APPENDIX B – HYDROLOGICAL ANALYSES

INTRODUCTION

In addition to extensive work conducted to understand the ecological structure and function and determine the most sensitive environmental values of priority waterbodies, assessing the status of minimum flows and levels (MFLs) also requires substantial hydrological analysis. Several steps were involved in performing the hydrologic analysis for Lake Prevatt, including:

1. Review of available data for compiling long-term datasets;
2. Historical groundwater pumping impact assessment;
3. Development of lake level datasets representing no-pumping and current-pumping conditions; and
4. Estimating available water (freeboard or deficit).

Figure B-1 depicts the steps involved in the Lake Prevatt hydrologic analysis. This document describes the first three steps and associated results. Appendix D includes the description of the last step.

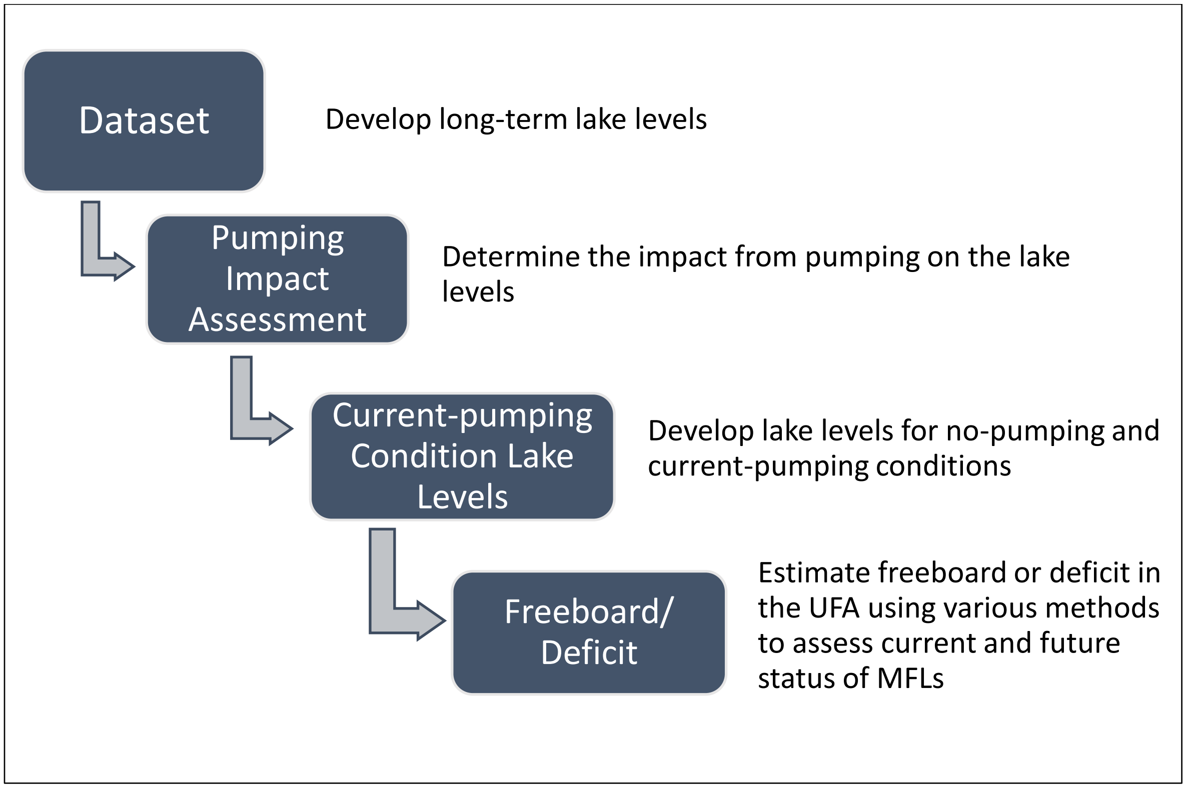

Figure B-1. Hydrologic analysis process.

BACKGROUND

Lake Prevatt is located in the Wekiva River watershed, within Orange County, Florida. It lies two miles north of the City of Apopka in Wekiwa Springs State Park. It has a surface area of approximately 100 acres, and discharges via Carpenter Branch and Mills Creek into Rock Springs Run. The location of the lake and its watershed are shown in Figure B-2. At low stages, the lake separates into two lobes, referred to here as the North Lobe and the South Lobe.

St. Johns River Water Management District (SJRWMD) staff developed a Hydrological Simulation Program - FORTRAN (HSPF) model (Sarker et al., 2024) to simulate the hydrologic and hydraulic processes, surface water-groundwater interaction, and water budget components of Lake Prevatt and its watershed. A review of available data was completed before developing, calibrating, and validating the model. Next, a sensitivity analysis was performed to identify key parameters and a long-term simulation was created to support the Lake Prevatt MFLs assessment. The HSPF model reasonably simulated the temporal variations and magnitude of observed stages for Lake Prevatt during both the calibration and validation periods and adequately replicated the observed low to medium stages. The HSPF model was then used to assist in the development of the groundwater no-pumping and current-pumping datasets and to generate the no-pumping and current-pumping simulated lake levels discussed here.

