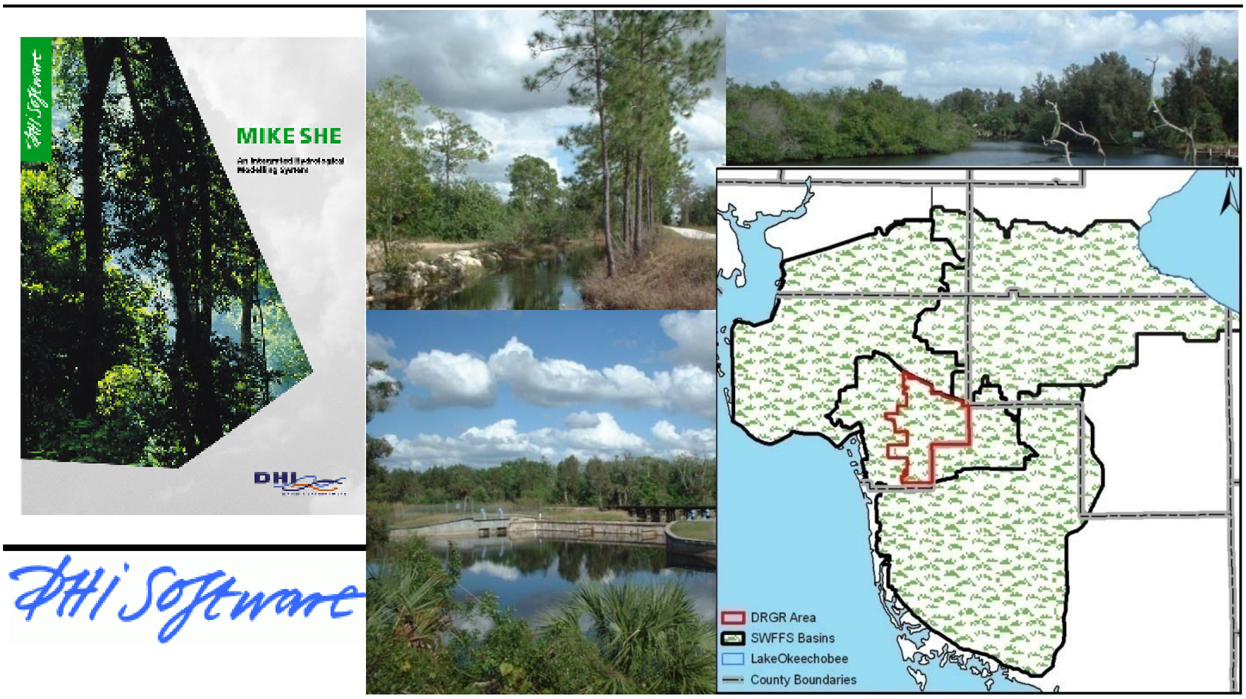
Comprehensive Hydrological Study of the Lee County Southeastern Density Reduction / Groundwater Resource (DR/GR) Area

Final Report of the MIKE SHE Model Development and Results

Lee County – Division of Natural Resources
Ft. Myers, FL 33901

MIKE SHE

dynamic modelling system for integrated groundwater and surface water resources



September 2009

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Project	Project No
Lee County DR/GR Model Study	4021.604
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Revision	Description	By	Checked	Approved	Date

Key words	Classification
Lee County Water Resources DR/GR Land use changes	☐ Open ☐ Internal ☒ Proprietary

Distribution	No of copies
Client DHI US	

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Acronyms and abbreviations

BC: Boundary condition
BCB: Big Cypress Basin
BLM: Base Line Model
DBHYDRO: South Florida Water Management District's corporate environmental database
DET: (spatially) distributed ET
DR/GR: Density Reduction/Groundwater Resources
DSS: Domestic self supply
ECM: Existing Conditions Model
ECWCD: East County Water Control District
EIC: Estero-Imperial River
ERP: Environmental Resource Permit
ET: Evapotranspiration
ETp: Potential Evapotranspiration
FAS: Floridan Aquifer System
FCM: Future Conditions Model
FCRB: Freshwater Caloosahatchee River Basin
FLUCCS: Florida Land Use, Land Cover Classification System
ft: feet
GSE: Ground surface elevation
IAS: Intermediate Aquifer System
ICA: Irrigation command area
KLECE: Kevin L. Erwin Consulting Ecologist, Inc.
LC: Lee County
LE: Lake evaporation
LIDAR: Light Detection and Ranging
LS: Local scale
MAE: Mean absolute error
ME: Mean error
MIKE 11: Hydraulic component in MIKE SHE
MIKE SHE: Dynamic modeling system for integrated groundwater and surface water resources
NEXRAD: Next-Generation Radar
NRD: Natural Resources Division
NSM: Natural System Model
PET: potential ET
PL: Performance level
R: Correlation coefficient
RET: reference ET
RMSE: Root mean square error
SAS: Surficial Aquifer System
SET: station-based ET
SFWMD: South Florida Water Management District

SWFFS: Southwest Florida Feasibility Study
TCRB: Tidal Caloosahatchee River Basin
USGS: United States Geological Survey
WTE: Water table elevation
WTP: Water treatment plant

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Executive Summary

The Lee County Density Reduction/Groundwater Resource (DR/GR) Area was designated as an area of limited land development to protect sustainable ground-water resources. This study evaluates the effects of land use changes (*e.g.,* urban, agricultural, wetlands, mining, etc.) on the storage and availability of water resources in the area.

In order to understand how land use changes affect the water resource distribution, a comprehensive hydrologic model has been developed to simulate hydrologic and hydraulic conditions for several land use conditions. The MIKE SHE model, developed by DHI, integrates all major hydrologic processes such as rainfall, evapotranspiration (ET), surface water runoff, infiltration, ground-water recharge, ground-water flow, and surface flow through canals. MIKE SHE has been widely used by government agencies and local governments in Florida for water resource management studies and has been identified by Lee County as the best tool available for evaluating the effects of land use change on ground-water resources.

The goal of the Lee County MIKE SHE modeling is to provide the County with a valuable planning aid which quantifies the potential outcomes of water resource balancing efforts. Furthermore, the model results can serve as input for site-specific models for evaluating mining permit applications.

The general approach implemented for this study consisted of developing several MIKE SHE models that simulate the hydrologic and hydraulic response to different land use development conditions in the DR/GR area. The land use conditions evaluated are the conditions that exist today and several future land-use alternatives. A comparative analysis of the results from these models provides quantitative insights into the benefits or stresses caused by specific land use changes on Lee County's water resources.

The Existing Conditions Model (ECM) is a baseline model to which the results of land use alternatives are compared. This model was developed using the most current data available to represent the existing land use conditions. Two scales of models were developed: 1. a large sub-regional scale model covers the entire Lee County area and additional areas to the north, south, and east that are hydraulically connected to the County; and 2. a local-scale model at a higher resolution focusing on the DR/GR area.

Two versions of the ECM were developed as part of this study. The first version is an intermediate version that was immediately updated with more accurate data that became available following its completion. The second version is the update to version one, and serves as the baseline for comparison of land use alternatives.

Observation data for the Existing Conditions Model was obtained from the South Florida Water Management District (SFWMD), Lee County, and the USGS. Some of the initial model development originated from a previously developed MIKE SHE model of the

Southwest Florida Feasibility Study (SWFFS) area. Updates to the SWFFS model input data for the Lee County model include meteorological, land use, irrigation and ground-water withdrawal, and topography.

The Lee County Model represents all the major hydrologic processes in a fully integrated and spatially distributed manner. The surface water model includes an extensive network of primary and secondary canals with many hydraulic structures, natural sloughs, rivers, and lakes. The ground-water model includes the Water Table, Lower Tamiami, and Sandstone aquifers and the Bonita Springs Marl and Upper Peace River confining units. The model simulates distributed irrigation and ground-water withdrawals based on actual well locations and land use maps and estimated rates based on permit data and other information.

As part of the model development, considerable effort was spent improving the representation of certain important features in the model, such as the mining pits and flow ways in the DR/GR area. Furthermore, a number of model parameters, such as overland flow roughness coefficients, hydraulic conductivities and storage parameters of the geologic layers, and subsurface drainage parameters, were tested and varied in order to produce a closer match between model results to observed data.

As part of the calibration process, the Existing Conditions Model results were compared with measured ground-water and surface water data. Since this study focuses on ground-water resources in the DR/GR area, the calibration efforts were prioritized accordingly. Thus, the highest calibration priority was given to the ground-water stations south of the Caloosahatchee River.

The determination of wetland hydroperiods has been an important indicator used in this study. For this evaluation, wetland hydroperiod is defined as the period during which water is above the ground surface. The hydroperiod output of the model, together with the water table elevation and the water balance computation, provides useful insight into the impact of the land use changes on wetland areas.

In order to evaluate the hydrological effects of land use changes in the DR/GR area, four Future Conditions Models (FCMs) were developed. The results of these models were analyzed by using relative measures, such as differences in hydroperiod, water table elevations, and overall water budget.

A natural systems model (NSM) was constructed using the intermediate ECM. The revised topography changed the hydroperiod prediction significantly and the NSM based on that intermediate step was not accurate enough to be useful in the analyses presented in this final report. As such, hydroperiod maps developed by KLECE corresponding to years 1953 and 2007 were used to evaluate how the present developments in the DR/GR Area have affected the water resources, and to evaluate at what extent the model predictions for the future conditions scenarios are going to impact them in the direction of the historical conditions.

The future land use modeling scenarios consist of four alternatives in the DR/GR Area that were provided by Lee County. The land use changes consist of three types: creation of urban areas, expansion or creation of mining pits, and restoration of agricultural lands into wetlands:

- Land use alternative 1 (FCM1) is conceptually similar to Scenario 1 in "Prospects for Southeast Lee County" [Dover, Kohl & Partners, July 2008]. Mining would be limited to already-approved mining pits plus some new pits north of Alico Road near the airport (but with fewer pits than in Scenario 1). A broad westerly flow way to Corkscrew Swamp would be restored southward from the Imperial Marsh.

- Land use alternative 2 (FCM2) is conceptually similar to Scenario 2 in the Dover Kohl report. Mining would be limited to already-approved pits plus a major expansion to the Green Meadows Mine. A broad flow way to Corkscrew Swamp would be restored southward from the east end of Corkscrew Road in Lee County.

- Land use alternative 3 (FCM3) is conceptually similar to Scenario 3 in the Dover Kohl report. Mining would be limited to already-approved pits plus proposed new pits that were in the application process in September 2007, including pits along Corkscrew Road east of the Flint Pen Strand. Both flow ways to Corkscrew Swamp would be restored to whatever extent is still possible after significant portions of each were mined.

- Land use alternative 4 (FCM4) is conceptually similar to an alternative scenario that emerged favorably during public meetings after release of the Dover Kohl report. Mining would be limited to already-approved pits plus a moderate expansion to the Green Meadows Mine. Both flow ways to Corkscrew Swamp would be restored in full.

The extent of the restored areas in all scenarios is less than originally proposed in the Dover Kohl report but would still be a major long-term undertaking for which funding is not currently available. The new urban areas added in the future conditions land use map were exactly the same in all four alternatives. The increase of new mining areas from smallest to largest is: FCM1, FCM4, FCM2, and FCM3. The new mining areas in FCM3 are nearly double the amount of mining areas than in FCM1. The total amount of newly restored areas increases in the order FCM1, FCM2, FCM3 and FCM4.

All land use based parameters in the model were modified to correspond to the new land use types. The irrigation setup in the future conditions model was modified to reflect future land use changes. For example, irrigation areas were removed in areas where the land use was converted from urban or agricultural to mining or wetland areas. The well field configuration of the ECM remained the same in the FCMs, i.e., no wells were added or removed. The groundwater withdrawal rates for public water supply in the last year of available data were repeated for every year in the simulation period for the four future conditions scenarios. The domestic self-supply rates vary according to land use changes.

In order to evaluate the effects of land use changes in the water resources of the DR/GR area, various types of results were generated and compared between the ECM and four future conditions alternatives. Water table elevation maps were created for all land use alternatives for two times of the year: at the end of the dry season (end of May) and at the end of the wet season (end of September). Additionally, water table levels at specific locations (where changes in land use occur) were generated to observe the changes in fluctuations throughout the five-year simulation period. Water budget calculations were extracted for the entire DR/GR to determine which hydrologic components were affected by the different alternatives. Finally, hydroperiod maps and maps of the mean water depth during the hydroperiod were also produced.

From the perspective of water table elevation and hydroperiod, the different scenarios produce changes that in some cases are quite notably distinct from one FCM to another. All of the future condition scenarios show areas where the water level and hydroperiod would decrease with respect to the existing conditions in some areas, while increasing in others. Decreases represent potentially negative impacts to the wetland ecosystems in those areas. The cause of the lower water table level and hydroperiod is the flattening effect of proposed single large mining pits or the combined flattening effect from several mining pits that have a high hydrological connectivity (i.e. via the ground-water).

The model results from the different land use scenarios indicate several concepts that may be useful during the planning process.

- Wetland areas converted from agricultural areas in the future condition alternatives help to increase the water table elevations during the dry season and to extend the period of time that those areas are wet (hydroperiod).

- The conversion of natural and agricultural areas to urban development slightly lowers the water table during the wet season due to the new urban drainage system. The water table in the new urban areas is typically higher at the end of the dry season compared to the existing conditions, which is likely related to a reduction in the ET losses.

