Appendix C

Lake Weir HSPF Model Calibration 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

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1. Calibration Period

The selected model calibration period for the Lake Weir HSPF model is from year 2003 to year 2014. The selected calibration period includes wet, dry and average hydrologic conditions. Year 2003 was used as the model spin-up year. The model uses an hourly time step.

2. Calibration Criteria

The following criteria were used to evaluate the Lake Weir HSPF model performance.

i. Maximize (at least 85%) the number of modeled lake stages within ±0.5 feet of measured values;
ii. Model Nash-Sutcliffe coefficient (NSE) should be at least 0.85.

The NSE can be calculated based on the following formula.

$$NS = 1 - \frac{\sum_{i=1}^{N}(O_i - X_i)^2}{\sum_{i=1}^{N}(O_i - O_m)^2}$$

Where: O is the observed stage; X is the corresponding modeled stage; N is the number of data/model pairs; and O_m is the mean of the observed stages.

3. Calibration Procedure

The modeled hydrological components of the Lake Weir HSPF model are given by Figure 1. The detailed information of the HSPF modules of PERLND, IMPLND, and REACH can be found in the HSPF manual (Bicknell et al., 2001). The general procedure to calibrate the Lake Weir HSPF model is described as below.

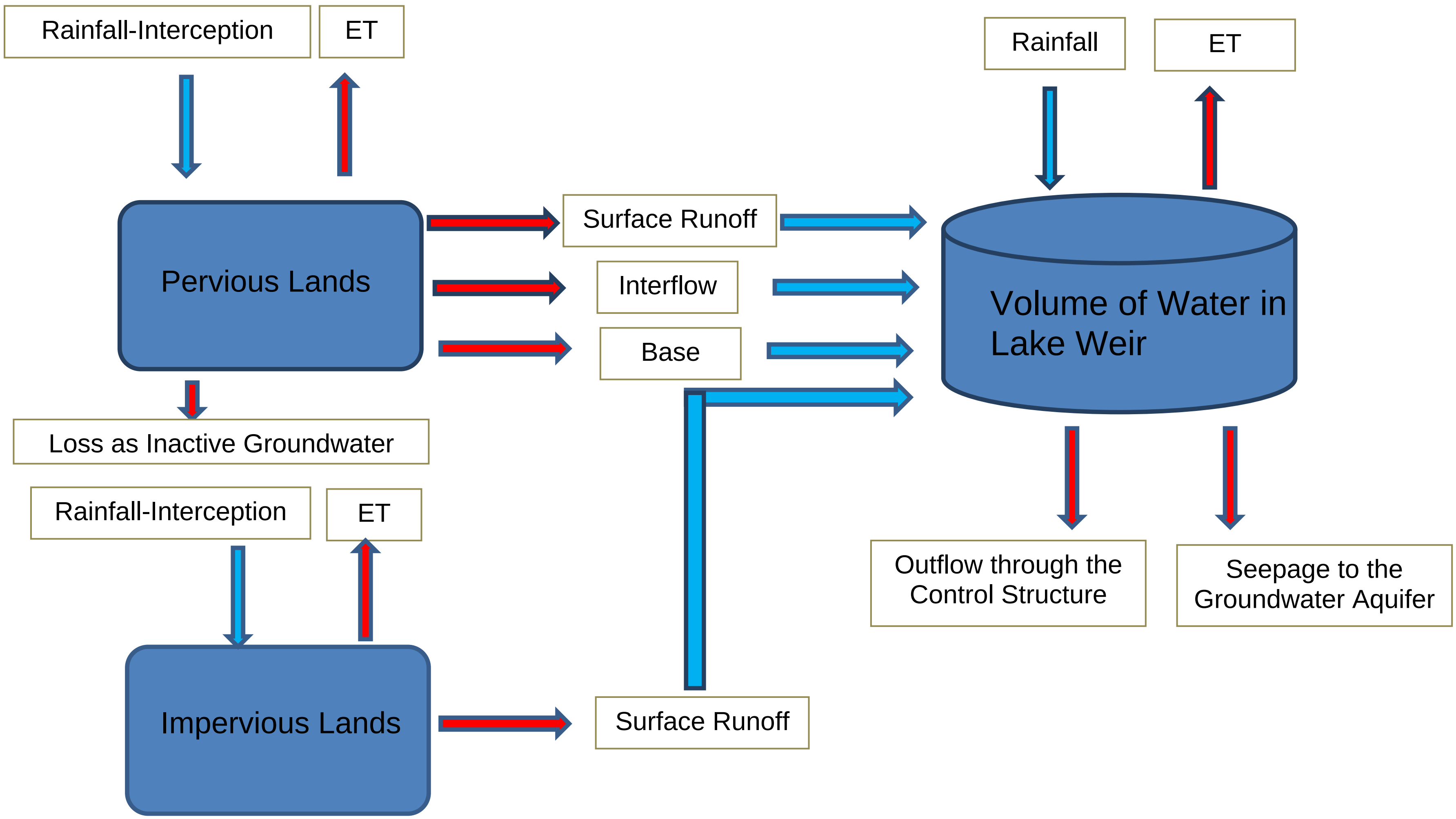

Figure 1 – Modeled Hydrological Components of the Lake Weir HSPF Model

3.1 Estimation of Initial Model Input Parameters

The initial/starting hydrological parameter values for Lake Weir HSPF model were obtained from the Lake Apopka and Upper Ocklawaha River HSPF model and Lower Ocklawaha River Basin HSPF model developed by the SJRWMD (Huang and Smith, 2015). The initial lake volume was estimated using the FTable based on the initial lake stage.

3.2 Estimation of Initial Seepage Rate

As described in the Letter Report for Task B, the water exchange between Lake Weir and the Upper Floridan Aquifer can be calculated based on Darcy's law (Robinson, 2003), as shown in Equation (1).

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

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 aquifer to lake.

