APPENDIX A

Gather Existing Data and Models

To: Nicole Iadevaia; Jennifer Hecker; Andrew Webb;
Coastal and Heartlands National Estuary Partnership (CHNEP)

From: Marcelo Lago, PhD; Maria C. Bravo, PE, PhD;
Lago Consulting and Services, LLC;

Date: March 3rd, 2021 (with minor revisions on November 14, 2021)

Re: South Lee County Watershed Initiative Hydrologic Modeling Project: Task 1. Gather Existing Data and Models.
City of Punta Gorda PO No. 050909

Background

The Coastal and Heartland National Estuary Partnership (CHNEP) has selected Lago Consulting & Services to perform updated surface and ground water integrated modeling of the South Lee County area under the South Lee County Watershed Initiative (SLCWI). The main objective of the project is to develop a new MIKE SHE model of the area. The model will be used to evaluate various alternative water management scenarios for enhancement of the water and environmental resources of the region for the interest of the SLCWI stakeholders.

This technical memorandum summarizes the Task 1 activities of the project related to the compilation of existing data and models to build a new preliminary model for the area.

Recent Modeling Efforts

Input data and parameters from recent model efforts in the South Lee County watersheds were reviewed and used as starting point to develop the new existing conditions MIKE SHE model, referred herein as SLCWI model. The parent or reference models used in this project are listed below.

- Edison Farm MIKE SHE Model. Derived from the Village of Estero (VoE) Model [WSA, 2018], which was based on the Density Reduction Groundwater Recharge (DRGR) Model of the South Lee County region [DHI, 2009].
- The Corkscrew Swamp Sanctuary (CSS) MIKE SHE Model [WSA, 2020b]. Derived from the Big Cypress Basin (BCB) model [LAGO and Stanley, 2020] and the Edison Farm models.
- The Lehigh Acres Municipal Improvement District (LA-MSID) MIKE SHE Model [WSA, 2020a].
- The South Lee County Flood Mitigation Plan (SLCFMP) MIKE SHE Model [AIM, 2020]. Derived from the Village of Estero and the LA-MSID models.
- The City of Bonita Springs ICPR Model [LAGO, 2019].

A preliminary SLCWI Model was built after merging the MIKE SHE input files from the CSS and the Edison Farm models and using information and existing data from other previous models, as needed.

MIKE SHE Setup Summary

Table 1 summarizes the input data used for the different components in the preliminary SLCWI Model.

Table 1. MIKE SHE components and input data.

Project Task	MIKE SHE Component	Input data in the preliminary SLCWI Model
1	Model domain and grid	The domain is defined based on the extends of past models, the latest digital elevation model (DEM), and permit information. Grid cell size is 375 ft.
1, 2	Topography	One-meter resolution DEM from the USGS (based on 2018 LiDAR). 50-ft resolution DEM from the SFWMD (based on 2007 LiDAR) is used to fill the north-east corner of the model domain.
1, 6	Climate/ Precipitation	Hourly NEXRAD rainfall data from the SFWMD for the period of record (i.e., years 1996 through 2019). Rain gauge data used for verification.
1, 6	Climate/ RET	Daily Reference Evapotranspiration (RET) data from the USGS for the period of record (i.e., years 1985 through 2019).
1, 4	Land use/ Vegetation	Land use/ land cover data from the SFWMD for years 2014-2016. Areas covered with Willow at Corkscrew Swamp taken from the CSS model. Some recent urban developments included from aerial images. Vegetation parameter database taken from the CSS model. See Table 4 for more details. Pre-development vegetation adapted from the South West Florida Feasibility Study (SWFFS). This data will be used to build a pre-development model version, as part of Task 9.
1, 5	Land use/ Irrigation	Irrigation areas, rates, sources, and demand taken from CSS and Edison Farm models. Irrigated cells refined based on the vegetation coverage and water use permit information.
1, 6	River and Lakes/ MIKE11	River network adopted from previous models and refined in some areas. Cross sections adopted from previous models. New cross sections cut from the 2018 LiDAR DEM as deemed necessary. Initial water levels are taken from previous simulation results.

Project Task	MIKE SHE Component	Input data in the preliminary SLCWI Model
		Boundary conditions from surface water levels at observation stations. Time series files updated to the current time.
1	River and Lakes/ Flood codes	Flood codes merged from previous models. New flood codes added in lakes. Flood coded area consistent with the MIKE11 cross-section width.
1	Overland (OL)/ Parameters	Parameters from correlation with vegetation coverage. Initial water depth taken from previous simulation results
1	OL/ SOLFA	Separated OL flow areas (SOLFA) consider surface water divides at roads and berms.
1	Unsaturated Zone (UZ)/ Soil	The 2-layer water balance option with Green-Ampt method for infiltration NRSC soil distribution and depth-averaged parameters.
1	Saturated Zone (SZ)/ Geological Layers	Vertical extents adopted from Edison Farm and CSS models. Sandstone and Mid Hawthorne Aquifers included. Pre-calibration conductivity maps adopted from the Edison Farm model.
1	SZ/ Geological Lenses	Conceptual water lens at ponds and mining pits. Shell lens at Corkscrew Swamp as in the CCS model.
1, 6	SZ/ Computational Layers	Initial heads taken from previous simulation results Time varying head maps generated by interpolating observation station water levels and used as lateral boundary conditions. Coastal boundary at deeper aquifers is assumed closed.
1	SZ/ Drainage	Parameters from correlation with vegetation coverage. Drain codes based on the SOLFA map. Negative codes used to consider drainage to depressions. Some urban managed areas drain to specific MIKE11 branches with outfall structures.
1, 6	SZ Pumping	Potable water supply wells adopted from previous models and time series of monthly SFWMD pumping rates updated up to year 2019. Injection wells used to apply reuse water as reported by Lee County and Bonita Springs Utilities.
1, 6	Storing of Results	Observation station data from previous models and time series files updated. Some new observation station data added.
1	Extra parameters	Extra parameters adopted from previous models, which include sheet piling and specified reaches for drainage. Flag added to use MIKE1D engine instead of the classic MIKE11.

The SLCWI MIKE SHE model is built in the geographic projection "NAD_1983_HARN_StatePlane_Florida_East_FIPS_0901", even though model files appear to be in "NON-UTM" map projection. This is a "old-school" approach to have control over the geographic projection outside of MIKE SHE. The elevations in the model are referred to the datum NAVD88. The model runs in the 2019 version of the DHI software.

Model Domain and Grid

The proposed SLCWI model domain is shown in **Figure 1** together with some of the previous MIKE SHE model domains used for South Lee County. A comparison of the sizes of model domains and grid parameters is also shown in **Table 2**.

Table 2. Comparison of model domain and grid parameters.

Model	Grid cell size (ft)	Number of active cells	Model Domain Area (miles^2)	Year of last update
Edison Farm / VoE / DRGR	750	20,669	417	2019
SLCR		33,084	668	2020
BCB	500	71,560	642	2020
LA-MSID		32,721	293	2020
CSS	375	56,556	285	2020
SLCWI		72,001	363	2021

The proposed SLCWI model boundary includes more areas to the west as used than was considered in the recent CSS model. However, some areas in the CSS model near the south boundary are excluded to limit the model domain area and maintain reasonable run times. The Mirasol Flowway (that connects some southwesterly wetland slough segments of the Corkscrew Swamp to the Cocohatchee Canal) may be important in the proposed scenario evaluations and is included in the SLCWI model domain.

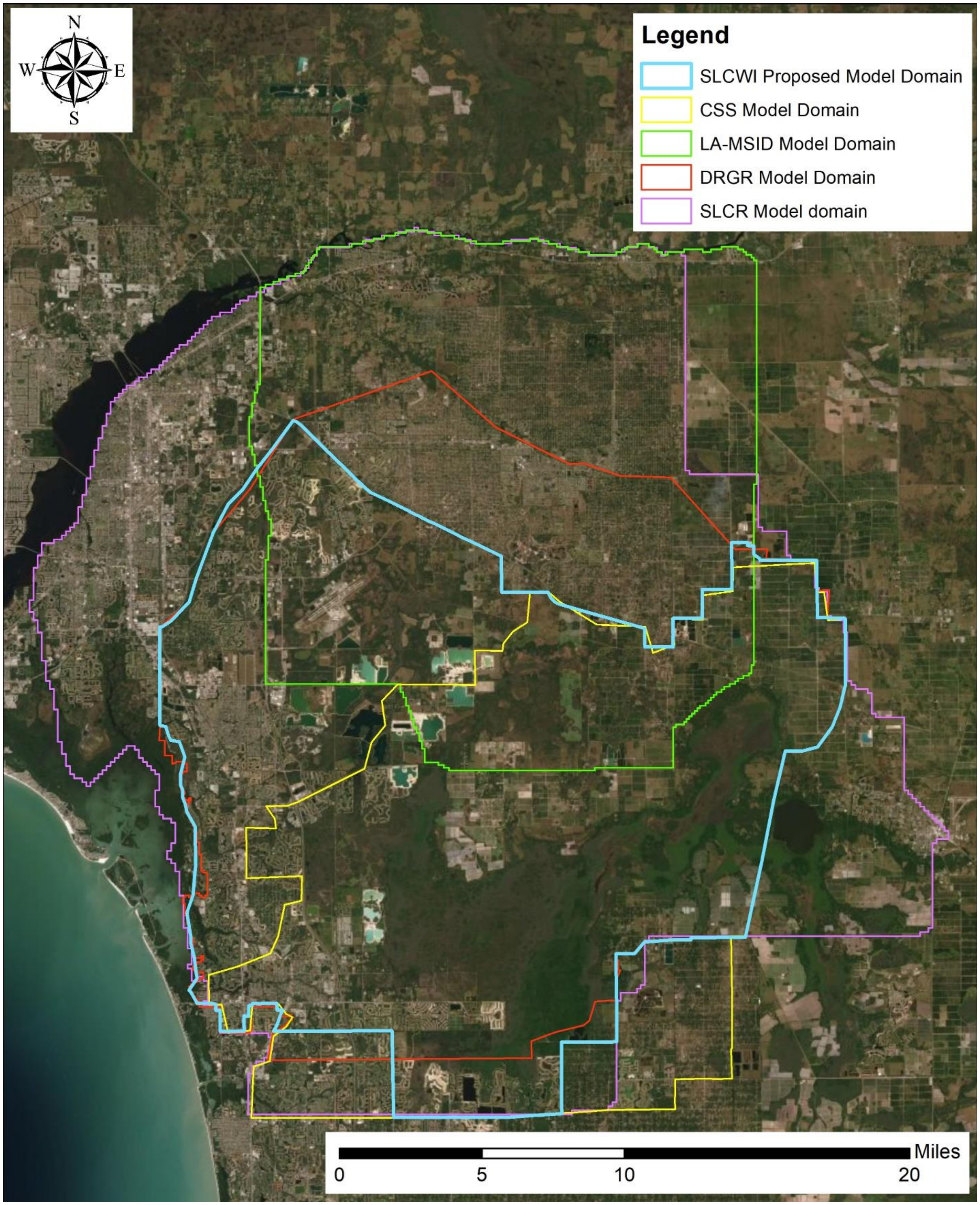

Figure 1. MIKE SHE model domains used for South Lee County.

Topography

The USGS has made available a 1-meter resolution digital elevation model (DEM) based on a LiDAR collected between May and October of 2018. This most recent LiDAR information, however, does not cover the northeastern corner of the model domain as shown in **Figure 2**. Hence, the 50-ft DEM from the SFWMD based on the 2007 LiDAR was used to fill that gap. **Figure 3** shows the composite map built by resampling the 2018-LiDAR DEM to 50-ft resolution (by using the center cell value method) and by filling the northeastern corner with the SFWMD 50-ft DEM. This composite 50-ft DEM will be used in this project to present model results such as hydroperiod and water depth maps at a finer resolution.

For input in the SLCWI model, the 50-ft DEM in Figure 3 was resampled to 375-ft resolution by using the area average method. In addition, the elevation in water classified cells was lowered 3 feet to compensate for the fact that the LiDAR does not penetrate the water surface. Water cells are typically ponds, lakes, or mining pits that are deeper than, for example, wetland classified cells. The resulting 375-ft DEM is presented in **Figure 4**.

During the CSS modeling project, it was noticed that the 2018-LiDAR based DEM may need modifications in certain areas of the Corkscrew Swamp Sanctuary. In Task 2, some ground elevation points have been proposed to be surveyed for comparison purposes. Thus, the DEMs presented in Figure 3 and Figure 4 are preliminary and may be modified from survey and other relevant data to be received during the project execution.

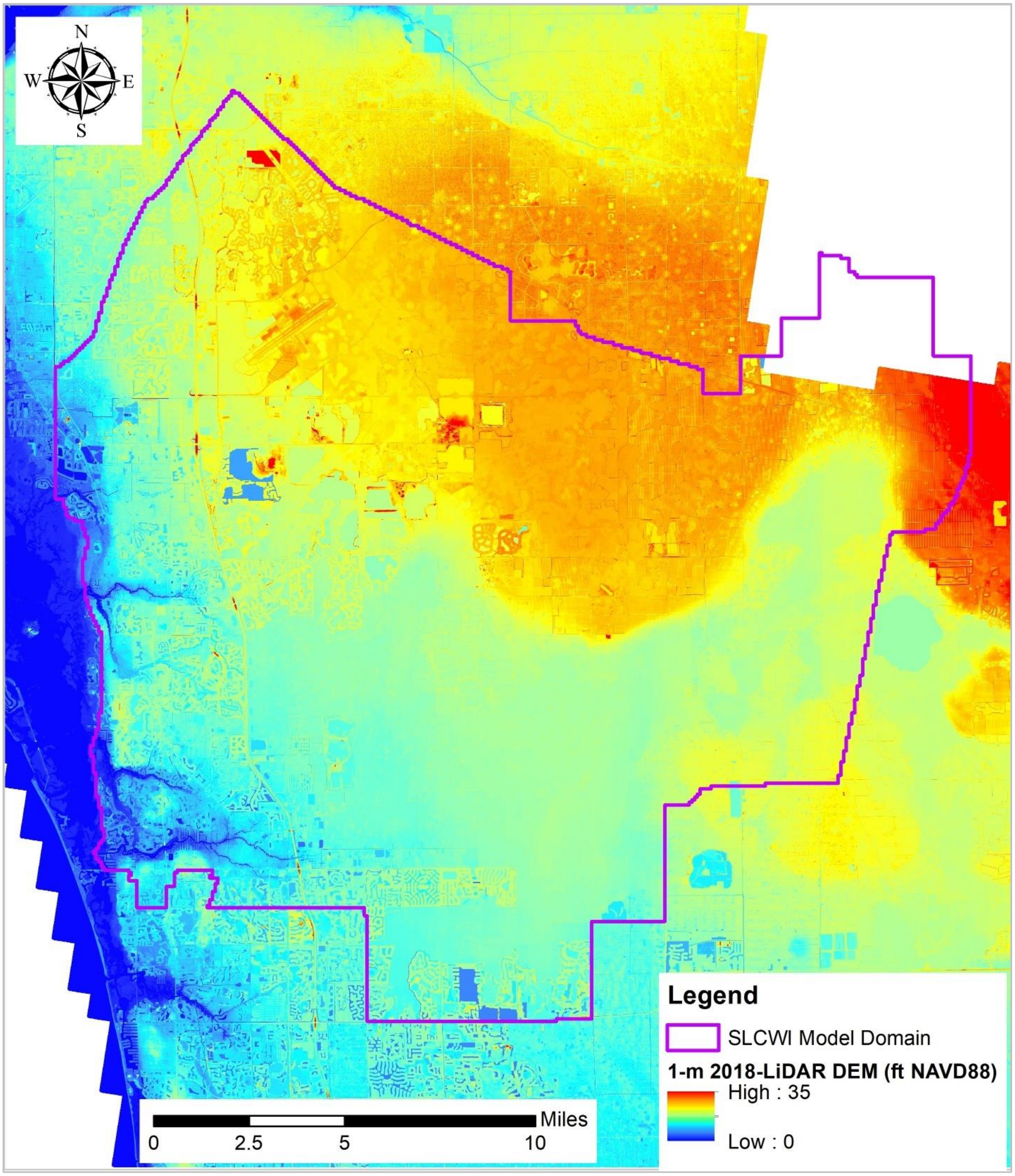

Figure 2. 1-meter resolution DEM based on 2018 LiDAR.

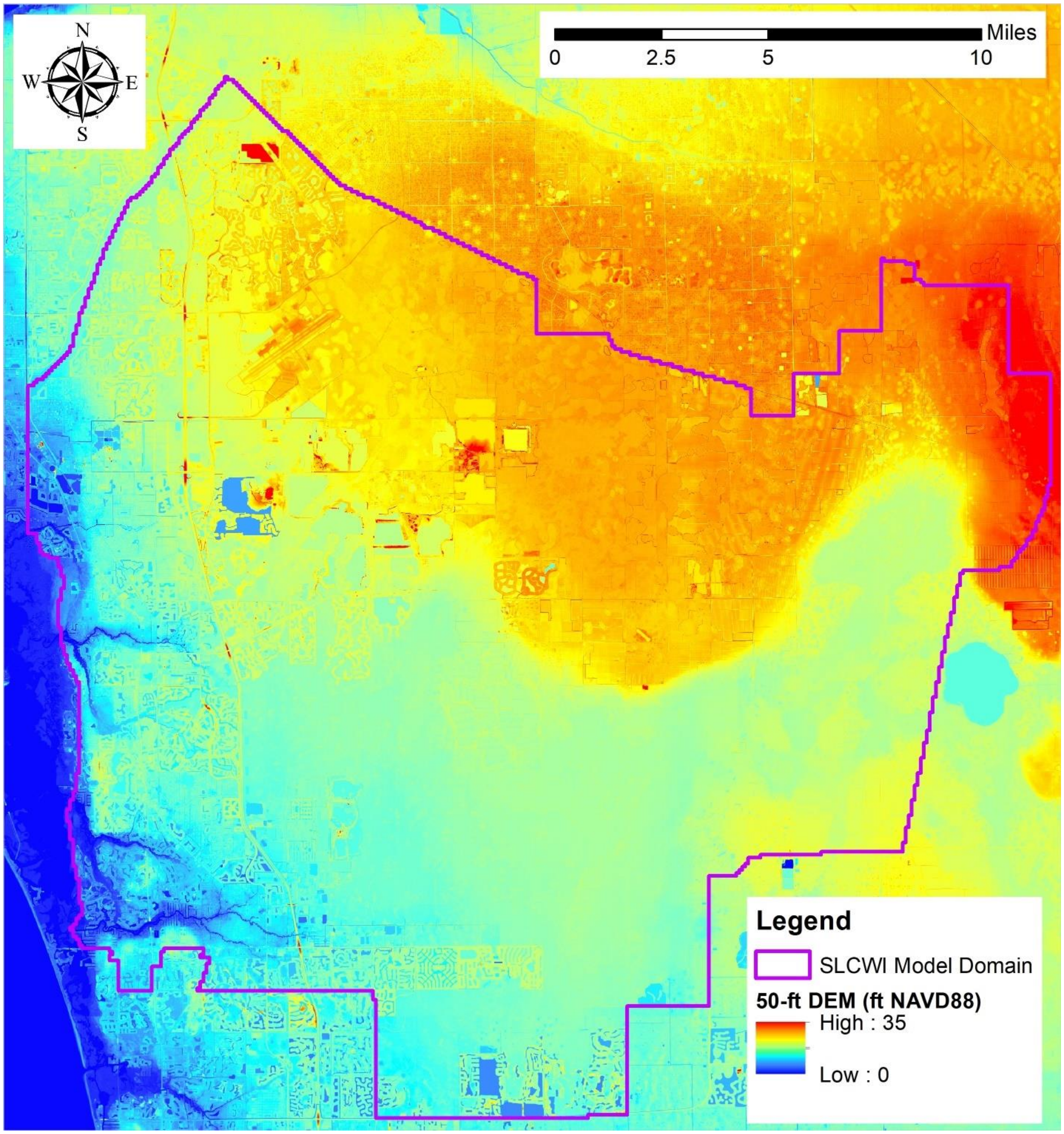

Figure 3. Composite 50-ft resolution topography for the SLCWI model domain area.

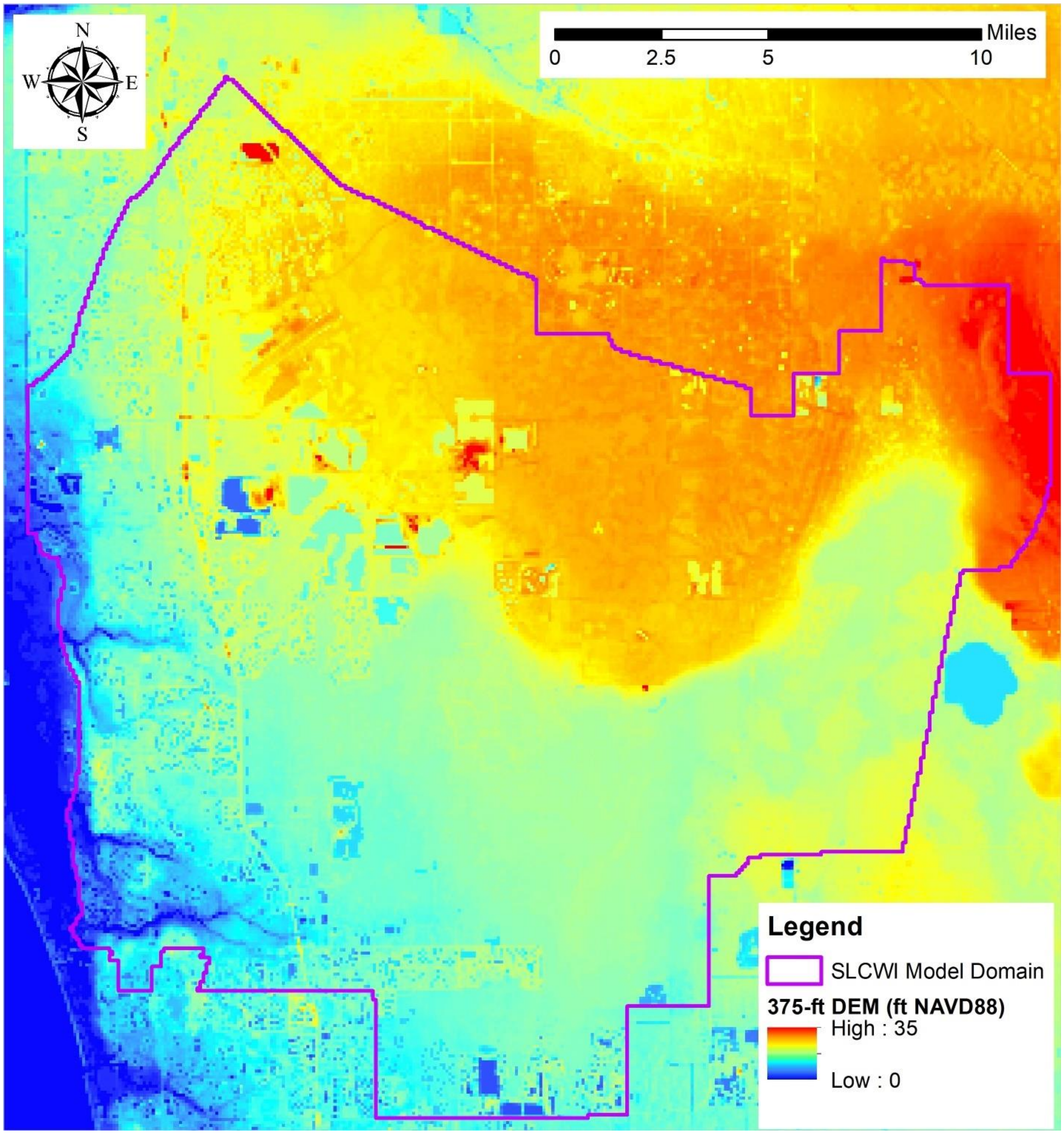

Figure 4. 375-ft resolution topography for the preliminary SLCWI model.

Climate

Precipitation

Previous MIKE SHE models for the South Lee County used typically NEXRAD rainfall datasets. The NEXRAD grid is approximate 2-km size, as shown in **Figure 6**. This data source provides a finer spatial distribution of the rainfall with respect to the alternative method of using rain gauge data distributed by using Thiessen Polygons as presented in **Figure 7**.

A comparison of the daily rainfall during Hurricane Irma from the two data sources around the City of Bonita Springs revealed that the rain gauge data was in average 1 inch/day (~ 15 %) higher than the NEXRAD data on the day of the maximum rainfall (i.e., on September 10^{th}, 2017) [LAGO, 2020]. Since both rainfall measures tend to underestimate the rainfall during heavy storms, previous models have used rain gauge data to model the Hurricane Irma event [LAGO, 2020] [AIM, 2020].

This modeling study is focused on long term simulations for which the NEXRAD rainfall has been used successfully in previous models. NEXRAD data is readily available for the 10-year period of interest (i.e., from year 2010 through 2019). Meanwhile, rain gauge station data generally have data gaps that have to be filled.

Based on the advantages and disadvantages of using the two rainfall data sources, the NEXRAD rainfall data has been selected to be used in this project. **Figure 5** and **Figure 8** present the temporal and the spatial distribution of NEXRAD rainfall data, respectively. More details about the rainfall data source and processing will be included in Technical Memorandum for Project Task 6.