- The water budget in all mines and lakes around the DR/GR Area suggests that the annual net rainfall (rainfall minus evaporation) is about zero on average. This is a consequence of the open water evaporation rate, which is commonly higher than the annual ET rate in pre-mined conditions. The model also predicts that the drainage system around some mines produces a positive net surface water outflow from the mines. As a result, the aquifers need to supply water to the mining pits (negative net groundwater recharge) in about the amount that is lost through the drainage system.

- This modeling has indicated, in general, that the annual averaged ET rates from the DR/GR Area would be higher with greater areal coverage of mining pits. The surface water outflow rate (runoff) from the DR/GR Area was lower in all the scenarios compared to the ECM, which is likely related to the greater mining pit coverage.

These results are expected due to the higher ET losses and the lower runoff from mining pits and its effect on the surface water flow in neighboring areas.

- Mining pits cause a flattening in the water table that affects the pre-developed water table gradient. This often implies a decrease in the water table elevation on the up-gradient side of the pits and an increase on the down-gradient side. On the down gradient side, there may also be a decrease in some situations. The most pronounced flattening effect is seen towards the end of the dry season. This also has an effect on the hydroperiod by shortening the up-gradient hydroperiod and increasing (or sometimes also decreasing) the down-gradient hydroperiod. The flattening effect of mine development on the water table is larger in areas with steeper water table gradients, in larger mine pits, and in the case of a number of mining pits that are closer and therefore more hydrologically connected (i.e. via groundwater).

Water budgets, hydroperiod maps, and water elevation maps resulting from the modeling were analyzed for all four FCMs. These maps and numbers were compared to the local scale existing conditions model (LS ECM) results, and the scenarios were ranked according to their impact on natural areas in the DR/GR Area. This comparison revealed that scenarios with higher proportions of restored land areas than mining areas had less negative impact on the overall DR/GR Area. In cases where the areal extent of newly restored land area exceeded the areal extent of new mining areas, there was an overall benefit to the water resources in the DR/GR Area. The scenario that minimizes stress on the current water resources within the DR/GR Area is FCM4. This is followed, from second best to worst, by FCM1, FCM2, and FCM3.

Introduction

The Lee County Density Reduction/Groundwater Resource (DR/GR) Area was designated as an area of limited land development in an effort to provide a sustainable use of groundwater resources for the County. This study evaluates through the use of a computer model the effect of the land use changes (*e.g.*, urban, agricultural, wetlands, mining, etc.) on the storage and availability of water resources in the area. In order to understand how land use changes affect the water resources distribution, a comprehensive hydrologic model has been developed to simulate hydrologic and hydraulic conditions for several land use conditions. The MIKE SHE model, developed by DHI, is capable of fully integrating all major hydrological processes including: rainfall, evapotranspiration (ET), surface water runoff, infiltration, groundwater recharge, groundwater flow, and surface flow through canals. MIKE SHE has been widely used by government agencies and local governments in Florida for water resources management studies and has been identified by Lee County as a suitable tool for evaluating the effects of land use change on groundwater resources. The goal of the Lee County MIKE SHE modeling is to provide the County with a valuable planning tool which aides in the understanding of the potential outcomes of water resource balancing efforts. Furthermore, the model will generate results that may serve as input for site-specific models for evaluating permit applications.

The general approach implemented for this study consisted of developing several MIKE SHE models that describe the hydrologic and hydraulic response to different land use development conditions in the DR/GR Area. The models represent all the major hydrologic processes in a fully integrated and spatially distributed manner. The land use conditions evaluated are existing and several future alternatives. A comparative analysis of the results from these models is intended to provide a quantitative insight into the benefits or stresses caused by specific land use changes on Lee County's water resources.

This report describes the development and calibration of two Existing Conditions Models (ECMs), one regional (ECM) and one local scale (LS ECM), and the development of four Future Conditions Models (FCMs) based on the LS ECM.

Development of the LS ECM was a multi-step process. The ECM was developed first, which has a resolution of 1500 ft and contains the entire Lee County area. This model was used to extract the LS ECM for the DR/GR Area at a 750-ft resolution and to establish its boundary conditions. The calibration process had been completed early in the development of the LS ECM when much more accurate topographic data became available. The County decided it was in their best interest to utilize the high resolution topographic data to generate a more accurate model, which also included the redefinition of the flow ways. This initially calibrated intermediate step in the development of the final LS ECM is referred to in places as LS ECM V1 in the report. Details about the calibration process for this intermediate model can be found in Appendix J. Results from LS ECM V1 are presented in some discussions regarding the calibration of the final model to demonstrate the sensitivity of the model to the refined topography and flow ways, and to highlight the importance these improvements had in the ultimate model performance. The final LS ECM is referred to in some graphs and figures as LS ECM V2, but it is otherwise referred to as LS ECM throughout the report.

Another significant change that was implemented in the LS ECM following the introduction of the high resolution topography in the model was the introduction of distributed evapotranspiration (ET) data instead of station based data. Similar to the occasional presentation of output from LS ECM V1, output from other intermediate model development steps is presented to show the sensitivity of the model to the distributed ET data.

This report is organized as follows. The data sources for the model are presented, as well as descriptions of how the data are used by the various model components. Plots that compare the observed data and ECM results for the DR/GR Area are included in the report. The changes in land use for the future scenarios are described in relation to the existing land use, as well as the components of the model that were altered to represent these changes. The final part of the report includes the results that show the effects of the land use changes, i.e., the hydrologic/hydraulic evaluation of the future condition scenarios. Finally, the limitations of the model are stated, as well as recommendations that may improve the accuracy of the results. Several appendices are included which provide more detailed results and additional information on the modeling.

Objectives

The main objective of this study is to quantitatively analyze the benefits or stresses caused by specific land use changes on Lee County's water resources to help the County during the planning process. The land use includes creating new urban areas, wetland areas and mining pits in the DR/GR Area. The effects are evaluated specifically on water balance components, water table elevations and hydroperiods. The study is expected to reveal generalities about the effect of the land use changes, and produce a ranking of the different future condition scenarios tested from a water resources perspective.

Existing Conditions Model

The Existing Conditions Model (ECM) is the base model to which the results of several land use alternatives will be compared. The model was developed using the most current data available to represent the existing land use conditions. The input data for the Existing Conditions Model was obtained from the South Florida Water Management District (SFWMD), the United States Geological Survey (USGS), and from Lee County. Two model scales were developed: 1. a larger scale 1500-ft grid model (ECM) that covers the entire Lee County area and additional areas to the north, south, and east that are hydraulically connected to the County; and 2. a local-scale model (LS ECM) that is a higher resolution model (750-ft grid) focused on the DR/GR Area. The purpose of the larger model is to generate representative boundary conditions at the sub-regional level for the local scale model. All the future land use alternatives were developed at the local scale level using the same boundary conditions and the LS ECM.

Baseline Model

Some of the initial model development originated from a previously developed MIKE SHE model of the Southwest Florida Feasibility Study (SWFFS) area. The SWFFS area consists of four major basins (Tidal Caloosahatchee River, Freshwater Caloosahatchee River, Estero River, and the Big Cypress Basin) and forms part of five counties (Charlotte, Glades, Lee, Henry, and Collier). Figure 1 shows the SWFFS model, ECM, and LS ECM areas. Since the SWFFS model simulates the period of 1995 to 1999, much of the data required updating for use in the Lee County Existing Conditions Model period of 9/1/2002 to 11/1/2007. The SWFFS model hydraulic features are limited to those critical canals, creeks, rivers and sloughs necessary to accurately route surface water flows at a regional scale. Thus, considerable hydraulic detail was added when developing the ECM and LS ECM from other modeling efforts at the sub-regional scale level within the SWFFS area.

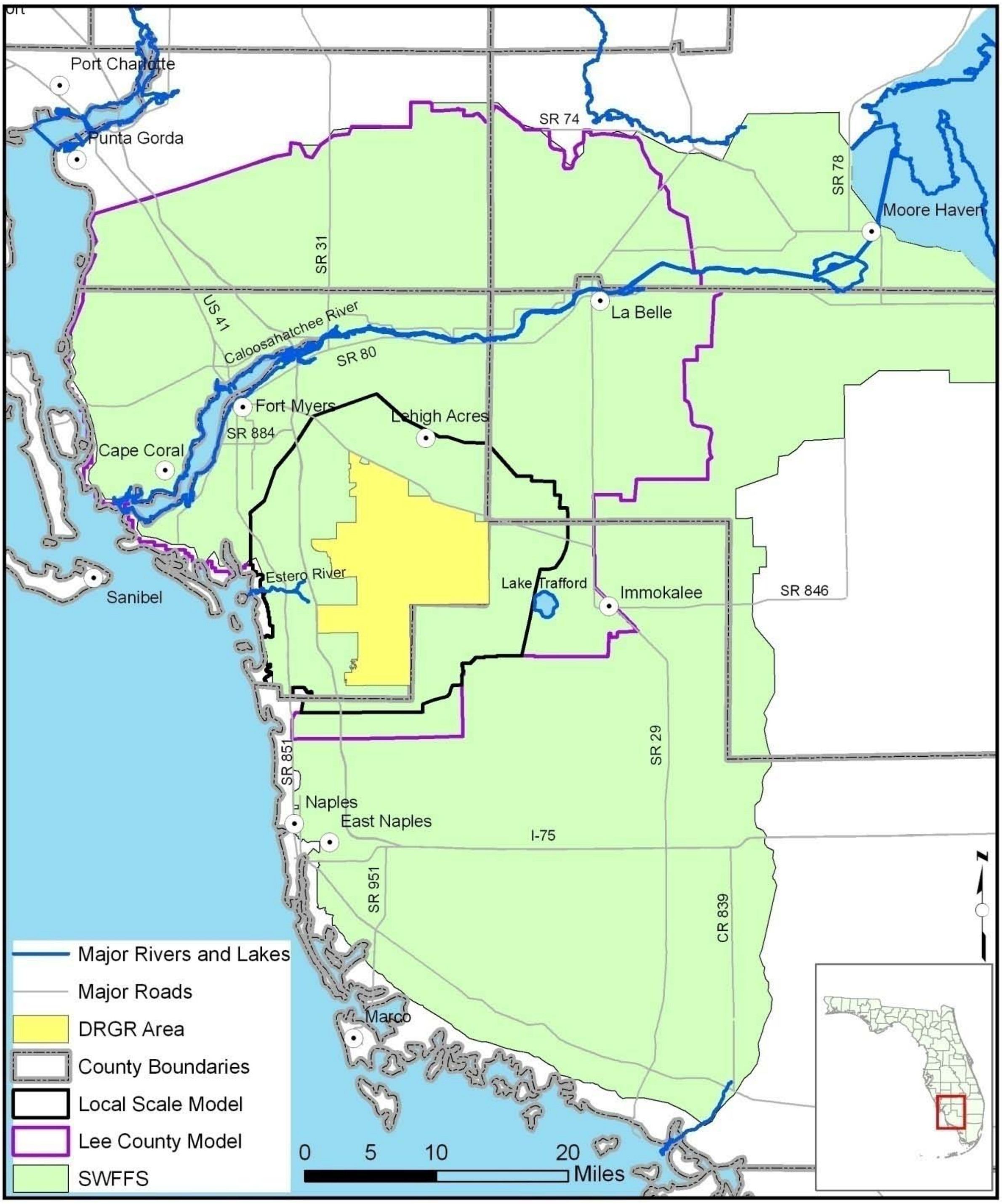

Figure 1. Model Domain Areas.

A preliminary comparison of the ECM and the SWFFS model was performed before any updates or improvements were made to the model. This preliminary model is referred to as Lee County Baseline Model (LCBLM). The differences between the SWFFS and the LCBLM are the size of the model domain, canals and structures added or modified from the

Estero-Imperial River (EIC), Big Cypress Basin (BCB), and Tidal Caloosahatchee River Basin (TCRB) sub-regional models, and the boundary conditions. Results of this comparison for two stations, one at Corkscrew and the other at Imperial River, are shown in **Figure 2**. The locations of these stations are shown in **Figure 3**. In general, both models produce similar results for stations within or close to the DR/GR Area. The differences between the simulated and the observed data are addressed during the development and the refinement of the existing conditions model (ECM). The modifications made to the ECM include: update of time-varying data for the period of 2002-2007, extension of the model area further to the south for better boundary representation, and improvements for better calibration performance.