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

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

Where: K is a constant that is a function of the local geology, and can be estimated by Equation (3).

$$\mathrm{K} = k\frac{\mathrm{A}}{\mathrm{L}} \qquad \text{Equation (3)}$$

Calculation of seepage flow was achieved in the Special Action block of the HSPF model. The Upper Floridan Aquifer (UFA) well stage data at station ID: 15912734, as shown in Figure 2, was written into the watershed data management (WDM) file. At each time step, the difference between the well stage called from the WDM file and model-simulated lake stage was calculated and the seepage flow was determined with the Special Action. The volume of lake was then updated by subtracting the seepage flow with the Special Action block.

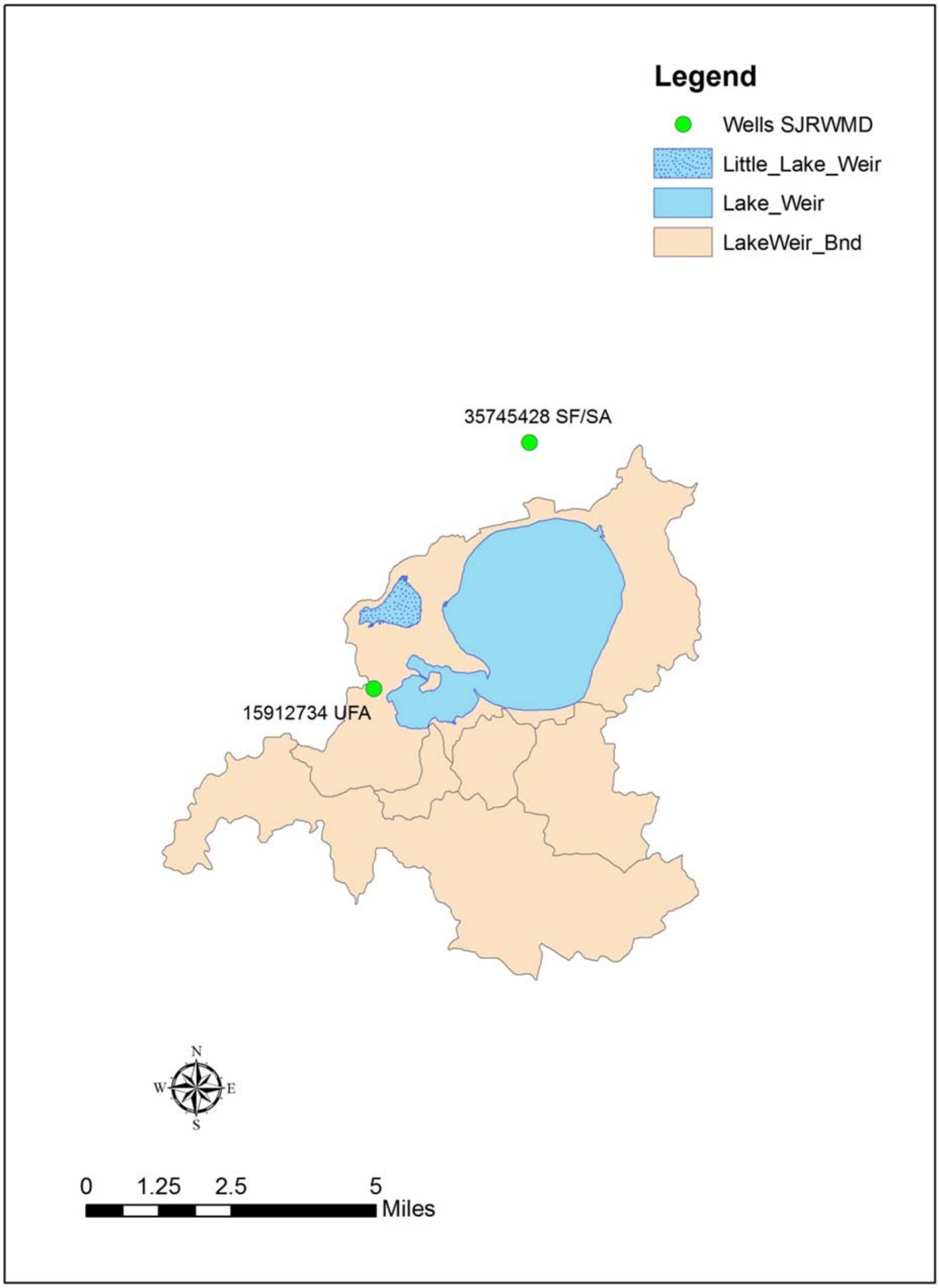

Figure 2 – Location of the UFA Well Used in the Lake Weir HSPF Model

According to Equation (3), in order to estimate the initial value of K, the value of cross-section area for seepage (parameter A) has to be determined first. The cross-section area can be approximated by the lake surface area. After the estimation of the cross-section area for seepage, the initial value of K can be determined based on the initial water depth and a constant hydraulic conductivity.

3.3 Adjustment of Hydrological Parameters

During the calibration process, the HSPF hydrological parameters were adjusted within reasonable range in order to match the observed lake stage data.

Parameters of KVARY, AGWRC, BASETP, and DEEPFR were held as basin-wide constants. Monthly values were used for CEPSC to represent the seasonal change in interception storage.

Parameter values of INFILT are different across different landuses. For the same landuse, different values were used for different sub-basins based on the SJRWMD 2015 recharge map, as shown in Figure 3. The area percentage of each recharge rate (low, medium, and high) was calculated for each sub-basin, as shown in Table 1.

The sub-basin having high rate of recharge rate is more likely to have higher value of infiltration capacity. Hence, the infiltration capacity of each landuse is set up in the sequence of Morriston > Weirsdale Slough > Tributary 1 > Tributary 2 > Lake Weir. The final calibrated values of INFILT are given in Table 2 .

