Appendix A

Summary of Data Review 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. Summary of Data Review

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

The SJRWMD provided Lake Weir bathymetry data, rainfall, evapotranspiration (ET), monitored stage in Lake Weir, and GIS spatial data in support of the development of watershed HSPF model. The provided spatial data include watershed boundary, land cover of 1994, 2004, and 2009, hydrological soil distribution, 10-m Digital Elevation Model (DEM), locations of monitoring wells and consumptive use permit, USGS quad map, DEM elevation contours of 1- and 5-foot, and the SJRWMD's 2015 recharge map.

1.1 Lake Stage Data

The SJRWMD monitors the long-term stage at Lake Weir and the location of the stage station (ID: 04720926) is shown in Figure 1. The monitored state data are available from January 1, 1942 to present, as shown in Figure 2. The minimum, maximum, and average stages from 1942 to 2016 are 48.86, 58.54, and 54.60 feet, respectively (NAVD 88).

The nearest Upper Floridan Aquifer well is located at Lake Weir Middle School at Lady Lake (Station ID: 15912734), as shown in Figure 1. The monitored well data, available from September 2001 to present, are consistently lower than the lake stage data shown in Figure 2, which indicates Lake Weir may potentially lose water to the Floridan Aquifer.

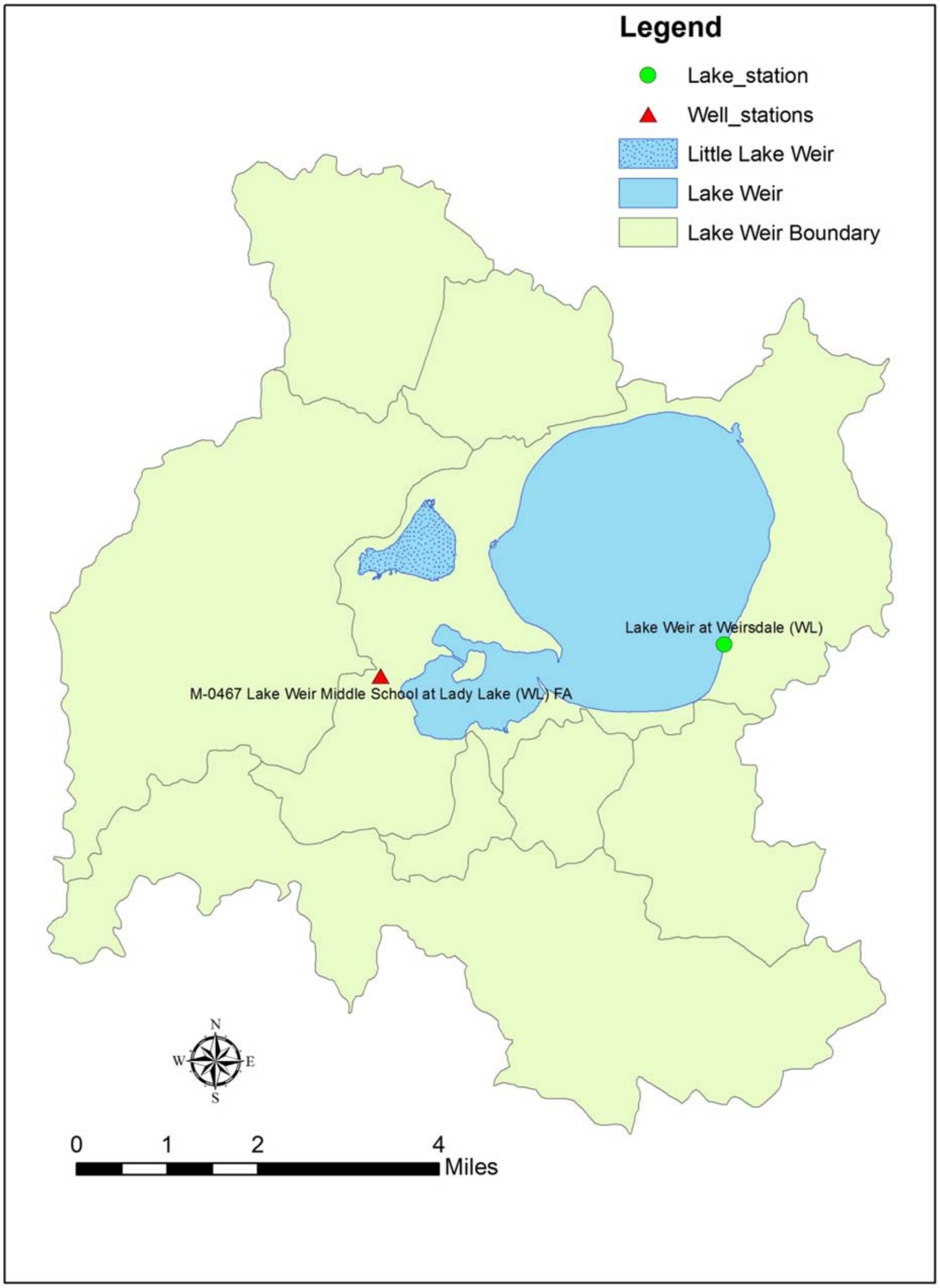

Figure 1 Locations of Lake Stage and Well Stations at Lake Weir

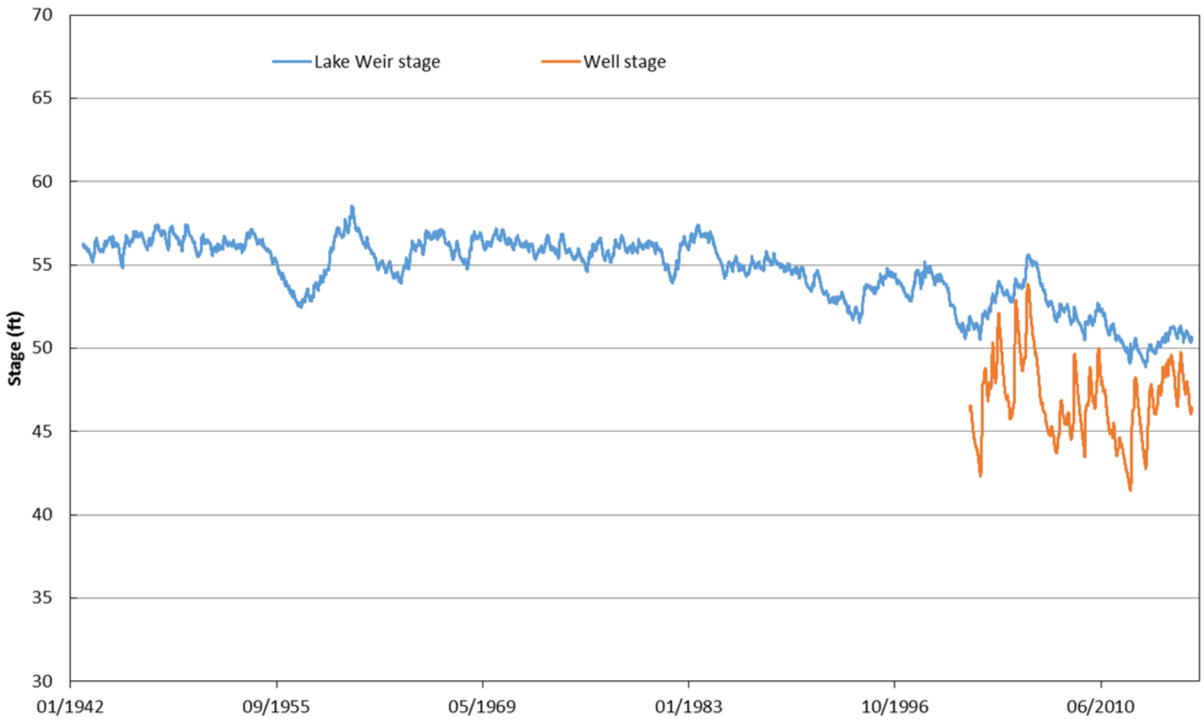

Figure 2 – Stage and Well Data at Lake Weir

1.2 Lake Weir Bathymetry Data

Lake Weir discharges into Marshall Swamp in the north via a flow control weir structure. The fixed-top elevation weir is approximate 20 feet in width. Robinson (2003) developed a Streamflow Synthesis and Reservoir Regulation (SSARR) model for Lake Weir in which a rating curve was developed for the weir The same rating curve developed by Robinson (2003) will be used for the development of F-table of the Lake Weir HSPF model with 1-foot adjustment of the weir top elevation from NGVD29 to NAVD88. The adjusted rating equation is

$$Q = 2.5 * 20 * (h - 56.4)^{1.5} \qquad \text{Equation (1)}$$

where, Q is the calculated discharge (cfs); h is the lake stage (ft) in NAVD88. The calculated F-table is given by Figure 3.

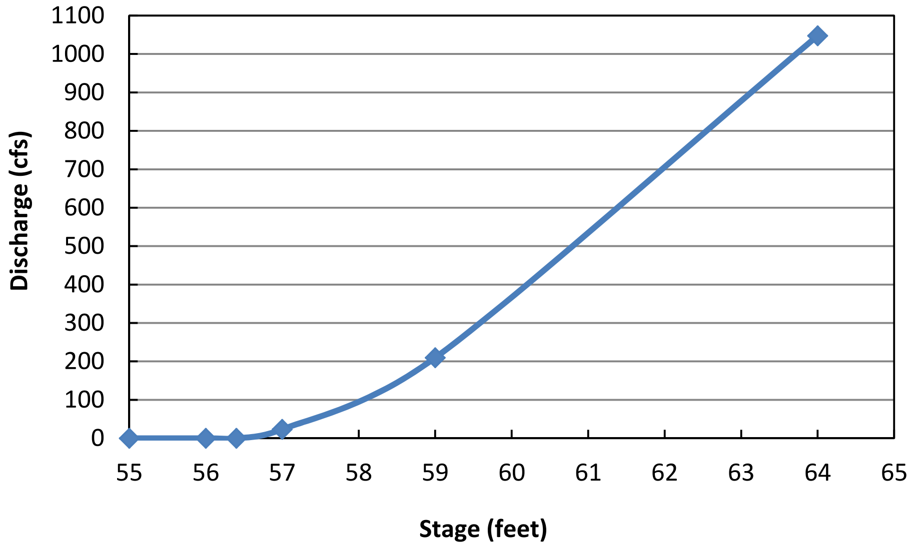

Figure 3 – Developed F-table for the Lake Weir HSPF Model

1.3 Rainfall and ET Data

Rainfall data is the driving factor for the watershed hydrological model and ET is the largest water loss in the overall water balance. The accuracy of the rainfall and ET data is vital for the development of the Lake Weir HSPF model.

The composite rainfall data were obtained by combining data at NOAA station of Lisbon (01/01/1948 – 05/26/1988) and SJRWMD station of Smith Lake at Belleview (05/27/1988 – 12/31/2015). Rainfall data from another NOAA station (Ocala) and three SJRWMD stations (Sunny Hill South #1, Sunny Hill C-D #5, and Blue House at Starkes Ferry) were used to fill in the missing rainfall data.

The provided rainfall data as shown in Figure 4 appear to be reasonable values. The average and median values of annual rainfall for the period of 1948-2015 are 47.6 and 46.9 inches, slightly lower than the reported average annual rainfall of 50.79 inches in Ocala, Florida (http://www.usclimatedata.com /climate/ocala/florida/united-states/usfl0355). Rainfall data in Ocala are collected from rain gauges at the NOAA station (network ID: USC00086414; Latitude: 29.1638°; Longitude: -82.0777°). Rhew (2016) reported that long-term average annual rainfall at Lake Weir based on the Doppler radar converted data for the period from 2000 through 2012 was 47 inches, close to the annual average rainfall of 45.35 inches for the same period calculated from the provided rainfall data.

The provided evaporation data is calculated using the Hargreaves approach. Locations of evaporation stations and Thiessen polygon are given in Figure 5. The calculated evaporation data from the closest station of Ocala will be used in the watershed HSPF model. A multiplier of 0.8101 was developed by the SJRWMD to adjust the calculated evaporation values by the Hargreaves approach to match the GOES PET estimates, as shown in Figure 6. The provided PET data as shown in Figure 6 appear to be reasonable values.

Theoretically, the measured lake evaporation is close to PET because there is always sufficient water available in the lake for evaporation. In cooperation with the SJRWMD and SFWMD, Schiffer (1998) of USGS reported that the average annual lake evaporation for the period of 1960-1988 for the central Florida area was about 51 inches based on the long term pan evaporation measurement and pan coefficient. This reported annual lake ET is very close to the annual PET of 50.5 inches provided by the SJRWMD for the same period of 1960 to 1988. Visher and Hughes (1969) developed the map of annual lake ET for Florida. Based on the reported values of annual lake ET by Visher and Hughes (1969), the annual PET at Lake Weir was approximately 46 – 48 inches. The average annual PET provided by the SJRWMD for the period of 1948 to 1969 is 49.7 inches which is close to that reported by Visher and Hughes (1969). Therefore, the provided PET data by the SJRWMD appears to be reasonable values.