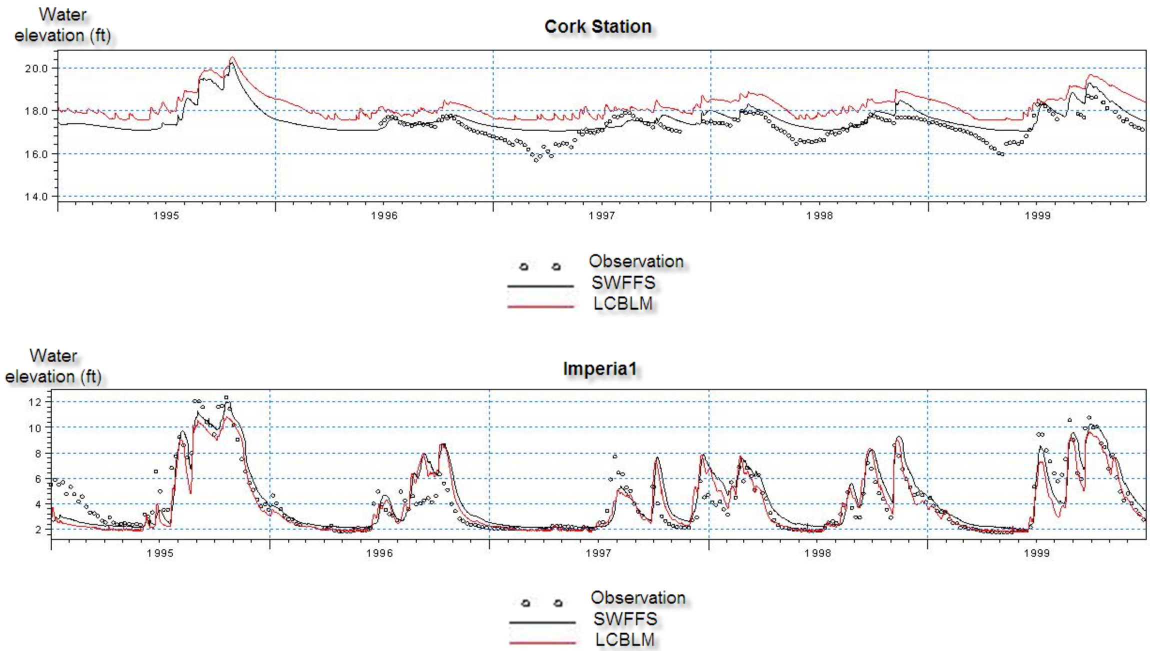

Figure 2. Comparison of the SWFFS model, LCBLM, and measured stages.

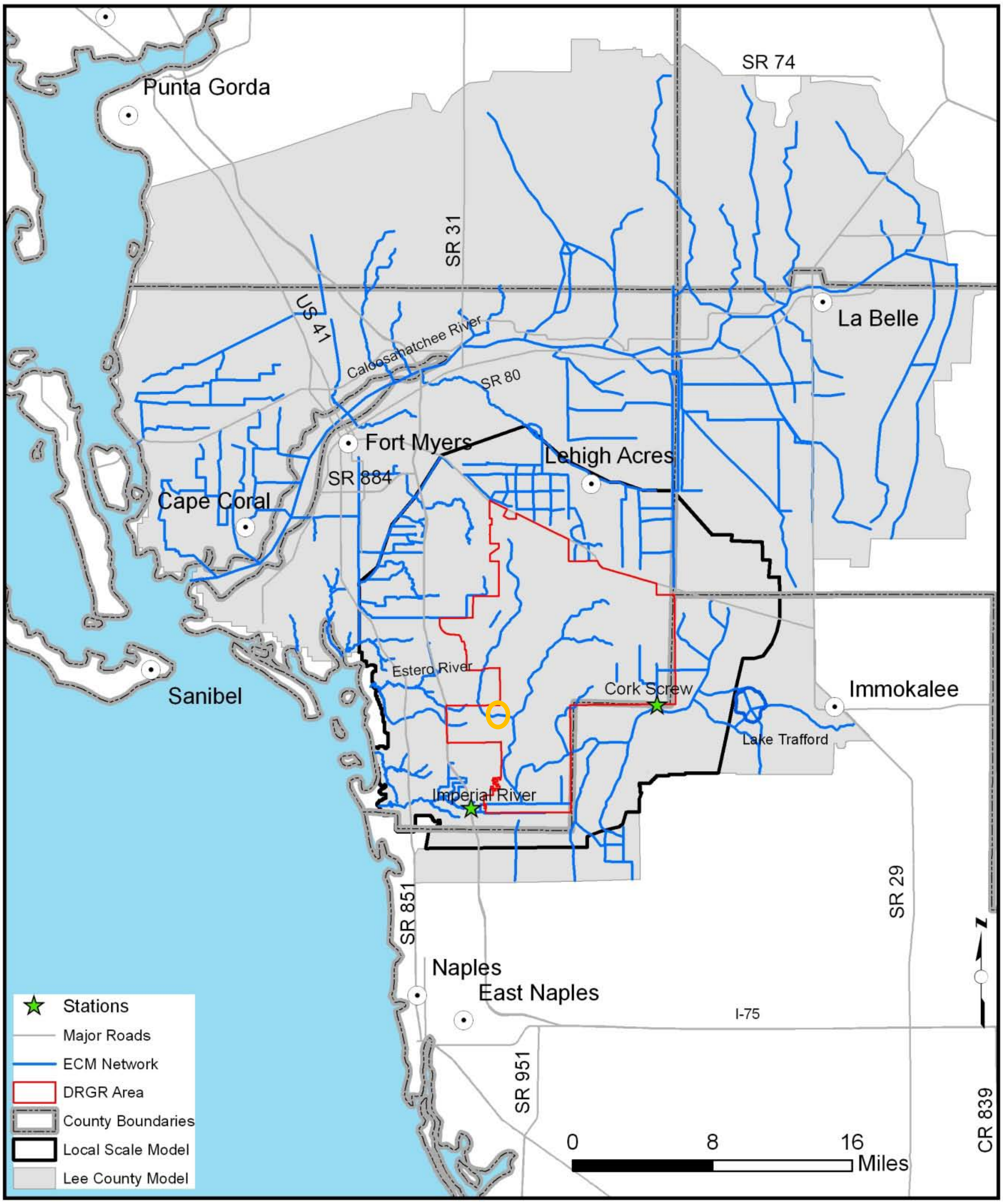

Figure 3. Location of stations that were used to compare SWFFS model to the LCBLM.

Note: the connection marked in the southern part of the DR/GR in the figure with the orange circle was adopted from the SWFFS model. However, as shown in the model results (Figure 40), there is not significant flow in that connection on a yearly averaged basis. The water flowing south from the western branch is diverted into the overland flow and collected by the branches that discharge in the Gulf of Mexico. This conceptualization of the surface water flow was improved in additional work described later in this report.

Local Scale Model

As previously mentioned, a Local Scale Existing Conditions Model (LS ECM) was derived from the Lee County ECM. The purpose of the LS ECM is to zoom into the DR/GR Area at a higher resolution. The LS ECM domain area is shown in previous figures. It covers a somewhat larger extent than the DR/GR Area (approximately 2-6 miles of surrounding area) in order to include all the features modified in future conditions scenarios and to avoid boundary condition effects. The LS ECM has a grid cell size of 750 feet, which is half the size of the original ECM grid size. The total number of grid cells remains approximately the same in both models. The vertical resolution was also increased by splitting the computational layer 3 in the ECM into 2 computational layers. Thus, the LS ECM has four computational layers in total.

The river network for the LS ECM was initially obtained from the ECM network portion that is in the local scale model boundary. A constant head boundary condition is applied by using the time series stage results of the ECM. The time series water levels applied as boundary conditions for the groundwater layers are also extracted from the ECM.

While the initial river network was obtained from the ECM, several significant modifications to the network were made. These modifications are discussed in detail in the Surface Water Model section. Other modifications made to the LS ECM are included in following sections.

The changes introduced in the local scale model make the use of initial conditions extracted from the ECM inappropriate. Thus, a preliminary run of the LS ECM was performed in order to extract the initial conditions from the model results. The model was then initialized using the results of September 1st, 2004 from the previous run. The LS ECM simulation period is from September 1st, 2001 to November 1st 2007.

Climate Data

The climate data input to the model consists of rainfall and potential evapotranspiration data.

Rainfall

The rainfall input data was obtained from high resolution radar (NEXRAD) data. The SFWMD provided 15-minute radar rainfall data sets from January 2002 to October 2007. This data set has a spatial resolution of approximately 1.9 km (1.2 miles). The radar rainfall grid in the model domain area is shown in **Figure 4**. Individual time series data for the period from 2005 to 2007 were also provided to correct the data values for some of the pixels.

During the NEXRAD processing, the original data was replaced with the corrected values for the specified pixel locations. The 15-min data was added to obtain daily rainfall values. Finally, the ASCII data was converted to a time varying dfs2 file, the two-dimensional grid format of MIKE SHE. The resulting dfs2 file has a spatial resolution of 1,500 ft and covers the ECM domain area.

The NEXRAD rainfall data was compared to rainfall gage data located around the DR/GR Area. The locations of the stations with available rainfall data in DBHYDRO are also shown on Figure 4. Total daily radar data does not exactly match the daily values measured at the observation stations. The differences are reasonable because the two data sets have a different error range and represent different spatial extents, i.e., radar rainfall data are spatial averaged values from indirect estimations and station data are more exact measurements at a specific location. Thus, the higher error in NEXRAD rainfall data estimation is compensated by capturing the high spatial variability of the rainfall, which is critical when the distance between rainfall stations is large.

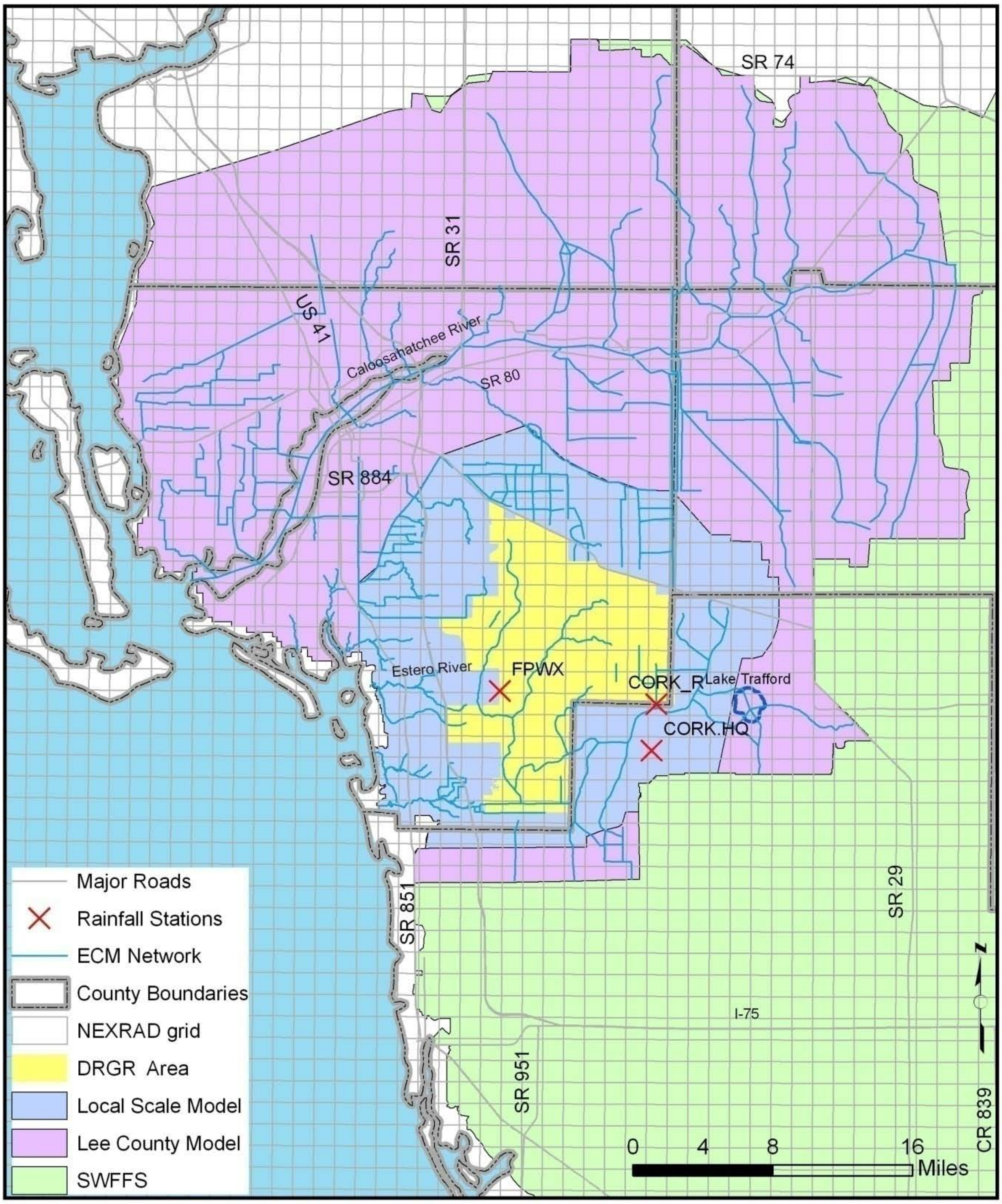

Figure 4. Rainfall Stations and NEXRAD Grid.

The differences between NEXRAD and station data sets decrease as the daily values are averaged over a longer period. The relatively good match between monthly cumulative rainfall values from both methods is shown in **Figure 5** at the CORK.HQ station.