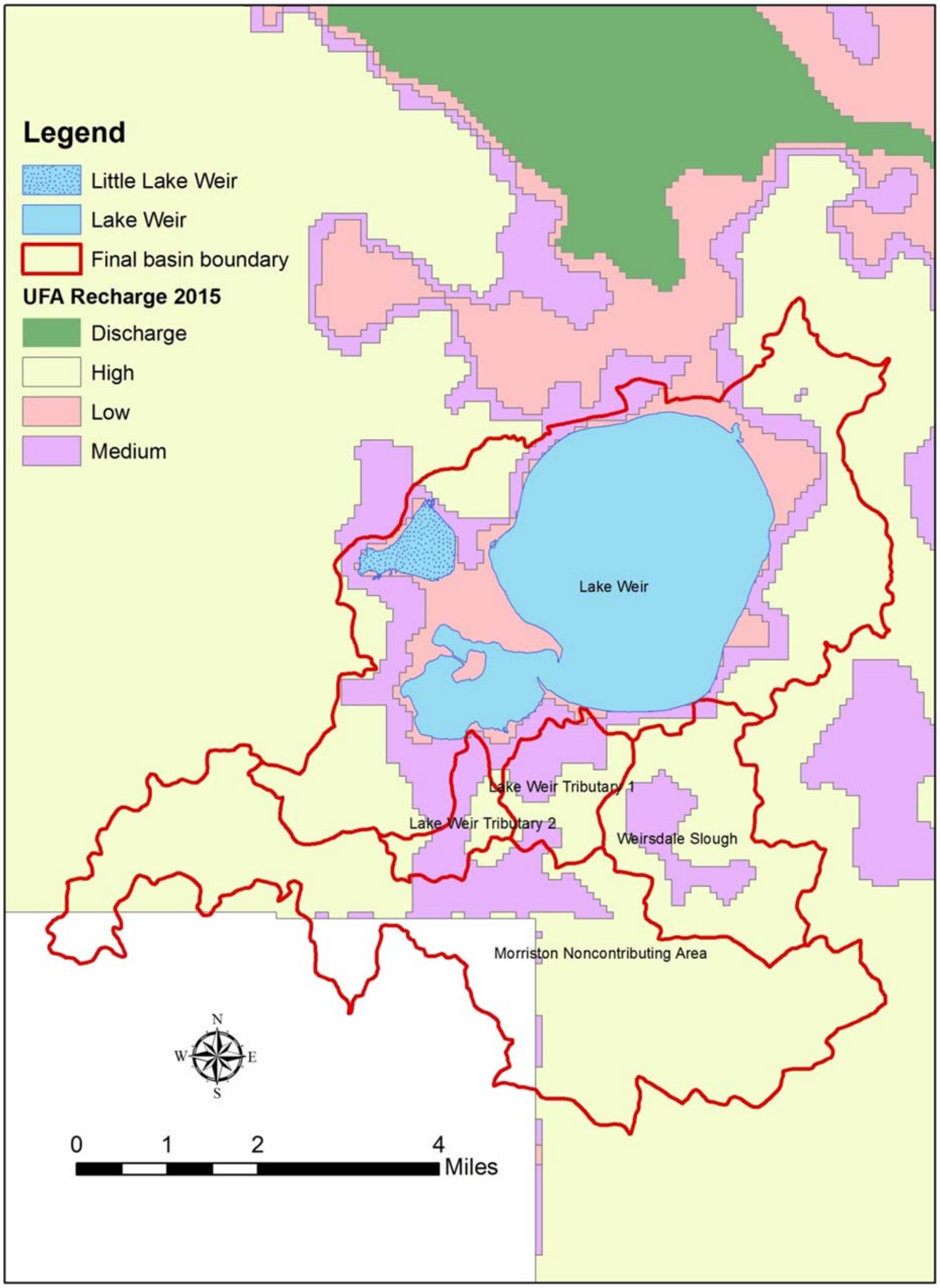

Figure 3 – The SJRWMD 2015 Recharge Map

Table 1 – The Area Percentage of Different Recharge Rate for Each Sub-basin

Recharge Rate	Low	Medium	High
Lake Weir	21%	27%	52%
Lake Weir Tributary 1	1%	45%	54%
Lake Weir Tributary 2	0%	56%	44%
Weirsdale Slough	0%	21%	79%
Morriston	0%	10%	90%

Table 2 – Calibrated Values of INFILT for Each Sub-basin

Landuses	Lake Weir	Tributary 2	Tributary 1	Weirsdale Slough	Morriston
LDR	0.42	0.43	0.45	0.46	0.47
MDR	0.42	0.43	0.45	0.46	0.47
HDR	0.42	0.43	0.45	0.46	0.47
Com/Ind	0.42	0.43	0.45	0.46	0.47
Mining	0.60	0.62	0.64	0.66	0.68
Open	0.60	0.62	0.64	0.66	0.68
Pasture	0.60	0.62	0.64	0.66	0.68
Agriculture	0.72	0.74	0.76	0.79	0.81
Groves	0.72	0.74	0.76	0.79	0.81
Range/Shrub	0.60	0.62	0.64	0.66	0.68
Forest	0.90	0.93	0.95	0.98	1.01
Water	0.03	0.03	0.03	0.03	0.03
Wetland	0.03	0.03	0.03	0.03	0.03
Average	0.50	0.51	0.53	0.54	0.56

3.4 Adjustment of the Fraction of Baseflow from Morriston to Lake Weir

Based on the groundwater table maps created for Task A, it can be determined that the general flow direction of the ground water in the surficial aquifer in the vicinity of Lake Weir is either from east to west or from southeast to northwest. Hence, there might be some small percentage of base flow contribution from the Morriston sub-basin when the groundwater flows from southeast to northwest.

At the beginning of the Lake Weir HSPF calibration, all the baseflow from sub-basin Morriston was routed to Lake Weir. The fraction of baseflow from sub-basin Morriston was adjusted during model calibration such that the simulated lake stage matched the observed lake stages best statistically.

3.5 Annual Water Budget

The annual water budget of Lake Weir was checked and can be expressed by Equation (5).

$$\Delta Volume = Rainfall + Runoff - ET - Overflow - Seepage \qquad \text{Equation (5)}$$

Where: $\Delta Volume$ is the change in lake volume (acre-feet); $Rainfall$ is the volume of water contributed by rainfall (acre-feet); *Runoff* is total runoff from the contributing sub-basins including surface runoff, interflow, and base flow; *ET* is the volume of water lost by ET (acre-feet); $Overflow$ is the volume of outflow from Lake Weir through the control structure (acre-feet); and $Seepage$ is the volume of water by seepage flow (acre-feet).
In this equation, *Rainfall*, *Runoff*, *ET*, and *Overflow* can be obtained directly from the HSPF output. $\Delta Volume$ can be estimated as the difference of the lake volumes between at the end of the year and at the beginning of the year. Hence, value of $Seepage$ can be estimated using Equation (5). The final average annual seepage rate calculated by HSPF will be compared with the annual downward leakage from Lake Weir reported by Deevey (1988) in section 4.2 below.