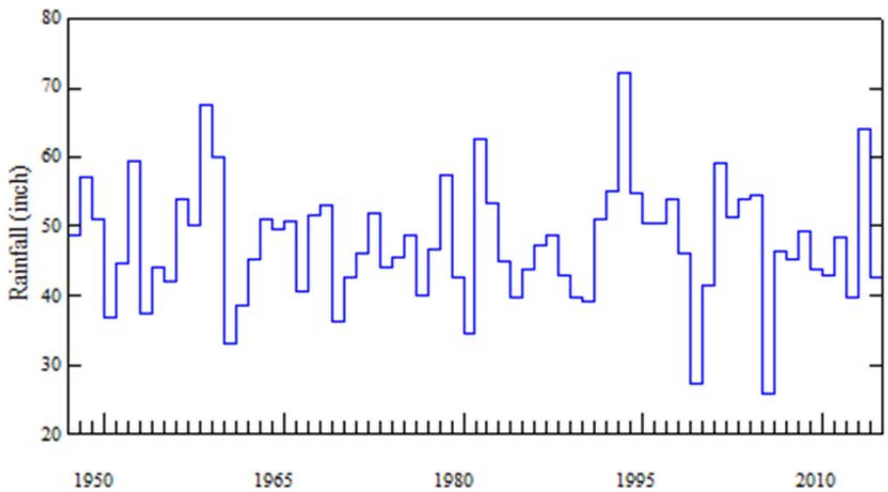

Figure 4 – Annual Rainfall Data at Lisbon station

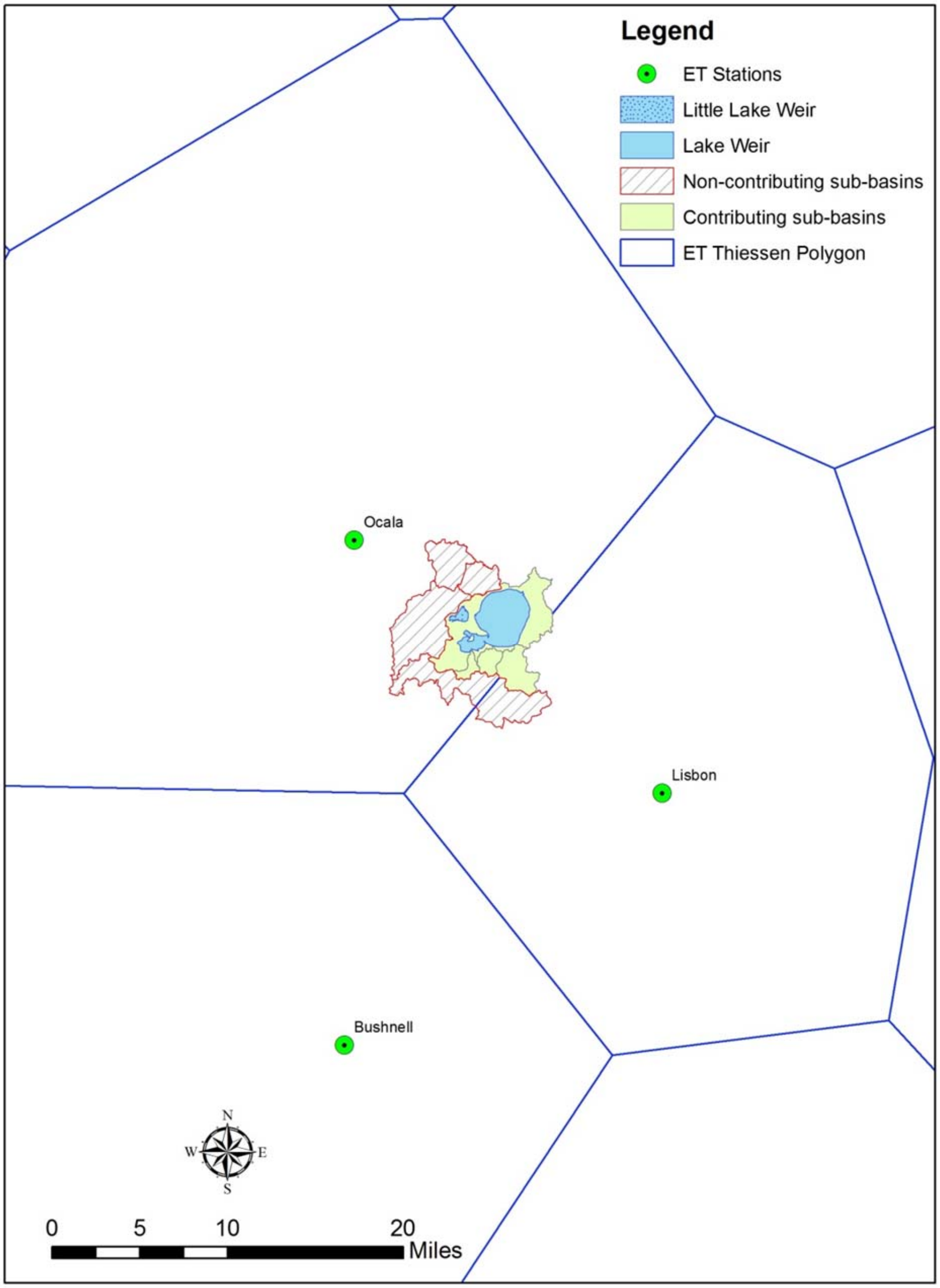

Figure 5 – Locations of ET Stations and Thiessen Polygon

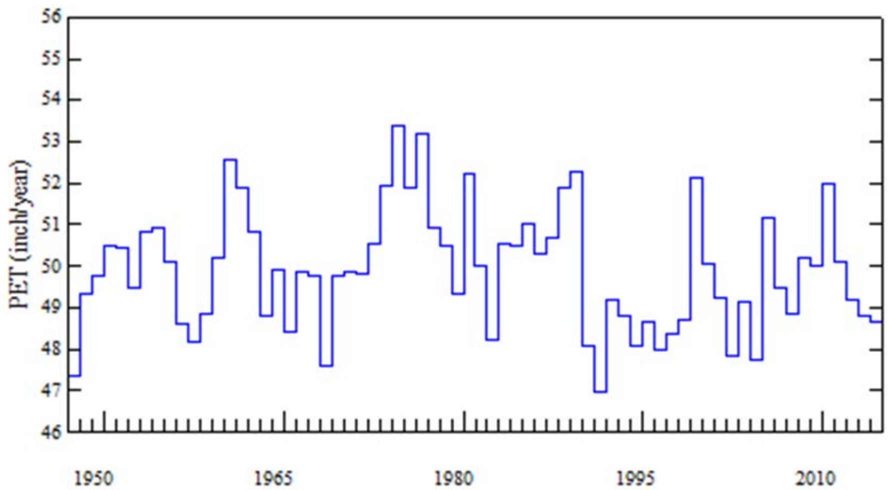

Figure 6 – Annual PET Data at Lake Weir

1.4 Surface Water Withdraw

There are three permits issued to withdraw water from Lake Weir and one permit issued to pump water from Little Lake Weir (Figure 7). A data request to the SJRWMD's Water Use Bureau originating from a SJRWMD staff showed that all the reported withdraws for these permits were either zeros or blank. Hence, these water withdraw facilities will not be included in the watershed model.

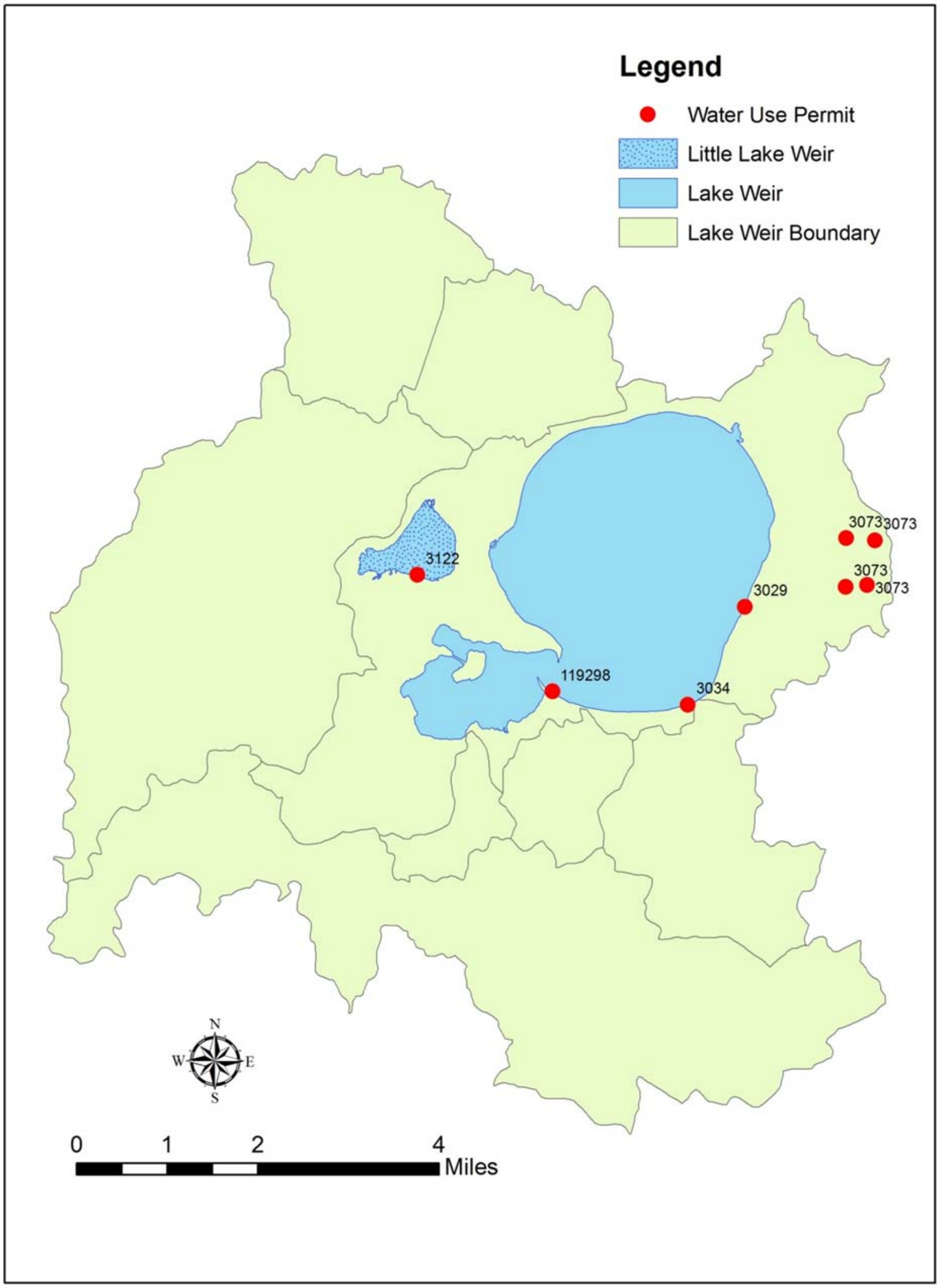

Figure 7 – Locations of Consumptive Use Permits from Surface Water in Lake Weir Basin

1.5 GIS Spatial Data

The SJRWMD land cover data will be used to set up the Lake Weir HSPF model, and the land uses will be aggregated into 13 categories that were provided by the SJRWMD. The soil map and recharge map will be used as the guidance to estimate the initial hydrological parameters. The DEM elevation data was used to delineate the Lake Weir basin and confirm the basin boundary provided by the SJRWMD, which is given in Section 3.

2. Proposed HSPF Model Calibration Period

To develop a robust HSPF model, a 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 proposed 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 annual rainfall data at Lisbon during 1948 to 2015 are given in Figure 4. The maximum, minimum, average, and median values of annual rainfall are 72.3, 25.7, 47.6, and 46.9 inches, respectively. The annual rainfall data at Lisbon for the calibration period are given in Figure 8. Year 2006 has the lowest rainfall of 25.7 inches, which is also the historical lowest value since 1948. Year 2014 is a wet year and has an annual rainfall of 64.1 inches, corresponding to the 95.6 percentile value of the annual rainfall for the period of 1948 to 2015. Several years in the calibration period has annual rainfall of 46 to 49 inches, which represents the normal hydrological conditions. Hence, the proposed calibration period of 2003 to 2014 covers all dry, wet, and normal hydrological conditions, as shown in Figure 9.

