Lake Jackson Watershed Hydrologic Investigation

Task 1b – Hydrologic Data Inventory and Recommendations For Additional Data Collection. FINAL Recommendations Report

Prepared For:

Highlands County, FL.

Prepared By:

AIM Engineering
& Surveying, Inc.

Interflow Engineering, L.L.C.
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Executive Summary

This report serves as a data inventory and review of the pertinent available hydrologic data near Lake Jackson/Little Lake Jackson and the surrounding water bodies within the proposed study area. The inventory and review focused on data that may be relevant and useful in future lake-level modeling efforts. The report provides an overview of the available data, including sources, period of record (POR) and some data analysis to enhance the understanding of the area before model development. Subsequent sections discuss the various types of data (Atmospheric, Surface water, and Ground water) and shows the location of each gage presented within the appropriate section of the report.

The data analysis presents Lake Jackson Stage, Avon Park Rainfall and selected public supply groundwater withdrawals near Lake Jackson. The intent is not to be an exhausting cause and effect analysis, rather a cursory or screening evaluation of the data sources to better the understanding of the interactions of rainfall, and pumpage with respect to Lake Jackson stage, and to guide the recommendations for data collection efforts to occur in the next phase of this project.

The final section of the report identifies potential data collection sites that might be implementable within the funding constraints. The majority of proposed monitoring sites are located on Highlands County or City of Sebring owned parcels to ensure the highest probability of site availability (land area for well installation). Additional groundwater monitoring locations are presented within the proposed study area and are locations of existing wells with the potential for future data collection.

The data collected and presented in this report as well as the proposed monitoring locations, will serve to inform a future modeling effort and provide additional calibration locations to build the most defensible and scientifically robust model of the area.

1.0 Introduction

The study area includes Lake Jackson in Highlands County and relevant portions of the surrounding Upper Josephine / Jackson Creek Watershed. This area was the focus of previous long-term hydrologic modeling which supported an evaluation of possible management scenarios designed to increase lake levels in Lake Jackson. The results of the previous work suggest that data available at the time was a limitation to the modeling approach that was utilized. The work effort described herein comprises the second of three tasks of a multi-year investigation to identify the causes of low water levels in Lake Jackson and Little Lake Jackson over the last decade, and to develop cost-effective recovery strategies.

2.0 Data Inventory/ Data Analysis

The following sections will detail data collected as part of Task 1b. This data will be incorporated into a future modeling effort, as well as provide the foundation with which to compare several results from the model. Each section will include a list of available data, details including: site/station name, period of record and a presentation of the data (i.e. graphs). A map will be provided showing all gage locations, from precipitation to groundwater.

2.1 Rainfall Data

Available rainfall data were gathered from SWFWMD, and NOAA. While not presented within this report, SWFWD maintains a repository of spatially and temporally variable radar rainfall, known as NEXRAD. For the purposes of this task, it was not necessary to obtain hourly data, but rather note the availability and usefulness in future modeling efforts.

Data found to date including POR:

- Daily data from NOAA – AVON PARK 2 W FL US - 07/01/1948 to 10/8/2015
- Daily data from SWFWMD – ROMP 28 KUHLMAN - 8/15/2000 to 10/15/2015
- Yearly totals for Highlands County: from SWFWMD – 1915 to 2015

Figures 2 to 4 present the annual total rainfall in inches for each of the aforementioned gages (data sources). Of note is the data presented in **Figure 4**, where the SWFWMD has gathered and processed rainfall data for the entire county and provided yearly totals from 1915 to present.

In the following figures, the annual rainfall for each gage, including Highlands County totals, is presented in each figure as the horizontal black line for the duration of each rainfall graph. As shown, the average for the rainfall data presented below is about 51-inches. Additionally, each graph shows some variability in the minimum and maximum rainfall totals observed, with the highest variability shown in the minimum yearly rainfall totals. Minimum yearly rainfall from the sources shown ranges from 20 to 30 inches in a given year. Maximum rainfall totals can range from 70 to 80 inches in a given year. This variability is quite normal for Florida, and is indicative of the extreme weather patterns the state experiences as a whole. Data trends will be further discussed in **Section 3.0 Data Analysis**.

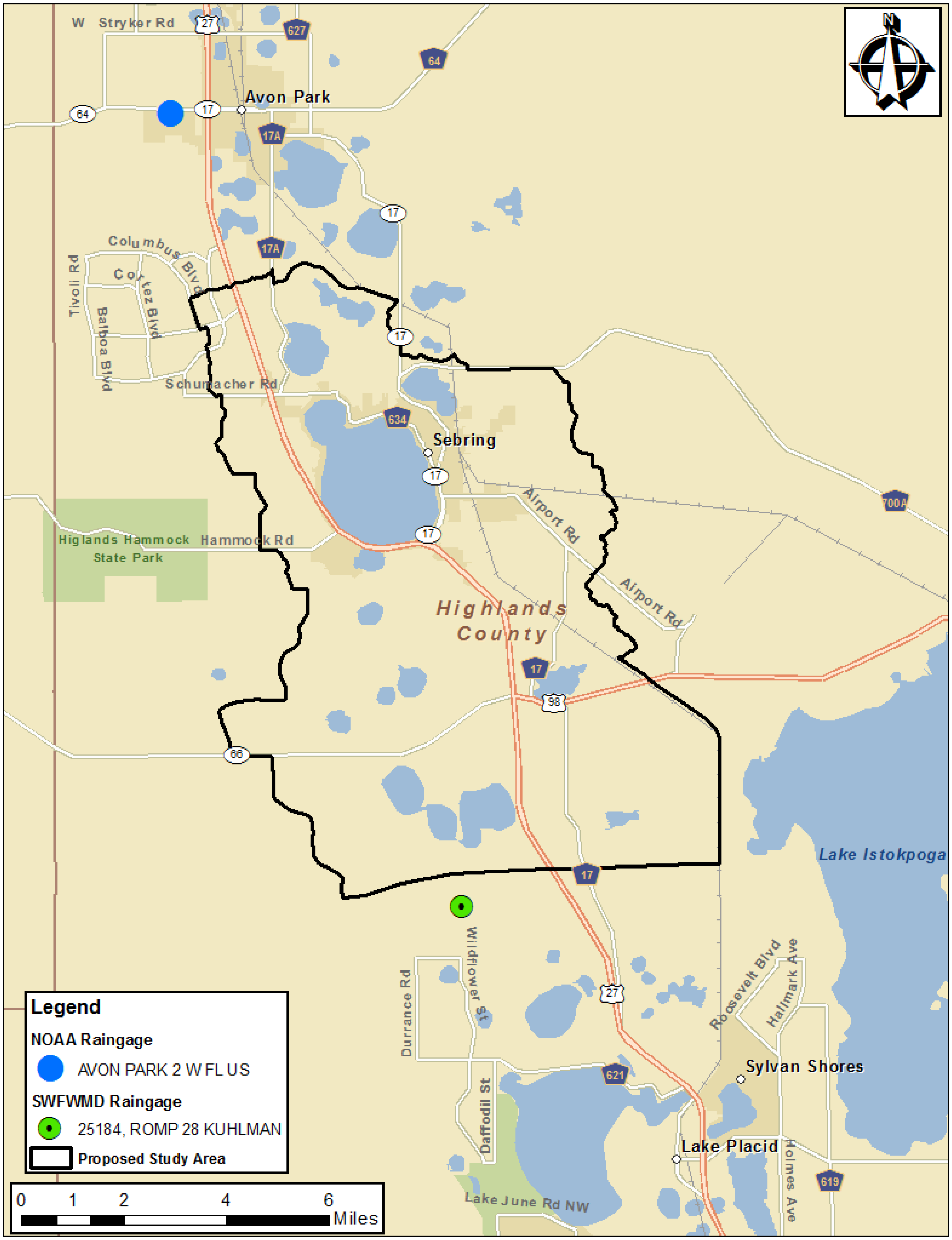

Figure 1. Precipitation Gages near Proposed Study Area.

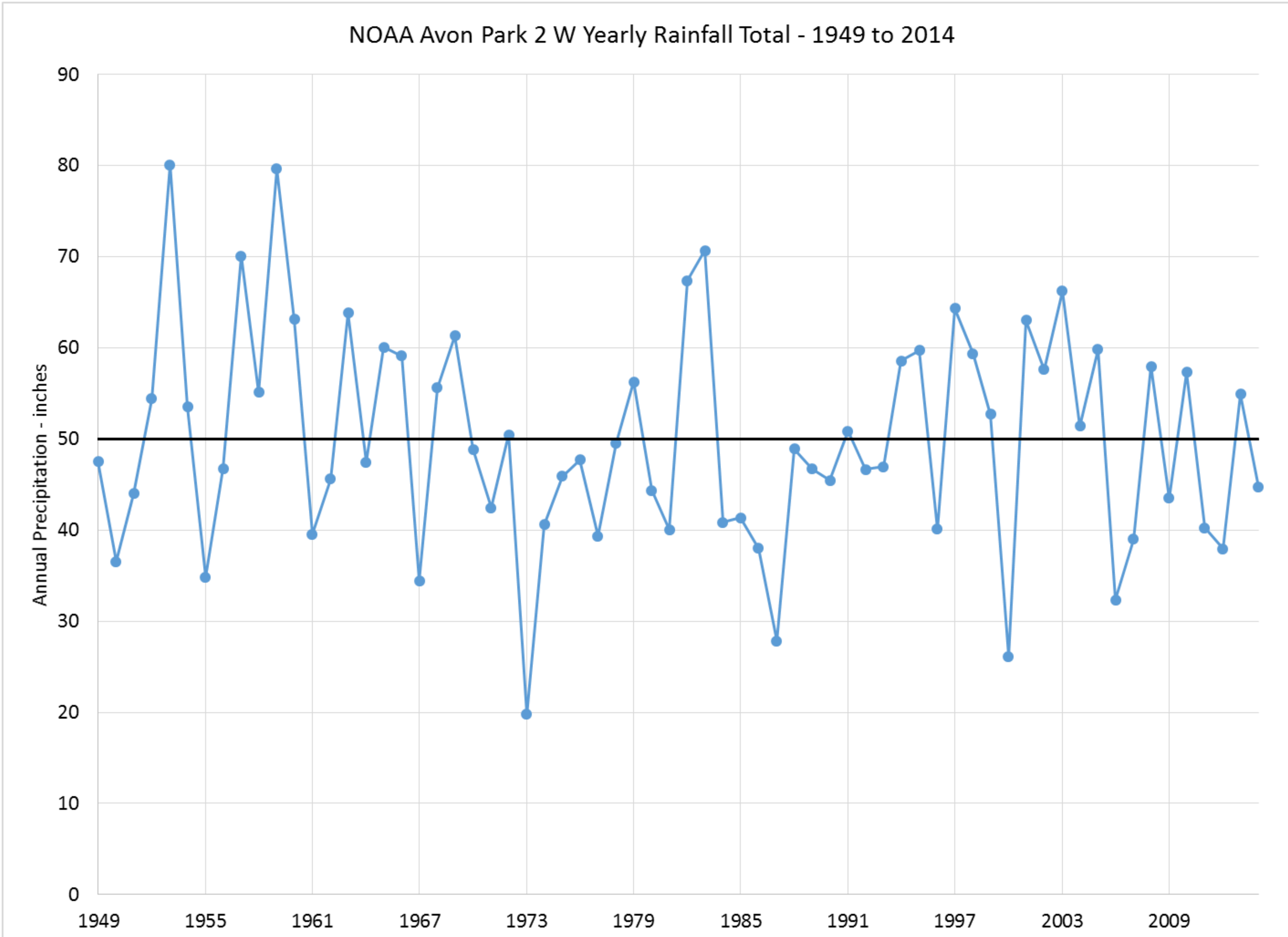

Figure 2. Yearly Rainfall Totals – NOAA Avon Park 2 W Gage.

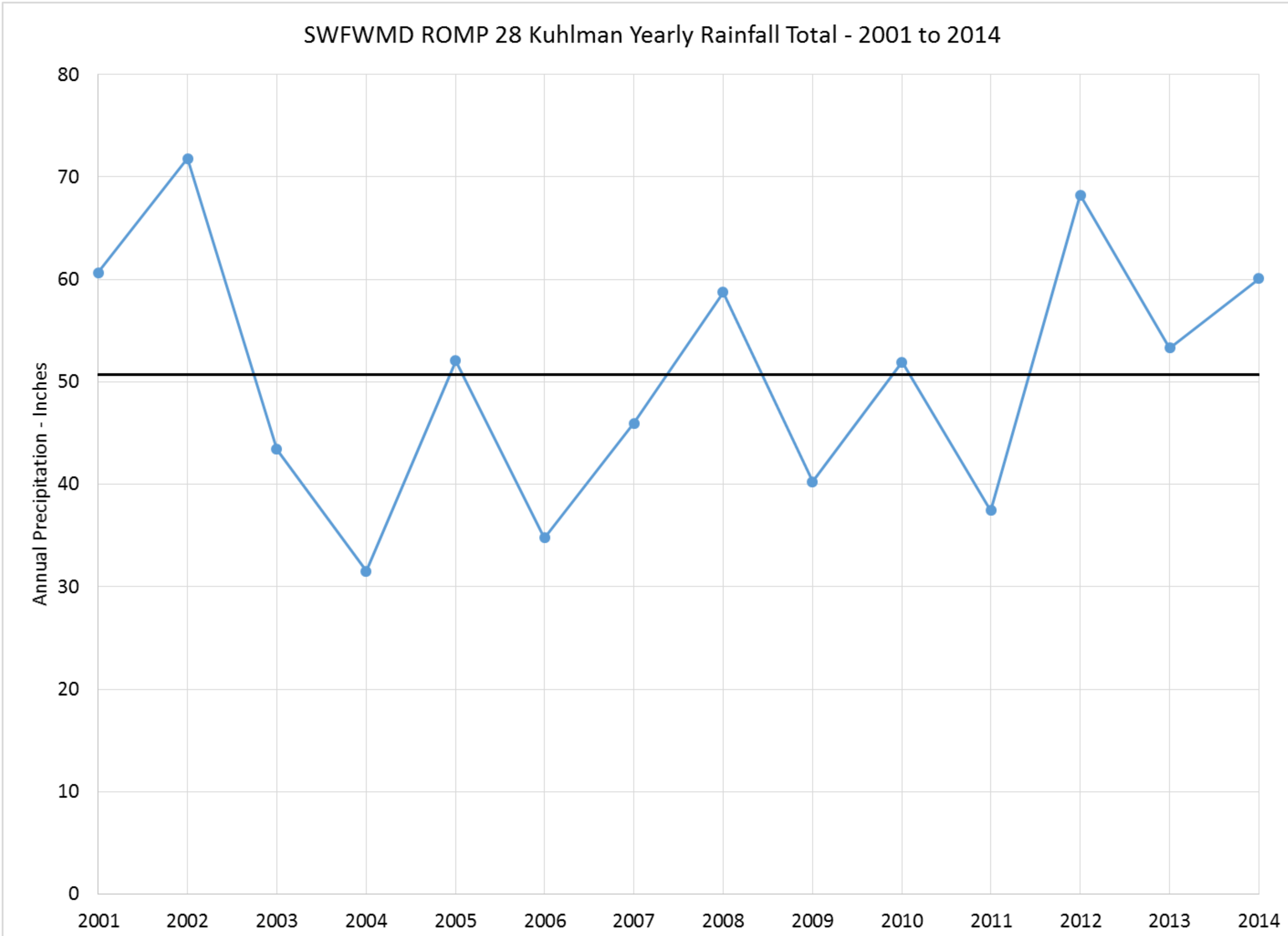

Figure 3. Yearly Rainfall Totals –SWFWMD ROMP 28 Kuhlman.

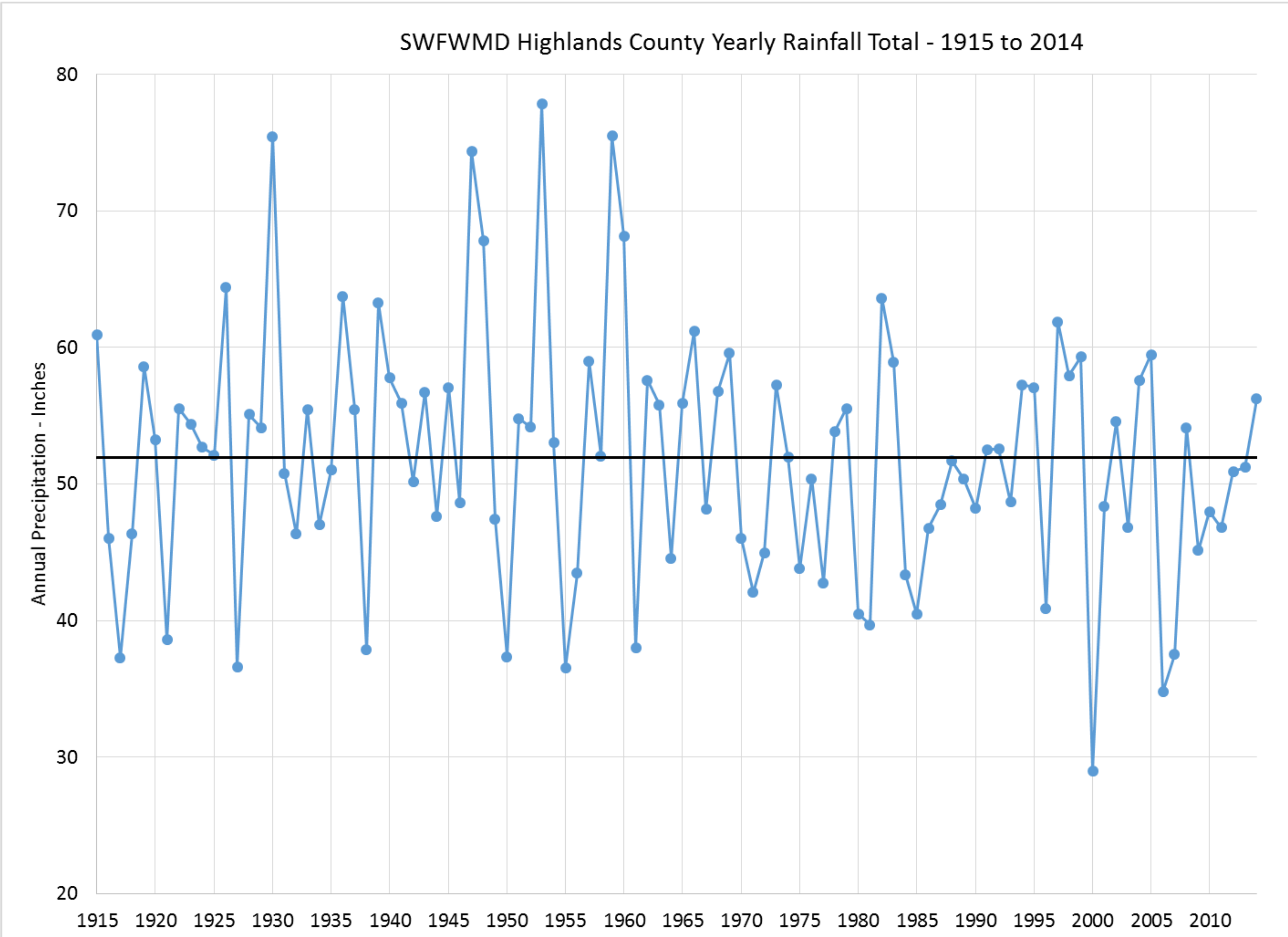

Figure 4. Yearly Rainfall Totals - SWFWMD Highlands County.

Figure 5 presents SWFWMD NEXRAD climate pixels which represent a 2km x 2km grid over the proposed study area. Each pixel within the grid shows the location of the available data coverage of SWFWMD NEXRAD rainfall data and USGS GOES RET data. NEXRAD rainfall data is available from 1995 to present in 15min, hourly, and daily time increments. Rainfall data with hourly resolution will be sufficient for model simulations to calculate the water budget of Lake Jackson.

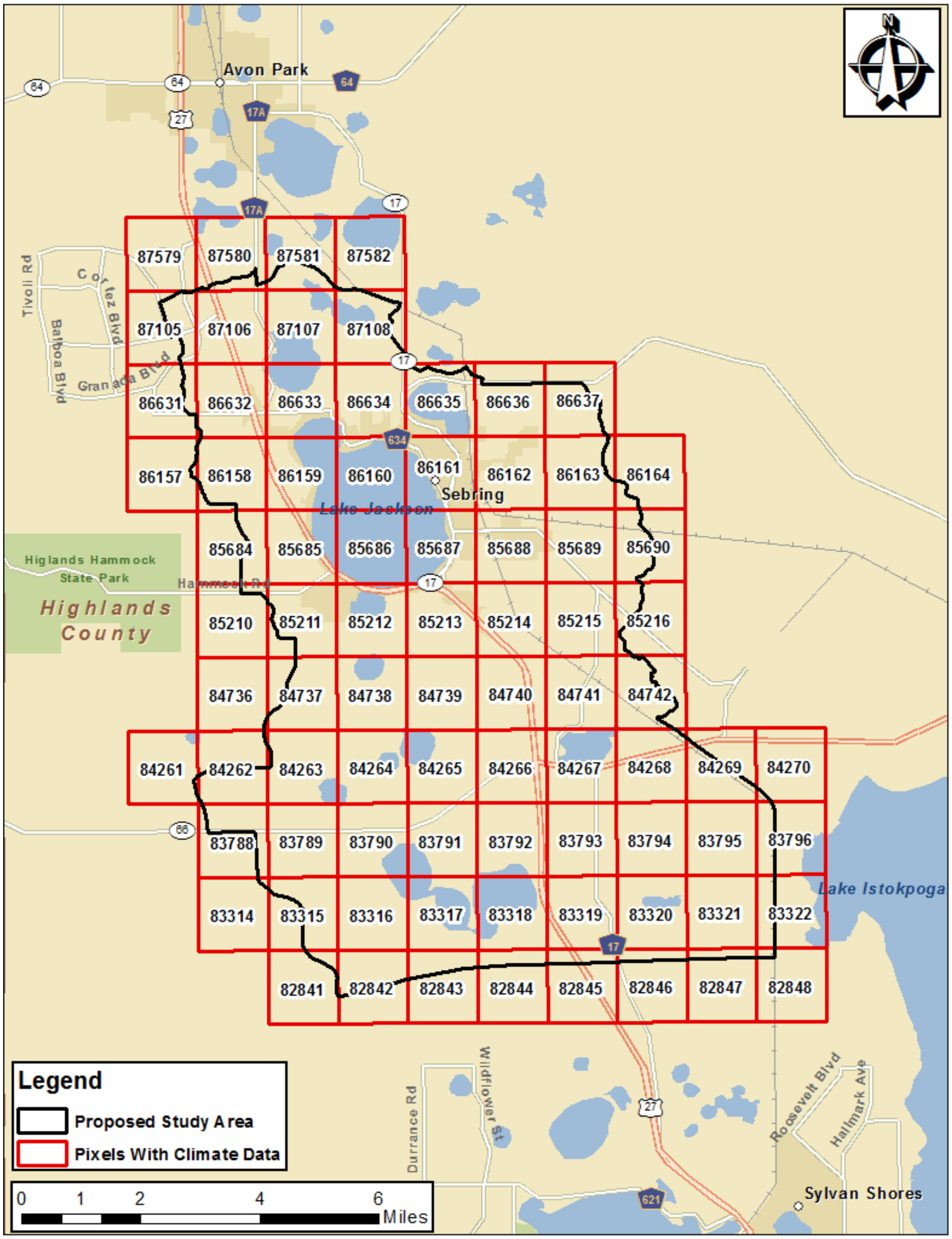

Figure 5. SWFWMD Climate PIXELS.

2.2 Evaporation and Evapotranspiration Data

Reference Evapotranspiration (RET) is one of the most important components of a water budget effort and subsequently building a watershed model, as evapotranspiration (ET) is typically the second-largest component of a watershed's overall water budget. Daily Geostationary Operational Environmental Satellite (GOES) Satellite Based RET data was obtained from the USGS, which is considered the best available data for a distributed watershed model such as that proposed in Task 1a. The USGS RET data is available on a daily time step and is applied on the same grid as the NEXRAD rainfall data. USGS GOES RET data was obtained and analyzed for the proposed Lake Jackson Study area. The available data provided coverage from 1996 through 2014. **Table 1** presents the yearly statistics of RET over the study area.

Table 1. USGS GOES RET Statistics for Proposed Study Area.

