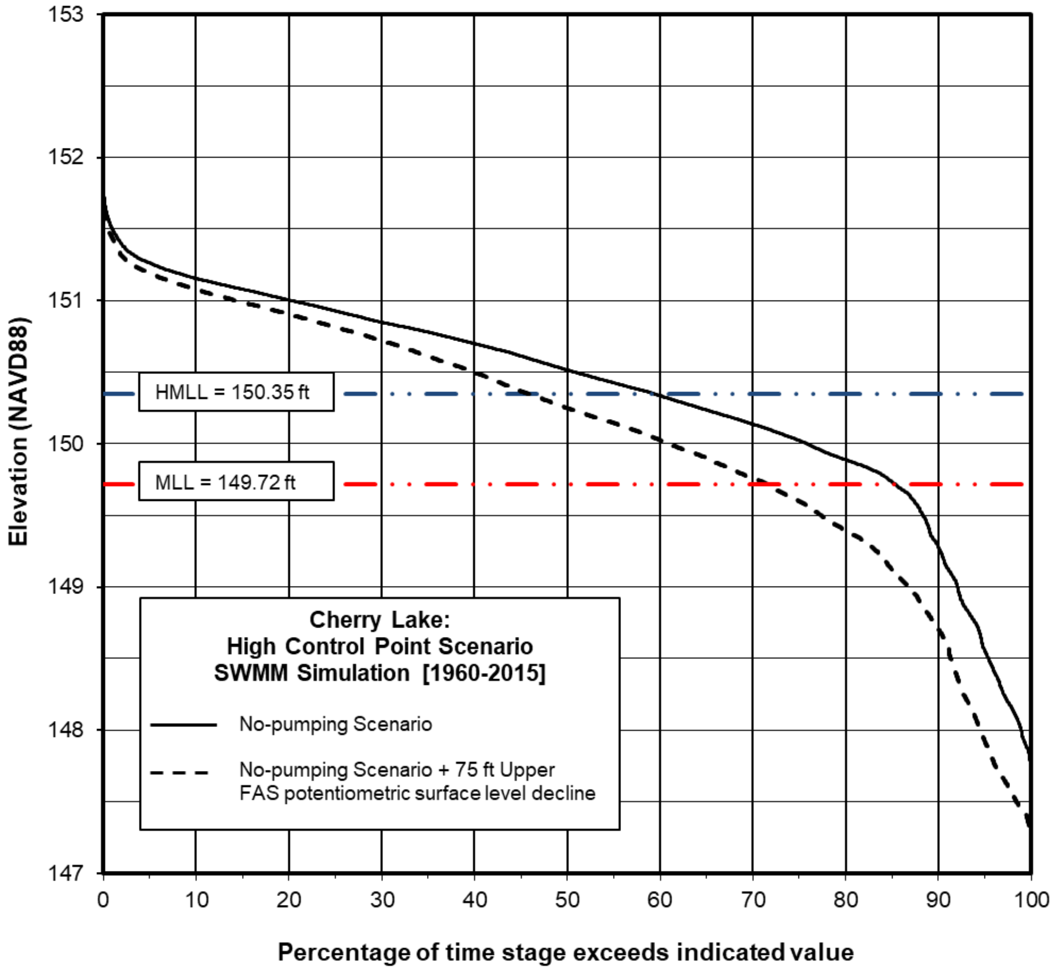


Figure 6-7. Stage Duration Curves Comparison – SWMM Simulation (1960-2015) for the High Control Point Scenario at Cherry Lake – No-pumping vs. No-pumping + 75 ft Upper FAS Potentiometric Surface Level Decline.