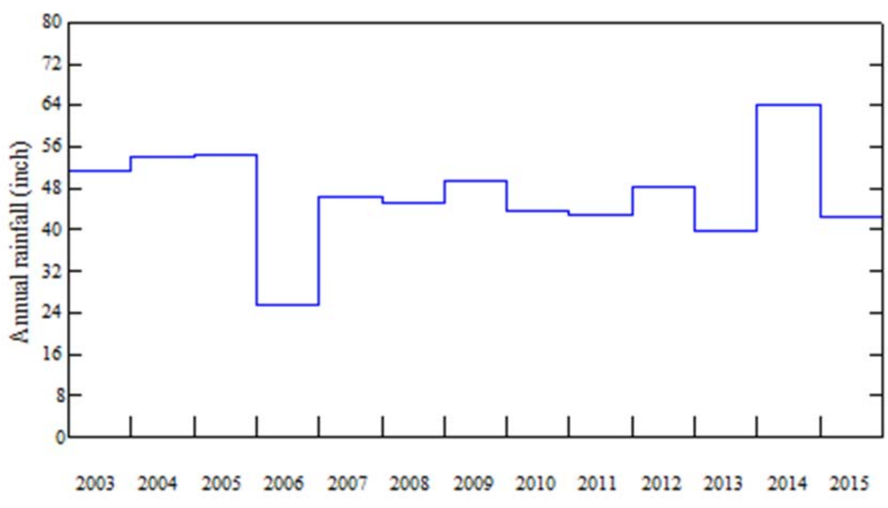

Figure 8 – Annual Rainfall at Lake Weir for the Calibration Period

3. CONFIRMATION OF LAKE WEIR BASIN BOUNDARY

The SJRWMD provided the boundary for Lake Weir basin as shown in Figure 9. ArcHydro was applied to delineate the Lake Weir Basin using the 10-m DEM data (Figure 10). The DEM contour data were not used because the 10-m DEM data provides better resolution than the 5-foot elevation contour and the 1-foot elevation contour is not complete and only covers the south part of the sub-basin of Morriston and Weirsdale Slough.

The standard steps for watershed delineation using ArcHydro include fill sinks, generate flow direction, generate flow accumulation, define stream, segment stream, delineate catchment grid, process catchment polygon, process drainage line, and process drainage point. When defining the stream, the stream threshold to initiate a stream is 0.45 square miles.

The total drainage area of the Lake Weir Basin provided by the SJRWMD is 40,215 acres, whereas the drainage area delineated by ArcHydro with the 10-m DEM is 41,535 acres, as shown in Table 1. The difference of the drainage area between the two drainage boundaries is about 3.3%. For the contributing area to Lake Weir including sub-basin of Lake Weir, Lake Weir Tributary 1, Lake Weir Tributary 2, and Weirsdale, the drainage area by the SJRWMD is 17,982 acre, whereas the area delineated by ArcHydro with the 10-m DEM is 19,912 acres. The difference of the calculated contributing area between the two drainage boundaries is about -10.7%.

Table 1 – Area of Sub-basins at Lake Weir

Sub-basin name	Sub-basin ID	Area by SJRWMD	Area by ArcHydro
Lake Weir	1	13,650	15,786
Lake Weir Tributary 1	2	1,041	770
Lake Weir Tributary 2	3	631	712
Weirsdale Slough	4	2,660	2,644
Morriston Noncontributing Area	5	8,866	9,629
Tiger Lake	6	7,967	5,978
Bowers Lake	7	2,154	2,181
Smith Lake	8	3,246	3,835
Total		40,215	41,535

It was noted that much smaller drainage area of Little Lake Weir, as shown in Figure 10, was obtained with the 10-m DEM data. However, based on the 5-foot contour line and Google Map Satellite Image, it was found that the sub-basin boundary by SJRWMD is a more representative delineation for the Little Lake Weir area and the other areas that do not completely overlap each other. In addition, it was found that the basin delineation by the District was obtained from QuadBasin (Hydrologic Surface Water Basin) by SJRWMD. QuadBasin applied the USGS 7.5 minute topographic map (scale of 1:24,000) with DEM resolution of 2.438 meter, which has much finer resolution than the 10-m DEM data used by the ArcHydro delineation. During the delineation process, the QuadBasin boundaries were corrected based on specific site knowledge (Adamus et al., 1997). Hence, it is determined that the basin boundary of

Lake Weir provided by the SJRWMD is reasonably accurate and sufficient for the development of a watershed hydrological model.

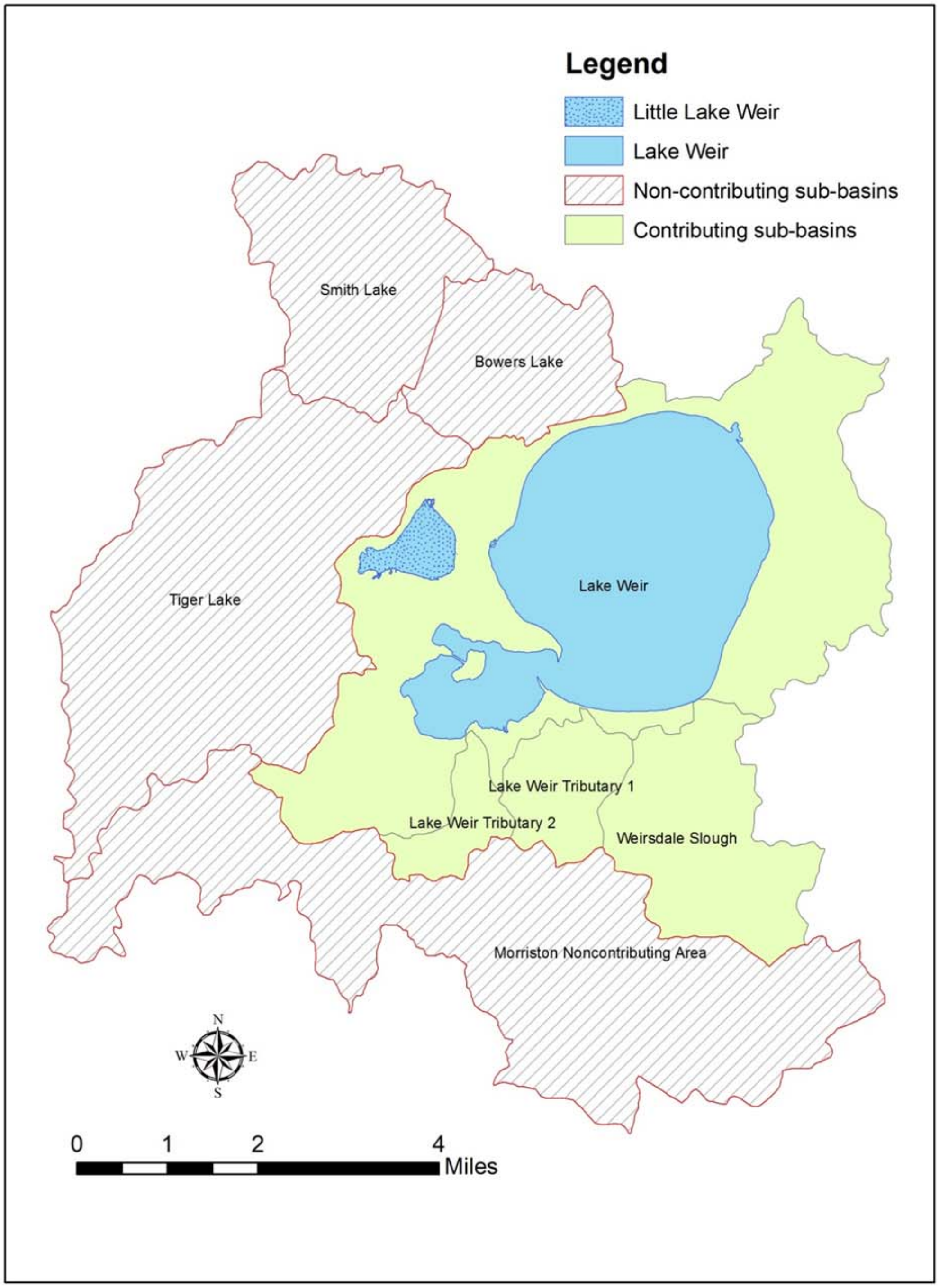

Figure 9 – Basin Boundary of Lake Weir provided by the District

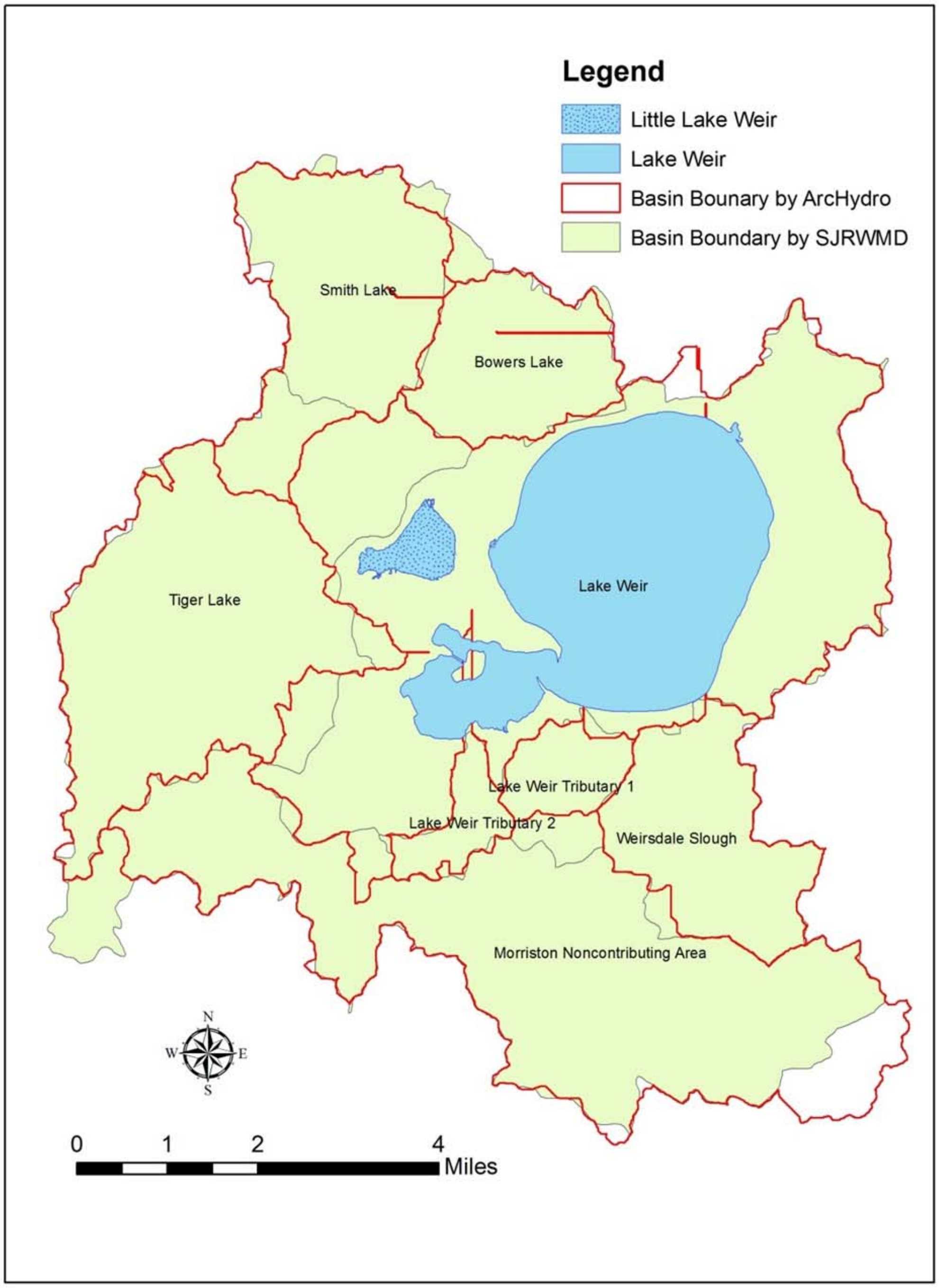

Figure 10 – Delineated Basin Boundary of Lake Weir by ArcHydro

For the Lake Weir watershed boundary as shown in Figure 9, there are four sub-basins which do not directly contribute their surface runoff to Lake Weir but might contribute their base flow to Lake Weir. These four sub-basins are the Bowers Lake, Smith Lake, Tiger Lake, and Morriston sub-basins.

Within HSPF, base flow is simulated as the outflow from active groundwater storage (Bicknell et al., 2001). The outflow from active groundwater storage is estimated based on a simplified model, which assumes that the discharge of an aquifer is proportional to the product of the cross-sectional area and the energy gradient of the flow (Bicknell et al., 2001).

In order to assess whether these four sub-basins contribute their base flow to Lake Weir, monthly average groundwater table maps were created using the groundwater well stage data collected from the surficial aquifer (SA) that are located in the jurisdiction of the SJRWMD and SWWMD as shown in Figure 11. Six time frames were chosen to represent the general condition of the groundwater flow. First, 2006, 2014, and 2012 were selected to represent the dry, wet, and normal hydrological conditions. Second, for each year, two months (a dry and wet month) were selected and the monthly average well stage was calculated for each well. Finally, the groundwater table maps were created for these six time frames.

The monthly rainfall data of 2006, 2012, and 2014 are given in Figures 12-14. The months of January and June are selected for all these three years. The groundwater table map for January 2006, June 2006, January 2012, June 2012, January 2014, and January 2014, are given in Figures 15-20.

Based on these groundwater table maps as shown in Figures 15-20, 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, it can be reasonably assumed that three of the four non-contributing sub-basins, that is, the Bowers Lake, Smith Lake, and Tiger Lake sub-basins do not contribute their base flow to Lake Weir since Lake Weir is located east of these sub-basins. There might be some small percentage of base flow contribution from the Morriston sub-basin when the groundwater flows from southeast to northwest. Results from the groundwater table analysis confirmed the District basin delineation that Bowers Lake, Smith Lake, and Tiger Lake are non-contributing sub-basins.