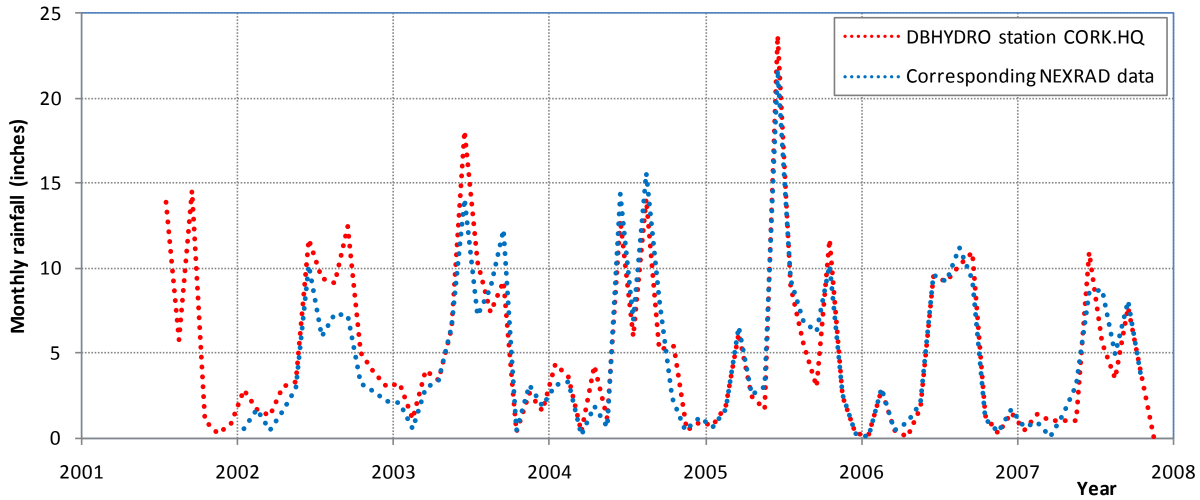

Figure 5. Comparison of monthly values between the daily rainfall of a DBHYDRO station and the radar rainfall data at the same location.

Evapotranspiration

The following sections discuss how this and other ET parameters were used in the ECM and the LS ECM.

Evapotranspiration in the ECM

The SFWMD defines potential evapotranspiration (ETp) as "actual evaporation for lakes, wetlands, and any feature that is wet year-round" (Abtew, 2005). It uses the following equation to estimate ETp rates:

$$ET = K_1 \frac{Rs}{\lambda}$$

where ET is daily evapotranspiration from wetland or shallow open water (mm/d), Rs is solar radiation ($MJ/m^2{\cdot}d$), λ is the latent heat of vaporization (MJ/kg), and K_1 is an empirical coefficient equal to 0.53 $mm{\cdot}m^2/kg$ (Abtew, 2005).

ETp is a time-varying and spatially distributed input to the MIKE SHE model, like rainfall.

Potential ET rate data from three stations within or near Lee County were extracted from the SFWMD DBHYDRO database. The station data period and locations are presented in **Table 1**. The observed daily ET rates were distributed across the model domain by using a

Thiessen polygon network, as shown in **Figure 6**. A more refined distributed ET was used in the LS ECM as described in the next section.

Table 1. DBHYDRO stations with potential ET data for the ECM.

Dbkey	Station	Start Date	End Date	County
OH520	FPWX	1-Jan-01	31-Dec-07	LEE
RW483	S78W	22-Oct-92	31-Dec-07	GLA
RW482	SILVER	6-Dec-00	31-Dec-07	COL

In MIKE SHE, actual evapotranspiration (ETa) is calculated for every cell of the model using several factors. The calculation of ETa uses meteorological and vegetative data to predict the total evapotranspiration and net rainfall after interception of rainfall by the canopy, drainage from the canopy to the soil surface, evaporation from the canopy surface, evaporation from the soil surface, and transpiration, based on soil moisture in the unsaturated root zone (DHI 2008).

The ET processes are split up and modeled in the following order (DHI 2008):

1. a proportion of the rainfall is intercepted by the vegetation canopy, from which part of the water evaporates;
2. the remaining water reaches the soil surface, producing either surface water runoff or percolating to the unsaturated zone;
3. part of the water standing on the soil surface is evaporated;
4. part of the infiltrating water is evaporated from the upper part of the root zone or transpired by the plant roots; and
5. the remainder of the infiltrating water recharges the groundwater in the saturated zone.

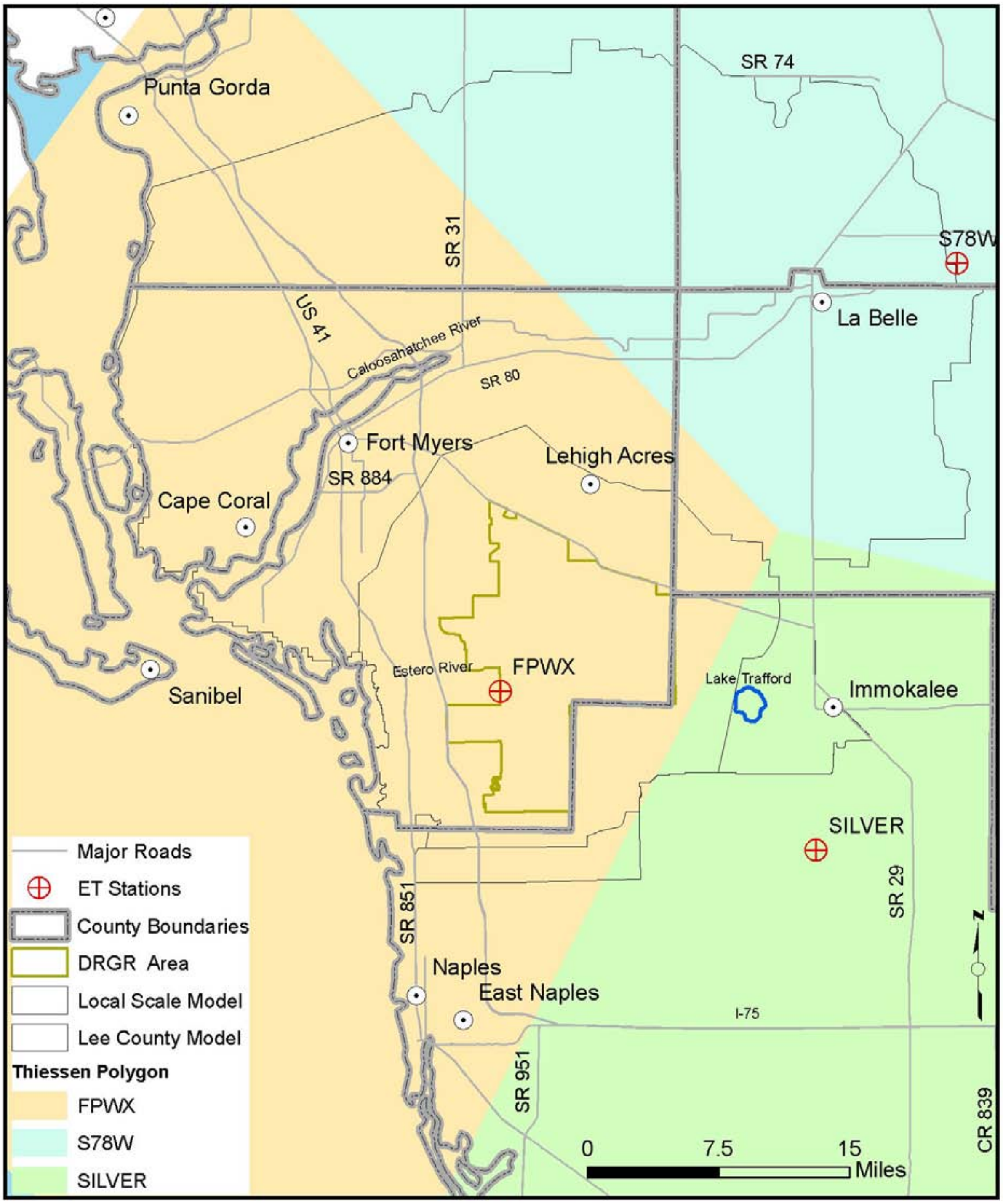

Figure 6. Potential Evapotranspiration Stations and Thiessen Polygons.

The ET parameters were divided into two groups: one for land use independent parameters (see **Table 2**) and the other for land use dependent parameters (see **Table 3**) such as leaf area index (LAI) and root depth (Rd).

Table 2. Constant ET Parameters.

Parameter	value
Canopy interception storage capacity	5 mm
Growth cycle	one year
Crop coefficient (Kc)	1
empirical parameter C1	0.2
Kristensen and Jensen empirical parameter C2	0.3
Kristensen and Jensen empirical parameter C3	20 mm/day
Kristensen and Jensen Root mass distribution parameter (Aroot)	0.25 m^{-1}

Table 3. Land use dependent ET Parameters.

Land Use/Vegetation	LAI	Rd (m)
Citrus	4.5	1.25
Pasture	3 - 4	0.75
Sugar Cane & Sod	1 - 6	0.5 – 1.5
Truck (Row) Crops	1.5 – 4.5	0.15 – 0.75
Golf Course	3	0.75
Bare Ground	0	0
Mesic Flatwood	1.5 - 3	1.219
Mesic Hammock	2.5 - 4	1.219
Xeric Flatwood	1 - 2	1.219
Xeric Hammock	2 - 3	1.219
Hydric Flatwood	1.5 - 3	1.219
Hydric Hammock	2.5 - 4	1.219
Wet Prairie	1.5 - 3	0.75
Dwarf Cypress	1 - 2	0.75
Marsh	2 - 4	0.75
Cypress	2 - 4	1.524
Swamp Forest	3 - 5	1.524
Mangrove	3 - 4	1.824
Water	4	2.3
Urban Low Density	2.5	0.6
Urban Medium Density	2	0.6
Urban High Density	2	0.5

Note: LAI = Leaf Area Index, Rd = root depth

Refined Evapotranspiration in the LS ECM

The USGS recently released spatially distributed ET data for the same 2-km grid as the rainfall distributed data introduced in the model (see grid in **Figure 7**), so this was used to define the ET rates for the model.

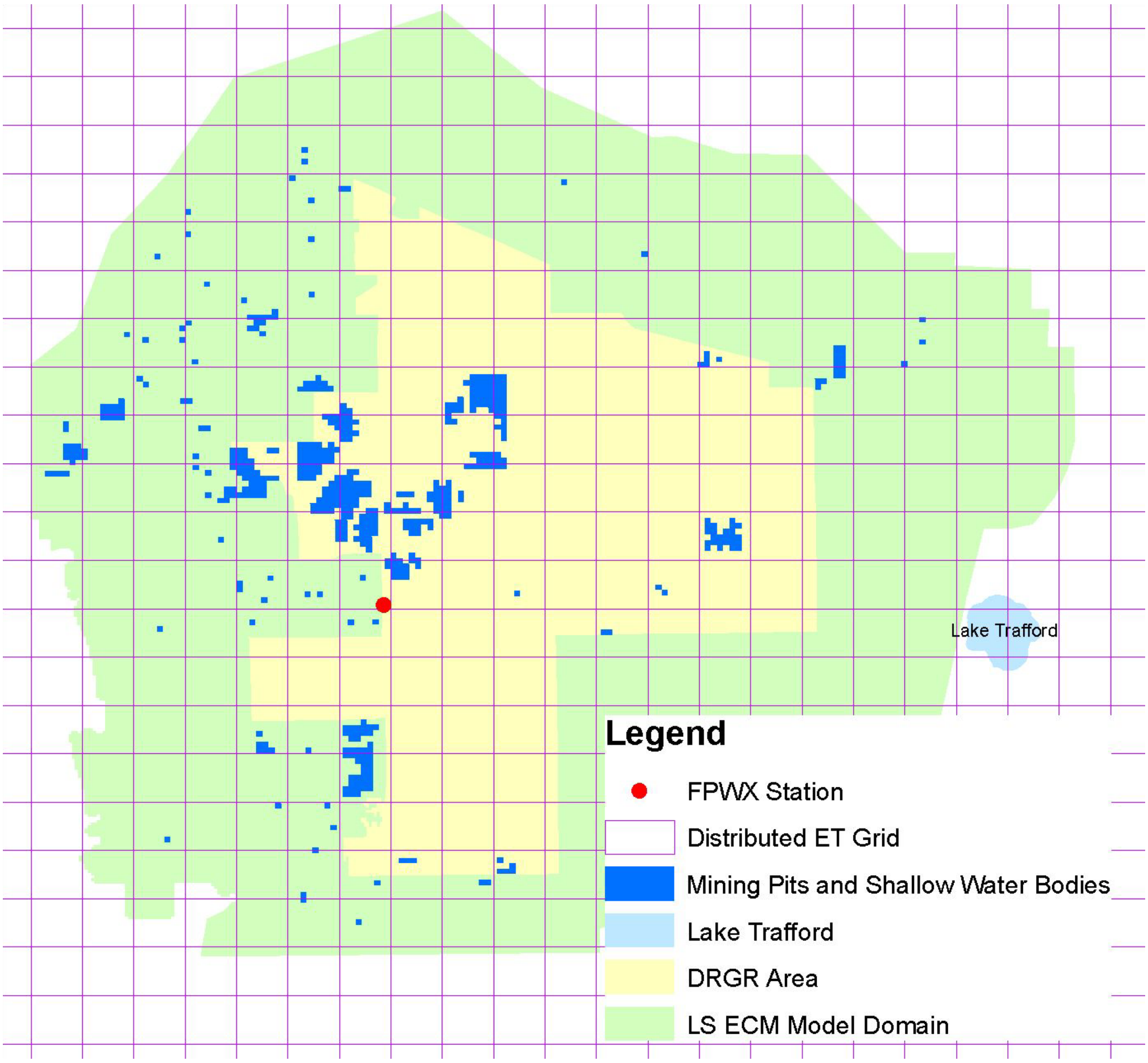

Figure 7. Distributed ET grid around the model domain area.

