Chapter 3 – Groundwater Resource Assessment

3.0 Key Points

Key Points

- The groundwater resource assessment is a planning-level evaluation that identifies areas in the WRWSA where groundwater will be generally available or where further investigation into aquifer supplies is needed. The evaluation uses regional groundwater flow modeling to simulate declines in aquifer levels due to projected groundwater withdrawals in 2030.
- The SWFWMD Northern District (ND) groundwater flow model is utilized for the SWFWMD jurisdiction in Marion, Citrus, Sumter, and Hernando Counties. The SJRWMD North-Central Florida (NCF) groundwater flow model is utilized for the SJRWMD jurisdiction of Marion County.
- The projected groundwater withdrawals used for the evaluation assume continued reliance on groundwater extracted from existing withdrawal locations at current levels of water conservation, based on population growth projections. The assessment does not simulate increases in supplies of beneficial reuse, alternative water supply development, or reductions in future water demand (conservation or diminished rates of population growth).
- Simulated declines in aquifer levels are evaluated to determine the potential to affect lakes and wetlands, spring flows, and MFL priority water bodies due to increased groundwater withdrawals. Water resource criteria are used to identify potential adverse impacts to groundwater resources due to the simulated declines in aquifer levels.
- SWFWMD and SJRWMD resource assessment methodologies are used in the respective jurisdictions to determine potential adverse impacts to groundwater resources due to model simulated declines in aquifer levels. The presence (or absence) of potential adverse impacts is used to interpret the viability of fresh groundwater to serve future water demands to 2030.
- Based on ND Model results within its domain and SWFWMD resource assessment methodologies, groundwater appears to be viable to serve projected water demand in 2030 in Citrus County and the SWFWMD jurisdiction in Marion County.
- Based on NCF model results within its domain and SJRWMD resource assessment methodologies, groundwater does not appear to be viable to serve all projected water demand in 2030 in the SJRWMD jurisdiction in Marion County.
- The potential effects of projected 2030 groundwater withdrawals in northern Sumter County and southern Marion County are difficult to interpret, but suggest a need for additional supplies or reductions in demand from conservation. Additional hydrogeologic data collection, monitoring, and analysis are warranted in this area.
- In Hernando County, projected water demand in 2030 could lead to restrictions on groundwater withdrawals in the Spring Hill area, potentially requiring additional supplies or demand reduction from conservation. Dispersed groundwater withdrawals in Hernando County located to the north or east of the Weekiwachee springshed appear to be viable.
- The SWFWMD and SJRWMD are developing an accelerated data collection and monitoring program in southern Marion, northwest Lake, and northern Sumter County over the next two years (SWFWMD, 2008). Information gained from this program will provide important data for refinement of the groundwater flow models used in this assessment. The information used for this groundwater resource assessment will be updated by the SWFWMD and SJRWMD at minimum 5 year intervals.

3.1 Introduction

The groundwater resource assessment is a planning-level evaluation that identifies areas in the WRWSA where groundwater will be generally available or where further investigation into aquifer supplies is needed. The evaluation uses regional groundwater flow modeling to simulate declines in aquifer levels due to projected groundwater withdrawals in 2030, based on the population growth projections discussed in Chapter 1.

The assessment evaluates the potential effect of projected water demand in 2030 on aquifer levels through comparison to pre-development or 1995 conditions. The simulated declines in aquifer levels are evaluated to determine the potential to affect lakes and wetlands, spring flows, and priority water bodies with adopted MFLs or proxy MFLs developed by the WRWSA. Water resource criteria are used to identify potential adverse impacts to these groundwater resources due to the simulated declines in aquifer levels. The presence (or absence) of potential adverse impacts is used to identify additional data needs and interpret the viability of fresh groundwater to serve future withdrawals to 2030.

The projected water demand in 2030 used for the evaluation assumes continued reliance on groundwater extracted from current withdrawal locations at current levels of water conservation to serve the projected increase in demand. Since the projected demand is determined assuming continued reliance on groundwater, the assessment does not simulate increases in supplies of beneficial reuse, alternative water supply development, or reductions in future water demand (conservation or diminished rates of population growth). An increase in the use of these supplies or additional demand reduction would adjust the groundwater demand. The model simulations use groundwater demands that are not adjusted (unadjusted)[1] for water resource management strategies such as additional conservation, increase in beneficial reuse, and alternative water supply development.

Significant regulatory and incentive measures have been implemented by the SWFWMD and SJRWMD to achieve additional demand reduction and beneficial reuse supply development in the WRWSA. [2] The largely rural nature of the WRWSA region and relative high historic per capita rates indicates that these measures will cause a significant adjustment in future groundwater demands as they are implemented, potentially more so than in more developed regions of the SWFWMD and SJRWMD. There is a strong likelihood that demand will be adjusted in the WRWSA region and that future groundwater will be extracted from more dispersed locations than current withdrawals given the rural setting of the region. In light of these region-specific factors, water supply assumptions that are relevant to the interpretation of fresh groundwater viability are included where appropriate.

3.2 Hydrogeologic Description of the WRWSA and Vicinity

The WRWSA and vicinity includes all of Hernando, Sumter, Citrus and Marion Counties and portions of Pasco, Polk, Lake, Putnam, Alachua and Levy Counties. The project region covers parts of the SWFWMD, SJRWMD, and SRWMD while WRWSA member governments Marion County and the City of Ocala span the SJRWMD and SWFWMD jurisdictions (Figure 3-1).

[1] Actual groundwater demand in the future will vary based on a variety of additional factors, including the actual rate of population growth.
[2] See Chapter 4 for information on water conservation and Chapter 5 for information on beneficial reuse in the WRWSA.

Hydrogeologic units underlying the region are listed in Figure 3-2. The stratigraphic or geologic units underlying area, as mapped by the Florida Geological Survey, form the framework of the hydrogeologic units. These units are the surficial aquifer (SA), intermediate confining unit (ICU), Upper Floridan Aquifer, Lower Floridan Aquifer, middle confining unit I (MCU I), and middle confining unit II (MCU II).

The SA occurs towards the eastern and southern extents of the region and comprises soils and undifferentiated sands and clays of Pleistocene/Pliocene age where it is present. The SA is conceptualized as a near surface permeable unit that is either continuously or intermittently saturated with rainfall recharge. Where the SA is continuously saturated, it is assumed to be underlain by the less permeable Miocene sediments of the ICU. In upland areas of the Ocala Hills, however, the SA may exceed 50 feet in thickness.

The ICU comprises low permeability clays, sands, and carbonates of Miocene age. The area where the ICU is present corresponds to the SA and the Semi-Confined Upper Floridan Aquifer Recharge Region. The ICU occurs in continuous fashion towards the eastern and southern extents of the region. For example, the Brooksville Ridge and Fairfield Hills areas are highly karst, ridge systems with relatively thick confinement where numerous, localized, hydraulically "perched" lakes and water tables exist because of the generally thick clays between the surface and the underlying Upper Floridan aquifer with hydraulic head differences varying from 20 to more than 100 feet (Basso, 2004).

The Floridan Aquifer was subdivided by Miller (1986) into an Upper Floridan Aquifer (UFA) and a Lower Floridan Aquifer (LFA). Miller (1986) proposed that middle confining units within the Avon Park Formation separated the UFA from the LFA. The UFA in the region consists mainly of the Suwannee Limestone (Oligocene), Ocala Limestone (Eocene), and the upper portion of the Avon Park Formation (Eocene); and the LFA is mainly composed of the lower portion of the Avon Park Formation. In some areas, the LFA contains poor-quality water and is not used as a potable water source. However, high sulfate concentrations have been observed in the UFA in western Marion County. In general, the geologic units that comprise both the Upper and Lower Floridan Aquifers dip and thicken to the south. The UFA is mostly unconfined over most of the WRWSA except along the eastern and southern portions of the area where the ICU becomes thicker and continuous.

Springs in west-central Florida are normally associated with karst terrains. Pervious soils, sinkholes and karst geology allow significant amounts of rainfall to recharge the FAS and discharge at the springs. An example is the Chassahowitzka Springs, which is a coastal spring complex, where flooded karst features form spring vents, fissures, and highly-eroded limestone at or near land surface.

Travel time and distance for groundwater migration to spring discharges vary based on geologic features such as transmissivity and the existence of fracture zones (which may serve as conduits for flow or clay-filled fractures may impede migration). Spring flows can exhibit seasonality, reaching a minimum at the end of the dry season and peaking at the end of the wet season (Jones et al, 1996). An example is Rainbow Springs, where the seasonal pattern is an indication that the groundwater flow system is recharged by precipitation falling in close proximity (5 to 10 miles radius) to the spring in addition to precipitation falling at a greater distance.

The springshed is the land area or drainage basin that contributes rainfall or runoff to a spring. These areas are difficult to define, especially at their distal ends, as the boundaries may change with season, climate, or land use. Figure 3-3 depicts the approximate location of the MFL-priority springsheds in the WRWSA. As shown, much of the region is located within these approximate springsheds, including large areas in Citrus, Marion, Sumter, and Hernando Counties.

Springsheds are located in areas with relatively high and moderate transmissivity values in the UFA due to the karst geology associated with each spring system. Almost all springsheds are located in areas where transmissivity exceeds 500,000 ft^2/ day. Particularly high transmissivity is associated with springs in areas of Marion, Citrus, and Hernando Counties. Transmissivities in areas outside these springsheds range from 50,000 to 500,000 ft^2/ day (Ryder, 1985).

3.3 Application of Groundwater Flow Models

WRWSA utilization of the SWFWMD ND and SJRWMD NCF groundwater flow models and the respective model boundaries is shown on Figure 3-4. As shown, the WRWSA utilizes the ND Model for the SWFWMD jurisdiction in Marion, Citrus, Sumter, and Hernando Counties. The NCF Model is utilized in the SJRWMD area of Marion County. The ND and NCF Models also have areas of coverage in Alachua, Putnam, Levy, Lake and Orange Counties. The respective model boundaries extend beyond the WRWSA and reflect the connectivity of the regional aquifer systems beyond the WRWSA jurisdictional boundaries. The ND Model does not include far northeast Marion County, while the NCF Model does not include far western Marion County.

The ND Model is used by the SWFWMD because it includes more up-to-date hydrogeologic data, represents the SA as an active layer, and has transient capabilities and a smaller grid size, in comparison to the USGS Peninsular Florida (PF) model. The NCF Model is preferred by the SJRWMD to the PF model because of the better treatment of recharge, the inclusion of the SA as an active layer, and smaller grid size in comparison to the PF model. The ND and NCF Models are described in more detail in subsequent sections of this chapter.

Current water demand projections for 2030 are provided by the SWFWMD and SJRWMD as inputs to the groundwater flow models. The current water demand projections are detailed in Chapter 1.

The ND and NCF Models are used for this evaluation to portray regional conditions and do not provide detailed, regulatory-level data regarding aquifer conditions in localized areas. The ND and NCF Models and the groundwater resource assessment are discussed below.

3.4 Groundwater Flow Models

This section describes the ND and NCF groundwater flow model used for the assessment in the SWFWMD and SJRWMD areas of the WRWSA, respectively.

3.4.1 Description of the SWFWMD ND Model

The SWFWMD ND Model domain includes three groundwater basins: the eastern, the northern, and the central groundwater basins (see Figure 3-5). The model western boundaries for the northern and the central basins are extended approximately five miles offshore to account for the discharge of freshwater into the Gulf of Mexico from the Floridan Aquifer System (FAS). The assignment of the western boundaries was based on the results from the saltwater intrusion model developed for Hernando County (HydroGeoLogic, 2002).

The regional grid consists of 182 columns and 275 rows and has uniform model cell spacing of 2500 by 2500 feet (see Figure 3-6). The grid spacing is modified in the vertical to conform to geological formation geometry and topography.

In the vertical direction, seven (7) layers of finite-difference cells are used to represent aquifer systems discussed above (e.g., Figure 3-2). Owing to the permeability contrasts between hydrogeologic units, each unit is simulated as a discrete model layer rather than using one model layer to represent a thick sequence of permeable units (e.g., UFA). In regions where the ICU is missing, the second model layer represents the SA sands. The ICU distribution is shown on Figure 3-7. The Suwannee Limestone is also missing north of Southern Citrus County. Where the Suwannee Limestone is absent, model layers 3 and 4 represent the Ocala Limestone. The Ocala Limestone does not exist in the northernmost region of the NDWRAP area. In this area, model layers 3 through 5 represent the Avon Park Formation. MCU I and MCU II are represented as a single confining unit. The elevation data for each layer was obtained from the Florida Geologic Survey. The ND Model is unique in west-central Florida in that it is a fully 3-dimensional groundwater flow model which does not rely on leakance coefficients to simulate flow through confining units. Additional details of the ND Model are provided in HydroGeoLogic (2008).

The lateral and lower model boundaries are assigned constant head (prescribed head), general head, or no-flow boundary conditions. The SA (Regional Model Layer 1) along the eastern and northeastern lateral model boundaries is represented by prescribed hydraulic heads. The western boundary conditions are specified as constant heads and are in hydrostatic equilibrium with the Gulf of Mexico. The equivalent freshwater heads extend across all layers present along the western boundary.

Previous regional scale modeling results (Sepulveda, 2002) were used to assign general head boundary conditions along the eastern and northeastern portions of the model domain for the Upper and Lower Floridan aquifers. The general head conditions along these boundaries were assigned to the Suwannee Limestone (Regional Model Layer 3), the Ocala Limestone (Regional Model Layer 4), and the Upper and Lower Avon Park Formations (Regional Model Layers 5 and 7). Model layers 2 and 6 (ICU and MCU) act as confining units with predominantly vertical groundwater flow. As a result, no-flow conditions were assigned along the perimeters of these model layers.

All lateral model boundaries not defined with constant head or general head boundaries were assigned no-flow boundary conditions.

The lower model boundary was chosen as the bottom of the Lower Avon Park (Regional Model Layer 7) or, where the Lower Avon Park is absent, the Middle Confining Unit (Regional Model

Layer 6). Because of the low permeability associated with evaporite lithology across these sections of the flow system, this bottom boundary was defined as a no-flow boundary.

Distributions of transmissivity in the Upper and Lower Floridan aquifers for the ND Model are given in Figures 3-8, and 3-9, respectively. The boundary of the LFA in the ND Model is also shown as the limit of the transmissivity distribution in Figure 3-9.

Recharge in the ND Model is based on rainfall, runoff, and evapotranspiration (HydroGeoLogic, 2008). Neither the septic tank inflow nor the return flow from domestic waste facilities is included in the current ND Model.