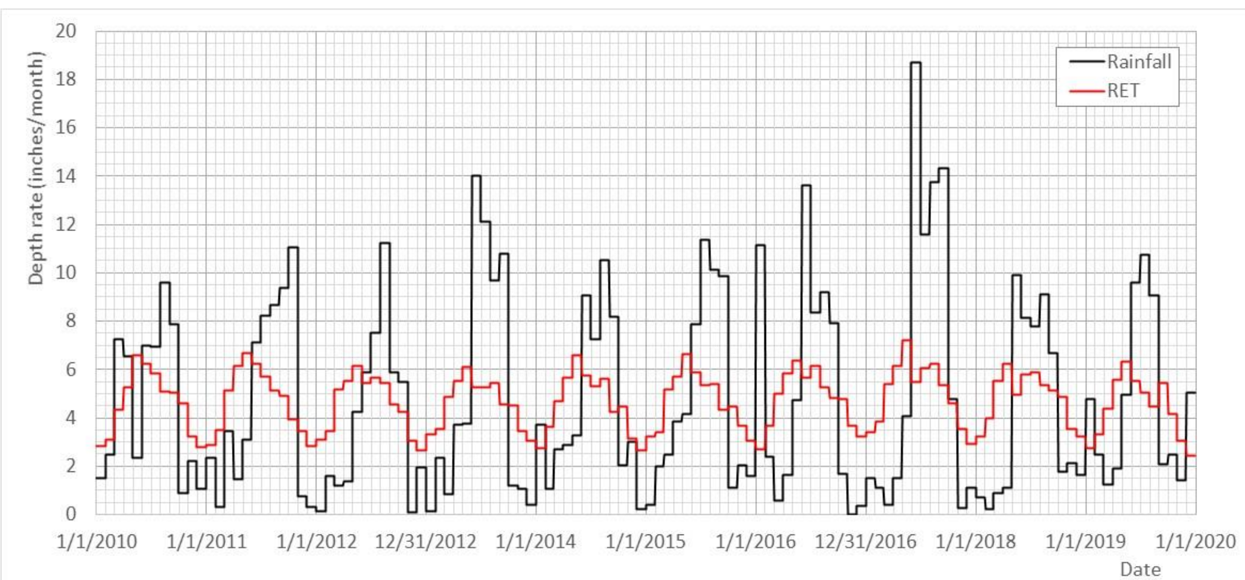

Figure 5. Spatial-averaged monthly NEXRAD rainfall and RET within the SLCWI model domain.

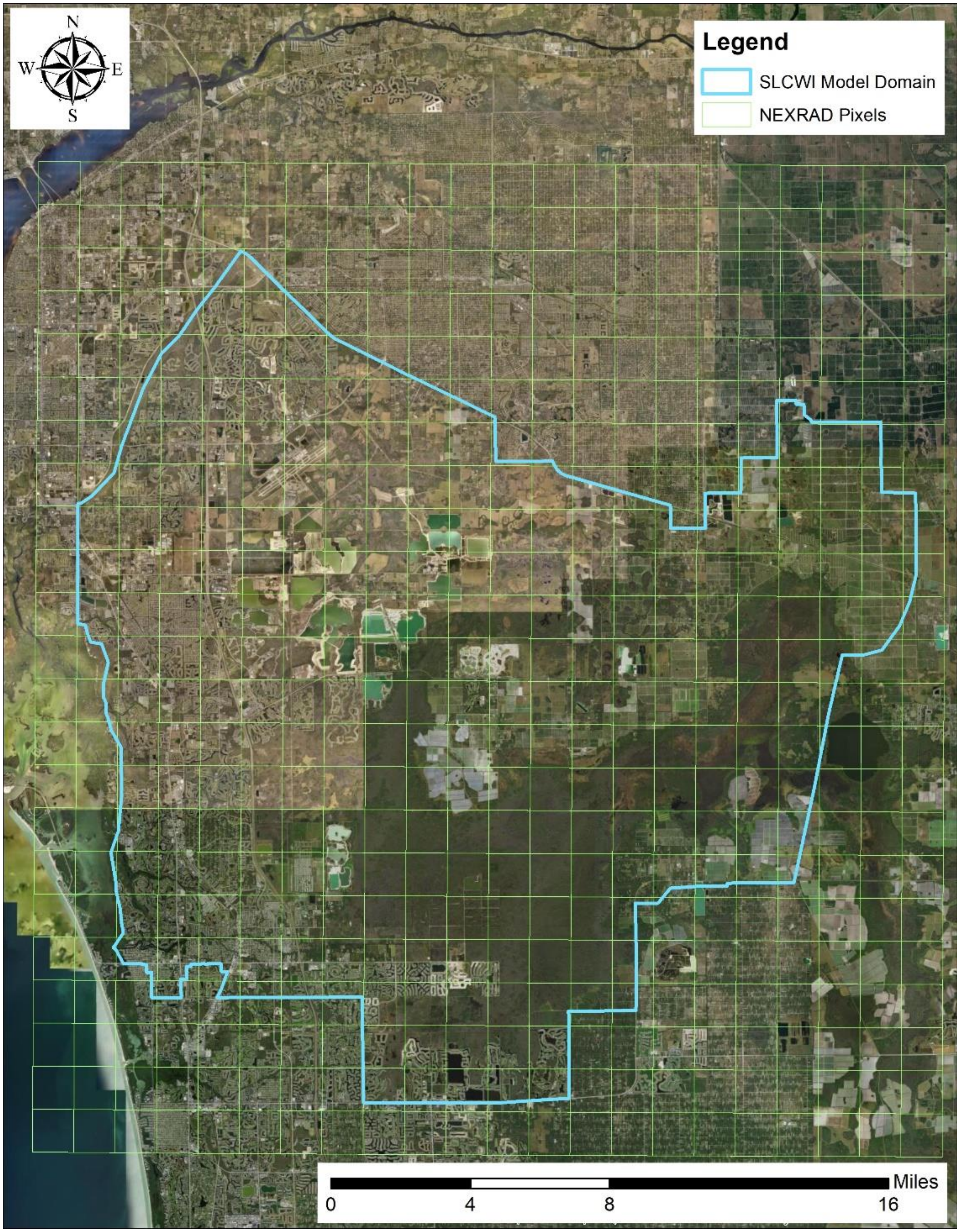

Figure 6. NEXRAD pixels around the SLCWI model domain.

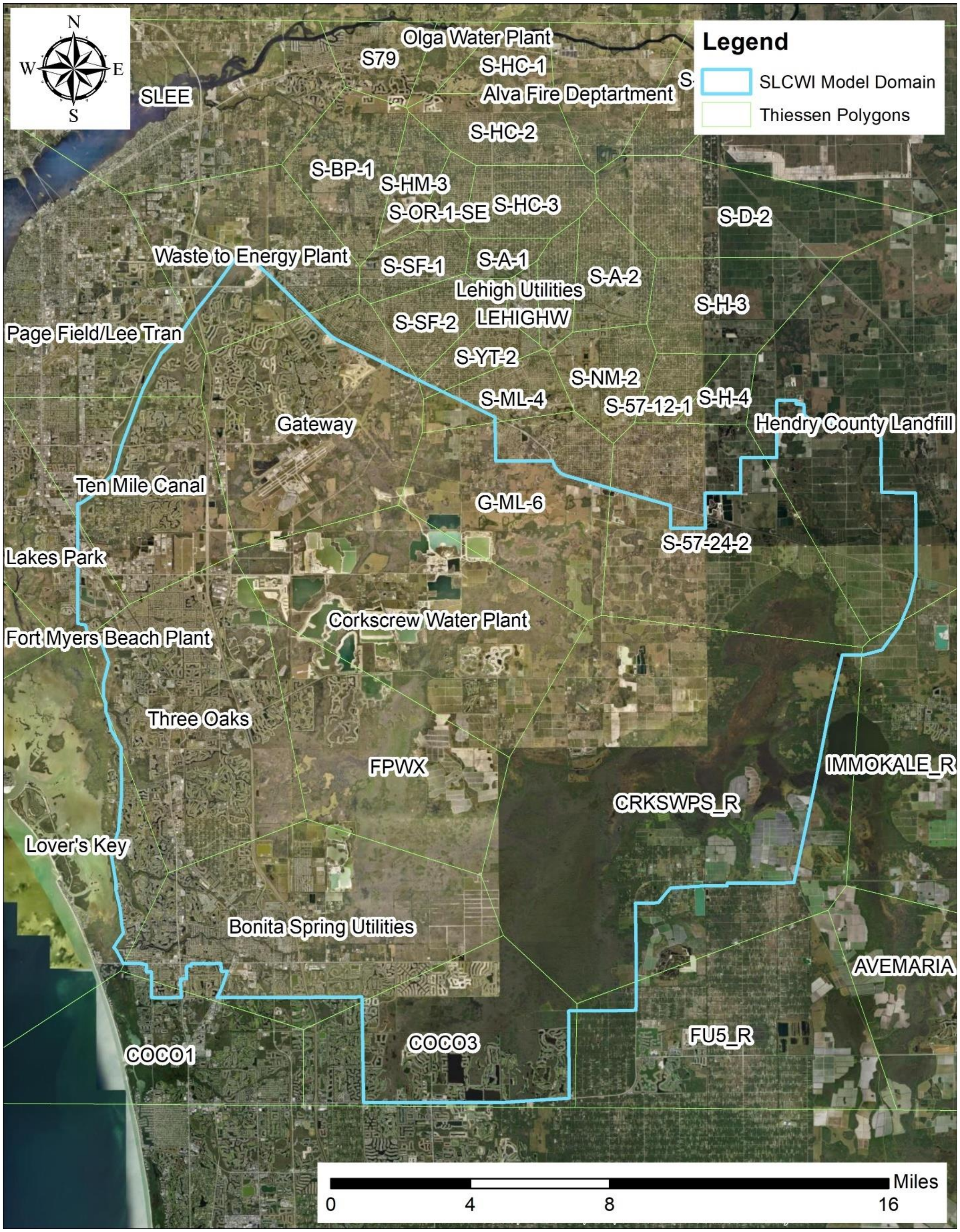

Figure 7. Thiessen polygons at rain gauge stations, as defined in the SLCFMP Model.

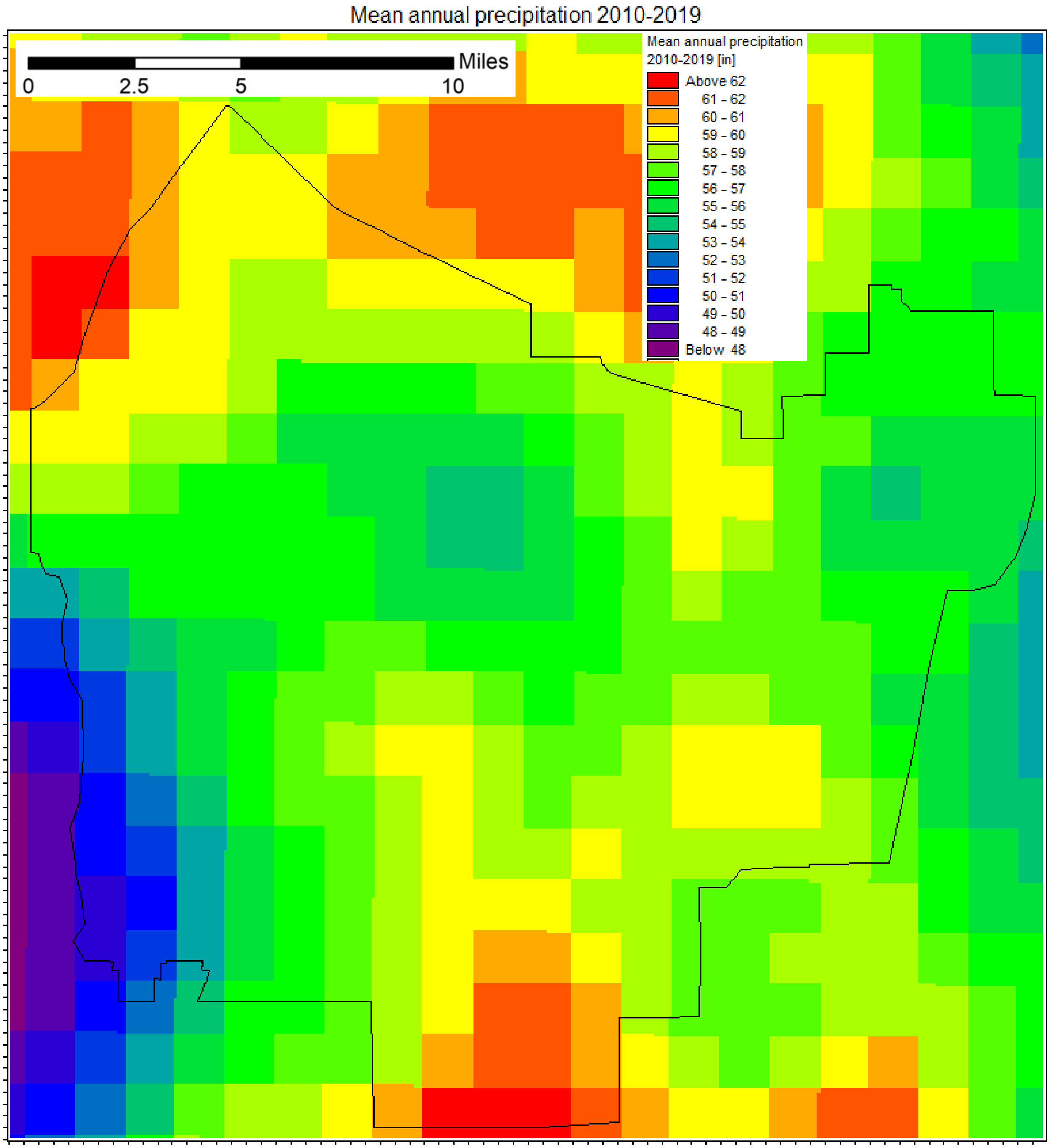

Figure 8. Average annual NEXRAD rainfall around the SLCWI model domain for the 10-year period 2010-2019.

Reference Evapotranspiration (RET)

Previous MIKE SHE models for South Lee County typically used the RET daily data reported by the USGS, which is spatially distributed in the NEXRAD grid presented in Figure 6. Figure 5 and **Figure 9** present the temporal and the spatial distribution of RET data, respectively. More details about the RET data source and processing will be included in Technical Memorandum for Project Task 6.

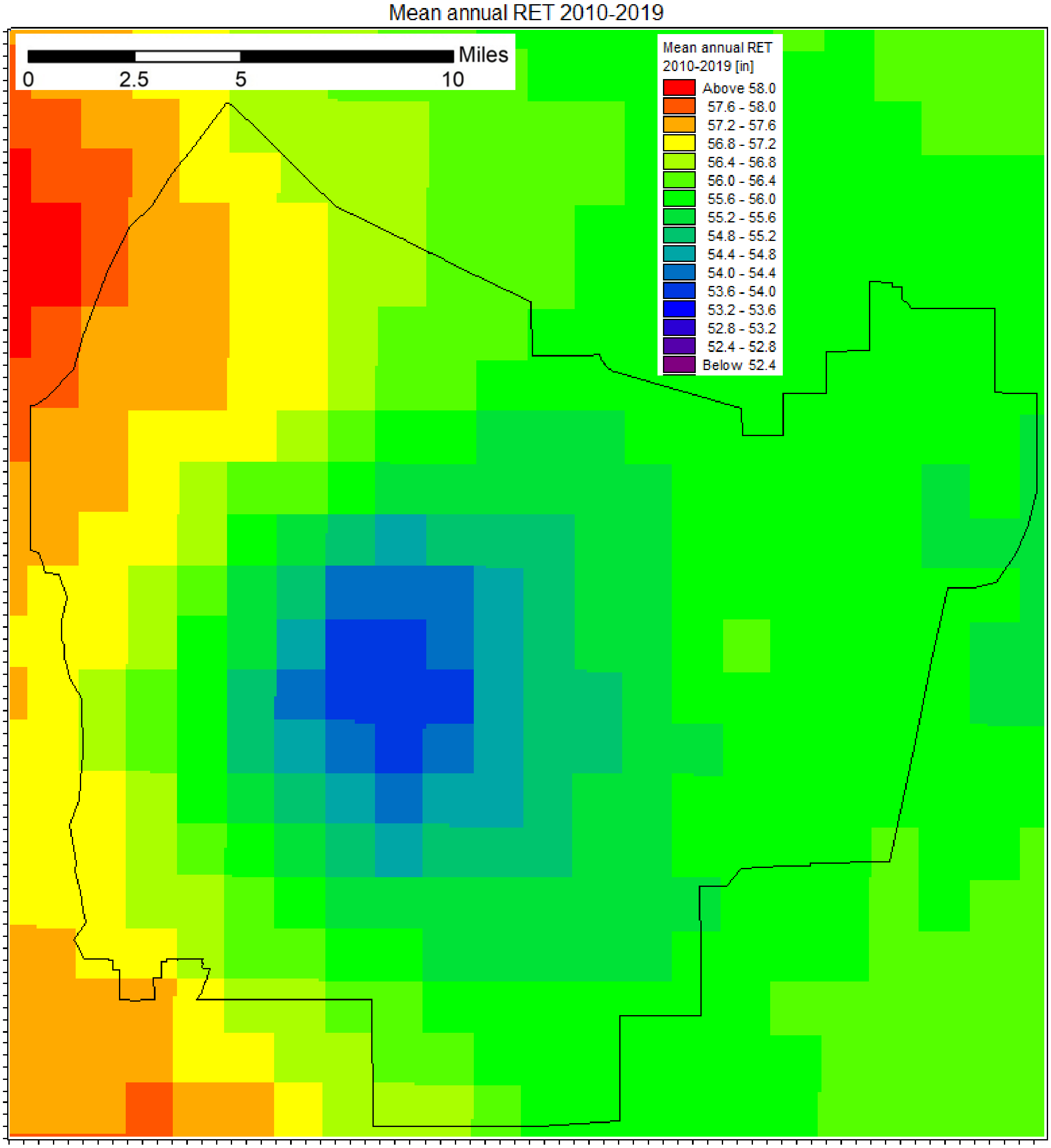

Figure 9. Annual average USGS RET data around the SLCWI model domain for the 10-year period 2010-2019.

Land Use Component

Vegetation / Land Use

The SLCWI model uses the vegetation/land use coverage available from the SFWMD, which corresponds to the period 2014-2016. The FLUCCS codes were converted to the smaller set of MIKE SHE codes by using the cross-walk table presented in **Table 3**. The resulting model vegetation map was adjusted to represent recent urban developments that are visible in more recent aerial imageries. The Willow coverage in the Corkscrew Swamp was also added as in the CSS model. A pre-development vegetation map was also adopted from the SWFFS. **Figure 10** and **Figure 11** present the resulting land use/vegetation maps for existing and predevelopment conditions, respectively. More details about the land use/vegetation coverage data source and processing will be included in Technical Memorandum for Project Task 4.

Table 3. Cross reference table to convert from FLUCCS to MIKE SHE Land use/Vegetation codes in the preliminary SLCWI Model.

MIKE SHE Code	MIKE SHE Land use / Vegetation Class	Land Use FLUCCS Code
1	Citrus	2210, 2230
2	Pasture	1920, 2110, 2120, 2130, 2240, 2510, 2610, 3100, 8320
5	Truck Crops	2140, 2150, 2500
6	Golf Course	1820
7	Bare Ground	1610, 1620, 1630, 1670, 1810, 7200, 7400, 8120, 8350
8	Mesic Flatwood	1650, 1900, 2410, 2430, 3200, 3210, 3300, 4110, 4370, 4410, 4430, 7470
9	Mesic Hammock	4200, 4220, 4270, 4271, 4300, 4340
10	Xeric Flatwood	4130
11	Xeric Hammock	3220
12	Hydric Flatwood	6240, 6250
13	Hydric Hammock	4240, 4280, 6180, 7430
14	Wet Prairie	6430
15	Willow	From CSS Model
16	Marsh	6400, 6410, 6440
17	Cypress	6200, 6210, 6215, 6216
18	Swamp Forest	6170, 6172, 6191, 6300
19	Mangrove	6120, 6420
20	Water	1660, 1840, 2540, 5110, 5120, 5200, 5300, 5410, 5420, 5720, 6510, 8360
41	Urban Low Density	1110, 1120, 1130, 1180, 1190, 1480, 1850, 1860, 1890
42	Urban Medium Density	1210, 1220, 1230, 1290, 8330, 8340
43	Urban High Density	1310, 1320, 1330, 1340, 1350, 1390, 1400, 1411, 1423, 1460, 1490, 1540, 1550, 1560, 1700, 1710, 1830, 2320, 8110, 8115, 8140, 8200, 8300, 8310

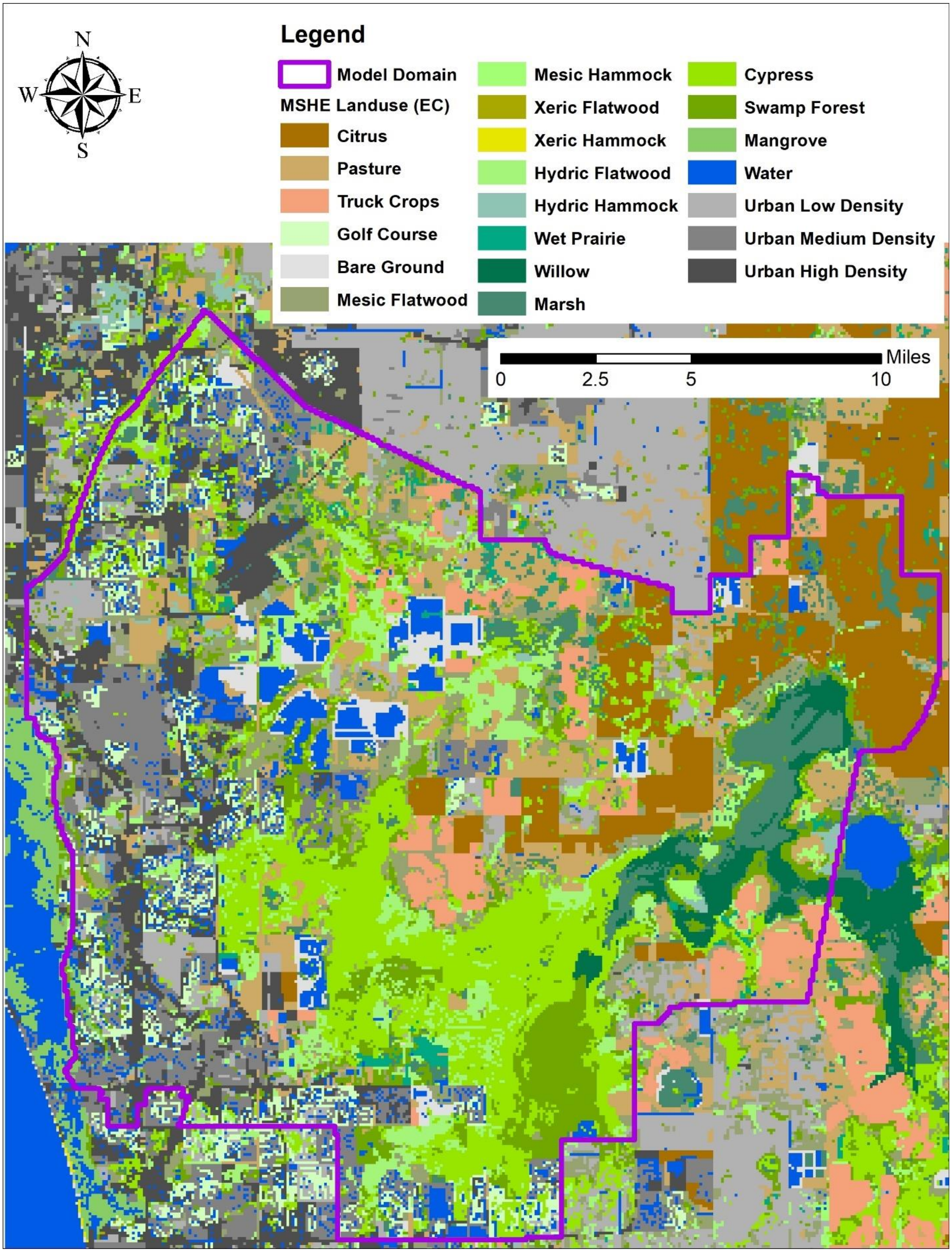

Figure 10. Existing conditions MIKE SHE vegetation codes in the SLCWI Model.

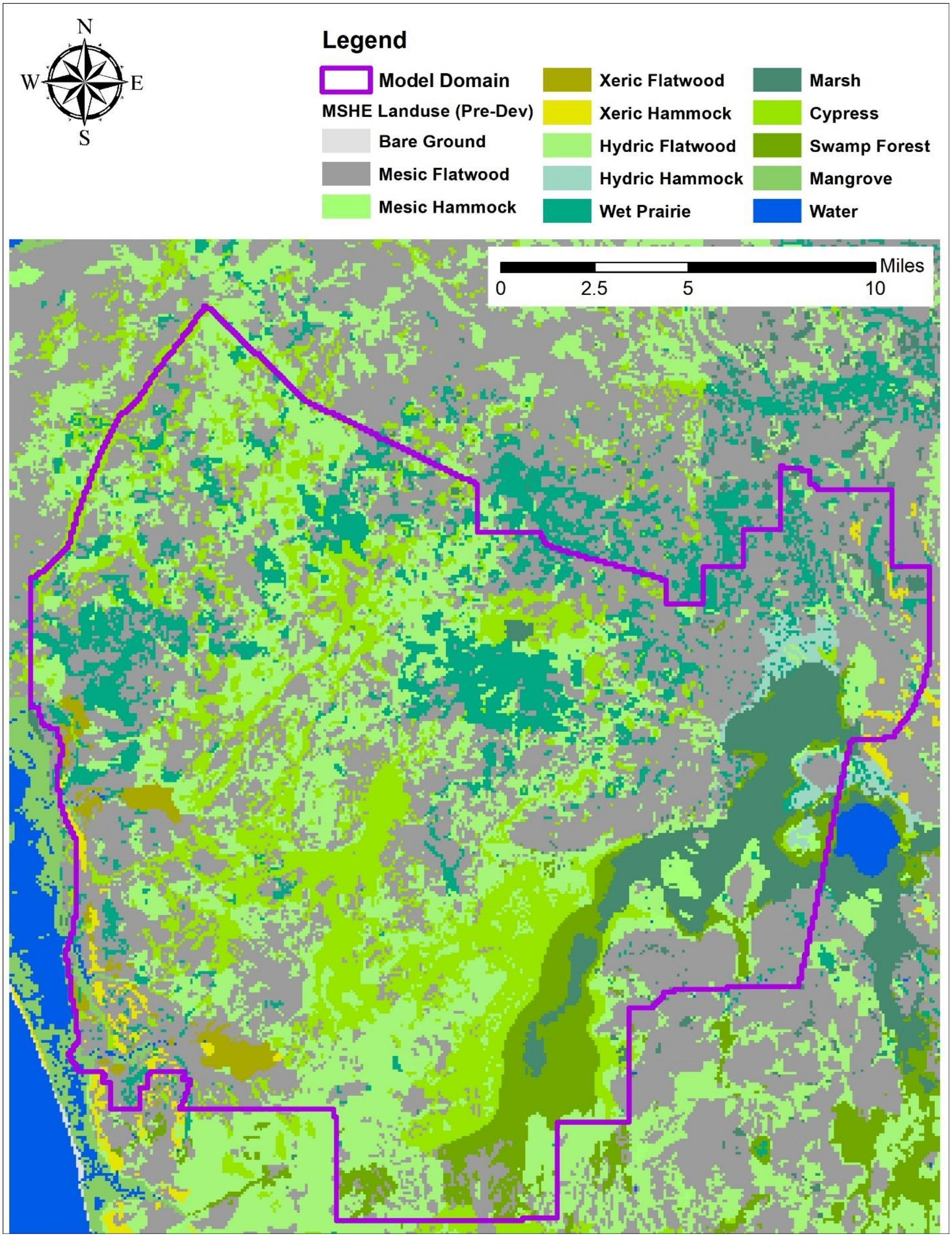

Figure 11. Pre-development MIKE SHE vegetation codes around the SLCWI Model domain.