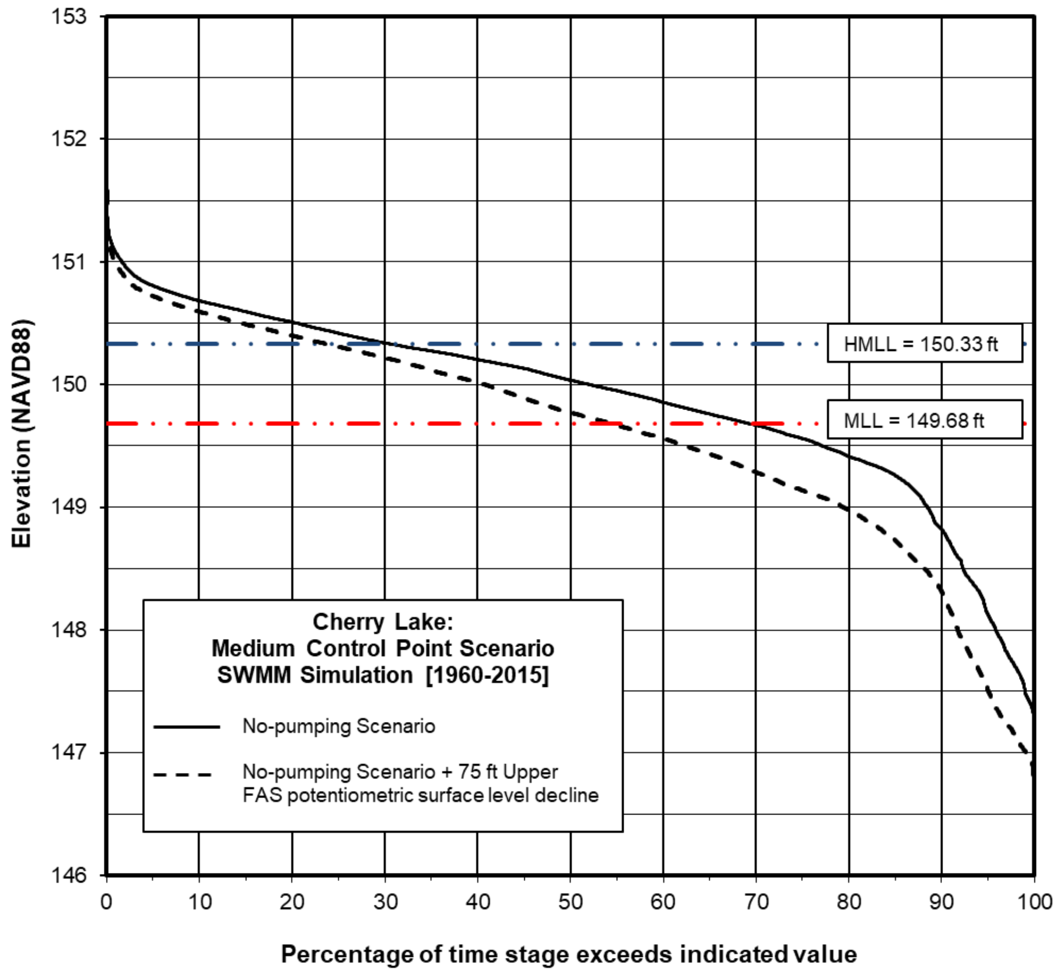


Figure 6-8. Stage Duration Curves Comparison – SWMM Simulation (1960-2015) for the Medium Control Point Scenario at Cherry Lake – No-pumping vs. No-pumping + 75 ft Upper FAS Potentiometric Surface Level Decline.