The ND Model was calibrated under steady-state conditions for 1995 and transient conditions from 1996-2002. The simulated heads from the 1995 steady-state simulation were used as starting heads for a seven-year transient simulation that used monthly stress periods (HydroGeoLogic, 2008).

The computer code MODFLOW-SURFACT (HydroGeoLogic, 2002) was selected for the groundwater flow modeling for the NDWRAP area. MODFLOW-SURFACT is an enhanced version of the U.S. Geological Survey modular three-dimensional groundwater flow code (McDonald and Harbaugh, 1988). MODFLOW-SURFACT was selected for the NDM because of the following potential capabilities and attributes:

1. Rigorous simulation of saturated and unsaturated conditions in unconfined aquifers;
2. Ability to simulate groundwater seepage faces;
3. Ability to simulate wells that are open to several aquifer units; and
4. Capability to simulate of density-dependent groundwater flow and solute transport (i.e., saltwater intrusion).

The ND Model is part of a long-term SWFWMD effort, the Northern District Water Resources Assessment Project (NDWRAP), to evaluate water resources in the northern part of the SWFWMD. The current version of the ND Model is described in detail in HydroGeoLogic (2008). The model is currently being updated, and another version is expected to be released in 2010.

3.4.2 Description of the SJRWMD NCF Model

The NCF Model (Motz and Dogan, 2004) covers a rectangular domain of approximately 5,650 sq.mi. in north-central Florida. The domain is divided into 150 columns and 168 rows with uniform grid spacing of 2,500 ft (Figure 3-10). The NCF Model, developed based on the USGS MODFLOW code (McDonald and Harbaugh, 1988), has three active layers: Layer 1 - the SA, Layer 2 – the UFA and Layer 3 - the LFA, and the ICU and the Middle Semi-Confining Unit/Middle Confining Unit (MSCU/MCU) as vertical leakances between the three layers.

Details of the three aquifers and the two intervening units are given in Motz and Dogan (2004) and references therein. It is noted by Motz and Dogan (2004) that in parts of Alachua and Marion Counties, the SA is very thin or absent. In these areas, the UFA is considered unconfined. Areas where the UFA is considered to be unconfined in the NCF Model are shown in Figure 3-11. The UFA in the NCF Model is a zone of relatively high permeability which is attributed to the combination of high primary and secondary porosity of the limestone that this unit comprises (Miller, 1986). The NCF Model distribution of transmissivity in the UFA is shown in Figure 3-12. The transmissivity value is as high as 10^7 ft^2/day in Marion County.

The NCF Model distribution of transmissivity in the LFA is shown in Figure 3-13. In the figure, the transmissivity value ranges from 10^5 to 10^6 ft^2/day. High chloride concentrations (>5,000 mg/L) are present in some areas in the LFA. Areas in the southwestern and eastern parts of the model, where groundwater with a high chloride concentration occupies the full thickness of the LFA, were not considered part of the flow domain. MODFLOW cells in Layer 3 are inactive in these areas. The locations of these inactive cells are also shown in Figure 3-13.

Areal recharge is applied to the uppermost active layer (the SA where present, the UFA where the SA is absent) over the entire model, through combined use of the Recharge and Evapotranspiration Packages in MODFLOW. Recharge in the NCF Model is based on rainfall, irrigation, septic tank inflow, runoff, and evapotranspiration (Motz and Dogan, 2004). The resulting is net recharge which was applied to the NCF Model. Return flow from domestic waste facilities was not included.

A general head boundary (GHB) is assigned around the lateral boundary of the UFA and LFA using the GHB Package in MODFLOW. The River Package is used to simulate direct discharge from the SA and UFA to the surface water system. The Drain Package is used to simulate the 46 springs found within the model area. The Well Package is used to simulate the estimated water-use within the model area.

The model was calibrated to average steady-state 1995 conditions, using 81 observation wells in the SA and 278 observation wells in the UFA, as well as observed or estimated discharges for the 46 springs simulated in the model. The model calibration is generally excellent, with a root mean square error of 4.51 ft for the SA and 3.27 ft for the UFA. Total simulated springflow equals 100% of the total observed or estimated springflow.

3.5 Groundwater Flow Simulation Considerations

3.5.1 Northern Sumter, Southern Marion and Northern Lake County Hydrogeology

An area of uncertainty in the simulation results occurs in the northern Sumter/southern Marion/northern Lake Counties' region due to complex transitional geology and limited hydrogeologic data. In this area, the hydrogeologic system is more complex than in most of the Northern West-Central Florida Groundwater Basin (NWCFGWB) domain, and only limited data is available to characterize this region in the ND and NCF Models.

Western Lake County forms the boundary between two separate groundwater basins having differing levels of surficial confinement: The NWCFGWB and the East-Central Florida Groundwater Basin (ECFGWB) (see Figure 3-5). Generally, the NWCFGWB is comprised of a regionally unconfined UFA with a deep water table while the ECFGWB contains a semi-confined UFA under shallow water table conditions. The location of the boundary between these two hydrogeologic systems is based on limited data in the ND and NCF Models. Impacts to lakes and wetlands may be significantly less in a semi-confined versus an unconfined region, because the confinement can protect surficial water features from drawdown experienced in the UFA. The location and depth of UFA water level declines may also vary based on the extent of confinement.

This region contains both the UFA and LFA which is separated by a MCU 1 from Miller (1986). The hydraulic characteristics and spatial extent of both MCU 1 and the LFA are poorly understood in the region.

Calibration of LFA water levels was not performed in the ND Model. In the ND Model, hydraulic conductivity within the unit was largely assigned a uniform value of 66 ft/d based on a previous USGS model of the Ocala National Forest area (Knowles and others, 2002). In addition, the vertical leakage through MCU 1 was not altered in the calibration process and a uniform vertical hydraulic conductivity of 1.1 ft/d was assigned to this layer. The leakance values of MCU 1 range from 1.0×10^{-5} to 6.4×10^{-1} 1/day. The values for transmissivity in the LFA range from 20,000 to 50,000 ft^2 /day.

In the NCF Model, the LFA and the MCU 1 layers were calibrated because there are some observation wells in the LFA. The calibrated leakance values of MCU 1 range from 1.0×10^{-6} to 5.0×10^{-3} 1/day. The calibrated values for transmissivity in the LFA range from 280,000 to 2.0×10^{6} ft^2 /day. In Marion County, the leakance values range from 1.0×10^{-6} to 1.0×10^{-3} 1/day, the predominant values of transmissivity range from 100,000 to 500,000 ft^2 /day.

Where the LFA exists, the LFA is simulated as a continuous layer in the ND Model. In the NCF Model, only the LFA in areas with chloride concentration less than 5,000 mg/L is included in the model. MCU 1 is simulated as a leaky layer in the both the ND and NCF Models.

The complex hydrogeology and limited available hydrogeologic data in northern Sumter/southern Marion/northern Lake County makes interpretation of groundwater modeling results somewhat difficult. Historically, observed drawdown impacts have been small or below measurable limits. To improve confidence in model results in this area, a series of pumpage analyses were performed by WRA and sensitivity analyses were performed by the SWFWMD using the ND Model to improve understanding of the system and increase confidence in groundwater model predictions. The analysis by WRA includes simulation of a well confined LFA and is discussed later in this report.

3.5.1.1 Hydrogeologic Sensitivity Analyses

Significant quantities of groundwater are projected to be extracted in 2030 from both the Upper and Lower Floridan aquifers in the Villages located in northeastern Sumter County. The modeled groundwater extraction rates from the two aquifers in 2030 are given in Table 3-1 below, based on the Villages' SWFWMD WUP. Impact to UFA levels due to LFA withdrawals may be significantly less in an area where the MCU 1 has a lower vertical hydraulic conductivity than that used in a groundwater model.

Table 3-1. Modeled Villages Extraction Rates from the Upper and Lower Floridan aquifers in 2030.

Rate (mgd)	
Aquifer	**2030**
UFA	10.3
LFA	10.4

Note:
1) *Projected extraction data taken from the Villages SWFWMD WUP No. 20013005.*
2) *The current Villages estimate for 2030 extraction rates is 8.0 and 11.0 MGD from the UFA and LFA, respectively.*

The sensitivity analyses conducted by the SWFWMD were undertaken to determine the potential groundwater withdrawal impacts associated with different ND Model parameter combinations in the northern Sumter County area that are within a realistic range based on prior knowledge of hydrogeology and other flow model simulations.

A total of nine model scenarios were run by the SWFWMD in which varying hydraulic conductivity, conductance values, and spatial extent of the semi-confined UFA were used. The results from the SWFWMD sensitivity analysis indicate that the maximum predicted drawdown impacts occurred to nearby springs and the downstream section of the Withlacoochee River when the semi-confined boundary of the UFA was moved further west from its current position in the ND Model, toward central Sumter County. This simulation produced greater overall drawdown in the UFA that expanded westward to further reduce Gum Springs flow and baseflow at the Holder reach of the Withlacoochee River. In contrast, water level drawdown in the SA was significantly diminished in northeast Sumter County due to the introduction of confinement between the surficial and UFA.

Both Gum and Fenny Springs showed the greatest variation in predicted flow reductions from non-pumping (eg, pre-development) conditions to 2025 projected groundwater demand based on the nine scenario runs. Gum Springs flow declines ranged from three to 13% with a median change of 8.5% (based on a pre-development flow of 61.1 cubic feet per second (cfs). Fenny Spring flow reductions varied from 11.6 to 16.5% with a median change of 12.4%. Silver Spring flow reductions varied from 2.2 to 5.8% with a median change of 4.4% (based on a pre-development flow of 665.9 cfs. All other springflow reductions varied by less than 1%. The Holder reach of the Withlacoochee River displayed the greatest variation in baseflow reductions among the scenarios, ranging from 3.9 to 11.6% with a median change of 6.9% (based on a pre-development flow of 235.58 cfs. All other Withlacoochee River segment baseflow reductions showed less variation, generally much less than 5%. A complete description of the model sensitivity analyses for the northern Sumter area is found in Basso (2008).

The results of the SWFWMD sensitivity simulations show that percent groundwater flow reductions to Gum Springs, Fenny Springs, the Holder reach of the Withlacoochee River, and aquifer water levels in northeast Sumter County can vary greatly depending on the nature of the hydrogeologic system. The complexity of this system with a poorly understood transition zone between the unconfined and semi-confined UFA, the degree of confinement provided by the ICU and MCU 1, the actual permeability of major flow zones in the UFA and LFA, and the degree of lake/river connection to the groundwater system directly affects the magnitude of predicted impacts.

To address this issue, both the SWFWMD and SJRWMD are developing an accelerated data collection and monitoring program that involves drilling and testing at 16 sites in the southern Marion, northwest Lake, and northern Sumter County over the next two years (SWFWMD, 2008). In addition, the City of Wildwood has entered into a cooperative funding agreement with the SWFWMD to test drill the LFA for potential future supplies, and the City of Ocala plans to test drill the LFA. More detail regarding the data collection and monitoring program is provided in a subsequent section. Information gained from this program will provide important data for refinement of the ND and NCF Models. This in turn will result in increased confidence in overall model predictions.

3.5.2 Water Management District Boundaries

The SJRWMD has designated the far southern extent of Marion County as a Priority Water Resource Caution Area (PWRCA), meaning that projected water needs within a 20-year planning horizon cannot be met by traditional groundwater sources without incurring unacceptable impact to natural resources (SJRWMD, 2005). [3] Additionally, the SJRWMD, SWFWMD, and SFWMD have approved interim rules to restrict groundwater withdrawals to 2013 demands in the Central Florida Coordination Area (CFCA), which includes southern Lake County.

The PWRCA designation does not have an equivalent in SWFWMD and adds jurisdictional complexity to the WRWSA's water supply planning efforts involving Sumter and Marion Counties. With respect to this groundwater resource assessment, the PWRCA designation indicates that it is important to consider the effect of projected withdrawals in the SJRWMD on the groundwater flow modeling, since projected water demands in the SJRWMD in 2030 are unlikely to be met by traditional groundwater sources.[4] The SJRWMD regulatory program will restrict future groundwater withdrawals to avoid unacceptable adverse impacts to natural resources.

To facilitate identification of potential jurisdictional complexities to groundwater development in Sumter and Marion Counties, pumpage and sensitivity analyses were performed involving rates of groundwater withdrawal in the SJRWMD jurisdiction. These analyses include:

- ND Model pumpage analyses involving both the 2005 and 2025 pumping packages in the SJRWMD.[5]
- Sensitivity analysis regarding the eastern boundary condition of the ND Model located in Orange and Lake Counties.
- Sensitivity analysis regarding the portions of the southern and eastern boundary condition of the NCF Model located in Orange, Lake, and Seminole Counties.

More detail regarding the sensitivity and pumpage analyses is provided in the following sections.

3.5.3. Existing Water Use Permit Considerations

As mentioned, the projected water demand in 2030 is determined assuming continued reliance on groundwater extracted from current withdrawal locations at current rates of water conservation. The groundwater resource assessment does not generally consider increases in supplies of beneficial reuse, alternative water supply development, or reductions in future water demand (conservation). Water resource management strategies such as additional conservation, increase in beneficial reuse, and alternative water supply development will adjust

[3] This determination was based on the SJRWMD regional groundwater modeling, water resource criteria, and other factors (SJRWMD, 2005).
[4] There will also be a significant adjustment in future groundwater demands in the WRWSA due to additional reclaimed water supply and conservation efforts in the region. Significant regulatory and incentive measures have been implemented by the SWFWMD and SJRWMD to achieve additional demand reduction and beneficial reuse supply development. See Chapters 4 and 5 of this report.
[5] A ND Model pumping package for 2030 in the SJRWMD was not available for use in this project.

the projected groundwater withdrawals.[6]

The existing SWFWMD WUP (No. 20013005) for the Villages contains a special condition that requires consideration of developing seven (7) mgd of alternative water supplies or regional groundwater supplies. To assist with interpretation of groundwater modeling results, a pumpage analysis was performed involving a seven mgd reduction in pumpage in the ND Model in the Villages area. The analysis assesses the response of the UFA to this reduction in pumpage. More detail regarding the analysis is provided in a subsequent section.

3.5.4 Data Collection and Future Model Refinement

The SWFWMD and SJRWMD are aggressively pursuing a drilling and testing program in their jurisdictional area to improve the understanding of the system and increase confidence in numerical model predictions. The SWFWMD has recently completed coring to 1,500 ft below land surface at its Regional Observation and Monitoring Program (ROMP) site no. 117 near Lake Okahumpka in northeast Sumter County. The SWFWMD plans to construct monitor wells and conduct hydraulic testing of the aquifer systems at this site which will provide invaluable data for the future refinement and calibration of models in this region. This site, along with many other planned sites, will provide important information relative to improvement of model predictions in the region.