USGS GOES RET Yearly Statistic	RET inches/year
Max	58.2
Min	50.9
Average	53.9

As mentioned, ET is the second largest component of the water budget and one of the most difficult to estimate. ET varies with changes in weather, land use, soil moisture conditions, and land cover.

Douglas, et al (2009) analyzed observed daily ET (DET) for 18 sites based on different Florida land cover types. **Table 2** presents a summary of these stations that are located within areas of land cover, soils, and weather patterns that are similar to those found in the Northwest and Central Florida area near the study area. These stations all have multiple years of continuous ET measurements.

Table 2. Measured Evapotranspiration Rates at Selected ET Stations (from Douglas, et al, 2009).

ET Station Name	County	Land Cover	Available Period of Record	Average Annual ET (in)
Alachua (Donaldson)	Alachua	Forest (immature pine)	January 1999-June 2003	29.03
Alachua (Austin Cary)	Alachua	Forest (mature pine)	July 2000-June 2002	44.26
Kennedy Space Center	Brevard	Forest (scrub oak)	March 2000-March 2003	32.62
Kennedy Space Center	Brevard	Forest (slash pine)	March 2002-February 2003	33.91
Blue Springs Tract	Hamilton	Forest (pine)	January 2003-December 2004	45.98

ET Station Name	County	Land Cover	Available Period of Record	Average Annual ET (in)
Disney Wilderness Preserve	Polk	Grass	July 2000-January 2006	36.36
Duda Farms	Brevard	Grass	June 2000-May 2005	43.97
Ferris Farm	Citrus	Grass	January 2003-February 2005	22.7
Starkey Wellfield	Orange	Grass	April 2003-December 2004	36.93
Reedy Lake	Pasco	Open water	December 2001-October 2005	60.07

Additional investigation into ET data was performed, whereby, the SWFWMD database was examined and found to contain an inactive weather station (Avon Park ET I). The period of record for Avon Park ET I was 1983 to 1988 and will not prove useful for calibration or other checks against USGS GOES RET data. As such the inactive weather station which contained air temperature data and other climate information including pan evaporation was not analyzed as a function of this task as the available data would not add value to the study.

2.3 Surface water Data

Available surface water data from active sites were collected from the SWFWMD database (WMIS) and includes nine (9) active surface water monitoring locations within the study area. **Figure 6** presents the existing surface water monitoring locations from the SWFWMD database. **Table 3** presents relevant surface water information obtained and analyzed during this task.

Six (6) of the nine (9) monitoring stations collect water level data manually (minimal streamflow data) through the utilization of a calibrated staff gauge. The remaining three (3) monitoring stations collect data through the use of data recorders, provided by USGS and SWFWMD. Most of the monitoring stations (with the exception of the Lake Josephine Outflow) provide water level data from the 1980's to present time , with minor data gaps, as shown in **Figure 7**.

Available surface water data was collected and analyzed to get a clear picture of historical lake level observations for Lake Jackson. Utilization of the existing monitoring sites will be highly dependent on the staff gauge condition, as well as available funding to update the current monitoring site to an automated condition. The existing monitoring stations are recommended to be assessed in the field to determine the condition, as well as accessibility to the sites. More information about the proposed automated lake level monitoring sites are presented in **Section 4.0 Monitoring Recommendations.**

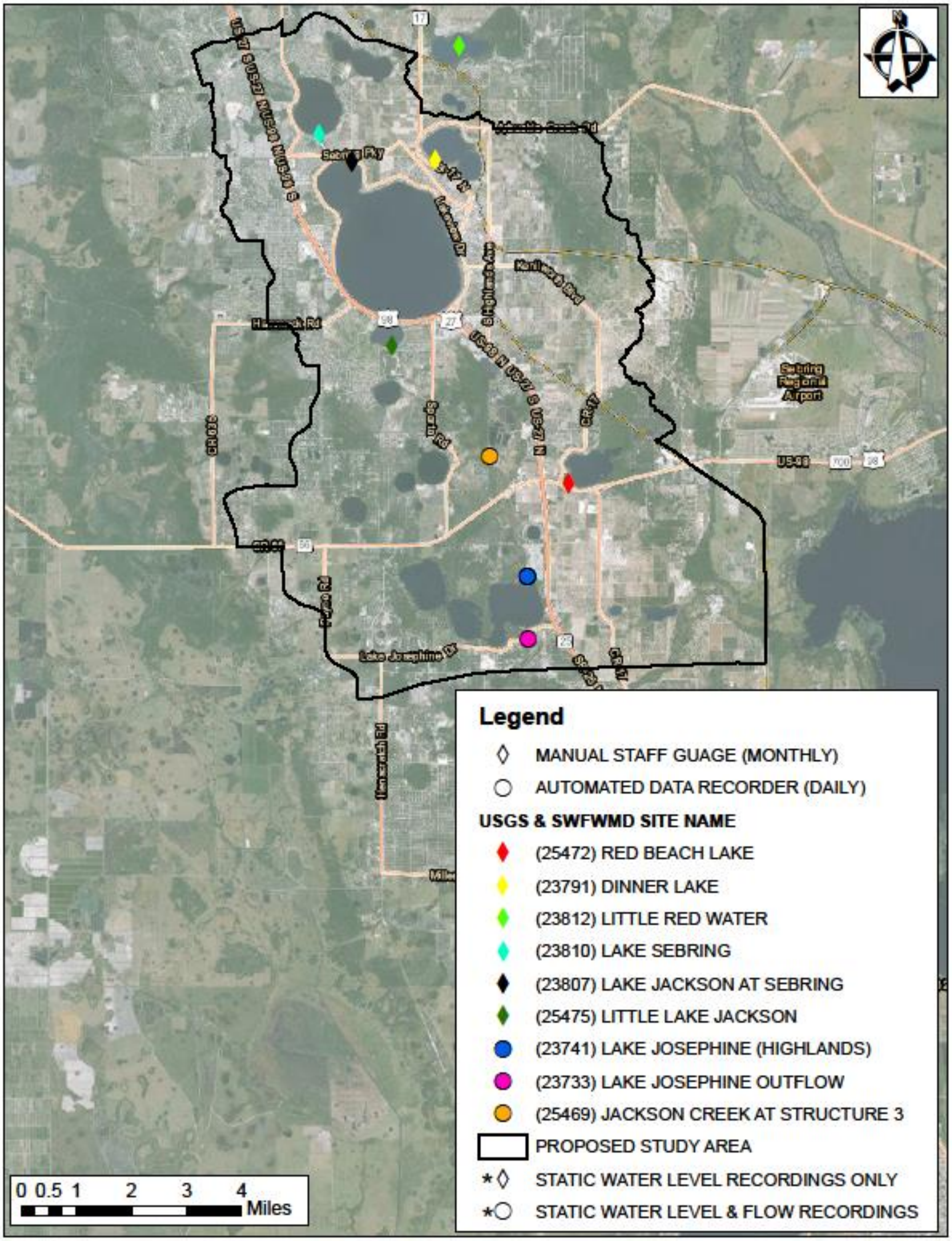

Figure 6. Surface Water Monitoring Sites within Proposed Study Area
(See Table 3 Below for Additional Details)

Table 3. Available Surface Water Level Data (SWFWMD Database).

SWFWMD ID	Site Name	Start Date	End Data	Data Source	Location	Collection Method	Data Frequency (% of Daily Data Coverage)
23807	Lake Jackson at Sebring	10/23/1984	10/26/2015	SWFWMD	Lake Jackson	Manual Staff Gauge	Monthly
23810	Lake Sebring	6/28/1984	12/7/2015	SWFWMD	Lake Sebring	Manual Staff Gauge	(1984-1996), Bi-Monthly & (1997-2015), Monthly
25472	Red Beach Lake	10/1/1985	12/9/2015	SWFWMD	Red Beach Lake	Manual Staff Gauge	Monthly
25475	Little Lake Jackson	7/1/1981	10/13/2015	SWFWMD	Little Lake Jackson	Manual Staff Gauge	Monthly
25469	Jackson Creek at Structure 3	10/2/1991	4/5/2012	SWFWMD	Jackson Creek	District Recorder	Daily (70)
23741	Lake Josephine (Highlands)	12/6/1984	10/12/2015	SWFWMD	Jackson Creek	USGS Recorder/Manual	(1984-1996) Daily (94), (1996-2015) Monthly
23733	Lake Josephine Outflow	12/2/2001	11/3/2015	SWFWMD	Lake Jackson	District Recorder	Daily (93)
23791	Dinner Lake	6/28/1984	11/12/2013	SWFWMD	Dinner Lake	Manual Staff Gauge	Monthly
23812	Little Red Water	6/25/1981	12/10/2015	SWFWMD	Little Red Water	Manual Staff Gauge	Monthly

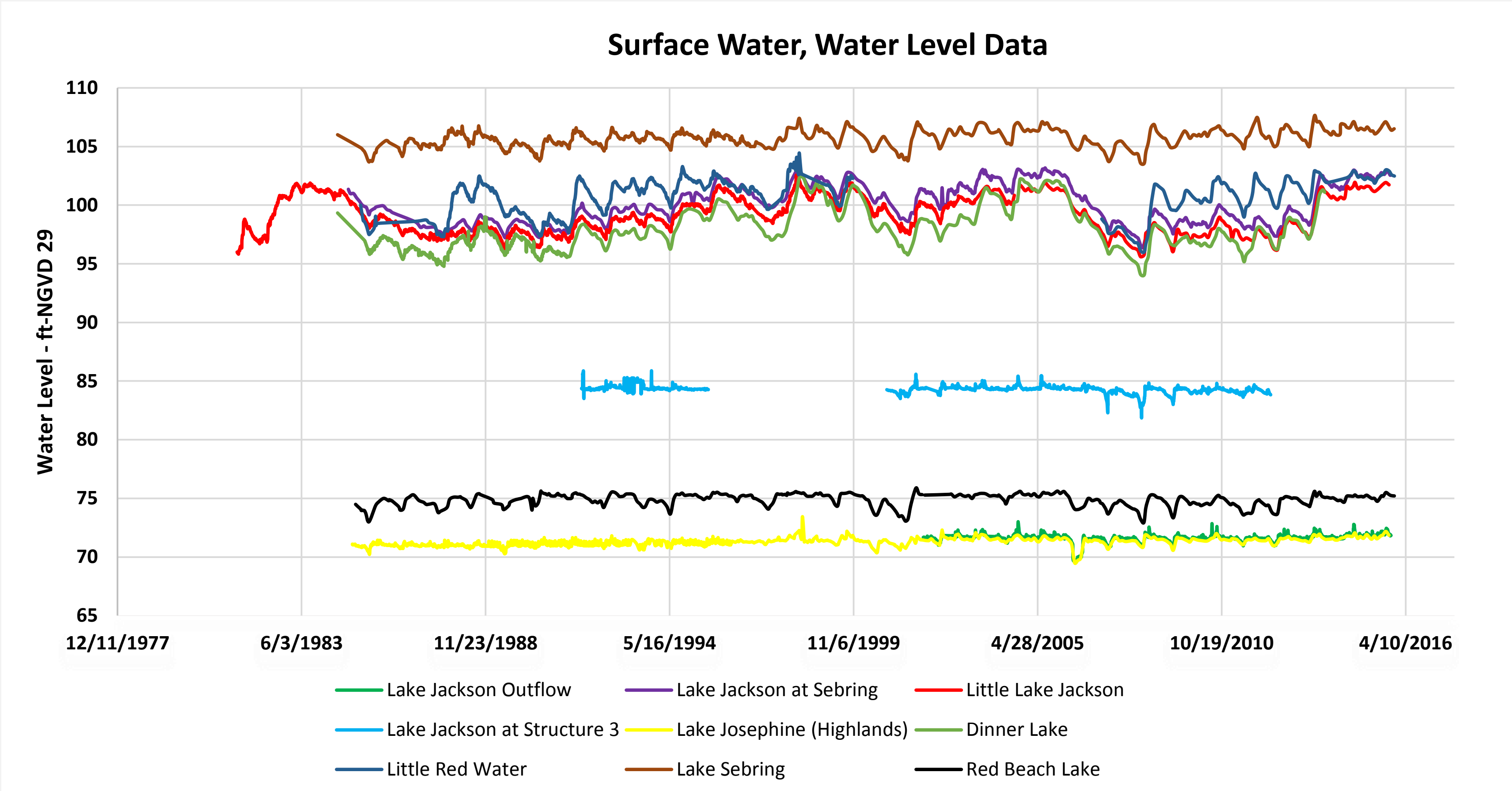

Figure 7. SWFWMD Surface Water Monitoring Sites, Water Level Data.

2.4 Infrastructure Data

To complement the overall hydrologic analysis and recommendations of that within, an inventory of existing water control structures within the proposed study area (As-Builts) were collected to verify hydraulic conveyance characteristics, as well as any potential water level impacts these structures may contribute to Lake Jackson, if any. **Figures 8 and 9** present the locations of these existing structures within the study area. These figures were provided by Highlands County, and were created by Kisinger Campo & Associates Corp.

Currently there is an existing conveyance ditch connecting Lake Sebring to Lake Jackson, which crosses under the Sebring Parkway, Lake Sebring Drive, Sunset Drive, and Lakeview Drive in a southerly direction, before discharging into Lake Jackson. The water levels within this said stormwater ditch is currently controlled by two sheet pile weirs. The upstream weir is designated as Structure HC-8 and the downstream weir at Structure HC-7 by Highlands County.

Additionally, six (6) structures were found within Jackson Creek and Lake Josephine to the south. Structures HC-9, HC-10, and HC-15 are the main structures within Jackson Creek. Structures HC-11 and HC-12 provide drainage control from areas east of Sparta Road, into Jackson Creek. Structure HC-17 is the existing outfall structure from Lake Josephine to Josephine Creek. A more detailed description of the aforementioned structures is presented in **Table 4.**

Table 4. Study Area Structure Inventory (Highlands County Structure Inventory).

Highlands County Site ID	Reference	Basin	Waterbody	Location Description	Structure Type	Weir Width, (ft.)	Control Elevation, (ft. NGVD)
7		Other	Lake Sebring to Lake Jackson	Lakeview Drive	Sheet Pile Weir	6	106.09
8		Other	Lake Sebring to Lake Jackson	Lake Sebring Drive	Sheet Pile Weir	6	106.16
9	STR 1	Jackson-Josephine Creek	Jackson-Josephine Canal	Tubbs Road	Concrete Sharp Crested Weir	30	102.7
10	STR 2	Jackson-Josephine Creek	Jackson-Josephine Canal	East of Sparta Road	Concrete Sharp Crested Weir w/ Radial Gates	24	97.13
11		Jackson-Josephine Creek	Jackson-Josephine Canal	East of Sparta Road	Improved Earthen Berm	25	94
12	S-6	Jackson-Josephine Creek	Jackson-Josephine Canal	North of Tubbs Pits	CMP Riser	7	90
15	STR 3	Jackson-Josephine Creek	Jackson-Josephine Canal	South of Tubbs Pits	Concrete Sharp Crested Weir w/ Radial Gates	48	85
17	STR 4	Jackson-Josephine Creek	Josephine Creek	North of Lake Josephine Drive	Concrete Wall Weir	100	71

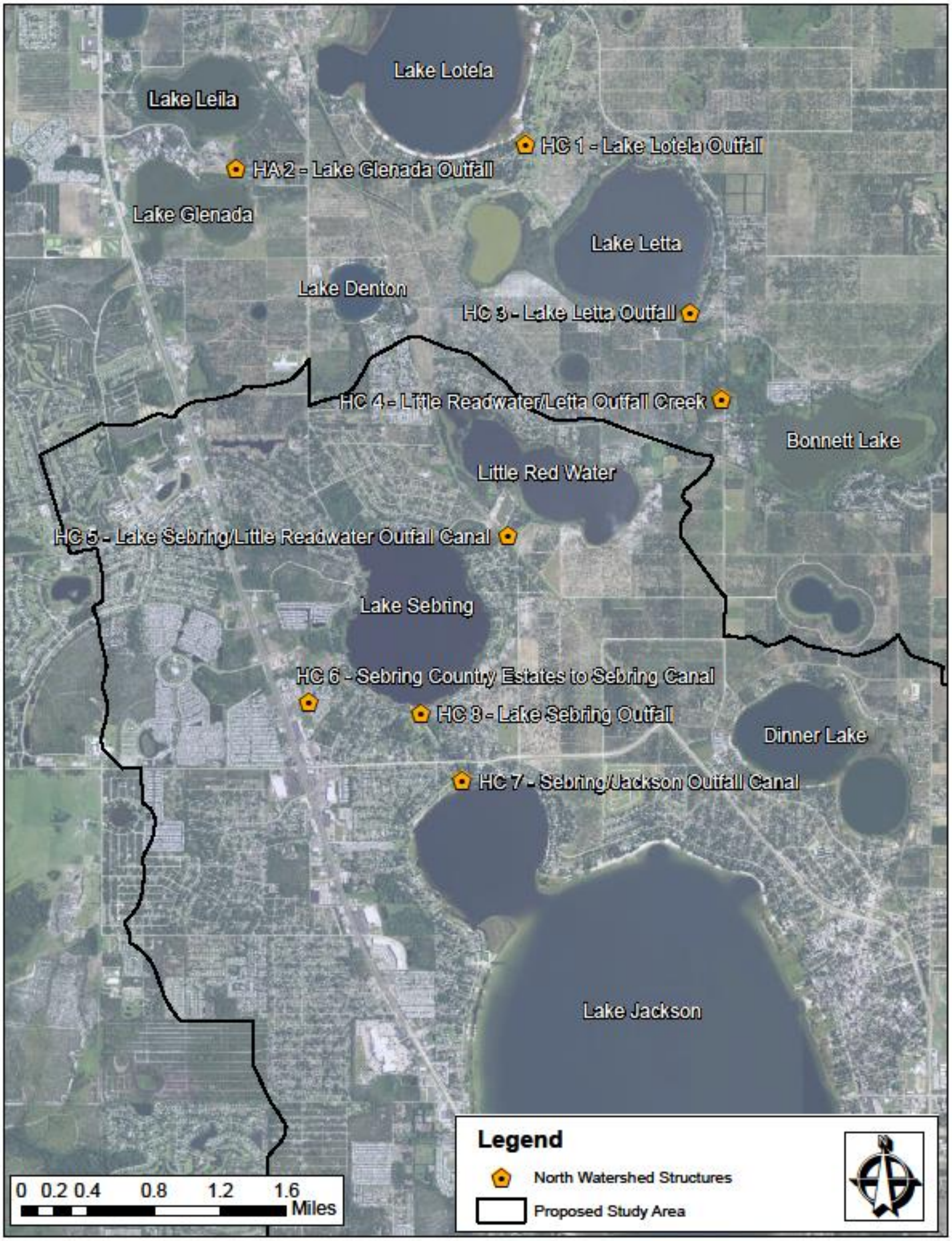

Figure 8. North Watershed Chain of Lakes Structure Inventory (After: KCA Corp.).

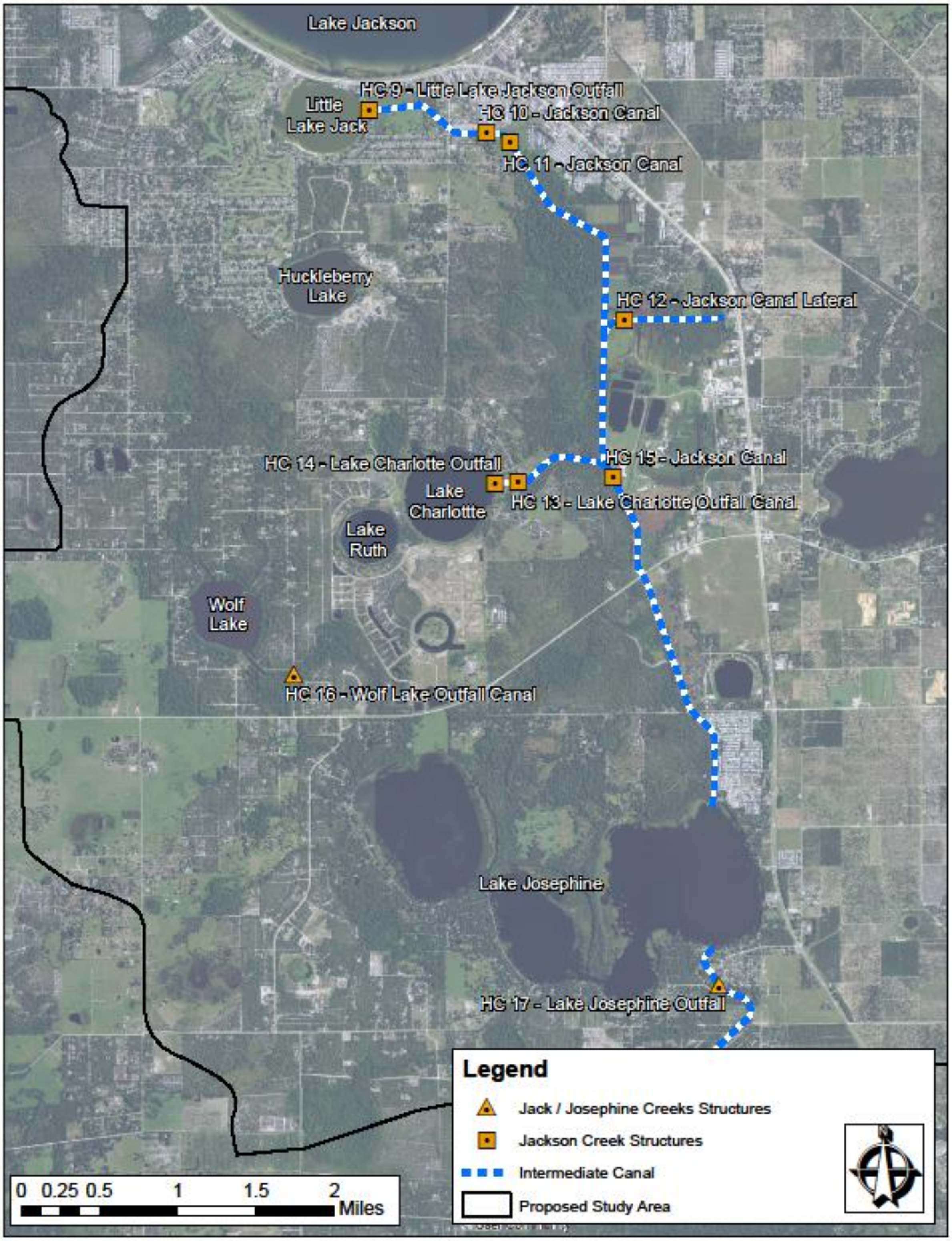

Figure 9. Jackson Creek Watershed Chain of Lakes Structure Inventory *(After: KCA Corp.)*

2.5 Groundwater Well Data

Readily available groundwater data from active and inactive monitoring wells were gathered and assessed. **Figure 10** presents well locations from the SWFWMD, and USGS data repositories, with relevant information from each source presented in **Tables 5 and 6**.

Table 5 presents well information obtained from the SWFWMD database (WMIS), and includes four USGS wells. While these wells are also available from the USGS, they are presented here as readily available data from the SWFWMD. Graphs of data will be presented in **Appendix A**

Table 6 presents additional USGS wells only available from the USGS database. These wells are in general considered “historical” as most do not contain data to present time. Additionally, most of the water level observations from wells presented in **Table 6** are sparse/sporadic in nature. Graphs of data will be presented in **Appendix A**.

This data was gathered and assessed to provide information with regards to past groundwater observations, as well as the potential location for a monitoring site(s) to be maintained by Highlands County. The monitoring sites from existing wells (either SWFWMD or USGS) is highly dependent on well condition (capped, plugged, removed, etc.) and available funding. Well condition would need to be assessed in the field, and funding is dependent on the availability of money and personnel to collect data from the proposed monitoring sites More information will be provided and a discussion presented in **Section 4.0 Monitoring Recommendations**.