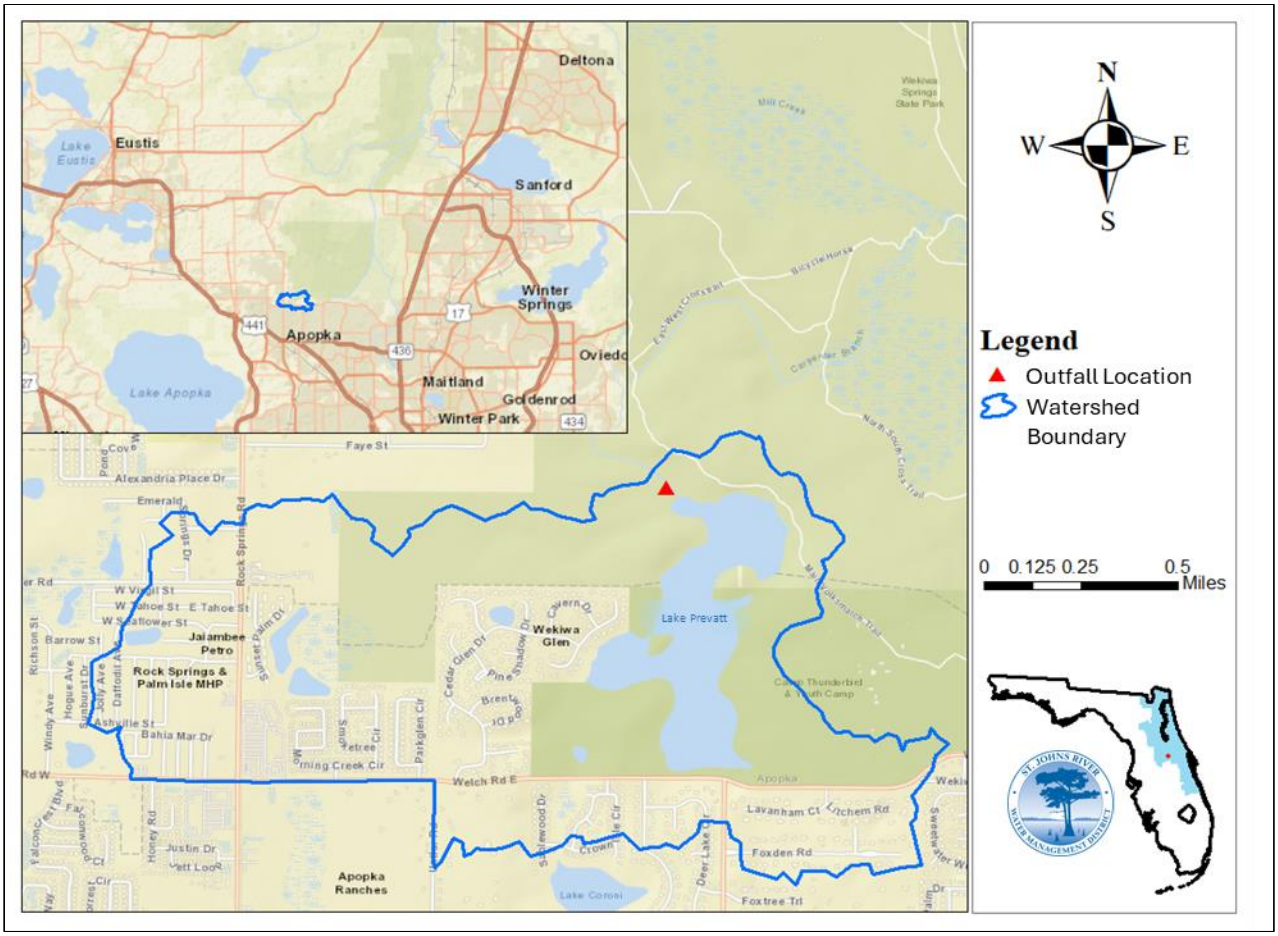

Figure B-2. Lake Prevatt and its watershed.

Development of No-pumping and Current-pumping Lake Levels

An important part of assessing MFLs for lake systems is the simulation of long-term lake levels under no-pumping and current-pumping conditions. These levels are used to perform freeboard and deficit analyses to assess current and future MFLs status. To generate no- and current-pumping condition lake levels, surface water models require no- and current-pumping condition Upper Floridan aquifer (UFA) levels developed using information extracted from a regional groundwater flow model. This process involves performing a pumping impact analysis using simulated groundwater levels in the UFA beneath the lake under different simulated pumping conditions and building a pumping-drawdown relationship to estimate impact from historical groundwater pumping data. This process is illustrated in Figure B-3.

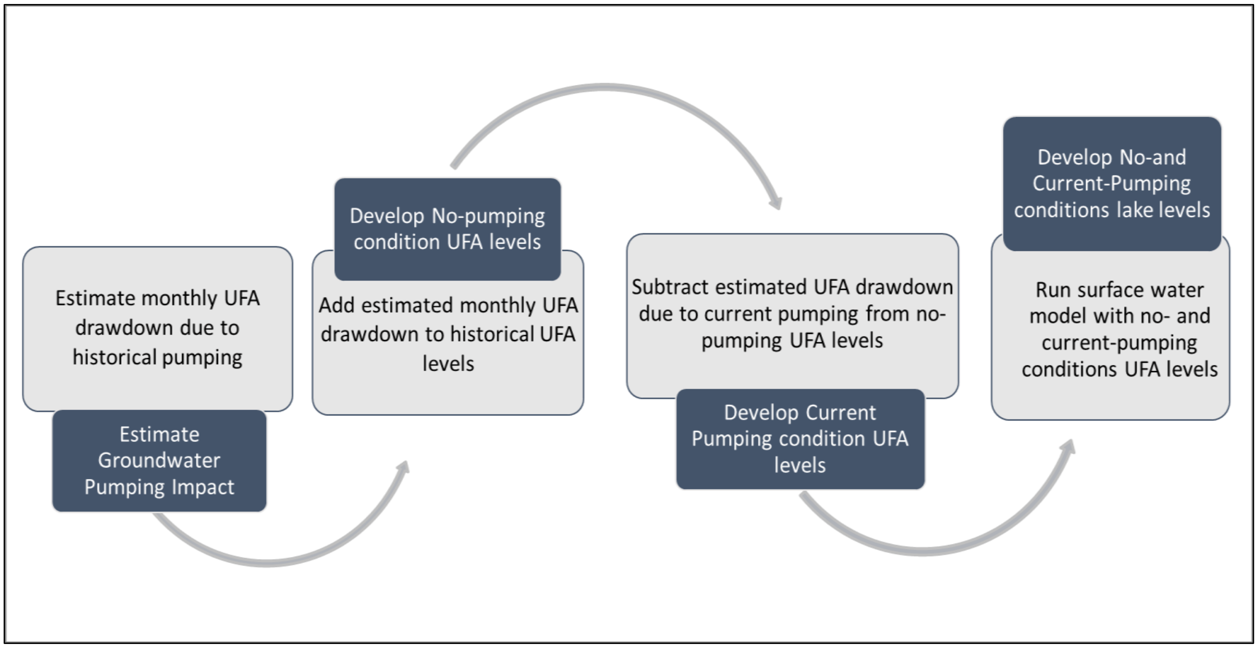

Figure B-3. Flow chart illustrating the groundwater flow model pumping impact analysis and development of no-pumping and current-pumping condition Upper Floridan aquifer and lake levels for an MFLs lake.

Groundwater Pumping Impact Assessment

Groundwater Modeling

The East-Central Florida Transient Expanded (ECFTX) groundwater flow model was developed by the Central Florida Water Initiative (CFWI) to support regional water supply planning and understand groundwater resource limitations for sustainable water supplies while protecting natural systems (CFWI HAT, 2020). The ECFTX model was recalibrated in 2022, referred to as ECFTX v2.0, to improve simulation of groundwater levels and flows within the Wekiva river basin (Gordu et al., 2022). ECFTX v2.0 was used for the Lake Prevatt pumping impact analysis. The ECFTX v2.0 consists of an initial stress period representing steady state conditions for the year 2003, followed by 132 monthly transient stress periods representing the years 2004 through 2014. The ECFTX v2.0 model domain and CFWI planning areas are shown in Figure B-4.