Continued refinements to the ND and NCF Models include improving the conceptualization of the groundwater system as new hydrogeologic, water level, and aquifer testing data become available. With the additional data, improvements can be made to the representation of lakes, rivers, and wetlands in the models.

Future enhancements to the ND Model are planned, such as using active model calculated groundwater recharge and/or an integrated (coupled groundwater and surface water) modeling technique. These enhancements will enable improved simulations of predevelopment water levels to better estimate cumulative changes due to pumping, as well as simulations to estimate effects of long-term changes in rainfall/recharge on water levels. A more in-depth model sensitivity analysis is also planned that examines changes in model parameters to ascertain the effect they might have on model calibration and prediction results. The SWFWMD will examine how lakes are represented in the model and their contributions to groundwater recharge through seepage.

The NCF Model will undergo a post-verification process to provide a second calibration point (in addition to the original 1995 calibration). The second calibration will be to a period of time in the 2004-2006 range and will provide verification that the model remains accurate in the vicinity of the calibration. The post-verification should improve the predictive capabilities of the NCF Model.

As changes to the ND and NCF Models are made, the SWFMWD and SJRWMD will provide for scientific peer review of the models by outside parties. Comments and suggestions made as part of the peer review will be addressed and incorporated into the NCF and ND Models as appropriate. Future refinements to the ND and NCF Models should improve the confidence in

[6] Actual groundwater demand in the future will vary based on a variety of additional factors, including the actual rate of population growth.

model predictions included in this report.

3.6 Projected Groundwater Withdrawals

3.6.1 Groundwater Withdrawals within the WRWSA

The SWFWMD and SJRWMD have estimated water use and projected future demand for their respective areas located within the WRWSA jurisdiction. These values were subsequently used by each agency to prepare the pumpage estimates and projections used for the model simulations contained in this report. Chapter 1 details the current water use estimates and demand projections. As discussed above, the pumpage discussed here assumes that the increased water demand will continue to rely on groundwater withdrawn from current extraction locations at current levels of water conservation (unadjusted groundwater demand), based on the population growth projections discussed in Chapter 1.[7] Refer to Tables 3-2 and 3-3 for a summary of 2030 pumpage in the ND and NCF Models in the WRWSA.

Table 3-2. Summary of 2030 ND Model Pumpage in WRWSA.

County	2030 (mgd)
Citrus	45.2
Hernando	48.9
Sumter	34.6
Marion – SWFWMD	31.3
Marion – SJRWMD[8]	53.5
Total	214.9

Table 3-3. Summary of 2030 NCF Model Pumpage in WRWSA.

County	2030 (mgd)
Marion – SWFWMD	32.6
Marion – SJRWMD	56.9
Citrus	28.1
Sumter	32.4

The available pumping packages for the SWFWMD area of the ND Model and the SJRWMD area of the NCF Model were prepared using different methodologies by the respective agency. For example, for the ND Model, domestic self-supply withdrawals were reduced by 60% in unconfined areas of the UFA to account for return flows (septic seepage) back into the aquifer. For the NCF Model, recharge is increased from 1995 to 2030 to account for return flows back into the aquifer which result from projected land use changes. Model boundaries also differ such that portions of Marion County are not covered by the ND Model, while portions of Citrus and Sumter Counties are not covered by the NCF Model. Other methodological differences are

[7] Actual groundwater demand in the future will vary based on a variety of additional factors, including the actual rate of population growth.
[8] A ND Model pumping package for 2030 in the SJRWMD was not available, so a 2025 pumping package was used for the SJRWMD area in the ND Model.

present between the agencies with respect to determination of pumpage, water use and projected demand. Comparison of agency methodologies is beyond the scope of this chapter. The respective pumping packages provided by the SWFWMD and SJRWMD are used for the analysis because they are the best available information.

3.6.2 Groundwater Withdrawals outside the WRWSA

The SWFWMD, SJRWMD and SRWMD have estimated water use and projected future demand for their respective areas located outside of the WRWSA jurisdiction. Similar to the areas within the WRWSA mentioned above, these values were subsequently used by each agency to prepare the pumpage estimates and projections used for the model simulations contained in this report. The areas outside of the WRWSA within the NCF and/or ND Model extents include portions of Levy, Putnam, Polk, Pasco, Hillsborough, Lake and/or Seminole Counties. Projected groundwater withdrawals in the ND and NCF Models in these areas are given in Tables 3-4 and 3-5, respectively.

For the ND Model, the 2025 pumping package for the SJRWMD region of the ND Model[9] was obtained from two existing SJRWMD groundwater models. The two existing groundwater models are the SJRWMD's NCF Model and the East-Central Florida (ECF) Model. The former includes the northern third of Lake County and northwards, whereas the latter encompasses all of Lake County and areas to east and southeast. Where the NCF and ECF models overlapped, the NCF Model pumping data were used per the recommendation of the SJRWMD. The 2025 pumping package for the SJRWMD region of the model were prepared by the SWFWMD based on data received from the SJRWMD in July 2007.

As discussed above, the pumpage discussed here assumes that the increased water demand will continue to rely on groundwater withdrawn from current extraction locations at current levels of water conservation (unadjusted groundwater demand).

Table 3-4. Summary of 2030 ND Model Pumpage Outside WRWSA.[10]

County	Rate (mgd)	
	Water Management District	2030[(1)]
Hillsborough	SWFWMD	70.4
Polk	SWFWMD	17.6
Pasco	SWFWMD	103.2
Levy	SWFWMD / SRWMD	10.0
Clay	SJRWMD	0.1
Orange	SJRWMD	2.4
Alachua	SJRWMD	3.2
Lake	SJRWMD[(2)]	85.2

(1) A small portion of Lake County is within the SWFWMD, but water use there is negligible.

[9] A ND Model pumping package for 2030 in the SJRWMD was not available, so a 2025 pumping package was used for the SJRWMD area in the ND Model.
[10] See footnote number 8 above.

Table 3-5. Summary of 2030 NCF Model Pumpage Outside WRWSA.

County	Rate (mgd)	
	Water Management District	2030
Seminole	SJRWMD	18.9
Putnam	SJRWMD	29.2
St. Johns	SJRWMD	33.0
Clay	SJRWMD	8.98
Lake	SJRWMD[(1)]	81.5
Orange	SJRWMD	6.00
Volusia	SJRWMD	19.8
Flagler	SJRWMD	6.4
Alachua	SJRWMD / SRWMD	43.1
Bradford	SRWMD	2.5
Levy	SWFWMD	2.8

(1) A small portion of Lake County is within the SWFWMD, but water use there is negligible.

3.7 SWFWMD Northern District Groundwater Modeling Results – Estimated and Projected

3.7.1 Estimated Pre-Development Conditions

The ND Model was used to determine potentiometric distributions for predevelopment conditions. The ND Model was run for one year with all groundwater withdrawals removed to approximate pre-withdrawal conditions over the model domain.

The ND Model was calibrated based on groundwater elevation data from 1995 to 2002 using estimates of net recharge (surface infiltration less evapotranspiration). In order to determine the head distributions at predevelopment (in both the surficial and Upper Floridan aquifers), the model was run in a transient mode with all the extraction wells removed until a good match was obtained between the published predevelopment UFA potentiometric elevation distribution (Johnston et al. 1980) and the model-simulated potentiometric surface.[11,12] ND Model predevelopment potentiometric surface distributions in the surficial and Upper Floridan aquifers are shown in Figures 3-14 and 3-15, respectively.

[11] The ND Model has not completed calibration for predevelopment conditions. For this project, the model was also run without withdrawals under a steady-state condition. However, examination of simulated SA heads in the southern and eastern domain (outside of the area of interest for this project) indicated areas where heads were above land surface. This occurred under the steady-state condition because the ND Model has not completed calibration for predevelopment conditions. To minimize the occurrence of water above land surface and better match the observed USGS predevelopment surface in the UFA, the pre-withdrawal period run time was selected as one year.

[12] It is recognized that simulating the ND Model under pre-pumping conditions for one year may not fully account for all water level change compared with a steady state simulation. The ND Model was not calibrated for a pre-pumping condition and therefore the one year simulation time is the best available approximation method given the current level of understanding of the system and SWFWMD analysis of long-term water level trends. In addition, this modeling approach was also used in model scenarios evaluating the impacts of the Northern Tampa Bay wellfields in the Tampa Bay Water Resources Assessment Project report (SWFWMD, 1996).

3.7.2 Projected 2030 Evaluation

The ND Model groundwater resource assessment is a planning level evaluation based on projected groundwater demands within the model domain for 2030. The groundwater simulations assume that the increased water demand within the model domain will be met solely by groundwater from current withdrawal locations at current levels of water conservation (unadjusted groundwater demand). As a regional-scale analysis, the evaluation is intended to evaluate the potential impact of projected 2030 water demand on aquifer levels and groundwater resources, and identify local areas based on these constraints where further investigation into aquifer supplies will be required.

3.7.2.1 2030 Methodology

The potentiometric distributions in 2030 were obtained by running the ND Model under long-term transient conditions (5 years) to approximate steady state conditions. Boundary conditions for the model domain are held at 1995 calibration levels for this evaluation.[13] The model was run with 2005 as the initial conditions and projected 2030 extraction rates until the changes in groundwater elevation were insignificant.

The ND Model simulated pre-withdrawal heads were compared to 2030 simulated heads to ascertain impacts to the groundwater system due to projected withdrawals. Model drawdown was determined by subtracting the 2030 aquifer heads from the pre-withdrawal heads. Using the projected withdrawals described above, the ND Model was utilized to determine potential changes in aquifer levels from pre-development to 2030.

3.7.2.2 2030 Simulations

Two 2030 ND Modeling scenarios were developed to help identify areas where groundwater may be available and where further investigation into aquifer supplies will be required. The development of these two scenarios was based on the groundwater flow modeling considerations, discussed above, regarding northern Sumter/southern Marion/northern Lake County geology and future withdrawals outside the SWFWMD jurisdictional boundary, as discussed above, to bracket a range of potential 2030 conditions based on unadjusted groundwater demands in the SWFWMD. As previously discussed, SJRWMD has determined that projected water needs in Marion and Lake Counties in 2025 may not be met by traditional groundwater sources.

The two scenarios were not applied to the aquifer systems in Citrus County and Hernando County, because the geology is not as complex and the counties lie entirely within the SWFWMD. The two model scenarios were conducted to assist with interpretation of modeling results, by bracketing the range of modeled conditions to the UFA and SA systems in Marion and Sumter Counties.

[13] More discussion on ND Model boundaries is presented later in this chapter.

The two scenarios selected for this purpose are described in Table 3-6 below.

Table 3-6. ND Model Simulations for Projected 2030 Withdrawals.

Scenario 1 Medium-Withdrawal Simulation Bounds	Rationale
Elimination of 2030 LFA withdrawal from Villages (see Note 1)	Simulation of well-confined LFA
Use of 2005 pumping package for the ND Model extent in the SJRWMD areas in Lake and Marion Counties (see Note 2)	PWRCA designation indicates that unadjusted 2025 demands in SJRWMD will not be met by groundwater (see Note 3)
Scenario 2 High-Withdrawal Simulation Bounds	**Rationale**
Inclusion of LFA withdrawal from Villages	Simulation of poorly-confined LFA
Use of 2025 pumping package for the ND Model extent in the SJRWMD areas in Lake and Marion Counties (see Note 4)	Simulation of potential growth in groundwater use in the SJRWMD

Note:

1) *The 2025 pumping rate was approximately 8.9 mgd in the LFA, which is 2.0 mgd less than that actually permitted for the LFA (SWFWMD WUP No. 20013005). Therefore, the entire LFA withdrawal plus 2.0 mgd of UFA withdrawal was removed from the Villages for the analysis (10.9 mgd).*
2) *The 2005 pumping rate for the ND Model extent in the SJRWMD area was 30.1 mgd in Marion County and 89.7 mgd in Lake County.*
3) *There will also be a significant adjustment in future groundwater demands in the WRWSA due to additional reclaimed water supply and conservation efforts in the region. Significant regulatory and incentive measures have been implemented by the SWFWMD and SJRWMD to achieve additional demand reduction and beneficial reuse supply development. See Chapters 4 and 5 of this report.*
4) *The 2025 pumping rate for the ND Model extent in the SJRWMD area was 52.9 mgd in Marion County and 84.5 mgd in Lake County.*

3.7.2.3 ND Modeling Results

Results for the high withdrawal simulation and the medium withdrawal simulations are presented below. As previously discussed, since these simulations are aimed at interpretation of model results for the Marion and Sumter County aquifer systems, the range of modeled conditions is not applicable to Hernando and Citrus Counties (i.e., there is no difference between the simulations for Hernando and Citrus Counties).

3.7.2.3.1 Aquifer Drawdown

High Withdrawal Simulation – Sumter County

The distributions of cumulative drawdown (difference between the 2030 and predevelopment potentiometric elevations) for the surficial and Upper Floridan aquifers are shown in Figures 3-16 and 3-17, respectively.

In Figure 3-16, projected cumulative drawdown from predevelopment to 2030 is on the order of 0.5 to over two feet in the SA in eastern Sumter County. In Figure 3-17, in northeastern Sumter County, projected cumulative drawdown ranges from one foot to over two feet in the UFA, with the area of drawdown in the range of 0.5 to 1 foot extending to northwestern Sumter County.

Medium Withdrawal Simulation – Sumter County

The distributions of cumulative drawdown (difference between the 2030 and predevelopment potentiometric elevations) in the surficial and Upper Floridan aquifers are shown in Figures 3-18 and 3-19, respectively.

In Figure 3-18, projected cumulative drawdown from predevelopment to 2030 is on the order of 0.5 to one foot in the SA in eastern Sumter County. In Figure 3-19, in northeastern Sumter County, projected cumulative drawdown ranges from 0.5 to two feet in the UFA.

High Withdrawal Simulation – Marion County

The distributions of cumulative drawdown (difference between the 2030 and predevelopment potentiometric elevations) for the surficial and Upper Floridan aquifers are shown in Figures 3-16 and 3-17, respectively.

In Figure 3-16, projected cumulative drawdown from predevelopment to 2030 is less than 0.5 foot in the SA in eastern Marion County. In Figure 3-17, in central Marion County, projected cumulative drawdown ranges from 0.5 foot to over one foot in the UFA, with the amount of drawdown less than 0.5 foot extending to northern Marion County.

Medium Withdrawal Simulation – Marion County

The distributions of cumulative drawdown (difference between the 2030 and predevelopment potentiometric elevations) in the surficial and Upper Floridan aquifers are shown in Figures 3-18 and 3-19, respectively.