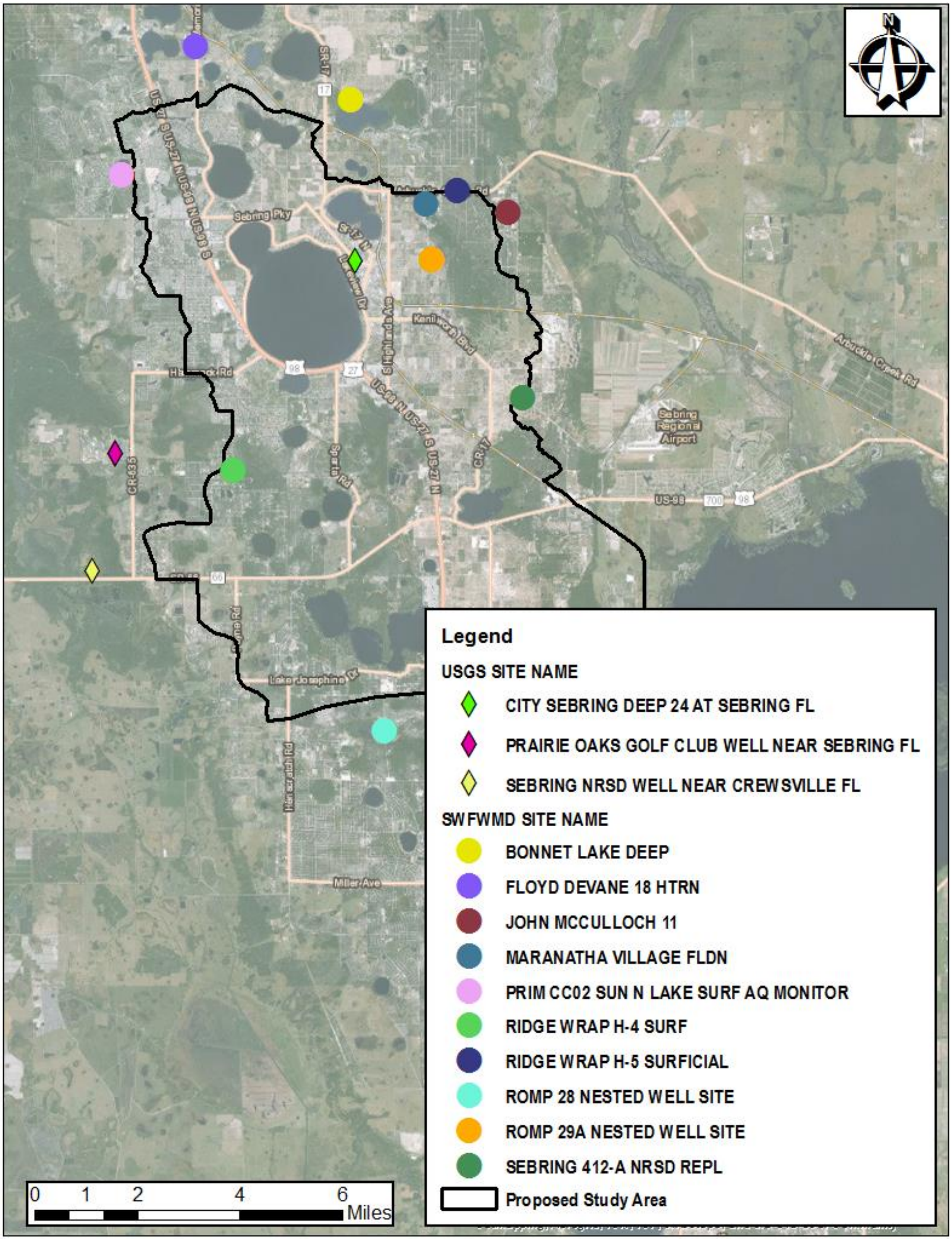

Figure 10. SWFWMD and USGS Well Locations within Proposed Study Area.

Table 5. Available Well Data (SWFWMD Database).

SWFWMD ID	Site Name	Start Date	End Date	Data Source	Aquifer	Well Depth (ft.)	Data Frequency (% of Daily Data Coverage)
711069	BONNET LAKE DEEP	5/18/1988	9/14/2011	USGS	Floridan	600	2x/yr. May and Sept.
711071	FLOYD DEVANE 18 HTRN	9/18/1986	9/14/2011	USGS	Intermediate (ICU/IAS)	340	2x/yr. May and Sept.
711067	JOHN MCCULLOC H 11	9/18/1986	9/20/2006	USGS	‡ Unknown (Likely ICU/IAS)	1029	2x/yr. May and Sept.
711037	MARANAT HA VILLAGE FLDN	5/15/1986	9/14/2011	USGS	Floridan	50	2x/yr. May and Sept.
758386	PRIM CC02 SUN N LAKE SURF AQ MONITOR	7/22/2010	9/10/2015	SWFWMD	Surficial	841	Daily (98)
25487	RIDGE WRAP H-4 SURF	4/3/1991	10/6/2015	SWFWMD	Surficial	370	Monthly
23795	RIDGE WRAP H-5 SURF	4/3/1991	7/13/1995	SWFWMD	Surficial	55	Monthly
Nested Wells	ROMP 28	2/5/1996	10/19/2015	SWFWMD	Surficial to Floridan	Varies	Daily (84)
Nested Wells	ROMP 29A	9/15/2008	10/14/2015	SWFWMD	Surficial to Floridan	Varies	Monthly
25481	SEBRING 412/412-A NRSD	3/05/1955	11/4/2015	USGS/ SWFWMD*	Surficial	63	Variable: Daily 1977 to Present (57)

*- SWFWMD currently monitors and maintains data for this well, previously USGS maintained site.

‡ - Aquifer labeled as “unknown” in database, assumed ICU/IAS based on well depth and published formation data.

Percent of Daily Data Coverage denotes the overall percentage within the period of record with available data.

Table 6. Available Well Data (USGS Database).

USGS ID	Site Name	Start Date	End Date	Aquifer	Well Depth (ft.)	Data Frequency (% of Daily Data Coverage)
272452081314101	SEBRING NRSD WELL NEAR CREWSVILLE FL	6/17/2004	2/01/2006	Surficial	21.7	Daily (96)
272652081311501	PRAIRIE OAKS GOLF CLUB WELL NEAR SEBRING FL	9/18/1986	9/15/1993	Intermediate (ICU/IAS)	239	2x/yr. May and Sept.
23007081263901	CITY SEBRING DEEP 24 AT SEBRING FL	9/18/1980	9/12/1995	Floridan	1400	2x/yr. May and Sept.

Figures 11 and 12 present data from the SWFWMD nested well sites ROMP 29A and ROMP 28 respectively. A nested well site is one in which multiple wells exist in close geographic proximity, with multiple wells monitoring several aquifers. This type of site is invaluable for hydrologic data collection and other groundwater research and modeling efforts, as it provides a complete picture of the groundwater at a single site. Nested wells are often preferred if the funding is available to construct and monitor such a site.

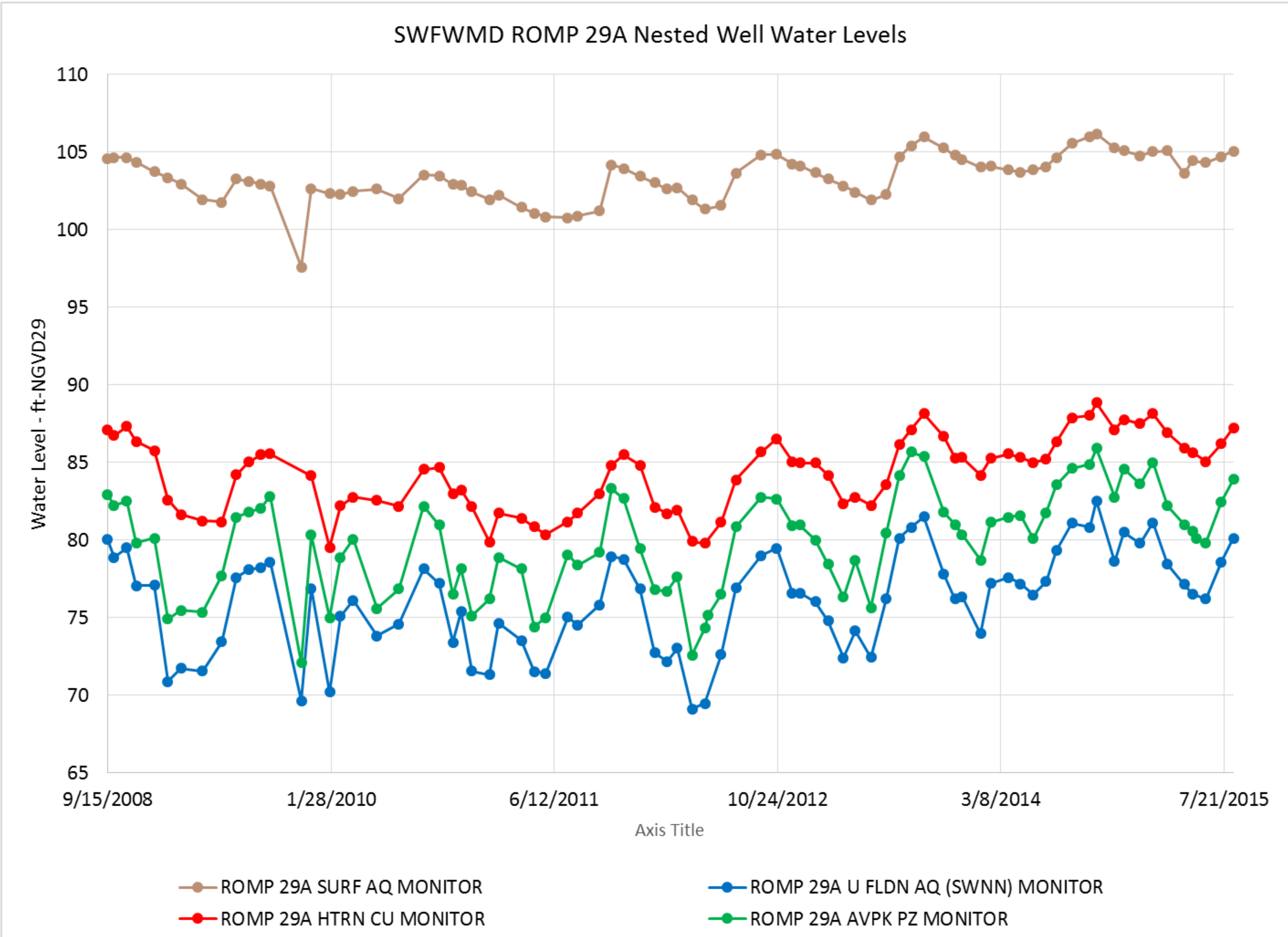

Figure 11. SWFWMD ROMP 29A Nested Well Graph

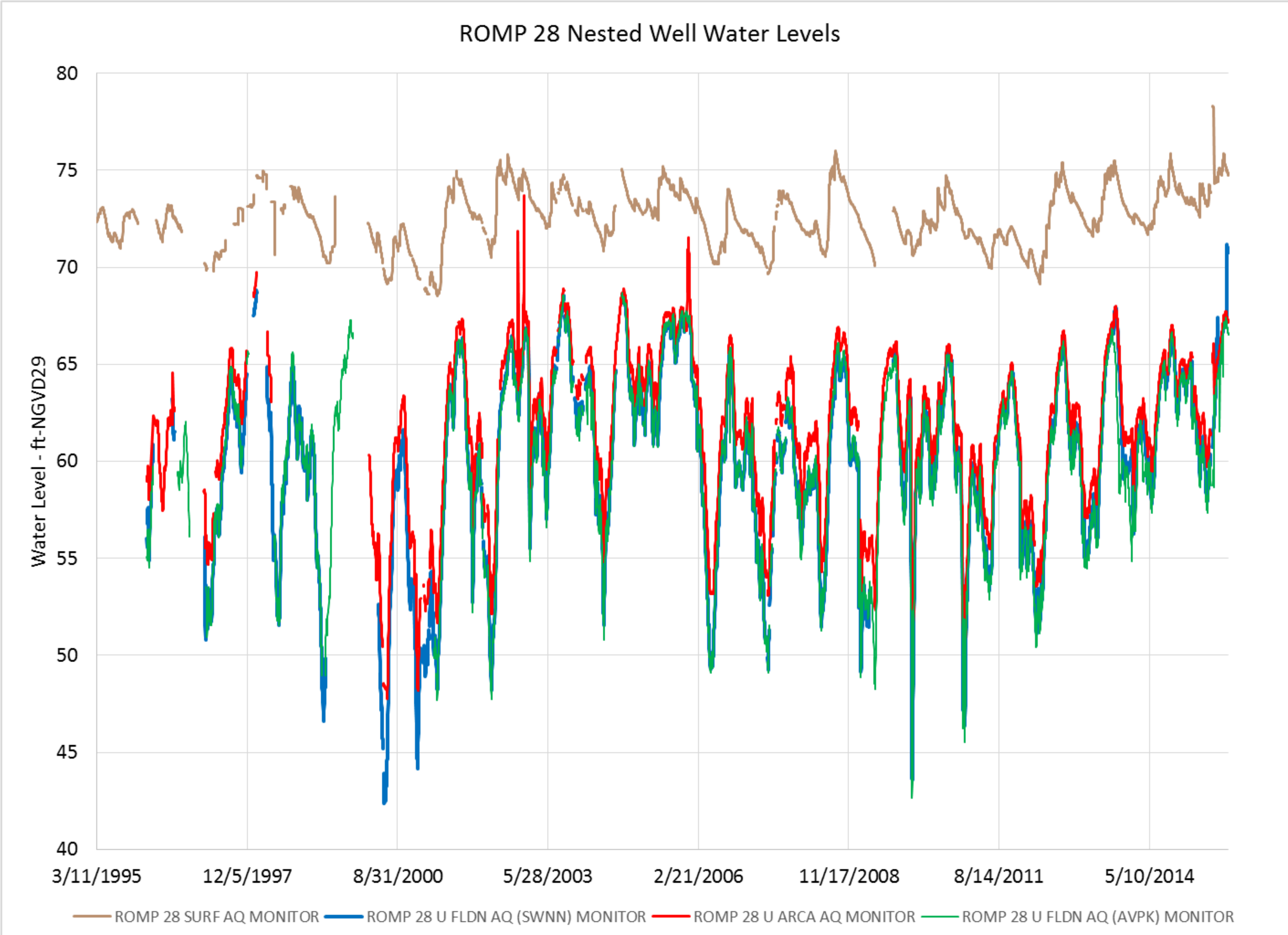

Figure 12. SWFWMD ROMP 28Nested Well Graph

2.6 Groundwater Use Data

Groundwater use data was obtained from the appropriate water use permit (WUP) located in the SWFMWD WMIS database. The selected WUP were shown as the largest users for Public Supply (P/S) withdrawals in the vicinity of Lake Jackson. **Figure 13** presents the location of these WUP boundaries (and associated pumping well locations), where withdrawals for the City of Sebring are in closest proximity to Lake Jackson, with sites along the East, and west borders of the lake. Additionally, the City of Avon Park has WUP boundaries along the majority of the border with Lake Sebring. Finally, the WUP of the Sun'N Lake of Sebring Imp. Dist. was included due to the relatively large withdrawals and the proximity of the district to Lake Jackson. Data presented in this section is not intended to be an all-inclusive dataset needed for modeling purposes, rather to illustrate a trend in public supply withdrawals in the vicinity of Lake Jackson. In future phases of this project, during model development, all available WUP data will be gathered from the SWFWMD database for metered withdrawals (P/S, agriculture, etc.) of 0.1 MGD or greater, as required by SWUCA rules.

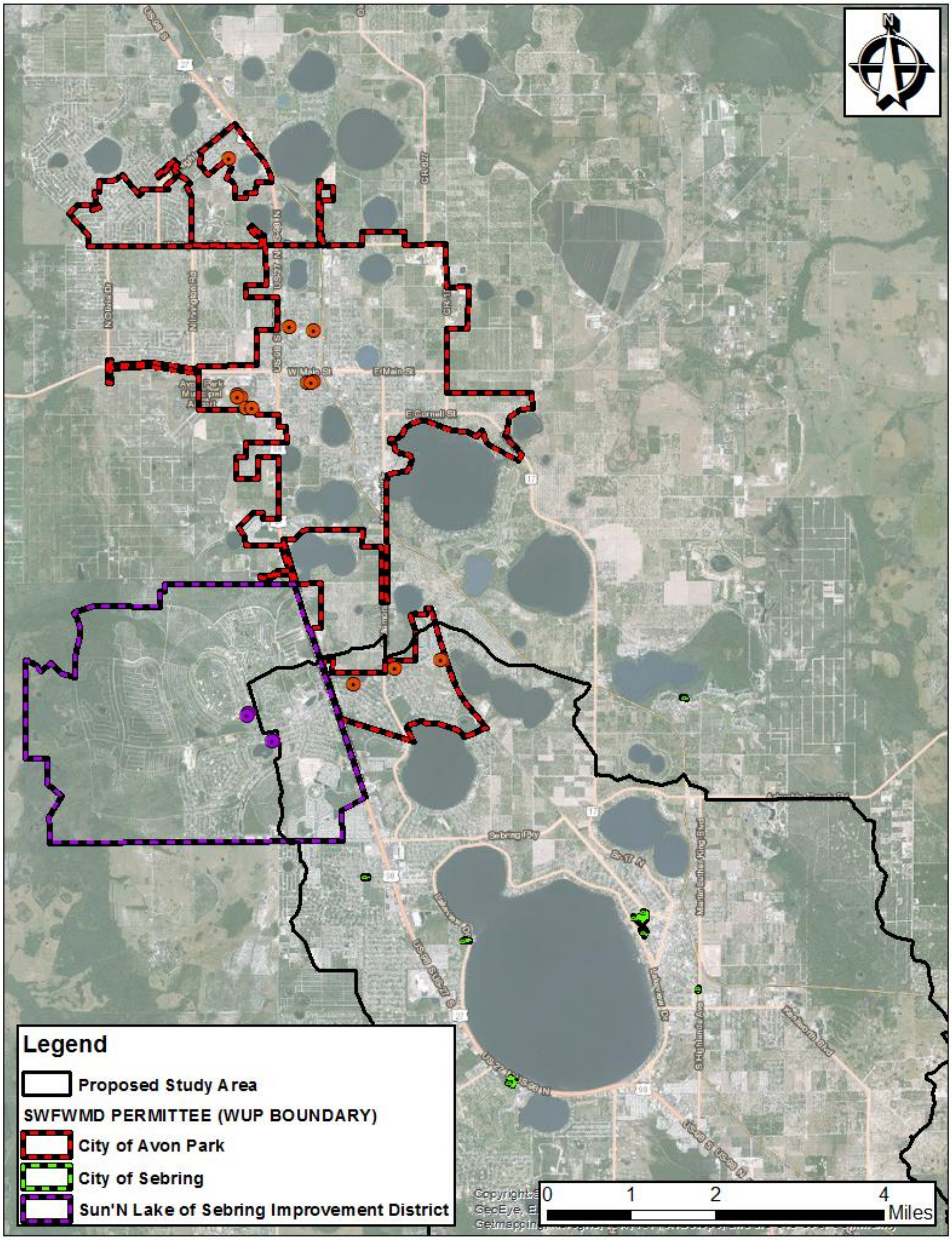

Figure 13. SWFWMD WUP Boundaries Near Lake Jackson.

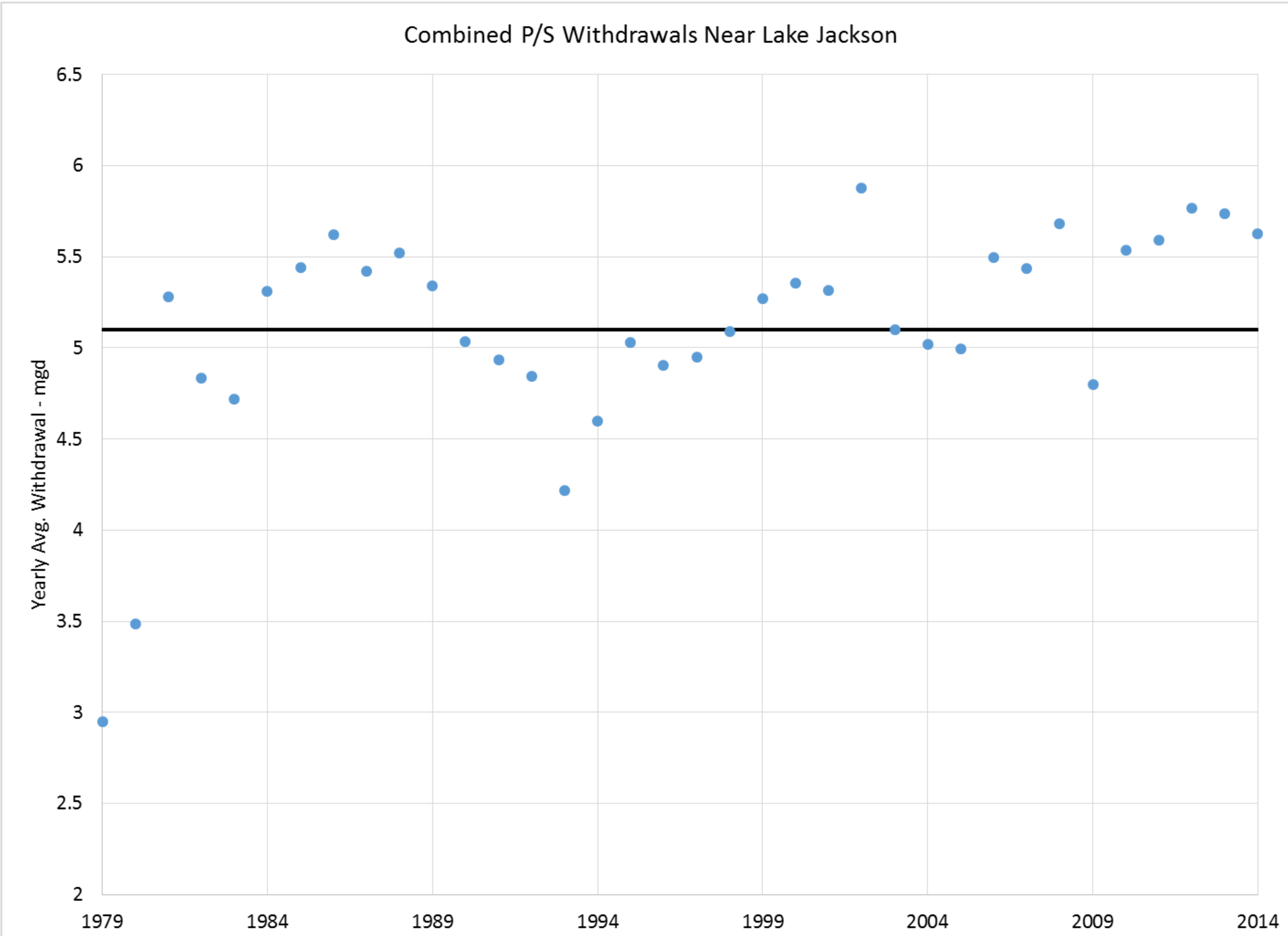

Figure 14. Combined Average Annual Withdrawals of Public Supply Water Near Lake Jackson.

As evidenced in **Figure 13** there are multiple public supply withdrawals of water around and in close proximity to Lake Jackson. **Figure 14** presents the average annual withdrawal of water from 1979 to present with an average withdrawal over the period of record of about 5.1 mgd (black horizontal line). In general, groundwater withdrawals for public supply near and around Lake Jackson appear to be increasing over the period analyzed. The WUP data presented in **Figure 14** will be further discussed in **Section 3.0 Data Analysis**.

2.7 Aquifer Tests (APT and Slug)

The SWFWMD provides data from Aquifer Performance Tests (APT) and/or slug tests for most aquifers in the district boundary. For the purposes of this report, APT test data was obtained and evaluated for sites within Highlands County, close to the proposed study area. **Figure 15**, presents the location of APT data for tests completed in the ICU/IAS

APT data provides insight for the hydraulic parameters of an aquifer, specifically the Transmissivity (T) which defines the amount of water that can be transmitted horizontally through a unit width by the full saturated thickness of the aquifer under a hydraulic gradient of 1 (Fetter, 2001). Another important aquifer parameter that can be calculated from slug tests and the APT data is saturated hydraulic conductivity (K), which defines the rate water moves through the aquifer material (ft./day). The availability of APT and slug test performed on the ICU/IAS will inform future modeling efforts as well as allow for the calculation of the potential leakage/flux from the overlying surficial aquifer through the ICU/IAS into the Upper Floridan Aquifer. For the purposes of this report, K was calculated for the wells with APT data using the published formation thickness of the entire aquifer (ICU/IAS) for wells shown in **Figure 15**. Additionally, the APT data was inconclusive for ROMP 29A, as such slug tests were performed to provide a K value, from the K value Transmissivity was calculated from published aquifer thickness. **Table 7** presents the SWFWMD APT and slug test results, as well as the calculated K and T values as previously described.

Table 7. ICU/IAS Aquifer Test Results.