The distributed ET data may have uncertainties since air temperature, relative humidity, and wind speed are interpolated from weather stations [D. Sumner, USGS, personal communication]. The comparison of the distributed ET data and the ET data at station FPWX is presented in Appendix E. The RET approximately reproduce the ET station data on a daily and annual basis.

The value of RET + 8.2% was found to provide the best estimate for the lake evaporation in mining pits and other shallow water bodies in the model domain. Additional details are provided in Appendix E. The lake evaporation is considered in the model by assigning a crop coefficient (Kc) of 1.082 in the land use classified as water.

The actual evapotranspiration (ETa) is calculated for every cell of the model in the same manor as for the ECM.

The ET parameters were divided into two groups: one for land use independent parameters (see Table 2) and the other for land use dependent parameters (see **Table 4**) such as leaf area index (LAI) and root depth (Rd). Numbers in bold in Table 4 were modified in the LS ECM compared to those used in the ECM.

Table 4. Land use dependent ET Parameters.

Land Use/Vegetation	LAI	Rd (m)
Citrus	4.5	1.25
Pasture	3 - 4	0.75
Sugar Cane & Sod	1 - 6	0.5 – 1.5
Truck (Row) Crops	1.5 – 4.5	0.15 – 0.75
Golf Course	3	0.75
Bare Ground	0	**100**
Mesic Flatwood	1.5 - 3	1.219
Mesic Hammock	2.5 - 4	1.219
Xeric Flatwood	1 - 2	1.219
Xeric Hammock	2 - 3	1.219
Hydric Flatwood	1.5 - 3	1.219
Hydric Hammock	2.5 - 4	1.219
Wet Prairie	1.5 - 3	0.75
Dwarf Cypress	1 - 2	0.75
Marsh	2 - 4	0.75
Cypress	2 - 4	1.524
Swamp Forest	3 - 5	1.524
Mangrove	3 - 4	1.824
Water	**0**	2.3
Urban Low Density	2.5	0.6
Urban Medium Density	2	0.6
Urban High Density	2	0.5

Note: LAI = Leaf Area Index, Rd = root depth

Topography

The topography data was obtained from the SFWMD Composite Topography Dataset (SWFFS 2005). This dataset has a cell size of 100 feet and it covers the Lower West Coast part of the South Florida Water Management District. It is composited from multiple sources, which include LIDAR (Light Detection and Ranging) data, aerial/photogrammetric data, and USGS contour and spot-elevation data. This dataset was also used in the SWFFS model. The topography data provided by Lee County does not cover the entire model domain, but it matched the SFWMD when both datasets were overlaid. The original 100-ft raster data was resampled by averaging the elevation values to a 750 ft grid and then converted to a dfs2 file for use in the ECM. The resulting map is displayed in **Figure 8**. This topographic map, however, does not contain the bathymetry of mine pits and other water bodies. These features were incorporated into the topographic map during the model development.

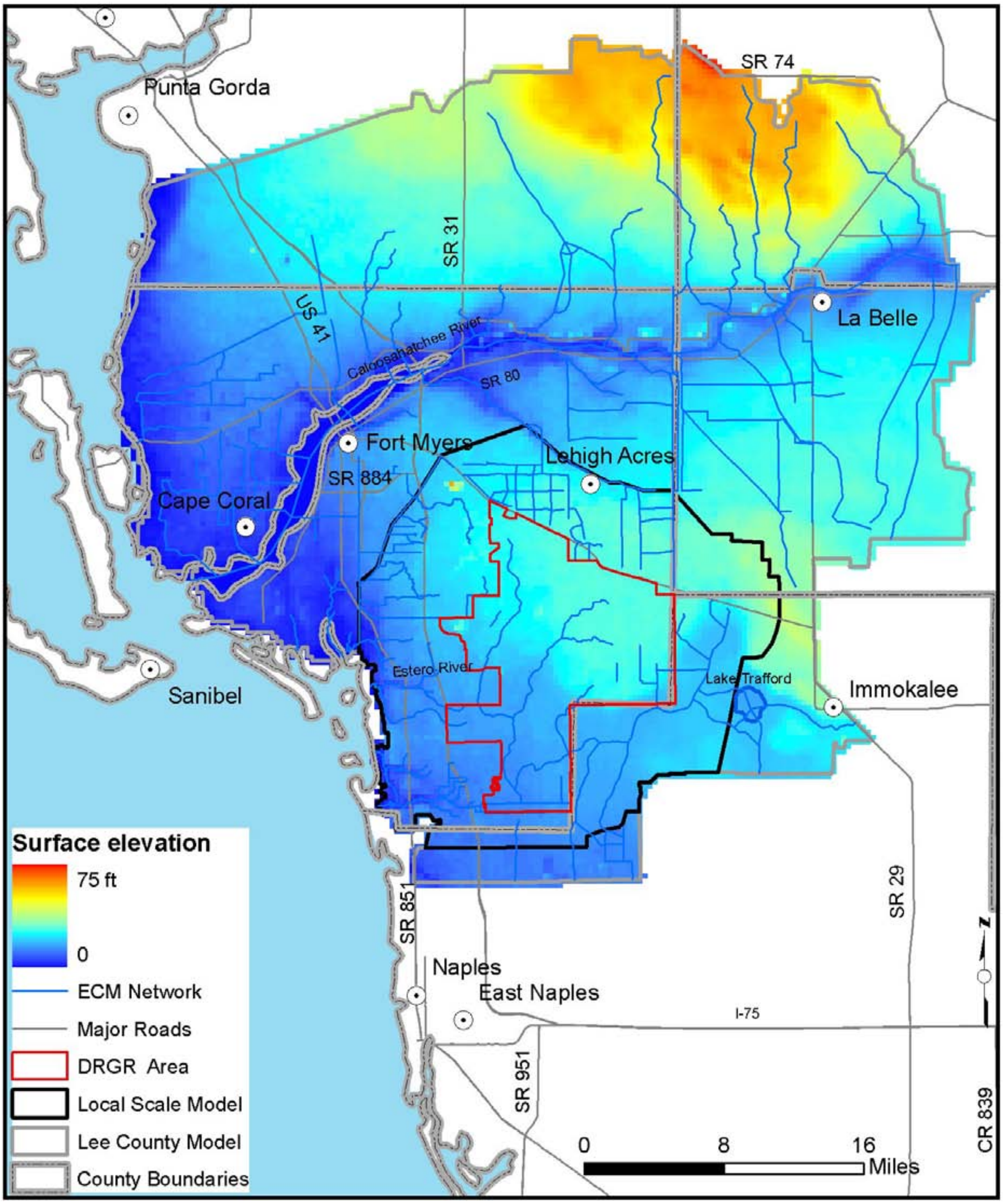

Figure 8. Model Topography in ECM.

Refined Model Topography For LS ECM

New LIDAR topographic data was flown in 2007 and became available in 2009. This updated topographic data was incorporated into the model after calibration of the first version had been completed. The County's goal in undertaking this update was to improve the accuracy of the model.

The 2007 LIDAR topographic data set was delivered by Lee County in a raster format with a grid size resolution of 5 ft by 5 ft. The data covers only Lee County and it was not available for Collier County areas included in the model domain. Thus, the 5-ft resolution topographic data was averaged in a 750-ft resolution raster file and superimposed on the topographic map previously described in order to build the updated topographic map that covers the entire model domain. **Figure 9** shows the resulting 750-ft surface elevation map. The elevations were decreased in mining pits and lakes in accordance with the conceptualization of the water bodies.

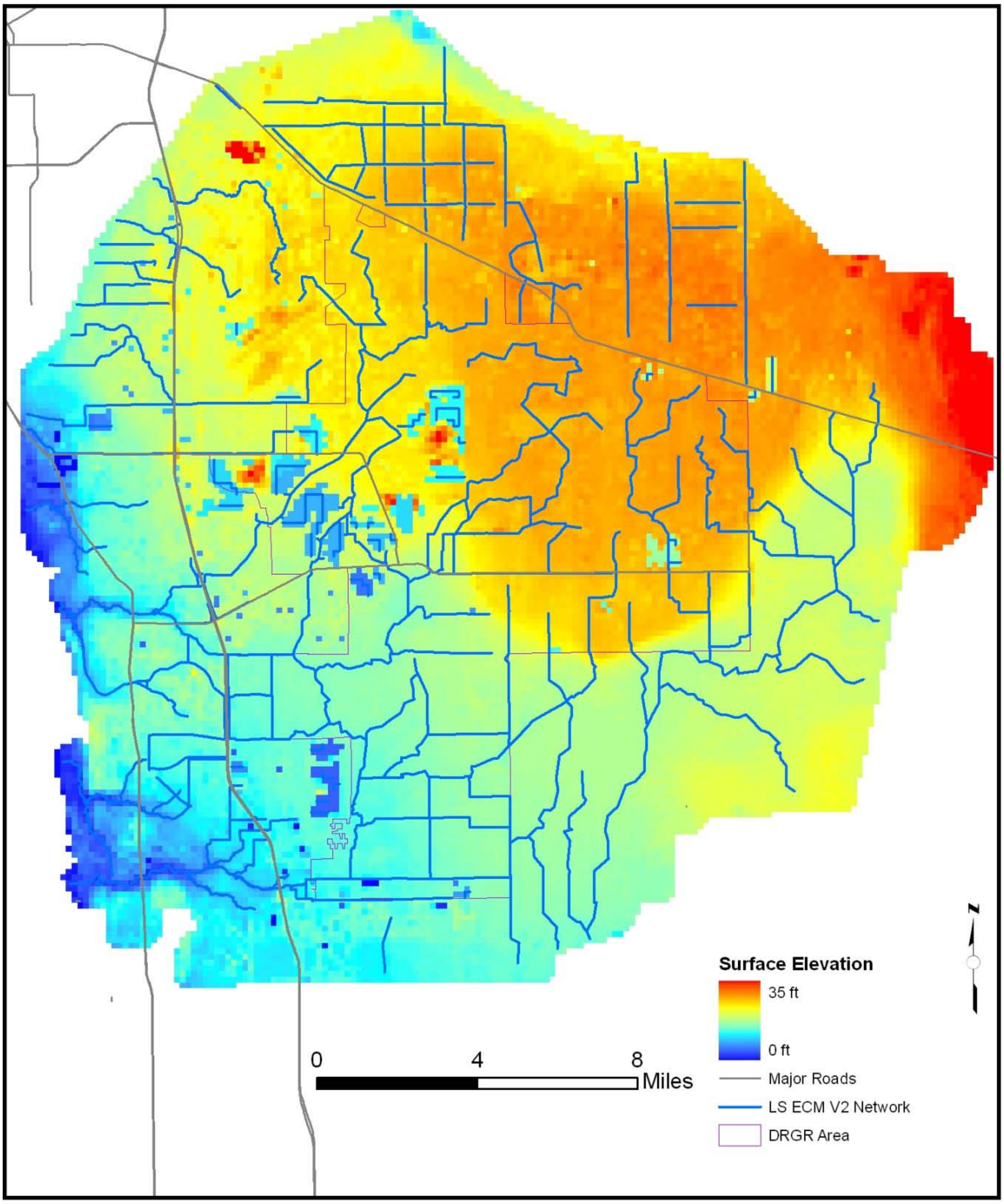

Figure 9. Model Topography in the LS ECM.

Land Use

This study uses several land use/vegetation maps to represent predevelopment, existing, and future conditions. The existing conditions land use represents the period from 2002 to 2006. The land use data for the ECM was developed from three different sources: the SFWMD, the Southwest Florida Water Management District (SWFWMD), and Kevin L. Erwin Consulting Ecologist, Inc. (KLECE). The SWFWMD 2004 land use data was used to fill in the north western portions of the model domain which are not covered by the SFWMD 2004 land use. The 2007 land use map developed by KLECE, which covers DR/GR areal extent, was superimposed on the 2004 land use data.

The land use categories are based on Florida Land Use, Land Cover Classification System (FLUCCS). The FLUCCS codes for each land use map were grouped in more general MIKE SHE land use categories as shown in **Table 5**. Land use based parameters in the model include overland roughness coefficients, detention storage, drainage parameters, and paved runoff coefficients. The land use parameter values used in the final model are presented in **Table 5**. The land use maps were merged and converted into 750-ft and 1500-ft resolution grid files that cover the entire model domain. The 1500-ft model land use map is shown in **Figure 10**. The 750-ft land use map used in the LS ECM is presented in Appendix D.

Table 5. MIKE SHE land use categories and corresponding FLUCCS codes.

