Appendix B

HSPF Model Development Report

Contract Number 27847:
Hydrology, Hydraulic, Hydrodynamics, and Groundwater Quantity and Water Quality

Work Order #4 – Hydrologic Modeling Services, Lake Weir Minimum Flows and Levels Evaluation

St. Johns River Water Management District
4049 Reid Street
Palatka, Florida 32177

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Dynamic Solutions LLC

6421 Deane Hill Drive Ste 1
Knoxville, Tennessee 37919

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

The purpose of this report is to provide St. Johns River Water Management District (SJRWMD) a summary of the Hydrological Simulation Program FORTRAN (HSPF) model setup for Lake Weir. The developed watershed model will be calibrated and then applied to evaluate the Minimum Flows and Levels (MFLs) of Lake Weir.

1. MODEL DOMAIN

The final basin boundary for Lake Weir is shown in Figure 1, and excludes the Bowers Lake, Smith Lake, and Tiger Lake sub-basins. The Morriston sub-basin is still included within the basin boundary, but it does not contribute its surface runoff and interflow to Lake Weir. A small percentage of its base flow, which will be determined during model calibration, will be routed into Lake Weir.

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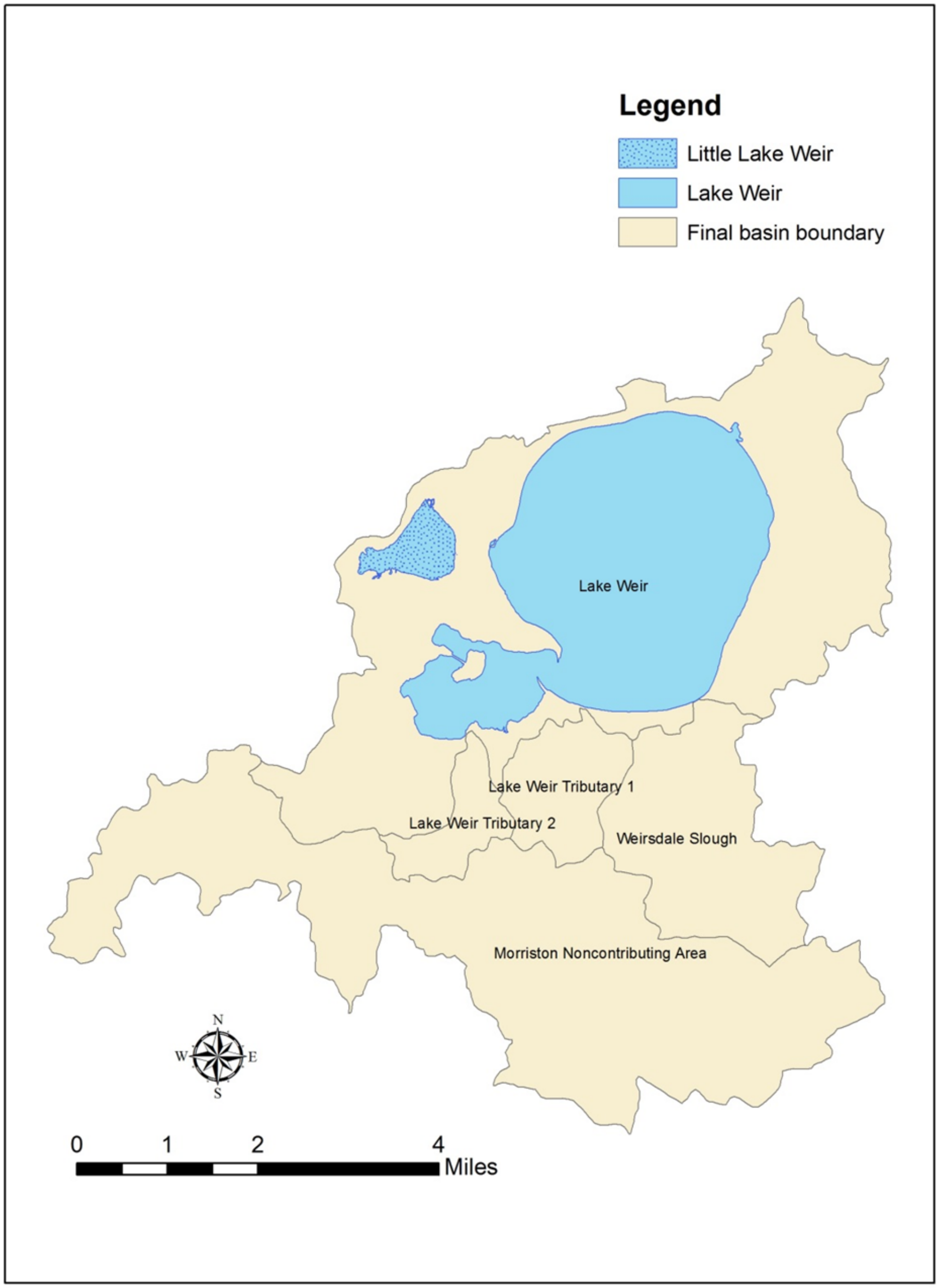