The final basin boundary for Lake Weir is shown in Figure 21 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.

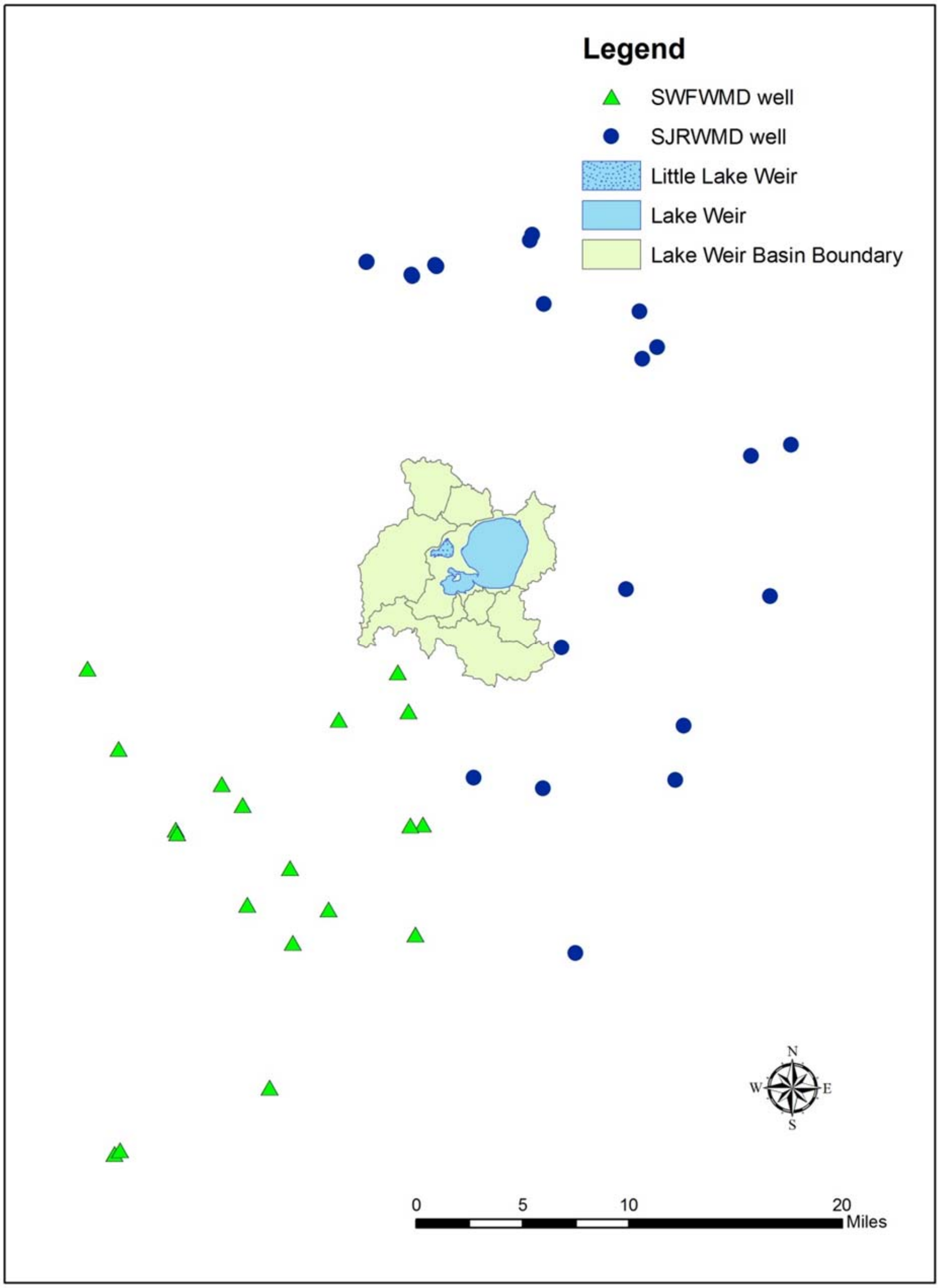

Figure 11 – Location of the SJRWMD and SWWMD Groundwater Wells in SA

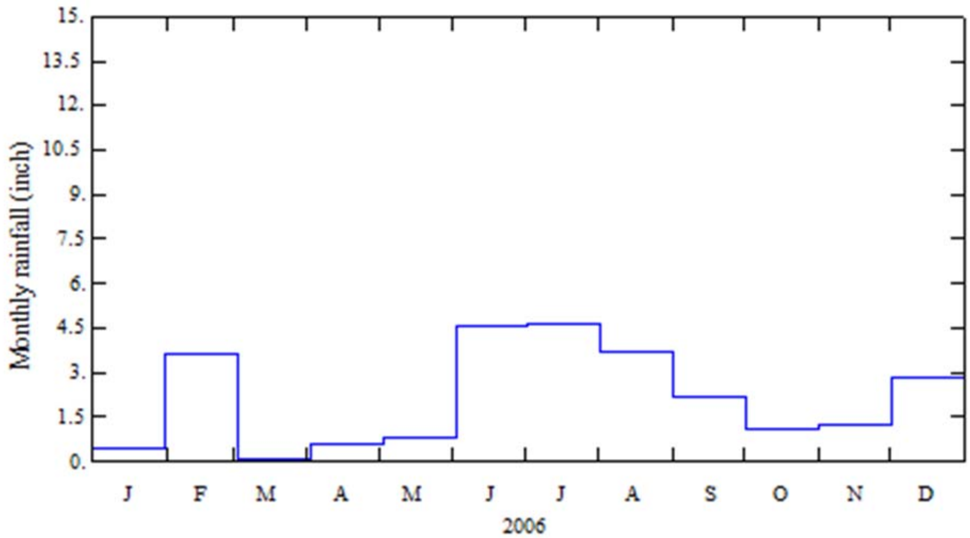

Figure 12 – Monthly Rainfall of 2006 at Lake Weir

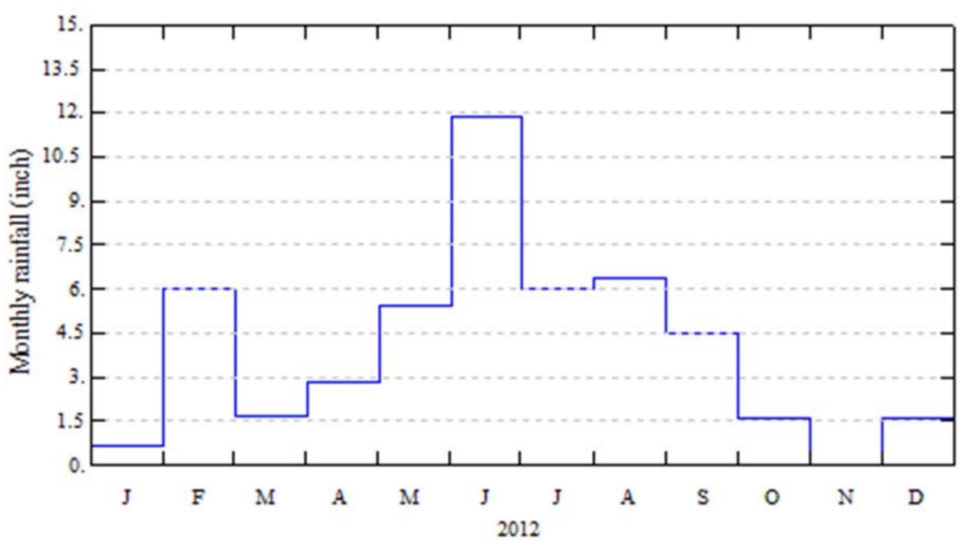

Figure 13 – Monthly Rainfall of 2012 at Lake Weir

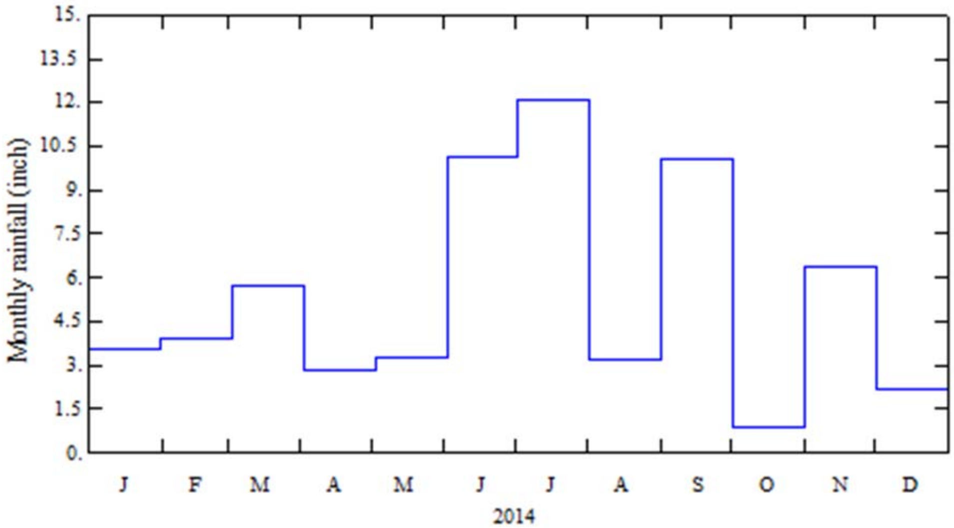

Figure 14 – Monthly Rainfall of 2014 at Lake Weir

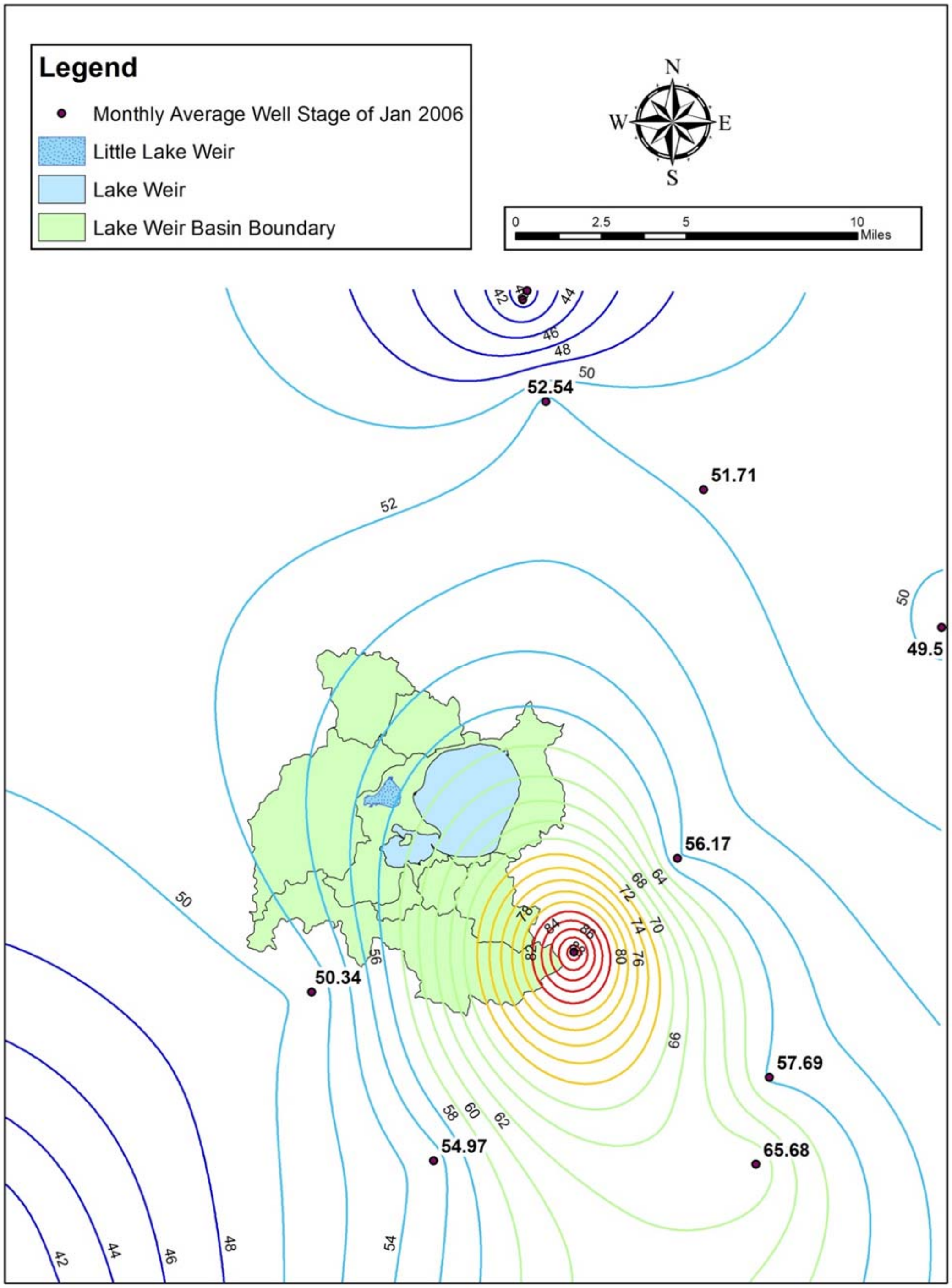

Figure 15 – Monthly Average Groundwater Table Map for January of 2006

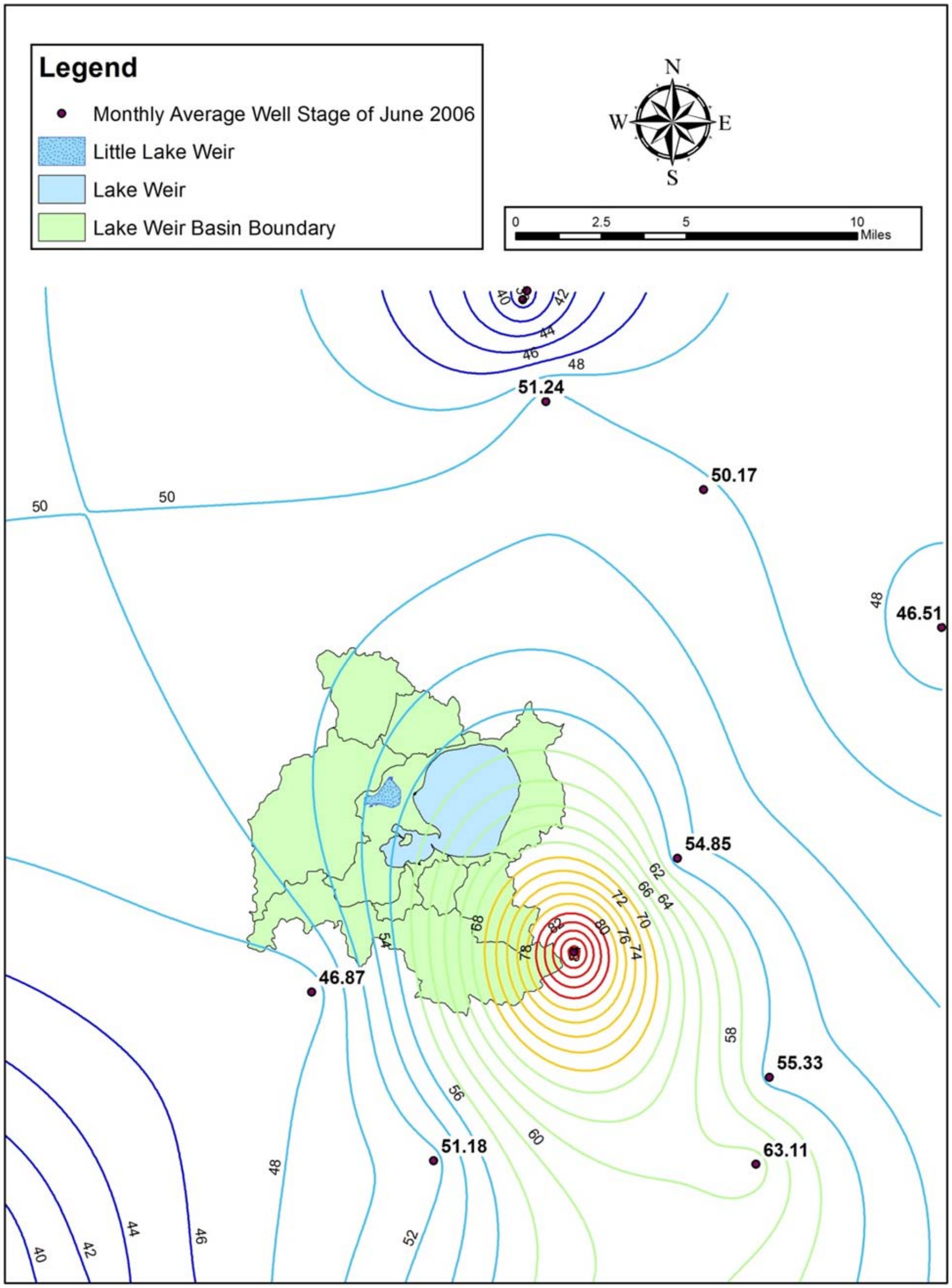

Figure 16 – Monthly Average Groundwater Table Map for June of 2006