Evapotranspiration (ET) Parameters

MIKE SHE uses vegetation-specific parameters such as Leaf Area Index (LAI), root depth (Rd), and crop coefficient (Kc) to convert the input RET rates into actual ET rates. The model database containing these ET parameters for the different MIKE SHE vegetation classes have been taken from the CSS model. Note that these parameters have been used with slight variations for all MIKE SHE models in Southwest Florida since the development of the Southwest Florida Feasibility Study Model in 2008. The preliminarily adapted ET parameters are summarized in **Table 4**, and they may be adjusted later during the model calibration task.

Table 4. Vegetation related parameters defined for the preliminary SLCWI Model.

MIKE SHE Code	Land use / Vegetation Class	LAI	Rd (ft)	Kc	Moisture Deficit	
					Start	Stop
1	Citrus	3.4 - 4.5	4.1	0.7	0.05	0.01
2	Pasture	3 - 4	2.5	0.75	0.10	0.01
5	Truck Crops	1 - 4.5	0. 5 - 2.5	0.75	0.03	0.01
6	Golf Course	2 - 3	2.5	0.85	0.02	0.01
7	Bare Ground	0.3	0.3	0.75	–	–
8	Mesic Flatwood	1.5 - 3	4	0.7	–	–
9	Mesic Hammock	2.5 - 4	2	0.7	–	–
10	Xeric Flatwood	1 - 2	5	0.7	–	–
11	Xeric Hammock	2 - 3	3	0.7	–	–
12	Hydric Flatwood	1.5 - 3	3	0.7	–	–
13	Hydric Hammock	2.5 - 4	1.5	0.7	–	–
14	Wet Prairie	1.5 - 3	2.5	0.75	–	–
15	Willow	4 - 8	5	0.75	–	–
16	Marsh	2 - 4	2.5	0.75	–	–
17	Cypress	2 - 4	5	0.7	–	–
18	Swamp Forest	3 - 5	5	0.7	–	–
19	Mangrove	3 - 4	6	0.7	–	–
20	Water	2	2.5	1	–	–
41	Urban Low Density	1.6	2.3	0.85	0.20	0.01
42	Urban Medium Density	1.45	2.1	0.85	0.12	0.01
43	Urban High Density	1.25	2.0	0.85	0.12	0.01

Irrigation

The irrigation module in MIKE SHE uses grid codes to define the Irrigation Command Areas (ICAs) or application areas. For each ICA, a maximum application rate and the source of the irrigation water is defined.

The ICAs information in the preliminary SLCWI model was copied initially from the CSS and the Edison Farm models. Then, the ICA setup was improved based on water use permit information, vegetation land use coverage, and aerial imageries. Irrigation is only applied to land use grid cells classified as agricultural and urban. The ICA codes in the preliminary SLCWI model and related information (such as source, maximum rates, and number of grid cells) are listed in

Table 5. In this table, SAS means Surficial Aquifer System, meanwhile WT refers to the Water Table, LT to the Lower Tamiami, SS to the Sandstone, MH to the Mid Hawthorne, and LH to the Lower Hawthorne Aquifers. The ICA codes map is also presented in **Figure 12**.

Monthly reported irrigation for several water use permits in the model area were compiled and processed to be compared with model predicted irrigation rates. ICA parameters such as maximum application rates may be adjusted during the calibration task to better match the reported pumping. More details about the irrigation data sources and processing will be included in Technical Memorandum for Project Task 5.

The irrigation demand in the SLCWI model uses the “Maximum Allowed Deficit” option, as in the CSS model. The start/stop moisture deficit parameters are also adopted initially from the CSS model (as shown in Table 4), but they may be adjusted during the calibration task.

Table 5. Irrigation sources and maximum rates in the preliminary SLCWI Model.

ICA Code	Vegetation type	Permit Number	Aquifer	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Capacity (in/day)	No. 375-ft Cells
100	Citrus	36-07002-W	LT/SS	118	656	0.1172	92
102	Citrus	36-00201-W	LT/SS	118	656	0.1172	55
104	Citrus	36-00167-W	WT	0	66	0.1172	468
106	Citrus	36-00167-W	SS	581	591	0.1172	433
108	Citrus	26-00883-W	WT	0	75	0.1172	160
110	Citrus	11-00094-W	SS	561	636	0.1172	759
112	Citrus	11-00324-W	SS	515	817	0.1172	29
114	Citrus	11-00323-W 11-00572-W	LT	194	344	0.1172	98
116	Citrus	36-00218-W	SS	699	892	0.1172	184
118	Citrus	36-00327-W	LT	194	246	0.1172	326
120	Citrus	36-00327-W	SS	591	656	0.1172	77
122	Citrus	36-00077-W	LT	194	377	0.1172	452
124	Citrus	36-00077-W	SS	699	817	0.1172	298
128	Citrus	36-00094-W	LT	128	344	0.1172	20
130	Citrus	36-01212-W	WT	0	85	0.1172	62
132	Citrus	11-00262-W	SS	463	656	0.1172	1529
134	Citrus	11-00128-W	LT	141	171	0.1172	666
136	Citrus	11-00128-W	SS	538	656	0.1172	425
140	Citrus	11-00128-W	LT	128	161	0.1172	53
200	Pasture	11-00352-W	LT	151	194	0.1172	92
202	Pasture	36-00771-W		0	108	0.0000	12
206	Pasture	36-00102-W	MH	741	850	0.1172	46
400	Urban	36-00093-W	LT	279	312	0.0599	191
402	Urban	36-03568-W	WT	0	52	0.0599	82
404	Urban	36-08061-W	WT	0	33	0.0599	100
406	Urban	36-04000-W	SS	453	538	0.0599	152
462	Urban	36-00688-W	SS/LH	0	33	0.0599	509
480	Urban			0	52	0.0599	109
482	Urban			52	161	0.0599	4119
484	Urban			161	269	0.0599	305
486	Urban			269	377	0.0599	4181
488	Urban			377	486	0.0599	282
490	Urban			486	591	0.0599	109
492	Urban			591	699	0.0599	653
500	Truck Crops	11-00113-W	LT	161	217	0.1172	837
502	Truck Crops	11-00055-W	WT	161	194	0.1172	156
504	Truck Crops	36-00612-W		0	108	0.0000	50

ICA Code	Vegetation type	Permit Number	Aquifer	Screen Top Depth (ft)	Screen Bottom Depth (ft)	Capacity (in/day)	No. 375-ft Cells
506	Truck Crops	36-00883-W	LT	151	194	0.1172	163
508	Truck crops	36-00084-W	SAS	203	217	0.1172	874
510	Truck crops	36-03768-W	SS	292	367	0.1172	104
512	Truck Crops	36-00413-W	LT	108	118	0.1172	609
514	Truck crops	36-06721-W	WT	0	52	0.1172	61
516	Truck crops	36-00093-W	WT	0	33	0.1172	128
518	Truck crops	11-02150-W	LT	0	0	0.1172	6
520	Truck crops	36-06587-W	WT	98	141	0.1172	95
522	Truck crops	26-00516-W	SS	591	646	0.1172	115
524	Truck crops	26-00681-W	SS	623	732	0.1172	134
526	Truck crops	36-01461-W	SS	591	712	0.1172	393
528	Truck crops	36-02094-W	SS	528	712	0.1172	44
600	Golf Course	36-00252-W	SS	354	397	0.1172	42
602	Golf Course	36-00282-W	LT	151	161	0.1172	381
604	Golf Course	36-00186-W	LT	259	397	0.1172	42
606	Golf Course	36-00433-W	WT	0	43	0.1172	56
608	Golf Course	36-03219-W	SS	344	430	0.1172	56
610	Golf Course	36-04122-W	SS	410	486	0.1172	51
612	Golf Course	36-00479-W	SS	344	397	0.1172	40
614	Golf Course	36-00308-W	WT	0	108	0.1172	30
616	Golf Course	36-01871-W	SS	335	367	0.1172	54
618	Golf Course	36-02571-W	SS	302	430	0.1172	38
620	Golf Course	36-03745-W	WT	0	43	0.1172	86
622	Golf Course	36-00441-W 36-00622-W	SS/MH	548	656	0.1172	21
624	Golf Course	36-03945-W	SS	292	397	0.1172	103
630	Golf Course	36-00405-W	SS	246	397	0.1172	40
634	Golf Course	36-00261-W	MH	636	656	0.1172	80
636	Golf Course	36-01070-W	SS	312	397	0.1172	55
638	Golf Course	36-04076-W	WT	0	66	0.1172	60
640	Golf Course	36-03145-W	LT	118	128	0.1172	44
642	Golf Course	36-00737-W	WT	0	66	0.1172	23
650	Golf Course			0	52	0.1172	546
652	Golf Course			52	161	0.1172	284
656	Golf Course			269	377	0.1172	182
658	Golf Course			377	486	0.1172	59
662	Golf Course			591	699	0.1172	42
700	Airport	36-00080-W	WT	0	108	0.0000	522

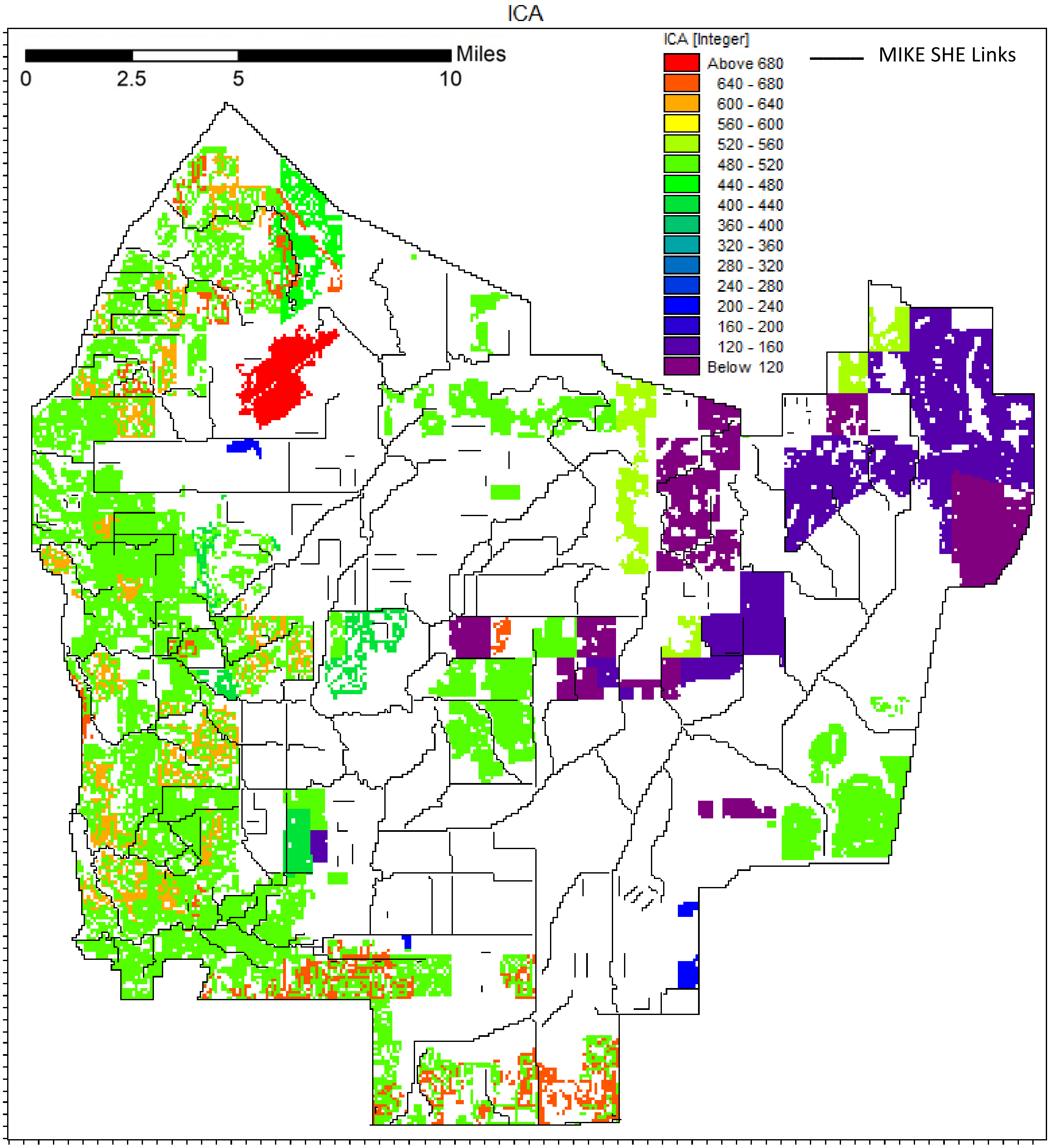

Figure 12. ICA map for the preliminary SLCWI Model.

Riverine Component

MIKE11

Figure 13 shows the MIKE11 branches and hydraulic structures used for the one-dimensional (1D) hydraulic simulation in the preliminary SLCWI Model. They were copied from previous models and refined in some areas.

Most of the cross sections were also taken from previous models. New cross sections were cut from the 2018 LiDAR DEM as needed.

Initial water levels for MIKE11 that are applied at the beginning of the simulation (i.e., 1/1/2013) are taken from the model results after two years (i.e., 1/1/2015). This assumption is supported by the observation station data. One can observe from the MIKE SHE comparison plots that the observed water levels are not the same on January 1st of every year. Coincidently, the observed water levels on 1/1/2013 and on 1/1/2015 match closely.

Boundary conditions are imposed in the west and south boundaries from surface water level data at observation stations. These time series data were updated to the current time, will be detailed in Technical Memorandum for Project Task 6.

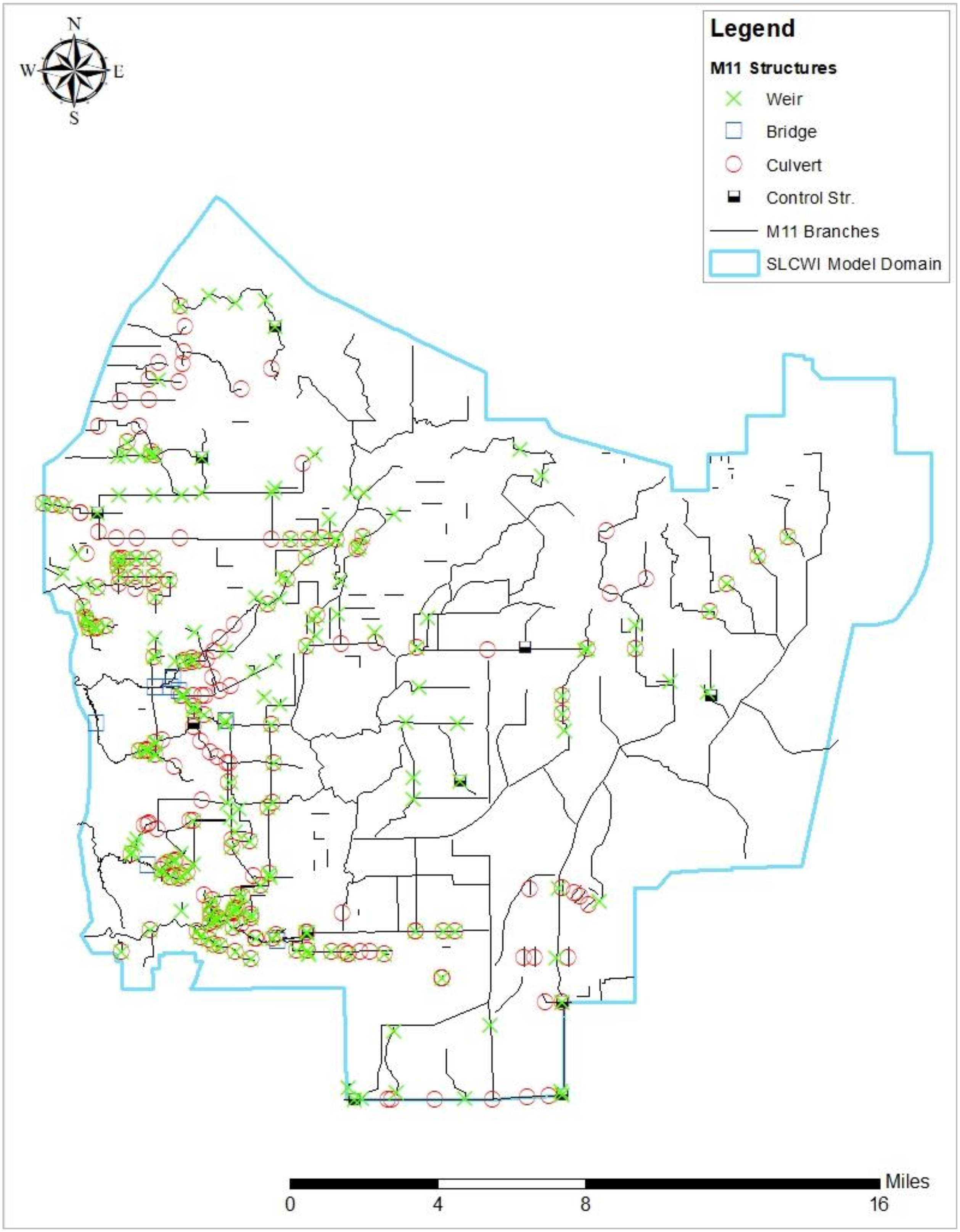

Figure 13. MIKE11 branches and structures in the preliminary SLCWI Model.

Flood Codes

Figure 14 presents the flood codes map in the preliminary SLCWI model. In general, a different flood code was chosen for each MIKE11 branch in order to assure that the flood coded cells are linked to the correct branch. Flood codes may be adjusted during the calibration task.

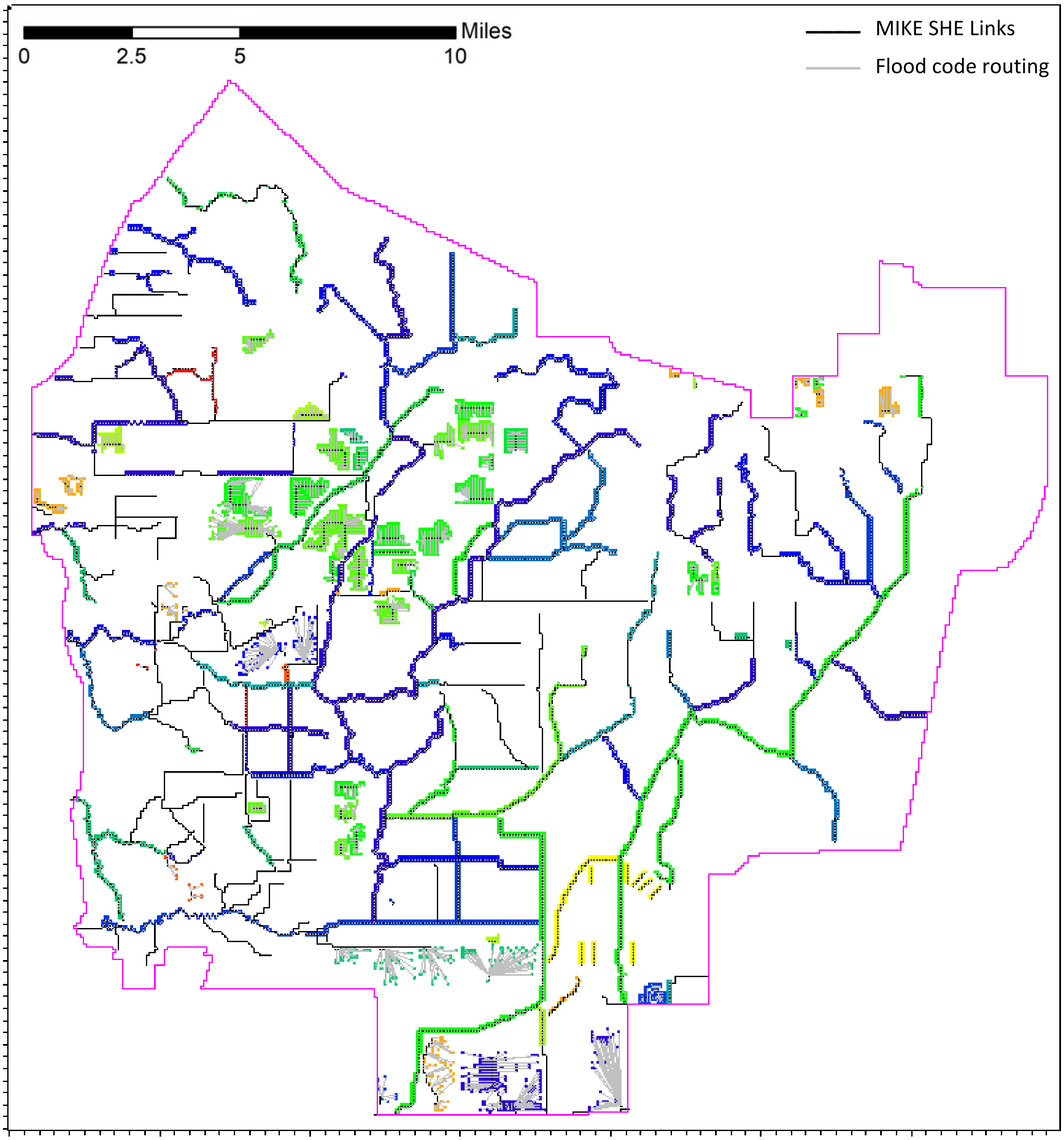

Figure 14. Flood code map for the preliminary SLCWI Model.

Overland (OL) Flow Component

OL Parameters

As in previous MIKE SHE models for the South Lee County Area, the overland flow input parameters, namely, Manning's M, Detention Storage, and Paved Runoff Coefficient are found from correlations assumed with the MIKE SHE land use code, as shown in **Table 6**. The resulting parameter maps are presented in **Figure 15**, **Figure 16** and **Figure 17**, respectively. These parameters may be adjusted during the calibration task.

The surface-subsurface leakage coefficient is set uniformly to 10^{-4} s^{-1}, as in the previous models. Initial water depths for the OL component that are applied at the beginning of the simulation (e.g., 1/1/2013) are taken from the model results at a later year (e.g., 1/1/2015).

Table 6. Correlation assumed between model parameters and land use/vegetation classes in the preliminary SLCWI Model. Adapted from [WSA, 2020b]

MIKE SHE Code	Land use / Vegetation Class	OL Manning's M	OL Detention Storage (inches)	Paved Runoff Coefficient	Drain Depth (ft)	Drain Time Constant (1/day)
1	Citrus	5.88	1	0	2	0.25
2	Pasture	7.14	1.2	0	0.5	0.25
5	Truck Crops	5.88	1	0	0.5	0.25
6	Golf Course	7.14	1.2	0	1	0.25
7	Bare Ground	11.36	1.2	0	0	0
8	Mesic Flatwood	5	1.2	0	0	0
9	Mesic Hammock	3.33	1.2	0	0	0
10	Xeric Flatwood	10	1.2	0	0	0
11	Xeric Hammock	5	1.2	0	0	0
12	Hydric Flatwood	4	1.2	0	0	0
13	Hydric Hammock	2.5	1.2	0	0	0
14	Wet Prairie	3.33	1.2	0	0	0
15	Willow	2.33	1.2	0	0	0
16	Marsh	2.33	1.2	0	0	0
17	Cypress	3.33	1.2	0	0	0
18	Swamp Forest	2.5	1.2	0	0	0
19	Mangrove	5	1.2	0	0	0
20	Water	2	1.2	0	0	0
41	Urban Low Density	7.14	1	0.05	0.5	0.25
42	Urban Medium Density	8.33	0.4	0.15	0.75	0.35
43	Urban High Density	9.01	0.13	0.45	1	0.5

OL Mannings M

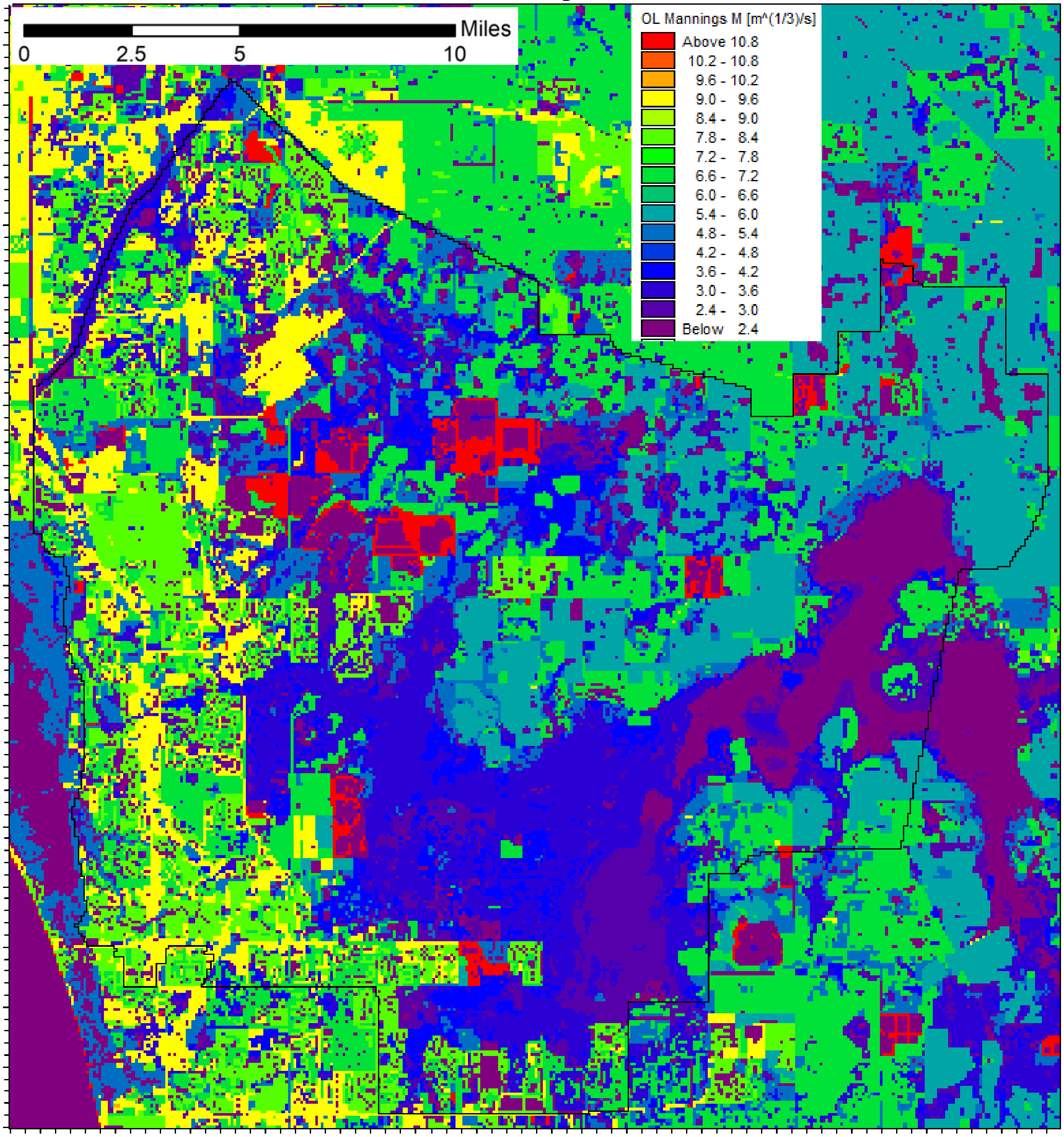

Figure 15. OL Manning's M map for the preliminary SLCWI Model.