4. Calibration Results and Discussion

4.1 Comparison between Observed and Modeled Stages

During the calibration process, it was found that the addition of all the baseflow from the sub-basin Morriston to Lake Weir deteriorated the model performance. Using five percent of the baseflow from sub-basin Morriston and routed to Lake Weir produced the best model performance. The annual rainfall and ET inputs and the calibrated input parameter values are given by Tables 9-19 at the end of this document.

The comparison of daily observed and modeled lake stages is given in Figure 4 and the summary statistics of daily and monthly stages are given in Table 3. As shown in Figure 4, the simulated daily lake stages closely follow the trend of observed stages. The scatter plot of observed and modeled stages is given by Figure 5

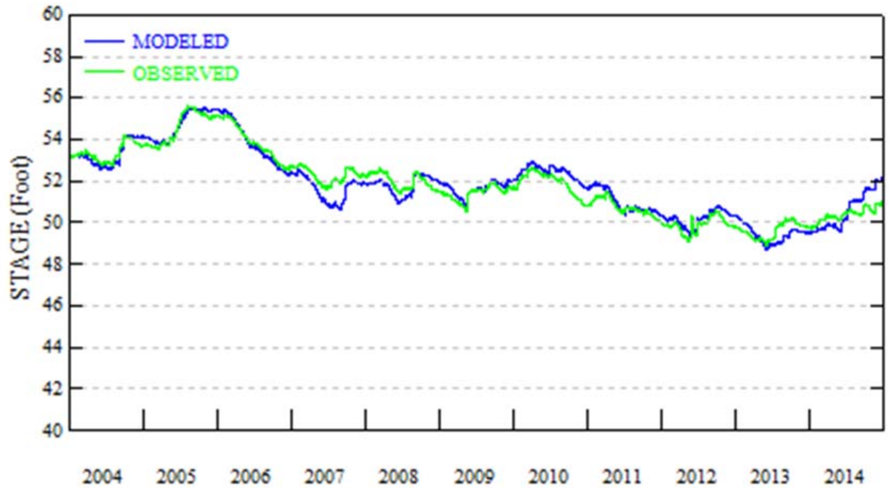

Figure 4 – Comparison of Observed and Modeled Lake Stages of Lake Weir

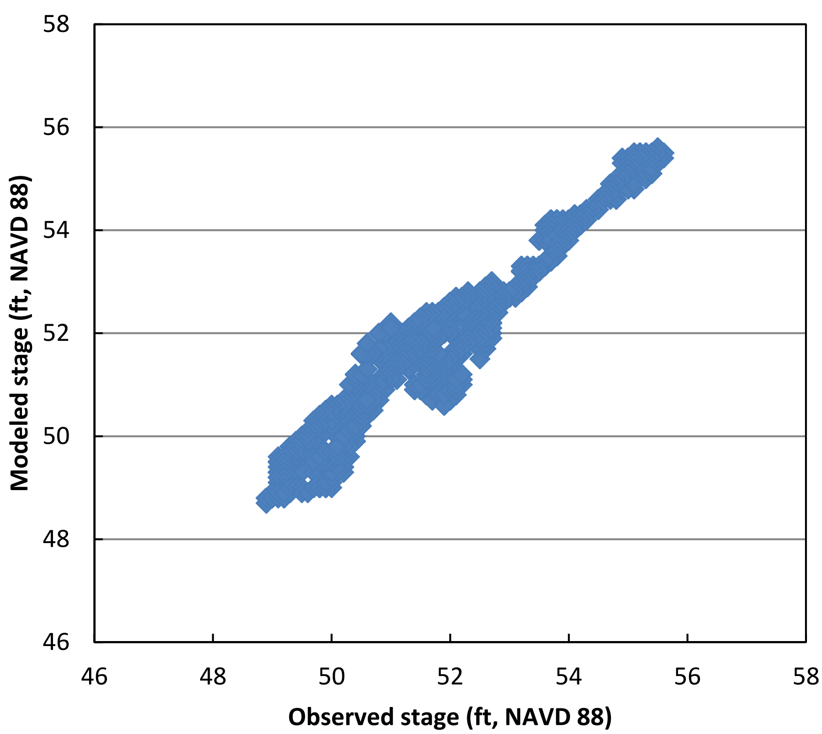

Figure 5 – Scatter Plot of Observed and Modeled Water Stages

The statistics for daily and monthly observed and modeled stages are given in Table 3. Approximately 83.9% of modeled daily stages fall within ±0.5 feet of measured data, whereas 84.8% of modeled monthly stages are within ±0.5 feet of measured values. The calculated Nash-Sutcliffe coefficient (NSE) between modeled and observed daily stages is 0.93, whereas the NSE value between modeled and observed monthly stages is also 0.93.

More statistics between daily observed and modeled stages, like minimum, maximum, median values, are shown in Table 4. The modeled and observed daily stages have almost identical statistics values.

Table 3 – Summary Statistics for Daily and Monthly Stages of Lake Weir HSPF Model

Stage	Sample size	Mean-Observed	Mean-Modeled	NSE	Percentage of modeled stages within ±0.5 feet of measured data
Daily	4,108	51.83	51.87	0.93	83.9%
Monthly	132	51.83	51.87	0.932	84.8%

Table 4 – Statistics between Daily Observed and Simulated Water Stages

Statistics	Observed	Modeled
Sample size	4,108	4,108
Minimum	48.90	48.70
Average	51.83	51.87
Maximum	55.60	55.60
Median	51.70	51.90
Standard Deviation	1.63	1.64

Apparently, the HSPF model did achieve the calibration criterion that the Nash-Sutcliffe score is at least 0.85. Moriasi et al. (2007) proposed guidelines to use the calculated NSE values between monthly modeled and observed data to evaluate the accuracy in watershed simulation and rate the model performance, as shown in Table 5. The Lake Weir HSPF model performance can be rated as "very good" based on Table 5. Generally speaking, the monthly comparison always generates a higher value of NSE than the daily comparison because the monthly average values smooth the extreme high and low daily values. However, for the Lake Weir HSPF model, the calculated NSE value between modeled and observed daily stages (0.93) is exactly same as the NSE based on monthly comparison (0.93), indicating a consistently good model performance.