Model Land Use Type	Model Code	FLUCCS Code
Citrus	1	220, 221, 222, 223
Pasture	2	165, 210, 2103, 211, 212, 213, 231, 260, 2603, 261, 262, 263
Sugar Cane & Sod	3	2156, 242
Truck (Row) Crops	5	214, 215, 216
Golf Course	6	182, 1821
Bare Ground	7	153, 1603, 161, 162, 163^{S}, 181, 2302, 740, 7403, 742^{S}, 743, 744, 747, 8113, 8115, 835
Mesic Flatwood	8	190, 1903, 191, 194, 310, 3102, 320, 321, 323, 330, 3302, 410, 4103, 411, 414, 429, 435, 440, 4403, 441, 442, 443, 7102, 7202, 741
Mesic Hammock	9	420, 4203, 422, 423, 426, 427, 4271, 434, 437, 438, 439
Xeric Flatwood	10	412, 413
Xeric Hammock	11	322, 421, 432
Hydric Flatwood	12	4119, 419, 624, 625
Hydric Hammock	13	329, 424, 425, 428, 433, 610, 6103, 611, 6111, 618
Wet Prairie	14	643, 6439
Dwarf Cypress	15	6219
Marsh	16	6171, 6172, 6403, 641, 6411, 6412, 644, 660
Cypress	17	620, 6203, 621, 6215, 6216, 6218, 629, 745
Swamp Forest	18	613, 614, 615, 616, 617, 619, 6191, 626, 628, 630, 6302, 631
Mangrove	19	612, 642
Water	20	163^{D}, 166, 184, 254, 5001, 510, 511, 512, 520, 525, 530, 533, 540, 541, 543, 560, 572, 650, 651, 653, 742^{D}
Urban Low Density	41	110, 1102, 111, 112, 113, 118, 119, 148, 164, 180, 1802, 185, 192, 193, 240, 2403, 241, 243, 245, 246, 247, 250, 2502, 251, 255, 821, 832
Urban Medium Density	42	1009, 120, 1202, 121, 122, 123, 129, 144, 176, 812, 833, 834
Urban High Density	43	130, 1302, 131, 132, 133, 134, 135, 139, 140, 1402, 141, 1411, 142, 1423, 146, 149, 150, 1503, 151, 152, 154, 155, 156, 159, 160, 170, 1702, 171, 183, 187, 252, 810, 8102, 811, 814, 820, 8202, 830, 8302, 8310

Note: The conversion is the same for the SFWMD and DR/GR land use maps, except in two FLUCCS codes that were noticed with super indices “S” and “D”, respectively.

Table 6. Vegetation-based global parameters used in the ECM and LS ECM.

MSHE Code	Land Use/Vegetation	OL Manning's (M)	Detention Storage (inches)	Paved Runoff Fraction	Drainage Depth (ft)	Drainage Time Constant (1/day)
1	Citrus	5.88	1.0	0	0.5	0.25
2	Pasture	7.14	1.2	0	0.5	0.25
3	Sugar Cane	5.88	1.0	0	0.5	0.25
5	Truck Crops	5.88	1.0	0	0.5	0.25
6	Golf Course	7.14	1.2	0	1.0	0.25
7	Bare Ground	11.36	1.2	0	0	0
8	Mesic Flatwood	5.00	1.2	0	0	0
9	Mesic Hammock	3.33	1.2	0	0	0
10	Xeric Flatwood	10.00	1.2	0	0	0
11	Xeric Hammock	5.00	1.2	0	0	0
12	Hydric Flatwood	4.00	1.2	0	0	0
13	Hydric Hammock	2.50	1.2	0	0	0
14	Wet Prairie	3.33	1.2	0	0	0
15	Dwarf Cypress	5.00	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	2.50	1.2	0	0	0
19	Mangrove	5.00	1.2	0	0	0
20	Water	16.67	1.2	0	0	0
41	Urban Low Density	7.14	1.0 (0.13)	0.05	0.5 (1.0)	0.25 (0.5)
42	Urban Medium Density	8.33	0.4 (0.13)	0.15 (0.22)	0.75 (1.0)	0.35 (0.5)
43	Urban High Density	9.01	0.13 (0.13)	0.45 (0.70)	1.0 (1.0)	0.5

Note: OL Manning's M is the reciprocal of the conventional Manning's Roughness Coefficient *n*. Values are shown in parenthesis when used differently in the ECM.

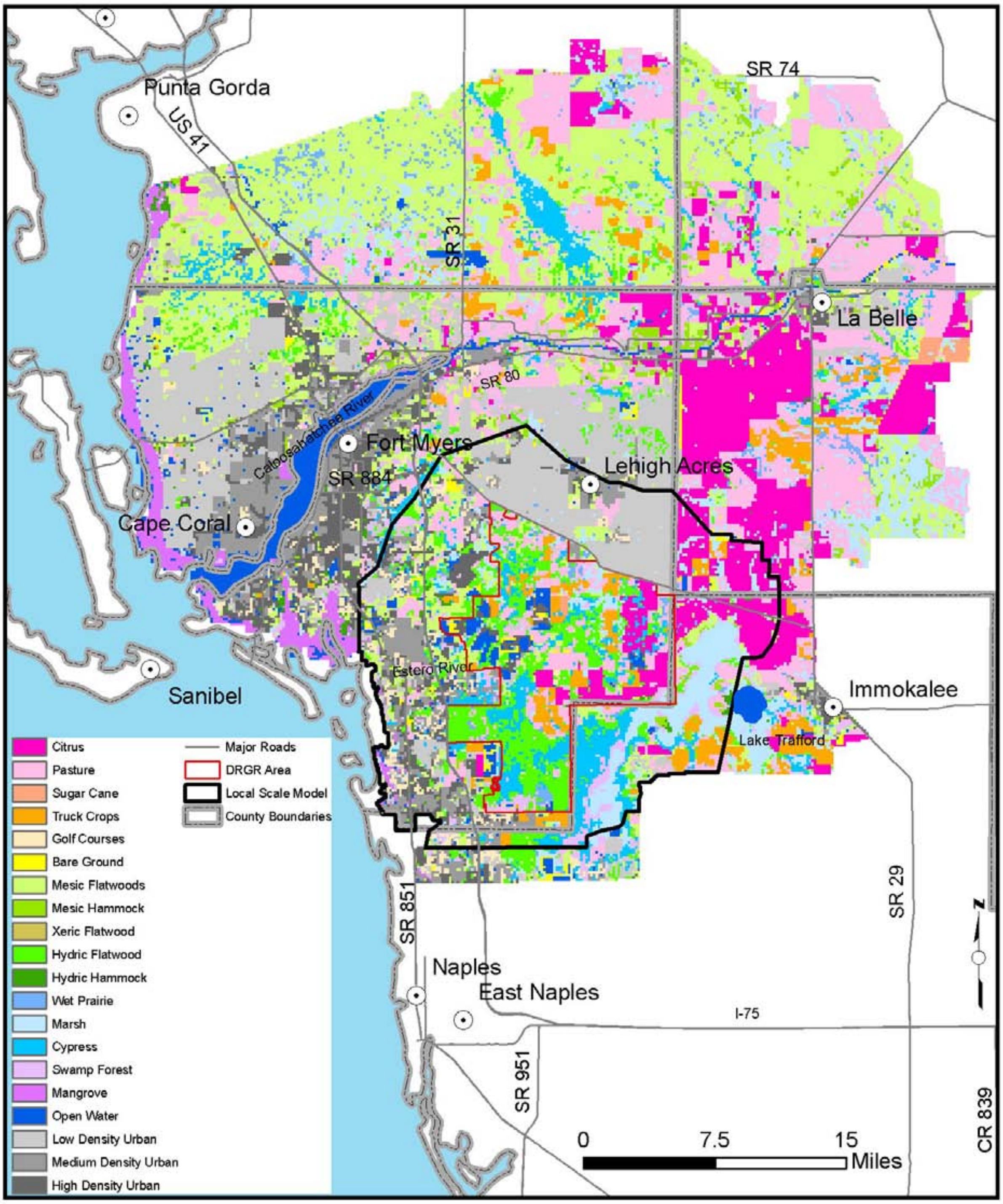

Figure 10. Existing Conditions Land Use Map.

Soils

The unsaturated zone in South Florida is shallow and the soils are sandy and highly permeable, except in wetlands where a surface deposit of fine-grained sediment may be present. Soil porosities are typically high for sandy soils in South Florida and it has been determined in previous MIKE SHE/MIKE 11 models developed in southwest Florida. Those models use the explicit gravity drainage unsaturated zone option, which does not consider the capillary pressure head term, but it is adequate for long-term regional applications. The texture and properties of soils vary on both local and regional scales. Soil types for the SWFFS area were classified into six different hydrologic response groups, shown in **Figure 11**. This soil classification was based on the predevelopment vegetation map prepared by the SFWMD in 2003, and better represents the conditions of the SWFFS area. The soil classification used in the SWFFS area and associated properties are summarized in **Table** 7**.**

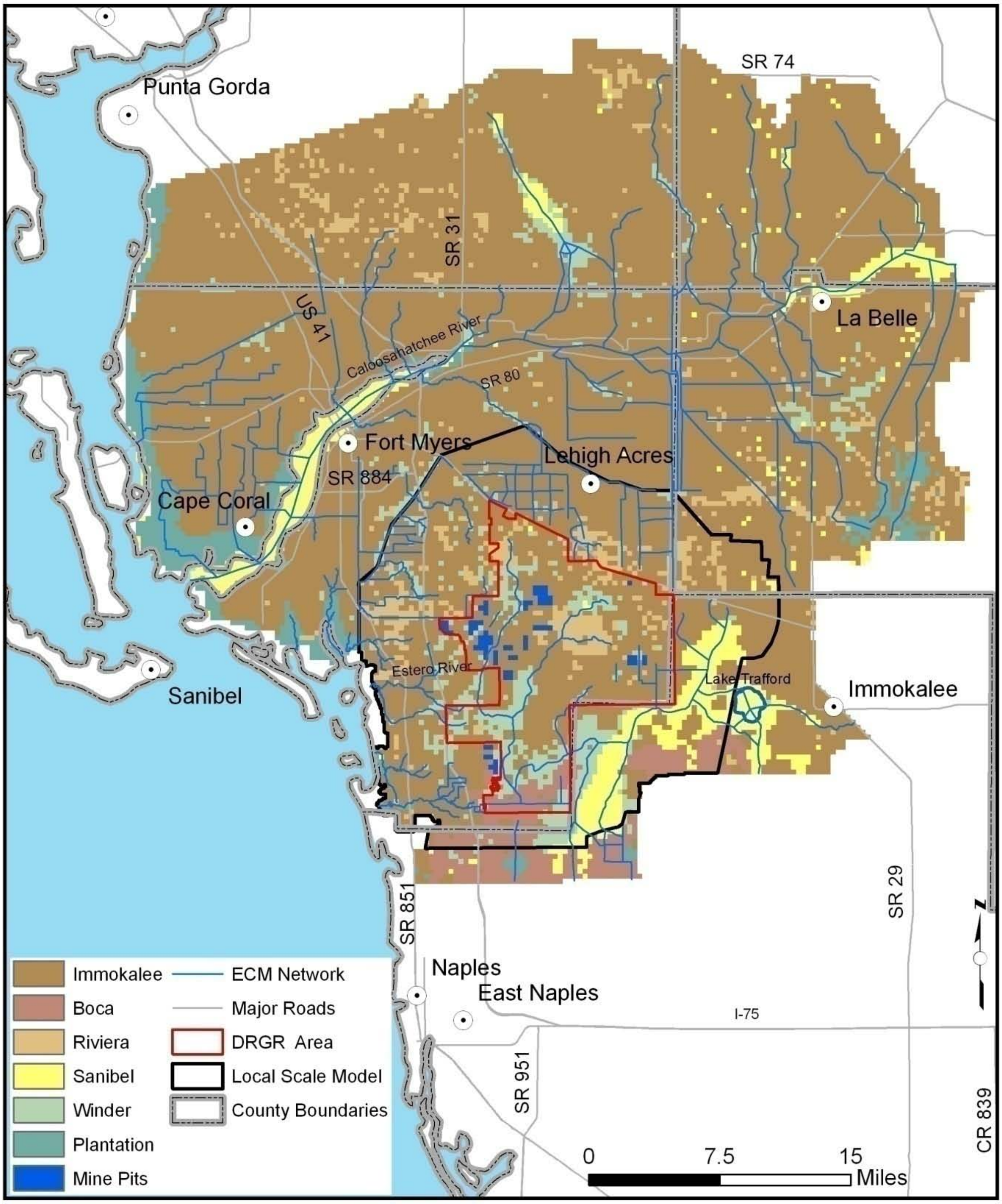

Figure 11. Soils Map.

Table 7. Soil Parameters.