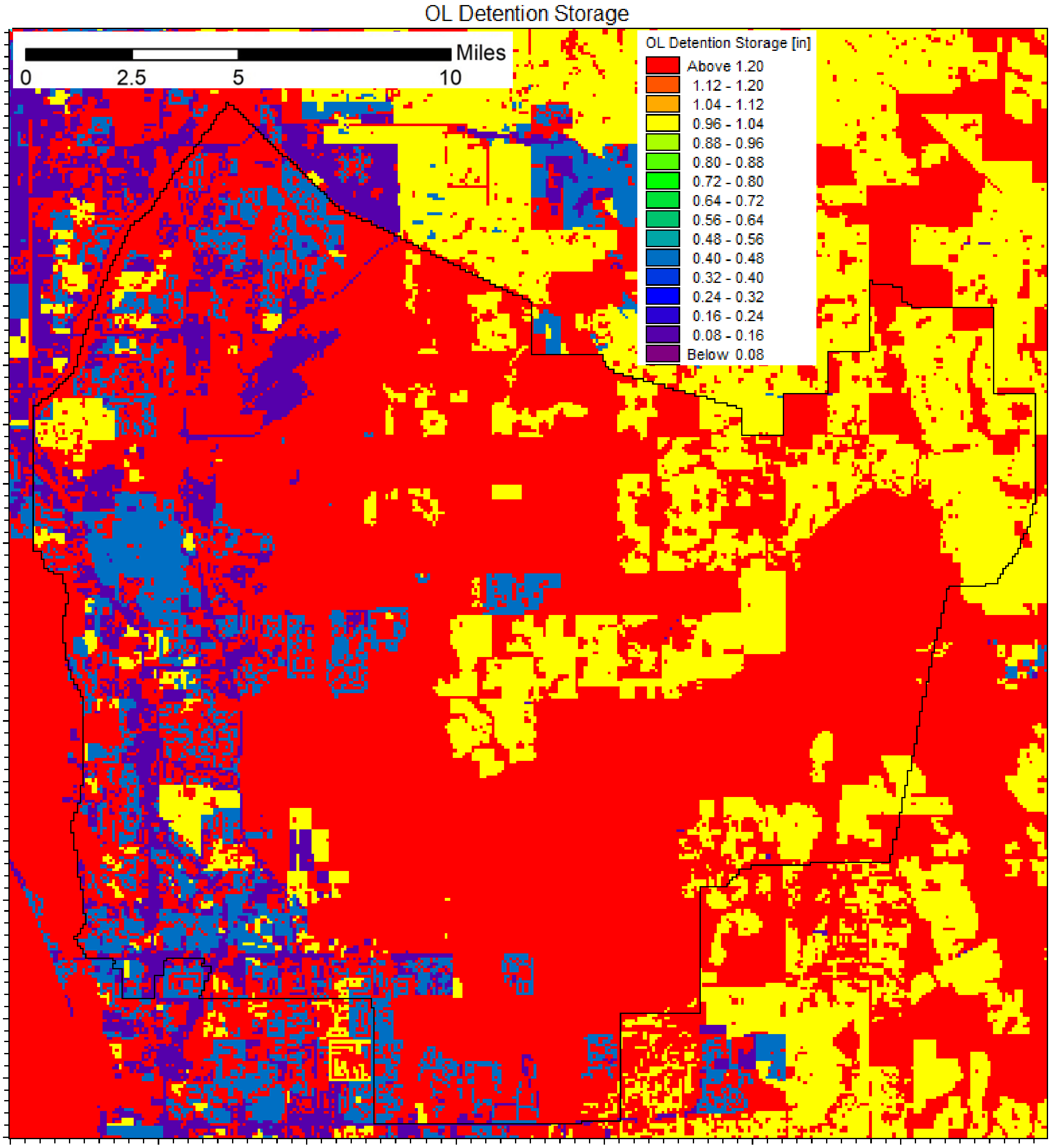

Figure 16. OL detention storage map for the preliminary SLCWI Model.

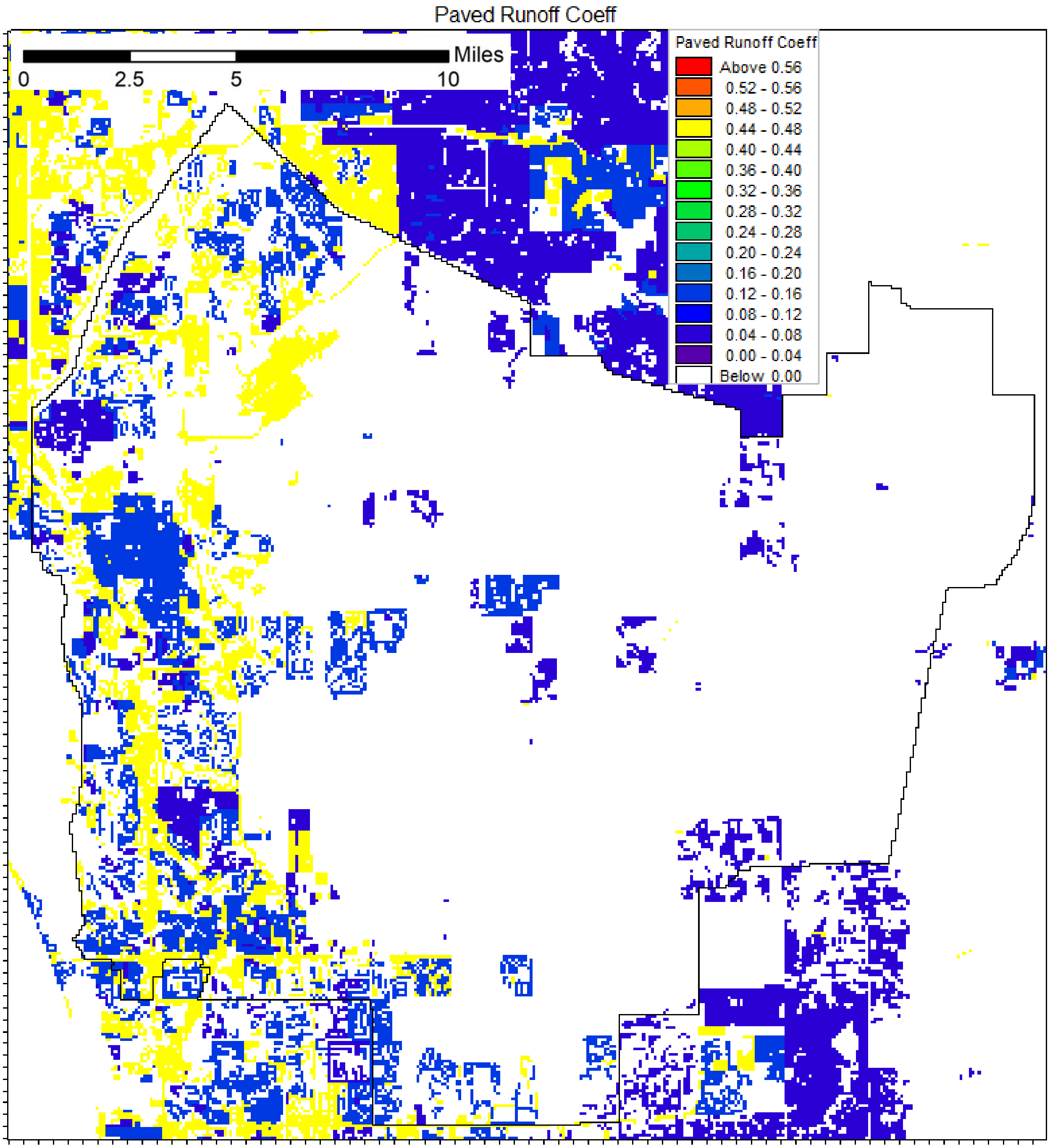

Figure 17. Paved runoff coefficient map for the preliminary SLCWI Model.

Separated Overland Flow Area (SOLFA)

The overland flow module in MIKE SHE uses a separated overland flow area (SOLFA) map to limit the overland flow across berms and roads. This option is useful when the road or berm width is smaller than the grid cell size and the increase in the ground elevation is not resolved at the model spatial scale, which is generally the case in the SLCWI Model that has a cell size = 375 ft.

The OL component allows flow only between cells with the same SOLFA grid code. Thus, different SOLFA grid codes are assigned on the different sides of the surface water divide to suppress OL flows. **Figure 18** shows the SOLFA map used in the preliminary model. This map may be updated during the calibration task when the conceptualization at some areas is to be revisited.

The following OL flow divides are represented in the SOLFA map of Figure 18:

1. Along some major street, railroad, and berm segments; where MIKE11 branches are the only way for the surface water to flow across those impediments.
2. Around some urban developments with retention ponds and discharge structures, which are represented in MIKE11.
3. Along mining pit boundaries in correspondence with the sheet piling module in the SZ component. This will prevent surface water flows between mining pits separated by a land bridge, as in the reality.
4. Around the model boundary, where the boundary conditions imposed in MIKE11 and in the SZ computational layers are controlling the flows across the boundary.
5. Along some MIKE SHE link segments. This is redundant since MIKE SHE links already prevent the OL flow across.

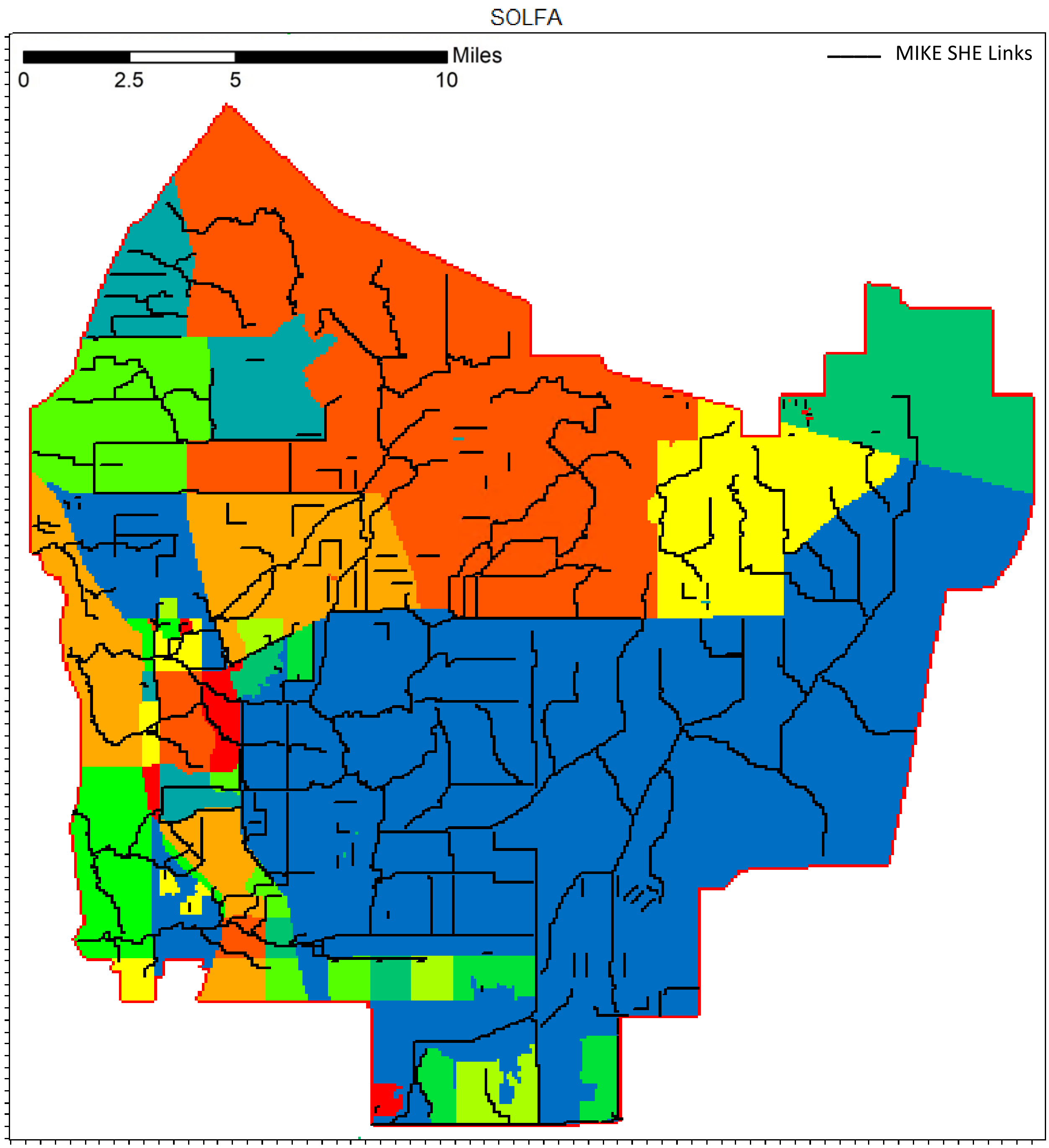

Figure 18. SOLFA map for the preliminary SLCWI Model.

Unsaturated Zone (UZ) Component

Most of the previous MIKE SHE models for the South Lee County area used typically the Richards' Equation or the Gravity Flow methods. The SLCWI model uses the 2-layer water balance method in combination with the Green-Ampt method to compute the infiltration, as in the SLCFMP model.

Soil Classes and Distribution

Many of the past South Lee County area models used a few soil classes corresponding to pre-development conditions, which were inherited from previous models (see for example [DHI, 1999]). The SLCWI model uses the soil classification from the most current NRCS soil database based on the MUKey code.

Polygon shape files with the Soil Survey Area (SSURGO) for Lee, Collier and Hendry Counties were downloaded from the NRCS Web Soil Survey webpage. The polygons with MUKey codes are combined and resampled to the 375-ft model grid by using the maximum combined area method (see **Figure 19**). The MUKey codes are unique for each County, and there is a total of 188 codes around the model grid area. Due to the large number of soil codes, Figure 19 does not include a legend defining each MUKey code. The location of each soil code can be viewed within the MIKE SHE graphical user interface.

Soil Parameters

Soil parameter values were obtained from the NRCS Soil Survey webpage. The ICPR software documentations offers a methodology to find depth average soil parameters for the different NCRS soil classes. Notice that each NCRS soil class is composed by layers or horizons, but the 2-layer water balance method in MIKE SHE needs depth-averaged soil parameters.

Depth-averaged soil parameters for each MUKey code are found by following the Green-Ampt Template Worksheet procedure from the ICPR documentation [ICPR, 2021]. The resulting five (5) soil parameters necessary for the 2-layer method are mapped in **Figure 20** through **Figure 24**. Mean, minimum, and maximum values from the soil parameters inside the model domain are also summarized in **Table 7**.

Table 7. Soil parameters mean and range inside the model domain.

Soil Parameters	min	mean	max
Water Content at Saturation	0.372	0.406	0.787
Water Content at Field Capacity	0.013	0.109	0.554
Water Content at Wilting Point	0.004	0.049	0.273
Hydraulic Conductivity (Kh) at Saturation (ft/day)	7.54	19.9	59.8
Suction Depth (inches)	-11.19	-1.76	-0.59

The soil parameter maps show a discontinuity at the county boundaries, which may affect (or not) the model results. This potential issue will be examined further during the calibration task.

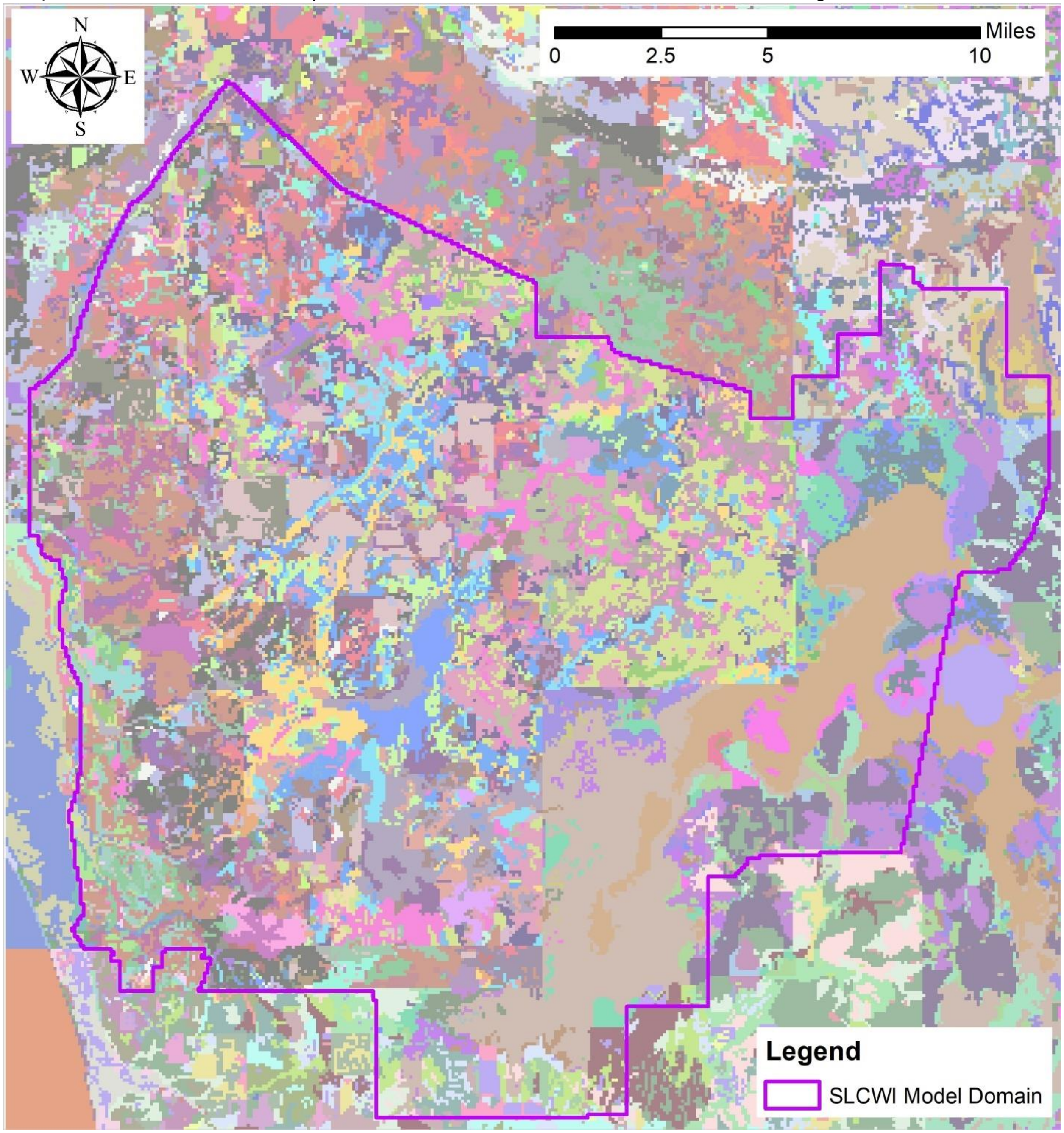

Figure 19. NRCS soil MUKey distribution.

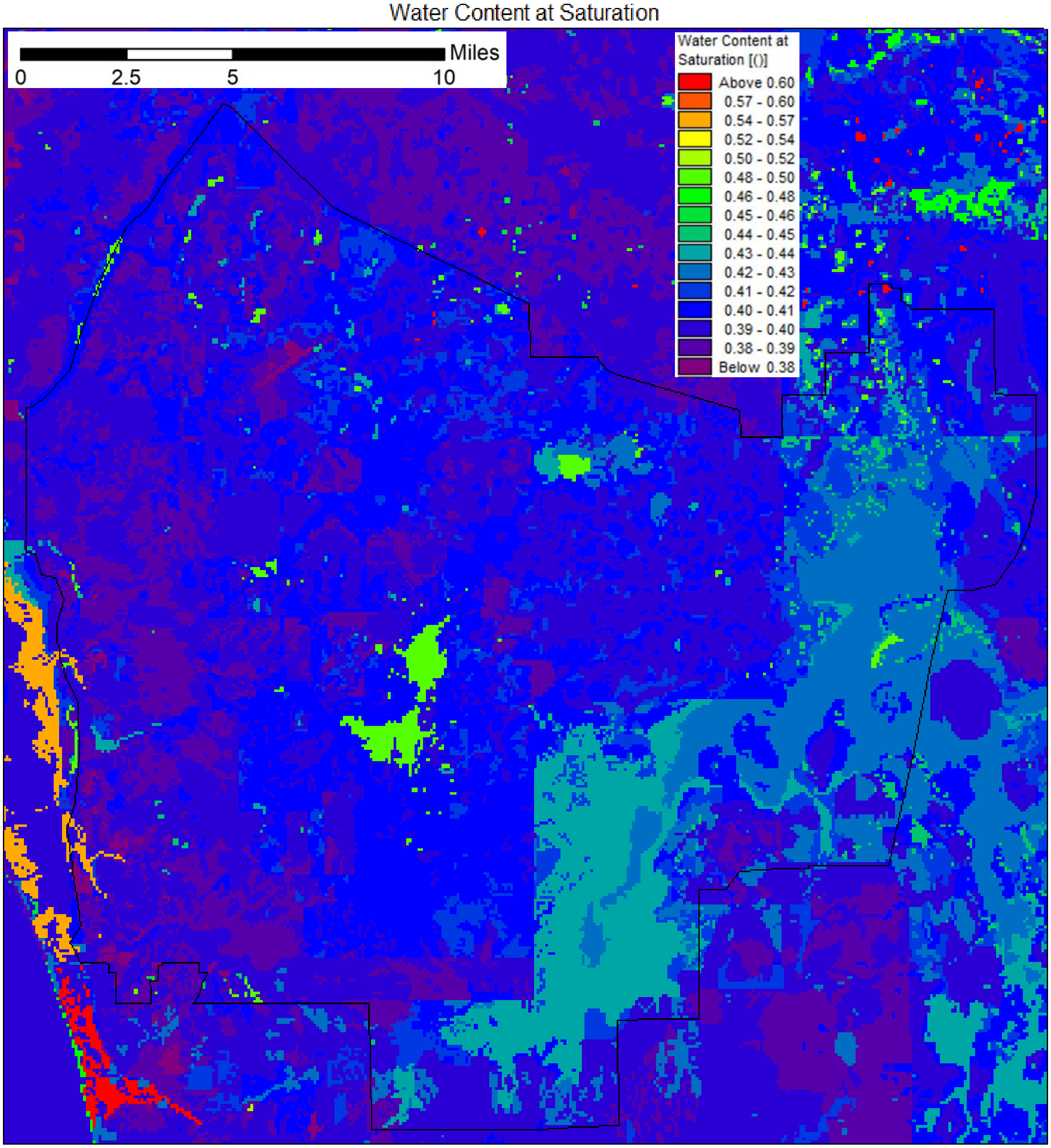

Figure 20. Soil water content at saturation.