Figure 1 – Lake Weir HSPF Model Domain

2. CALIBRATION PERIOD

To develop a robust HSPF model, the selected model calibration period needs to cover dry, wet and average hydrologic years so that the calibrated model is capable of simulating different hydrologic conditions. The selected model calibration period for the Lake Weir HSPF model is from year 2003 to year 2014, which covers these three different hydrologic conditions. Year 2003 will be used as the model spin-up year. The model time step is hourly.

3. METEOROLOGICAL DATA

The long term (1948-2015) hourly rainfall and evapotranspiration (ET) were obtained from the SJRWMD. The provided rainfall and ET data will be applied to all the sub-basins and Lake Weir.

4. LANDUSE AGGREGATION

In the Lake Weir basin, there are a total of 67 landuses based on the SJRWMD 2009 landuse data, as shown in Table 1. These 67 SJRWMD landuses are re-classified into 13 categories for HSPF application. A summary of landuse area distribution in HSPF model is given in Table 2. Excluding water, forest is the largest land use, covering 17.4% of the total area. Pasture is the next largest landuse covering 12.8% of the total area. The spatial distribution of the HSPF landuses is given in Figure 2.

For the Lake Weir HSPF model, it is assumed that the directly connected impervious area only exist in four urban landuse categories (Low Density Residential, Medium Density Residential, High Density Residential, and Commercial/Industrial). The percentage imperviousness of these urban landuses are 5%, 15%, 35%, and 50% for Low Density Residential, Medium Density Residential, High Density Residential, and Commercial/Industrial, respectively, following the values used in the HSPF model for Lake Apopka and Upper Ocklawaha River (Huang and Smith, 2015).

Table 1 – Summary of Landuse Aggregation

HSPF Landuse Code	HSPF Landuse	SJRWMD Landuse Code	SJRWMD Landuse
1	Low Density Residential	1100	Residential, Low Density - Less than 2 dwelling units per acre
1	Low Density Residential	1180	Residential, Rural - Less than or equal to 0.5 dwelling units per acre (one unit on 2 or more acres)
1	Low Density Residential	1190	Low Density Under Construction
2	Medium Density Residential	1200	Residential, Medium Density - Two to five dwelling units per acre
2	Medium Density Residential	1290	Medium Density Under Construction
3	High Density Residential	1300	Residential, High Density
4	Commercial/Industrial	1400	Commercial and Services
4	Commercial/Industrial	1490	Commercial and Services Under Construction
4	Commercial/Industrial	1510	Food Processing
4	Commercial/Industrial	1550	Other Light Industrial
4	Commercial/Industrial	1700	Institutional
4	Commercial/Industrial	1840	Marinas and Fish Camps
4	Commercial/Industrial	8110	Airports
4	Commercial/Industrial	8140	Roads and Highways
4	Commercial/Industrial	8310	Electrical Power Facilities
4	Commercial/Industrial	8330	Water Supply Plants
4	Commercial/Industrial	8340	Sewage Treatment Plants
5	Mining	1620	Sand and Gravel Pits
5	Mining	7420	Borrow Areas
6	Open	1480	Cemeteries
6	Open	1800	Recreational
6	Open	1850	Parks and Zoos
6	Open	1860	Community Recreational Facilities
6	Open	1890	Other Recreational
6	Open	7400	Disturbed Land
6	Open	7410	Rural Land in Transition without Positive Indicators of Intended Activity
6	Open	7430	Spoil Areas
6	Open	8200	Communications
6	Open	8320	Electrical Power Transmission Lines
7	Pasture	2110	Improved Pastures
7	Pasture	2130	Woodland Pastures
7	Pasture	2510	Horse Farms
8	General Agriculture	1820	Golf Course
8	General Agriculture	2140	Row Crops
8	General Agriculture	2150	Field Crops
8	General Agriculture	2400	Nurseries and Vineyards
8	General Agriculture	2430	Ornamentals