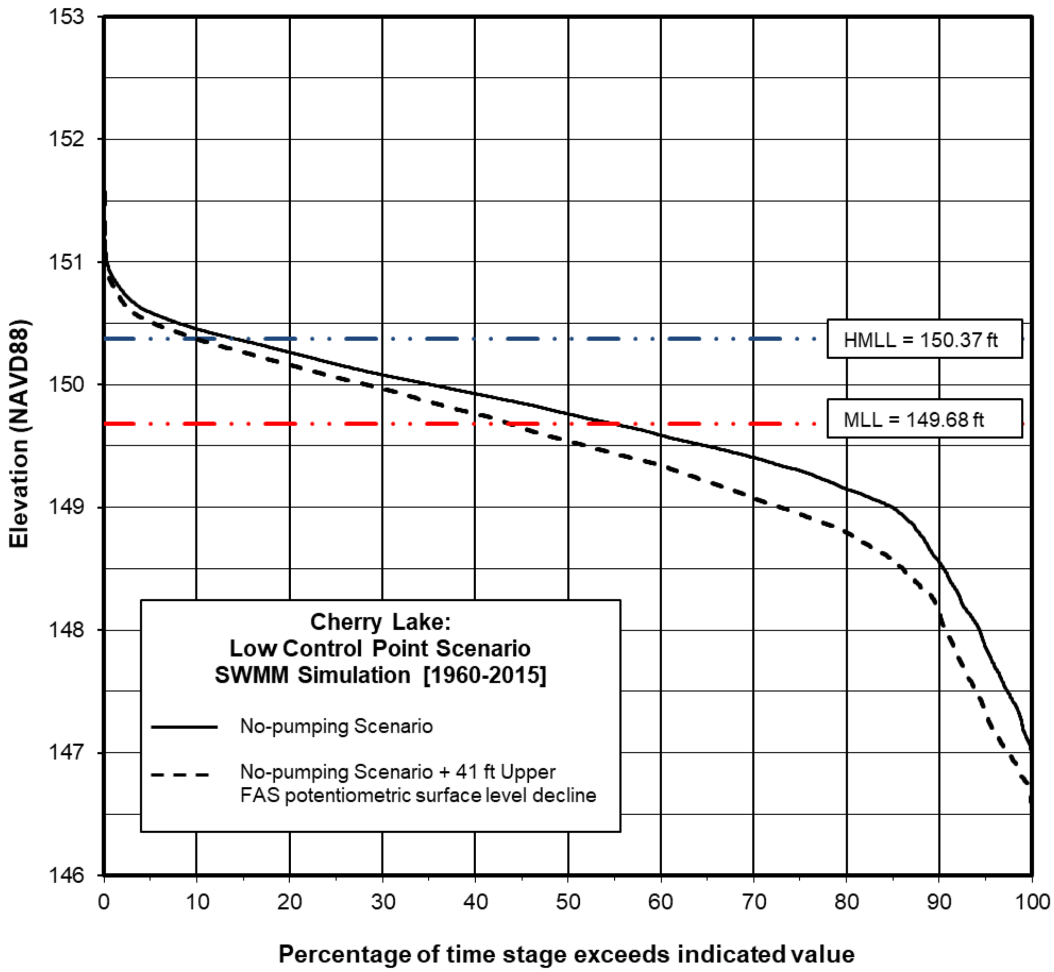


Figure 6-9A. Stage Duration Curves Comparison - SWMM Simulation (1960-2015) for the Low Control Point Scenario at Cherry Lake - No-pumping vs. No-pumping + 41 ft Upper FAS Potentiometric Surface Level Decline.

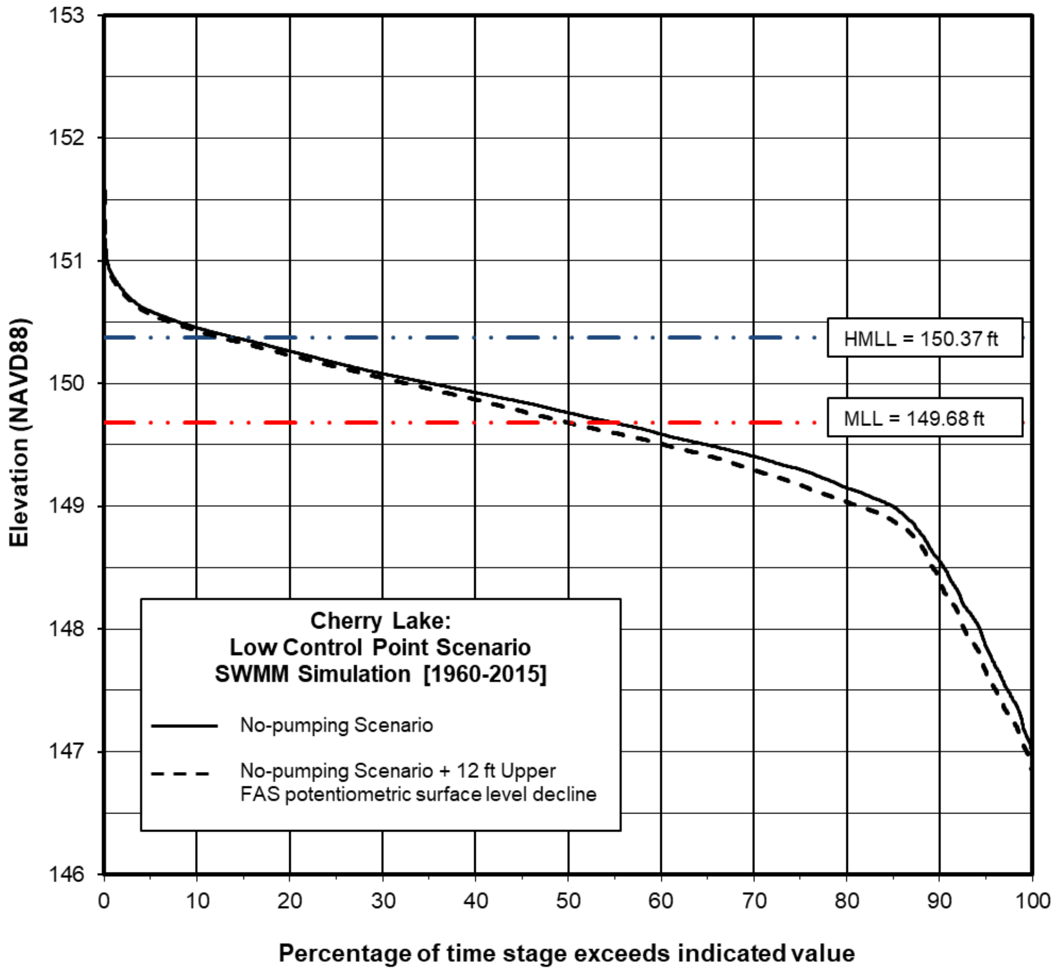


Figure 6-9B. Stage Duration Curves Comparison - SWMM Simulation (1960-2015) for the Low Control Point Scenario at Cherry Lake - No-pumping vs. No-pumping + 12 ft Upper FAS Potentiometric Surface Level Decline.