SWFWMD APT SITE	Transmissivity (T) ft^2/day	Saturated Hydraulic Conductivity (K) ft./day	Aquifer Thickness (b) feet °
Hicoria ROMP 14 Well #3	31.2	0.10 ‡	300
ROMP 28 Kuhlman	162	0.62 ‡	260
ROMP 43 Bee Branch (Zone 2)	800	3.81 ‡	210
ROMP 43 Bee Branch (Zone 3)	400	1.90 ‡	210
ROMP 29A *	7.8	0.03	260

Notes for Table 7:

1. * - APT data inconclusive. K value comes from slug test, calculated T from, K and published formation thickness.
2. ‡ - K values calculated from published formation thickness and T values for each site.
3. *°* - Data obtained from *USGS Scientific Investigations Report 2010-5097.*

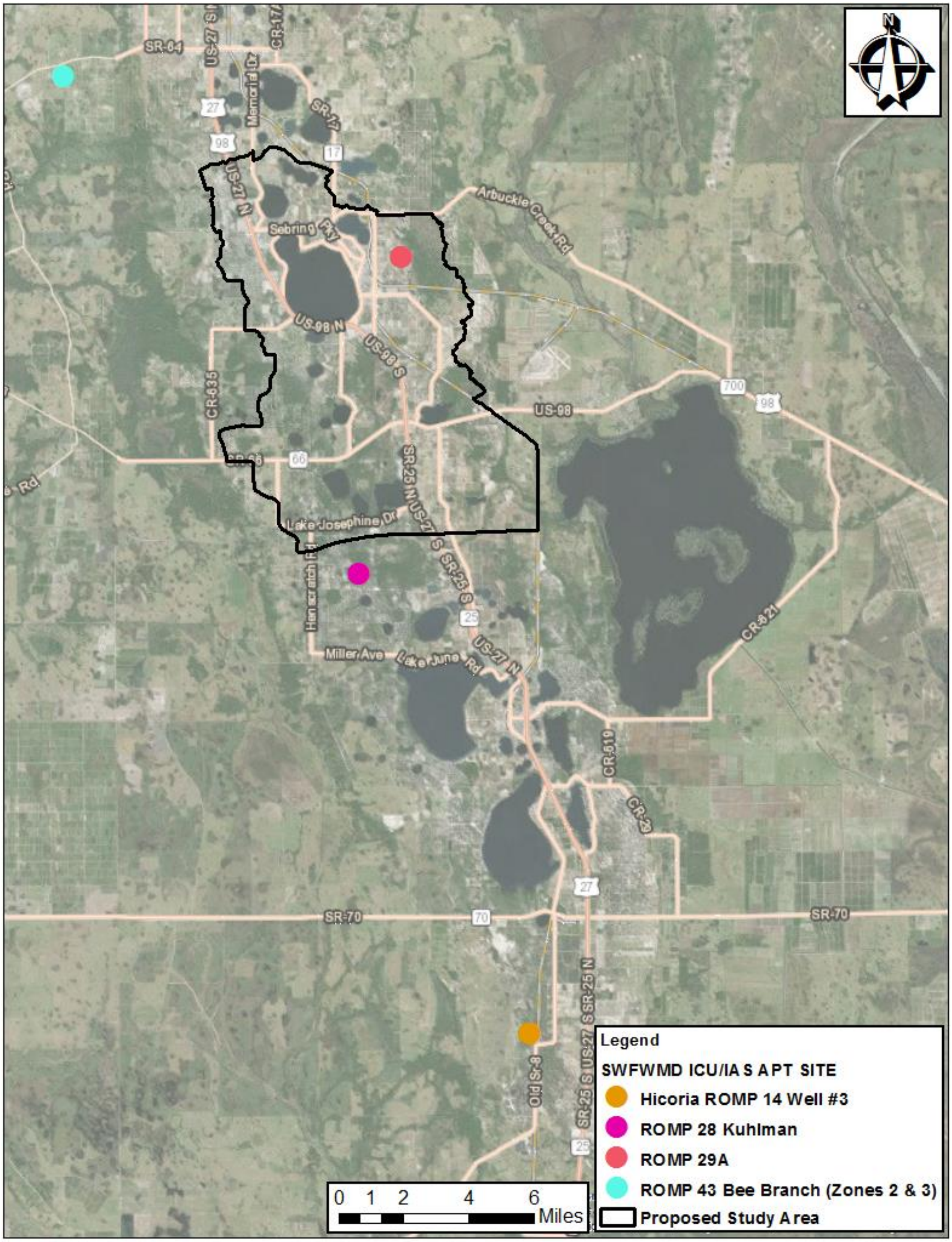

Figure 15. SWFWMD APT Sites – ICU/IAS.

3.0 Data Analysis

Rainfall, public supply (p/s) groundwater withdrawal (pumpage), and stages in Lake Jackson have been compared from 1985 to 2014. **Figure 16** presents comparisons of annual average P/S pumpage, Lake Jackson water levels and rainfall totals from the NOAA Avon Park rain gage. In addition to annual averages (and rainfall totals), are trend lines of the 7-year moving average for each data source. While lake levels in general respond to changes in rainfall and pumpage on a shorter timescale. The 7-year moving average presented in **Figure 16** was chosen due to the statistical significance shown in long term trends in Lake Jackson water level response (i.e. Lake Jackson levels vs rainfall and P/S pumpage). Statistical significance determined through multiple regression analyses are discussed later in this section.

A moving average is the average computed over a given period (i.e. number of years prior) over the selected data period. In the case below, a seven year moving average was chosen to show trends and smooth out the data from 1985 to present. As shown in the figure below there is a slight decreasing trend in the lake stage data from about 2005 to present. This same decreasing trend in lake stage is accompanied by an increasing trend in P/S pumpage and a decreasing trend in rainfall for the 7-year moving average.

With respect to the public supply withdrawal of water, it is the intention of this document, to analyze the selected sub-set of available pumpage data to determine if any trends between lake stage, pumpage and surficial aquifer water levels can be shown. This document does not serve as a robust statistical comparison of cause and effect, rather attempts to identify trends in readily available data, using standard statistical methods.

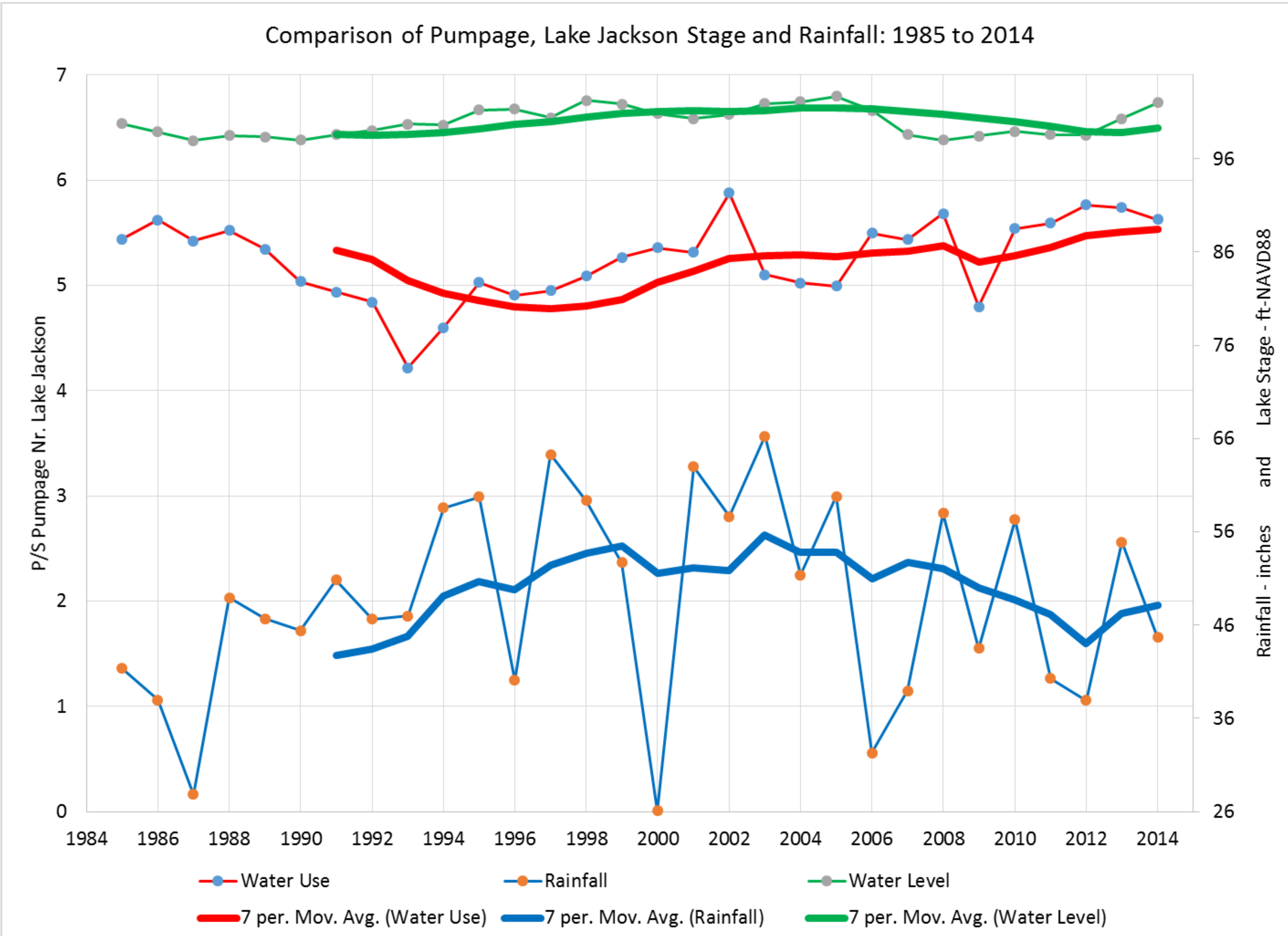

Figure 16. Comparison of Avg. Annual P/S Pumpage, Lake Jackson Water Levels and Annual Rainfall including 7-yr Moving Avg. 1985-2014.

Additionally, multiple regression statistical analyses were performed on annual data as well as, 3-yr 5-yr, and 7-yr moving averages over the same time period presented in **Figures 17 & 18.**

Multiple regression is a technique where a single dependent variable is compared against multiple independent variables. In the case of the analyses presented here, the dependent variable was Lake Jackson Water Level, and independent variables were rainfall and p/s pumpage. Statistics for all the multiple regressions are shown in **Appendix B**.

A brief discussion of each multiple regression analysis and plot for the corresponding moving average are presented below. Annual and 7-yr moving average data are not presented in separate plots as this has been previously shown in **Figure 16**.

Annual Data

With the two independent variables, the Significance F (p-value) was 0.18 meaning the regression was not significant at the 10% level (Assume significance of F of 0.10 or lesser). However, in examining the two independent variables, rainfall was significant at p-value of 0.09, but pumpage was not significant at 0.68.

3-year Moving Average

The 3-year moving average was much more significant (0.005) than the annual series but the significance was being governed primarily by rainfall with a p-value of 0.001. Pumpage remained not significant at a p-value of 0.65.

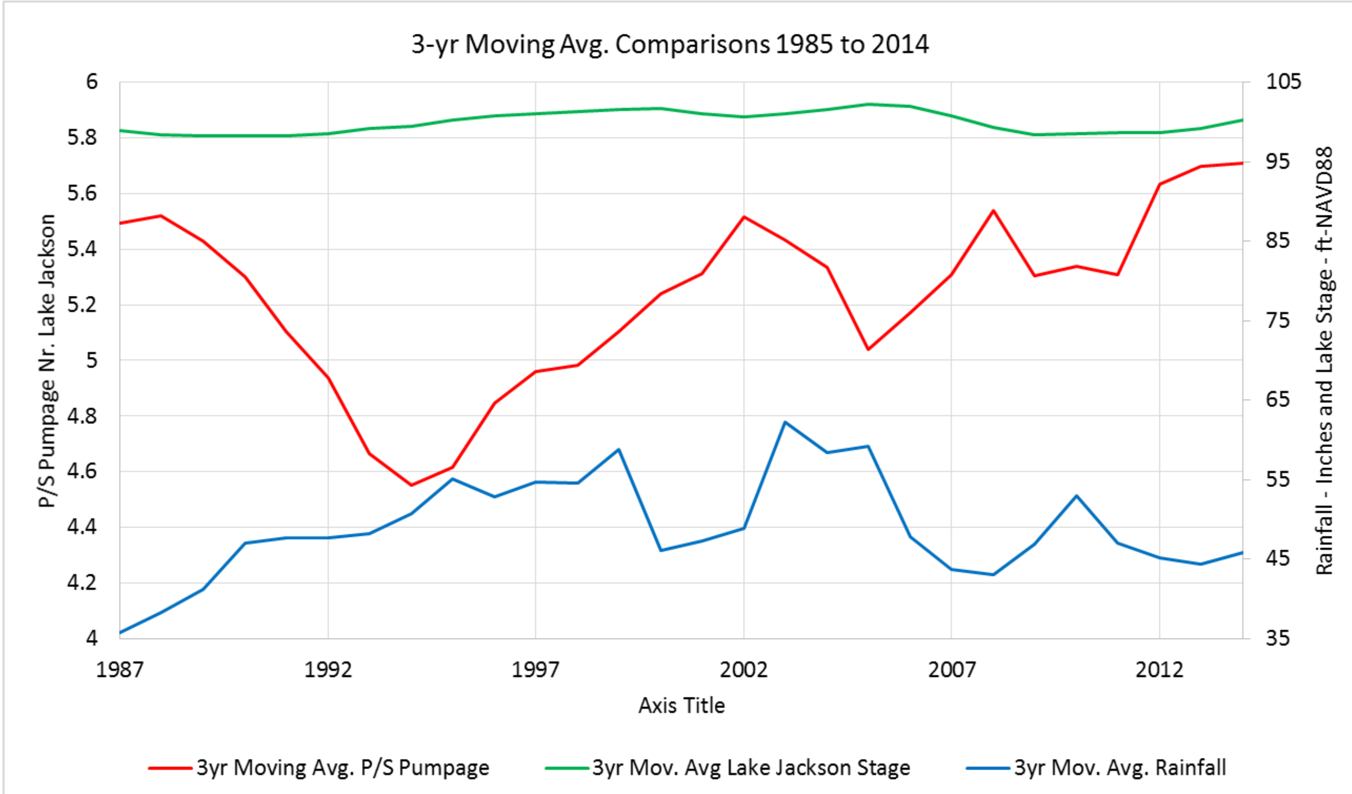

Figure 17. 3-yr Moving Avg. Comparison of Pumpage, Rainfall and Lake Stage 1985-2014.

5-Year Moving Average

The significance F continued to improve with the increasing years for the moving average. Significance F was 7.53E-06. P-value for rainfall was 1.78E-06 and pumpage only slightly outside the 10% level at 0.12

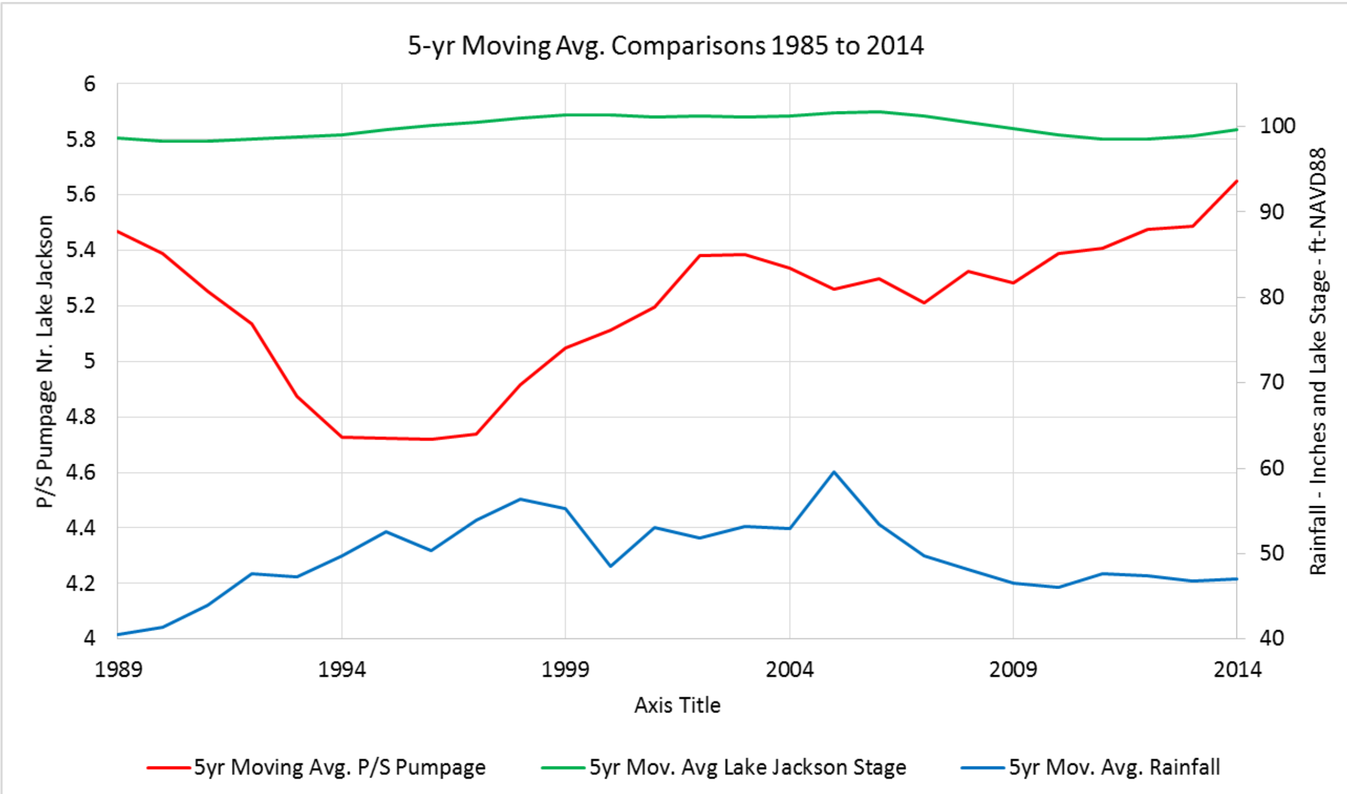

***Figure 18.** 5-yr Moving Avg. Comparison of Pumpage, Rainfall and Lake Stage 1985 to 2014.*

7-Year Moving Average

The 7-year average was by far the best of the relationship with a Significance F of 2.86E-08. Both rainfall and pumpage were significant with 5.5E-09, and 0.013 p-values, respectively.

4.0 Monitoring Recommendations

Based on the previous Sections, extensive research was conducted by the consultant to verify the necessary recommendations for additional data collection to fill gaps in the POR of existing wells (i.e., Re-instrument a USGS, SWFWMD well, & staff gage or recorder in a water body). Additionally the data research conducted in the previous sections painted a picture of what additional data should be needed to adequately and efficiently create the basis for a hydraulic model to be conducted on the requested study area. Based on the availability of the existing data, the consultant has proposed additional monitoring sites (Surface water/Groundwater) as presented in the following sub-sections.

4.1 Meteorological/Weather Station

Per Exhibit "A" of the County's Project Plan, under Agreement No. 14C00000039, within Project Tasks "Field Assessment" section, "the County will design and construct (1) automated weather station pursuant to DISTRICT specifications". After extensive research, two manufacturers were selected as viable options given the weather variable parameters that they could potentially collect data for.
Global Water's WE-800 Weather Station is a fully integrated, easy-to-use, computer-based weather station for monitoring and reporting weather conditions. In addition to the data logger, the included sensors are:

- Wind Speed Sensor
- Wind Direction Sensor
- Temperature Sensor
- Humidity Sensor
- Solar Shield

The base price for the Global Water's WE-800 Weather Station Data logger is **$3,742.00**

Through coordination with Highlands County staff and reviewing the design needs of the project a list of additional sensor costs was generated and presented in **Table 8**.

Table 8. Additional WE-800 Weather Station Sensors Description/Costs.

Item No.	Item Description	2015 List Price
EA0000	WE100, Barometric Pressure Sensor	$ 493.00
EB0000	WE300, Solar Radiation Sensor	$ 935.00
FN0000	BC100 Smart Battery Charger	$ 134.00
EN0000	EP180, Evaporation Pan	$ 1,492.00
EK0000	RG600, Rain Gauge, 8" Tipping Bucket	$ 549.00
FH0000	SP102, Solar Panel	$ 415.00
	Total Additional Sensor Costs	**$ 4,018.00**
	Total Weather Station Costs including Add. Sensors	**$ 7,760.00**

(Weather Station Costs Referenced from www.globalw.com/products/we800.html)

Based on conversations with County staff, the consultant has provided a conceptual location for the proposed weather station. It is assumed that the County would prefer to place the proposed weather station within County or the City of Sebring's lands, which is located adjacent to or near Lake Jackson and is free of vegetation so that the station can operate as efficiently as possible. The proposed location is shown in **Figure 19**. As previously stated, all proposed locations are suggestions, and may be modified upon further coordination with County and SWFWMD staff.

Figure 19. Proposed Weather Station Location (Highlands County Property Appraiser, additional graphics by AIM Engineering & Surveying, Inc.).

4.2 Lake Seepage

While there are not existing lake seepage data for Lake Jackson, or any other lake in the proposed study area it is the intent of this subsection to identify a potential method to monitor lake seepage from the bottom of Lake Jackson.

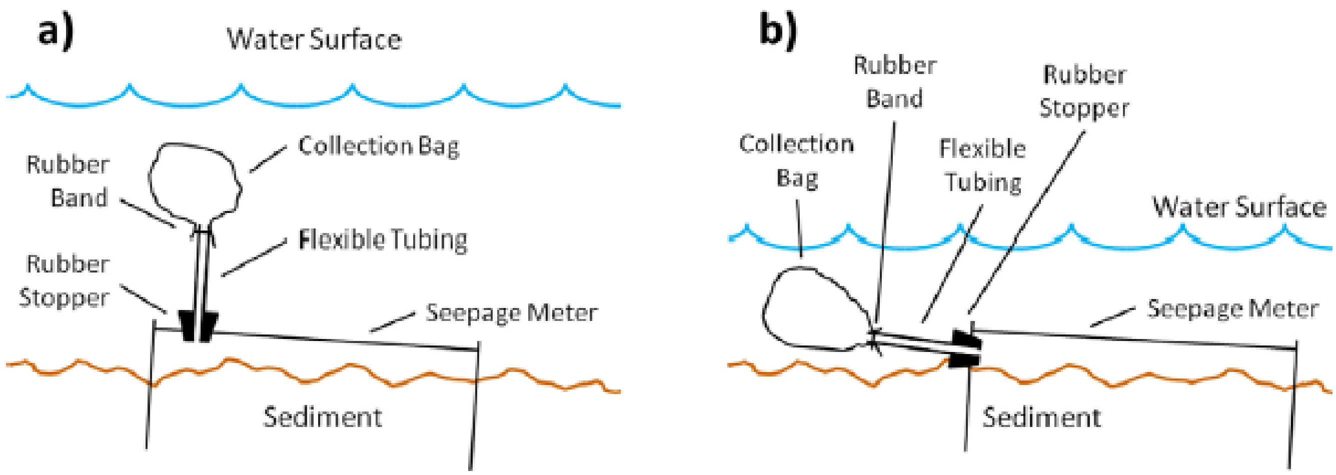

Figure 1. Cross-section view showing a typical installation of a seepage meter at left (a) and for an installation in shallow water (b).

Figure 20. Seepage Meter Diagram (After: Martinez, 2013).

As shown in **Figure 20**, a basic seepage meter can be a simple, effective and inexpensive piece of equipment, consisting of a 55-gallon drum, flexible tubing, a rubber stopper, rubber band and collection bag. The collection bag has a known volume of water at the time of installation, where the 55-gallon drum (or other large opened bottom container) with the bottom cut off is driven into the lake sediments. Over a set time interval, the volume of water in the bag is recorded. The difference in volume from the collection bag is the amount gained or lost over the time period. Accounting for the change in the volume of water, a vertical groundwater flux (seepage rate) in units of length per time can be calculated based on the exposed area of the 55-gallon drum, over the time interval (USGS, 2007). In other words, a flow rate is determined by the volume of water gained or lost over a time interval, where water gained indicates an upward flux of water (water into the lake from the surficial aquifer), and water lost indicates a downward flux of water (water from the lake into the surficial aquifer). Once this data is collected, Darcy's Law can be solved for K (hydraulic conductivity) by incorporating lake stage data and surficial aquifer elevations to calculate the hydraulic gradient. It should be noted here that a piezometer installed alongside or in close proximity to the seepage meter is best in determining hydraulic gradient. However, surficial aquifer wells near Lake Jackson should suffice for this purpose.