8	General Agriculture	2500	Specialty Farms
9	Groves	2200	Tree Crops
9	Groves	2210	Citrus Groves
9	Groves	2240	Abandoned Tree Crops
10	Range/Shrub	3100	Herbaceous Upland Nonforested
10	Range/Shrub	3200	Shrub and Brushland
10	Range/Shrub	3300	Mixed Upland Nonforested
11	Forest	4110	Pine Flatwoods
11	Forest	4120	Longleaf Pine - Xeric Oak
11	Forest	4200	Upland Hardwood Forest
11	Forest	4210	Xeric Oak
11	Forest	4340	Upland Mixed Coniferous/Hardwood
11	Forest	4400	Tree Plantations
11	Forest	4410	Coniferous Pine
11	Forest	4430	Forest Regeneration
12	Water	5100	Streams and Waterways
12	Water	5200	Lakes
12	Water	5250	Marshy Lakes
12	Water	5300	Reservoirs
12	Water	8360	Other Treatment Ponds
13	Wetland	6110	Bay Swamps
13	Wetland	6170	Mixed Wetland Hardwoods
13	Wetland	6210	Cypress
13	Wetland	6250	Hydric Pine Flatwoods
13	Wetland	6300	Wetland Forested Mixed
13	Wetland	6410	Freshwater Marshes
13	Wetland	6430	Wet Prairies
13	Wetland	6440	Emergent Aquatic Vegetation
13	Wetland	6460	Mixed Scrub-Shrub Wetland
13	Wetland	8370	Surface Water Collection Basins

Table 2 – Summary of Landuse Distribution of HSPF Model

HSPF Landuse	HSPF Landuse Code	Area (acre)	Percentage
Low Density Residential	1	2,219	8.3%
Medium Density Residential	2	1,571	5.9%
High Density Residential	3	3,187	11.9%
Commercial/Industrial	4	1,146	4.3%
Mining	5	3	0.0%
Open	6	148	0.6%
Pasture	7	3,437	12.8%
General Agriculture	8	1,692	6.3%
Groves	9	852	3.2%
Range/Shrub	10	491	1.8%
Forest	11	4,675	17.4%
Water	12	6,410	23.9%
Wetland	13	1,018	3.8%
Total		26,848	100.0%