Table 5 – Model Performance Evaluation with Nash-Sutcliffe Efficient (NSE)

Performance Rating	Nash-Sutcliffe Coefficient (Monthly)
Very good	0.75 < NSE <1.00
Good	0.65 < NSE <0.75
Satisfactory	0.50 < NSE <0.65
Unsatisfactory	< 0.50

*Adapted from Moriasi et al. (2007)

The developed Lake Weir HSPF model almost achieved the calibration criterion that 85 percent of modeled stages are within +/-0.5 foot of observed stages (with a value of 83.9 percent). More summary statistics of the differences between daily observed and modeled stages are shown in Table 6. At the 85 percent level, the difference between daily observed and modeled stages was +/- 0.6 feet. The most possible reasons for the discrepancy between the modeled and observed water stages include 1) the difference between the actual rainfall in Lake Weir watershed and gauge rainfall used in the model; 2) the difference between the actual PET in Lake Weir watershed and the calculated PET using Hargreaves approach from the closest station of Ocala, which may not be representative of Lake Weir for some particular time periods; and 3) the difficulties in representing the complex water exchanges among Lake Weir, the SA, and the UFA due to data limitation.

Table 6 – Summary Statistics of Difference between Observed and Modeled Stages

Difference between Observed and Modeled Stages	Percentage (%)
<= 0.25 feet	38.7
<= 0.50 feet	83.9
<= 0.75 feet	91.1
<= 1.00 feet	97.0

Lake Weir discharges into Marshall Swamp in the north via a flow control weir structure. The weir top elevation is 56.4 feet at NAVD88. As shown in Figure 4, both modeled and observed lake stages never exceed 56.0 feet; hence, there are no outflows through the flow control weir during the calibration period. Hence, Lake Weir is acting like a ponding lake without outlets for the calibration period.

Under this condition, any errors in the major hydrological components might cause long-term accumulating errors for the watershed model. For example, there are some localized storm events, which might not be represented by the rain gauge data used in the HSPF model. The potential ET used in the HSPF was calculated using Hargreaves approach from the closest station of Ocala, which might not be representative of the Lake Weir for some particular time periods.

Another potential reason for differences between the modeled and observed stages could be attributed to the fact that the Lake Weir HSPF model does not explicitly simulate the water exchange between Lake Weir and the Surficial Aquifer (SA) due to the lack of long-term monitored well data of the SA near Lake Weir. The nearest SA well is at Tiger Den (ID: 35745428), as shown in Figure 2. The monitored stage data at Tiger Den (ID: 35745428) are only available for a couple of months (since June 1, 2016). The stage data from the Upper Floridan Aquifer (UFA) well of Lake Weir Middle School at Lady Lake (ID: 15912734) shown in Figure 2 was used in the HSPF to calculate the seepage flow between the lake and the UFA.

Comparison of the stages among the SA well at Tiger Den (ID: 35745428), the UFA well at Middle School Lady Lake (ID: 15912734), and Lake Weir is given in Figure 6. The common period is only available since June 1, 2016. Clearly, the stages in the SA are constantly higher than the lake stages and the lake stages are constantly higher than the well stages in the UFA, as shown in Figure 6, indicating that Lake Weir gains water from the SA and loses water to the UFA. However, Lake Weir constantly loses water to the groundwater aquifer simulated by current HSPF model during the calibration period (2003-2014) because the observed and modeled Lakes stages are systematically higher than the observed well stages in the UFA (ID: 15912734), as shown in Figure 7.

The inclusion of the water exchange between the SA and Lake Weir may further improve the overall model performance. For example, the HSPF modeled lake stages showed a significant drop in September of 2007, while the observed stages only have a mild drop, as shown in Figure 4. This discrepancy may be due to significant recharge from the SA and the Lake Weir HSPF model's incapability to simulate this recharge from the SA to Lake Weir. Hence, it is recommended that a SA well be established near the UFA station of Lake Weir Middle School at Lady Lake (ID: 15912734) to monitor the long-term well stages in the SA so that the water exchange between Lake Weir and the SA can be included in the model.