In Figure 3-18, projected cumulative drawdown from predevelopment to 2030 is less than 0.5 foot in the SA in Marion County. In Figure 3-19, in central Marion County, projected cumulative drawdown ranges from less than 0.5 to one foot in the UFA.

Citrus County and Hernando County

The distributions of cumulative drawdown (difference between the 2030 and predevelopment potentiometric elevations) in the surficial and Upper Floridan aquifers are shown in Figures 3-16 and 3-17, respectively. As previously discussed, the high and medium withdrawal simulations are identical for Citrus County and Hernando County.

In Figure 3-16, projected cumulative drawdown from predevelopment to 2030 is generally less than one foot in the SA in south Hernando County. In Figure 3-17, projected cumulative drawdown from predevelopment to 2030 is on the order of 0.5 to two feet in the UFA in the unconfined areas of southwest Hernando County, with the area of drawdown in the range of 0.5 to 1 foot extending to central Hernando County.

Difference between the High Withdrawal and Medium Withdrawal Simulations - Sumter and Marion Counties

A comparison between Figures 3-16 to 3-17 and 3-18 to 3-19, respectively, indicates that the possible difference in terms of groundwater level response in some areas is on the order of 0.5

foot for both the UFA and SA systems in northern Sumter County. In central and southern Marion County, the possible difference in the unconfined UFA is on the order of 0.5 foot.

3.7.2.3.2 Spring Flows

Discharge rates at a number of springs in the WRWSA were extracted from the model simulations described above. Spring discharge rates were modeled during the predevelopment period and with projected groundwater extraction simulations in 2030 (both high-withdrawal and medium-withdrawal simulations). These rates are given for the ND Model in Table 3-7. Spring discharge rates as fractions of respective predevelopment discharge rates are given in Table 3-8 for the ND Model.

Table 3-7. ND Model WRWSA Spring Discharge Rates.

Spring	Rate		
	Pre-Development (cfs)	High Withdrawal 2030 (cfs)	Medium Withdrawal 2030 (cfs)
Silver Spring	665.9	633.4	643.0
Rainbow Spring	639.9	628.9	638.3
Weekiwachee Spring	143.7	134.0	133.9
Crystal River Group	346.9	339.6	339.4
Blind Springs	43.0	42.9	42.9
Gum Springs	61.1	55.6	57.0
Homosassa River System	71.6	70.2	70.0
Chassahowitzka Spring	64.1	62.9	62.6
Fenney Spring	19.8	17.7	

Table 3-8. ND Model WRWSA Spring Discharge Rate Ratios.

Spring	Ratio		
	Pre-Development	High Withdrawal 2030	Medium Withdrawal 2030
Silver Spring	1.00	0.95	0.97
Rainbow Spring	1.00	0.98	1.00
Weekiwachee Spring	1.00	0.93	0.93
Crystal River Group	1.00	0.98	0.98
Blind Springs	1.00	1.00	1.00
Gum Springs	1.00	0.91	0.93
Homosassa River System	1.00	0.98	0.98
Chassahowitzka Spring	1.00	0.97	0.98
Fenney Spring	1.00	0.89	

In 2030, discharge rates at the majority of the springs are reduced by less than 5% of the respective predevelopment discharge rates. At Weekiwachee and Fenney Springs, the cumulate reductions are projected to be 7 and 11%, respectively.

Difference between the High Withdrawal and Medium Withdrawal Simulations - Sumter and Marion Counties

The difference between the high-withdrawal and medium-withdrawal simulation for springs in Marion County is in the area of 2%. The difference between the high-withdrawal and medium-withdrawal simulation for springs in Sumter County is also in the range of 2%.

3.7.3 Other Northern District Model Analyses

Additional pumpage analyses were performed to assist with the interpretation of groundwater modeling results. The methodology and model results for these analyses are discussed in the next section.

3.7.3.1 Existing Water Use Permit Considerations

As previously discussed, it is possible that up to seven (7) mgd of the projected groundwater demand in the Villages area may not be met by groundwater, due to a special condition in their SWFWMD WUP (No. 20013005). To account for this possibility, a sensitivity analysis was performed by removing seven (7) mgd from the 2030 high-withdrawal simulation for the UFA in the Villages area. The response was determined by subtracting the potentiometric surface without the removal from the surface with the removal.

The UFA response to the removal is shown in Figure 3-20. As shown, the regional UFA aquifer response in northeastern Sumter County and northwestern Lake County is in the vicinity of 0.5 foot, with a small area of response as great as one foot. In other words, the predicted drawdown between 2005 and 2030 could be up to one foot less than that otherwise predicted for 2030. It should be noted that the SA does not exist in northeastern Sumter County in the ND Model.

3.7.3.2 Orange County

There are large groundwater withdrawals in Orange County located outside the ND Model eastern boundary. As previously discussed, in order to limit adverse impacts to water resources from these withdrawals, the SJRWMD, SWFWMD, and SFWMD have developed interim rules to restrict groundwater withdrawals in an area of Orange County and Lake County within the CFCA. According to the SJRWMD, additional groundwater extraction in Orange County has occurred since 1995 (the date of the eastern boundary condition for the ND Model) and will be restricted in 2013. In order to assess the impact due to additional groundwater extraction on the drawdown within the ND Model, a sensitivity analysis was conducted.

Predicted drawdown due to additional pumping between 1995 and 2013 along the model's eastern boundary was first generated by the SJRWMD using the existing ECF Model (SJRWMD, 2007). In order to assess the extent that the drawdown may propagate westward from the model's eastern boundary, the ECF-Model-generated 2013 potentiometric surface was incorporated into the ND Model eastern boundary, and the ND Model was run in a steady-state mode. Shown in Figures 3-21 and 3-22 are the distributions of drawdown in the surficial and Upper Floridan aquifers, respectively, attributed to the additional drawdown along the eastern boundary. The results indicate that the propagation of drawdown resulting from pumping in the Orange County area is confined to the Lake County region in the ND model.

3.8 SJRWMD North Central Florida Groundwater Modeling Results – Estimated and Projected

3.8.1 Estimated 1995 Conditions

The NCF Model was used to determine the potentiometric elevation distribution for 1995 conditions based on the calibrated average steady-state 1995 conditions. The distribution of pumping throughout the model for 1995 was provided by the SJRWMD. 1995 potentiometric surface distributions in the surficial and Upper Floridan aquifers are shown in Figures 3-23, and 3-24, respectively.

3.8.2 Projected 2030 Evaluation

The NCF Model groundwater resource assessment is a planning level evaluation based on projected groundwater demands within the model domain for 2030. The groundwater simulations included here assume that the increased water demand will be met solely by groundwater from current withdrawal locations at current levels of water conservation (unadjusted groundwater demand). As a regional-scale analysis, the evaluation is intended to evaluate the potential impact of projected 2030 water demand on aquifer levels and groundwater resources, and identify local areas based on these constraints where further investigation into aquifer supplies will be required.

3.8.2.1 2030 Methodology

The potentiometric distributions in 2030 were obtained by running the NCF Model under steady state conditions. The distribution of pumping and recharge throughout the model for 2030 was provided by the SJRWMD. Boundary conditions for the model domain adjusted the 1995 calibrated boundaries for the 2030 simulation. The southern boundary is adjusted by the SJRWMD using 2013 drawdown from the ECF model. The northern and eastern model boundaries are adjusted by the SJRWMD using 2030 drawdown from the NEF Model (Durden, 1997).[14] The model was run with 1995 as the initial conditions and projected 2030 extraction rates. Net recharge was changed in 2030, using a parcel-based method to project increases or decreases in return flows from septic tanks and irrigation. The projected increase in recharge in the model at 2030 is shown on Figure 3-25. As shown, recharge tends to decrease in areas with an unconfined UFA and may increase or decrease in areas where the SA is present in the NCF Model.

The NCF Model simulated 1995 heads were compared to 2030 simulated heads to ascertain impacts to the groundwater system due to projected withdrawals. Model drawdown was determined by subtracting the 1995 aquifer heads from the 2030 heads. Using the projected withdrawals described above, the NCF Model was utilized to determine potential changes in aquifer levels from 1995 to 2030.

[14] More discussion on NCF model boundaries is presented later in the chapter.

3.8.2.2 NCF Modeling Results

3.8.2.2.1 Aquifer Drawdown

Marion County

The distribution of increased drawdown (difference between the 2030 and 1995 potentiometric elevations) for the surficial and Upper Floridan aquifers is shown in Figures 3-26 and 3-27, respectively.

As shown in Figure 3-25, the projected increase in drawdown in the SA from 1995 to 2030 ranges from 0.5 to one foot in northeast Sumter County. As shown in Figure 3-27, a potential increase in drawdown ranging from 0.5 foot to two feet is predicted in the UFA in northeast Sumter.

3.8.2.2.2 Spring Flows

Table 3-9. NCF Model WRWSA Spring Discharge Rates.

Spring	Rate	
	1995 (cfs)	2030 (cfs)
Silver Spring	706.8	641.1
Rainbow Spring	653.0	638.3
Silver Glen Spring	105.4	104.7
Salt Springs	74.0	73.6
Sweetwater Spring	13.0	12.7
Juniper and Fern Hammock Springs	24.5	23.2

Table 3-10. NCF Model WRWSA Spring Discharge Rate Ratios.

Spring	Ratio	
	1995	2030
Silver Spring	1.00	0.91
Rainbow Spring	1.00	0.98
Silver Glen Spring	1.00	0.99
Salt Springs	1.00	1.00
Sweetwater Spring	1.00	0.98
Juniper and Fern Hammock Springs	1.00	0.94

3.8.3 Other NCF Model Analyses

Additional pumpage analyses were performed to assist with the interpretation of groundwater modeling results. The methodology and model results for these analyses are discussed in the next section.

3.8.3.1 Model Boundaries

There are large groundwater withdrawals in the SJRWMD located outside the NCF Model boundary. As previously discussed, in order to limit adverse impacts to water resources from these withdrawals, the SJRWMD, SWFWMD, and SFWMD have developed interim rules to restrict groundwater withdrawals in an area of Orange County and Lake County within the CFCA. According to the SJRWMD, additional groundwater extraction has occurred since 1995 (the date of the calibration boundary condition for the NCF Model). Additional groundwater development will be restricted in 2013 within the CFCA. Areas in Flagler, Lake and Volusia Counties have been designated PWRCAs indicating that projected water needs within a 20-year planning horizon can not be met by traditional groundwater sources without incurring unacceptable impact to natural resources (SJRWMD, 2005). [15] In order to assess the impact due to additional groundwater extraction on the drawdown within the NCF Model, a sensitivity analysis was conducted.

Predicted drawdown due to additional pumping after 1995 along the model's boundary was generated by the SJRWMD using the ECF and NEF Models (SJRWMD, 2007; Dugan, 1997). ECF drawdown in 2013 and projected NEF drawdown in 2030 are used by the SJRWMD to adjust the NCF Model boundary in 2030. In order to assess the extent that the drawdown may propagate from the model's southern, eastern and northern boundaries, the ECF and NEF Model-generated drawdowns were incorporated into the NCF Model boundary, and the NCF Model was run. Shown in Figures 3-28 and 3-29 are the distributions of drawdown in the surficial and Upper Floridan aquifers, respectively, attributed to the additional drawdown along the boundary. The results indicate that the propagation of drawdown resulting from 2013 pumping in the Orange County area extends through Lake County and into southern Marion County in the NCF Model. Drawdown resulting from projected 2030 pumping north of the model boundary does not propagate into Marion County.

3.8.3.2 Recharge Sensitivity

Marion County

As previously mentioned, net recharge was changed from 1995 in 2030 using a parcel-based method to project increases or decreases in return flows from septic tanks and irrigation (see Figure 3-25). The net recharge tends to decrease in areas with an unconfined UFA and increase slightly in areas where the SA is present in the NCF Model. Notable changes in recharge occur in the Villages area, where increases of over two-inches occur; and in central Marion County, where decreases from one to 2.5 inches predominate.

Changes in aquifer levels stemming from increases in net recharge were identified through a comparative analysis. The NCF Model was run for 2030 pumping using the 1995 recharge package. The potentiometric surface from this simulation was then subtracted from the surface of the 2030 simulation which used the 2030 recharge package. The distribution of increased

[15] This determination was based on the SJRWMD regional groundwater modeling, water resource criteria, and other factors (SJRWMD, 2005). There will also be a significant adjustment in future groundwater demands in the WRWSA due to additional reclaimed water supply and conservation efforts in the region. Significant regulatory and incentive measures have been implemented by the SWFWMD and SJRWMD to achieve additional demand reduction and beneficial reuse supply development. See Chapters 4 and 5 of this report.

drawdown (difference between the 2030 potentiometric elevations due to change in recharge) for the surficial and Upper Floridan aquifers is shown in Figures 3-30 and 3-31, respectively. As shown in Figure 3-30, the simulated drawdown in the SA in 2030 due to the net recharge change increases from 0.5 to about one foot in central Marion County. As shown in Figure 3-31, the simulated change in drawdown in the unconfined UFA in 2030 due to the net recharge change increases from 0 foot to 0.5 feet in central Marion County.

Simulated Silver Spring discharges are also affected by the net change in recharge. The projected discharge in 2030 using the 2030 recharge package is 641.1 cfs, which is a discharge rate ratio of 0.91 from 1995 conditions. The projected discharge in 2030 using the 1995 recharge package is 665.4 cfs, which is a discharge rate ratio of 0.94 from 1995 conditions. The simulated change in discharge due to the change in net recharge is approximately 24 cfs, or 3% of 1995 spring discharge.

3.9 Potential Impact to Groundwater Resources

The projected groundwater withdrawals have the potential to affect aquifer levels, spring flows, and surface water features such as lakes and wetlands, due to declines in aquifer levels. Predicted impacts to these features can constrain the permitting of groundwater withdrawals per the SWFWMD and SJRWMD Chapter 40C-2 and 40D-2, F.A.C. permitting criteria, respectively.

In addition, the SWFWMD and SJRWMD have adopted or scheduled MFLs for priority water bodies pursuant to Section 373.042, Florida Statutes. Predicted impacts to these features are intended to serve both as planning and regulatory constraints to water supply development. See Chapter 2 for more information on MFLs, including the development of proxy MFLs within the WRWSA.

This section identifies the potential impact of the 2030 model results on applicable groundwater resources, and identifies potential concerns that may affect the development of groundwater resources.

3.9.1 Effect on Spring Flows

3.9.1.1 Citrus County

MFL-priority springs, and their springsheds, are located in Citrus County, including the Crystal River Springs, Homosassa Spring, and Chassahowitzka Spring (see Figure 2-2 in Chapter 2). The projected 2030 reduction in Citrus County spring flows, based on ND regional groundwater modeling, is much less than the proxy MFL allowable reductions and therefore significant environmental impacts are not anticipated to the springs. Additionally, with the unconfined nature of the UFA in Citrus County, environmental permitting criteria for water use permits will prevent harm to surface lakes and wetlands and thus limit the likelihood of inducing significant reductions in spring flow.