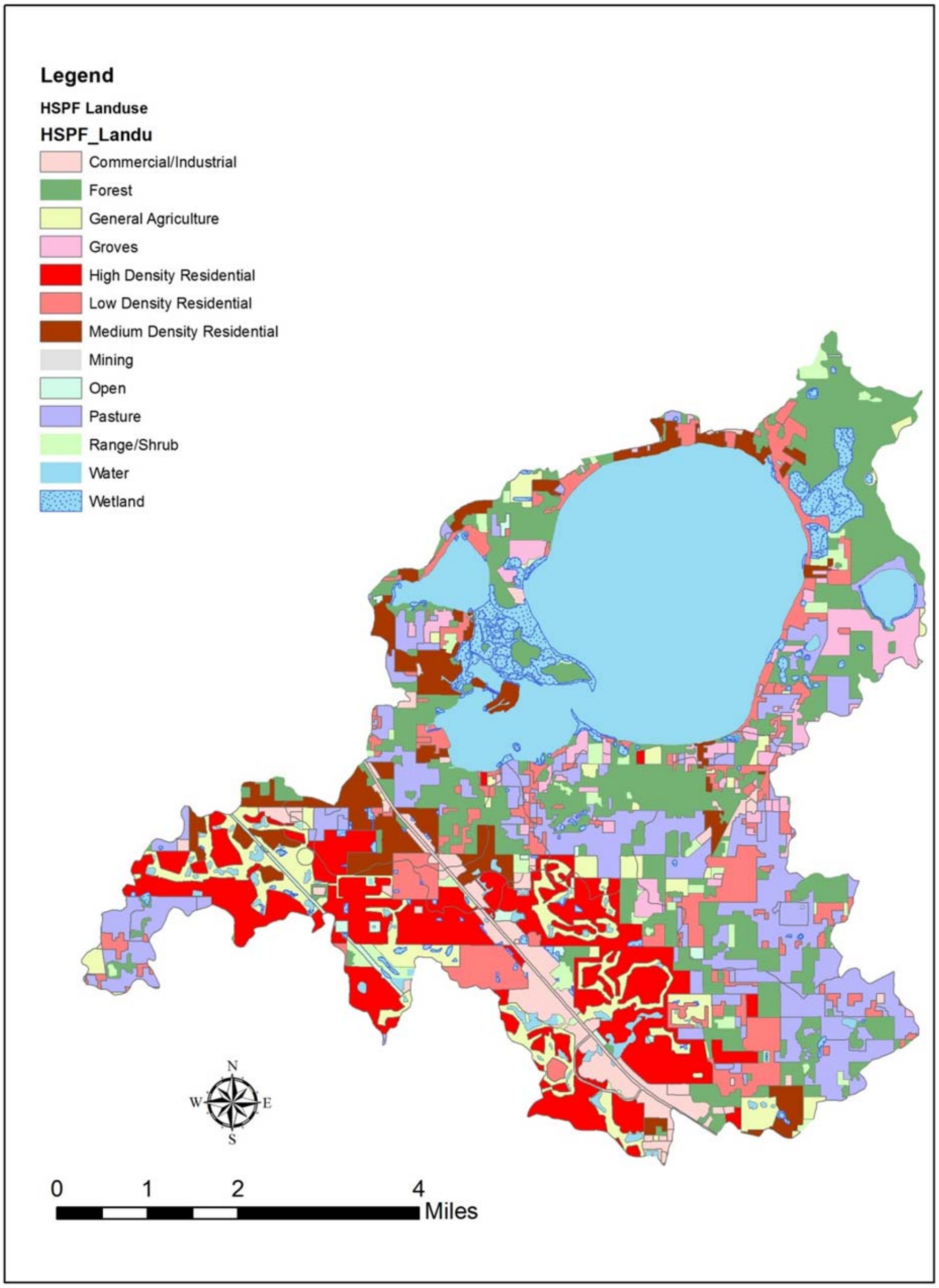

Figure 2 – Spatial Distribution of Landuses in the Lake Weir Basin

5. Sub-basin Slope Calculation

The average slope for each sub-basin is calculated based on the 10-m DEM data provided by SJRWMD using the Spatial Analyst Tools of ArcGIS. The calculated average slope for each sub-basin is given in Table 3. For HSPF model development, it is assumed that all landuses in each sub-basin, as shown in Figure 1, have same slope.

Table 3 – Summary of Average Slope for Each Sub-basin

Sub-basin ID	Sub-basin Name	Slope
1	Lake Weir	0.016
2	Lake Weir Tributary 1	0.033
3	Lake Weir Tributary 2	0.030
4	Weirsdale Slough	0.035
5	Morriston Noncontributing Area	0.026

6. Soil Distribution

The distribution of hydrological soil group (HSG) information is given in Table 4. The area percentage of the HSG is shown in Figure 3. HSG of A is the major soil in Lake Weir basin, covering 92% of the total area excluding water. HSG of A/D covers approximately 6% of the total area excluding water, and the majority of HSG A/D is located in wetland, as shown in Figure 4.

Table 4 – Summary of the Hydrological Soil Group Information (acre)

Sub-basin	A	A/D	B	B/D	C	C/D	D
Lake Weir	6,434.9	860.4	54.4	126.1		4.2	
Lake Weir Tributary 1	972.4	58.5					
Lake Weir Tributary 2	628.7		2.4				
Weirsdale Slough	2,581.5	13.0	66.0				
Morriston Noncontributing Area	8,477.8	116.8	52.8		3.2	144.2	1.2