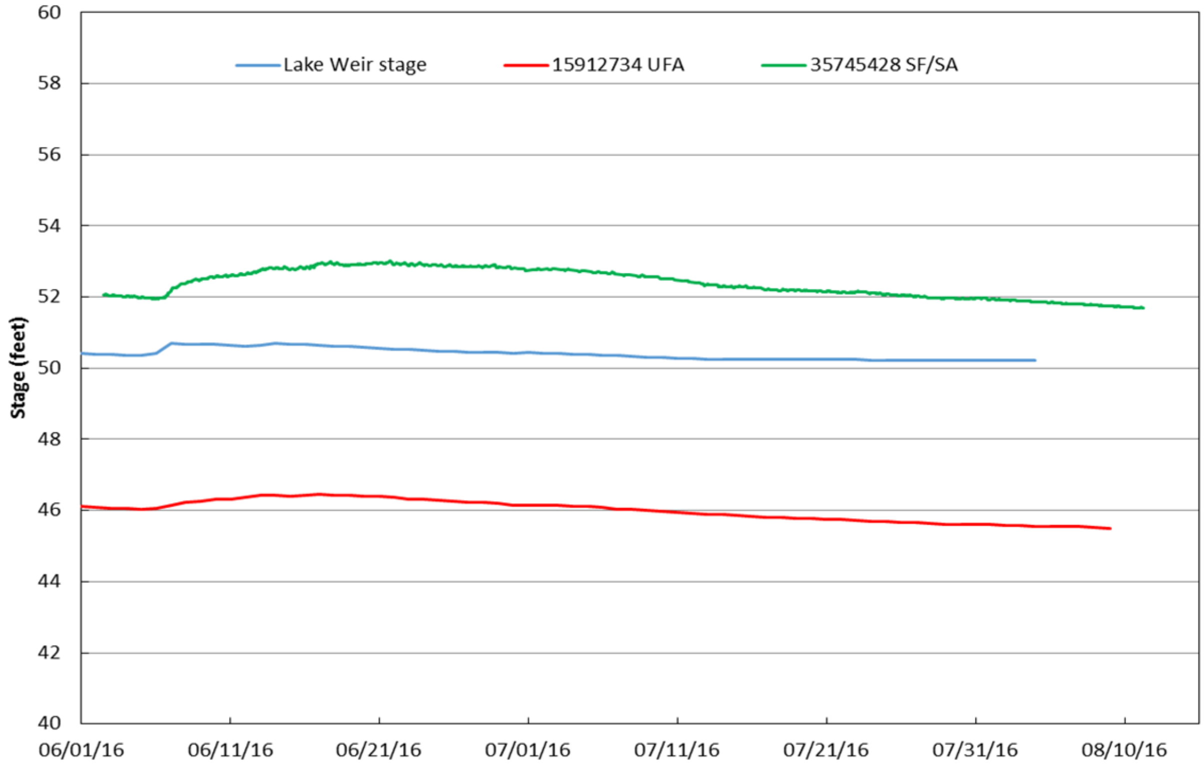

Figure 6 – Comparison of Well Stages in the SA and UFA and Lake Stages

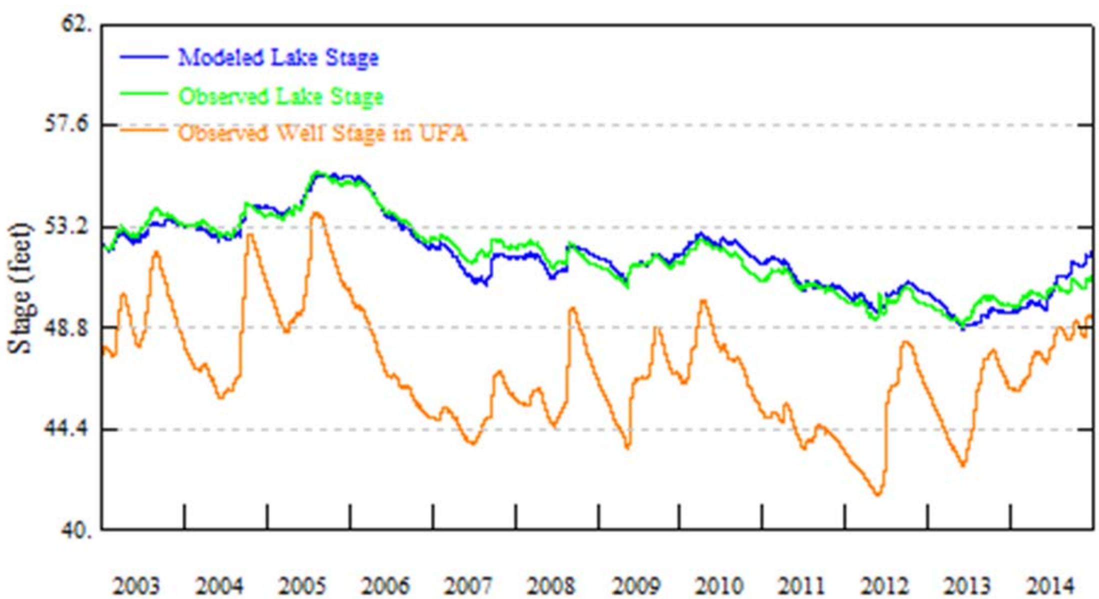

Figure 7 – Comparison of Modeled and Observed Lake Stages and Well Stages in the UFA for the Calibration Period

4.2 Annual Water Budget

Based on the calibrated Lake Weir HSPF model, each component in the water balance equation can be calculated. The final annual water budget results are given in Table 7.

Over the 11-year calibration period (2004-2014), the average annual rainfall is 22,382 acre-feet and the total runoff (*Runoff*) from the contributing sub-basins is 6,805 acre-feet. The average annual ET from Lake Weir is 23,891 acre-feet, even higher than the volume of water contributed by rainfall. The total inflows (rainfall plus runoff), total outflows (sum of ET, overflow, and seepage), and their percentages to the lake volume are given in Table 8.

The average annual water seepage from Lake Weir to the Upper Floridan Aquifer is 5841 acre-feet, which is approximately 12.14 inch/year if the cross-section area is approximated by the 11-year averaged lake surface area. Based on 32-year data, Deevey (1988) estimated an average of 34.2 cm/year (13.47 inch/year) of downward leakage from Lake Weir to groundwater aquifer, very close to the estimated average annual seepage of 12.14 inch/year by the HSPF model.

Table 7 – Estimated Annual Water Budget based on the Lake Weir HSPF Model

Year	ΔVolume	Rainfall	Runoff	ET	Overflow	Seepage
2004	5,600	26,700	8,590	24,300	0	5,390
2005	8,000	27,800	9,010	24,500	0	4,310
2006	-18,000	12,800	1,960	25,700	0	7,060
2007	-2,900	22,000	6,270	23,600	0	7,570
2008	200	21,600	8,190	23,400	0	6,190
2009	300	23,600	6,820	24,000	0	6,120
2010	-2,300	21,300	6,780	24,400	0	5,980
2011	-7,200	20,200	4,680	24,500	0	7,580
2012	0	22,400	7,090	23,200	0	6,290
2013	-4,700	17,900	4,360	22,400	0	4,560
2014	15,000	29,900	11,100	22,800	0	3,200
Average	-545	22,382	6,805	23,891	0	5,841

Note: Unit is acre-feet; sign – means that lake loses water.