As anticipated increases in future water demand occurs, each of the three large springsheds should be monitored relative to springflow and water quality. But, seeing as predicted drawdown is low in Citrus County, significant impacts to water quality and quantity appear unlikely to the 2030 planning horizon.

3.9.1.2 Hernando County

One MFL-priority spring, Weekiwachee Spring, and its springshed are located in Hernando County (see Figure 3-3). Weekiwachee Spring is located in western Hernando County in a future water demand area where the UFA is unconfined. As groundwater demands increase over time, spring flow may be affected by withdrawals in the springshed. The Weekiwachee Spring has an MFL adopted in 2009, which protects both spring flow and water quality from significant harm due to water withdrawals.

The MFL adopted for this spring has an estimated cumulative allowable reduction of 10% of springflow to prevent significant harm to the resource. The ND Model projects a 2030 springflow decline of 7% from predevelopment conditions, assuming local increases in water demand are met by groundwater. This potential reduction remains within the 10% allowable criteria. However, since this is a regional model prediction, spring flow reductions should be verified by field data and monitoring to ensure that adverse impacts do not occur.

3.9.1.3 Sumter County

One MFL-priority spring, Gum Spring, and its springshed are located in northwestern Sumter County (see Figure 3-3). A second spring, Fenney Spring, is also located in northern Sumter County. As groundwater demands increase over time, spring flow may be affected by withdrawals in the springsheds. The Gum Spring is scheduled for MFL establishment in 2010, which will protect both spring flow and water quality from significant harm due to water withdrawals.

The proxy MFL developed for Gum Spring has a cumulative allowable reduction of 16.6%. The ND Model projects a maximum 2030 springflow decline of 9% from predevelopment conditions, assuming local increases in water demand are met by groundwater. A maximum 2030 springflow decline of 11% is projected by the ND Model for Fenney Springs. The potential reductions remain within the 16.6% proxy allowable criteria. However, since these are regional model predictions, spring flow reductions should be verified by field data and monitoring to ensure that adverse impacts do not occur.

This interpretation that projected withdrawals meet springflow criteria is based on the proxy MFL for Gum Springs discussed in Chapter 2. The actual MFL adoption in 2010 for Gum Spring could affect this conclusion.

3.9.1.4 Marion County

Three MFL-priority springs are located in Marion County, including Silver Springs, Silver Glen Springs, and Rainbow Springs. The City of Ocala is located within the Silver Springs springshed (see Figure 3-3). Silver Springs is proposed for MFL adoption by the SJRWMD in 2011; Silver Glen Springs by the SJRWMD in 2013; and Rainbow Springs by the SWFWMD in 2010. These MFLs will protect both spring flow and water quality from significant harm due to water withdrawals.

The SJRWMD uses an allowable 15% springflow reduction from 1995 conditions and the SWFWMD uses an allowable 15% springflow reduction from predevelopment conditions (where more detailed information is not available). The NCF Model projects a springflow reduction in

2030 of 9% for Silver Springs, and 1% to 2% for Rainbow Springs. The ND Model projects a springflow reduction in 2030 of 5% from predevelopment conditions for Silver Springs and 2% for Rainbow Springs.

A number of smaller springs are also located in Marion County, including Sweetwater Springs, Salt Springs, and Juniper and Fern Hammock Springs. The NCF Model projects springflow reductions in 2030 ranging from 0% to 6% for these springs.

Based on SJRWMD and SJRWMD planning criteria, these springflow declines should be acceptable.

3.9.2 Effect on Lakes and Wetlands

3.9.2.1 Citrus County

A number of lakes with SWFWMD-established minimum guidance levels are located in Citrus County. These lakes may be a concern for specific or local withdrawals. The minimum guidance levels are used in determining whether a lake meets the SWFWMD "stressed" designation; however, this designation does not bear directly on water supply. On a regional basis the primary lake of concern is Lake Tsala Apopka, whose MFLs have been adopted. A MFL for Fort Cooper Lake has also been adopted. The most restrictive of the MFLs are the Hernando Pool and the Inverness Pool in Lake Tsala Apopka. The allowable reduction on a long-term median stage basis is the Minimum Lake Level (MLL)[16] of 0.8 ft. This suggests that a projected cumulative regional drawdown of less than 0.8 ft will remain within limits to prevent significant ecological harm.

The model prediction for the projected cumulative drawdown in Citrus County in general is less than the planning level criterion of one (1) foot which is assumed by the SWFWMD to be capable of incurring harm to wetlands and lakes.[17,18] Much of the Citrus County is predicted to have less than 0.5 ft drawdown, based on ND Model results using unadjusted demands. The establishment of MFLs for the coastal springs and Withlacoochee River should additionally limit the potential for harm to natural resources due to water withdrawals.

3.9.2.2 Hernando County

Lakes and wetlands are present throughout Hernando County. Lakes Hunters, Lindsey,

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[16] Tsala Apopka's High Minimum Lake Level (HMLL) is influenced by and reflects surfacewater flow patterns and not directly comparable to groundwater drawdown.

[17] The SWFWMD regional planning level criterion is based on work done in the Northern Tampa Bay area where it was observed that impacted wetlands in the wellfield areas were more likely to be found in areas where the models predicted greater than one (1) foot of drawdown in the SA. The planning level criterion is generally consistent with the SWFWMD wetlands MFL methodology, developed using cypress wetlands in the flatwoods environment of the Northern Tampa Bay area that presumes that significant harm will occur when the long-term median water level in a wetland is lowered by greater than 0.8 feet. Work is ongoing at the SWFWMD to evaluate the use of the wetland MFL methodology in the sandhill environment common in the Northern SWFWMD. The resource monitoring evaluates the predictive capabilities of modeling tools and monitors their results. Water resource management decisions can be adjusted over time based on results of the resource monitoring.

Mountain, Neff, Spring and Weekiwachee Prairie have adopted MFLs which will protect these features from significant harm due to water withdrawals. Lake Tooke and Whitehurst Pond are scheduled for MFL adoption in 2013. Lakes Lindsey, Elizabeth, Francis, Geneva, and Sparkman are located within the Withlacoochee River Basin with established minimum guidance levels under the F.A.C.

Mountain, Neff, and Spring Lakes are near the area of greatest projected localized drawdown impacts to the UFA in the entire WRWSA, but are also located on the Brooksville Ridge, an area of hydraulic separation between the surficial and Upper Floridan aquifers due to a thick clay confining unit. As a result, these lakes and the wetlands along the ridge should be generally isolated from drawdown in the UFA. This is reflected in model results generally showing less than 0.25 ft SA drawdown for much of the Brooksville Ridge.

An area of concern is the potential UFA drawdowns of greater than one (1) foot projected for the southwest-central portion of the county, with the Spring Hill area exceeding two feet. The Weekiwachee springshed, Weekiwachee Prairie Lake, Hunters Lake, Lake Tooke and Whitehurst Pond are located within this region. The UFA is generally unconfined in this area. The projected drawdown, based on ND Model results using unadjusted demands, exceeds the one foot planning level criterion which is assumed to be capable of harming lakes and wetlands.

Since the model reduction in Weekiwachee Spring springflow to 2030 is not predicted to exceed its adopted MFL, it is possible that the primary constraint to groundwater withdrawals in the unconfined southwest-central portion of Hernando County will be harm to lake and wetland features. The ND Model is calibrated to regional conditions and is not suitable for site specific investigations concerning specific lakes and wetlands. As groundwater use is intensified over the planning horizon, the relationship between the quantity and distribution of groundwater withdrawals and the individual levels of sensitive water features should be established and monitored on a programmatic basis. Lakes and wetlands located in the unconfined western areas of Hernando County will be sensitive to withdrawals and many of the lakes have or will have MFL protection.

Possible environmental constraints to groundwater extraction will necessitate careful evaluation of future withdrawals in western Hernando County. Dispersal and rotation of groundwater withdrawals can eliminate or reduce the potential for harm to lakes and wetlands. Water resource management strategies including additional conservation, beneficial reclaimed water use and dispersed withdrawals will reduce local groundwater demands. In this region, coordination between regulatory and incentive measures utilized by the WMDs can effectively deploy these management tools where they are needed. The management tools can be adjusted and optimized based on environmental and economic considerations and the ability to reduce water demands.

3.9.2.3 Sumter County

Lake Panasoffkee, Lake Miona, Lake Deaton, Big Gant Lake and Lake Okahumpka have adopted MFLs in Sumter County. These lakes should be protected from significant drawdown impacts by their MFLs, but other local lakes and wetlands should also be closely monitored. The effects of projected 2030 groundwater withdrawals in Sumter County are difficult to assess, but withdrawals could cause a cumulative reduction of up to two feet in unconfined areas of the UFA and up to about one foot in the SA, based on ND Model results.

A specific area of concern is the potential UFA drawdowns of greater than two feet projected for the far northeast portion of Sumter County, based on model results using unadjusted demands. In much of this region, the UFA is unconfined. The projected drawdown exceeds the SWFWMD one foot planning level criterion which is assumed to be capable of harming lakes and wetlands. In addition, Lake Miona is located within this area and its MFL will also constrain future groundwater withdrawals.

The difference between the high- and medium- projected 2025 withdrawal simulations is meaningful in Sumter County. Compared to the high-withdrawal simulation, the medium-withdrawal simulation shows less area with projected unconfined UFA and SA system drawdowns exceeding the SWFWMD one foot planning level criterion.

Both high- and medium- withdrawal simulations suggest that some reduction in groundwater demand may be necessary in the far northeast portion of Sumter County to avoid adverse impacts to lakes and wetlands. The Villages sensitivity analysis shows a regionally significant increase in aquifer levels based on the removal of seven (7) mgd of withdrawals from the UFA, suggesting that a decrease or dispersal of groundwater withdrawals could eliminate or reduce the potential for harm to lakes and wetlands in northeast Sumter County.

Possible lake and wetland constraints to groundwater extraction will necessitate careful evaluation of future withdrawals in northeastern Sumter County. Water resource management strategies including additional conservation, beneficial reclaimed water use and dispersed withdrawals can reduce local groundwater demands. In this region, coordination between regulatory and incentive measures utilized by the WMDs can effectively deploy these management tools where they are needed. The management tools can be adjusted and optimized based on environmental and economic considerations and the ability to reduce water demands.

3.9.2.4 Marion County

Lakes Charles, Bowers, Halfmoon, Hopkins Prairie, Nicotoon, Smith, Weir and Kerr have adopted MFLs in Marion County. Lakes Bonable, Little Bonable, and Tiger are scheduled for MFL adoption in 2011. These lakes should be protected from significant drawdown impacts by their MFLs, but other local lakes and wetlands should also be closely monitored. The effects of projected 2030 groundwater withdrawals in Marion County are difficult to assess, but could cause an aquifer level decline of up to two feet in unconfined areas of the UFA and over one foot in the SA, based on NCF Model results using unadjusted demands. Projected impacts to lakes and wetlands appear to be the most significant potential environmental constraint to groundwater development in Marion County; however, in the SWFWMD, the 2030 ND Model simulation of projected cumulative drawdown in Marion County is less than the planning level criterion of one (1) foot aquifer decline which is assumed by the SWFWMD to be capable of incurring harm to wetlands and lakes.

Lake MFLs have been adopted in Marion County by the SJRWMD for Lakes Kerr and Halfmoon. The MFLs for these lakes allow less than 0.3 feet of drawdown from 1995 conditions. The drawdown limit for each is exceeded by the simulated aquifer level decline in 2030. Other adopted lake MFLs in Marion County are projected to be met in 2030. MFLs for Lakes Kerr and

Halfmoon were established in the 1990's and are likely to be re-evaluated prior to 2030.[19] The lakes are located in the Ocala National Forest away from population centers. These MFLs are unlikely to serve as a significant constraint to WRWSA member government permits because the cone of influence of any individual member (such as the City of Ocala) will be negligible at their distance between the population center and Lakes Kerr and Halfmoon. Area wide rulemaking similar to the CFCA is not anticipated by the SJRWMD in Marion County.

Projected 2030 regional groundwater withdrawals based on unadjusted demands outside the WRWSA could cumulatively contribute to unacceptable aquifer declines at Lakes Kerr and Halfmoon. However, projected 2030 regional withdrawals based on unadjusted demands are unlikely to occur from areas outside the WRWSA[20] designated as PWRCAs. As shown in Table 3-11, projected 2030 water demands in PWRCAs outside the WRWSA (excluding the CFCA) exceed the water demands that have already been determined by the SJRWMD to be unsustainable. The SJRWMD regulatory program will restrict the projected regional withdrawals in the PWRCA to avoid unacceptable adverse impacts to natural resources. Over 30 mgd in projected 2030 withdrawals that are unlikely to occur are incorporated to the NCF model simulation (either through pumpage within the model domain or boundary condition adjustments) which predicts unacceptable aquifer declines at Lake Kerr.

Table 3-11. Comparison of Projected Groundwater Use in PWRCA in Flagler, Lake and Volusia Counties.[21,22]

	Projected Groundwater Use Determined to be Unsustainable in Flagler, Lake and Volusia Counties (2025) (1)	Projected Groundwater Use in Flagler, Lake and Volusia Counties Contributing to Modeled Aquifer Declines (2030) (2)	Difference (mgd)
Total (mgd)	172.64	210.51	37.87

(1) Source: SJRWMD 2003 Water Supply Assessment.
(2) Source: SJRWMD 2008 Water Supply Assessment – Draft (SJRWMD, 2009).