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 Cherry Lake located in northern Madison County, Florida.

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

The Cherry Lake water budget model was well calibrated using a 10-year lake gauge data record from 1/1/2006 through 12/31/2015. 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 Cherry Lake water budget model was employed in a long-term simulation for a 55.7-year period from 4/29/1960 through 12/31/2015. Based on the recent reference timeframe (RTF) analysis results provided by the District, the groundwater level data set for the no-pumping scenario was created and implemented in the long-term model simulations.

The 55.7-year long-term model was employed to simulate the measured and no-pumping scenarios with the high lake Control Point (CP) elevation at 150.80 ft NAVD88 and utilized in developing no-pumping lake stage exceedance percentiles for two additional fixed CP scenarios (medium and low CP scenarios). The model was also utilized in assessment of hypothetical allowable upper FAS drawdowns in the context of MFLs for Cherry Lake for the high, medium, and low CP scenarios.

The minimum levels assessed at Cherry Lake, including High Minimum Lake Levels (HMLLs) of 150.35 and 150.33 ft NAVD88 and Minimum Lake Levels (MLLs) of 149.72 and 149.68 ft NAVD88 for the high and medium CP scenarios, respectively, would still be met with a drawdown of 75 ft beyond the no-pumping scenario. While for the low CP scenario, the HMLL of 150.37 ft NAVD88 and MLL of 149.68 ft NAVD88 would be met with a maximum drawdown of 41 and 12 ft beyond the no-pumping scenario, respectively.

The drawdown results for the high and medium CP scenarios indicate that Cherry Lake is well buffered from upper FAS drawdowns due to a thick clay confining unit underlying the lake. The low CP scenario represents a condition in which the outfall canal that drains Cherry Lake has eroded to the extent that the culvert under NE Cherry Lake Circle becomes the control point. The drawdown results for the low CP scenario reflect that a relatively small change in lake levels over time (0.08 ft) could impact lake-fringing cypress wetlands if this condition were to occur.

Finally, it should be acknowledged that no model can possibly simulate all the 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. A total of six principal modeling assumptions and/or limitations were made in developing the water budget model of Cherry Lake as follows:

1. In the SWMM model, the lower groundwater loss rate parameter (DP) and the depth of the lower saturated groundwater zone (d_L) are the two model parameters used to estimate groundwater loss from the surficial aquifer to the upper FAS (Equation D). The assumption is made that influence on water budget model results by the upper FAS potentiometric surface

level fluctuation is considered insignificant in the lake watershed where it is confined. However, for the area immediately beneath the lake, an "outlet" link was employed in the SWMM model with a functional rating curve (a power function of the head difference between the water elevations at the lake and the groundwater levels in the upper FAS, see Equation E) to calculate the deep percolation from the lake to the upper FAS.

2. Topographic surveys at the outfall canal and major drainage structures and bathymetry survey at Cherry Lake were provided by the District. However, the topographic and bathymetric survey data may not be sufficient to determine the highest point of the outfall canal because a beaver dam was found in the middle of the canal and the 42" RCP beneath NE Cherry Lake Cir. seems to have been blocked by debris at the time of the survey. The beaver dam and culvert blockage together seem to control the outfall flow discharge from the lake during years preceding the survey but is no longer present. The crest elevation at Weir RB0090W was estimated at the top of beaver dam or 150.80 ft NAVD88. It is also assumed that culvert beneath NE Cherry Lake Cir. is fully open throughout the 10-yr model calibration and long-term model simulation durations.
3. The 10-year calibration period of 1/1/2006 through 12/31/2015 covers a wide range of hydrologic conditions. It was assumed that the calibrated model can provide a realistic simulation over a much longer period.
4. Various data sources with different techniques and levels of accuracy (e.g., NEXRAD vs. ORNL Daymet daily rainfall data and NOAA weather station data, NOAA pan evaporation vs. USGS PET data, observed vs. estimated groundwater level data) were assembled and utilized in developing the long-term model.
5. It was assumed that the 55.7-year (4/29/1960 through 12/31/2015) rainfall, ET, and groundwater data sets are reasonable representation of the long-term climate in the watershed, absent significant anthropogenic or climatological changes, for Cherry Lake.
6. To assess future water resource developments, a constant upper FAS drawdown value beyond the no-pumping scenario throughout the entire model simulation period was assumed and considered adequate for the assessment.

The limitations 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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Appendix A -
SWMM Model Input and Output Data

(Located on DVD)