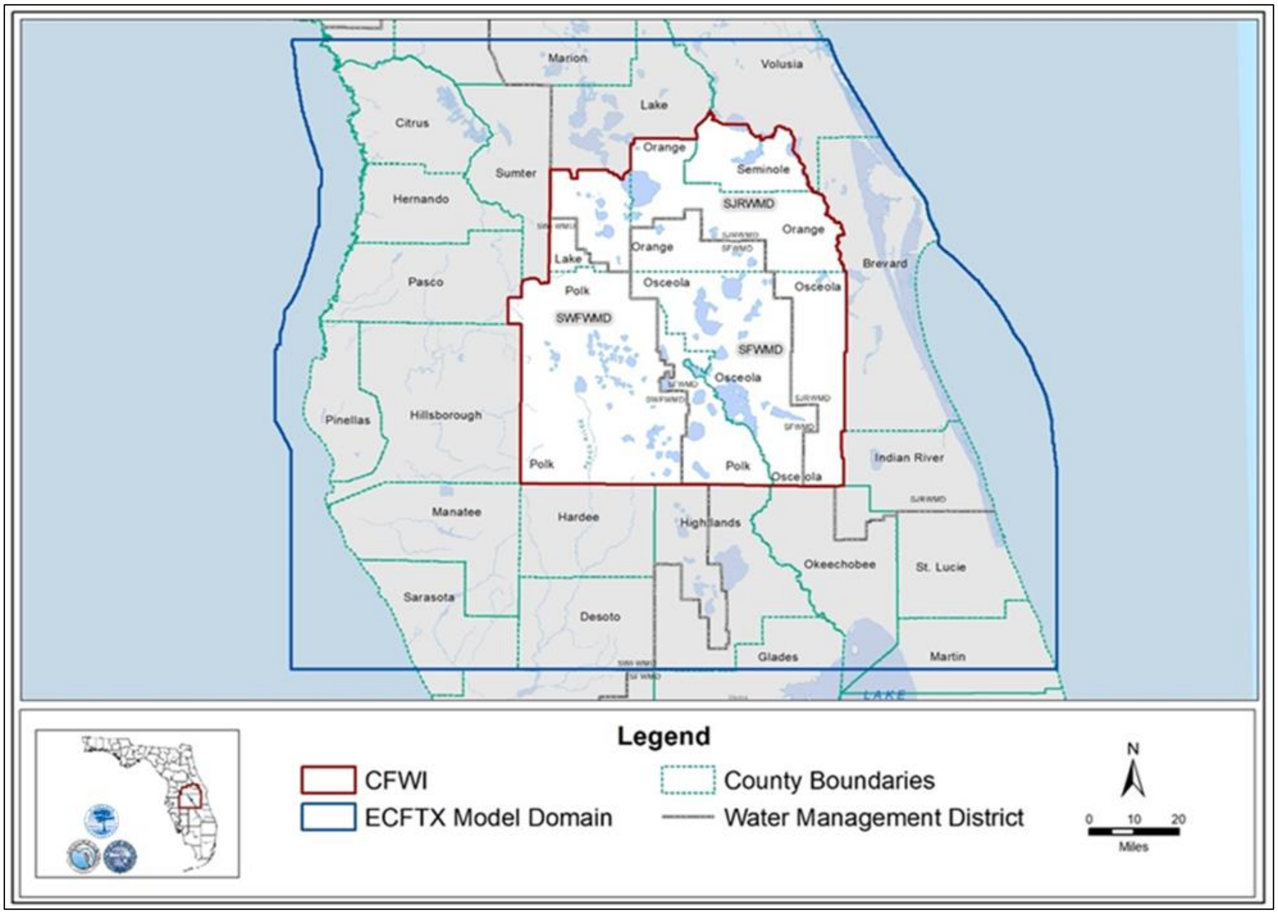

Figure B-4. ECFTX v2.0 model domain boundary (blue) and CFWI planning area (red).

An estimate of daily UFA drawdown beneath Lake Prevatt resulting from regional pumping for the period of 1930 to 2020 was necessary to develop the no-pumping condition UFA levels. Since the ECFTX v2.0 model was not designed to simulate monthly conditions over this long-term period, a methodology was developed using available ECFTX v2.0 model data to estimate the impact of regional pumping on groundwater levels outside of the model simulation period. This methodology includes the development of a relationship between groundwater pumping and UFA drawdown beneath Lake Prevatt using the ECFTX v2.0 model. To develop this relationship, and capture a wide range of pumping conditions, the following model simulations were used:

- Pumping reduced by 50%
- Pumping reduced by 25%
- Calibration period condition

- Pumps off

For each simulation, the simulated UFA levels beneath Lake Prevatt were extracted from the ECFTX v2.0 model for each transient monthly stress period (2004 through 2014) by taking an average of the simulated UFA levels at model grid cells intersecting the lake boundary. For example, the impact for the calibration pumping condition was calculated by subtracting the simulated calibrated model UFA levels from the simulated pumps off UFA levels beneath Lake Prevatt for each transient stress period. This calculation was repeated for the 50% and 25% reduced pumping scenarios. This resulted in 132 simulated impact values for each pumping scenario, corresponding to each month in the transient simulation. Groundwater pumping information was also extracted from the ECFTX v2.0 model for the calibration, 25% reduced pumping and 50% reduced pumping scenarios to develop a pumping-drawdown relationship. Groundwater pumping within close proximity of Lake Prevatt is assumed to have a direct impact on the groundwater levels beneath the lake. To develop the relationship and estimate the pumping impact from 1953 to 2020, three buffer zones within 10-, 15-, and 20- mile radius of Lake Prevatt were tested. Figure B-5 shows the extent of the boundaries used in the groundwater pumping impact assessment at Lake Prevatt. It should be noted that groundwater pumping within a buffer area was used to develop the pumping-impact relationship and capture the variation of regional pumping over time. Using this relationship, the impact of groundwater pumping on lake levels was assessed based on all groundwater pumping within the groundwater model domain.

For each scenario, the total pumping in model layers 3 through 11 (Upper UFA to LFA) was extracted from each buffer area shown in Figure B-5 and summarized for each transient monthly stress period in the model. The modeled impact and pumping data for each scenario and transient stress period were combined into a single table, yielding a total of 396 pumping-impact paired data values to use to fit a relationship between impact and groundwater pumping. A linear regression model was fit to the modeled impact (response variable) and groundwater pumping (predictor variable) data at Lake Prevatt. Figure B-6, FigureB-7, and FigureB-8 show the linear relationships between UFA impact and groundwater pumping within the 10-, 15-, and 20-mile radius of Lake Prevatt. Strong linear relationships existed between UFA impact and groundwater pumping within the 10-mile (R^2 = 0.97), 15-mile (R^2 = 0.99), and 20-mile (R^2 = 0.98) buffers to the lake.