MSHE Code	Soil Type	Depth interval (m)	Saturated Hydraulic Conductivity Ks (m/s)	Saturated Water Content Θ_s	Water Content at Field Capacity Θ_{fc}	Water Content at Wilting Point Θ_w	Residual Water Content Θ_r
1	Immokalee A1	(0.0-0.1)	2.00E-4	0.420	0.15	0.013	0.010
	Immokalee AE	(0.1-0.23)	1.10E-4	0.420	0.15	0.020	0.031
	Immokalee E1	(0.23-0.41)	8.60E-5	0.390	0.14	0.020	0.015
	Immokalee E2	(0.41-0.91)	1.00E-4	0.380	0.14	0.010	0.010
	Immokalee Bh1	(0.91-1.27)	1.20E-6	0.380	0.33	0.057	0.031
	Immokalee Bh2	(1.27-1.4)	6.10E-6	0.380	0.28	0.050	0.043
	Immokalee Bw/Bh	(1.4-30)	7.50E-5	0.380	0.20	0.030	0.020
2	Boca A	(0.0-0.08)	1.10E-4	0.487	0.11	0.040	0.029
	Boca E1	(0.08-0.23)	9.70E-5	0.460	0.11	0.034	0.023
	Boca E2	(0.23-0.36)	8.00E-5	0.408	0.09	0.024	0.015
	Boca Bw	(0.36-0.64)	5.40E-5	0.396	0.10	0.009	0.006
	Boca Btg	(0.64-30)	8.30E-6	0.355	0.33	0.122	0.071
3	Riviera Ap	(0-0.15)	3.64E-5	0.528	0.23	0.049	0.020
	Riviera A	(0.15-0.28)	4.20E-5	0.520	0.22	0.047	0.040
	Riviera E1	(0.28-0.41)	5.00E-5	0.460	0.12	0.022	0.001
	Riviera E2	(0.41-0.64)	5.50E-5	0.400	0.06	0.003	0.001
	Riviera Bw	(0.64-0.74)	3.50E-5	0.380	0.06	0.004	0.001
	Riviera Btg	(0.74-30)	2.50E-7	0.380	0.32	0.102	0.080
4	Sanibel Oa1	(0-0.12)	2.00E-5	0.752	0.72	0.207	0.200
	Sanibel Oa2	(0.12-0.15)	7.80E-5	0.730	0.69	0.205	0.100
	Sanibel A1	(0.15-0.23)	9.40E-5	0.510	0.39	0.025	0.010
	Sanibel A2	(0.23-0.3)	1.70E-4	0.410	0.17	0.013	0.010
	Sanibel C1	(0.3-0.66)	1.40E-4	0.370	0.09	0.013	0.010
	Sanibel C2	(0.66-30)	1.10E-4	0.380	0.08	0.011	0.010
5	Winder A1	(0.0-0.08)	3.60E-5	0.374	0.26	0.024	0.014
	Winder E	(0.08-0.33)	5.00E-5	0.370	0.15	0.008	0.004
	Winder B/E	(0.33-0.41)	1.60E-6	0.328	0.23	0.048	0.027
	Winder Btg	(0.41-0.58)	7.40E-6	0.430	0.40	0.153	0.101
	Winder BCg	(0.58-0.74)	7.40E-6	0.340	0.26	0.050	0.028
	Winder C1	(0.74-0.89)	1.00E-4	0.332	0.27	0.038	0.021
	Winder C2	(0.89-1.04)	5.00E-6	0.347	0.23	0.042	0.024
	Winder C3	(0.89-30)	1.90E-5	0.358	0.31	0.107	0.062
6	Plantation Oap	(0-0.23)	1.00E-4	0.770	0.66	0.200	0.150
	Plantation A/E	(0.23-0.48)	8.40E-5	0.491	0.19	0.029	0.022
	Plantation Bw	(0.48-30)	1.20E-4	0.392	0.10	0.003	0.002

Hydrogeology

The major hydrogeologic units in southern Florida in descending order are: the Surficial Aquifer System (SAS), the Intermediate Aquifer System (IAS), and the Floridan Aquifer System (FAS). According to Missimer and Martin (2001), Lee County has more individual aquifers with unique hydraulic properties within these systems than any other region in Florida, many of these having high transmissivities. The Water Table Aquifer (SAS), the Sandstone Aquifer (IAS), and the Lower Hawthorn Aquifer (FAS) are the aquifers with the highest production zones for public supply and irrigation. The Lee County MIKE SHE model includes the Water Table Aquifer and the Sandstone Aquifer, but excludes the FAS.

Saturated Zone Model

The saturated zone groundwater model in MIKE SHE is fully three-dimensional and thus, allows for the spatial distribution of the hydrogeologic unit thickness, horizontal and vertical hydraulic conductivities, and storage parameters. The geologic model can include both geologic layers and geologic lenses. Geologic layers cover the entire model domain whereas lenses exist in only parts of your model area. Both geologic layers and lenses are assigned the geologic parameters mentioned above. The numerical model, i.e. computational layers, is defined by the user to assign an appropriate vertical discretization for the model. The parameters of the layers and lenses that are part of a single computational layer are interpolated into the numerical grid (DHI 2008).

The geologic characterization in the ECM includes essentially the same hydrogeologic units used for the SWFFS model, plus the addition of a conceptual lens to represent the mining pits. The geologic model consists of three geologic layers and three lenses. The geologic layers are the Holocene-Pliocene, the Lower Tamiami and the Peace River Sandstone units, which correspond to the Water Table Aquifer (SAS), Lower Tamiami Aquifer (SAS), and the Sandstone Aquifer (IAS), respectively. The geologic lenses are the Bonita Spring Marl (SAS) and the Upper Peace River (IAS) confining units. The numerical model is divided initially into three computational layers (see **Figure 12**) defined as:

- Computational Layer 1 – Holocene-Pliocene
- Computational Layer 2 – Bonita Spring Marl confining unit + Lower Tamiami Aquifer
- Computational Layer 3 – Upper Peace River confining unit + Sandstone Aquifer.

The Mining Pit conceptual lens in some cases extends down to the upper portion of computational layer 3. The MIKE SHE preprocessing tool converts all the hydrogeological parameters specified for all the geological layers and lenses into the equivalent parameters for the computational layers.

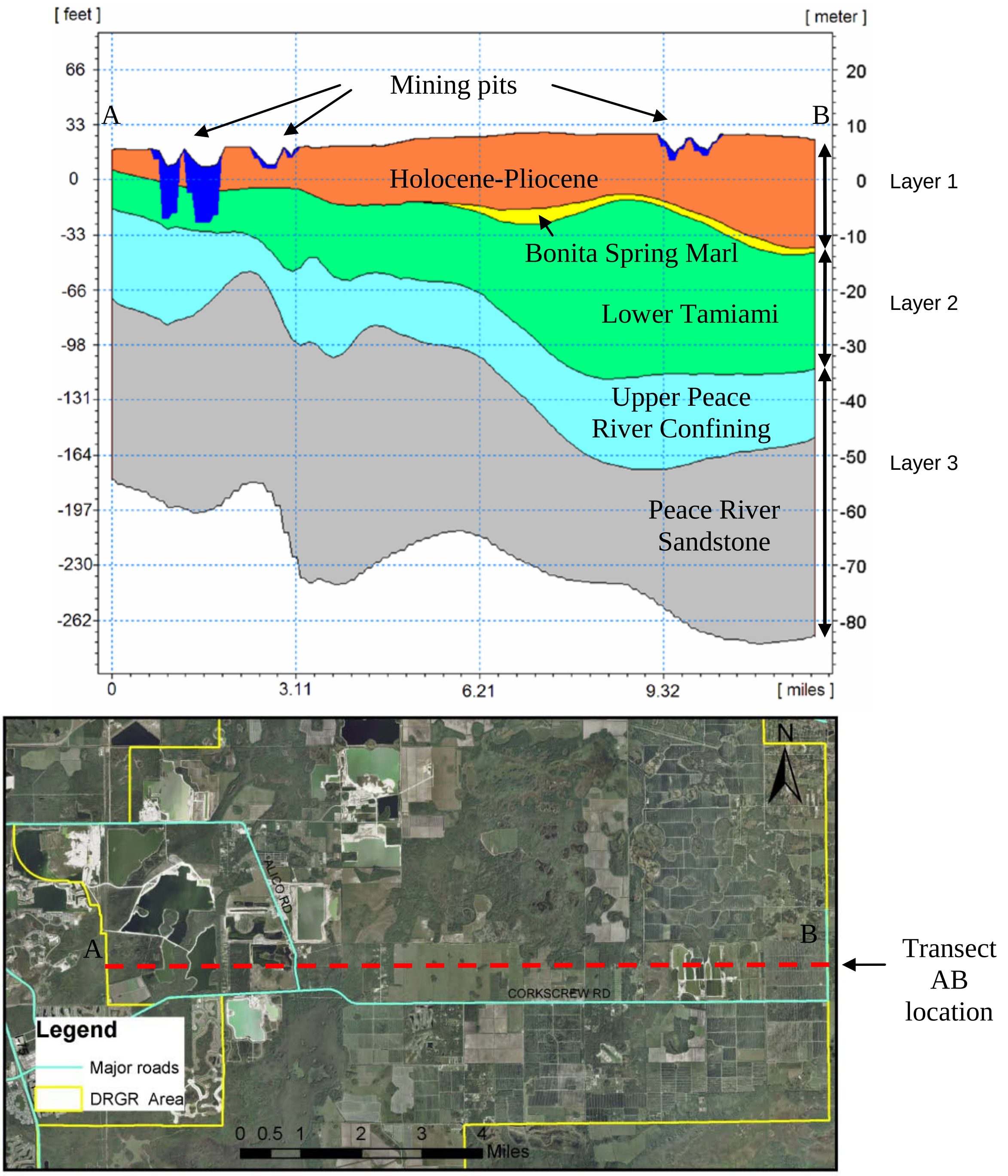

Figure 12. Geologic Model and Computational Layers along a transect in the DR/GR Area.
Note: blue color in above profile corresponds to the extent of the mining pit conceptual lenses and does not include the water above it, which is conceptualized in the overland component of the model.

Groundwater Boundaries

The Local Scale and Lee County model boundaries are shown in **Figure 13**. The boundary conditions in the groundwater layers at the eastern and southern boundaries were extracted from the SWFFS model results for the 1995-1999 simulation period. The time-varying groundwater heads from the SWFFS were used to calculate the averaged heads for every five Julian days for all simulation years in the three groundwater layers. Those averaged heads for a one year period are extended periodically and used for all the years in the ECM simulation period in order to simulate seasonal changes at the eastern and southern boundaries. The northern and western boundaries coincide with the ones in SWFFS model boundaries and thus, the ECM uses the same type of boundary conditions that was used in the SWFFS model. The northern boundary was set as zero-flux boundary and the western (coastal) boundary was set to a constant head value approximate to the mean see level elevation (0 m NAVD88).

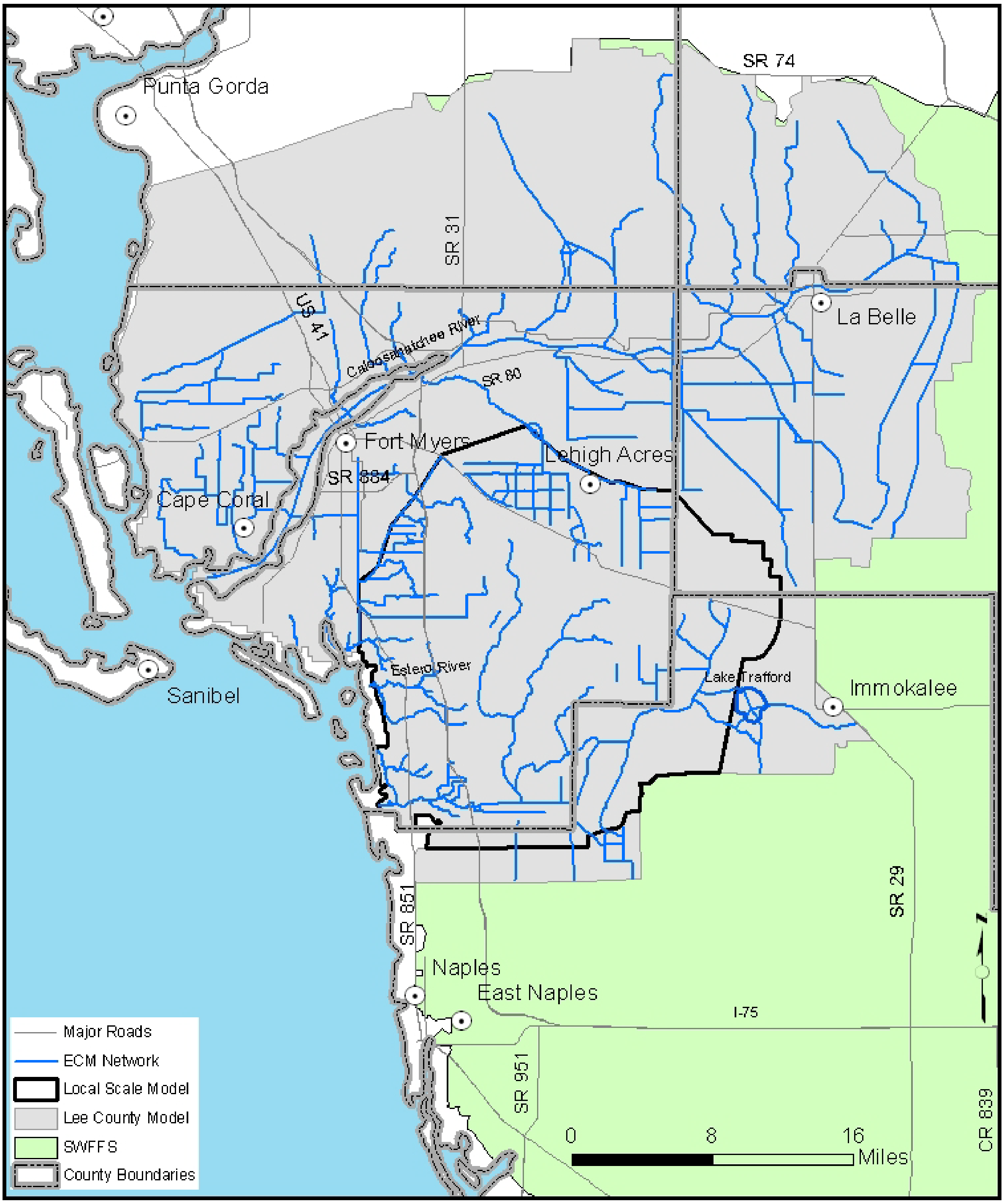

Figure 13. Model Boundaries.