Figure 21 presents a conceptual seepage meter grid design based on a 1,000-ft x 1,000 ft. grid resolution. Each proposed seepage meter would be installed in the centroid of each grid cell, pending the grid cell lies within Lake Jackson. Grid cells lying outside of the Lake Boundary are included for graphical purposes but not included in the final count of proposed seepage meters to be installed.

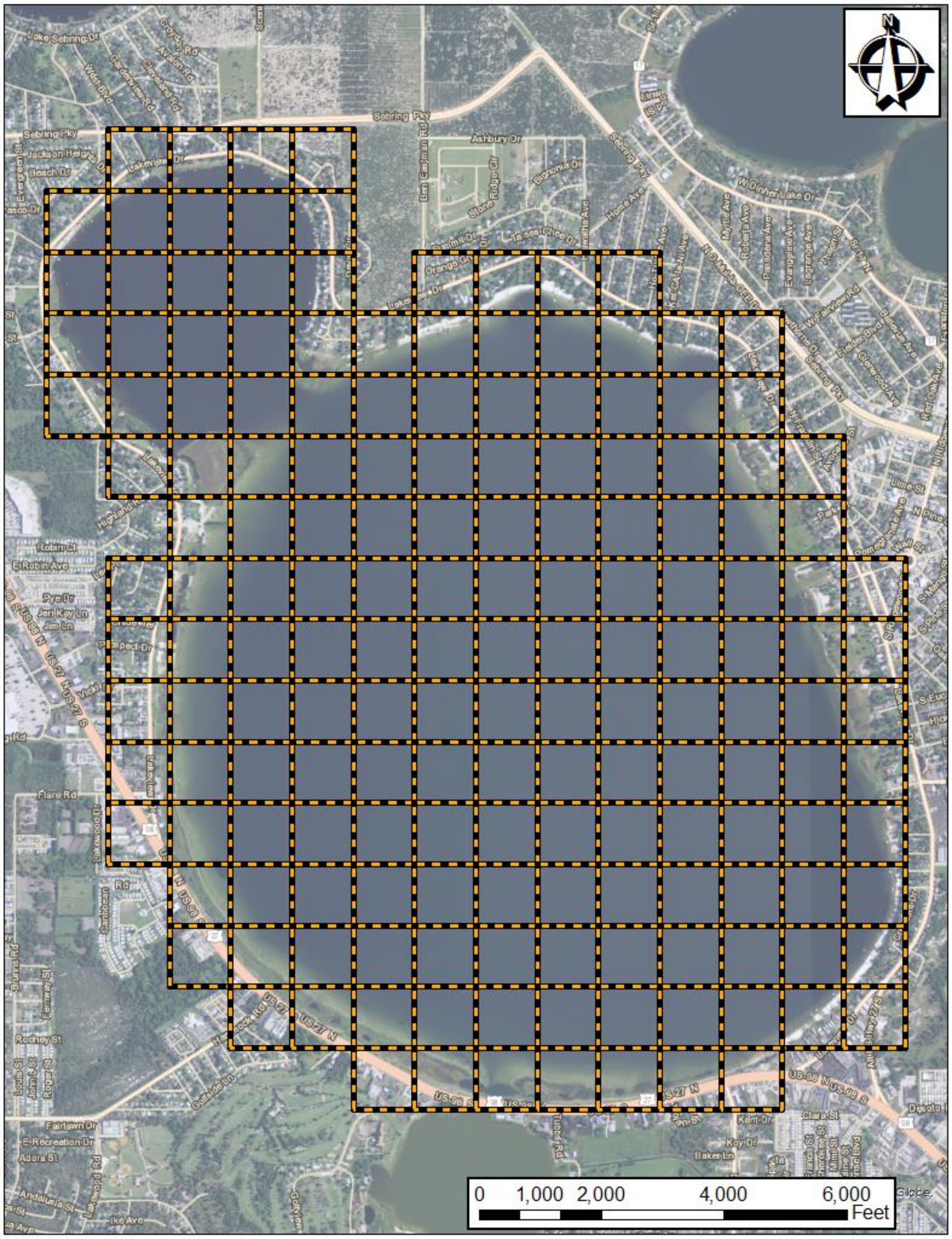

Figure 21. Conceptual Seepage Meter Grid Spacing for Lake Jackson (1,000ft. x 1,000ft).

The main limitation is the resolution (number of seepage meters) necessary to obtain a reasonable dataset. From GIS measurements, Lake Jackson is about 17,000 feet at the longest axis and about 11,500-feet at the widest axis. Assuming a resolution (spacing of seepage meters in a gridded pattern within the boundary of Lake Jackson) of 1,000-feet, this would equate about 162 seepage meters in a gridded pattern along the bottom of Lake Jackson. A coarser resolution (say, 2,000') may yield useful results, but with about 40 seepage meters. However, even at the coarser resolution, the resources required to install and monitor the instruments would likely be cost-prohibitive; as it would require periodic visits to each meter by certified divers, with the associated equipment, boats, insurance, etc. While seepage meters in Lake

Jackson would yield valuable information, it is understood that at this time, funding is not available for this type of monitoring effort regardless of the resolution (grid size) for the proposed seepage meters.

4.3 Groundwater Sites

As presented in **Section 2.5** groundwater data from the SWFWMD and USGS in the vicinity of Lake Jackson is sparse in both temporal resolution and areal extent. This is likely due to loss of funding, or past projects aimed at data collection periods of short duration.

Figure 22 presents the potential location of seven (7) proposed Surficial Aquifer (SAS) well sites to be installed around Lake Jackson. Each newly proposed well will consist of: a casing diameter of 2-inches, PVC material and depths will vary from 20 to 150-feet below land surface (BLS) and are proposed to be screened for the bottom 5 to 10-ft of each well. At this time it is not feasible to recommend specific screening intervals or depth (BLS), as final installation of an individual well will depend on site specific conditions. However, the FDEP guidance manual for monitoring wells was consulted, and suggest well screen lengths between 5 and 10-ft with well screens rarely exceeding 20-ft (FDEP, 2008). Installation of each 2-inch diameter well has been assumed to cost $2,500/well (up to 150-feet deep). In the event that larger diameter (6-inch) wells are necessary or preferred, the associated cost increases are substantial for deeper wells (up to 150-ft.). Conversations with contractors in Highlands County indicate that a 6-inch well to 150-feet deep will cost $8,250 per well, while a 6-in. well to 50-ft. will cost $2,750. This will add an additional $18,000 in well construction costs should this option be chosen (additional costs determined by increased well cost for three wells to 50-ft. {$250/well} and three wells to 150-ft {$5,750/well}).

It is assumed that all proposed well construction will follow the SWFWMD Hydro Data SOP standards and that data will be collected on a monthly interval by employing the measure down method. These proposed wells are all located in close proximity to Lake Jackson, on parcels owned by Highlands County or the City of Sebring. Proposed well sites were selected with the intention that the parcel owner (County or City) was assumed to be a cooperative party for the well installation on lands considered to be public.

Proposed wells would provide the most valuable data if they are installed in pairs, where one well was at a depth of 20-50-ft below land surface (BLS) and another between 100-150-feet BLS depending on the topography and site specific hydrogeology. For the purposes of this study, Lake Jackson has been assumed to have an average depth of 24-feet and the surficial aquifer is 200-ft thick in the vicinity of Lake Jackson.

A paired well installation would greatly improve the understanding of shallow groundwater dynamics in the study area, specifically interactions between Lake Jackson and the surficial aquifer. In future modeling efforts, the surficial aquifer system will likely be modeled as two layers. The ability to collect data representing two depths at a single location within the surficial aquifer will be invaluable for modeling efforts. Due to the limited budget for these sites, considerations have been made to provide a best case scenario (three (3) paired well sites in combination with single wells at four (4) of the remaining locations) and two other scenarios where only paired wells or a single well will be installed at each of the proposed site locations (site ID).

Table 9 and **Table 10** present well placement information with respect to well depth at each proposed site ID (**Figure 22**) under different funding possibilities. Under a best case scenario, wells (site ID) presented in **Table 9** would be installed in pairs as previously described, with the remaining well sites installed as a single well from a combination of the remaining sites found in **Table 10**, for a total of ten (10) wells.

In the event that paired wells with infilling of single well sites is found infeasible due to budgetary limitations, paired wells (**Table 9**) are preferential to single well sites. In other words, if budgetary constraints prohibit the option of the paired well plus single well site configuration, then paired wells at three sites, for a total of six (6) wells is preferred.

Alternatively, in the event that single well sites are the only form of available proposed well sites, **Table 10** may be used to guide the installation of all wells as a single point for each proposed site ID, for a total of seven (7) wells.

These proposed wells will allow for the collection of data around Lake Jackson to inform the team of shallow groundwater interactions near and across the lake. It should be noted here that the proposed wells around Lake Jackson are of primary importance to this study. **Appendix C** provides higher resolution location maps of each of the proposed wells. In addition to well location maps, **Appendix C** also provides a table of well locations, well depth, casing depth and casing diameter for the proposed wells shown in **Figure 22**.

Table 9. Proposed Paired Well Site Information.

Proposed Site Location	DEM Elevation (ft.-NAVD)	Shallow SAS Well Depth (ft. BLS)	Deep SAS Well Depth (ft. BLS)
3	101	30	100
6	123	50	150
7	105	30	150

Table 10. Proposed Well Site Information.

Proposed Site Location	DEM Elevation (ft.-NAVD)	SAS Well Depth (ft. BLS)
1	123	50
2	102	150
3	101	150
4	108	50
5	102	100
6	123	50
7	105	30

Additional wells shown on **Figure 22** are existing well sites owned and previously maintained by SWFWMD. From **Figure 22** there are multiple wells within the surficial aquifer, and a potential site in the Floridan aquifer, and one in an "unknown formation." According to the SWFWMD database these wells are still active in terms of "Well Status". What this means is that the well is not plugged, capped, abandoned or otherwise destroyed. These wells, subject to site verification to ensure functionality, are excellent sources of data, and are considered the most cost effective option for monitoring locations in future data collection efforts. Cost effective in that the well is already in place, negating any capital investment for well construction. All that is needed is a monthly measurement taken as a measure down from a known datum on each well, assuming access and well availability. Additional information on these existing SWFWMD wells is presented in **Table 11**. All information presented in **Table 11** was found directly from the GWIS well database and the consultant does not provide any assurances as to location accuracy, or other well characteristics. As previously stated, all well characteristics (location, depth, casing diameter, etc.), will need to be field verified before any data collection efforts are initiated.

Table 11. Existing SWFWMD Well Sites Recommended For Future Monitoring.

SWFWMD Site ID	SWFWMD Site Name	Well Depth (feet - BLS)	Casing Diameter (inches)	Aquifer Monitored	LATITUDE (Deg. Min. Sec.)	LONGITUDE (Deg. Min. Sec.)
23751	JOSEPHINE 7 SURF	9	2	SURFICIAL	27 24 45.46	81 26 32.37
25471	JOSEPHINE 9 SURF	6	2	SURFICIAL	27 26 08.67	81 25 19.21
23744	17th STREET SOUTH SURF	80	2	SURFICIAL	27 24 59.08	81 24 04.42
23743	DESOTO TOWER FLDN	UNKNOWN	4	FLORIDAN	27 25 14.01	81 24 00.19
25489	LLJ W1 SURF	50	2	SURFICIAL	27 28 09.27	81 28 10.35
25495	LLJ W2 SURF	50	2	SURFICIAL	27 27 52.39	81 28 02.89
25490	LLJ W3 SURF	50	2	SURFICIAL	27 27 35.00	81 28 26.00
25492	LLJ W4 SURF	50	2	SURFICIAL	27 27 55.00	81 28 37.00
23737	JOSEPHINE 2 SURF	7	2	SURFICIAL	27 23 20.86	81 27 09.89
23739	JOSEPHINE 3 SURF	7	2	SURFICIAL	27 24 21.40	81 27 52.83
23740	JOSEPHINE 4 SURF	11	2	SURFICIAL	27 23 57.25	81 25 04.93
23747	JOSEPHINE 6 SURF	9	2	SURFICIAL	27 24 45.44	81 25 41.42
23792	ARBUCKLE CREEK ROAD SURF	50	2	SURFICIAL	27 31 21.94	81 27 12.61
23669	PARADISE ROAD SURF	32	2	SURFICIAL	27 28 01.04	81 24 14.40
23735	JOSEPHINE 1 SURF	11	2	SURFICIAL	27 23 07.07	81 26 07.68
23748	JOSEPHINE 5 SURF	13	2	SURFICIAL	27 24 46.54	81 25 06.11
23754	JOSEPHINE 8 SURF	5	2	SURFICIAL	27 25 20.20	81 26 46.41
23742	JW YONCE & SONS 3	130	12	UNKNOWN	27 24 21.09	81 23 21.06

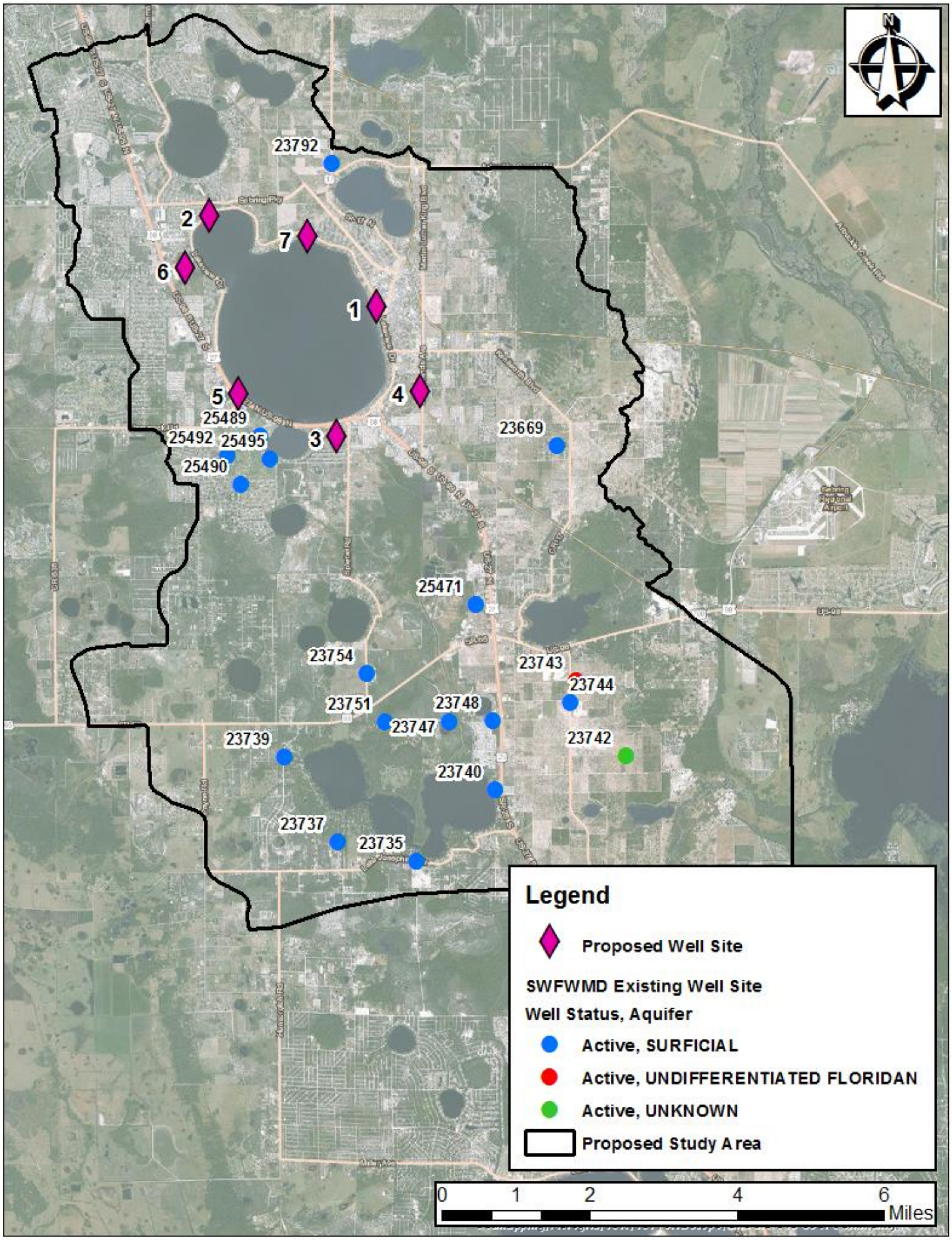

Figure 22. Proposed Monitoring Locations and Locations of Other SWFWMD Wells.

4.4 Surface water Sites

As presented in **Section 2.3**, there are currently nine (9) active collection sites within the study area. However, the data from these locations are mainly water level data that, is collected both automated and manually, as described in **Section 2.3**. The County's Project Plan under Agreement No. 14C00000039 calls for the design and construction of two (2) automated lake stage/flow recorders pursuant to **DISTRICT data specifications**. Following correspondence with the stakeholders, they believed that the addition of a water level/flow recorder on the downstream end of Structure HC-10 (within Jackson/Josephine Creek) would be beneficial and meet the project's plan description. The consultant recommends that the automated lake stage/flow recorders not only record lake levels, but streamflow data as well. Currently there is one inflow and one outflow between the Lake Jackson and Little Lake Jackson Chain. It is recommended that one automated lake stage/flow recorder be placed at the downstream end of the inflow area, and one at the upstream end of the structure (Structure 1) where the outflow location is to Jackson Creek. Also, one recorder is proposed to be installed at the Structure HC-10 location, as stated above. Approximate locations are shown in **Figure 24**. **Appendix D** provides higher resolution location maps of each of the proposed surface water/flow monitoring stations.

Based on previous project experience, water level monitoring and data collection is most efficient with the use of a small platform that extends out into the water body to collect accurate streamflow and water level data. In **Figure 23** (**informational purposes only),** is an example design specification for a platform with monitoring transducer. The proposed infrastructure should also be fitted with a calibrated staff gauge for data calibration comparison. The average estimated cost for each platform water level monitoring station is approximately **$3,500 each.**

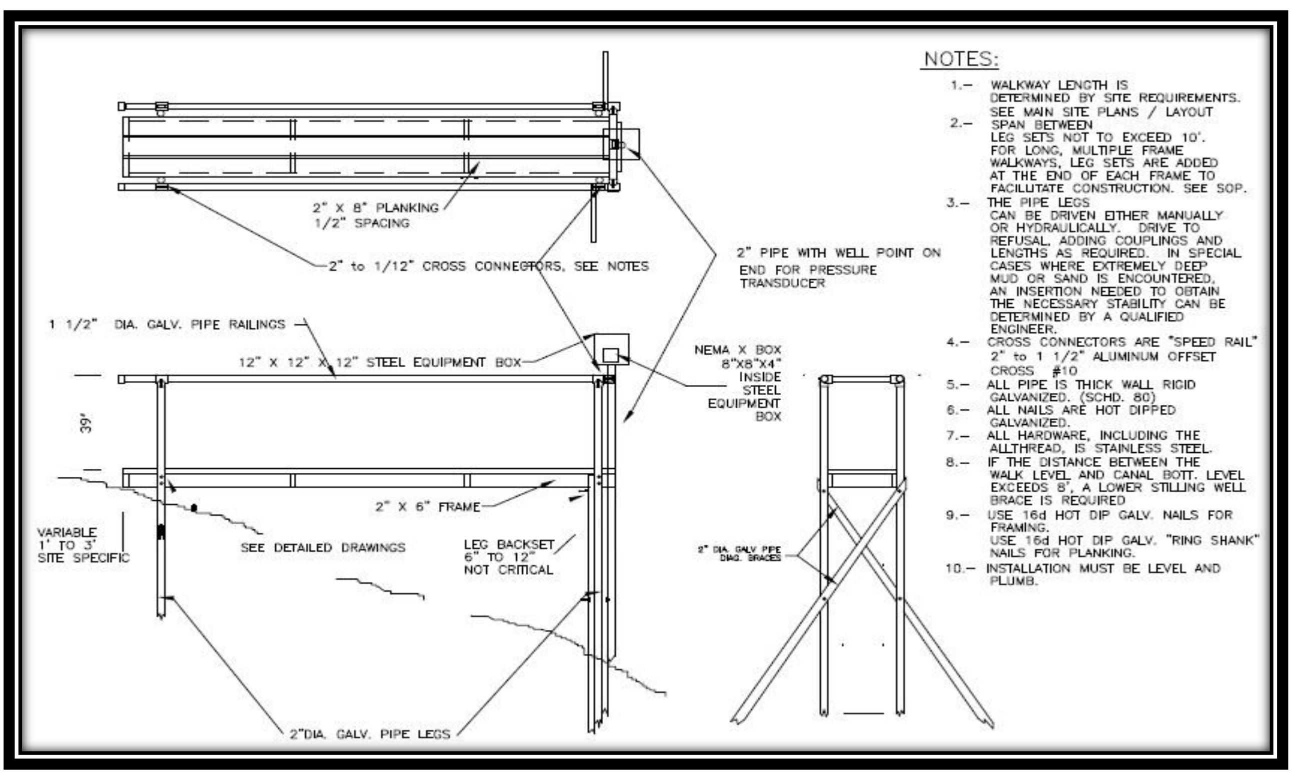

Figure 23. Proposed Automated Water Level/Streamflow Monitoring Platform Station (Designed by AIM Engineering & Surveying, Inc.).

Figure 24. Proposed Automated Water Level/Streamflow Monitoring Locations.

4.5 Summary and Cost Analysis of Proposed Monitoring Recommendations

Table 12 presents the cumulative proposed costs associated with the various monitoring plan options discussed within **Section 4.** The differences in proposed costs depend on the available budget and level of detail decided on when funding becomes available. For example, a total of 4 options are presented, relating proposed costs to monitoring well, monitoring surface water/streamflow, and weather station configurations. That is, depending on monitoring well configuration, and weather station needs, equipment and installation costs can vary considerably ($33k to $51k).

Table 12. Summary and Associated Costs for Monitoring Plan Options.

Description of Proposed Monitoring Costs	**Option ID**
Projected Cumulative Costs for (7) Proposed 2" Single Well Monitoring Sites Global Water With Additional Sensors, (3) automated water level/streamflow monitoring platforms	A
Projected Cumulative Costs for (10) Proposed 2" Single and Paired Well Monitoring Sites Global Water With Additional Sensors, (3) automated water level/streamflow monitoring platforms	B
Projected Cumulative Costs for (6) Proposed 2" Paired Well Monitoring Sites Global Water With Additional Sensors, (3) automated water level/streamflow monitoring platforms	C
Projected Cumulative Costs for (6) Proposed 6" Paired Well Monitoring Sites Global Water With Additional Sensors, (3) automated water level/streamflow monitoring platforms	D

Option ID	**Option Total Cost (USD)**
A	**$35,760**
B	**$43,260**
C	**$33,260**
D	**$51,260**

Note: 2" Single Well - $2,500.00 each
2" Paired Wells - $5,000.00 combined costs
6" Well - $8,250.00 each, 6" paired well - $11,000.00 each
Global Weather Station (including add. Sensors) - $7,760.00 each
Automated Water Level/Streamflow Monitoring Platform - $3,500.00 each

5.0 References

Douglas, E.M., J. Jacobs, D. Sumner, R. Ray, 2009. A comparison of models for estimating potential evapotranspiration for Florida land cover types. Journal of Hydrology 373, p. 366-376.

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Fetter, C.W., 2001. Applied Hydrogeology – Fourth Edition. Prentice Hall Inc. Upper Saddle River, New Jersey 07458.