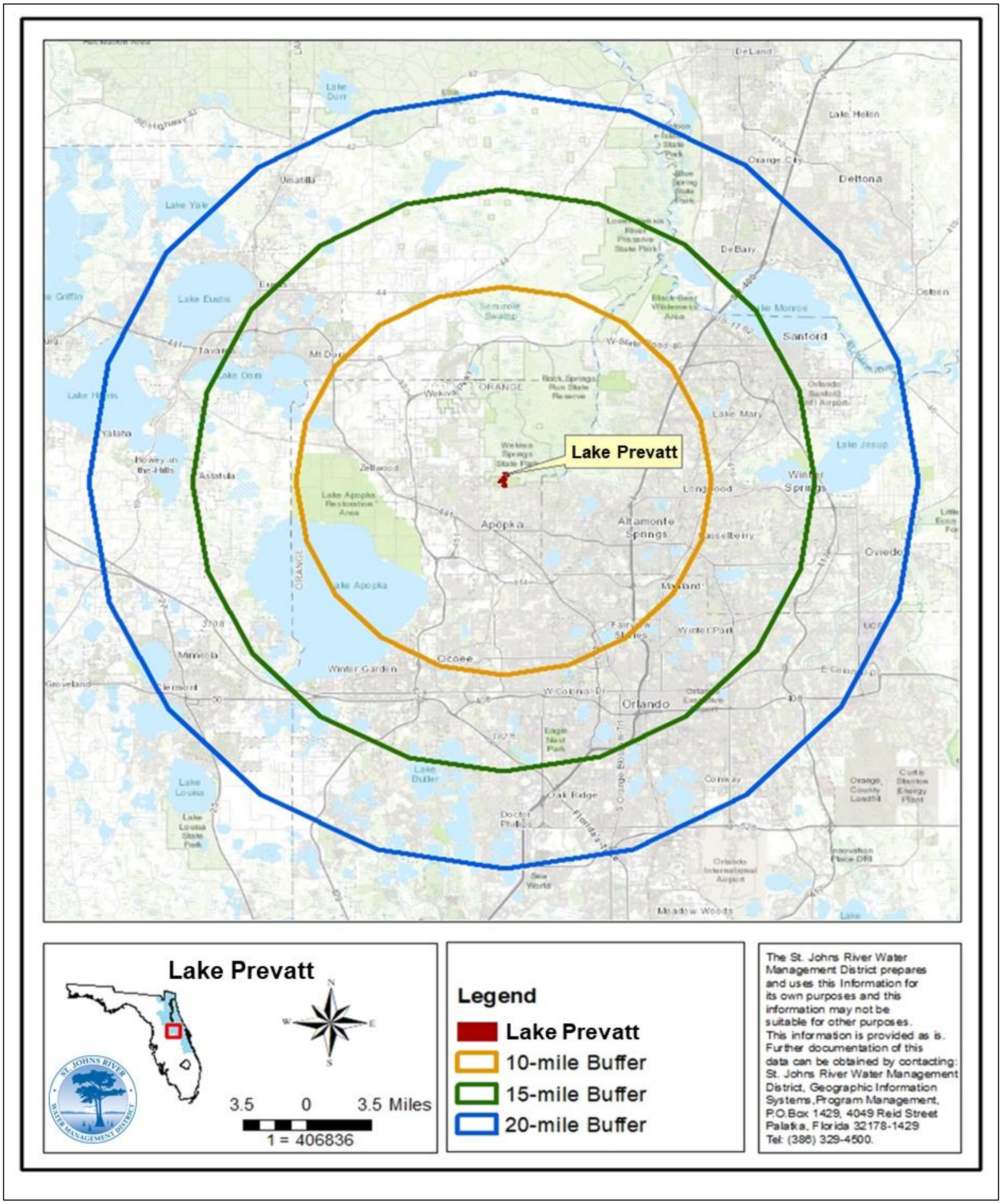

Figure B-5. Lake Prevatt 10-, 15-, and 20-mile buffer zones.

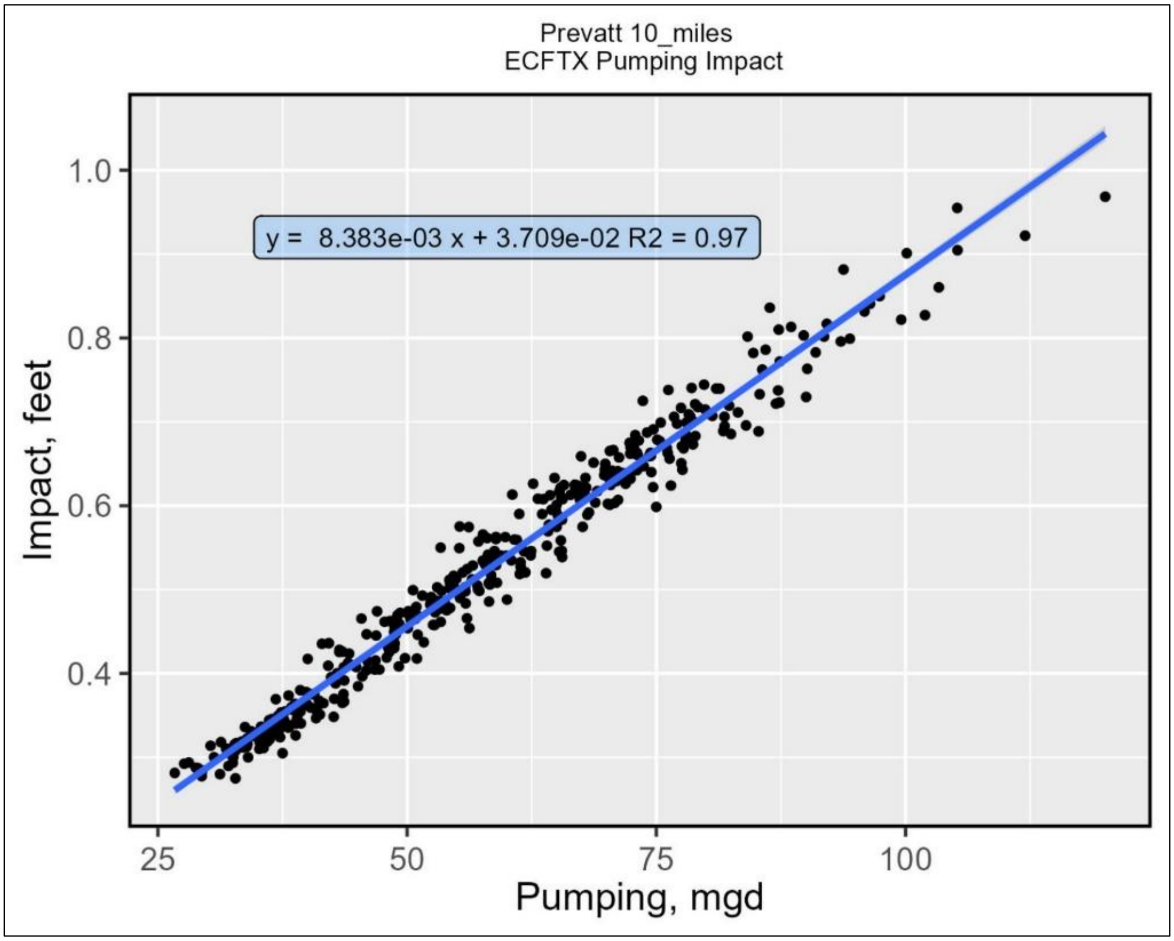

Figure B-6. Linear regression between UFA drawdown near Lake Prevatt and groundwater pumping within the Lake Prevatt 10-mile buffer area.