Table 8 – Percentage of Total Inflows and Outflows to Lake Volume

Year	Lake Volume	Inflows	Percentage of Inflows	Outflows	Percentage of Outflows
2004	95,300	35,290	37.0%	29,690	31.2%
2005	104,000	36,810	35.4%	28,810	27.7%
2006	98,500	14,760	15.0%	32,760	33.3%
2007	85,600	28,270	33.0%	31,170	36.4%
2008	86,600	29,790	34.4%	29,590	34.2%
2009	85,600	30,420	35.5%	30,120	35.2%
2010	90,000	28,080	31.2%	30,380	33.8%
2011	82,100	24,880	30.3%	32,080	39.1%
2012	77,400	29,490	38.1%	29,490	38.1%
2013	73,300	22,260	30.4%	26,960	36.8%
2014	79,600	41,000	51.5%	26,000	32.7%
Average	87,091	29,186	33.5%	29,732	34.1%

In summary, the performance of the calibrated Lake Weir HSPF model is very good and can be used to evaluate the developed minimum flows and levels (MFLs) of Lake Weir.

Table 9 – Annual Rainfall and ET used in the Lake Weir HSPF Model

Year	PET	Rainfall
2004	49.1	54
2005	47.7	54.4
2006	51.2	25.7
2007	49.5	46.3
2008	48.8	45.2
2009	50.2	49.4
2010	50	43.7
2011	52	42.8
2012	50.1	48.5
2013	49.2	39.6
2014	48.8	64.1
2015	48.7	42.5

Table 10 – The Calibrated PWAT-PARM2 Parameters for Sub-basin Lake Weir

HRU #	Forest	LZSN (in)	INFILT (in/hr)	LSUR (ft)	SLSUR	KVARY (1/in	AGWRC (1/day)
101	0.0	4.0	0.42	100	0.016	0.001	0.9801
102	0.0	4.0	0.42	100	0.016	0.001	0.9801
103	0.0	4.0	0.42	100	0.016	0.001	0.9801
104	0.0	4.0	0.42	100	0.016	0.001	0.9801
105	0.0	3.0	0.60	100	0.016	0.001	0.9801
106	0.0	4.5	0.60	100	0.016	0.001	0.9801
107	0.0	4.5	0.60	100	0.016	0.001	0.9801
108	0.0	5.0	0.72	100	0.016	0.001	0.9801
109	0.0	5.0	0.72	100	0.016	0.001	0.9801
110	0.0	4.5	0.60	100	0.016	0.001	0.9801
111	1.0	6.0	0.90	100	0.016	0.001	0.9801
112	0.0	0.5	0.03	100	0.016	0.001	0.9801
113	0.0	0.5	0.03	100	0.016	0.001	0.9801

Table 11 - The Calibrated PWAT-PARM2 Parameters for Sub-basin Lake Weir Tributary 1

HRU #	Forest	LZSN (in)	INFILT (in/hr)	LSUR (ft)	SLSUR	KVARY (1/in	AGWRC (1/day)
101	0.0	4.0	0.45	100	0.016	0.001	0.9801
102	0.0	4.0	0.45	100	0.016	0.001	0.9801
103	0.0	4.0	0.45	100	0.016	0.001	0.9801
104	0.0	4.0	0.45	100	0.016	0.001	0.9801
105	0.0	3.0	0.64	100	0.016	0.001	0.9801
106	0.0	4.5	0.64	100	0.016	0.001	0.9801
107	0.0	4.5	0.64	100	0.016	0.001	0.9801
108	0.0	5.0	0.76	100	0.016	0.001	0.9801
109	0.0	5.0	0.76	100	0.016	0.001	0.9801
110	0.0	4.5	0.64	100	0.016	0.001	0.9801
111	1.0	6.0	0.96	100	0.016	0.001	0.9801
112	0.0	0.5	0.03	100	0.016	0.001	0.9801
113	0.0	0.5	0.03	100	0.016	0.001	0.9801

Table 12 - The Calibrated PWAT-PARM2 Parameters for Sub-basin Lake Weir Tributary 2

HRU #	Forest	LZSN (in)	INFILT (in/hr)	LSUR (ft)	SLSUR	KVARY (1/in	AGWRC (1/day)
101	0.0	4.0	0.43	100	0.016	0.001	0.9801
102	0.0	4.0	0.43	100	0.016	0.001	0.9801
103	0.0	4.0	0.43	100	0.016	0.001	0.9801
104	0.0	4.0	0.43	100	0.016	0.001	0.9801
105	0.0	3.0	0.62	100	0.016	0.001	0.9801
106	0.0	4.5	0.62	100	0.016	0.001	0.9801
107	0.0	4.5	0.62	100	0.016	0.001	0.9801
108	0.0	5.0	0.74	100	0.016	0.001	0.9801
109	0.0	5.0	0.74	100	0.016	0.001	0.9801
110	0.0	4.5	0.62	100	0.016	0.001	0.9801
111	1.0	6.0	0.93	100	0.016	0.001	0.9801
112	0.0	0.5	0.03	100	0.016	0.001	0.9801
113	0.0	0.5	0.03	100	0.016	0.001	0.9801

Table 13 - The Calibrated PWAT-PARM2 Parameters for Sub-basin Weirsdale Slough

HRU #	Forest	LZSN (in)	INFILT (in/hr)	LSUR (ft)	SLSUR	KVARY (1/in	AGWRC (1/day)
101	0.0	4.0	0.46	100	0.016	0.001	0.9801
102	0.0	4.0	0.46	100	0.016	0.001	0.9801
103	0.0	4.0	0.46	100	0.016	0.001	0.9801
104	0.0	4.0	0.46	100	0.016	0.001	0.9801
105	0.0	3.0	0.66	100	0.016	0.001	0.9801
106	0.0	4.5	0.66	100	0.016	0.001	0.9801
107	0.0	4.5	0.66	100	0.016	0.001	0.9801
108	0.0	5.0	0.79	100	0.016	0.001	0.9801
109	0.0	5.0	0.79	100	0.016	0.001	0.9801
110	0.0	4.5	0.66	100	0.016	0.001	0.9801
111	1.0	6.0	0.98	100	0.016	0.001	0.9801
112	0.0	0.5	0.03	100	0.016	0.001	0.9801
113	0.0	0.5	0.03	100	0.016	0.001	0.9801