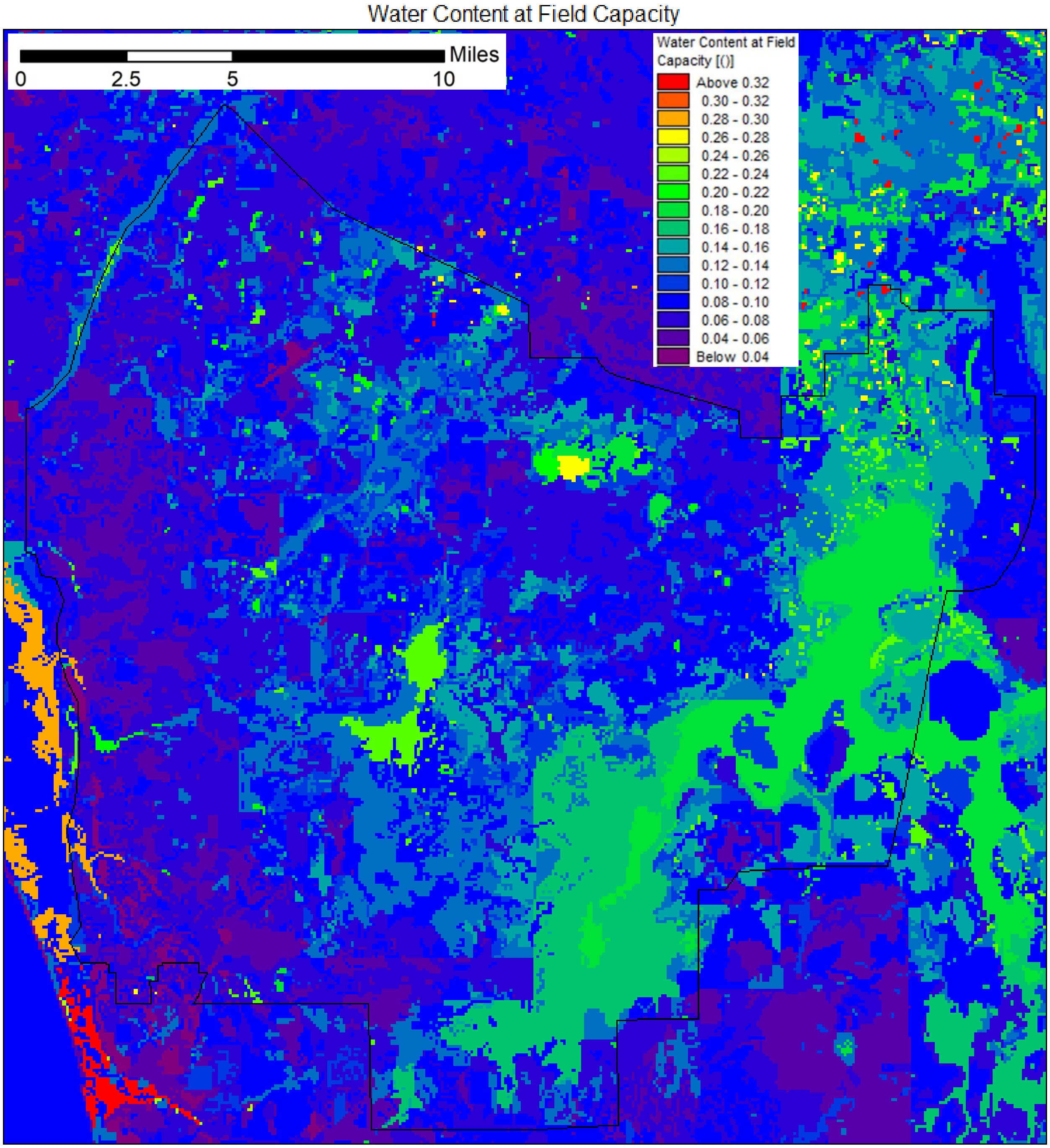

Figure 21. Soil water content at field capacity.

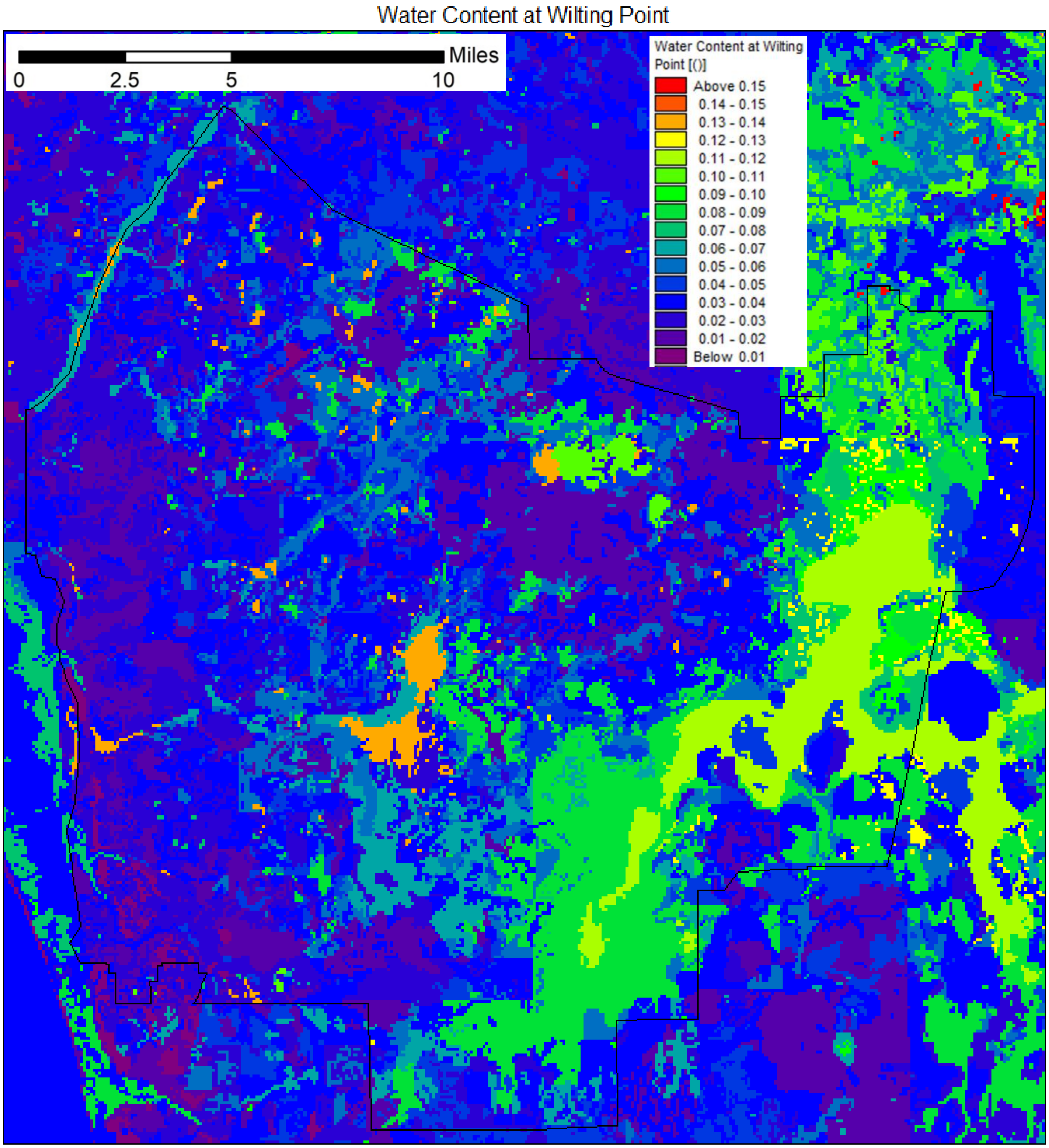

Figure 22. Soil water content at wilting point.

Kh Saturated

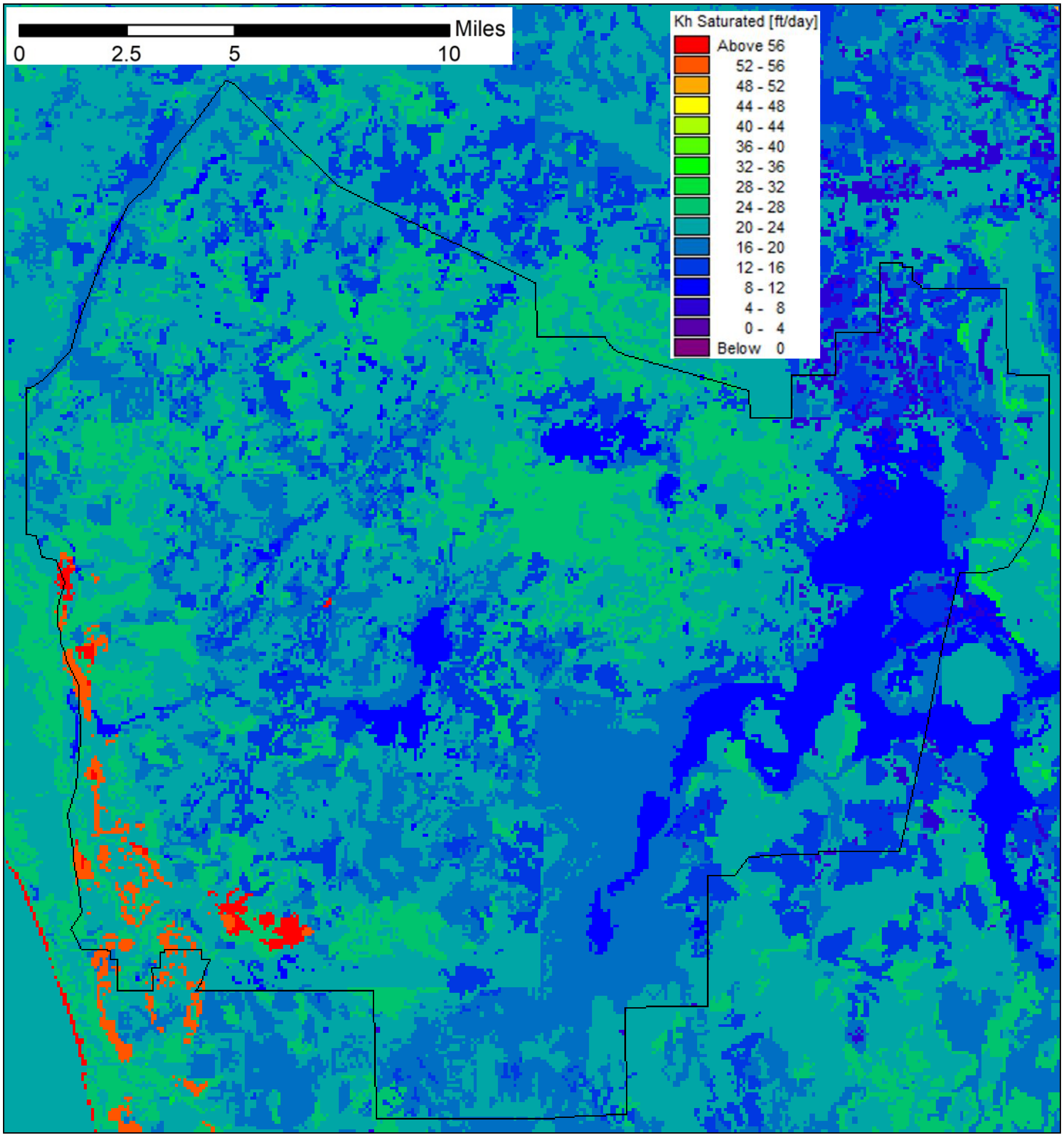

Figure 23. Soil hydraulic conductivity at saturation.

Suction Depth

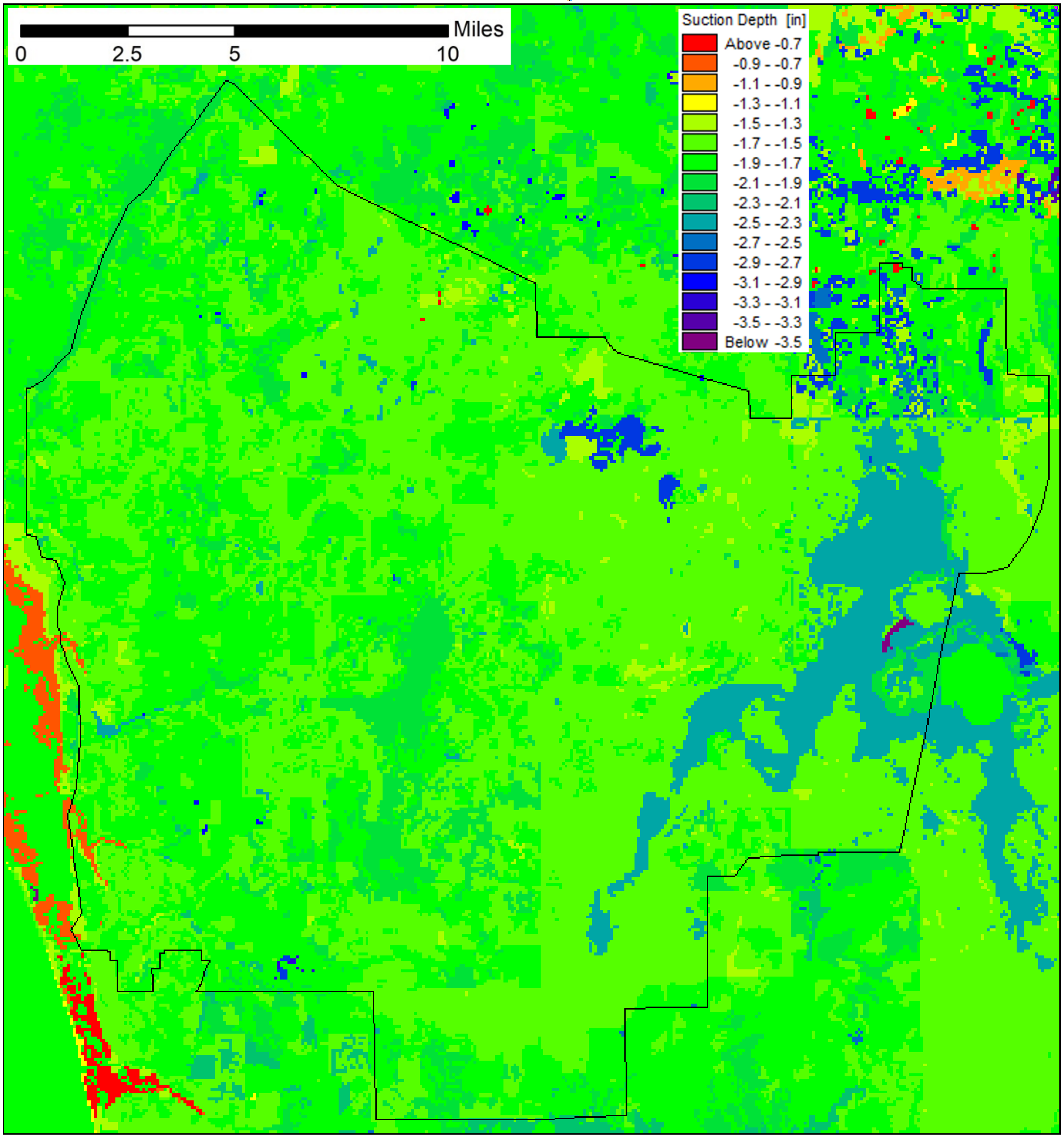

Figure 24. Soil suction depth.

Saturated Zone (SZ) Component

Geological Layers

The geological layers defined in previous MIKE SHE models for South Lee County areas are presented in **Table 8**. The CSS model reached down to the Sandstone Aquifer. The Mid-Hawthorn layers are included in this model since there are some irrigation wells from the Mid-Hawthorne Aquifer in the northwest area of the model domain.

Table 8. Geological layers in the SLCWI Model.

Geologic Layer	Hydrogeologic Unit	Computational Layer in the SLCWI Model
Holocene-Pliocene	Water Table (WT) Aquifer	1
Bonita Springs Marl	Tamiami Confining Unit	2
Ochopee	Lower Tamiami (LT)	
Upper Peace River Confining Unit	Upper Hawthorn Confining Unit	3
Peace River Sandstone	Sandstone (SS) Aquifer	
Basal-Peace River Sandstone	Mid-Hawthorn Confining Unit	4
Arcadia	Mid-Hawthorn (MH) Aquifer	

The vertical limits of the geological layers were compiled in Hydrogeologic Unit Mapping Update for the Lower West Coast Water Supply Planning Area (LWCSASIAS) [SFWMD, 2015]. During the Edison Farm modeling project, stratigraphy from some additional wells in South Lee County was combined with the LWCSASIAS data to refine the layer top and bottom elevations maps.

Figure 25 through **Figure 31** present the thickness of the geologic layers in the SLCWI model area. Notice that the Tamiami confining unit is absent in some areas. The Lower Tamiami Aquifer in areas with Tamiami confining unit thicknesses less than 5 feet may be considered unconfined. In any case, MIKE SHE uses the layer thicknesses and their hydraulic conductivities to compute SZ heads and flows.

Hydraulic conductivities for the different geological layers are adopted preliminarily from the Edison Farm Model. They will be adjusted during the calibration process.

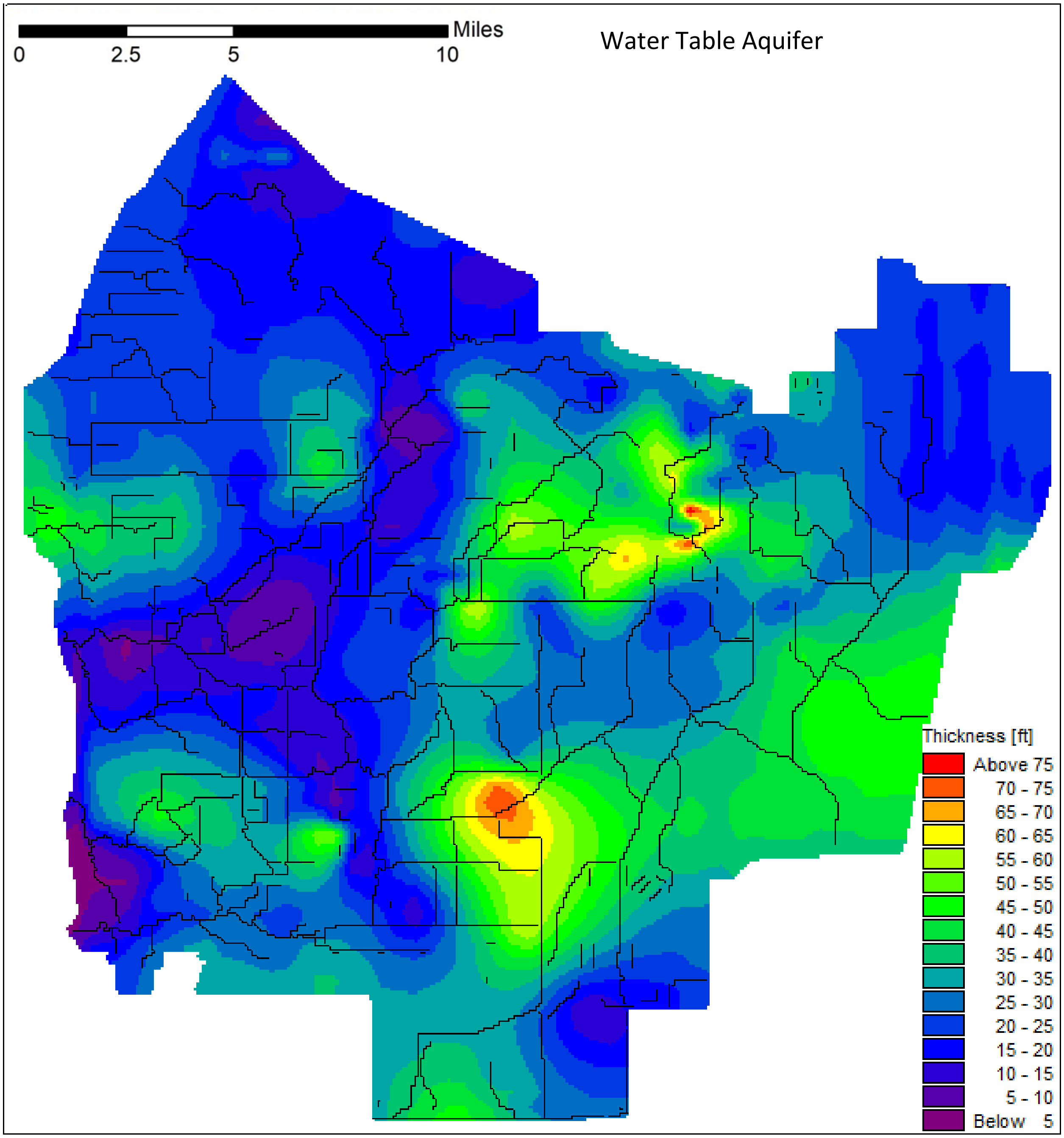

Figure 25. Water Table Aquifer thickness in the SLCWI model.

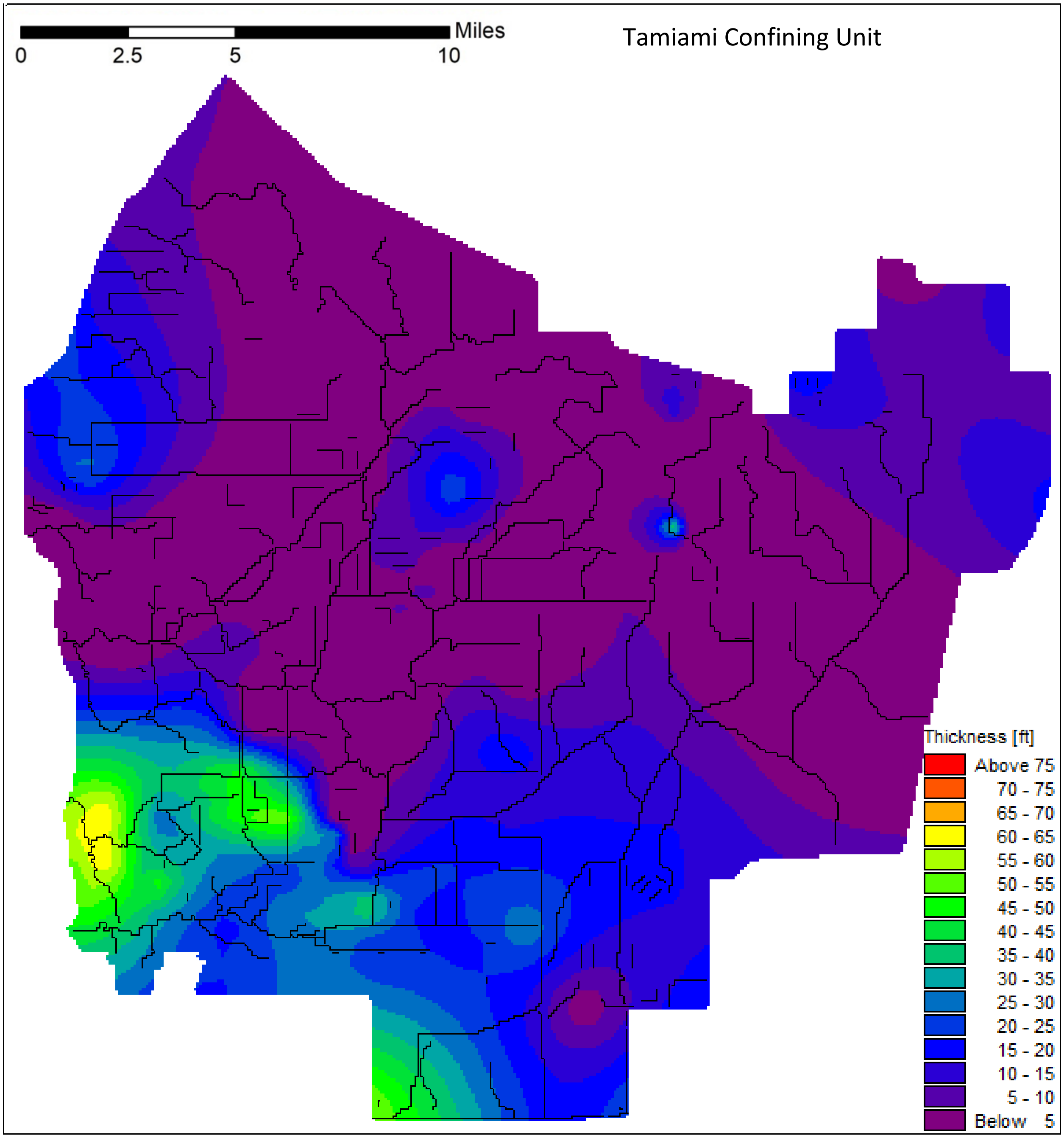

Figure 26. Tamiami Confining Unit thickness in the SLCWI model.

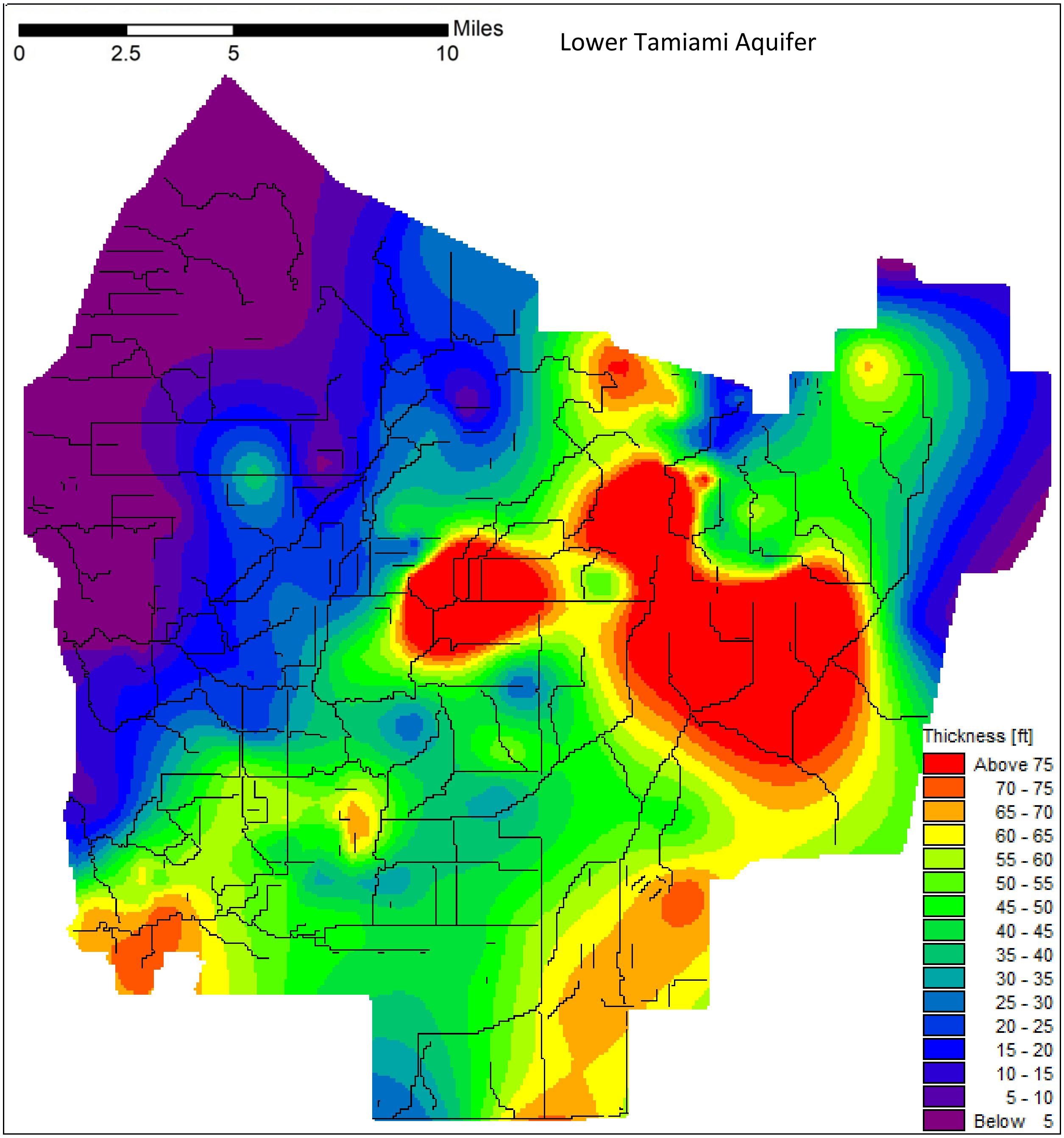

Figure 27. Lower Tamiami Aquifer thickness in the SLCWI model.