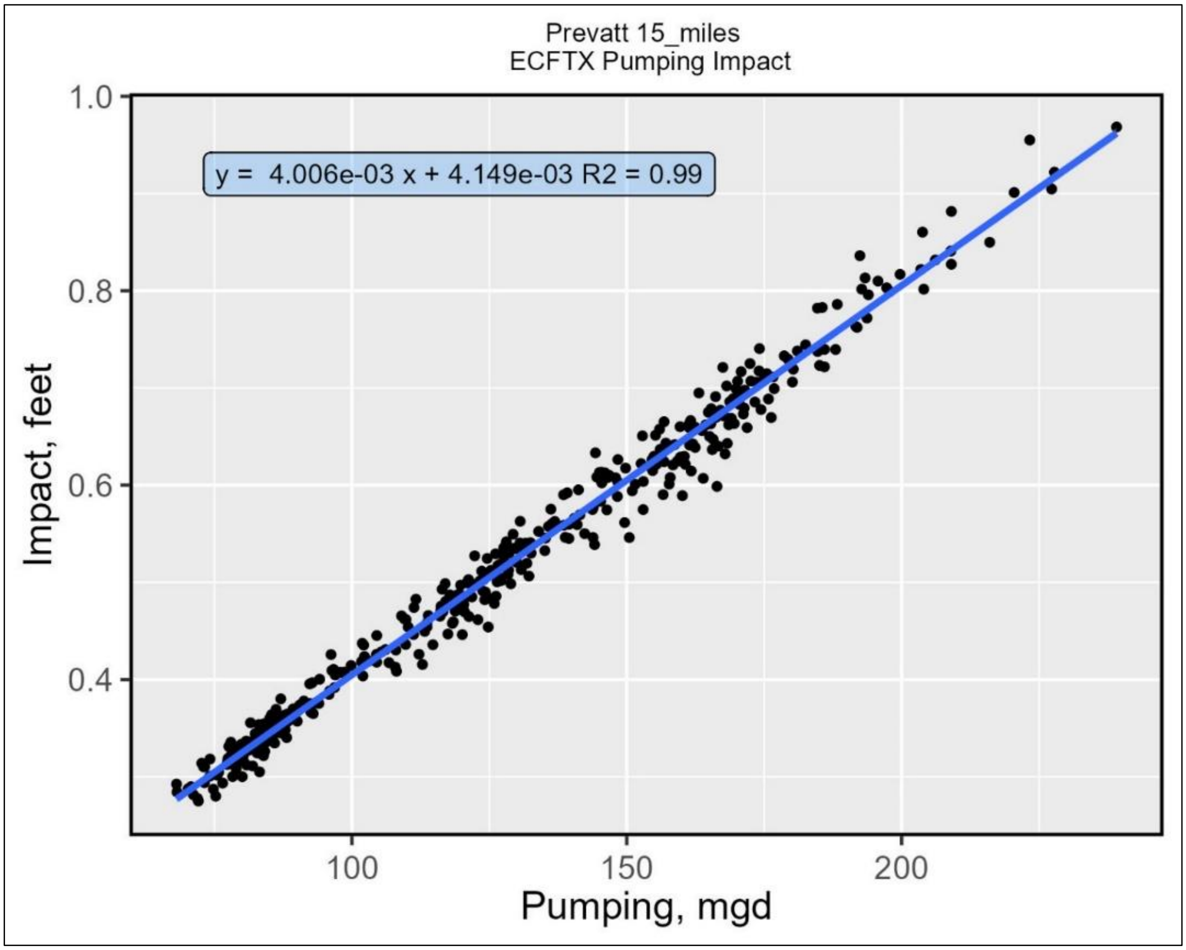

Figure B-7. Linear regression between UFA drawdown near Lake Prevatt and groundwater pumping within the Lake Prevatt 15-mile buffer area.

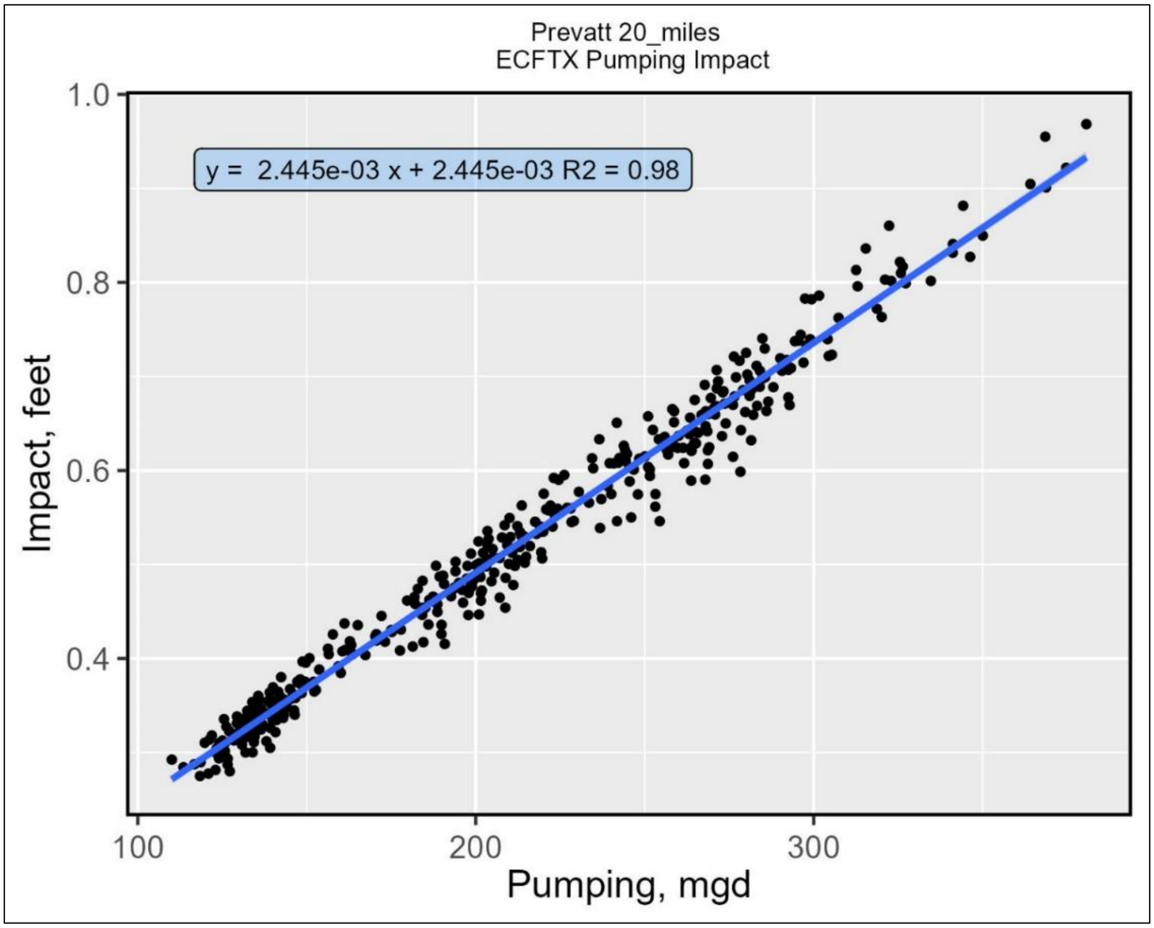

Figure B-8. Linear regression between UFA drawdown near Lake Prevatt and groundwater pumping within the Lake Prevatt 20-mile buffer area.

To evaluate the performance of pumping-drawdown relationships for determining the most appropriate buffer to use for the final analysis, the impact from the average 2016-2020 pumping was calculated by inputting the average 2016-2020 pumping rate to each linear regression equation shown in Figures B-6, B-7, and B-8 and compared with the average 2016-2020 transient model simulation average drawdown in the UFA beneath the lake. Table B-1 includes the average 2016 to 2020 pumping and estimated impact from pumping drawdown relationships developed for each buffer area. At Lake Prevatt, the 15-mile simulated current-pumping impact was calculated to be 0.64 feet and was the closest value to the ECFTX v2.0 model impact of 0.67 feet.

Table B-1. Estimated impact from average 2016 to 2020 pumping in the model for the 10-, 15-, and 20-mile buffer areas compared with regression and ECFTX model simulated impact.

Buffer Area	Avg 2016-2020 Q (MGD)	Regression CP Impact (feet)	ECFTX v2.0 CP Impact (feet)
10-mile	58.96	0.53	0.67
15-mile	157.76	0.64	0.67
20-mile	257.35	0.63	0.67

Groundwater Use

To estimate the impact on groundwater levels from historical pumping, monthly groundwater use data were compiled or estimated at all stations within a 15-mile radius of the Lake Prevatt centroid from 1930 to 2020. It should be noted that the groundwater pumping within the buffer zone was only used as a proxy to understand the variation of regional groundwater pumping from 1953 to 2020. The impact of groundwater pumping on lake levels was assessed based on all groundwater pumping within the groundwater model domain.