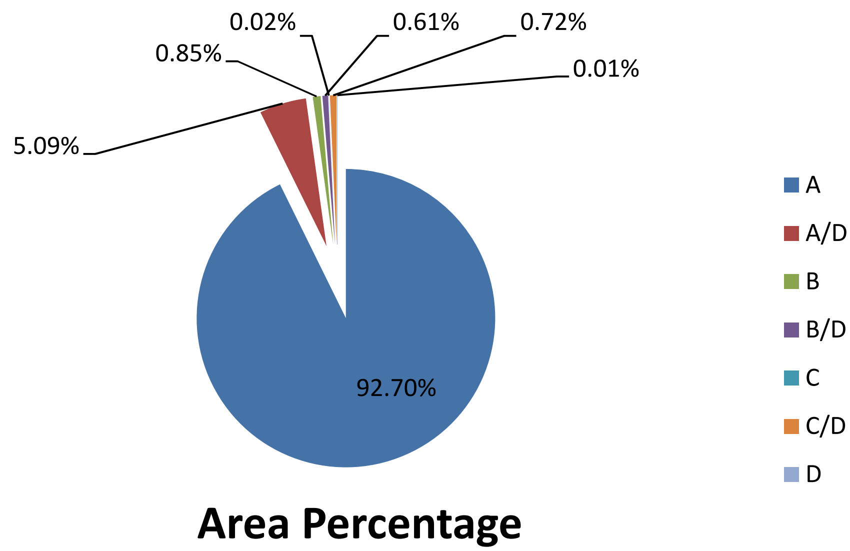

Figure 3 – Area Percentage of the Hydrological Soil Group

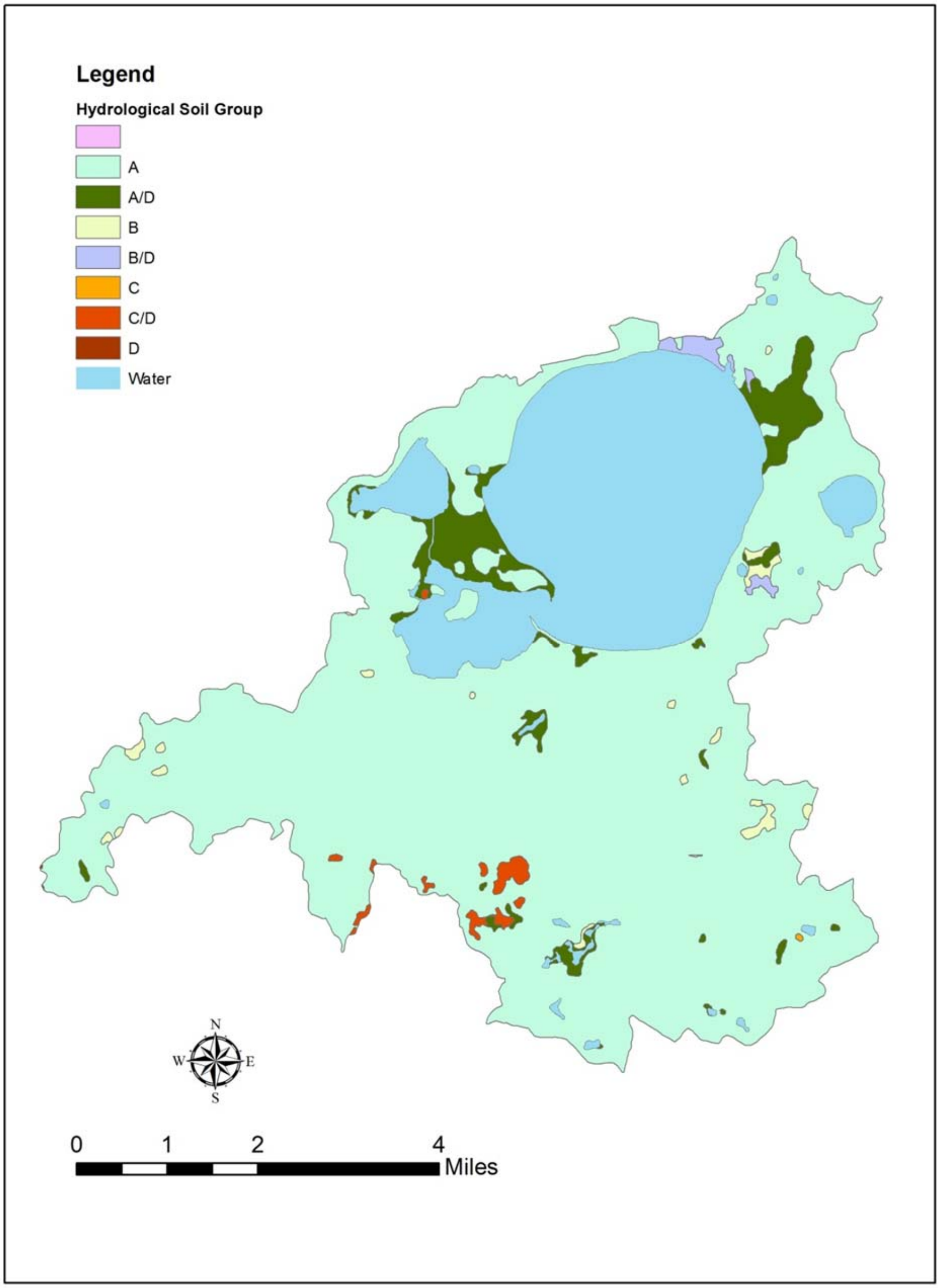

Figure 4 – Spatial Distribution of Hydrological Soil Group at Lake Weir

7. Hydrological Response Unit (HRU) Determination

After comprehensive consideration of the sub-basin delineation, meteorological data, landsue data, and soil distribution, it is determined that there are a total of 85 HRUs (13 landuse categories and 4 impervious landuses for each sub-basin).