In the SJRWMD, the results of the 2030 NCF Model simulation of 1995 drawdown is greater than likelihood of harm criteria under which aquifer declines are assumed by the SJRWMD to be capable of incurring harm to wetlands and lakes. The methodology for the SJRWMD likelihood of harm analysis is summarized in SJRWMD (2009) and in WRA (2009). Figure 3-32 shows 2030 SA NCF Model drawdown contours and the associated wetland areas captured by the likelihood of harm analysis. Approximately 4,001 acres of wetlands are determined to exhibit moderate or higher likelihood of harm in the SA.[23] It should be noted that the difference in

[19] The SJRWMD has a regular re-evaluation program for lakes whose MFLs were adopted under prior methods. This program typically revises the previously adopted MFLs using more recent data. The Lake Kerr MFL is scheduled for re-evaluation by the SJRWMD in 2012.
[20] There will also be a significant adjustment in future groundwater demands in the WRWSA due to additional reclaimed water supply and conservation efforts in the region. Significant regulatory and incentive measures have been implemented by the SWFWMD and SJRWMD to achieve additional demand reduction and beneficial reuse supply development. See Chapters 4 and 5 of this report.
[21] There are small areas in Flagler and Volusia counties which are not designated PWRCAs.
[22] Southern Lake County is within the CFCA, where groundwater use will be restricted in 2013. Modeled quantities in Draft WSA in southern Lake County were held at 2013 levels.
[23] Likelihood of harm methodology in the unconfined UFA eliminates perched wetlands (depth to water table greater than 15 feet) from consideration since they are disconnected from the water table (Kinser et

drawdown due to differences between the 1995 and 2030 recharge packages discussed above contribute significantly to the area captured by the likelihood of harm analysis in the SA. Figure 3-34 shows the 2030 likelihood of harm analysis in the SA using constant recharge in the NCF Model. As shown, approximately 3,186 acres of the 4,001 acres of wetlands determined to exhibit moderate or higher likelihood of harm are generated due to the recharge difference (80%). The wetlands determined to exhibit moderate or higher likelihood of harm using constant recharge are located only in southern Marion County. Figure 3-33 shows the 2030 unconfined UFA NCF Model drawdown contours and the associated wetland areas captured by the likelihood of harm analysis. Approximately 67 acres of wetlands are determined to exhibit moderate or higher likelihood of harm in the unconfined UFA, based on National Wetlands Inventory (NWI) maps.

The NCF model simulation suggests that some reduction in unadjusted 2030 groundwater demand may be necessary in southern Marion County to avoid adverse impacts to lakes and wetlands, though additional investigation into groundwater supplies is needed. Pre-1995 drawdown, where present, can contribute to actual wetland and lake impacts and cumulative drawdowns of greater than 2 feet from pre-development conditions are much more likely to correlate with observed impacts.[24] Cumulative model results are not available for the NCF Model, and neither the SWFWMD nor the SJRWMD has developed a confident metric for assessing wetland harm due to drawdown in the sandhill areas prevalent in Marion County (WRA, 2009). The NCF and ND groundwater models also have a different conceptualization of the groundwater flow system in Marion County. As shown in Figure 3-35, the extent of the SA in the NCF Model is much greater than that in the ND Model. Impacts to lakes and wetlands may be significantly less in a semi-confined versus an unconfined region, because the confinement can protect surficial water features from drawdown experienced in the UFA. The location and depth of UFA water level declines may also vary based on the extent of confinement.

Possible lake and wetland constraints to groundwater extraction will necessitate resource monitoring, hydrogeologic data collection and careful evaluation of future withdrawals in southern Marion County. Water resource management strategies including additional conservation, beneficial reclaimed water use and dispersed withdrawals can reduce local groundwater demands where needed. In this region, coordination between regulatory and incentive measures utilized by the WMDs can effectively deploy these management tools where they are needed. The management tools can be adjusted and optimized based on environmental and economic considerations and the ability to reduce water demands.

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al, 2008). Perched wetlands are included in the likelihood of harm methodology for the SA. Perched wetlands in the SA in Marion County are elevated from approximately 15 to 40 feet above the water table. These systems are primarily located east and west of the Ocklawaha River where the river floodplain transitions to the Mount Dora ridge. Since they are disconnected from the water table, perched wetlands in the SA are unlikely to constrain the permitting of groundwater withdrawals.

[24] Observed impacts and preliminary cumulative drawdown to 1997 were determined by the SJRWMD, SWFWMD, and SFWMD in the CFCA. See September 25, 2009 CFCA project progress and activities for the future available at www.cfcawater.com.

3.9.3 Effect on Seepage Contributions to River Systems

The ND Model simulates Withlacoochee River groundwater contributions at various reaches along the river (see Tables 3-12 and 3-13.). An entry corresponding to a gauging station represents a cumulative river flux at that location, excluding springs which discharge to the river from above land surface. Although the relative effect of groundwater withdrawals on the river will vary by reach, the cumulative fluxes are selected for evaluation because observed data at gauging stations are available to assess possible effects on river flows. The river stages used in the ND Model were interpolated from the median value at USGS flow recording stations for 1995.

In the projected 2030 simulation, river discharge rates at the majority of the gauges are either reduced or increased by a few percent of the respective predevelopment discharge rates, due to the corresponding local increase or decrease in groundwater pumping. On a cumulative basis from predevelopment to 2030, the downstream reach in the vicinity of Holder is predicted to see a 9% reduction in seepage baseflow. The maximum difference between the high-withdrawal and medium-withdrawal simulation is about 4%. The ND Model simulates river baseflow declines of less than 2% at all other Withlacoochee River gauging stations from predevelopment to 2030.

Table 3-12. Summary of Cumulative Withlacoochee River Gain/Loss Rates.

River Reach/Gauging Station	Discharge Rate (cfs)		
	Pre-Development	High Withdrawal 2030	Medium Withdrawal 2030
Withlacoochee near Cumpressco	8.92	8.88	8.84
Withlacoochee near Dade City	12.61	12.36	12.55
Withlacoochee at Trilby	56.62	56.10	58.36
Withlacoochee at Croom	99.36	99.49	103.9
Withlacoochee near Floral City	95.16	95.24	99.89
Withlacoochee at Wysong Dam	152.54	151.07	155.03
Withlacoochee near Holder	235.58	215.21	227.84

Table 3-13. Summary of Cumulative Withlacoochee River Gain/Loss Rate Ratios.

River Reach/Gauging Station	Discharge Rate Ratio		
	Pre-Development	High Withdrawal 2030	Medium Withdrawal 2030
Withlacoochee near Cumpressco	1.00	1.00	0.99
Withlacoochee near Dade City	1.00	0.98	1.00
Withlacoochee at Trilby	1.00	0.99	1.03
Withlacoochee at Croom	1.00	1.00	1.05
Withlacoochee near Floral City	1.00	1.00	1.05
Withlacoochee at Wysong Dam	1.00	0.99	1.02
Withlacoochee near Holder	1.00	0.91	0.97

Seepage fluxes to the Ocklawaha River and Rodman Reservoir are not simulated in the NCF Model, although springs discharging above land surface and submerged springs which discharge to the river system are simulated. Additional hydrologic evaluation would be required to determine projected reductions to seepage fluxes for the Ocklawaha River system.

3.9.3.1 Discussion of River Seepage Results and Proxy MFLs

Chapter 2 developed proxy MFLs for the Withlacoochee River system. The proxy MFLs characterized the seasonal river flow regime into three intervals delineated by low-flow and high-flow thresholds. Three locations on the river were characterized based on the availability of a long-term flow dataset – Trilby, Croom, and Holder. The proxy MFLs assigned percent-of-flow reductions to each of the intervals in each of three seasonal blocks, at each location. The percent-of-flow reductions were based on surface water flow records that integrate both surface- and ground- water components of river hydrology. They are intended to be protective of river hydrology and ecology with respect to the cumulative effects of water withdrawals. On a river-wide average basis, the contribution of groundwater seepage to Withlacoochee River flow is thought to be significant (USFWS, 2005).

The projected changes to the river groundwater contribution reflect potential changes to the aquifer system at a median river stage in 1995. The Holder gage is the furthest downstream location with a proxy MFL, and changes at this location will integrate potential changes to the contribution of groundwater to river flow over most of the river system. The middle seasonal block for the proxy MFLs near Holder gage is Block 2, which has a median flow of 438 mgd. At a percent-of-flow reduction of 13%, 57 mgd or 88 cfs is estimated for withdrawal at the Block 2 median flow. The projected cumulative reductions to the contribution of groundwater to river flow near Holder, depending on whether the high-withdrawal or medium-withdrawal simulation is selected, vary from 20.4 CFS to 7.8 CFS as shown in Table 3-7. These reductions are well within the corresponding percent-of-flow reduction in Block 2.

As previously discussed, river groundwater contributions were calibrated and modeled based on the calendar year 1995 condition. The proxy MFLs were established using three seasonal blocks, so additional hydrologic evaluation would be required to determine whether the projected reductions to groundwater flow are within the percent-of-flow reductions for the other blocks.

The location of the three proxy MFLs and the calendar year 1995 condition to calibrate and model groundwater contribution also limits evaluation of specific river reaches. Additional hydrologic study would be required to adjust the three proxy MFLs for the other reaches that lack long term data sets. Specific reaches of the river may function as both recharge and discharge areas, depending on the river stage and the season. Additional hydrologic evaluation would be required to identify these reaches and determine whether the projected reductions to groundwater flow are within the percent-of-flow reductions for each seasonal block.

The proxy MFL developed for Gum Springs – which has a relatively direct connection to the Holder reach - has a cumulative allowable reduction of 16.6% based on flow contributions to the river during low-flow periods and maintenance of habitat in the spring run. Although the river will have different MFL-water resource considerations than will Gum Springs, the predicted cumulative reductions to the river groundwater contribution are well within this value.

3.10 Water Supply and Projected Aquifer Level Decline

Since groundwater is the primary potable water source in the WRWSA, the groundwater resource assessment carries significant implications for future potable water supplies. Projected groundwater withdrawals have the potential to cause aquifer declines and affect spring flows and surface water features such as lakes and wetlands. Predicted impacts to these features will affect and constrain approaches to water supply development.

There are areas in the WRWSA where groundwater may not be available to the 2030 planning horizon based on unadjusted demands, and areas where further investigation into water supplies will be required to established groundwater availability. This section is a qualitative discussion of the water supply development considerations resulting from the potential impacts to groundwater resources. It discusses areas where further investigation into water supplies will be required and identifies water resource management strategies that may be employed to meet water supply and environmental needs.

3.10.1 Citrus County

With Citrus County drawdown expected to be well below the SWFWMD planning criterion based on ND regional groundwater modeling, groundwater should be an environmentally acceptable supply to the 2030 planning horizon. Increases in future water demand and aquifer levels should be monitored for changes over time.

3.10.2 Hernando County

Significant UFA drawdown is projected in southwestern Hernando County based on unadjusted demands. With some of this withdrawal occurring from the UFA beneath areas of the Brooksville Ridge, surface environmental features along the Ridge should be isolated from UFA water level declines. However, wetlands and lakes in the unconfined portion of the UFA to the west of the ridge (i.e., the Spring Hill area) are projected to experience drawdown capable of incurring environmental harm if water demand continues to be met with local groundwater. Additional supplies or reductions in demand from conservation will be needed in the Spring Hill area within the 2030 planning horizon. A recent SWFWMD WUP[25] contained a condition requiring Hernando County to plan for alternative or non-local groundwater supplies in the western utility service area.

Possible water supply options for the Spring Hill area include rotating withdrawals within the area and dispersing projected groundwater withdrawals in Hernando County towards the northern and eastern areas of the County. Hernando County's recent SWFWMD WUP[26] fit this resource strategy by authorizing new withdrawals in the eastern county (eastern utility service area). Additional conservation or increases in beneficial reuse supplies could also help to meet future water needs in Hernando County; both of these strategies are currently planned for deployment in Hernando County.

[25] SWFWMD WUP No. 2983.009
[26] SWFWMD WUP No. 20005879.004

3.10.3 Sumter County

The potential effects of projected 2030 groundwater withdrawals in Sumter County are difficult to interpret, but significant UFA drawdown is projected in northeastern Sumter County if unadjusted water demand continues to be met with local groundwater. Projected drawdown, if it materializes, has the potential to cause environmental harm to wetlands and lakes in the unconfined portion of the UFA in far northeastern Sumter County.

The location, magnitude and extents of drawdown are difficult to identify and additional data collection, monitoring and analysis will be required to refine the interpretation of ND Model results in Sumter County. The presence of the SA in east-central Sumter County and semi-confinement of water features in the eastern County should facilitate some withdrawals.
The model results suggest a need for additional supplies or reductions in demand from conservation in northeastern Sumter County to avoid potential impacts to environmental features. The recent SWFWMD WUP[27] contained a condition requiring the Villages to plan for alternative or non-local groundwater supplies if unacceptable adverse impacts are observed.

In conjunction with increased monitoring and data collection, possible water supply options for the Villages area include additional demand reduction, dispersal of projected groundwater use, increased use of reclaimed water, and alternative water supplies. The Villages' recent acquisition of additional reclaimed water supplies from utilities in Marion and Lake Counties is an example of an effort to manage water resources through alternative water supply development. A groundwater dispersal option for potable supply is discussed in more detail as a conceptual wellfield project in Chapter 6.

3.10.4 Marion County

The potential effects of projected 2030 groundwater withdrawals in Marion County are difficult to interpret, but moderate UFA drawdown is projected in southern Marion County if unadjusted water demand continues to be met with local groundwater. Projected drawdown may be capable of causing environmental harm to wetlands and lakes in the unconfined UFA and the SA in southern and central Marion County.

The location, magnitude and extents of drawdown are difficult to identify and additional data collection, monitoring and model updates will be required to refine the interpretation of groundwater flow model results in Marion County. The presence of the SA in east-central Marion County and perched wetlands and lakes throughout the county should facilitate some withdrawals.

The model results suggest a need for reductions in demand from conservation and increased beneficial reuse in Marion County to avoid drawdown levels that may affect environmental features. The recent SJRWMD CUP[28] contained a condition requiring Ocala to plan for alternative or non-local groundwater supplies by 2013, with implementation beginning in 2027.

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[27] SWFWMD WUP No. 20013005
[28] SJRWMD CUP No. 50324.

In conjunction with increased monitoring and data collection, possible water supply options in Marion County include additional conservation, dispersal of projected groundwater use, and increased use of reclaimed water.

3.10.5 Lower Floridan Aquifer

As previously indicated, this region contains both the UFA and LFA which is separated by a MCU 1 from Miller (1986). The hydraulic characteristics and spatial extent of both MCU 1 and the LFA are poorly understood in the region. However, the LFA has been developed successfully as a water supply source both within the WRWSA region at the Villages and elsewhere in the SJRWMD. Where adequate confinement and water quality are present, the LFA may provide a local water source that is not anticipated in this assessment.

Additional hydrogeologic data collection is underway in the region to improve the understanding of the supply potential of the LFA. The SWFWMD and City of Wildwood are collaborating on a test well to assess the viability of the LFA to serve the City of Wildwood. The City of Ocala is planning a LFA test well in response to a permit requirement seeking alternative or additional non-local supplies. As this report was being completed, preliminary results from LFA tests near the Cities of Wildwood and Bushnell were received which suggest that the LFA may offer adequate confinement and water quality to be a significant potable water supply for these cities.

The interpretation of groundwater resources in this chapter is predicated on the assumption that the LFA does not offer adequate confinement and water quality to be a significant water supply for member governments. Confirmed results from the test wells may alter the interpretation of this assessment and should be closely monitored by the SJRWMD, SWFWMD, and WRWSA.