The groundwater pumping data were estimated from 1930 through 2020 using the best available data from different sources. The data from 1965 to 1995 were based on the United States Geological Service (USGS) published county-level water use (available every five years starting in 1965) and the annual SJRWMD county-level Annual Water Use Survey (AWUS) starting in 1978. Using these two sources, the water use data were aggregated to the county for every five years and some years in between from 1965. Any missing years for each county were estimated using an exponential growth assumption to create a complete aggregate table. If the USGS and AWUS estimates did not match, the published AWUS data were used. To estimate annual groundwater use by county for the period before 1965, per capita groundwater use was estimated for each county. Multiplying the 1965 per capita water use by the historic county-level population from U.S. Census, the annual groundwater uses by county were estimated for the period before 1965. The U.S. Census data were reported in 10-year intervals. Exponential growth was assumed to estimate the annual population between 10-year intervals. The 1995 proportion of county water use was multiplied by the county aggregate from 1953 to 1994 to estimate the water use within the Lake Prevatt buffer zone (Figure B-5Figure). To disaggregate the annual data to monthly groundwater use, the average monthly proportions by county, estimated from the monthly SJRWMD database from 2004 to 2014, were applied to the annual data. Figure B-9 shows the monthly estimated groundwater use in the Lake Prevatt 15-mile buffer zone from 1930 to 2020.

Monthly reported data from 1995 – 2020 are stored in a water use database except for Domestic Self Supply (DSS) stations which are pulled from their own geodatabase. Gaps in the monthly data were filled by calculating the average proportion of water use for each month for every station from previous years. That proportion was applied to years with missing data to create gap filled monthly data. Then using this gap filled monthly data, the average monthly proportion by county was calculated. This proportion was applied to the annual data by county to create a table of monthly water use estimates.

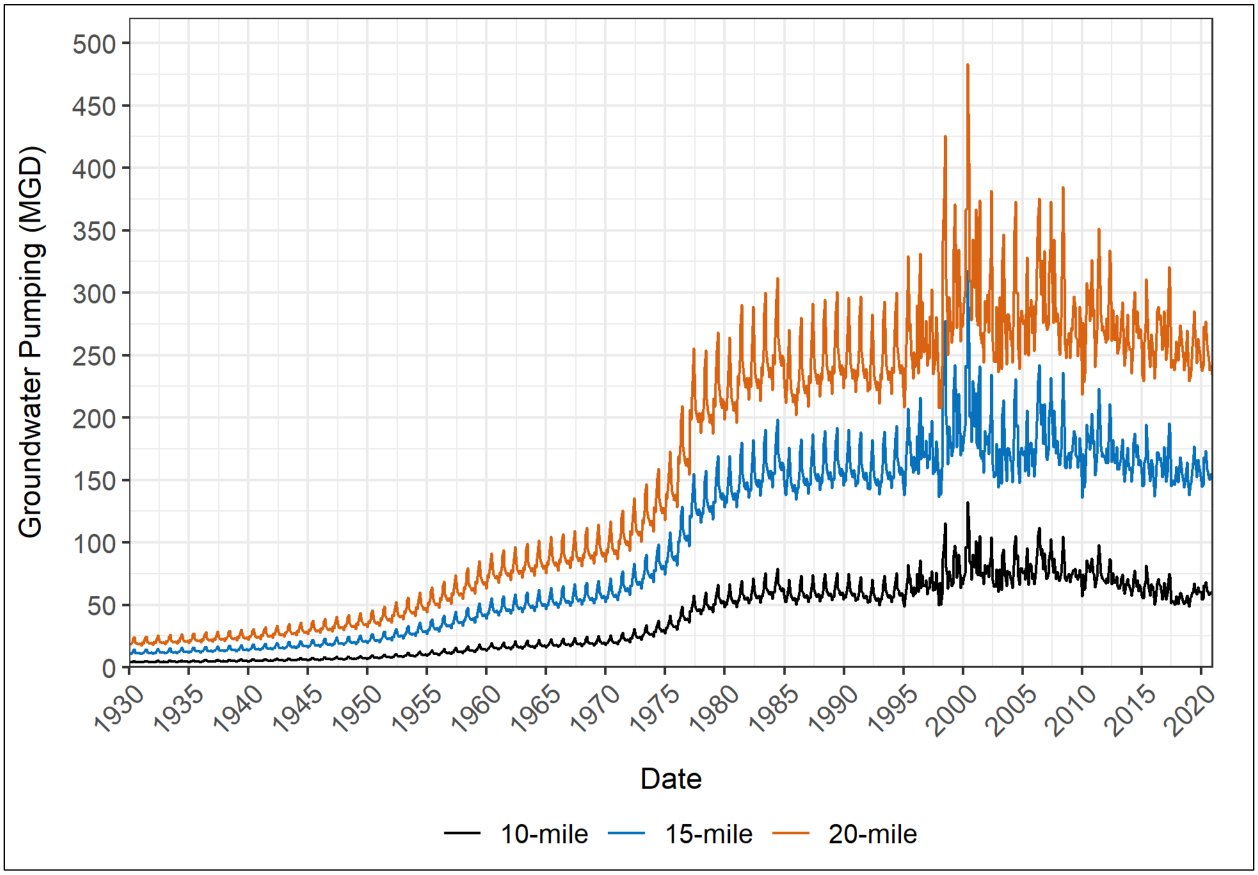

Figure B-9. Estimated historical groundwater use around Lake Prevatt 10- (black), 15- (blue), and 20-mile (orange) buffer areas.

Historical Impact on Groundwater Levels

The linear regression equation derived for the 15-mile buffer shown in Figure B-7 was used to calculate a monthly historical impact from long-term (1953 to 2020) estimated monthly pumping data within the buffer area. The monthly estimated historical impact due to pumping was disaggregated to a daily time series extending from 1953 to 2020 using linear interpolation. The daily estimated historical impact from pumping on UFA levels near Lake Prevatt within the 15-mile buffer area for the period of 1953 to 2020 is shown in Figure B-10Figure B-101.