8. Calculation of Seepage Flow

The lake can gain/lose water from/to the local groundwater aquifer depending on the head gradient between the lake stage and the local groundwater level. There might be water exchange between both Surficial Aquifer and Upper Floridan Aquifer and Lake Weir because Lake Weir is located in a transition zone between unconfined UFA on the west to semi-confined/confined systems in the Ocklawaha River valley to the east.

The Tiger Den well (Well ID: 35745428) is the closest well to Lake Weir as shown in Figure 5, which has surficial aquifer stage data; however, the data are only available from June 2, 2016, as shown in Table 5. The second closest surficial aquifer well to Lake Weir is the Blue House well at Starkes Ferry (Well ID: 18403750) as shown in Figure 5. The Blue House well at Starkes Ferry is located at more than 5 miles east of Lake Weir, which might be too far to represent the local groundwater table at Lake Weir.

The Lake Weir Middle School well at Lady Lake (Well ID: 15912734), is located near Lake Weir and has daily Upper Floridan Aquifer stage data since September of 2001 (Figure 5 and Table 5), which covers the entire proposed calibration period.

After discussion with -the SJRWMD staff, it was decided that the complex water exchange between Lake Weir and Surficial and Upper Floridan Aquifers will be simplified with a water exchange relationship between Upper Floridan Aquifer and Lake Weir.

The seepage flow between the lake and the Upper Floridan aquifer was calculated based on Darcy's law (Robinson, 2003), as shown in Equation (1).

$$\mathrm{Q} = \mathrm{k}\frac{\Delta \mathrm{h}}{\mathrm{L}}A \qquad \text{Equation (1)}$$

Where: Q is the seepage flow; k is the coefficient of permeability of hydraulic conductivity; $\Delta\mathrm{h}$ is the difference in elevation between lake and potentiometric surface; L is the length of the material through which water seeps from lake to aquifer; and A is the cross-section area of material through which water seeps from lake to the aquifer.

It is noted that the seepage flow Q can be either positive (i.e., lake loses water to the aquifer) or negative (i.e., lake gains water from the aquifer) depending on the head gradient. In the case of Lake Weir, the lake loses water to the Upper Floridan Aquifer as the lake stage is consistently higher than the Upper Floridan Aquifer stage.

if L and A are assumed to be constant, then Equation (1) can be re-written as follows.

$$Q = K\Delta h \qquad \text{Equation (2)}$$

Where: K is a constant that is a function of the local geology.

The local monitored well stage data is written into the watershed data management (WDM) file. The calculation of seepage flow is achieved in the Special Action block. At each time step, the difference between the model-calculated lake stage and well stage called from the WDM file is calculated with the Special Action. The volume of lake will then be updated by subtracting the seepage flow with Special Action block. The value K will be determined during the later calibration process.

Table 5 - Summary of Well Stage Data near Lake Weir

Well_ID	Location	Aquifer type	Data availability
15912734	Lake Weir Middle School at Lady Lake (WL) FA	Upper Floridan Aquifer	Daily since September of 2001
35745428	Tiger Den near CR464	Surficial Aquifer	Hourly since June 2, 2016
18403750	Blue House at Starkes Ferry (WL) SF	Surficial Aquifer	2003 – 2016; monthly data before 2005 and daily after 2005
18403749	Blue House at Starkes Ferry (WL) FA	Upper Floridan Aquifer	1936 – 2016; monthly data or less frequent before 2005 and daily after 2005