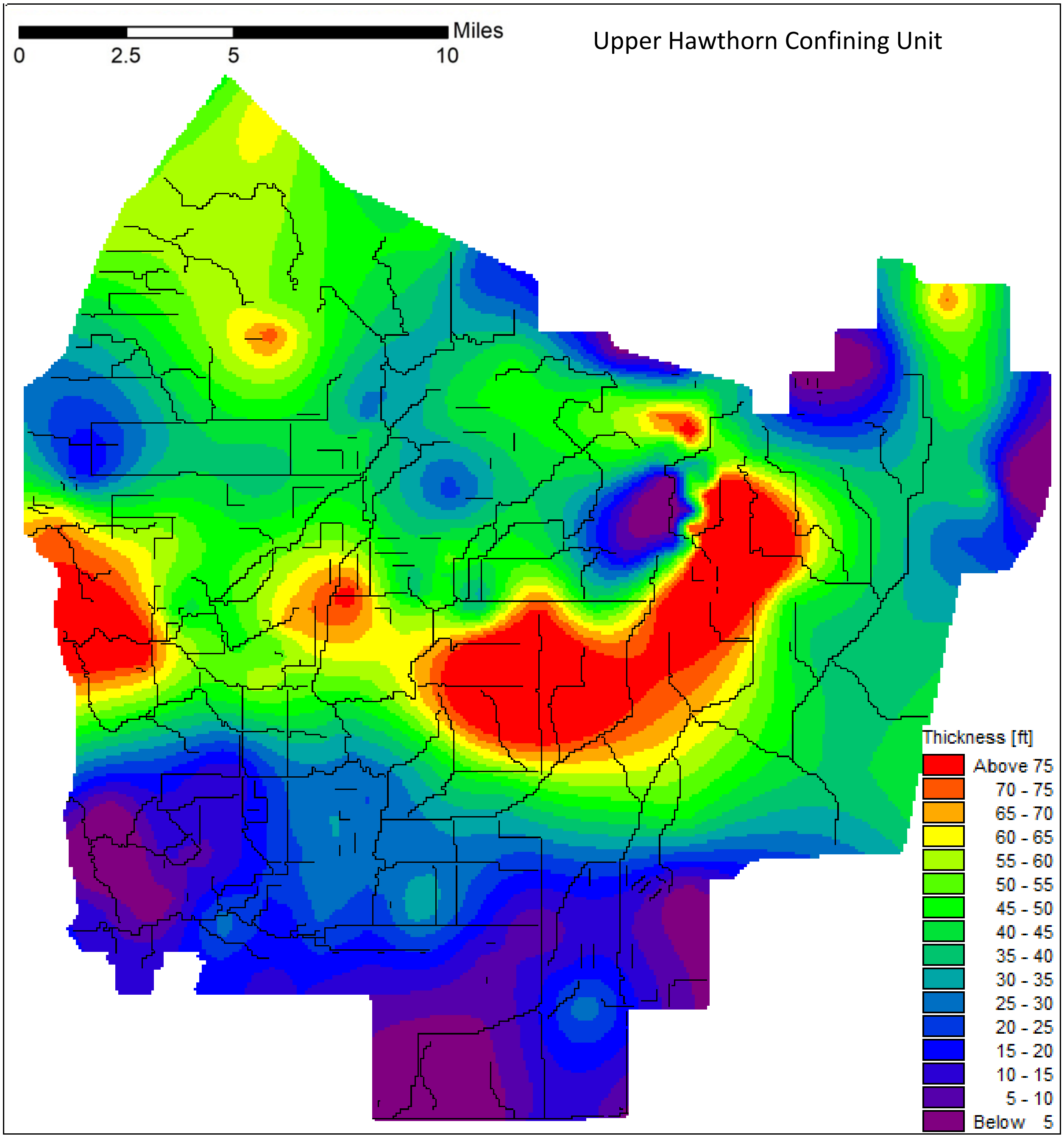

Figure 28. Upper Hawthorn Confining Unit thickness in the SLCWI model.

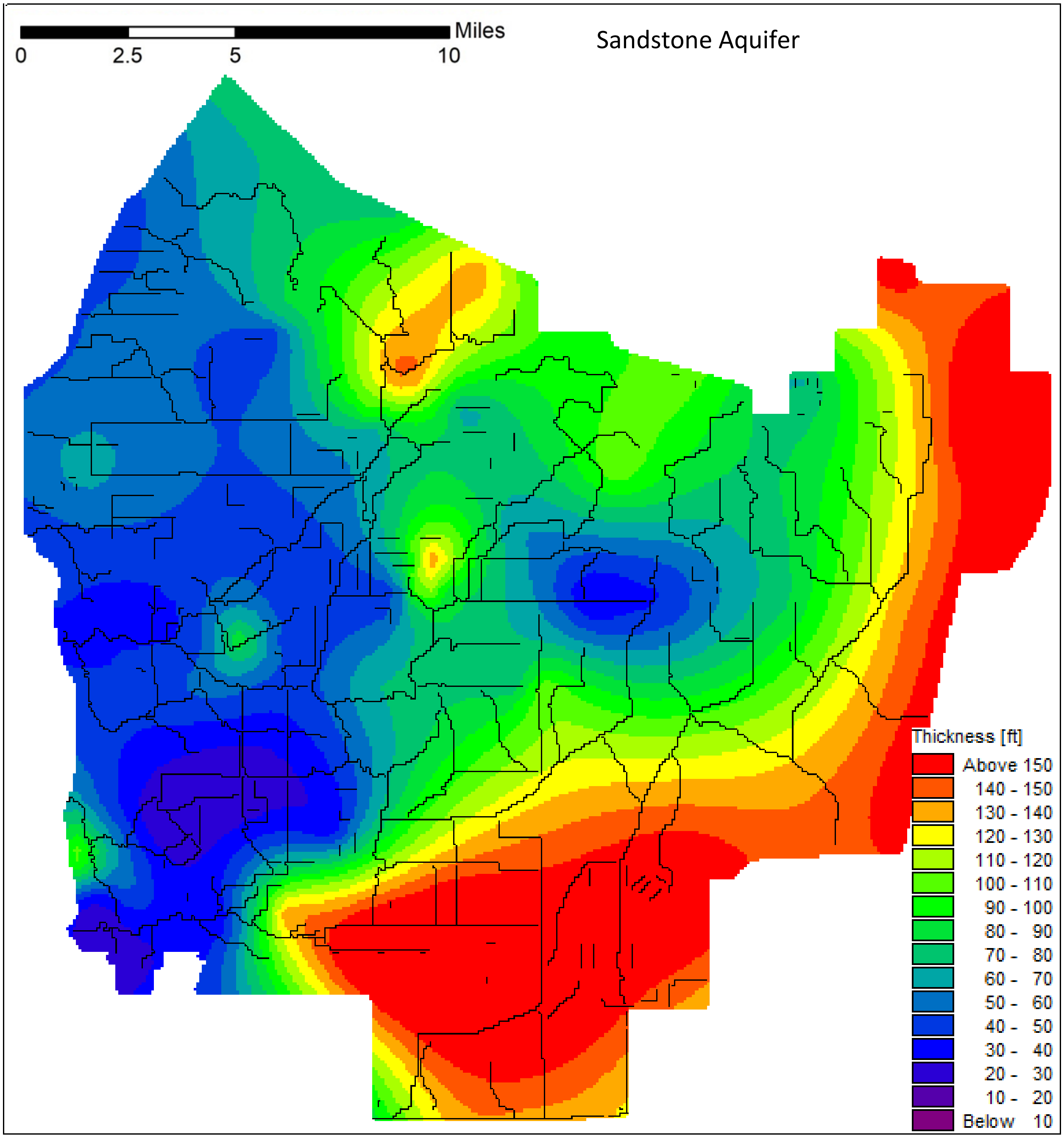

Figure 29. Sandstone Aquifer thickness in the SLCWI model.

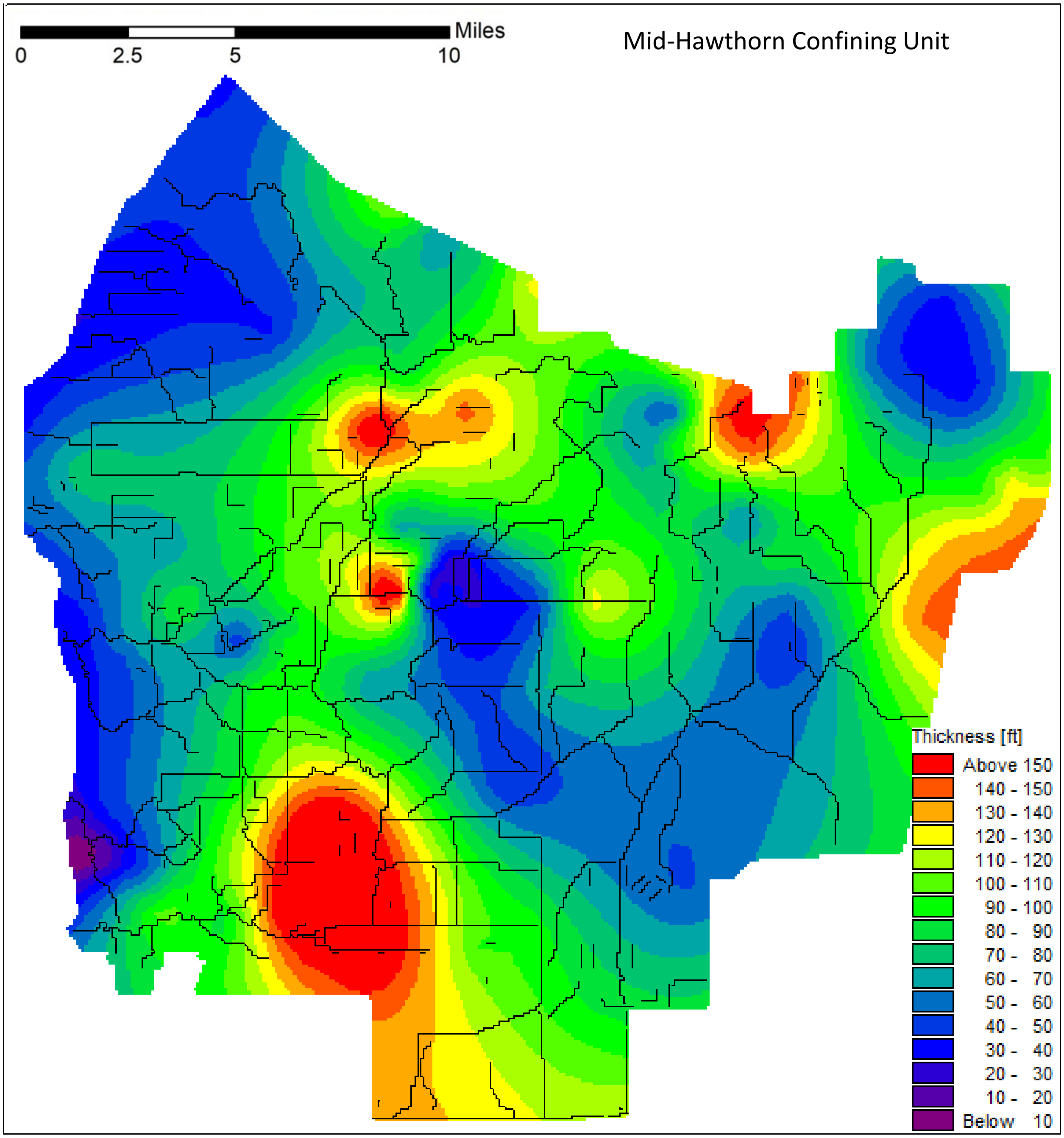

Figure 30. Mid-Hawthorn Confining Unit thickness in the SLCWI model.

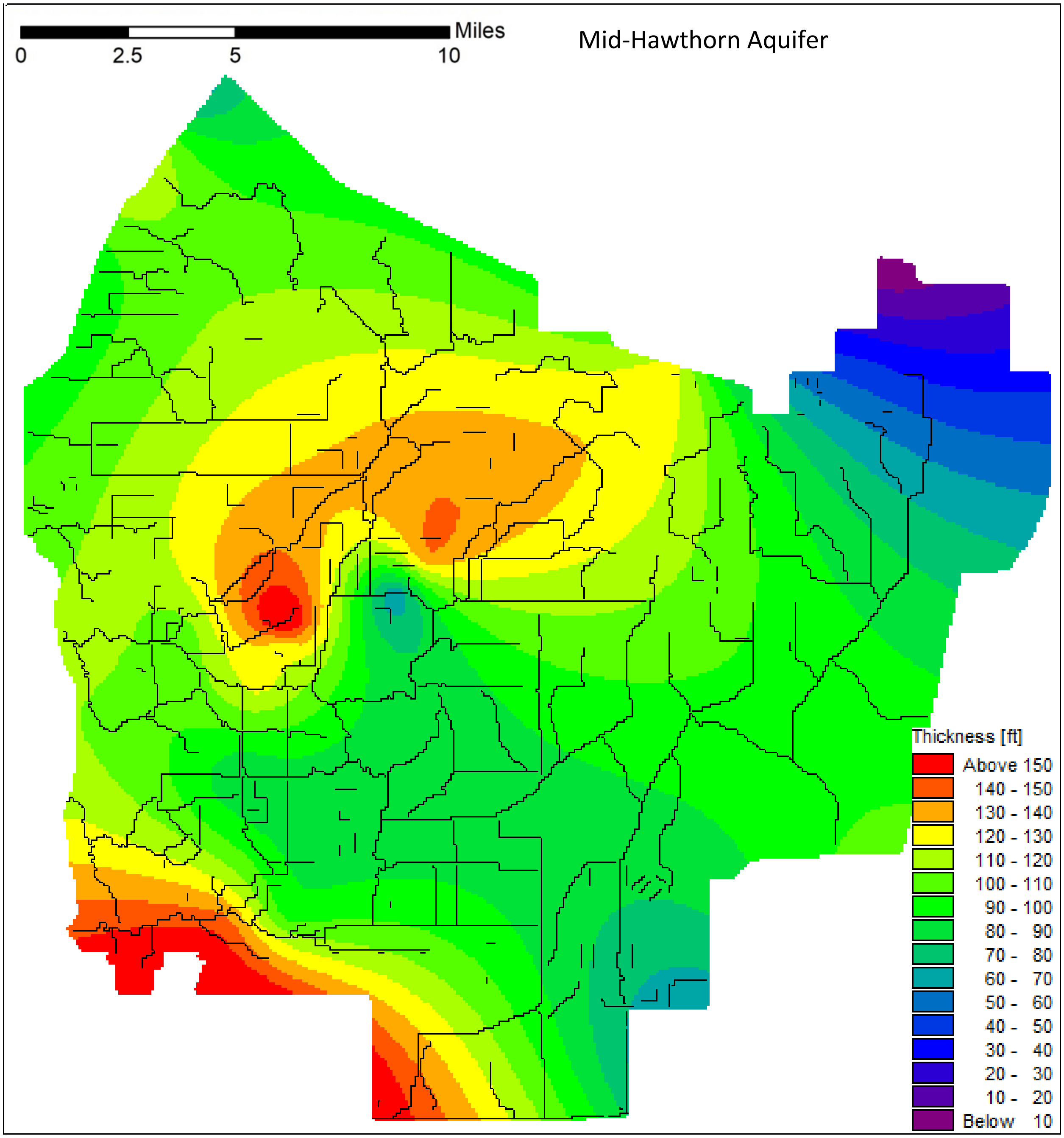

Figure 31. Mid-Hawthorn Aquifer thickness in the SLCWI model.

Geological and Conceptual Lenses

Two (2) lenses have been included in the SZ component of the SLCWI model:

1. The shell lens in the Corkscrew Swamp Sanctuary, which was first introduced in the CSS MIKE SHE model.

2. The conceptual water lens, which has been used since the DRGR model to better conceptualize deep lakes and mining Pits in South Lee County areas. In this case, two thicknesses of 10 ft and 30 ft are used to account for shallower and deeper water bodies, respectively.

The extend of the lenses is presented in **Figure 32**.

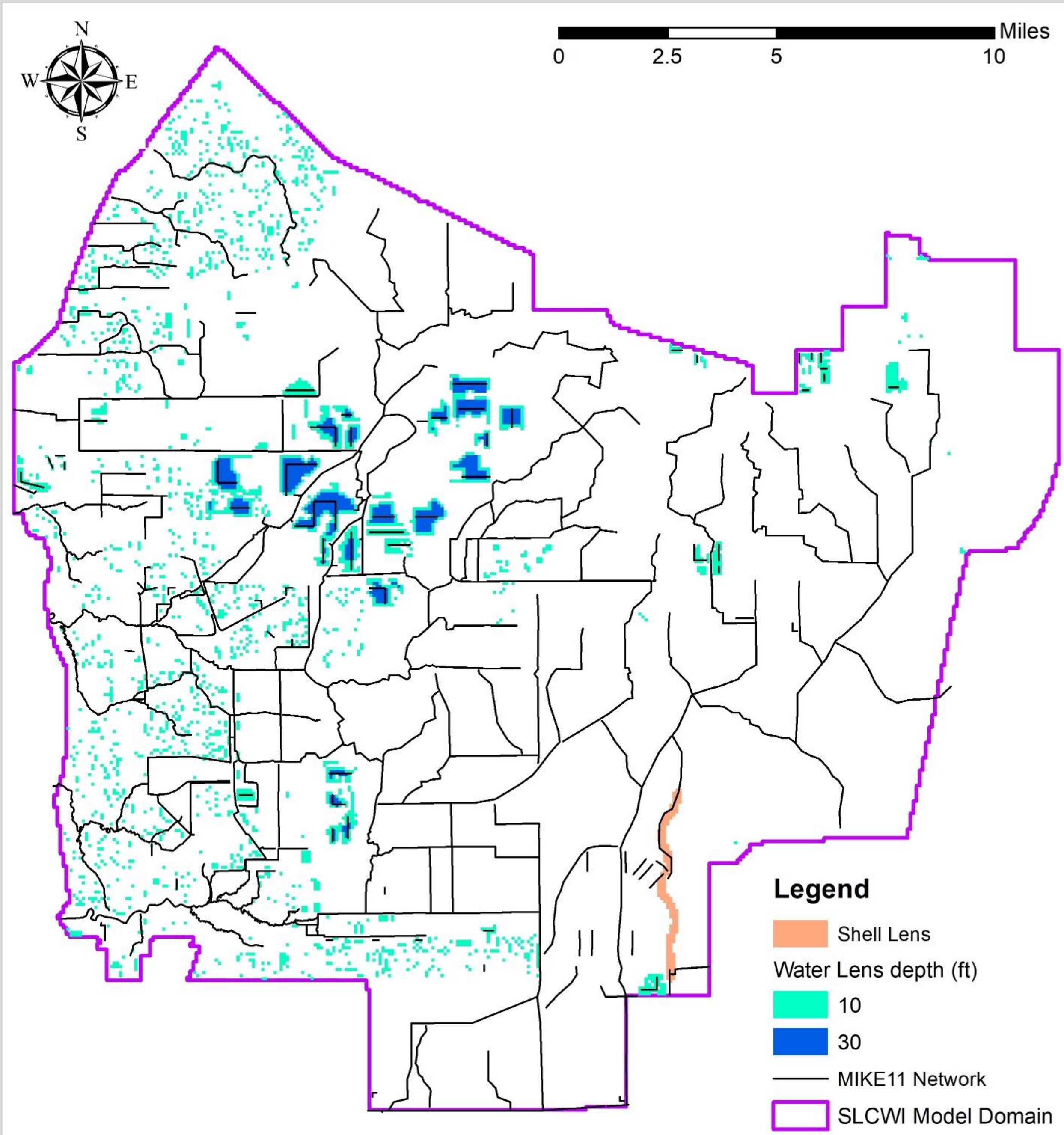

Figure 32. Lenses extent in the SLCWI model.

Computational Layers

There are four (4) computational or numerical layers in the SLCWI model, as detailed in Table 8.

The approach of merging the top confining unit with the underlaying aquifer in a single computational layer has been used successfully in previous MIKE SHE models for South Lee County as a way to reduce the simulation run times without significantly affecting model performance. In this case, MIKE SHE computes composite properties for each computational layer. Typically, the confining unit and the aquifer control the vertical and horizontal conductivities of the composite layer, respectively.

Time-varying interpolated head maps were generated from observation well data from the four (4) aquifers to be used as lateral boundary conditions in the computational layers. **Figure 33** through **Figure 36** show average heads during the 10-year period 2010-2019 for the different aquifers. The time-varying heads are applied along the entire boundary except in layers 3 and 4, where the coastal boundary is assumed closed. More details about the data source and processing to obtain the time-varying interpolated head maps will be included in Technical Memorandum for Project Task 6.

Initial heads for the computational layers that are applied at the beginning of the simulation (i.e., 1/1/2013) are taken from the model results after two years (i.e., 1/1/2015).

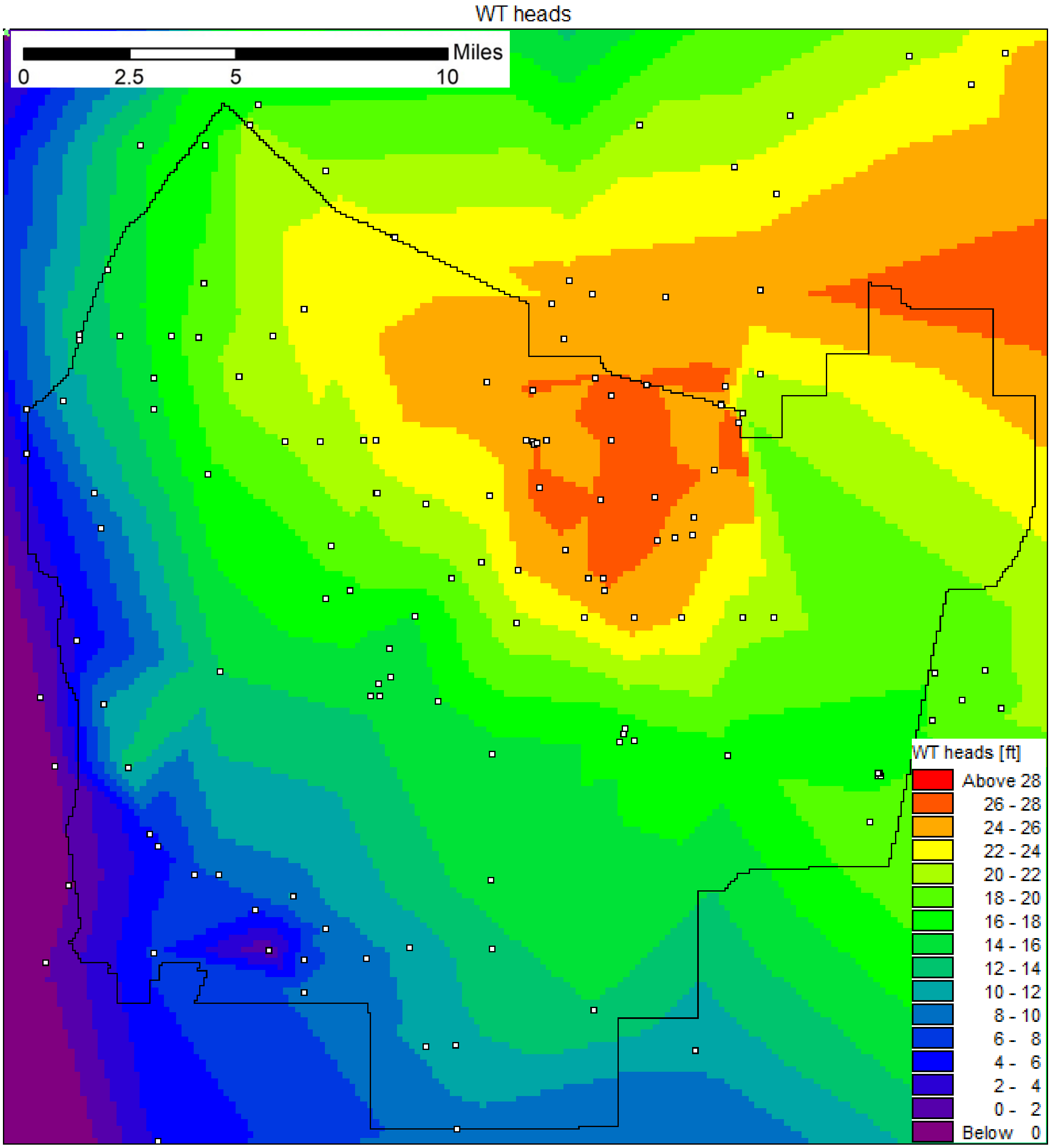

Figure 33. 10-year average interpolated heads from Water Table Aquifer stations.