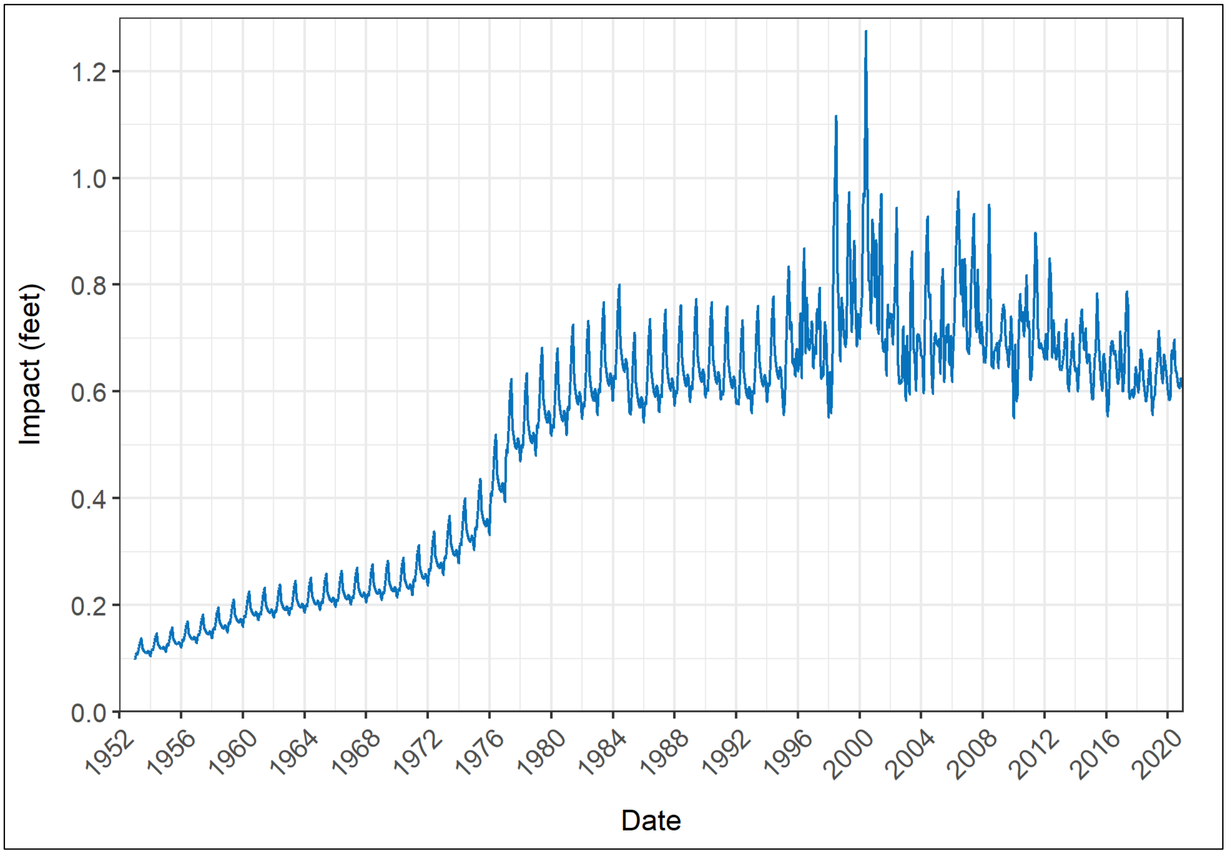

Figure B-101. Daily estimated historical impact from pumping on UFA levels near Lake Prevatt using the 15-mile buffer area.

No-Pumping Condition Groundwater Levels

The daily estimated impacts from pumping shown in Figure B-10 were added directly to the daily historical, composed of observed and estimated, groundwater levels near Lake Prevatt available from 1953 to 2020 to create the no-pumping condition groundwater level dataset.

Current-Pumping Condition Groundwater Levels

To generate the current-pumping condition groundwater levels, the average drawdown over the transient simulation period was calculated for the 2016-2020 pumping condition using the ECFTX v2.0 model. The impact from average pumping from 2016 to 2020 was calculated by subtracting the transient average simulated UFA level at Lake Prevatt under average 2016 to 2020 pumping rates and return flows in the model from the transient average simulated groundwater levels with no pumping or return flows in the model. The simulated impact from current pumping in the UFA at Lake Prevatt using this approach is 0.67 feet.

The current pumping impact was then subtracted from the no-pumping condition groundwater levels to generate the current-pumping condition groundwater levels for the long-term period of 1953 to 2020. Figure B-11 shows the daily no-pumping and current-pumping condition groundwater levels for Lake Prevatt for the 15-mile buffer area.

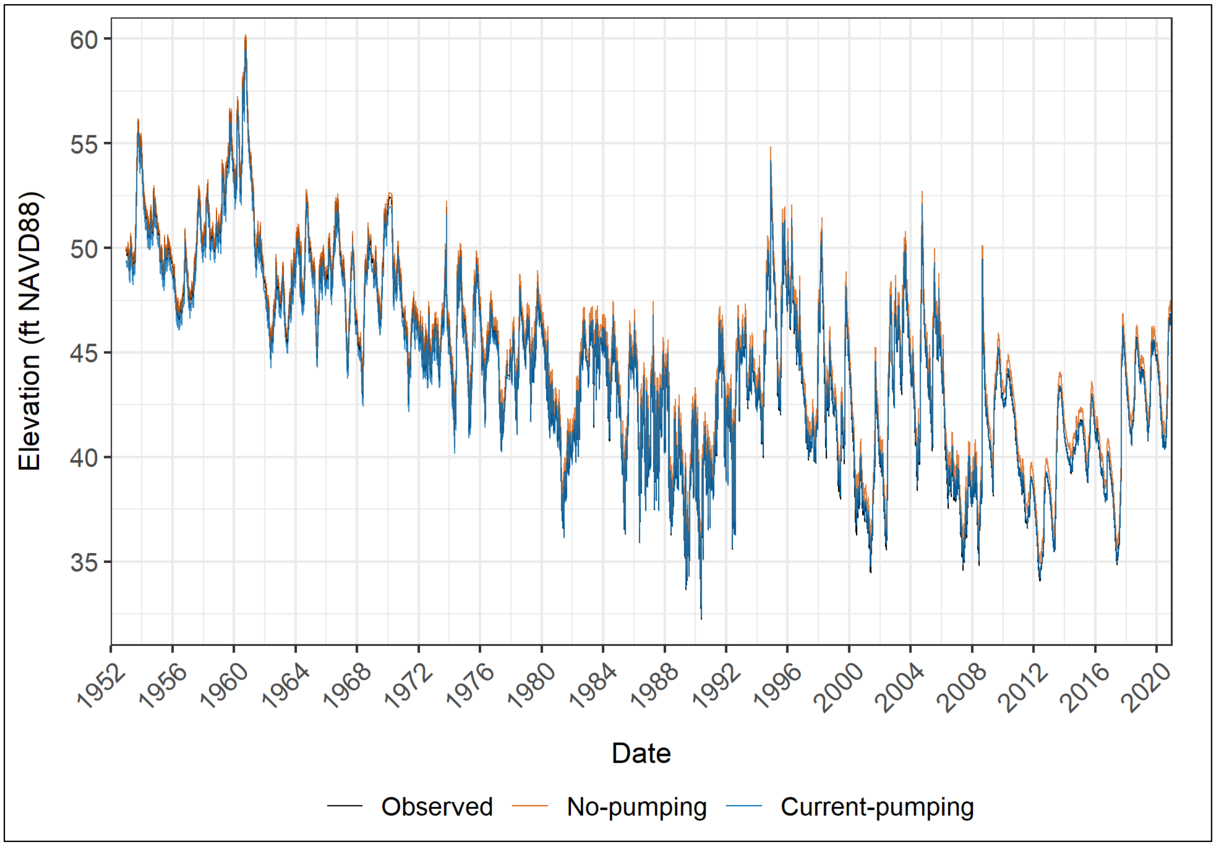

Figure B-11. ECFTX Observed (black), no-pumping (orange), and current-pumping (blue) condition of UFA levels near Lake Prevatt from groundwater use within 15-mile buffer.