Groundwater Withdrawals

Two types of groundwater extraction wells are included in the model: municipal potable water supply wells and domestic self supply wells. The Pumping Wells Module in MIKE SHE uses a well database in which the location, the depths of the screen interval, and the pumping rates for wells are specified. All of the municipal water supply wells are included in this module. The Irrigation Module, on the other hand, can be used to represent groundwater withdrawals and water from other sources that are applied as irrigation water in the model. The domestic self supply wells are represented in the irrigation module as an irrigation source.

Municipal Water Supply

Lee County provided the most current locations and depths of the potable water supply wells. This information was used to update the well data from the SWFFS model. The deep wells that extract water from the Hawthorn and Floridan aquifers were not added to the well database since these geological layers are not included in the model.

The pumping wells included in the model are listed in **Table 8** and the well locations are shown in **Figure 14**. The monthly extraction rates were obtained from the SFWMD Public Record Office for the period from year 2000 to 2007. The pumping rates for individual wells were used if it was available. If the data was only available for individual wells, the total rate for the well field was used and a fraction of the total pump rate for each well based on the number of wells in a given well field was applied. There was no data reported for individual wells at two well fields (CCI and GES shown in Table 8) and the total pumping rate was distributed uniformly in each well. For the well labeled as WF, the nominal maximum rate in the permit was applied.

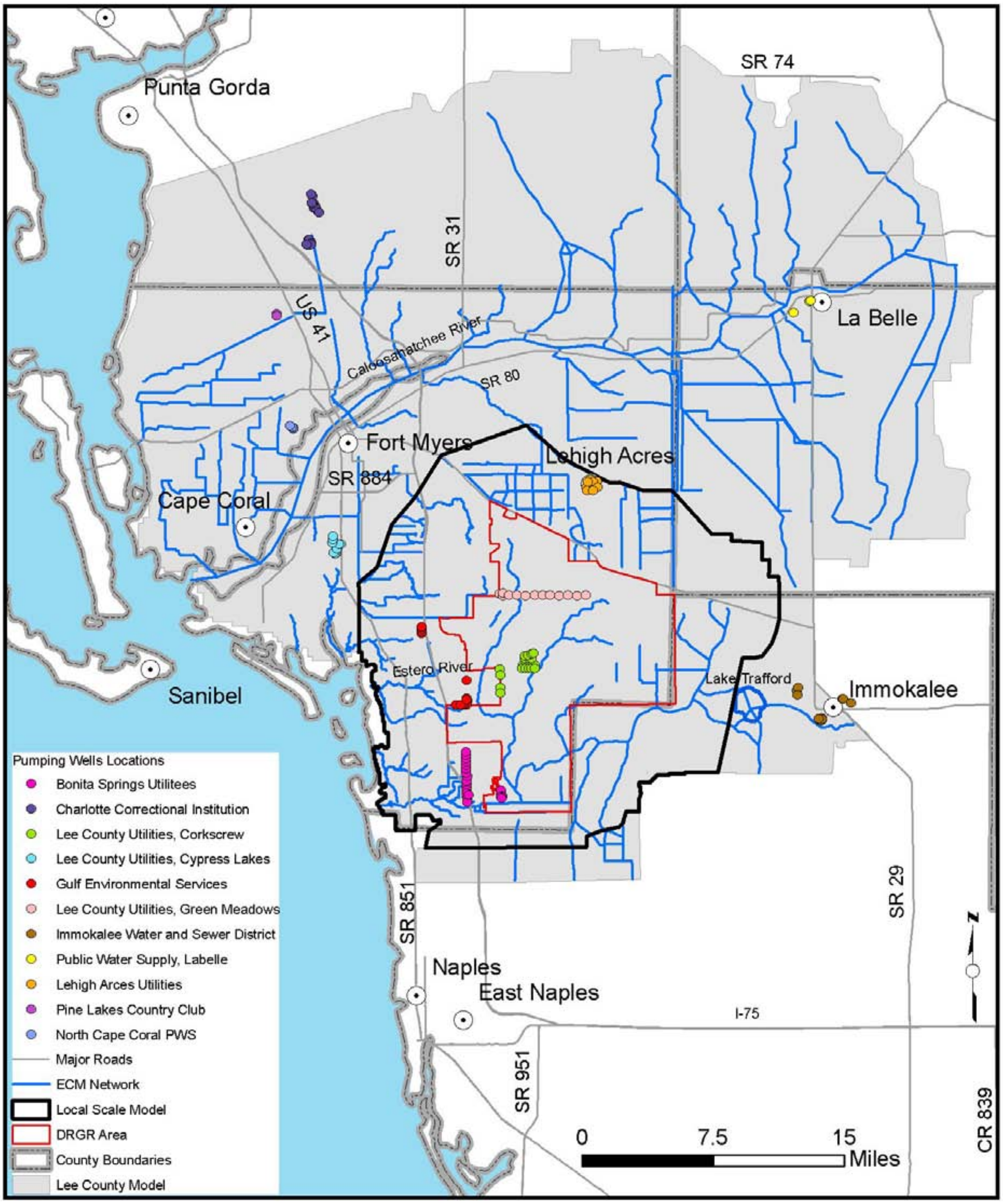

Figure 14. Municipal potable water supply well locations.

Table 8. Municipal potable water supply well included in the MIKE SHE model.

Permit Number	Project Name	ID	Well Numbers
08-00047-W	Charlotte Correctional Institution	CH-	218,219,220,221,222,227,228, 229,230,231,1,2,3,4,5,6,7
11-00013-W	Immokalee Water & Sewer District	IWSD	7,8,9,10,10A,11,12,13, 102,103,104,201,202,203,
26-00105-W	Public Water Supply, Labelle Wellfield	LAB	5,7,10,11
36-00003-W	Lee County Utilities, Green Meadows	GM-	1,1D,2,2A,3,3A,3B,4,4A,5,5A,6, 6A,7,7A,8,8A,9,9A,10,10A, 11,11A,12,12A,13,13A
	Lee County Utilities, Corkscrew	COR	2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,18,19,20,21,22,23,24,25D,25S,26 D,26S,27D,27S,28D,28S
	Lee County Utilities, Cypress Lakes	CP-	2,3,4,6,7,8,14,15,17
36-00008-W	Bonita Springs Utilities	BSU	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,1 7,18,19,20,21,22,23,24
36-00081-W	Pine Lakes Country Club	PL-	1,2
36-00122-W	Gulf Environmental Services, Pinewoods	GES	1,2,3,4,5,6,7,8,9,10,11,12,19,22
	Gulf Environmental Services, Bartow		13,14,15,16,16A
36-00152-W	Waterway Estates, North Cape Coral PWS	WENCC	1,2,4,12
36-00166-W	Lehigh Acres Utilities, Florida Water Services	LAC	1,2,3,4,5,6,7,8,9A,10,19,20,21
36-02986-W	Waldee Farm	WF-	3

<u>Domestic Self-Supply Wells</u>

The domestic self-supply (DSS) wells were represented in the Irrigation Module. The method used to represent these wells is described below in the urban irrigation section.

Irrigation

The Irrigation Module in MIKE SHE includes two main components: Irrigation Command Areas (ICAs), which is a map that indicates the cells in the model where irrigation is applied, and Irrigation Demand, where the criteria used to start and stop irrigation are specified. For each command area, several sources of irrigation (wells, rivers, external) and types of application (sprinkle, drip, sheet) can be specified. The Irrigation demand is based on "the maximum allowed global deficit" option. Irrigation is activated when the water saturation in the soil is lower than a land-use dependent value between the wilting point and the field capacity of the soil, and it stops when the field capacity is reached. The Irrigation Command Areas for the ECM are shown in **Figure 15**. The ICAs specified in the model are either agricultural or urban areas.

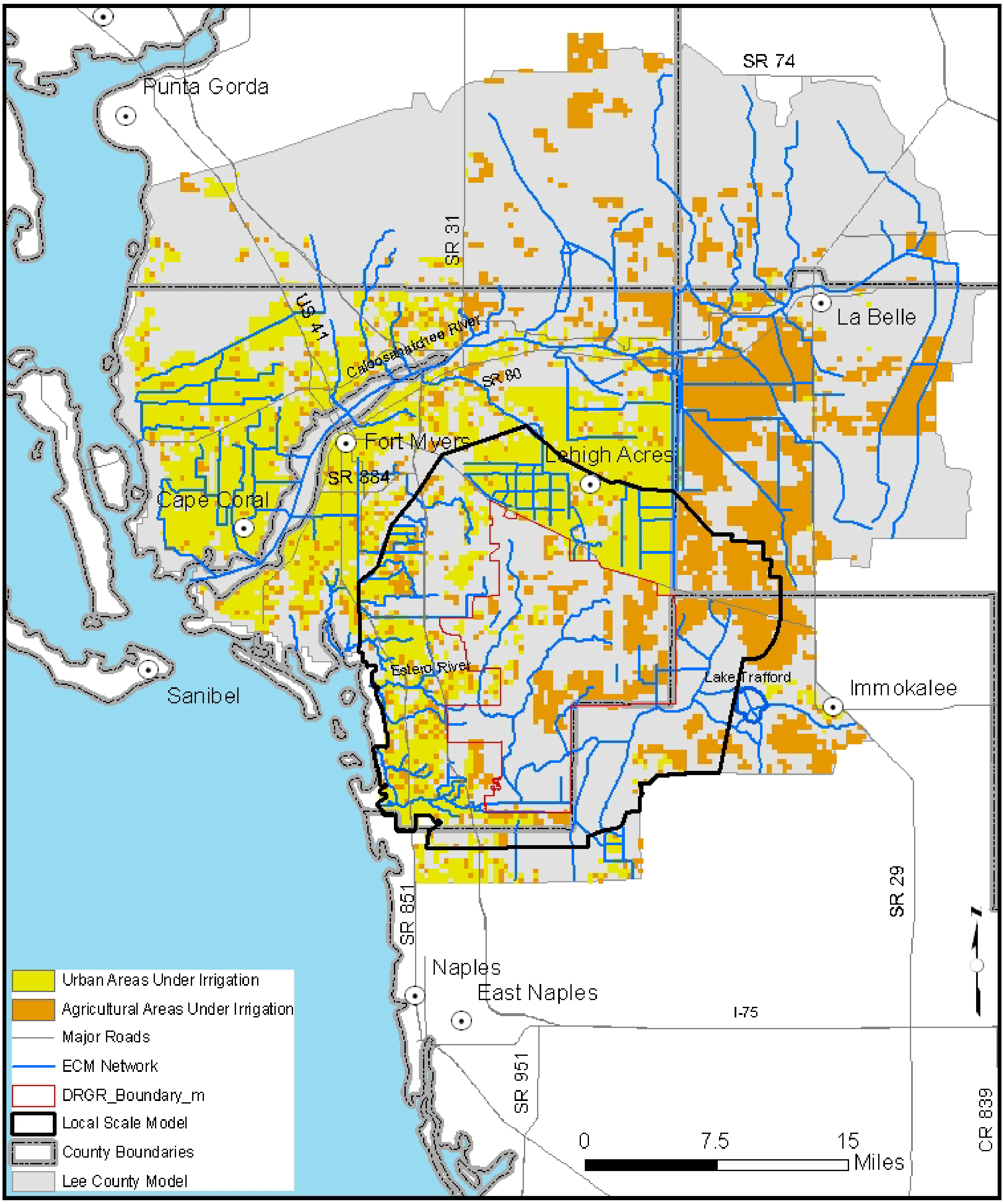

Figure 15. Irrigation Command Areas.

Some of the ECM irrigation setup in the model was taken from the SWFFS model. ICAs that rely primarily upon surface water supply from the C-43 Canal were not modified. These areas are mainly located in the Freshwater Caloosahatchee River Basin portion of the model and upstream of the S-79 structure. Some of the irrigation setup was updated to account for land use changes after year 2000. For example, agricultural irrigation was removed from the model or modified in areas where agricultural uses have converted to other uses.

For the LS ECM, the 1,500-ft resolution map with ICA codes was converted to a 750-ft resolution and the maximum pumping rates per cell for shallow well sources were decreased by four, accordingly.

Agricultural Irrigation

For agricultural lands located within and near the DR/GR Area, the most current permit information was obtained from the Florida Water Management Districts Permitting Portal (http://webapub.sjrwmd.com/agws/permitportal). For the areas where current or active permits were not available, the most recent (expired) permit was used. The permit information was used to update the source of irrigation (usually one groundwater well with a given screened interval) and the maximum pumping rate allowed. The actual amount of irrigation for a given area at a given model time step depends on the calculated soil moisture content. The soil moisture irrigation criteria differ depending of the type of crop.

Many of the row crop farms utilize flood irrigation methods. The drip irrigation method, in which the water is added directly to the ground surface of the irrigation (ICA) cells, was applied for those areas. Although there is a flood (sheet) irrigation method available in MIKE SHE, it is designed for finer grid scale applications where the flood routing can be more accurately represented. For other types of crops and for urban areas, the sprinkle irrigation method is used. The difference of the water applied as sprinkle (which is incorporated to the rainfall component) and as drip (which is placed on the ground surface) is that the former can have vegetative interception losses.

Urban Irrigation

Domestic Self-Supply (DSS) wells were specified in the model as part of the irrigation processes. This method was selected because irrigation makes up approximately 75 percent of total usage for domestic wells. Lee County provided the location of domestic self supply wells, which was used to determine the number of domestic self supply wells in each 1,500-ft grid cell as shown in **Figure 16**. The County also provided the information of the aquifers used by each DSS well that was processed to assign them an appropriate screen interval. DSS wells were grouped according to location and type of well usage. The green