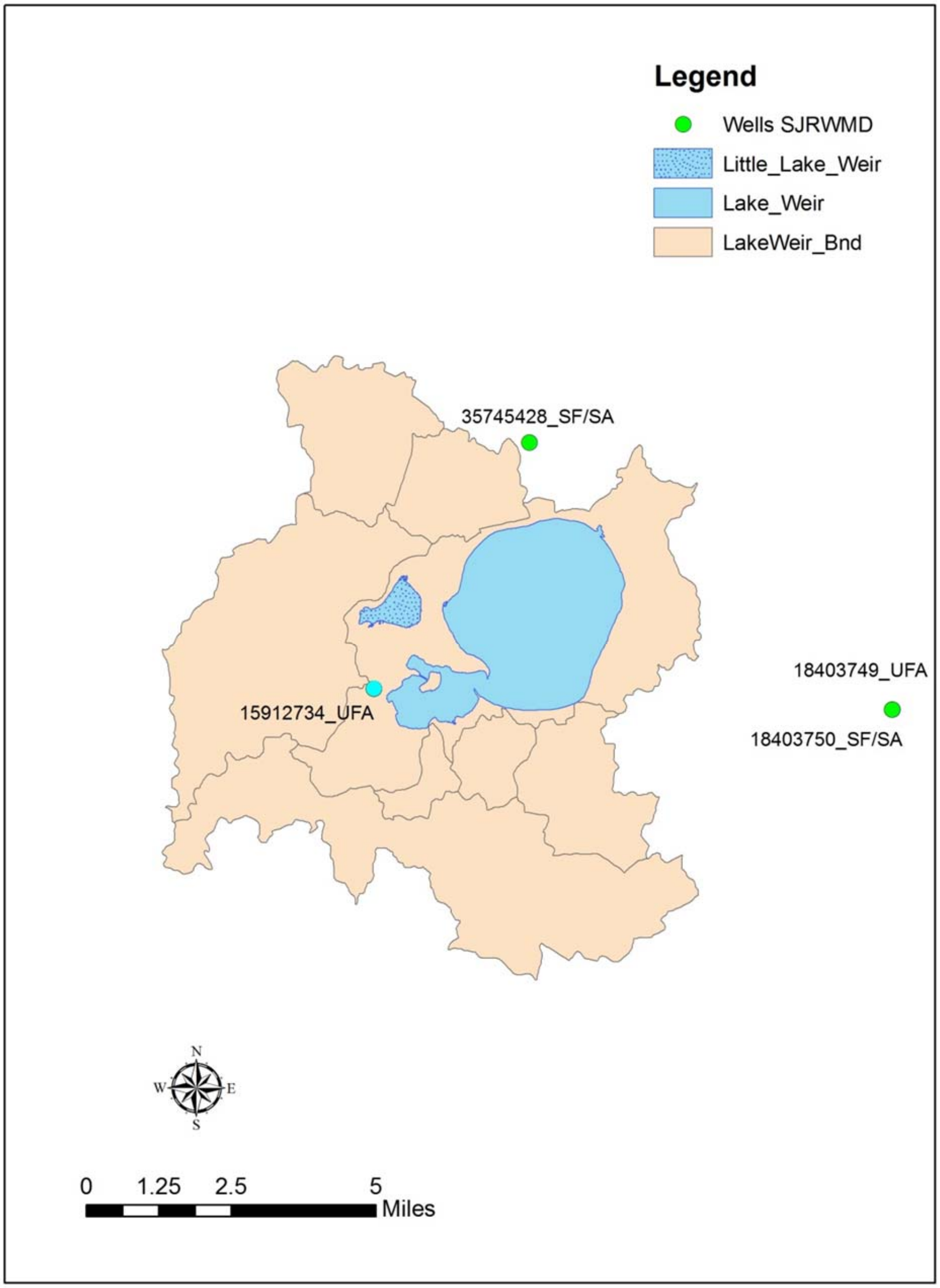

Figure 5 - Locations of SJRWMD Monitored Wells

9. RIPARIAN WETLAND SIMULATION

The riparian wetland area fluctuates with the rise and fall of the lake stage. With the rise of the lake stage, the lake surface area will increase and the riparian wetland area will decrease and vice versa. The shrinking and expansion of the riparian wetland area is simulated using the Special Action developed by the District.

The 1-foot contour line for Marion County (NGVD 29) was obtained from the SJRWMD website. The 1-foot contour data were adjusted by 1-foot from NGVD29 to NAVD88. The highest monitored stage at Lake Weir since 1943 was 58.5 feet (NAVD 88) in 1959. The contour line of 59-foot (NAVD 88) at Lake Weir was extracted and overlapped with the land use as shown in Figure 6. Clearly, almost 100% of the landuse submerged under the highest lake stage of 59-foot is wetland, which is already included in model simulation by Special Action.