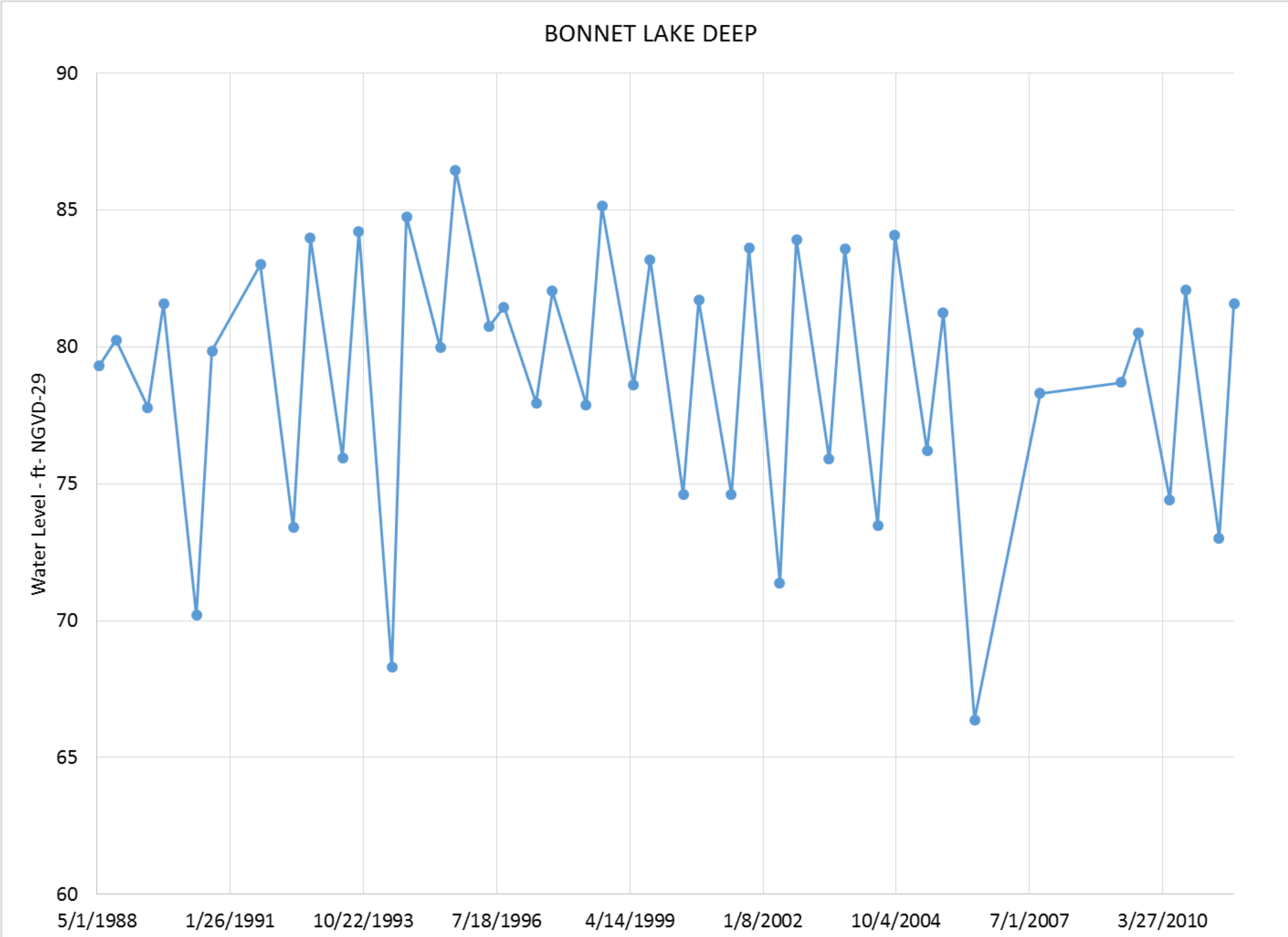
Martinez, C.J., 2013. Seepage Meters for Measuring Groundwater – Surface Water Exchange. UF/IFAS Document: AE435. University of Florida, Gainesville, Florida.

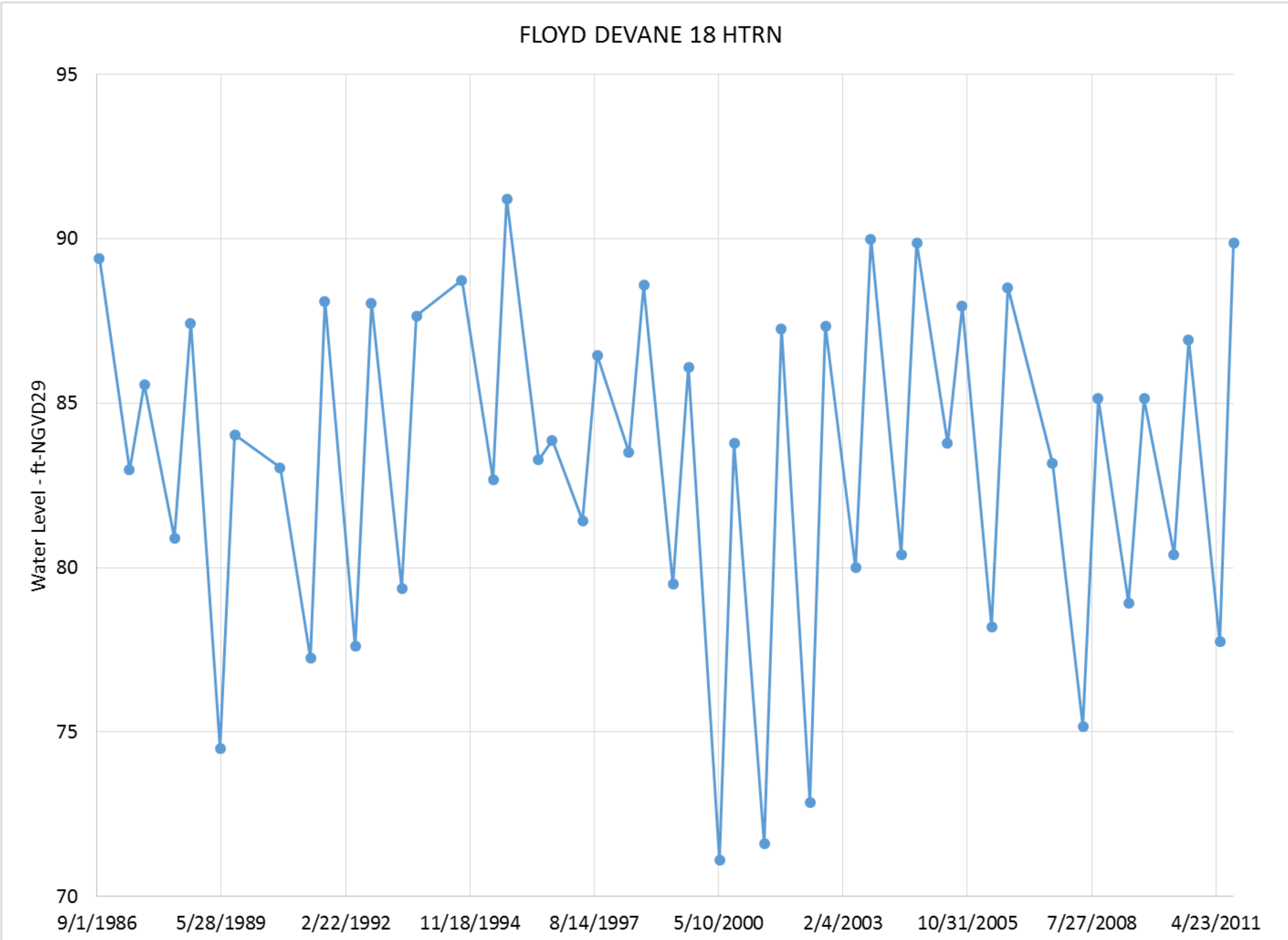
Spechler R.M., 2010. Hydrogeology and Groundwater Quality of Highlands County, Florida. USGS Scientific Investigations Report 2010-5097.

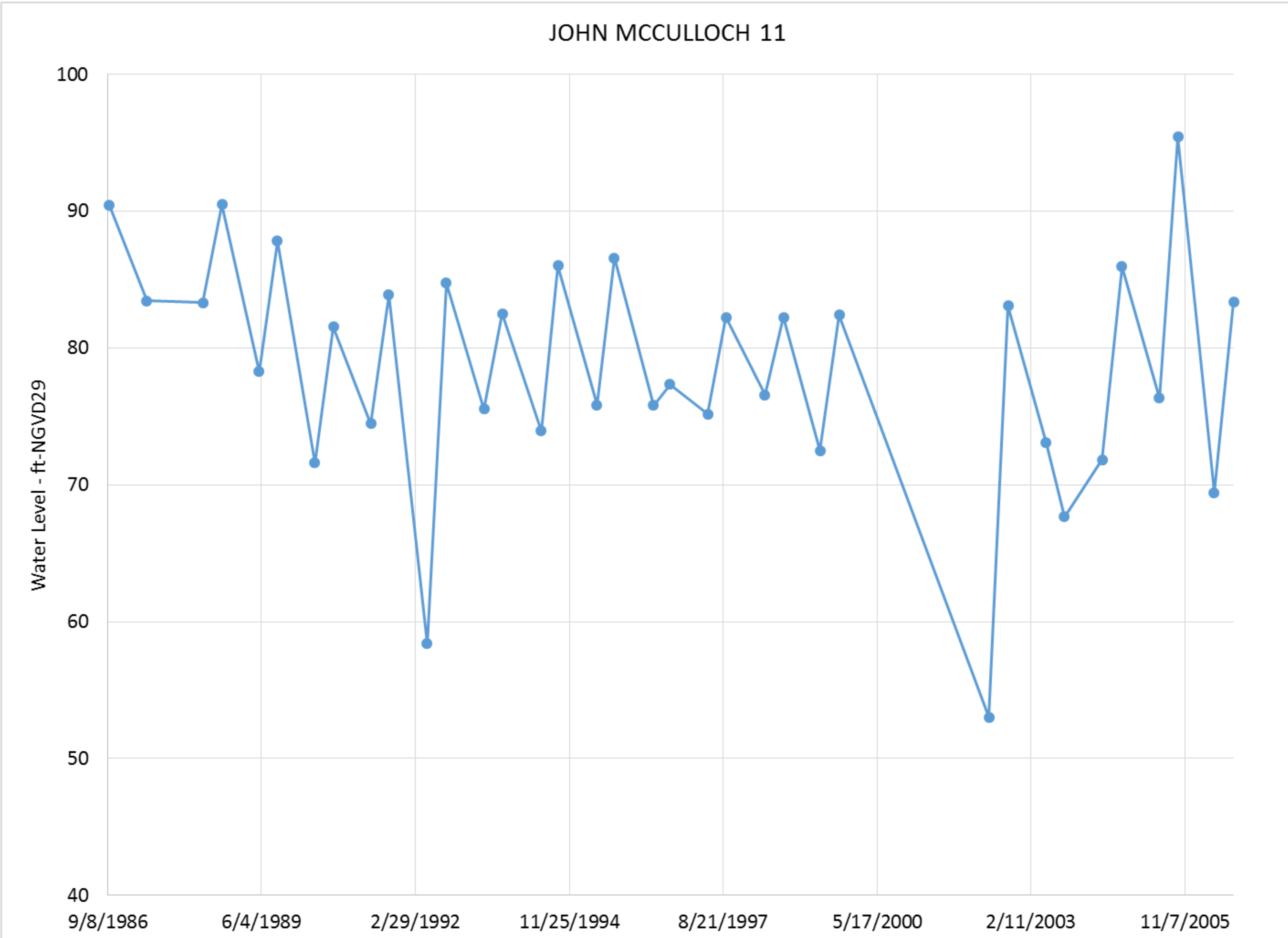
Zamoria, C., 2007. Estimating Water Fluxes Across the Sediment – Water Interface in the Lower Merced River, California. USGS Scientific Investigations Report 2007-5216.

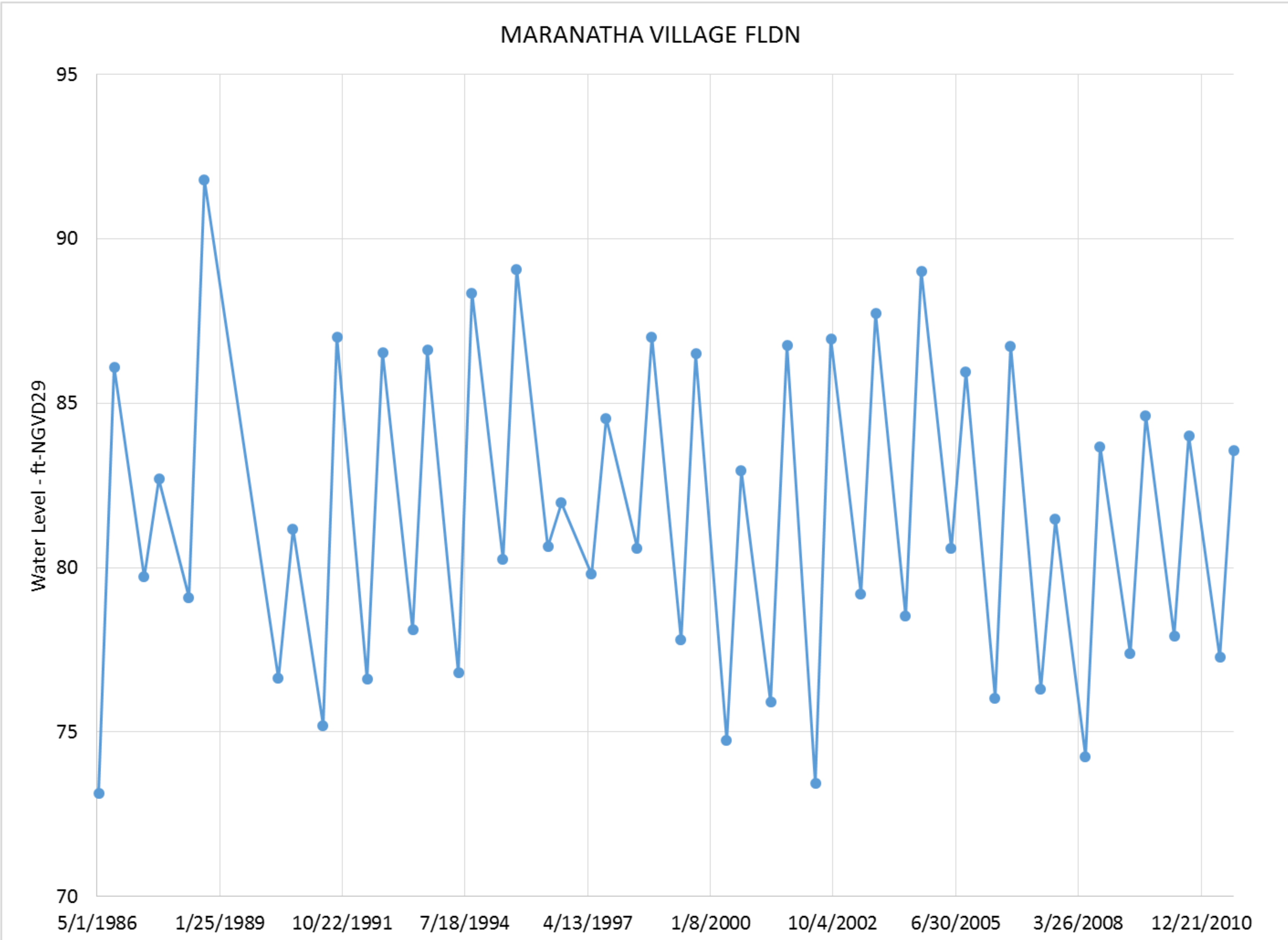
Appendix A

The following figures present the available groundwater data for each well described in **Section 2.5**. A trendline of the data is presented for a graph if the trend (up or down) in waterlevel was found significant using the Significance F test of less than 0.10. Statistical output for a significant trendline is presented on the following page after each appropriate figure.


BONNET LAKE DEEP
Water Level - ft- NGVD-29
90
85
80
75
70
65
60
5/1/1988
1/26/1991
10/22/1993
7/18/1996
4/14/1999
1/8/2002
10/4/2004
7/1/2007
3/27/2010


FLOYD DEVANE 18 HTRN
Water Level - ft-NGVD29
95
90
85
80
75
70
9/1/1986
5/28/1989
2/22/1992
11/18/1994
8/14/1997
5/10/2000
2/4/2003
10/31/2005
7/27/2008
4/23/2011


JOHN MCCULLOCH 11
Water Level - ft-NGVD29
100
90
80
70
60
50
40
9/8/1986
6/4/1989
2/29/1992
11/25/1994
8/21/1997
5/17/2000
2/11/2003
11/7/2005


MARANATHA VILLAGE FLDN
Water Level - ft-NGVD29
95
90
85
80
75
70
5/1/1986
1/25/1989
10/22/1991
7/18/1994
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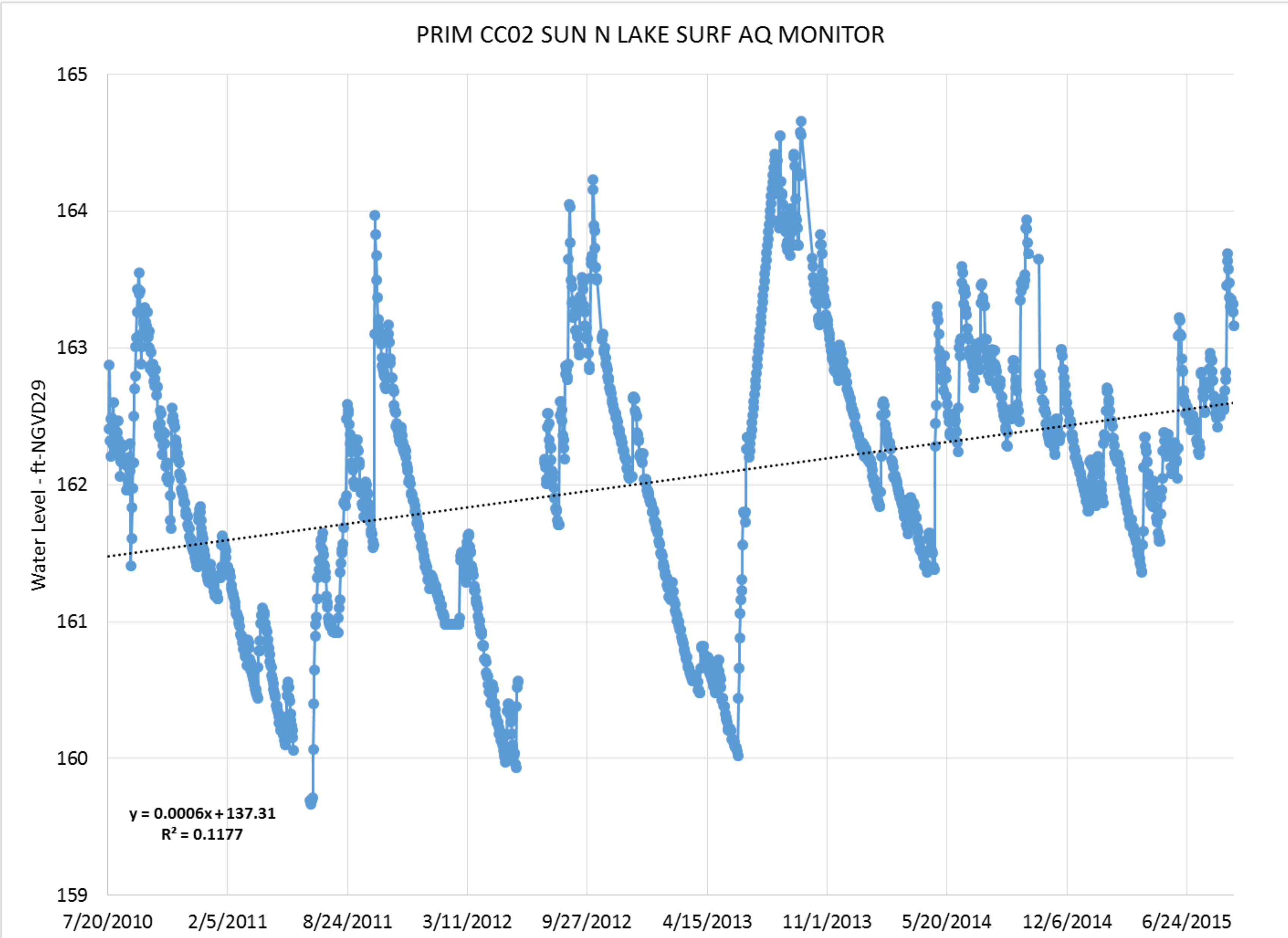
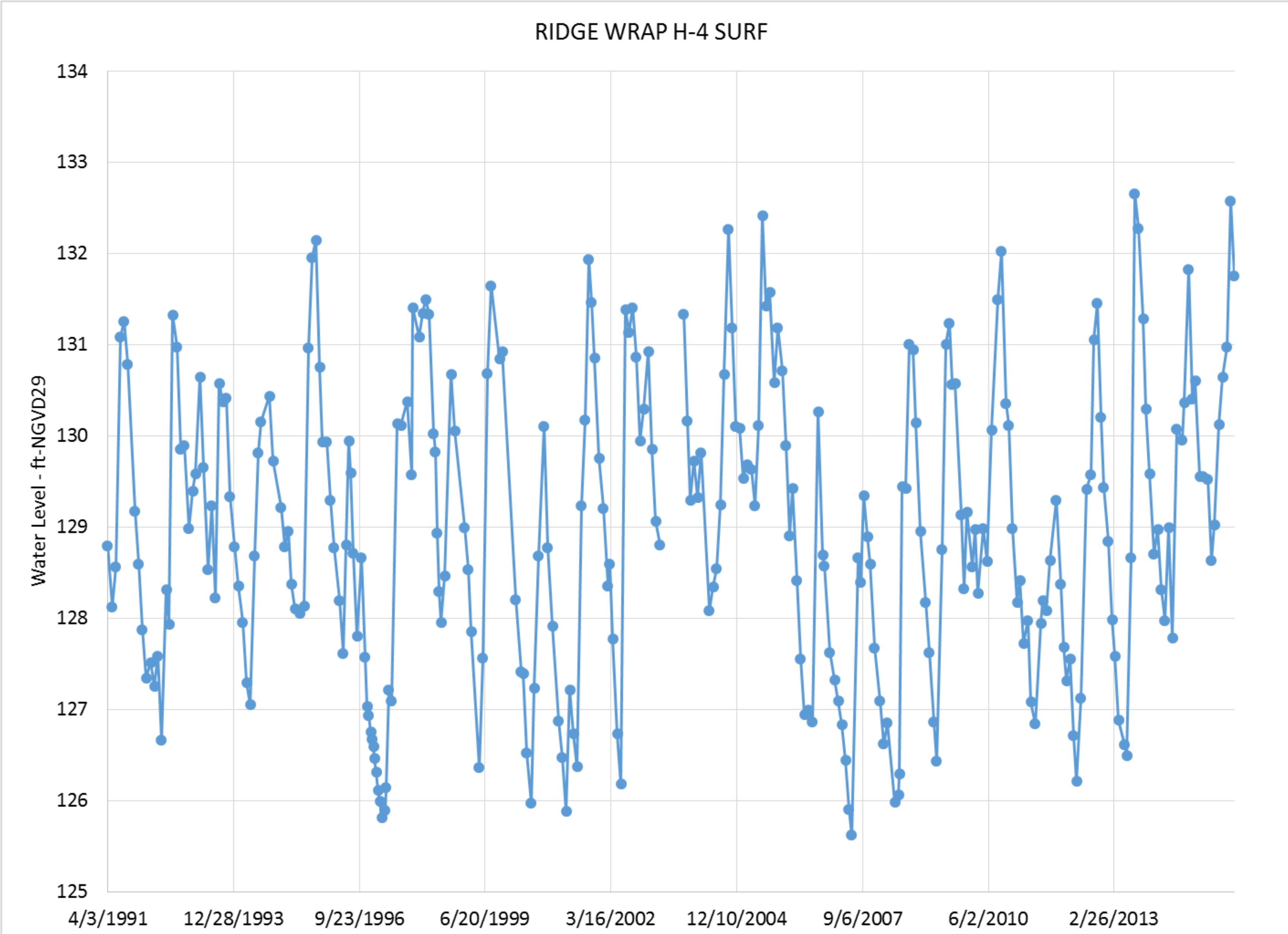
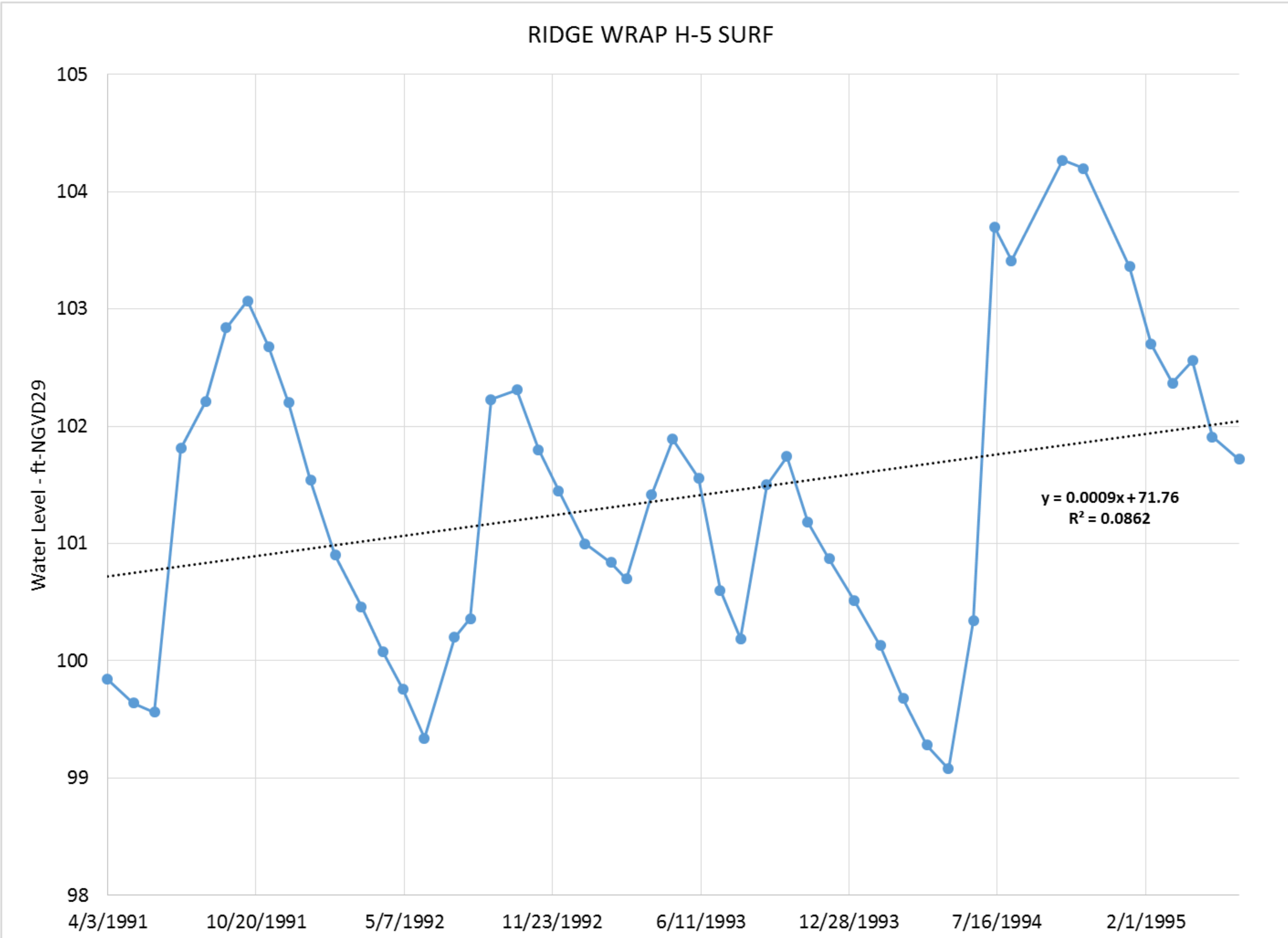
1/8/2000
10/4/2002
6/30/2005
3/26/2008
12/21/2010