LT heads

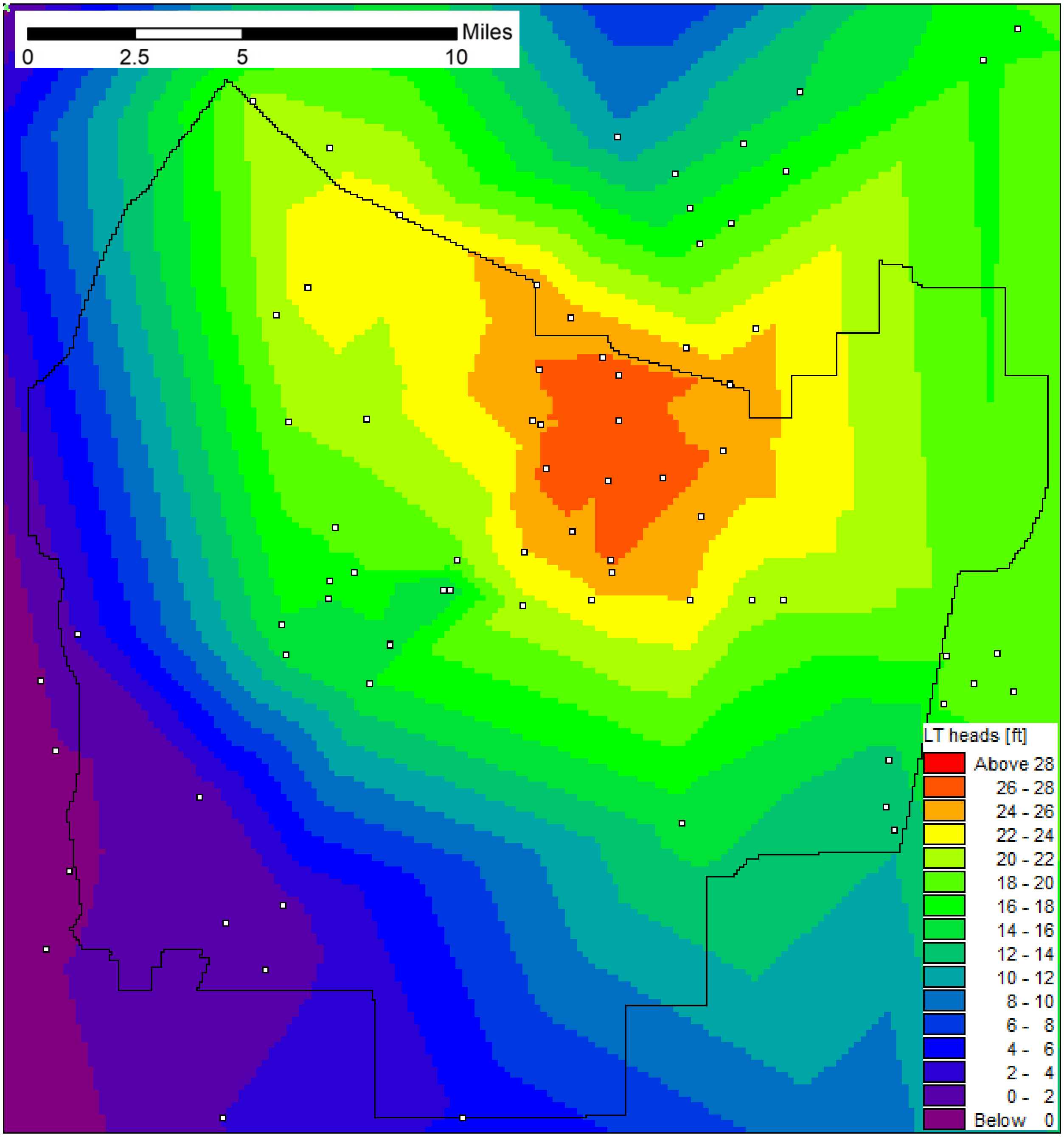

Figure 34. 10-year average interpolated heads from Lower Tamiami Aquifer stations.

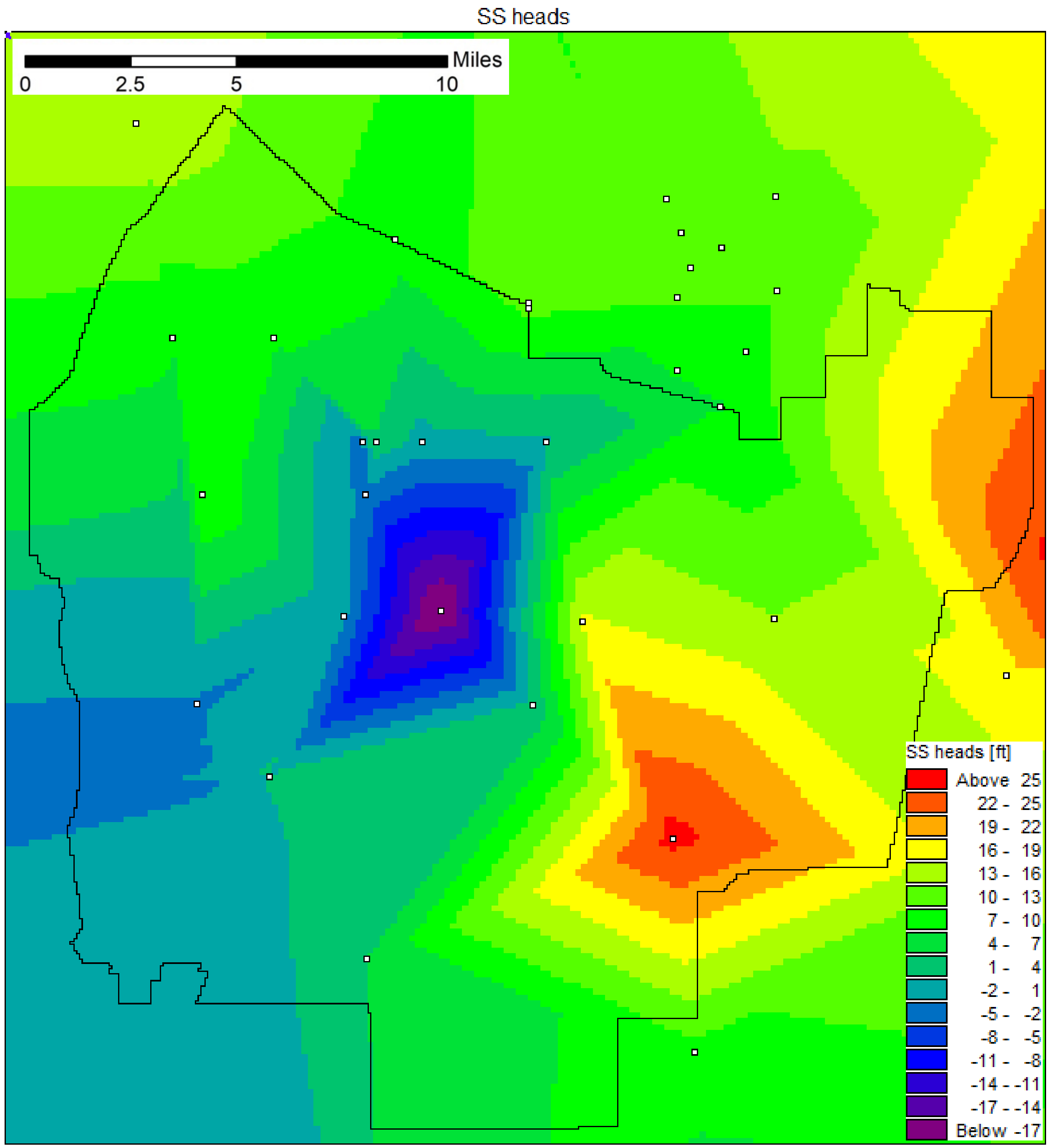

Figure 35. 10-year average heads interpolated heads from Sandstone Aquifer stations.

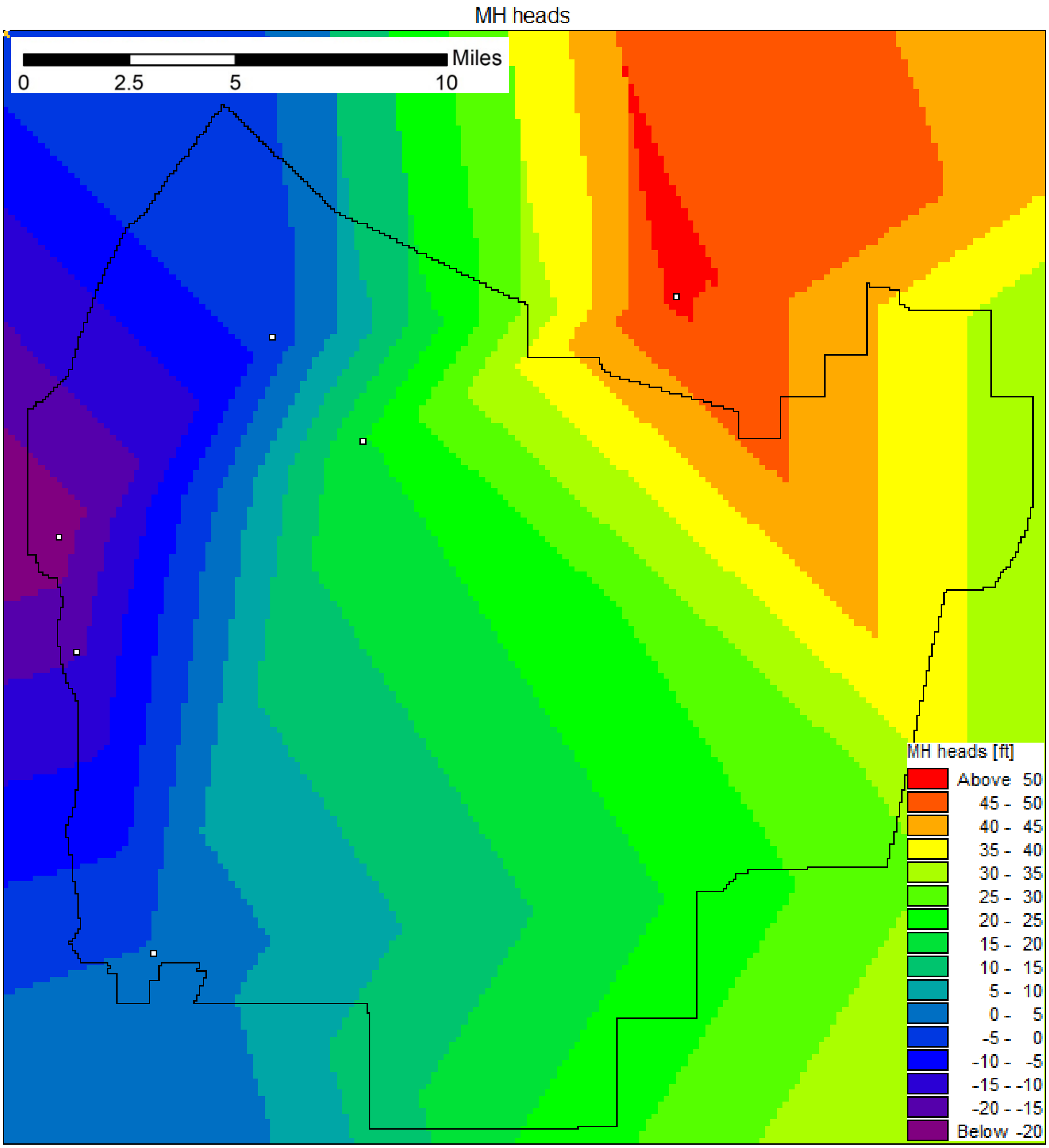

Figure 36. 10-year average heads interpolated heads from Mid-Hawthorne Aquifer stations.

Drainage

Previous MIKE SHE models for the area used the drainage component to represent the drainage from agricultural and urban areas. This model component is one of the few empirical components in MIKE SHE. The drainage component is part of the geologic portion of the model set-up because it routes shallow groundwater to the drainage destination (i.e., MIKE11 branches, local depressions, or model boundary).

As in previous MIKE SHE models of the South Lee County Area, the input parameters for drainage levels and time constants are found from correlations with the MIKE SHE land use codes, as shown in Table 6. They are utilized for agricultural and urban areas and set as zero elsewhere to suppress the drainage. The resulting parameter maps are shown in **Figure 37** and **Figure 38**, respectively. These parameters may be adjusted during the calibration task.

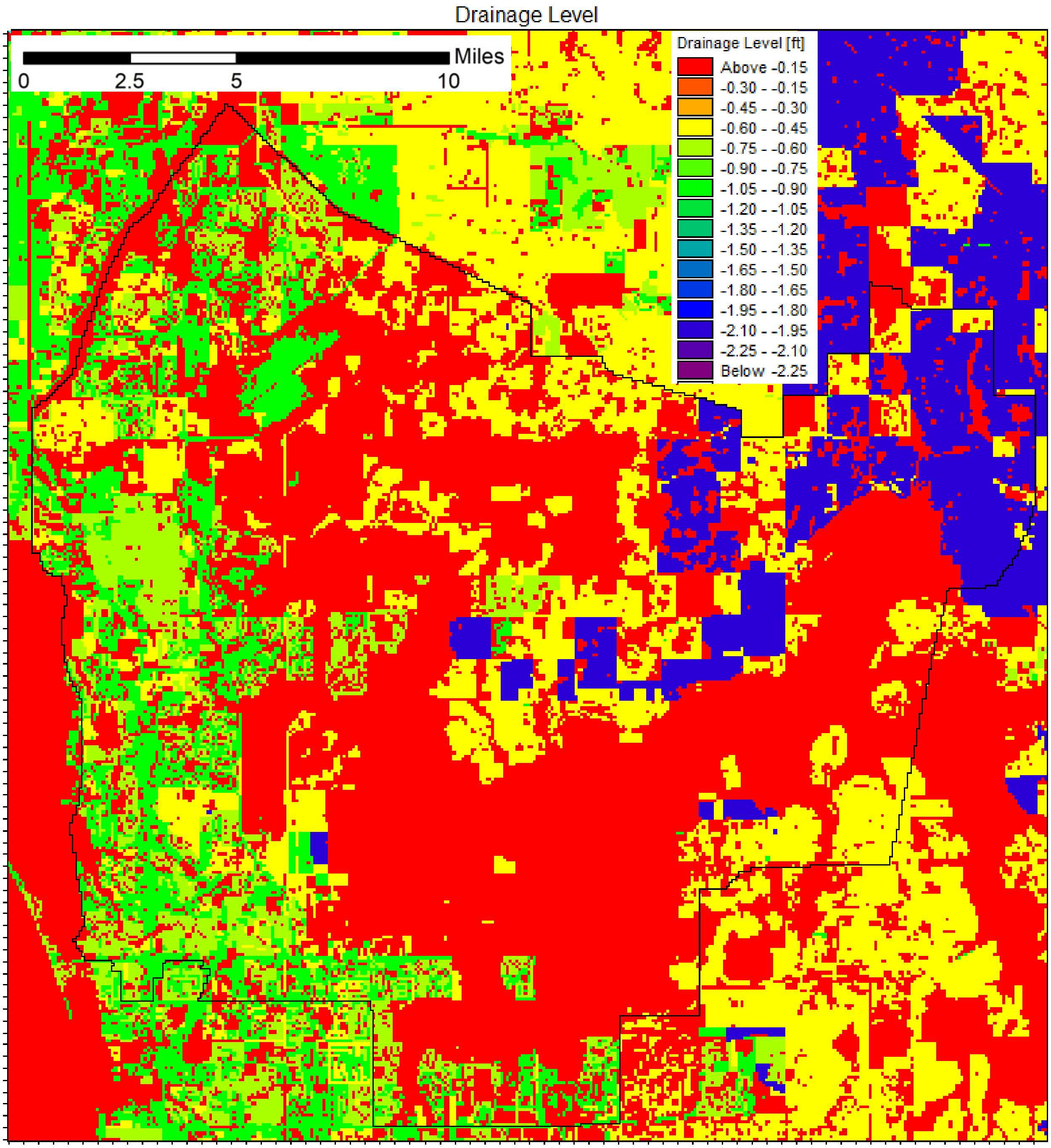

Figure 37. Drainage level map in the preliminary SLCWI Model.

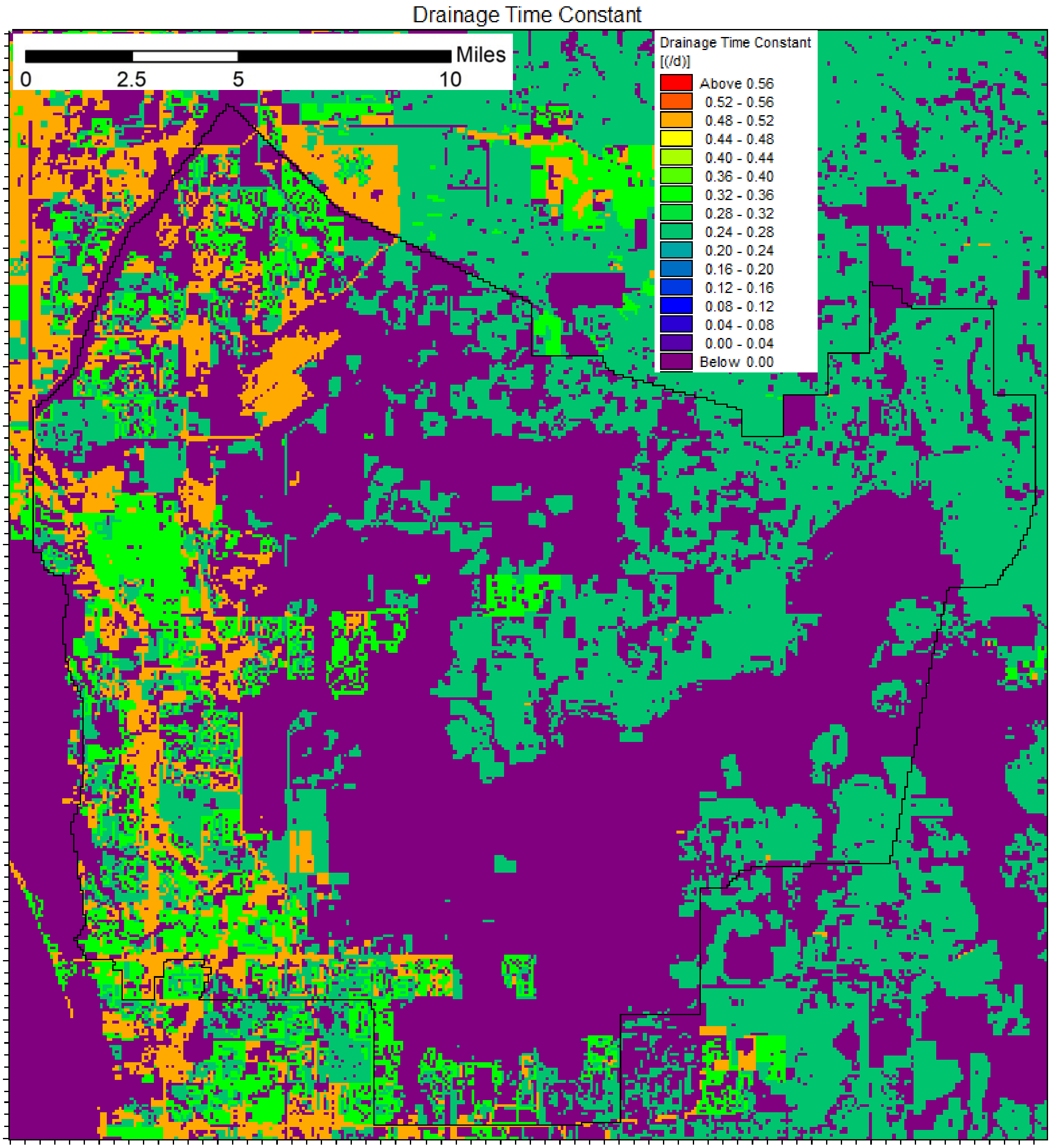

Figure 38. Drainage time constant map in the preliminary SLCWI Model.

Drainage codes presented in **Figure 39** are based on the SOLFA codes presented in Figure 18. Most of the areas have negative drain code values to indicate drainage to a local depression. Only areas draining to a specific branch segment have positive drain codes, which are listed in **Table 9**. Drain codes may be adjusted during the calibration task.

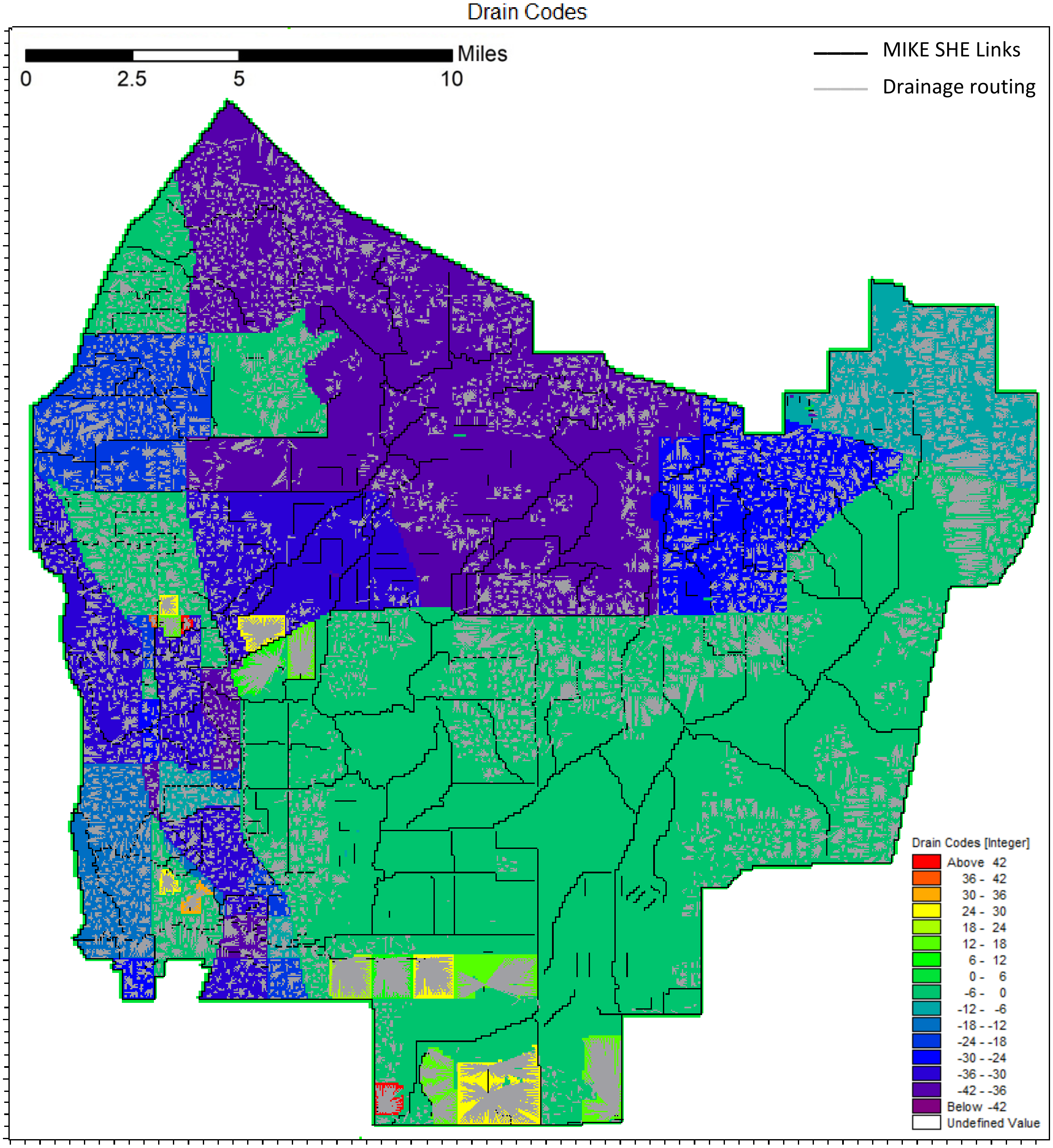

Figure 39. Drain code map in the preliminary SLCWI Model.

Table 9. Drainage to specific MIKE11 branch segments in the preliminary SLCWI Model.

Drain Code	Branch Name	Upstream Chainage (m)	Downstream Chainage (m)
10	Palmira	0	1
11	StoneyBrook_Outfall	0	1
12	Esplanade	208	2850
13	GolfClub	0	1
14	TwinEagles_Outfall	0	1
15	WildcatRun4	0	1
16	Cascade_Outfall1	0	1
23	Worthington	0	1
24	GrandezzaOutfall	0	1
25	QuarryLakes_Outfall	0	1300
26	VIllageWalk	0	1
27	Reserve_WestDitch	0	1
28	HighlandWoods	0	1
30	BonitaFairways	0	1
37	Cascade_Outfall2	0	1
43	Woodland_Outfall	0	1
44	RookeryPoint	0	1

Pumping Wells

The information from potable-water supply (PWS) wells in previous MIKE SHE models for the South Lee County is used in the SLCWI model. Monthly pumping reported data available from the SFWMD water use permits were used to update the pumping rate time series input data through 2019. Typically, municipal wells and other wells with significant extraction rates are included in this component. Meanwhile, irrigation and self-supplied domestic water supply wells are conceptualized in the irrigation component.

Table 10 lists the PWS wellfields inside the model domain. Pumping well locations are also presented in **Figure 41**. The evolution of the total monthly pumping inside the model domain is plotted in **Figure 40.** More details about the observation data source and processing will be included in Technical Memorandum for Project Task 6.

Table 10. PWS wellfields in the SLCWI Model.