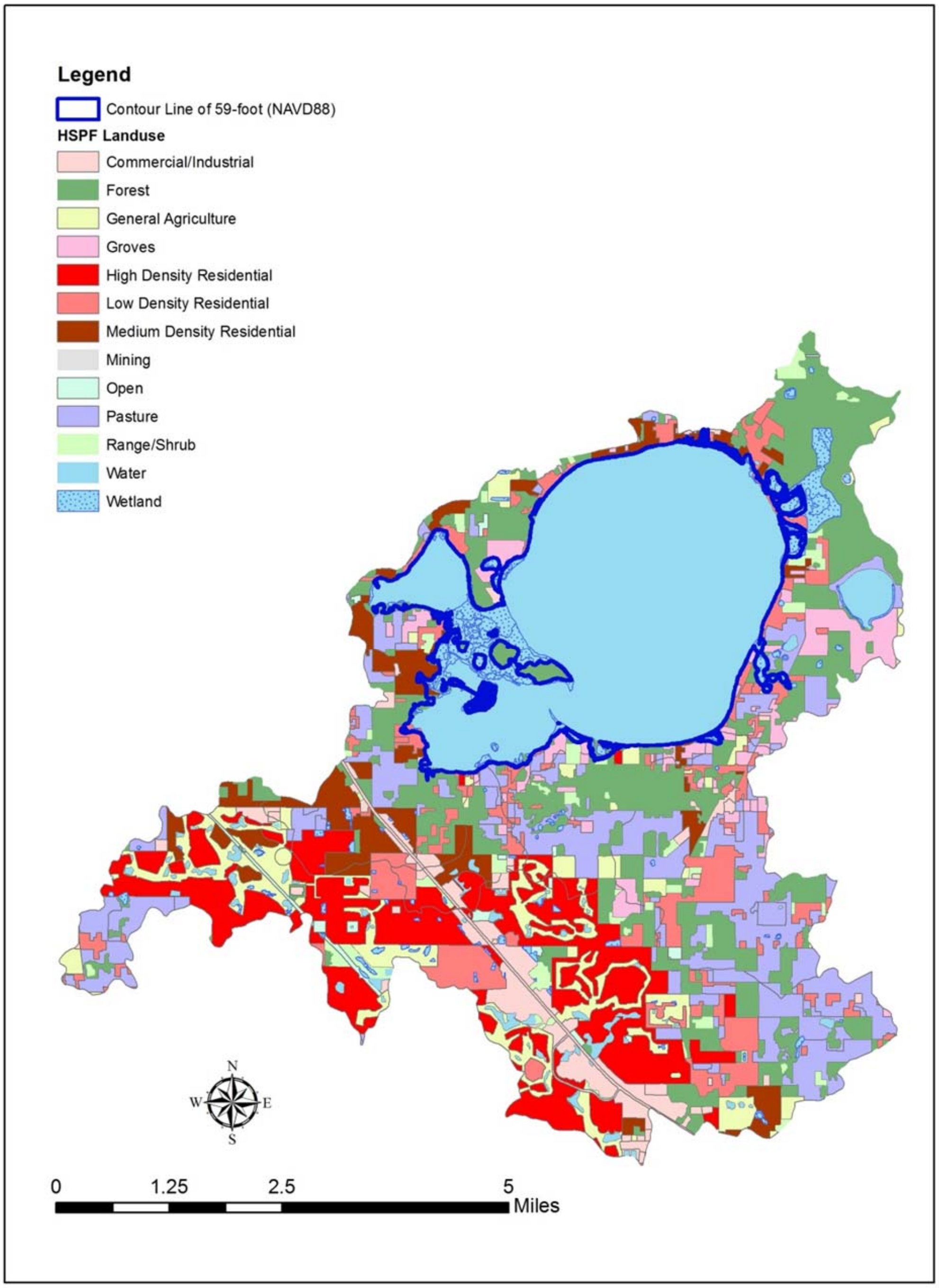

Figure 6 – Landuse Distribution at Lake Weir Intersected with Contour Line of 59 Foot (NAVD 88)

10. References

Robinson, C.P., 2003. Lake Weir Minimum Flows and Levels Hydrologic Method Report, St. Johns River Water Management District. Palatka, Florida.

Huang and Smith. 2015. Draft Report of Lake Apopka and the Upper Ocklawaha River Minimum Flows and Levels Hydrological Assessment Method Report. Online available at http://www.sjrwmd.com/minimumflowsandlevels/documents/UORB_HSPF_assessment_method_draft2015.pdf