3.11 Groundwater Resource Assessment Summary

The ND and NCF regional groundwater model results predict the potential effect of projected 2030 increases in water use on the Upper Floridan and SAS in the WRWSA. The model results are based on unadjusted water demand using the population projections discussed in Chapter 1. They assume that future water demands will continue to be served by groundwater withdrawn from current extraction locations at current levels of water conservation.[29]

Groundwater appears to be viable to serve future water demand to 2030 in Citrus County. Cumulative drawdown impacts in the UFA will be small (less than 0.5 ft), and cumulative reductions in springflow at Homosassa, Chassahowitkza, and Crystal River are projected to be minimal (less than 3%), which is below the proxy MFLs developed by the WRWSA.

In Hernando County, future water demand in 2030 could lead to restrictions on groundwater withdrawals in the Spring Hill area if unadjusted demands continue to be met with local groundwater. In southwestern Hernando County, cumulative drawdown impacts to the unconfined UFA (> 1.0 foot) will be capable of adversely impacting lakes and wetlands, although perched water features along the Brooksville Ridge should allow some withdrawals there. The MFL for Weekiwachee spring has been adopted by the SWFWMD and may limit future groundwater supplies in the Weekiwachee springshed.

[29] Actual groundwater demand in the future will vary based on a variety of additional factors, including the actual rate of population growth.

Possible supply options in Hernando County include additional conservation, increases in beneficial reuse supply, and dispersal of projected groundwater uses to other areas of Hernando County. Additional groundwater withdrawals to the north or east of the Spring Hill area appear viable in 2030.

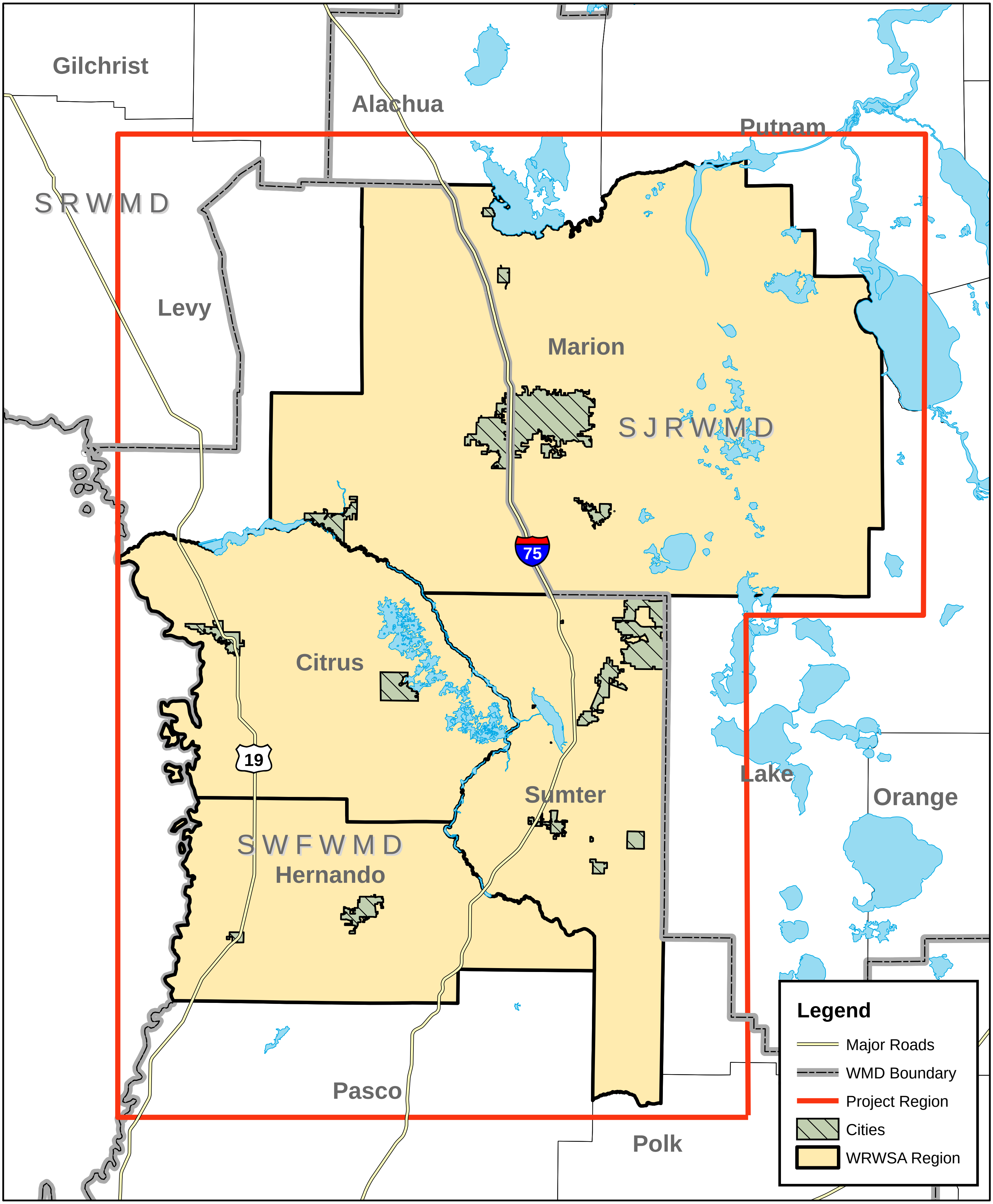
The potential effects of projected 2030 groundwater withdrawals in Sumter County are difficult to assess, but suggest a need for additional supplies or reductions in demand from conservation in northeastern Sumter County to avoid potential impacts to environmental features. Projected cumulative drawdown impacts to the unconfined UFA (> 1.0 foot) in Sumter County based on unadjusted demands, if they materialize, have the potential to adverse impact lakes and wetlands, though the presence of the SA in east-central Sumter County and semi-confinement of water features in the eastern County should facilitate some withdrawals. A proxy MFL for Gum Springs has been developed by the WRWSA, and the adoption of the Gum Springs MFL in 2010 may affect estimates of groundwater supply in Sumter County. Additional hydrogeologic data collection, monitoring, and analysis are warranted in this area.

Possible water supply options for the Villages area include additional conservation, dispersal of projected groundwater use, and increased use of reclaimed water and alternative water supplies.

The potential effects of projected 2030 groundwater withdrawals in Marion County are difficult to assess, but suggest a possible need for additional beneficial reuse or reductions in demand from conservation to prevent drawdown levels that may be capable of affecting environmental features. Projected cumulative reductions in springflow in Marion County at Rainbow, Silver, and Silver Glen are projected to be moderate (less than 10%), which is below the planning thresholds used by the SWFWMD and SJRWMD. The adoption of the Rainbow Springs MFL in 2010, the Silver Springs MFL in 2011, and the Silver Glen Springs MFL in 2013 may affect estimates of groundwater supply in Marion County. Additional hydrogeologic data collection, monitoring, model updates, and analysis are warranted in this area.

Generally, increased groundwater withdrawals can affect the hydrology and ecology of lakes, wetlands, springs, and other water features. The ND and NCF regional models analyze regional groundwater conditions and do not provide detailed, regulatory-level investigation of impacts to groundwater conditions in localized areas. Additional field data collection and model updates in Sumter and Marion Counties may affect the results included in these simulations. Refinements to the ND and NCF Models and additional data collection are planned in the future by the SWFWMD, SJRWMD and WRWSA to improve confidence in the model predictions included in this report.

Member government requests for water withdrawals must address the potential for impacts at a more local scale than that in this chapter. Future requests for water withdrawals will require further analysis and will be assessed by the applicable SWFWMD or SJRWMD regulatory program for compliance with water use permitting criteria, including requirements to utilize feasible lower quality sources and reduce demand through conservation.



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PROJECT: 0468 - Withlacoochee Phase II

FIGURE 3-1
WRWSA AND VICINITY

ORIGINAL DATE: 12-03-09
REVISION DATE: NA
JOB NUMBER: 0468
FILE NAME: Figure 4-1.mxd
GIS OPERATOR: DR

N W E S

1 inch equals 11 miles

<table>
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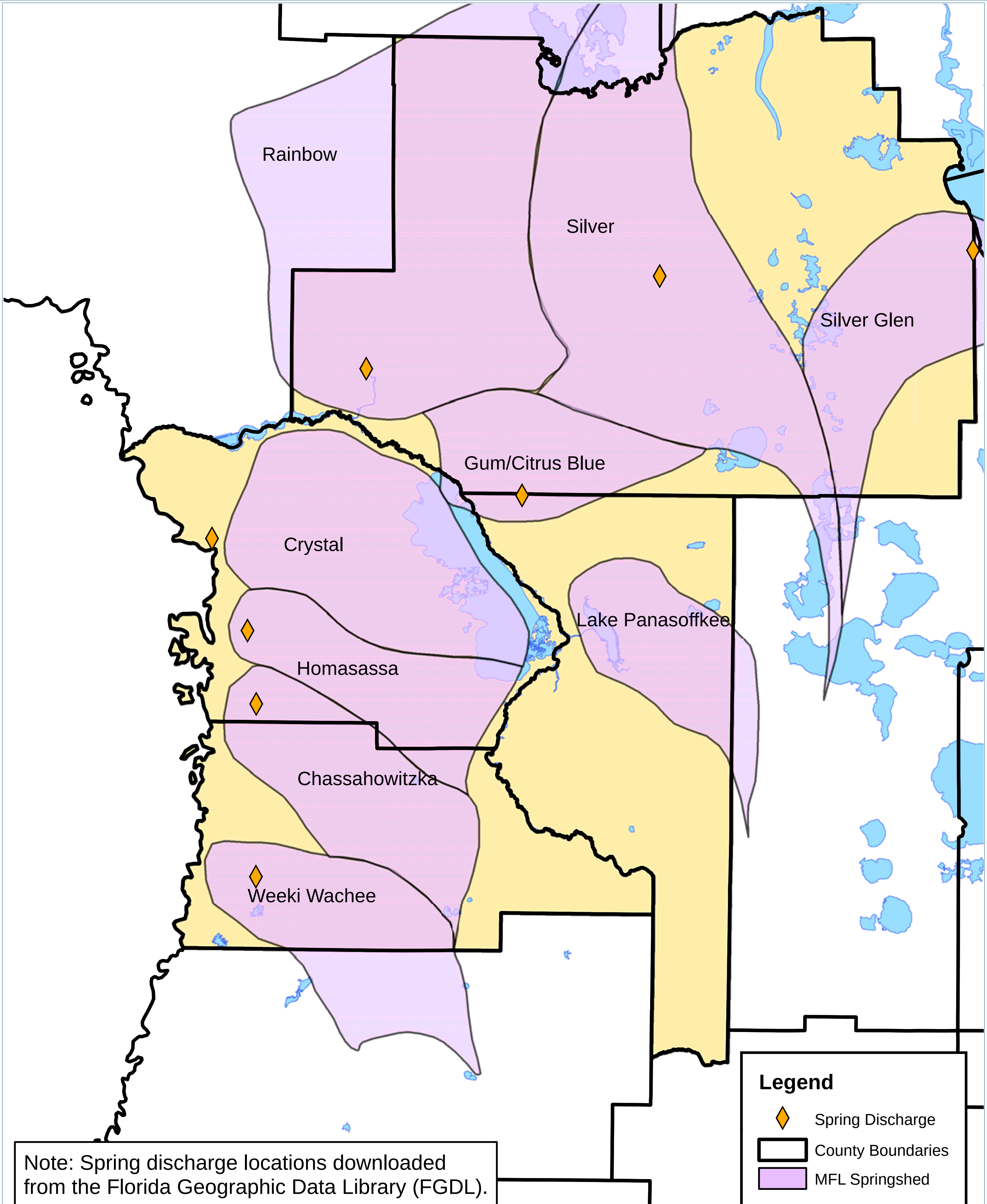
<tr><td colspan="2">Pleistocene to Pliocene</td><td>Undifferentiated</td><td colspan="3">Surficial Aquifer (Where Present)</td></tr>
<tr><td colspan="2" rowspan="2">Miocene</td><td>Hawthorn</td><td colspan="3">Intermediate Confining Unit (Where Present)</td></tr>
<tr><td>Tampa Limestone (where permeable)</td><td colspan="3" rowspan="3">Upper Floridan</td></tr>
<tr><td colspan="2">Oligocene</td><td>Suwanne Limestone</td></tr>
<tr><td rowspan="3">Eocene</td><td>Upper</td><td>Upper</td></tr>
<tr><td>Middle</td><td>Avon Park Formation</td><td>Middle semiconfining unit</td><td colspan="2">Middle confining unit</td></tr>
<tr><td>Lower</td><td>Oldsmar Formation</td><td colspan="3">Lower Floridan</td></tr>
<tr><td colspan="2">Paleocene</td><td>Cedar Keys Formation</td><td colspan="3">Lower Confining Unit</td></tr>
</table>

Figure 3-2. Project Region Hydrostratigraphic Interpretation (Adapted from Johnson and Bush, 1988)



Note: Spring discharge locations downloaded from the Florida Geographic Data Library (FGDL).