Table 14 - The Calibrated PWAT-PARM2 Parameters for Sub-basin Morriston

HRU #	Forest	LZSN (in)	INFILT (in/hr)	LSUR (ft)	SLSUR	KVARY (1/in	AGWRC (1/day)
101	0.0	4.0	0.47	100	0.016	0.001	0.9801
102	0.0	4.0	0.47	100	0.016	0.001	0.9801
103	0.0	4.0	0.47	100	0.016	0.001	0.9801
104	0.0	4.0	0.47	100	0.016	0.001	0.9801
105	0.0	3.0	0.68	100	0.016	0.001	0.9801
106	0.0	4.5	0.68	100	0.016	0.001	0.9801
107	0.0	4.5	0.68	100	0.016	0.001	0.9801
108	0.0	5.0	0.81	100	0.016	0.001	0.9801
109	0.0	5.0	0.81	100	0.016	0.001	0.9801
110	0.0	4.5	0.68	100	0.016	0.001	0.9801
111	1.0	6.0	1.01	100	0.016	0.001	0.9801
112	0.0	0.5	0.03	100	0.016	0.001	0.9801
113	0.0	0.5	0.03	100	0.016	0.001	0.9801

Table 15 – The Calibrated PWAT-PARM3 Parameters for All Sub-basins

Landuse	PETMAX (degree F)	PETMIN (degree F)	INFEXP	INFILD	DEEPFR	BASETP	AWGETP
LDR	40.0	35.0	2.0	2.0	0.555	0.02	0.00
MDR	40.0	35.0	2.0	2.0	0.555	0.02	0.00
HDR	40.0	35.0	2.0	2.0	0.555	0.02	0.00
Com/Ind	40.0	35.0	2.0	2.0	0.555	0.02	0.00
Mining	40.0	35.0	2.0	2.0	0.555	0.02	0.00
Open	40.0	35.0	2.0	2.0	0.555	0.02	0.00
Pasture	40.0	35.0	2.0	2.0	0.555	0.02	0.00
Agriculture	40.0	35.0	2.0	2.0	0.555	0.02	0.00
Groves	40.0	35.0	2.0	2.0	0.555	0.02	0.00
Range/Shrub	40.0	35.0	2.0	2.0	0.555	0.02	0.00
Forest	40.0	35.0	2.0	2.0	0.555	0.02	0.00
Water	40.0	35.0	2.0	2.0	0.555	0.02	0.25
Wetland	40.0	35.0	2.0	2.0	0.555	0.02	0.25

Table 16 - Table 17 – The Calibrated PWAT-PARM4 Parameters for All Sub-basins

Landuse	CEPSC (in)	UZSN (in)	NSUR	INTFW	IRC (/day)	LZETP
LDR	NA	1.40	0.10	0.75	0.5495	0.34
MDR	NA	1.40	0.10	0.75	0.5495	0.34
HDR	NA	1.40	0.10	0.75	0.5495	0.34
Com/Ind	NA	1.40	0.10	0.75	0.5495	0.34
Mining	NA	1.40	0.20	0.75	0.5495	0.30
Open	NA	1.40	0.20	0.75	0.5495	0.30
Pasture	NA	1.40	0.25	0.75	0.5495	0.40
Agriculture	NA	1.60	0.25	0.75	0.5495	0.50
Groves	NA	1.60	0.30	0.75	0.5495	0.50
Range/Shrub	NA	1.40	0.20	0.75	0.5495	0.55
Forest	NA	2.00	0.35	0.75	0.5495	0.60
Water	NA	0.08	0.30	0.00	0.5495	0.90
Wetland	NA	0.08	0.30	0.00	0.5495	0.90

Table 18 - The Calibrated Monthly CEPSC Parameters for All Sub-basins

Landuse	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LDR	0.04	0.04	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.04
MDR	0.04	0.04	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.04
HDR	0.04	0.04	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.04
Com/Ind	0.04	0.04	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.04
Mining	0.04	0.04	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.04
Open	0.04	0.04	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.04
Pasture	0.03	0.03	0.05	0.08	0.10	0.10	0.10	0.10	0.10	0.08	0.07	0.03
Agriculture	0.03	0.03	0.05	0.08	0.10	0.10	0.10	0.10	0.10	0.08	0.07	0.03
Groves	0.03	0.03	0.05	0.08	0.10	0.10	0.10	0.10	0.10	0.08	0.07	0.03
Range/Shrub	0.10	0.10	0.12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.12	0.10
Forest	0.10	0.10	0.12	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.12	0.10
Water	0.07	0.07	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.07
Wetland	0.07	0.07	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.07

Table 19 – The Calibrated PWAT-STATE1 Parameters for All Sub-basins

Landuse	CEPS (in)	SURS (in)	UZS (in)	IFWS (in)	LZS (in)	AGWS (in)	GWVS (in)
LDR	0.0	0.0	1.40	0.0	4.0	0.5	0.0
MDR	0.0	0.0	1.40	0.0	4.0	0.5	0.0
HDR	0.0	0.0	1.40	0.0	4.0	0.5	0.0
Com/Ind	0.0	0.0	1.40	0.0	4.0	0.5	0.0
Mining	0.0	0.0	1.40	0.0	3.0	0.5	0.0
Open	0.0	0.0	1.40	0.0	4.5	0.5	0.0
Pasture	0.0	0.0	1.40	0.0	4.5	0.5	0.0
Agriculture	0.0	0.0	1.60	0.0	5.0	0.5	0.0
Groves	0.0	0.0	1.60	0.0	5.0	0.5	0.0
Range/Shrub	0.0	0.0	1.40	0.0	4.5	0.5	0.0
Forest	0.0	0.0	2.00	0.0	6.0	0.5	0.0
Water	0.0	0.0	0.08	0.0	0.5	0.5	0.0
Wetland	0.0	0.0	0.08	0.0	0.5	0.5	0.0

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