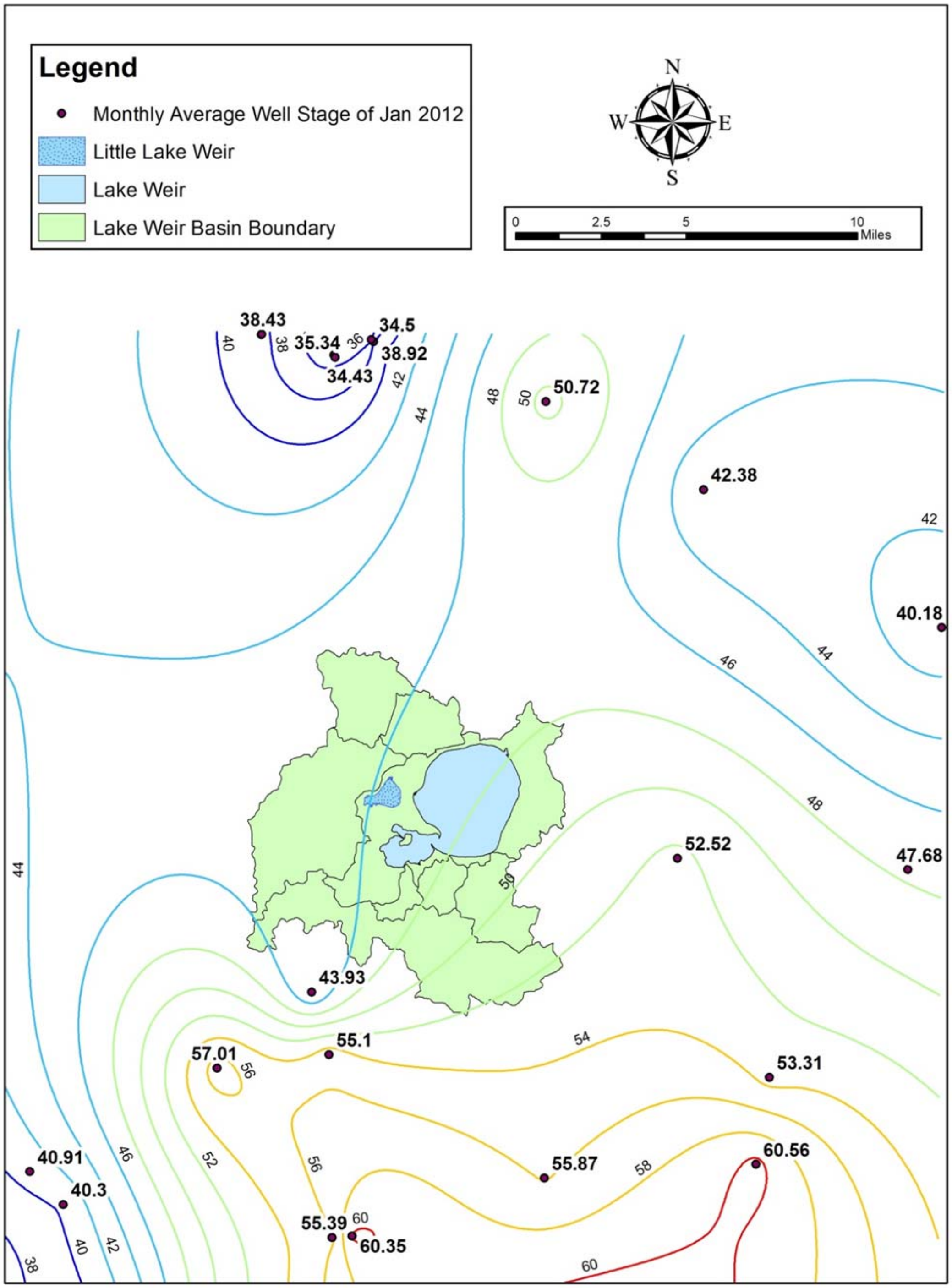

Figure 17 – Monthly Average Groundwater Table Map for January of 2012

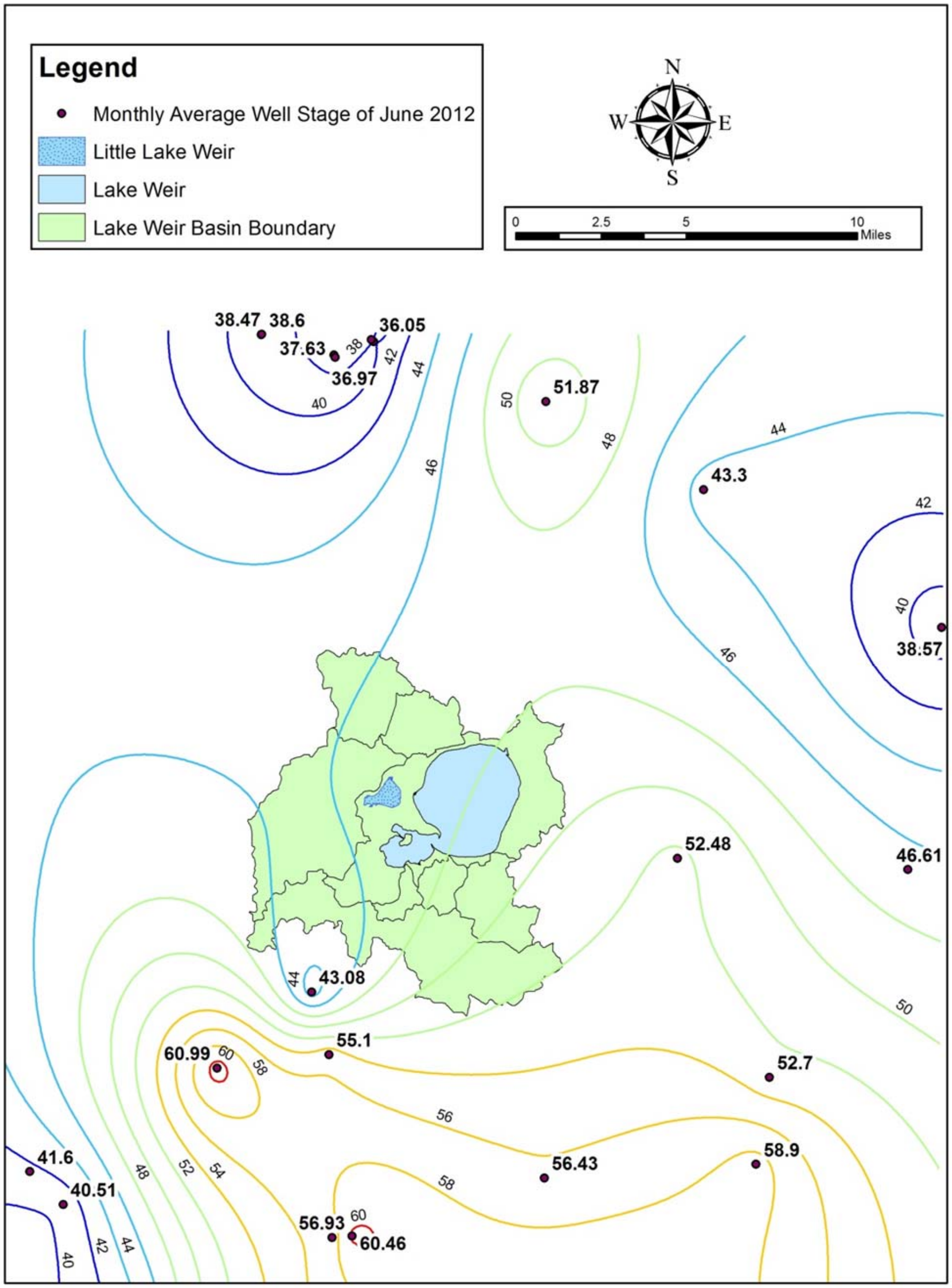

Figure 18 – Monthly Average Groundwater Table Map for June of 2012

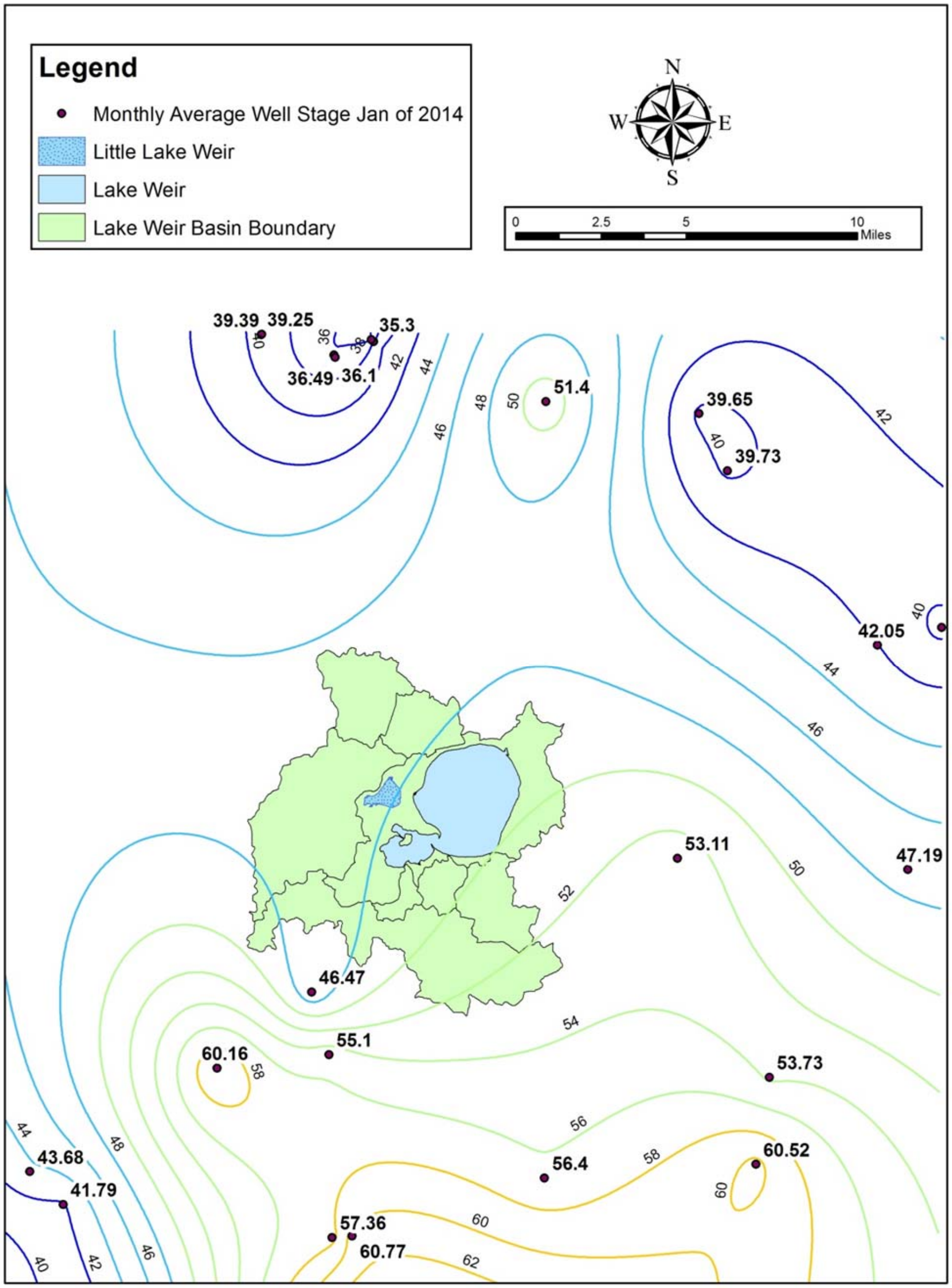

Figure 19 – Monthly Average Groundwater Table Map for January of 2014

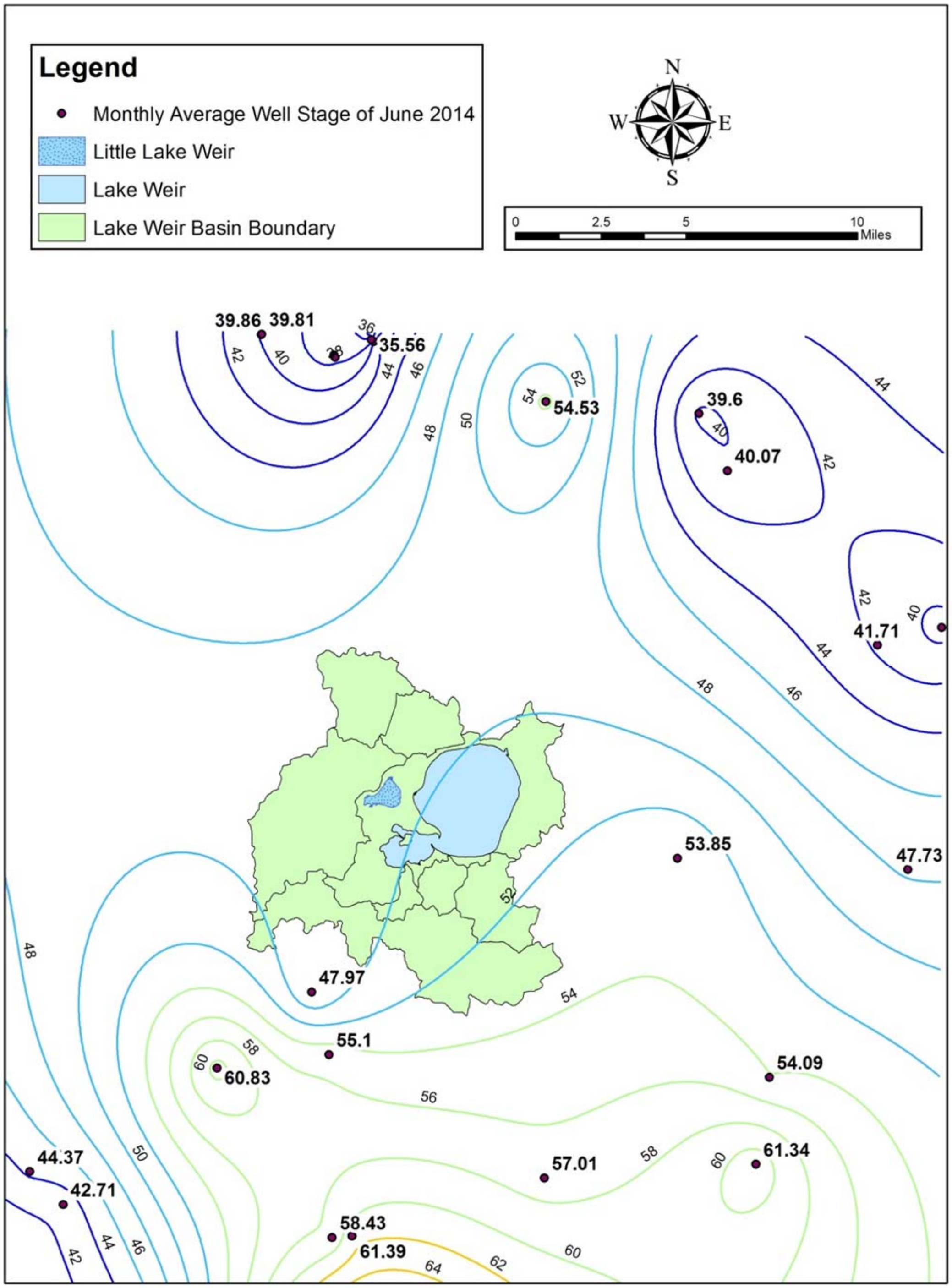

Figure 20 – Monthly Average Groundwater Table Map for June of 2014

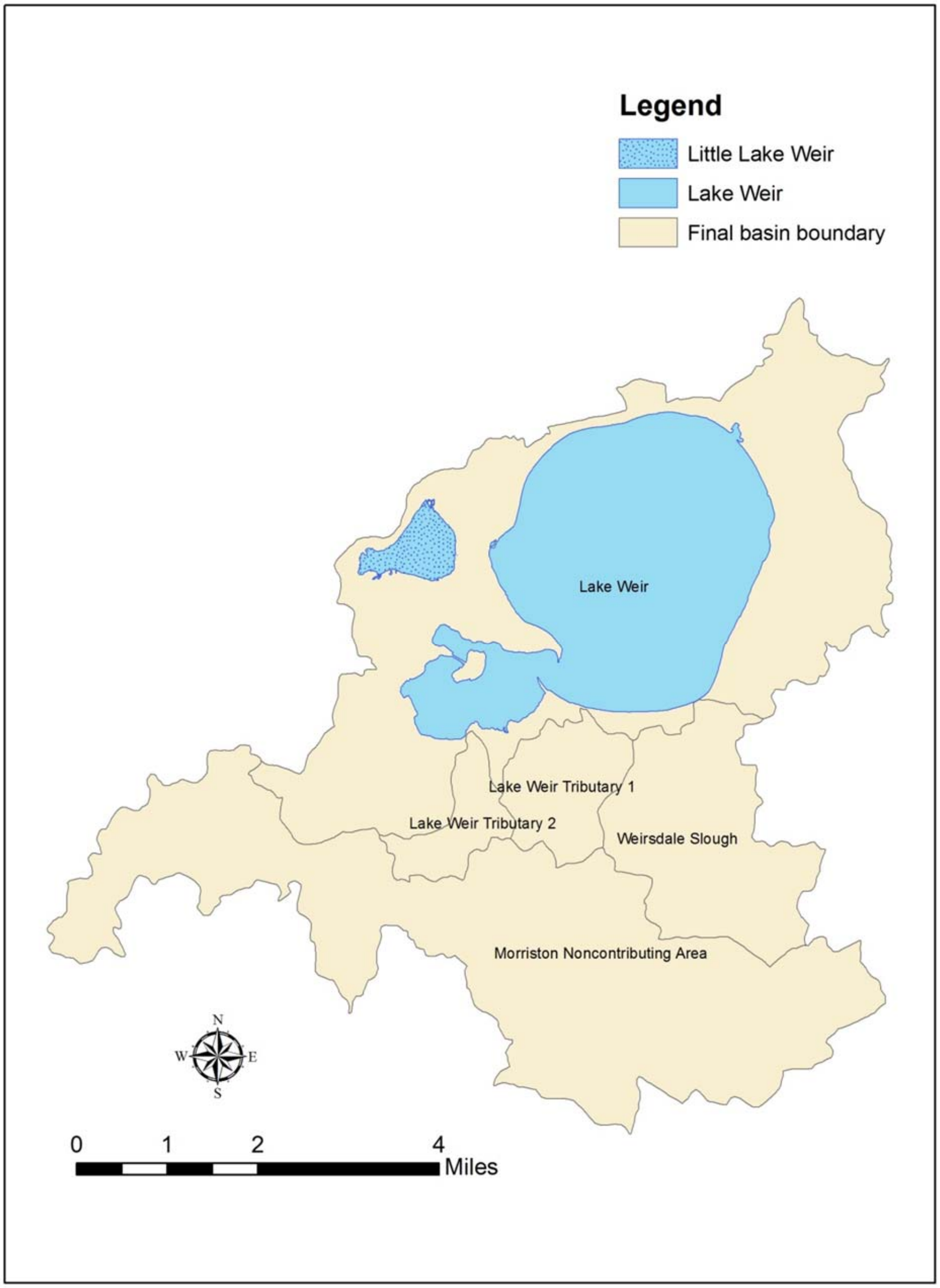

Figure 21 – Final Basin Boundary for Lake Weir

4. FLOW DIRECTION OF THE UPPER FLORIDAN AQUIFER

Following the same procedure of creation of the monthly average groundwater table maps discussed in Section 3, the monthly average groundwater potentiometric maps of the Upper Floridan Aquifer (UFA) were created to assess the general flow direction of the groundwater in the UFA using the well stage data collected from the UFA that are located in the jurisdiction of the SJRWMD and SWWMD, as shown in **Error! Reference source not found.**.

The groundwater potentiometric maps for January 2006, June 2006, January 2012, June 2012, January 2014, and January 2014, are given in Figures 23-28. Based on these groundwater potentiometric maps as shown in Figures 23-28, it can be determined that the general flow direction of the ground water in the UFA in the vicinity of Lake Weir is either from east to west or from southeast to northwest.