Water use permit number	Well field Name	Aquifer	Number of wells	Annual allocation (MGD)	Average pumping 2010-2019 (MGD)
36-00003-W	Lee County Utilities - Green Meadows (GM)	LT/SS	27	< 34.27	4.81
	Lee County Utilities – Corkscrew (CS)	LT/SS	53		9.31
36-00008-W	Bonita Springs Utilities	LT	21	5.74	3.83
36-00122-W	Gulf Environmental Services	WT/SS	12	7.36	1.67
36-00208-W	Citrus Park	WT/LT	3	0.23	0.20
Total			**116**		**19.82**

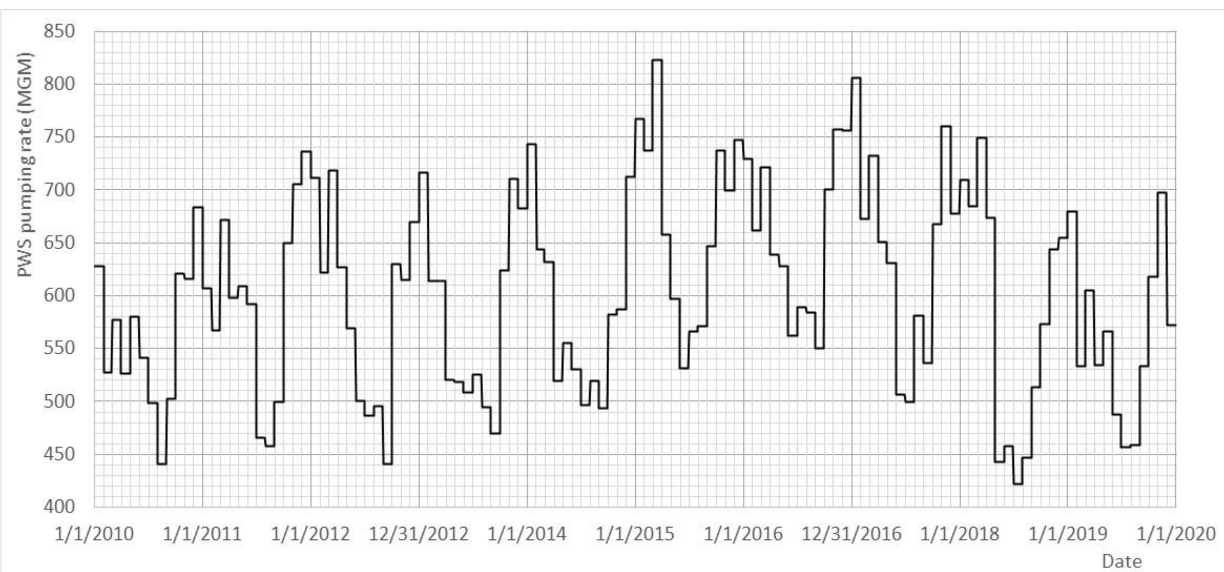

Figure 40. Total monthly PWS pumping inside the SLCWI model domain.

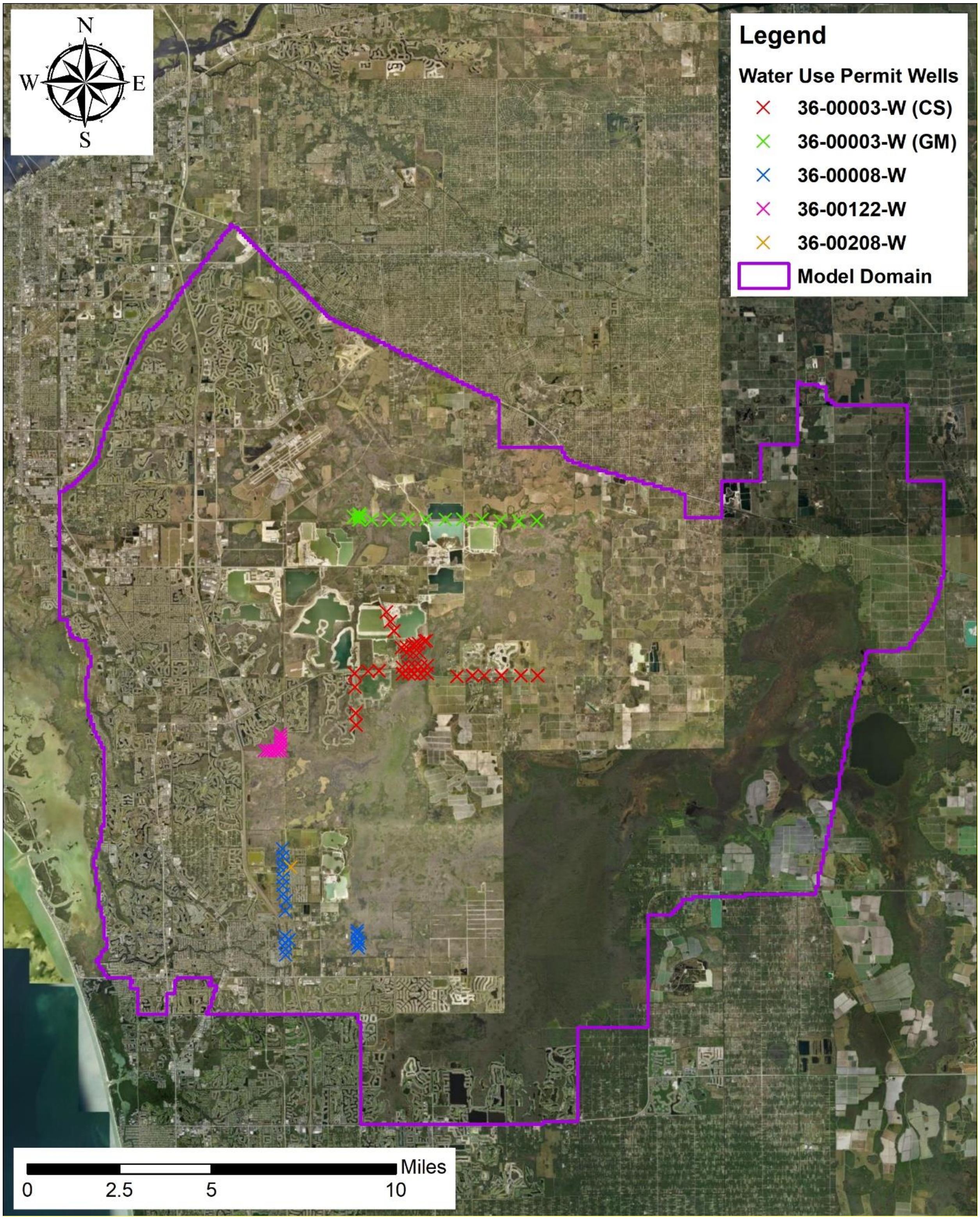

Figure 41. Potable water supply wells in the SLCWI model.

The reuse water application was also conceptualized in the pumping well component of the SLCWI model. Application location and annual averaged application rates were received from Lee County and Bonita Springs Utilities. Contrary to the PWS well pumping rates, the reuse application rates have a negative value in the model. More details about the reuse water data source and processing will be included in Technical Memorandum for Project Task 5.

Observation Station Data

MIKE SHE software allows for comparison of simulated and observed time series data at individual monitoring stations. Most of the station information was taken from previous MIKE SHE model for the area such as CSS and Edison Farms. Moreover, time series data were extended to current period and new station data were added. The observation station data locations are presented in **Figure 42** and **Figure 43**. More details about the observation data source and processing will be included in Technical Memorandum for Project Task 6.

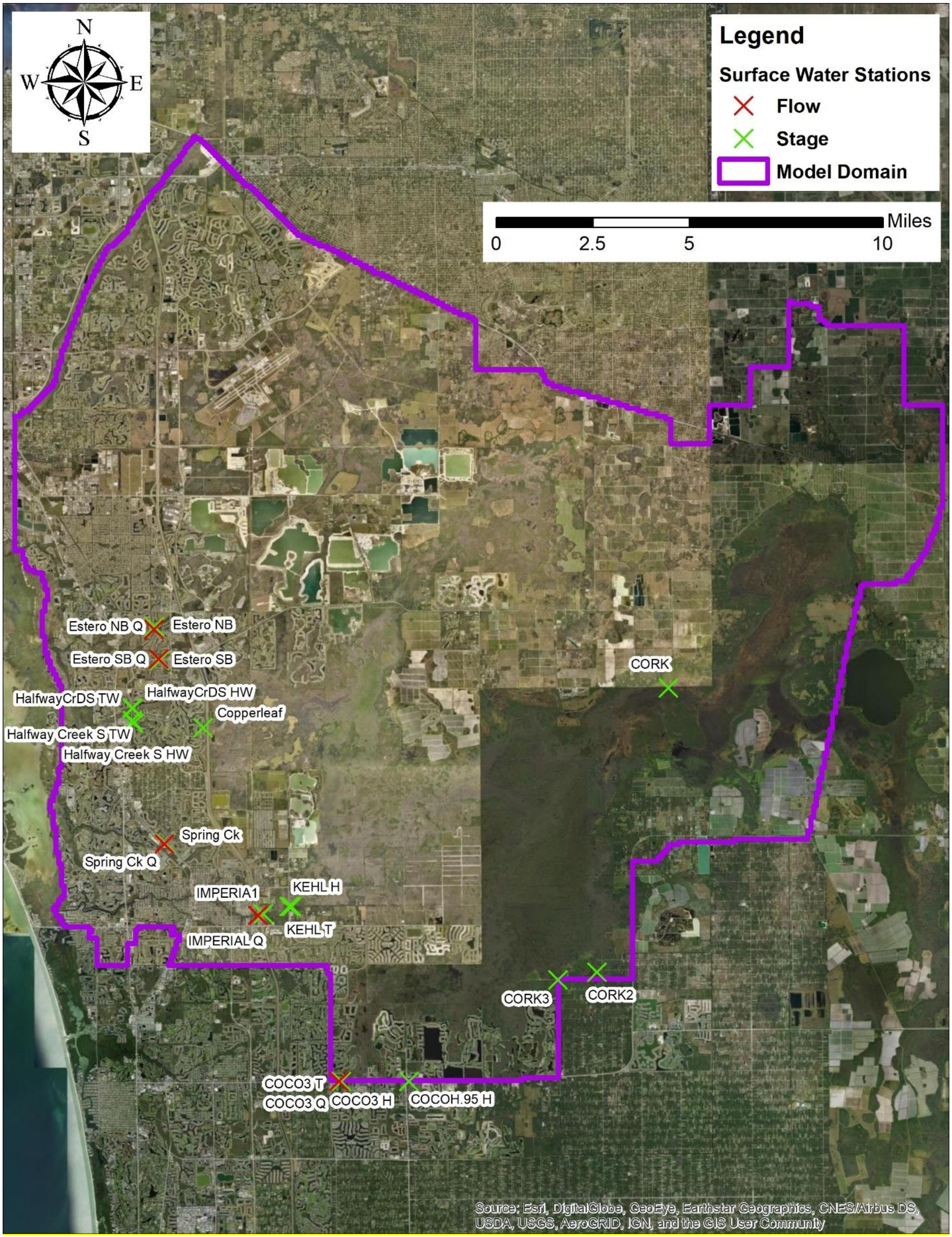

Figure 42. Surface water observation stations in the preliminary SLCWI model.

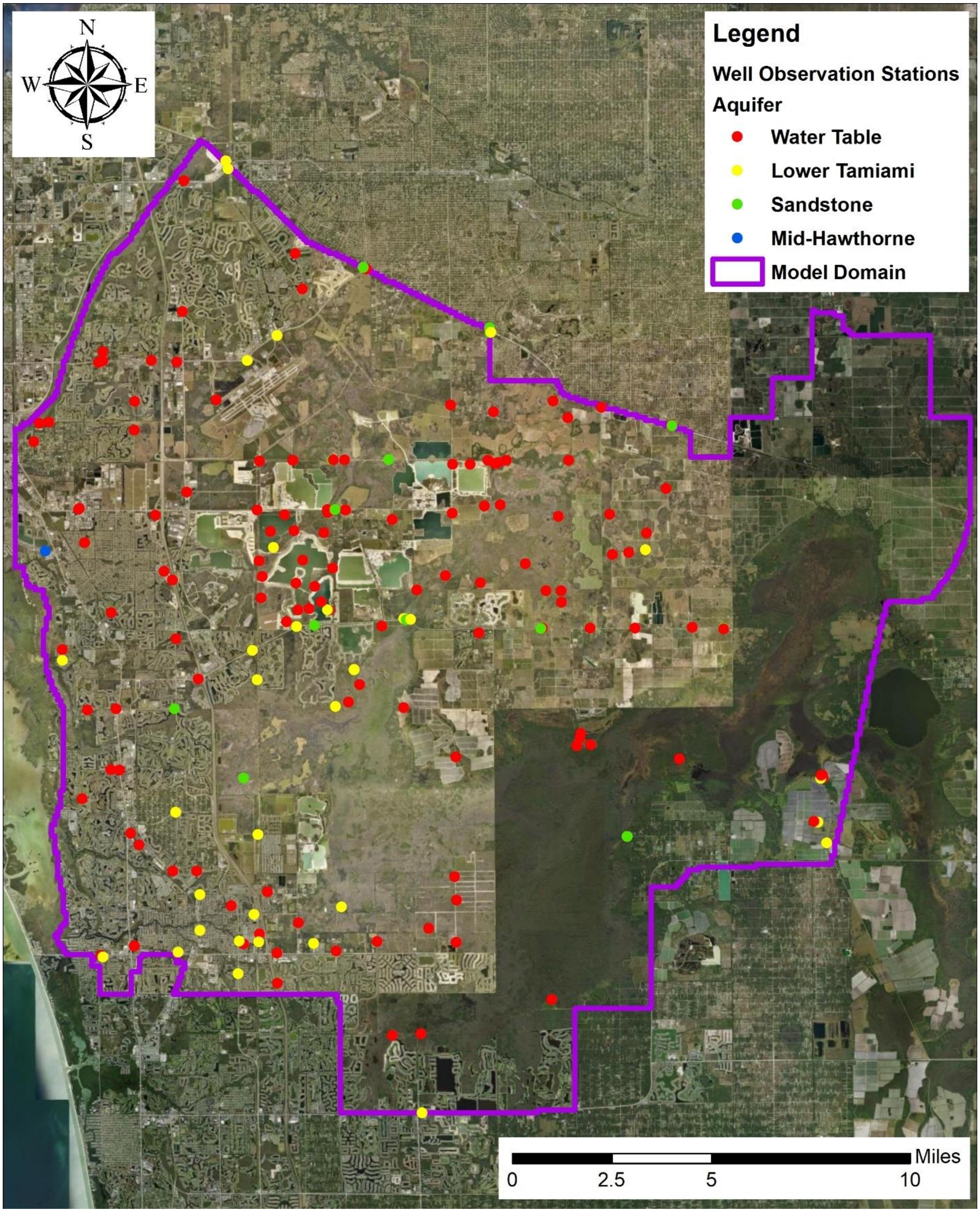

Figure 43. Groundwater water observation stations in the preliminary SLCWI model.

Extra Parameters

Table 11 presents the list of MIKE SHE extra parameters in the preliminary model. These parameters may be modified during the calibration task.

Table 11. Extra parameters defined in the preliminary SLCWI Model

Extra parameter	Type	Value	Comments
disable harmonic mean of SZ conductivity	Bool	1	SZ engine calculates groundwater flows at cell faces as in MODFLOW.
Check gradient for drainage to river or mouse	Bool	1	Drainage stops if water level at destination is higher than at the source, which corresponds to a gravity driven system.
Check gradient for drainage to local depression	Bool	1	
extended pp print	Bool	1	More information included in the PP_print.log file
max number of detailed ts plots per html file	Integer	10	More number of plots per html file. Default value = 5.
use mike 1d	Bool	1	Use MIKE1D instead of the classic MIKE11 engine
use specified reaches for drainage	Bool	1	To specify drainage to specific MIKE11 branch segments
specified reaches for drainage	Filename	\PFS\ Drainage_Option PFS_SLCWI.pfs	
sheet piling module	Bool	1	To consider land bridges that separate mining pits in the SZ component. See locations in **Figure 44**
sheet piling file	Filename	\PFS\ mining_sheet_ piling_SLCWI.pfs	

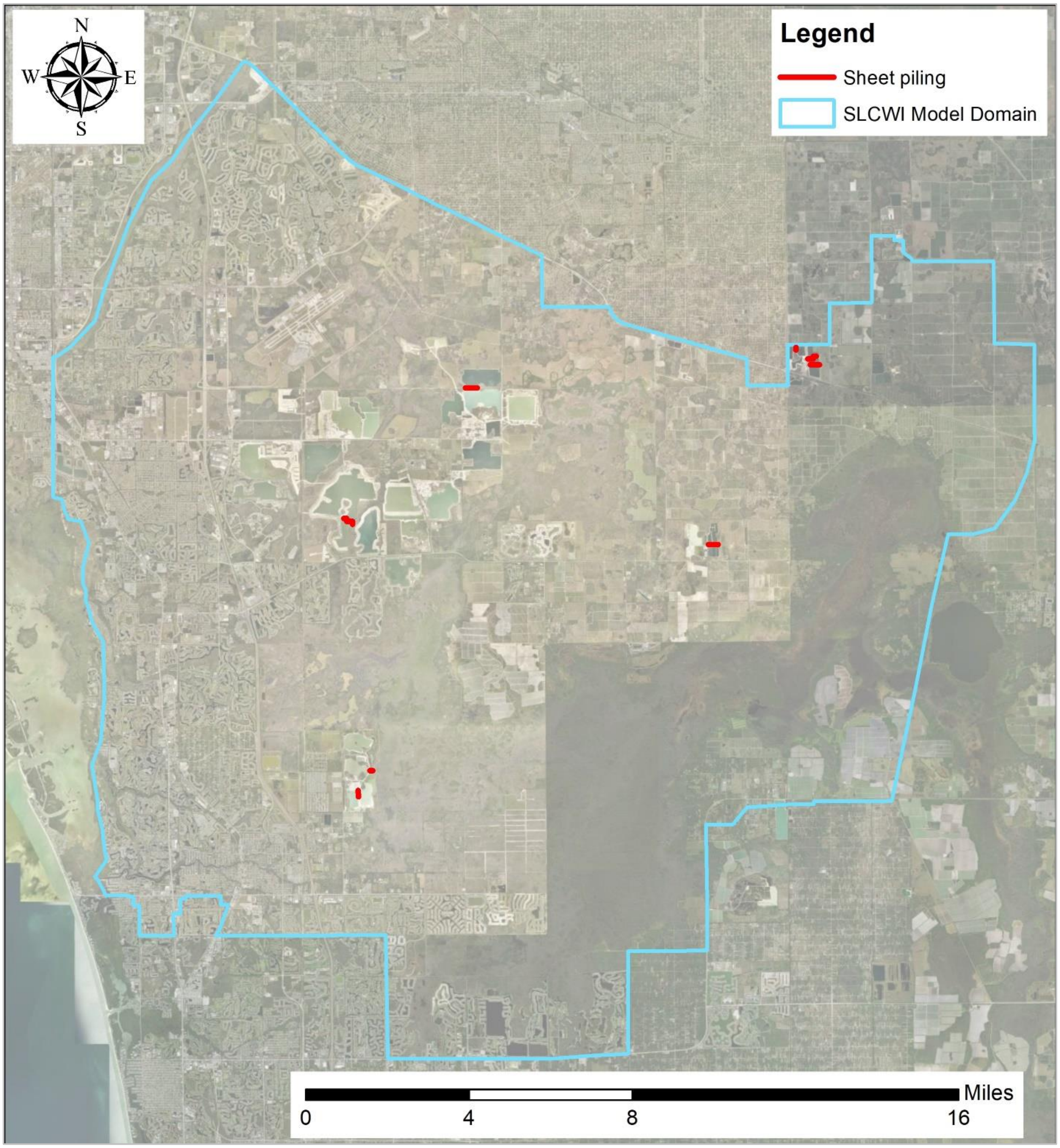

Figure 44. Sheet piling locations in the preliminary SLCWI model.

Preliminary Model Results

Some results from the preliminary model simulations are included in this section. A more detailed evaluation of the preliminary model performance will be included in Technical Memorandum for Project Task 7.

Runtime

Table 12 summarizes the preliminary SLCWI model runtime obtained during a 7-year simulation period (i.e., years 2013-2019). Notice that the preliminary model takes 13 and 45 hours to complete a simulation period of 2 and 7 years, respectively, which is a reasonable runtime to have during the calibration task.

Table 12. Preliminary SLCWI Model runtime in hours per simulated year.

Component	Runtime (hours to simulate one year)
SZ	2.0
UZ + ET	0.0
Overland	1.0
River	2.3
Irrigation	0.2
Meteorologic input	0.6
Vegetation input	0.0
Grid series output	0.0
Detailed TS output	0.1
Admin	0.2
Other	0.0
Total	**6.4**

Water Budgets

The preliminary mean annual water budget chart presented in **Figure 45** was computed from the 7-year simulation results by using the water budget calculation tool in MIKE SHE. This result shows a negligible cumulative error for the simulation period, which is an indication of good numerical stability and low mass balance errors in the model.

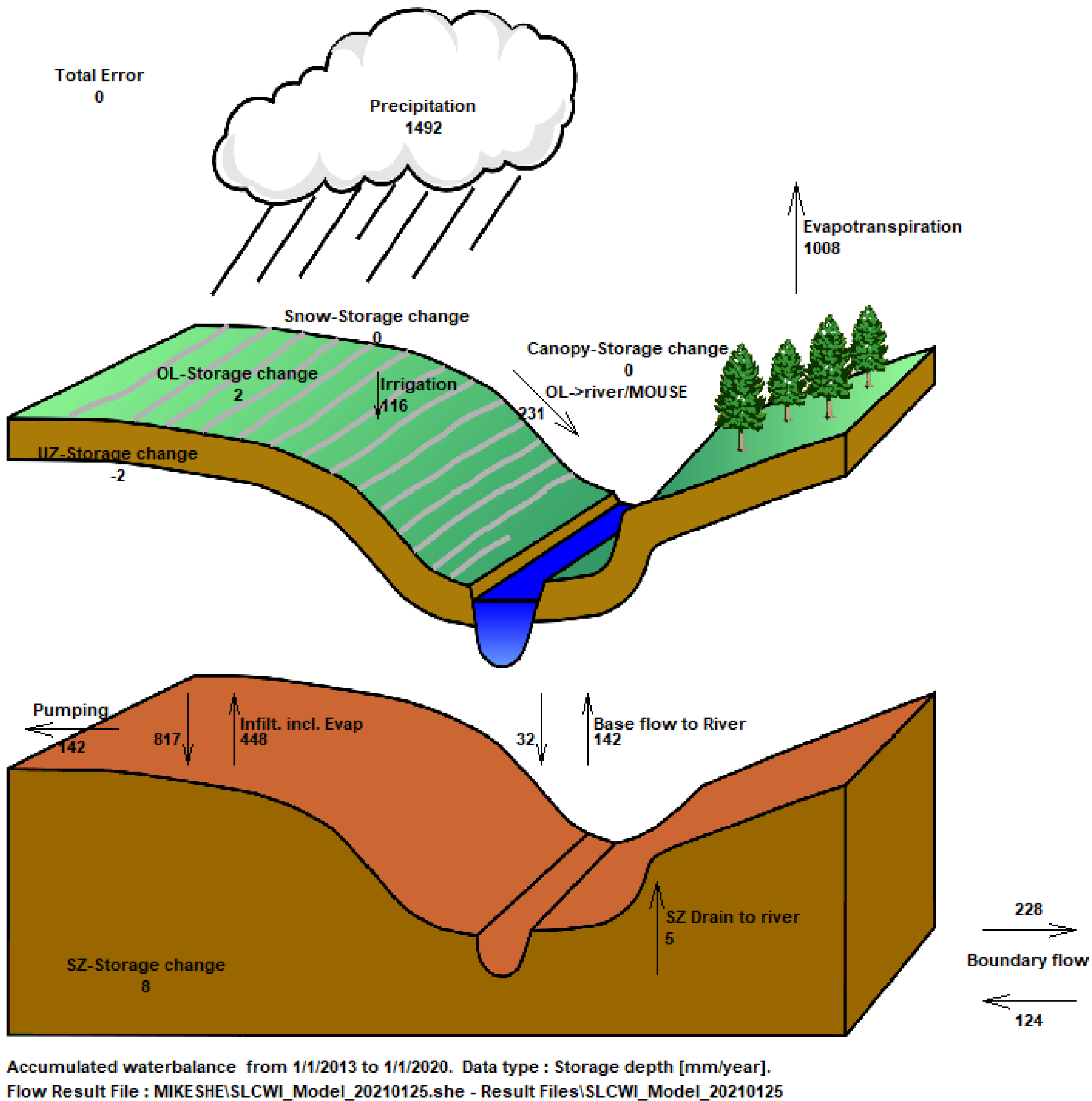

Figure 45. Annual average water budget for the entire domain from the preliminary SLCWI Model.

References

AIM, 2020. Southern Lee County Flood Mitigation Plan. Development and Calibration of the Southern Lee County Regional Model. Revised Report submitted by AIM Engineering & Surveying, Inc on August 14th, 2020.

DHI, 1999. Caloosahatchee Basin Integrated Surface Water – Groundwater Model, June 1999.

DHI, 2009. Comprehensive Hydrological Study of the Lee County Southeastern Density Reduction / Groundwater Resource (DR/GR) Area. Final Report of the MIKE SHE Model Development and Results submitted by DHI Water & Environment on September, 2009.

DHI, 2019. MIKE SHE Volume I User Guide and Volume 2: Reference Guide for software version 2019.

ICPR, 2021. ICPR Documentation for software version 4.07.04

LAGO, 2019. City of Bonita Springs: ICPR Model Update. Evaluation of Hurricane Irma Flood Mitigation Projects. Technical Memorandum submitted by Lago Consulting & Services on December 3rd, 2019.

LAGO & Stanley, 2020. Big Cypress Basin I-75 Canal and Green Canal Hydrologic & Hydraulic Assessment / Survey / Geotechnical. Task 4: Model Update & Simulation with Newly Surveyed Existing Canal Geometry. Report prepared for the SFWMD by Lago Consulting & Services and Stanley Consultants on October 16, 2020.

LAGO, 2021. South Lee County Watershed Initiative Hydrologic Modeling Project. Technical Memorandums for Task 2 through 6 in preparation.

SDI, 2008. Southwest Florida Feasibility Study Integrated Hydrologic Model. Model Documentation Report Prepared for South Florida Water Management District, Ft. Myers, FL. Contract No. CN040922—Work Order 04, Task 6. SDI Project No. SFF-100. January 2008

SFWMD, 2015. Hydrogeologic Unit Mapping Update for the Lower West Coast Water Supply Planning Area. Technical Publication WS-34. February 2015.

WSA, 2018. Integrated Surface/Ground Water Modeling for the Village of Estero Watershed Lee County, Florida. Report prepared for J. R. Evans Engineering on July, 2018.

WSA, 2020a. Management of Flood Levels in Nine Mile and Hendry Canal Extension Basins, LA-MSID. Report prepared for Lehigh Acres MSID on September, 2020.

WSA, 2020b. Corkscrew Swamp Watershed Hydrologic Modeling Project. Draft report submitted by Water Science and Associates on December 2020.