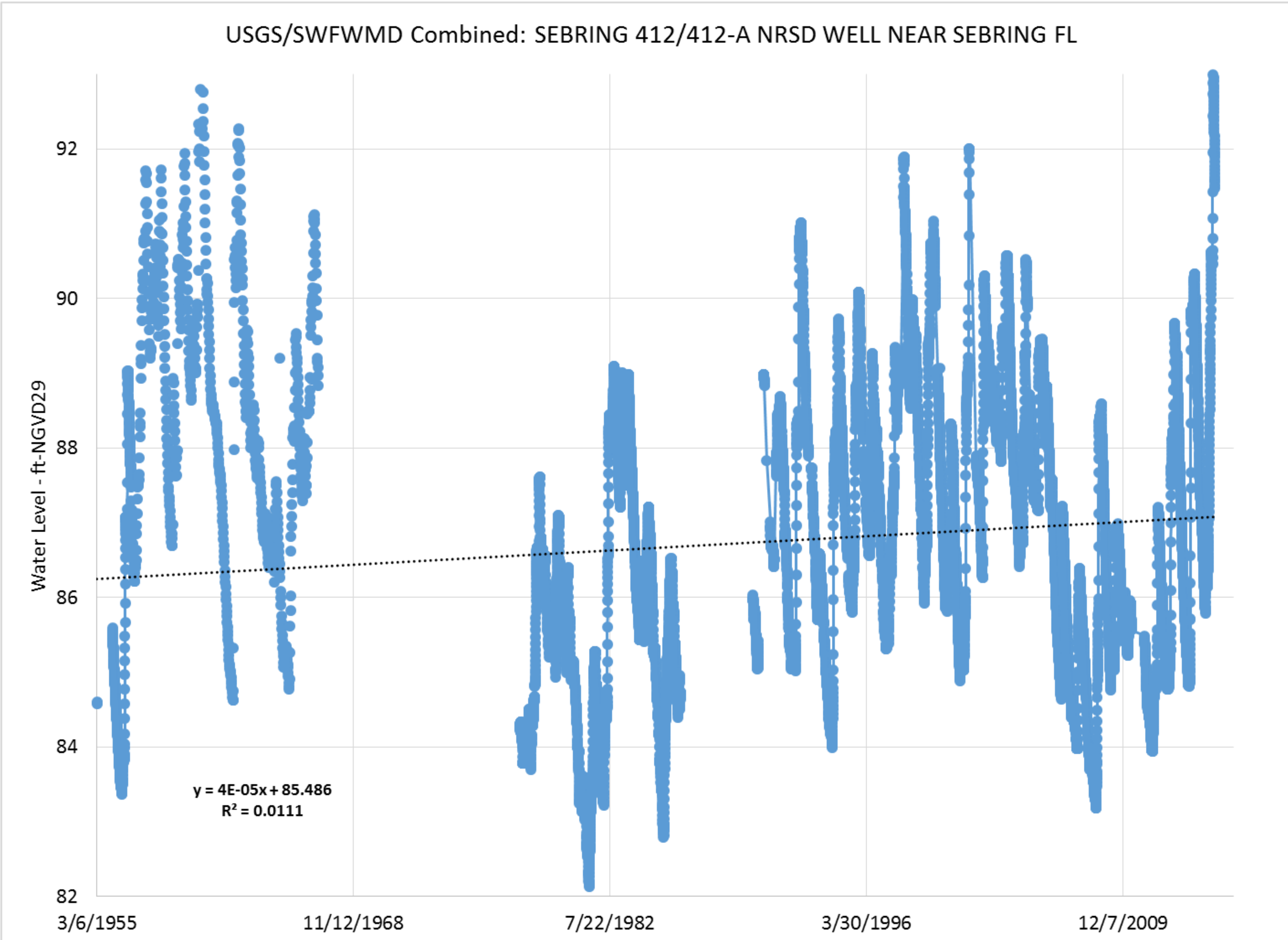

PRIM CC02 SUN N LAKE SURF AQ MONITOR
Water Level - ft-NGVD29
165
164
163
162
161
160
159
7/20/2010
2/5/2011
8/24/2011
3/11/2012
9/27/2012
4/15/2013
11/1/2013
5/20/2014
12/6/2014
6/24/2015
y = 0.0006x + 137.31
R² = 0.1177

PRIM CC02 SUN N LAKE SURF AQ MONITOR STATISTICAL OUTPUT								
Regression Statistics								
Multiple R	0.343							
R Square	0.118							
Adjusted R Square	0.117							
Standard Error	0.900							
Observations	1765							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	190.370	190.370	235.208	6.28189E-50			
Residual	1763	1426.913	0.809					
Total	1764	1617.282						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	137.305	1.613	85.114	0.000	134.141	140.469	134.141	140.469
Date	0.001	0.000	15.337	6.28E-50	0.001	0.001	0.001	0.001

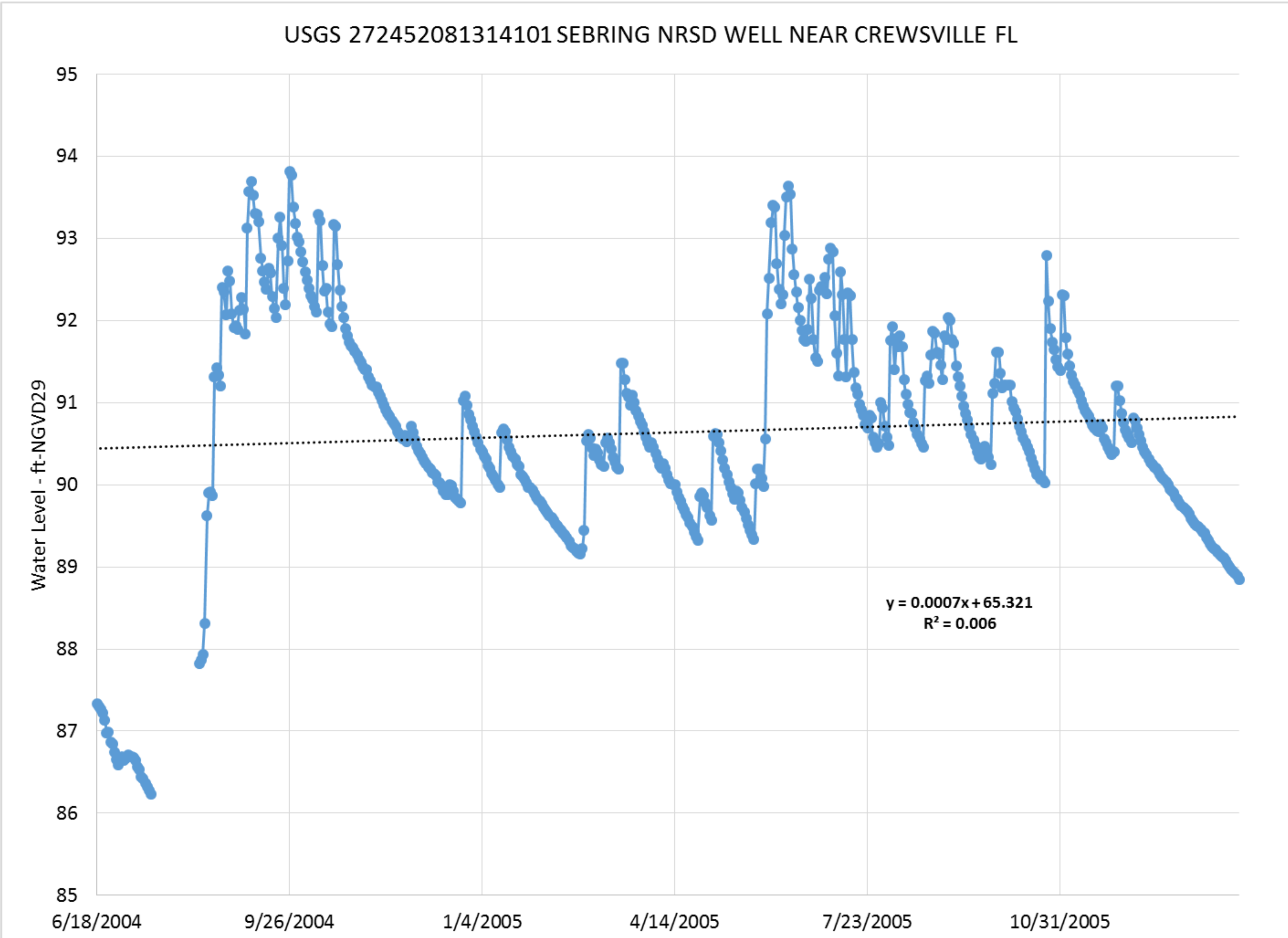

RIDGE WRAP H-4 SURF
Water Level - ft-NGVD29
134
133
132
131
130
129
128
127
126
125
4/3/1991
12/28/1993
9/23/1996
6/20/1999
3/16/2002
12/10/2004
9/6/2007
6/2/2010
2/26/2013


RIDGE WRAP H-5 SURF
Water Level - ft-NGVD29
105
104
103
102
101
100
99
98
4/3/1991
10/20/1991
5/7/1992
11/23/1992
6/11/1993
12/28/1993
7/16/1994
2/1/1995
y = 0.0009x + 71.76
R² = 0.0862

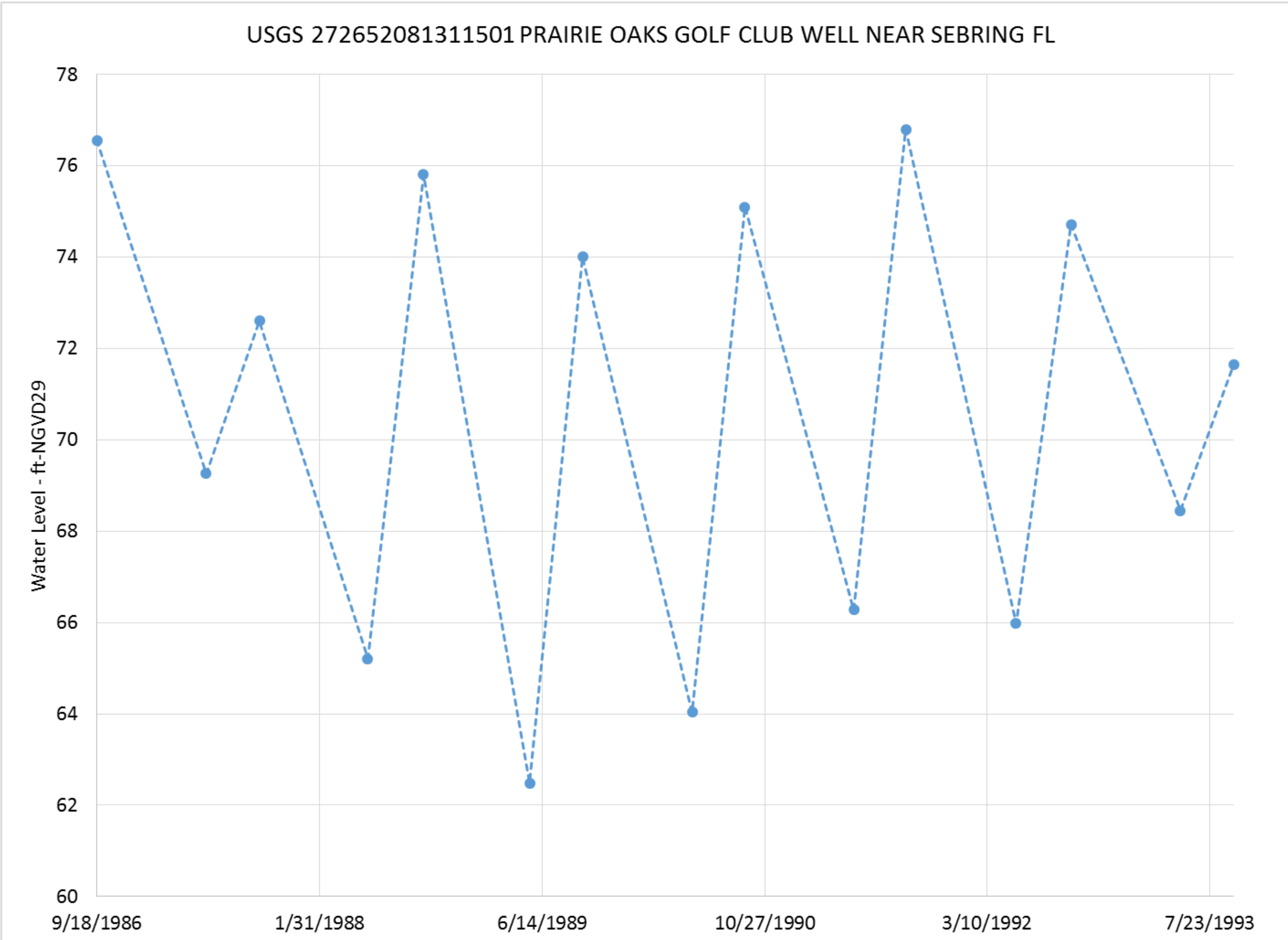
RIDGE WRAP H-5 SURF STATISTICAL OUTPUT								
Regression Statistics								
Multiple R	0.294							
R Square	0.086							
Adjusted R Square	0.067							
Standard Error	1.282							
Observations	49							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	7.295	7.295	4.435	0.041			
Residual	47	77.304	1.645					
Total	48	84.599						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	71.760	14.059	5.104	5.91E-06	43.47608	100.044	43.476	100.044
Date	0.001	0.000	2.106	0.041	3.89E-05	0.002	3.89E-05	0.002

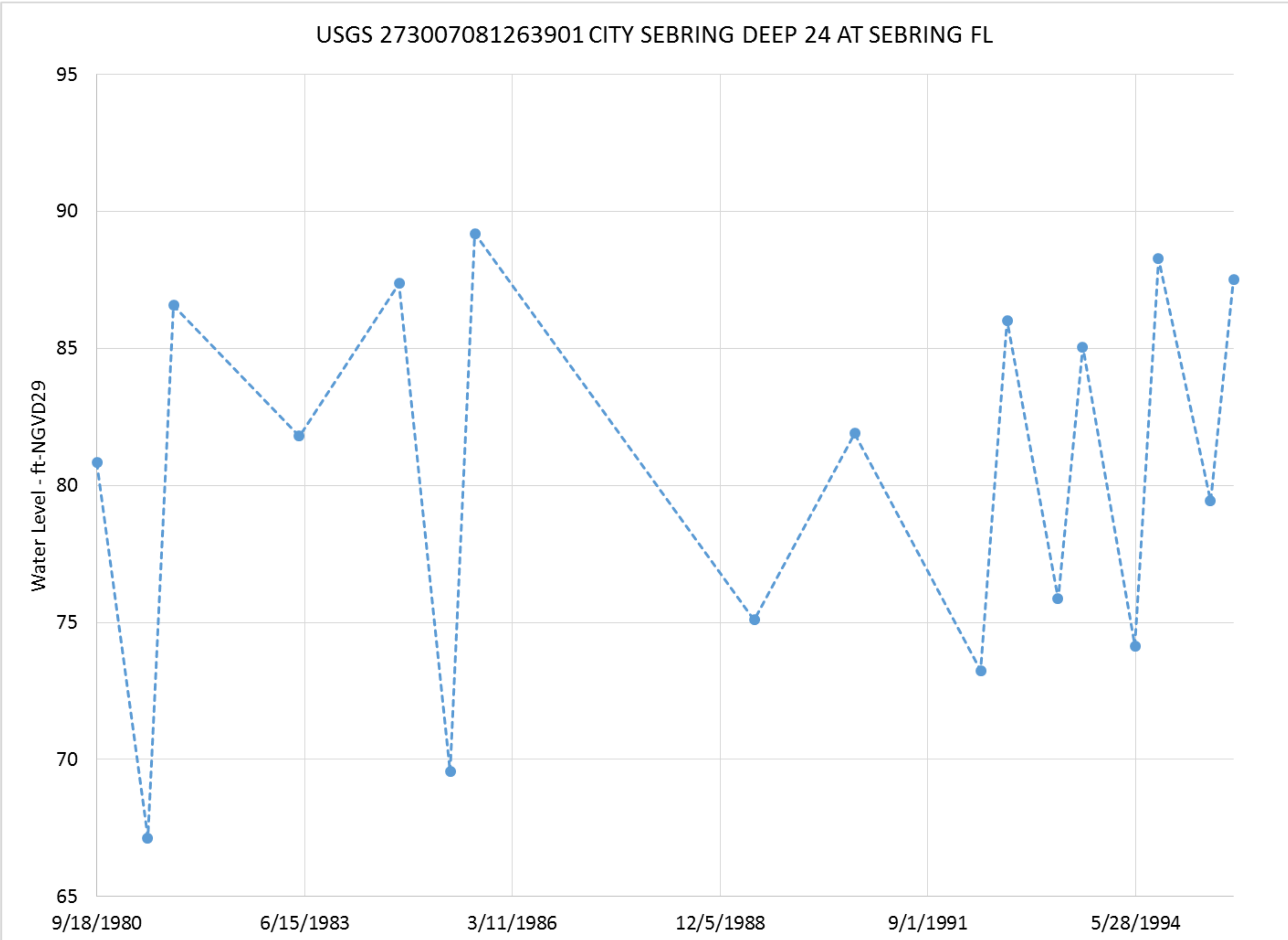

USGS/SWFWMD Combined: SEBRING 412/412-A NRSD WELL NEAR SEBRING FL
Water Level - ft-NGVD29
92
90
88
86
84
82
3/6/1955
11/12/1968
7/22/1982
3/30/1996
12/7/2009
y = 4E-05x + 85.486
R² = 0.0111

USGS/SWFWMD Combined: SEBRING 412/412-A NRSD WELL NEAR SEBRING FL STATISTICAL OUTPUT								
Regression Statistics								
Multiple R	0.153							
R Square	0.024							
Adjusted R Square	0.023							
Standard Error	1.971							
Observations	12719							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	1190.163	1190.163	306.271	8.81E-68			
Residual	12717	49418.02	3.886					
Total	12718	50608.18						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	84.954	0.111	766.323	0	84.737	85.172	84.737	85.172
Date	5.56E-05	3.18E-06	17.501	8.81E-68	4.93E-05	6.18E-05	4.93E-05	6.18E-05


USGS 272452081314101 SEBRING NRSD WELL NEAR CREWSVILLE FL
Water Level - ft-NGVD29
95
94
93
92
91
90
89
88
87
86
85
6/18/2004
9/26/2004
1/4/2005
4/14/2005
7/23/2005
10/31/2005
y = 0.0007x + 65.321
R² = 0.006

USGS 272452081314101 SEBRING NRSD WELL NEAR CREWSVILLE FL STATISTICAL OUTPUT								
Regression Statistics								
Multiple R	0.078							
R Square	0.006							
Adjusted R Square	0.004							
Standard Error	1.413							
Observations	571							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	6.899	6.899	3.457	0.063			
Residual	569	1135.447	1.996					
Total	570	1142.346						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	65.321	13.618	4.797	2.06E-06	38.574	92.068	38.574	92.068
Date	0.001	0.0004	1.859	0.063496	-3.7E-05	0.001	-3.7E-05	0.001


USGS 272652081311501 PRAIRIE OAKS GOLF CLUB WELL NEAR SEBRING FL
Water Level - ft-NGVD29
78
76
74
72
70
68
66
64
62
60
9/18/1986
1/31/1988
6/14/1989
10/27/1990
3/10/1992
7/23/1993


USGS 273007081263901 CITY SEBRING DEEP 24 AT SEBRING FL
Water Level - ft-NGVD29
95
90
85
80
75
70
65
9/18/1980
6/15/1983
3/11/1986
12/5/1988
9/1/1991
5/28/1994

Appendix B

Multiple Regression on Yearly Average Data	
SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.349
R Square	0.122
Adjusted R Square	0.054
Standard Error	1.488
Observations	29

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	7.991	3.995	1.805	0.184
Residual	26	57.538	2.213		
Total	28	65.528			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	99.301	4.333	22.920	9.046E-19	90.396	108.207	90.396	108.207
Avg. Rainfall	0.046	0.027	1.738	0.094	-0.008	0.101	-0.008	0.101
Avg. P/S Pumpage	-0.304	0.739	-0.411	0.685	-1.822	1.215	-1.822	1.215

Multiple Regression on 7-yr Moving Average Data	
SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.899
R Square	0.809
Adjusted R Square	0.791
Standard Error	0.488
Observations	24

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	21.155	10.577	44.412	2.86E-08
Residual	21	5.001	0.238		
Total	23	26.156			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	79.655	3.198	24.910	4.47E-17	73.005	86.305	73.005	86.305
7yr Mov. Avg. Rainfall	0.279	0.030	9.416	5.5E-09	0.217	0.340	0.217	0.340
7yr Moving Avg. P/S Pumpage	1.253	0.461	2.719	0.013	0.295	2.211	0.295	2.211

Multiple Regression on 5-yr Moving Average Data	
SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.801
R Square	0.641
Adjusted R Square	0.610
Standard Error	0.757
Observations	26

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	23.591	11.795	20.575	7.53E-06
Residual	23	13.185	0.573		
Total	25	36.776			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	83.337	4.246	19.629	7.27E-16	74.554	92.120	74.554	92.120
5yr Mov. Avg. Rainfall	0.233	0.037	6.347	1.78E-06	0.157	0.309	0.157	0.309
5yr Moving Avg. P/S Pumpage	0.981	0.614	1.598	0.124	-0.289	2.250	-0.289	2.250