Lake Level Datasets for MFL Analysis

No-pumping and current-pumping were created separately for the North Lobe (Figure B-12) and South Lobe (Figure B-13) at Lake Prevatt. The hydrographs suggest that there is little visual difference between no-pumping, current-pumping, and the historical observed. There are instances earlier in the period of record in both lobes where the estimated no-pumping stage is slightly higher, as well as around 2011-2012. The summary statistics in Table B-2 and Table B-3 confirm that the average statistics between no-pumping, current-pumping, and the historical observed are similar to one another. For example, the mean stage at the North Lobe for the no-pumping scenario is 54.47 feet, while the historical observed is 54.34 feet and current-pumping is 54.30 feet. Similarly, for the South Lobe the mean stage for the no-pumping scenario is 54.21 feet, the historical observed is 54.03 feet and current-pumping is 54.00 feet.

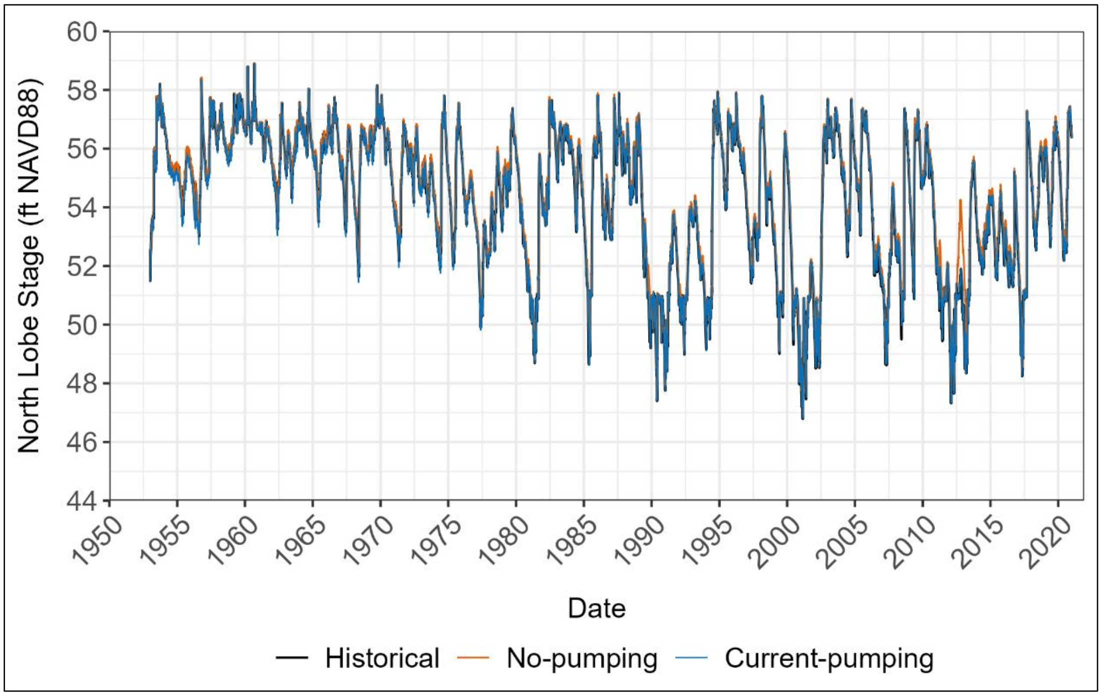

Figure B-12. Simulated stage levels of historical, no-pumping, and current-pumping at the North Lobe of Prevatt.

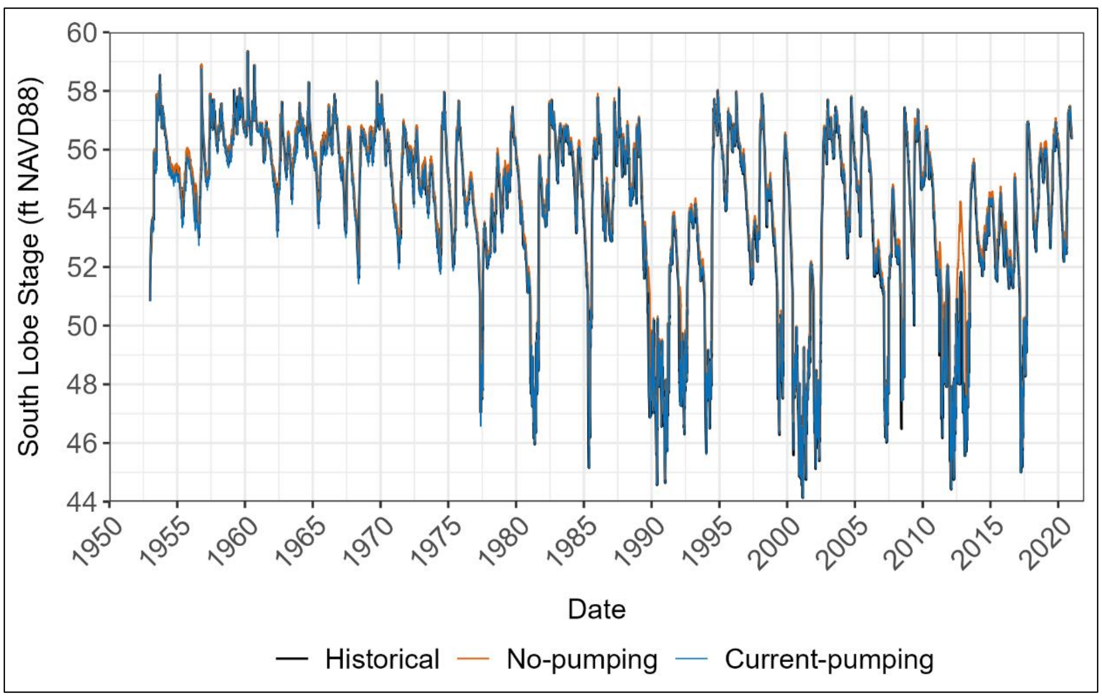

Figure B-13. Simulated stage levels of historical, no-pumping, and current-pumping at the South Lobe of Prevatt.

Table B-2. Summary stage (No-pumping, Historical Observed, and Current-pumping) descriptive statistics for the North Lobe of Lake Prevatt.

Statistics	No-pumping	Historical Observed	Current-pumping
Mean	54.47	54.34	54.30
Median	55.01	54.88	54.81
Standard Deviation	2.21	2.28	2.27
Range	11.99	12.11	12.08
Minimum	46.91	46.79	46.81
Maximum	58.90	58.90	58.89

Table B-3. Summary stage (No-pumping, Historical Observed, and Current-pumping) descriptive statistics for the South Lobe of Lake Prevatt.

Statistics	No-pumping	Historical Observed	Current-pumping
Mean	54.21	54.03	54.00
Median	55.00	54.87	54.80
Standard Deviation	2.78	2.91	2.89
Range	15.17	15.22	15.21
Minimum	44.18	44.13	44.13
Maximum	59.35	59.35	59.34

The current-pumping condition lake levels represented a reference hydrologic condition of the lakes in which the total regional groundwater pumping impacting the lakes was constant from 1959 to 2018 at a rate of averaged pumping from 2014 to 2018. Assuming climatic, rainfall, and other conditions present from 1959 to 2018 would repeat over the next 59 years, the current-pumping condition lake levels reflected the future condition of the lake levels if the average regional groundwater pumping does not change from 2014-2018 condition. Because of our limited understanding of possible future climatic conditions and significant uncertainties in global climate model predictions, using historical conditions to generate current-pumping condition lake levels was reasonable. Therefore, the no-pumping and current-pumping condition lake level datasets shown in Figure B-13 were used to assess the MFLs at Lake Prevatt.

REFERENCES

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