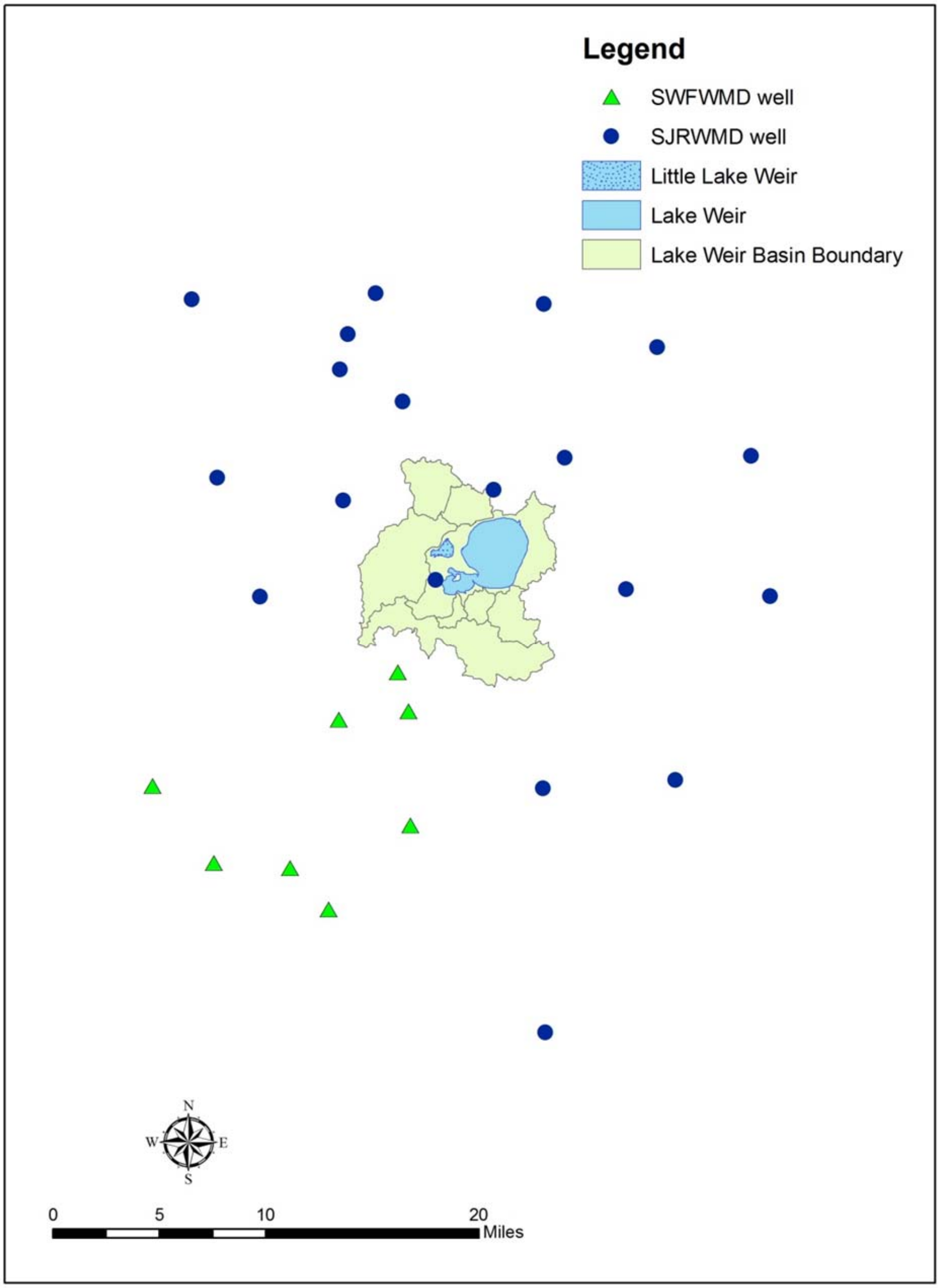

Figure 22 – Location of the SJRWMD and SWWMD Groundwater Wells in the UFA

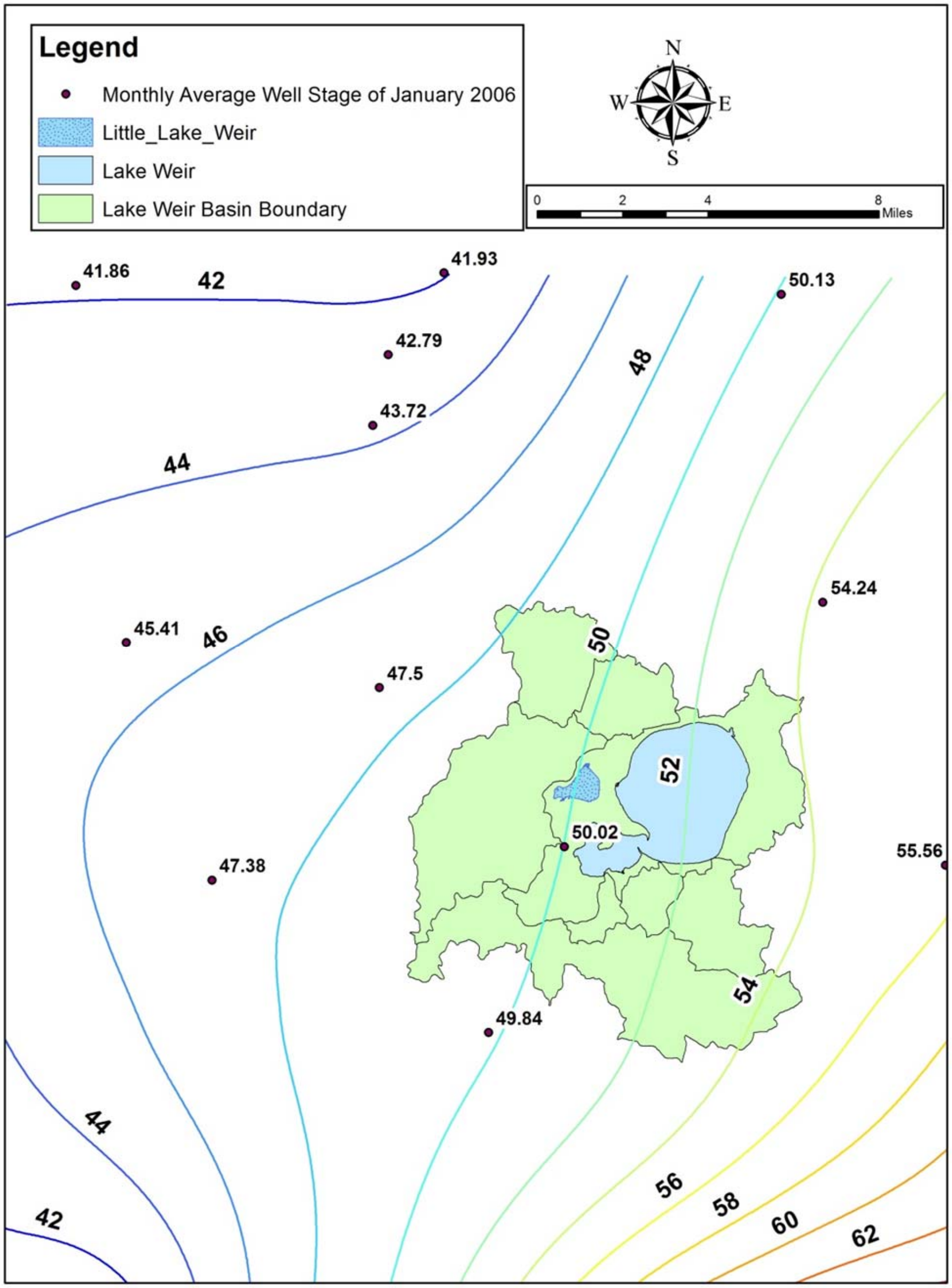

Figure 23 – Monthly Average Groundwater Potentiometric Map for January of 2006

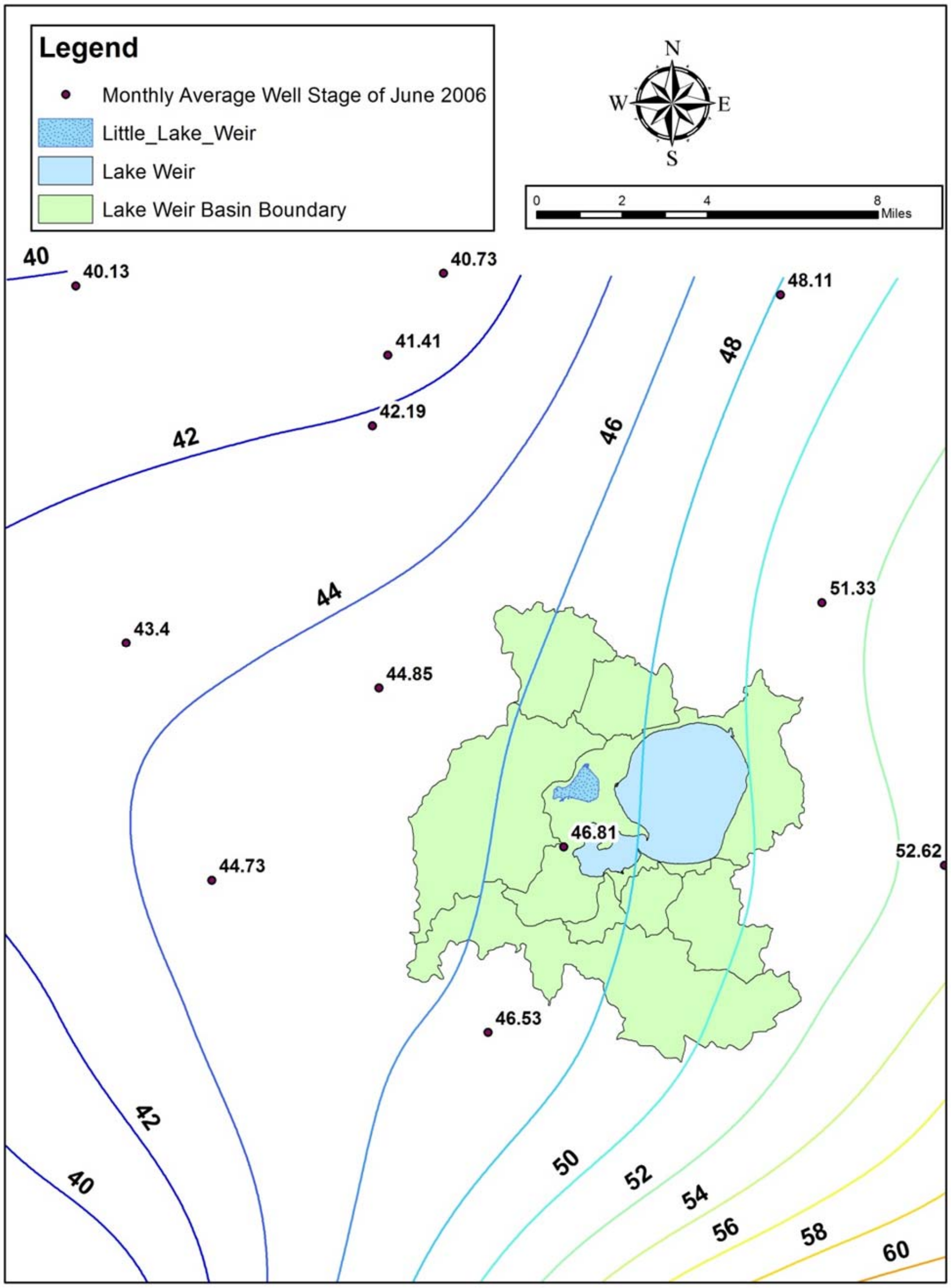

Figure 24 – Monthly Average Groundwater Potentiometric Map for June of 2006

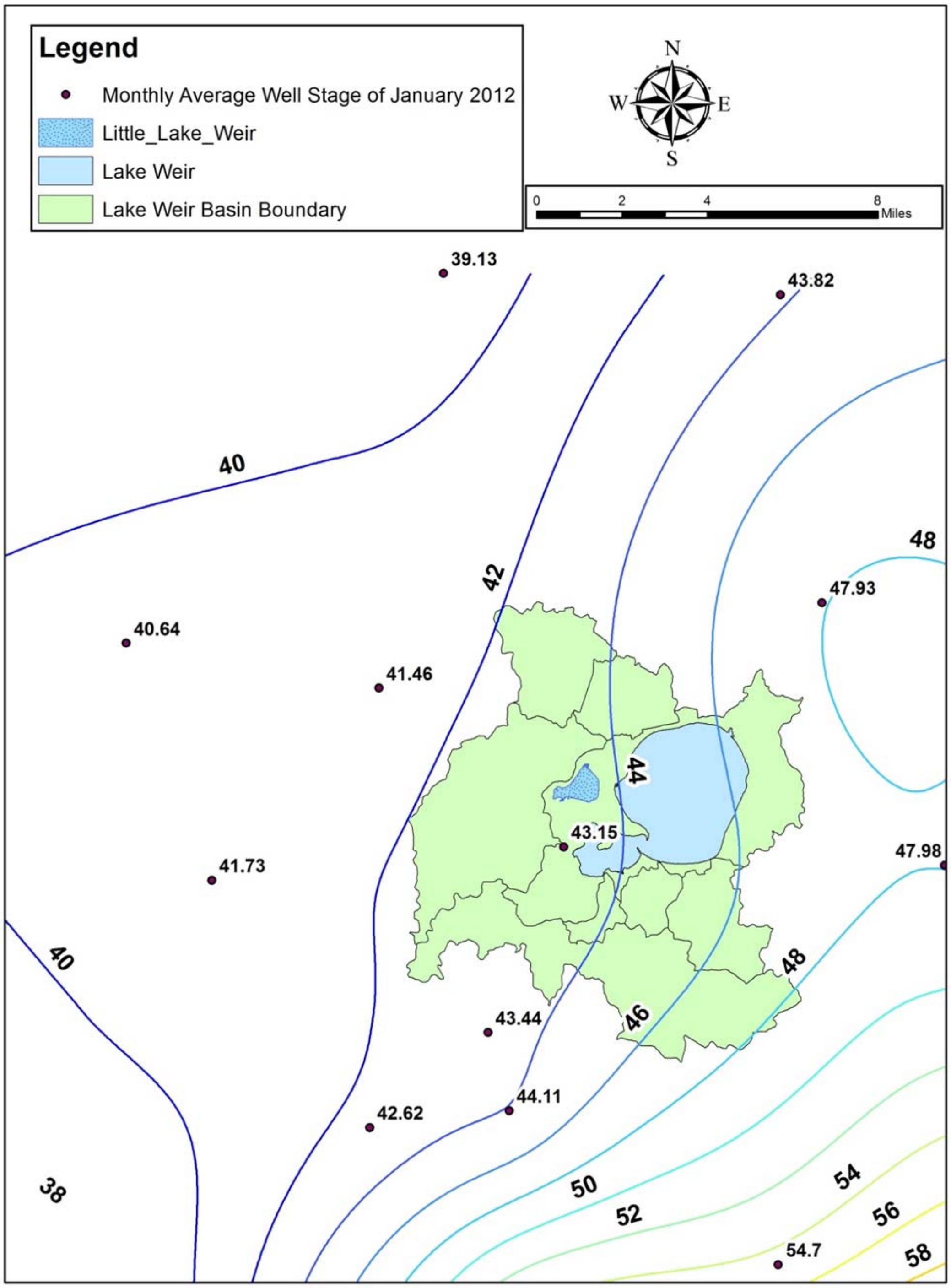

Figure 25 – Monthly Average Groundwater Potentiometric Map for January of 2012

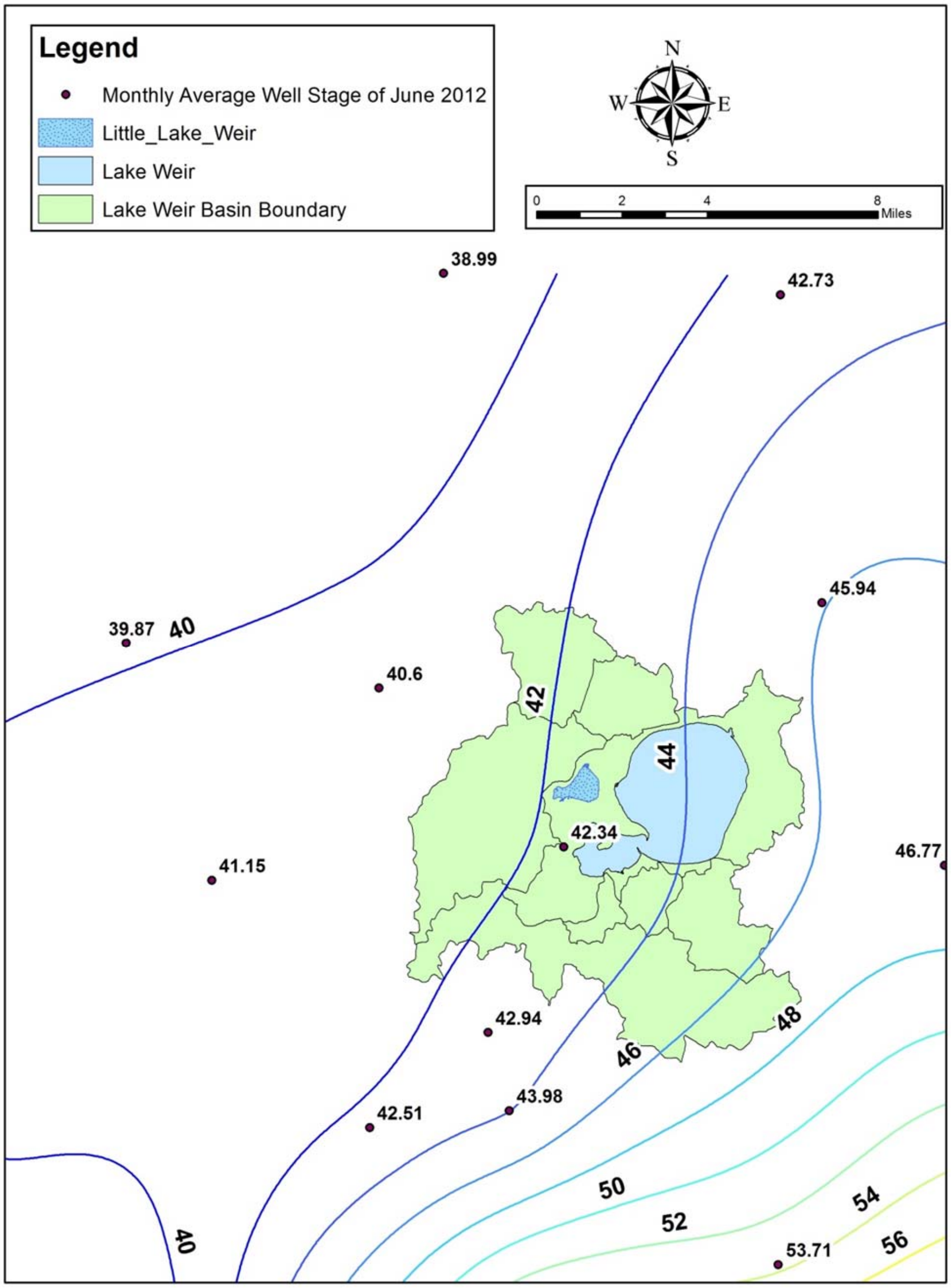

Figure 26 – Monthly Average Groundwater Potentiometric Map for June of 2012

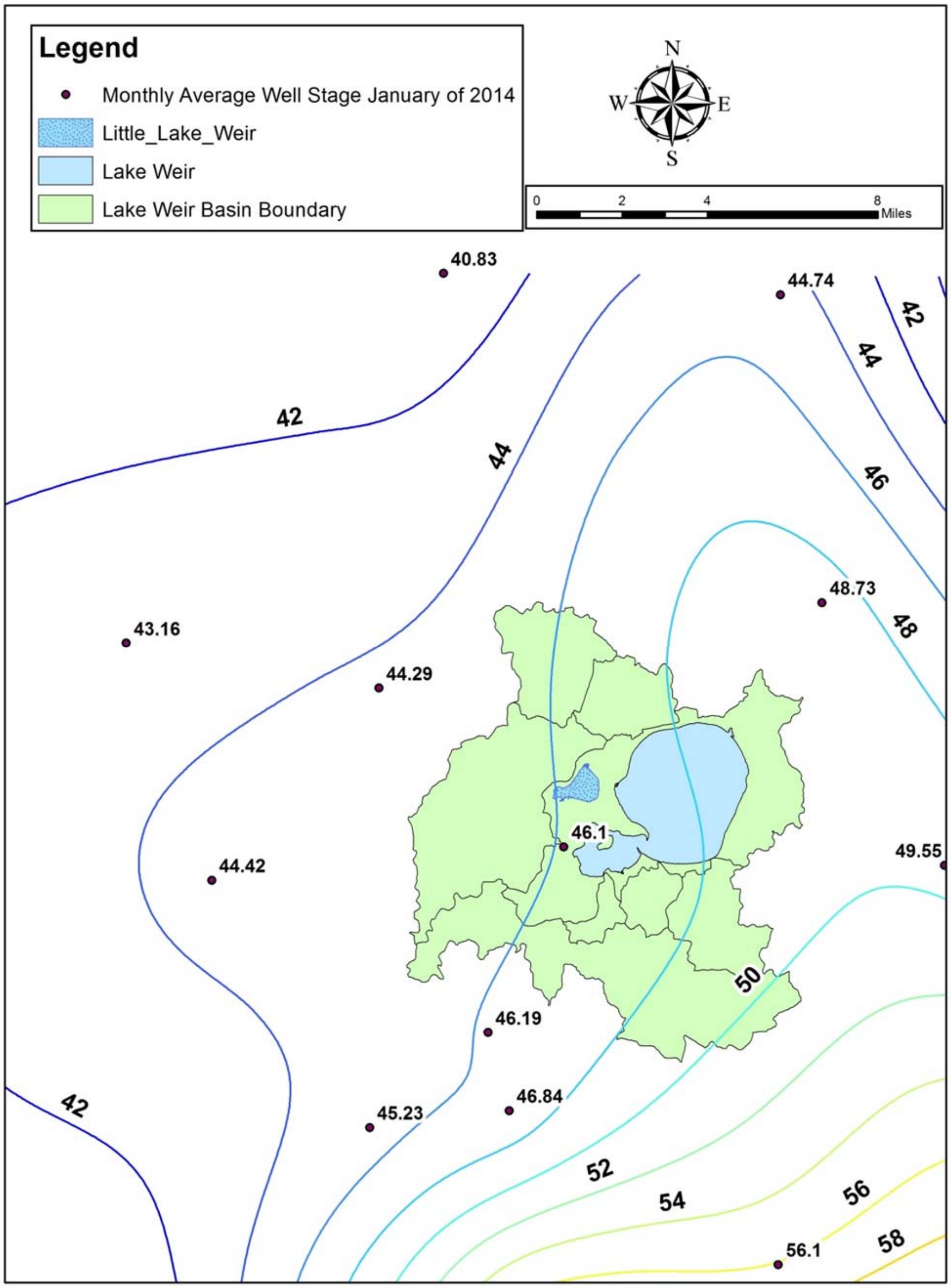

Figure 27 – Monthly Average Groundwater Potentiometric Map for January of 2014

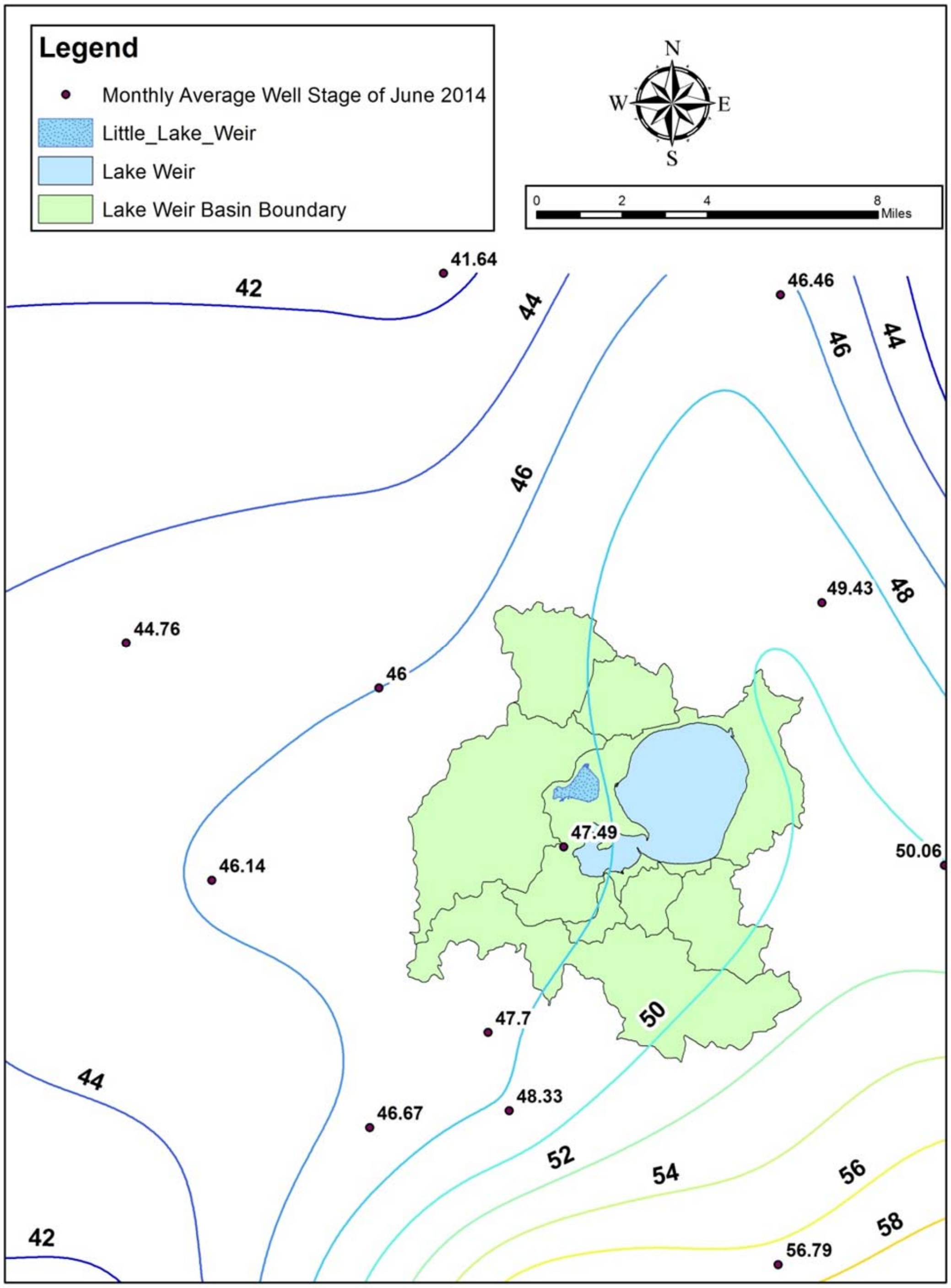

Figure 28 – Monthly Average Groundwater Potentiometric Map for June of 2014

5. REFERENCES

Adamus, C., Clapp, D., and Brown, S. 1997. Technical Publication Sj97-1 Surface Water Drainage Basin Boundaries St. Johns River Water Management District: A Reference Guide. Online available at: http://www.sjrwmd.com/technicalreports/pdfs/TP/SJ97-1.pdf

Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jobes, T.H., and Donigian, A.S. 2001. Hydrological Simulation Program Fortran (HSPF) User's Manual for Release 12. U.S. EPA National Research Laboratory. Athens, GA.

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

Rhew, Kyeongsik, 2016. Revised Draft Nutrient TMDL for Lake Weir (WBID 2790A). Water Quality Evaluation and TMDL Program. Division of Environment Assessment and Restoration. Florida Department of Environment Protection.

Schiffer, D.M. 1998. Hydrology of Central Florida Lakes: a Primer. U.S. Geological Survey, In Cooperation with the St. Johns River Water Management District and the South Florida Water Management District.

Visher, F.N. and Hughes, G.H. 1969. The Difference between Rainfall and Potential Evaporation in Florida, 2nd Ed. Florida Bureau of Geology Map Series 32, Tallahassee, FL.