Multiple Regression on 3-yr Moving Average Data	
SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.591
R Square	0.349
Adjusted R Square	0.297
Standard Error	1.122
Observations	28

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	16.879	8.439	6.703	0.005
Residual	25	31.475	1.259		
Total	27	48.353			

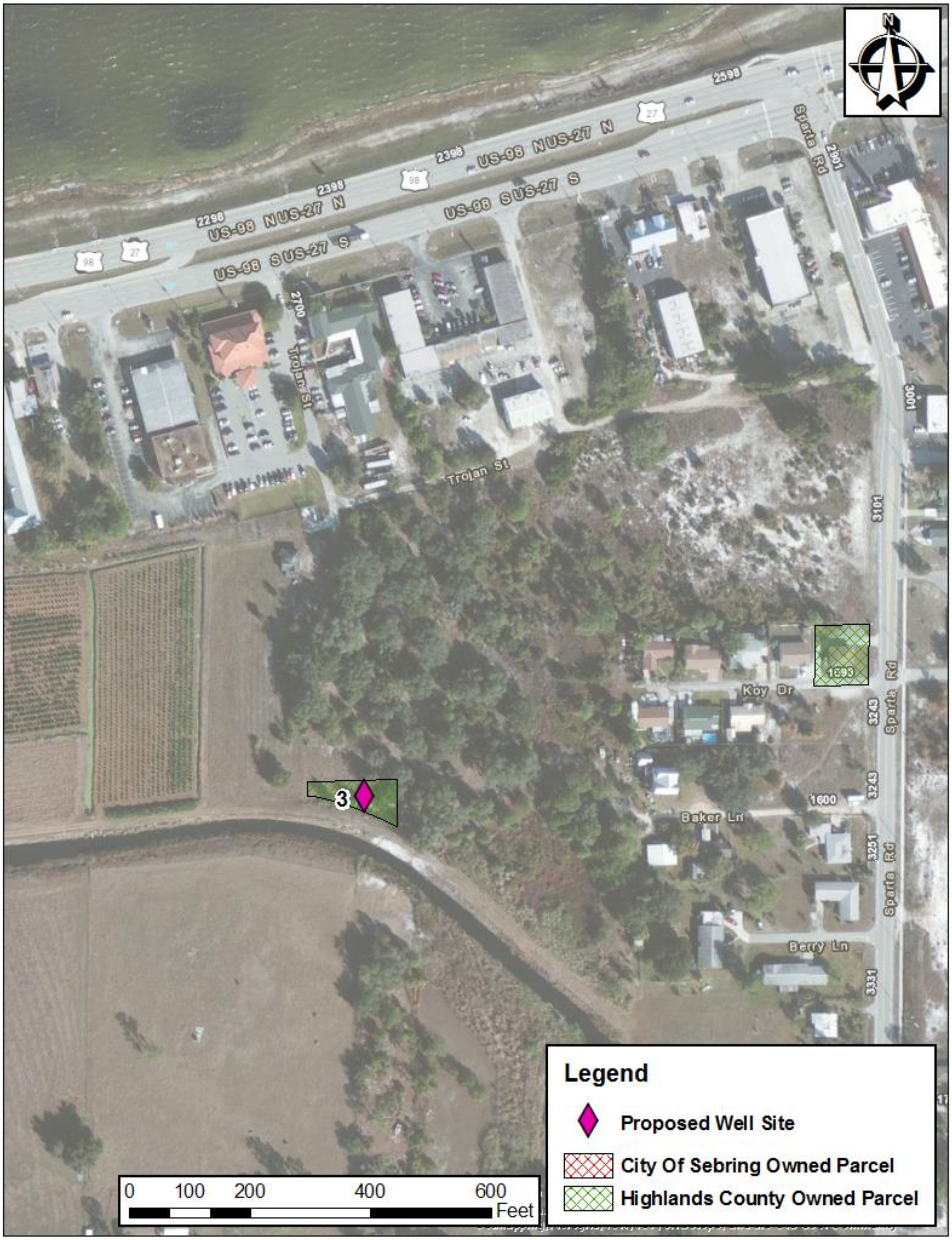
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	91.694	5.085	18.031	7.68E-16	81.221	102.168	81.221	102.168
3yr Mov. Avg. Rainfall	0.131	0.038	3.466	0.002	0.053	0.209	0.053	0.209
3yr Moving Avg. P/S Pumpage	0.347	0.763	0.455	0.653	-1.225	1.919	-1.225	1.919

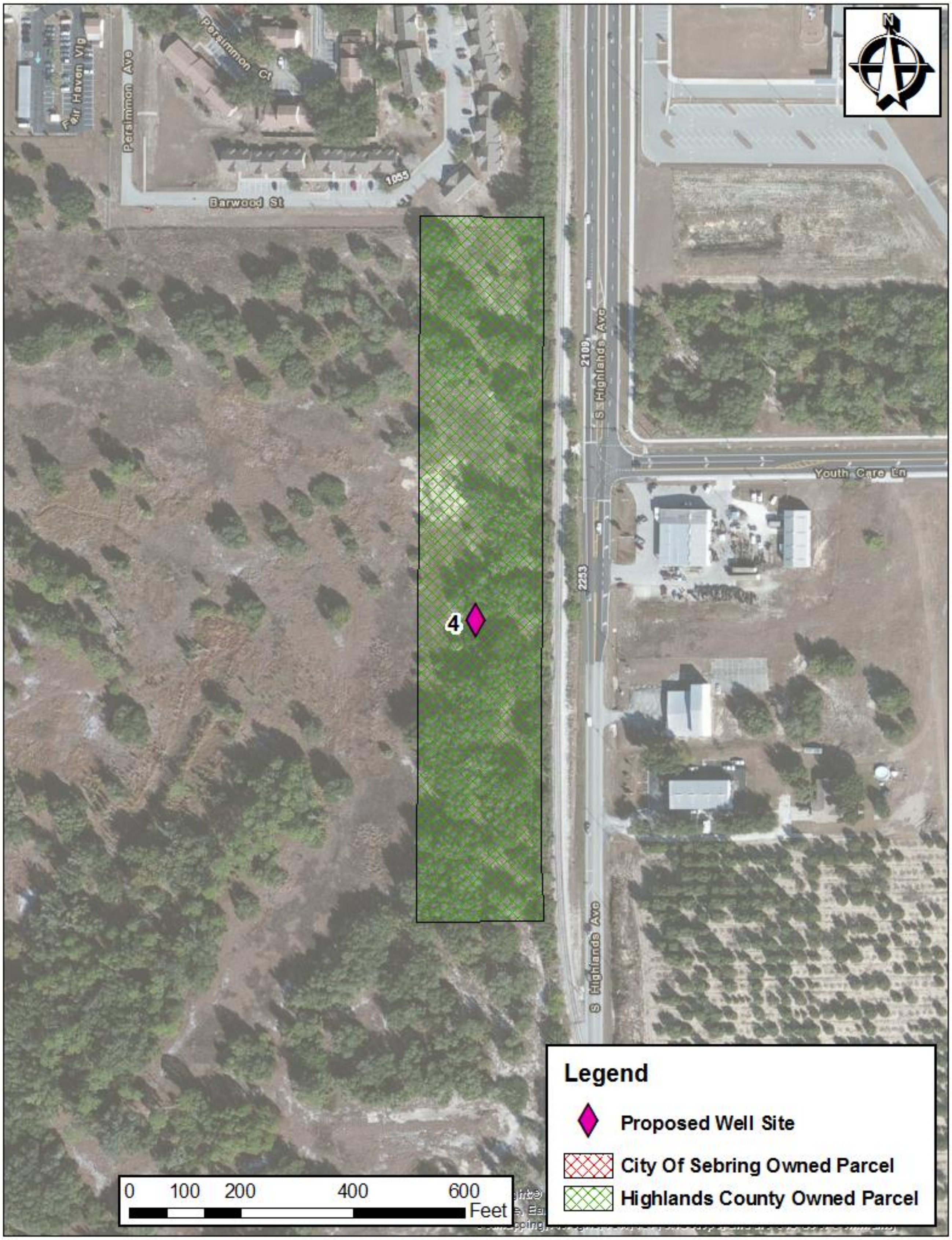
Appendix C

Proposed Well Site	STRAP	Parcel Number	Neighborhood	Parcel Owner
1	29342907009300011S	S29342907009300011	SEBRING SIDE STREET REDEV.	HIGHLANDS COUNTY BOARD OF CNTY COMM
2	28342302000M0006AS	S23342802000M0006A	LAKE JACKSON N.W.	HIGHLANDS COUNTY BOARD OF CNTY COMM
3	29350611000000080C	C06352911000000080	SPARTA RD NORTH END	HIGHLANDS COUNTY BOARD OF CNTY COMM
4	29343209000300070S	S32342909000300070	SEBRING SE LAKEVIEW DR AREA	HIGHLANDS COUNTY BOARD OF CNTY COMM
5	28342302000B00051S	S23342802000B00051	US 27 FAIRMOUNT DR TO SPARTA RD	CITY OF SEBRING
6	283423A0004500000C	C233428A0004500000	RURAL TRACTS IN 34/28	HIGHLANDS COUNTY BOARD OF CNTY COMM
7	29341906025200000S	S19342906025200000	LAKE JACKSON HIDDEN BEACH AREA	CITY OF SEBRING

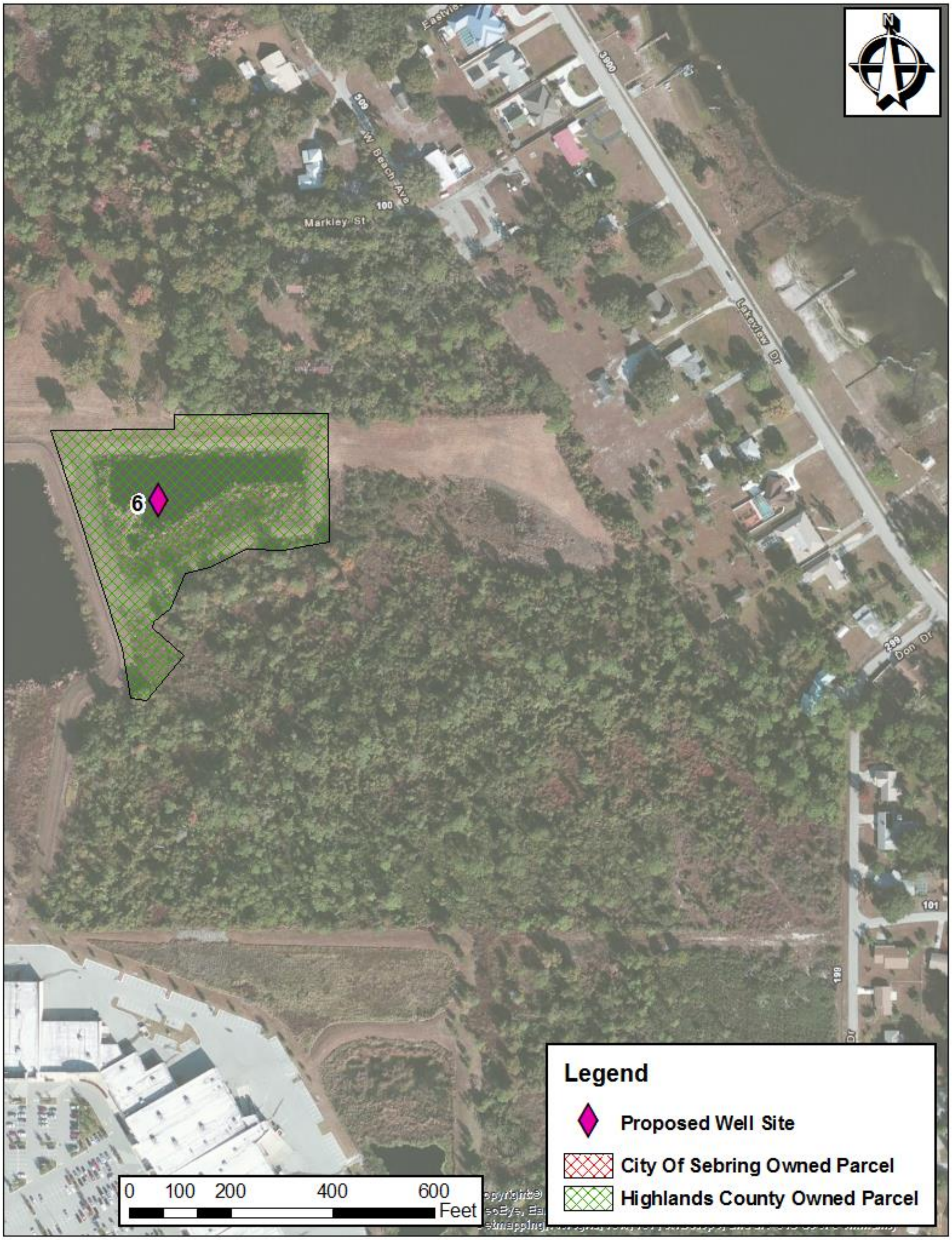

Commerce Ave
Pomegranate Ave
N Franklin St
W Center Ave
Lakeview Dr
S Ridgewood Dr
1
Legend
Proposed Well Site
City Of Sebring Owned Parcel
Highlands County Owned Parcel
0 100 200 400 600
Feet

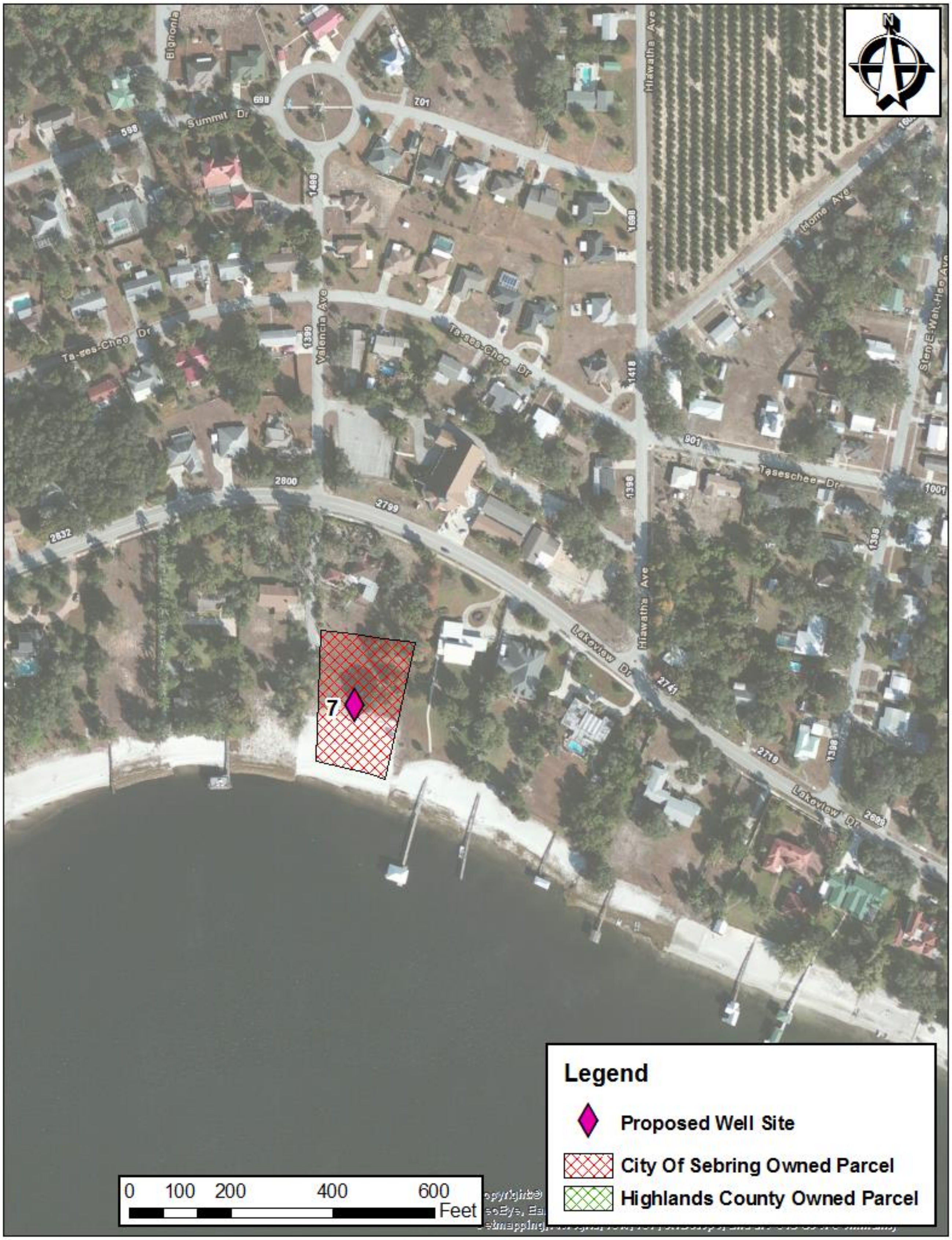

Sunset Dr
Eastview Rd
West Blvd
Sebring Pky
Sandra Blvd
Lakeview Dr
1749
199
3710
3700
3610
3512
3509
1899
1849
1803
1727
1700
1800
1722
1631
3500
3520
3532
2017
2
Legend
Proposed Well Site
City Of Sebring Owned Parcel
Highlands County Owned Parcel
0
100
200
400
600
Feet


US-98 N US-27 N
US-98 S US-27 S
Trojan St
Sparta Rd
Koy Dr
Baker Ln
Berry Ln
3
Legend
Proposed Well Site
City Of Sebring Owned Parcel
Highlands County Owned Parcel
0 100 200 400 600
Feet


Persimmon Ct
Fair Haven Vlg
Persimmon Ave
Barwood St
1055
2109
S Highlands Ave
Youth Care Ln
2233
S Highlands Ave
4
Legend
Proposed Well Site
City Of Sebring Owned Parcel
Highlands County Owned Parcel
0 100 200 400 600
Feet

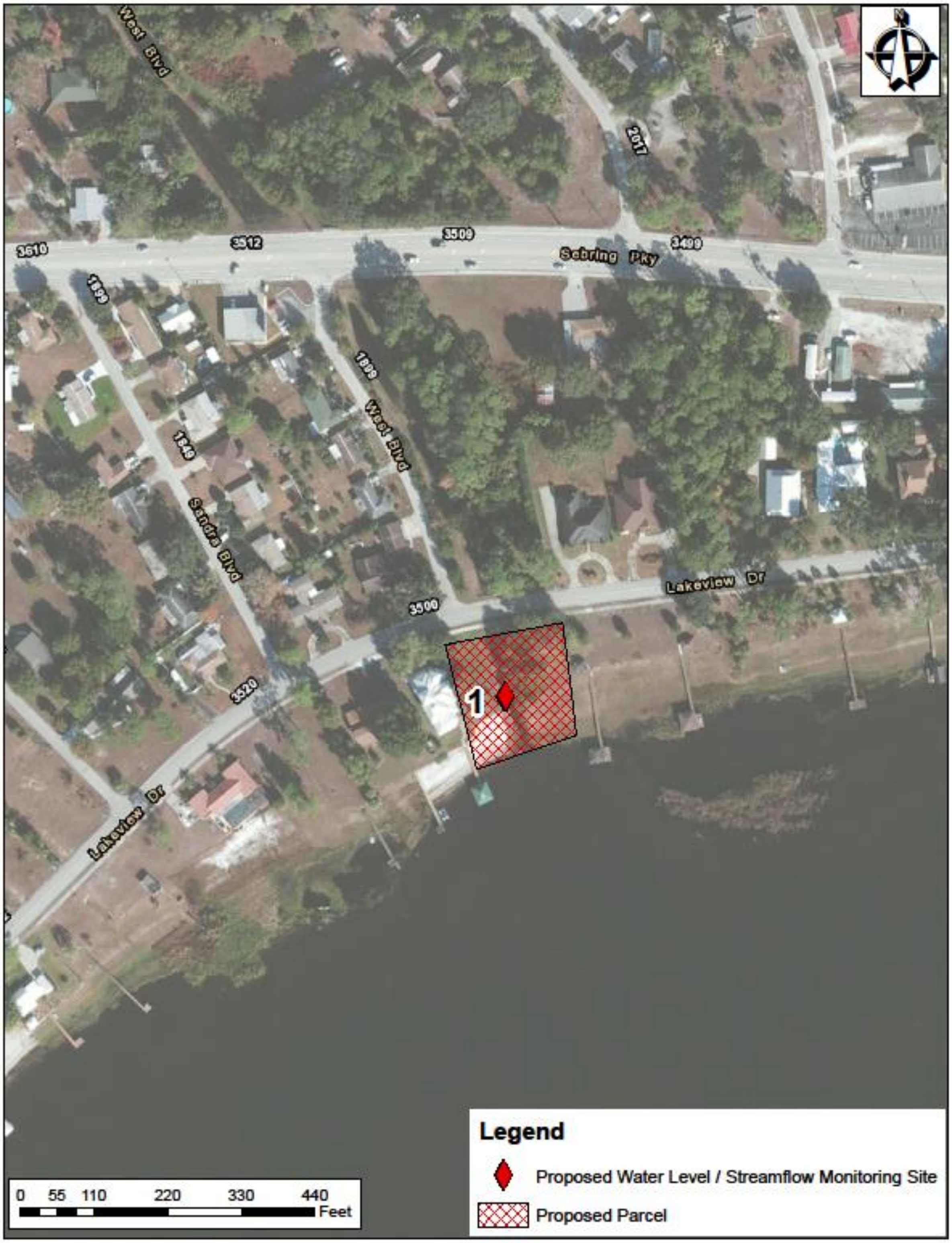

US-98 N US-27 N
US-98 S US-27 S
US-27 N US-98 N
US-27 S US-98 S
5
Lloyd Dr
Horizon Vw
Nanette Pl
Garner Ln
Royal Palm Dr
Starlight Ln
Curtis Pl
Hammock Rd
Ashley Oaks Cir
Ashley Oaks Ln
Legend
Proposed Well Site
City Of Sebring Owned Parcel
Highlands County Owned Parcel
0 100 200 400 600
Feet


W Beach Ave
Markley St
Lakeview Dr
Don Dr
6
Legend
Proposed Well Site
City Of Sebring Owned Parcel
Highlands County Owned Parcel
0 100 200 400 600
Feet


Legend
Proposed Well Site
City Of Sebring Owned Parcel
Highlands County Owned Parcel
0 100 200 400 600 Feet
7
Lakeview Dr
Hiawatha Ave
Valencia Ave
Ta-ses-Chee Dr
Summit Dr
Home Ave

Appendix D

Proposed Automated Water Level/Streamflow Monitoring Site	Parcel Number	Latitude	Longitude	Parcel Owner
1	N/A (Drainage Easement)	27° 30’ 48.26” N	81° 28’ 44.63” W	N/A
2	C063529A0000220000	27° 28’ 06.81” N	81° 27’ 30.74” W	Jack Morton & Alexander Debay
3	C05352906000000610	27° 27’ 59.48” N	81° 26’ 45.22” W	Francis I Cooperative Assn Inc.


West Blvd
2017
3610
3512
3509
Sebring Pky
3499
1899
1899
West Blvd
1849
Sandra Blvd
Lakeview Dr
3500
3520
Lakeview Dr
1
Legend
Proposed Water Level / Streamflow Monitoring Site
Proposed Parcel
0 55 110 220 330 440
Feet


US-98 N US-27 N
US-98 S US-27 S
27
US-98 N US-27 N
US-98 S US-27 S
Tubbs Rd
Trojan Ave
2
Tubbs Rd
Killarn
Kerry Dr
Killarney Dr
Shamrock Dr
Erin Rd
Legend
Proposed Water Level / Streamflow Monitoring Site
Proposed Parcel
0 95 190 380 570 760
Feet


Clara St
Kent Dr
Eva St
Sebring
US-27
Renaud St
Tanglewood St
Koy Dr
Sebring Dr
Cherokee St
Mimi St
Sunrise Blvd
Sparta Cir
Tiger Tail Rd
Francis St
Pauline St
Sunshine Ln
Pepper Dr
Bonds Ave
Von Maxcy Rd
Addison St
3
Jason Creek Cir
Leeway Ct
Schlosser Rd
Stiles Ln
Legend
Proposed Water Level / Streamflow Monitoring Site
Proposed Parcel
0 100 200 400 600 800
Feet