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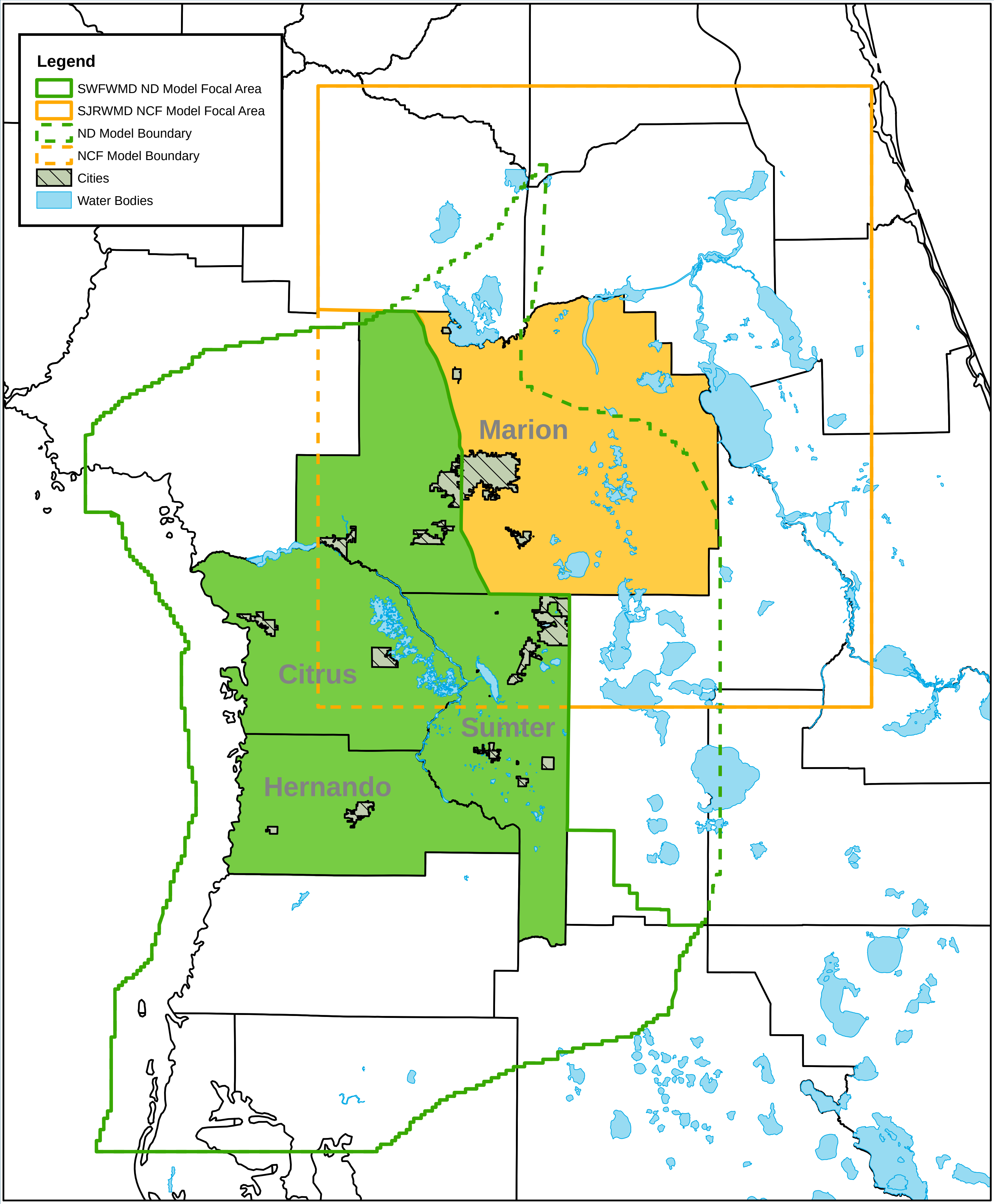
FIGURE 3-3
APPROXIMATE MFL PRIORITY SPRINGSHEDS IN WRWSA

ORIGINAL DATE: 10-28-09
REVISION DATE:
JOB NUMBER: 0468
FILE NAME: Springshed.mxd
GIS OPERATOR: DR

N W E S
1 inch equals 10 miles



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PROJECT: 0468 - Withlacoochee Phase II

FIGURE 3-4
WRWSA UTILIZATION OF GROUNDWATER FLOW MODELS

ORIGINAL DATE: 12-03-09
REVISION DATE: NA
JOB NUMBER: 0468
FILE NAME: Figure 3-4.mxd
GIS OPERATOR: DR

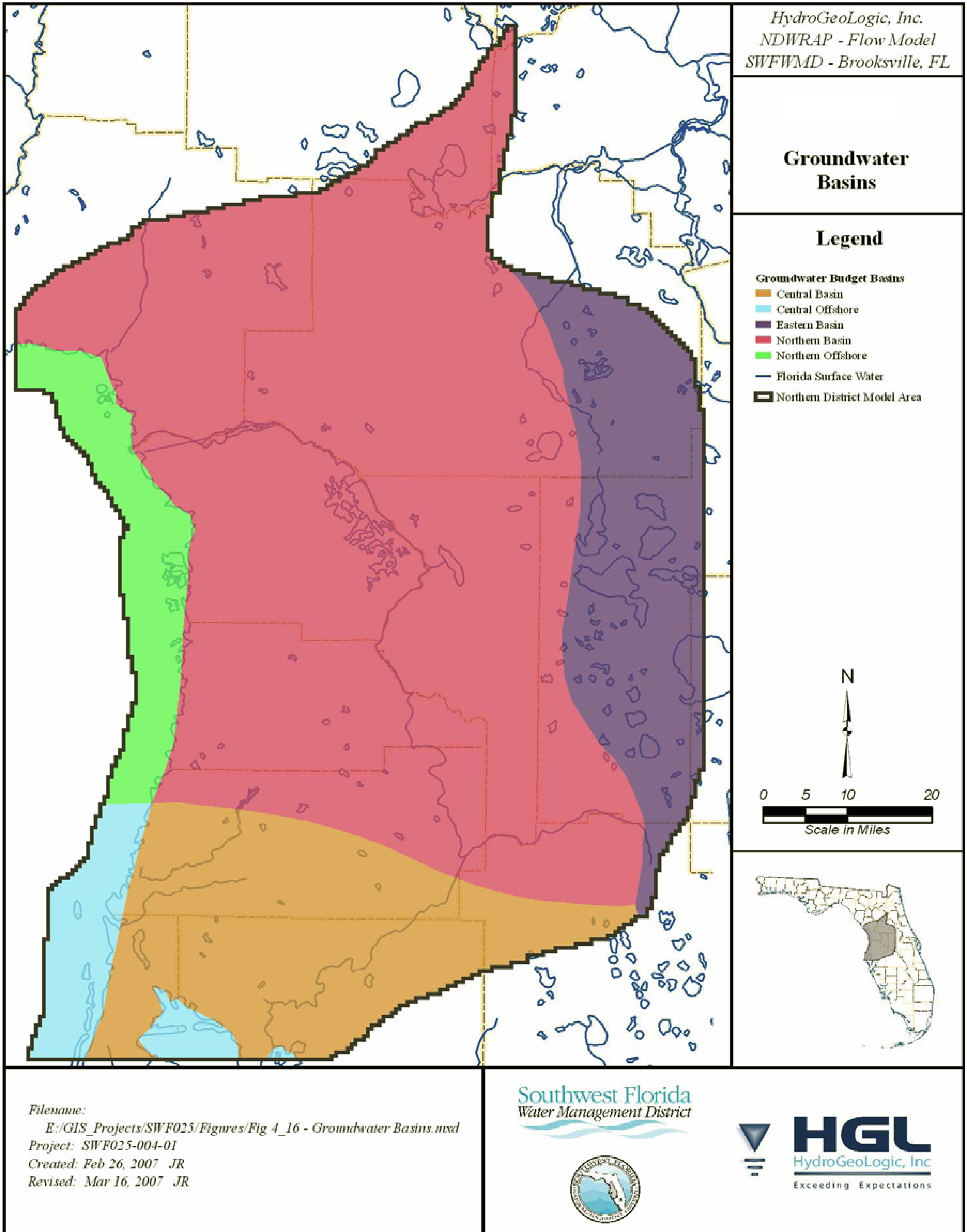

Figure 3-5. ND Model Groundwater Basins (Hydrogeologic, 2008)

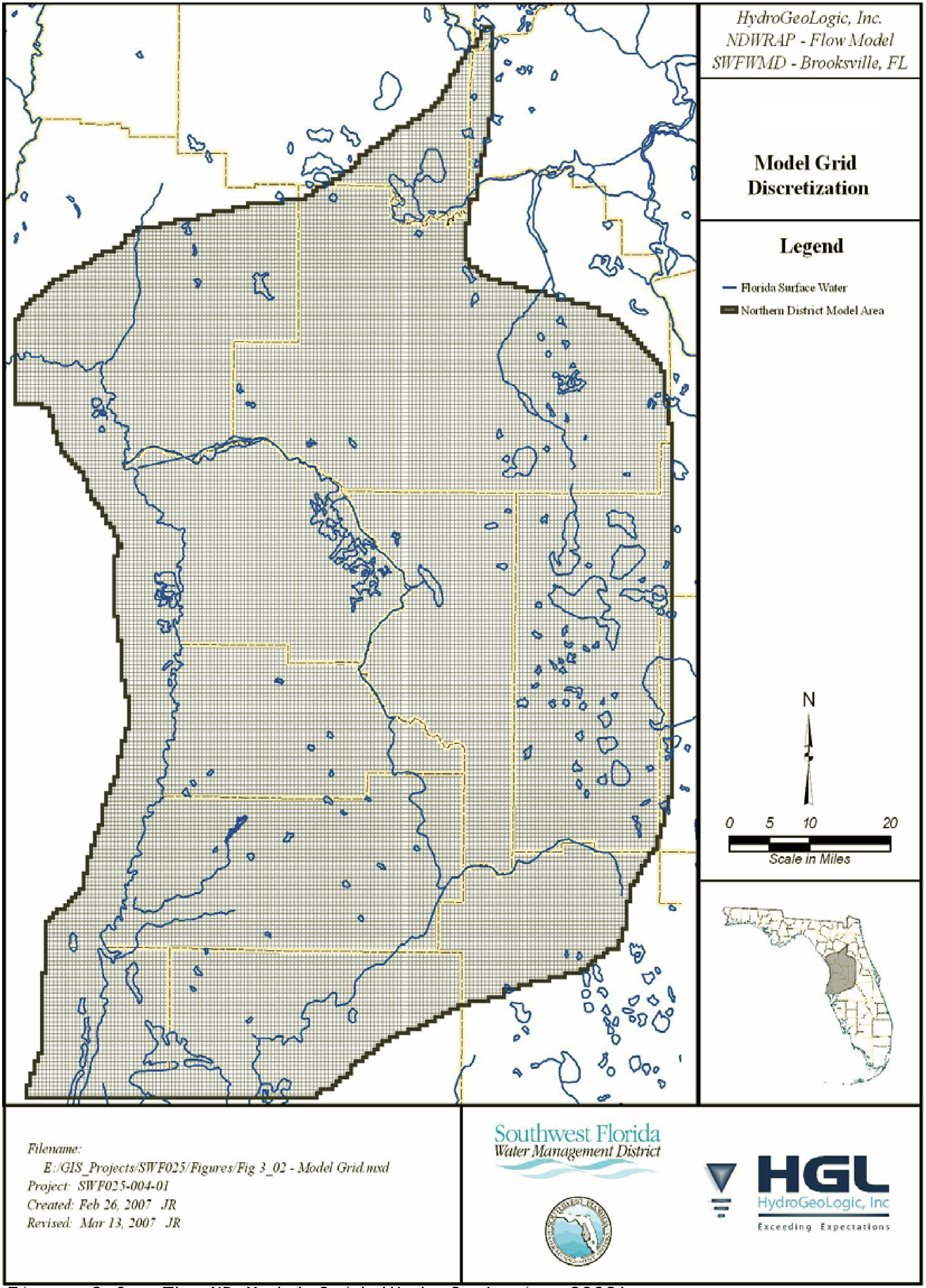

Figure 3-6. The ND Model Grid (HydroGeoLogic, 2008)

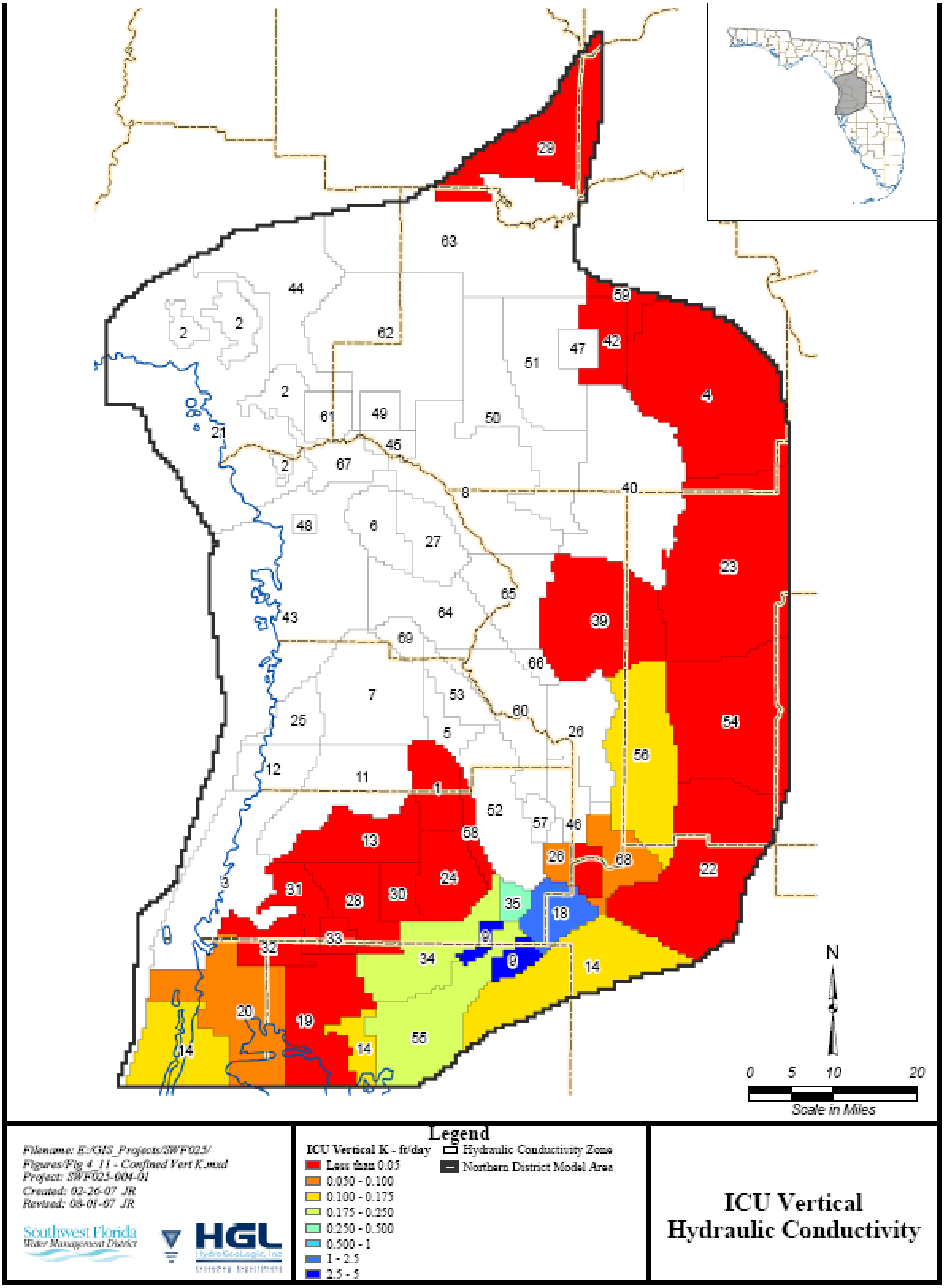

Figure 3-7. ICU Distribution in the ND Model (HydroGeoLogic, 2008)

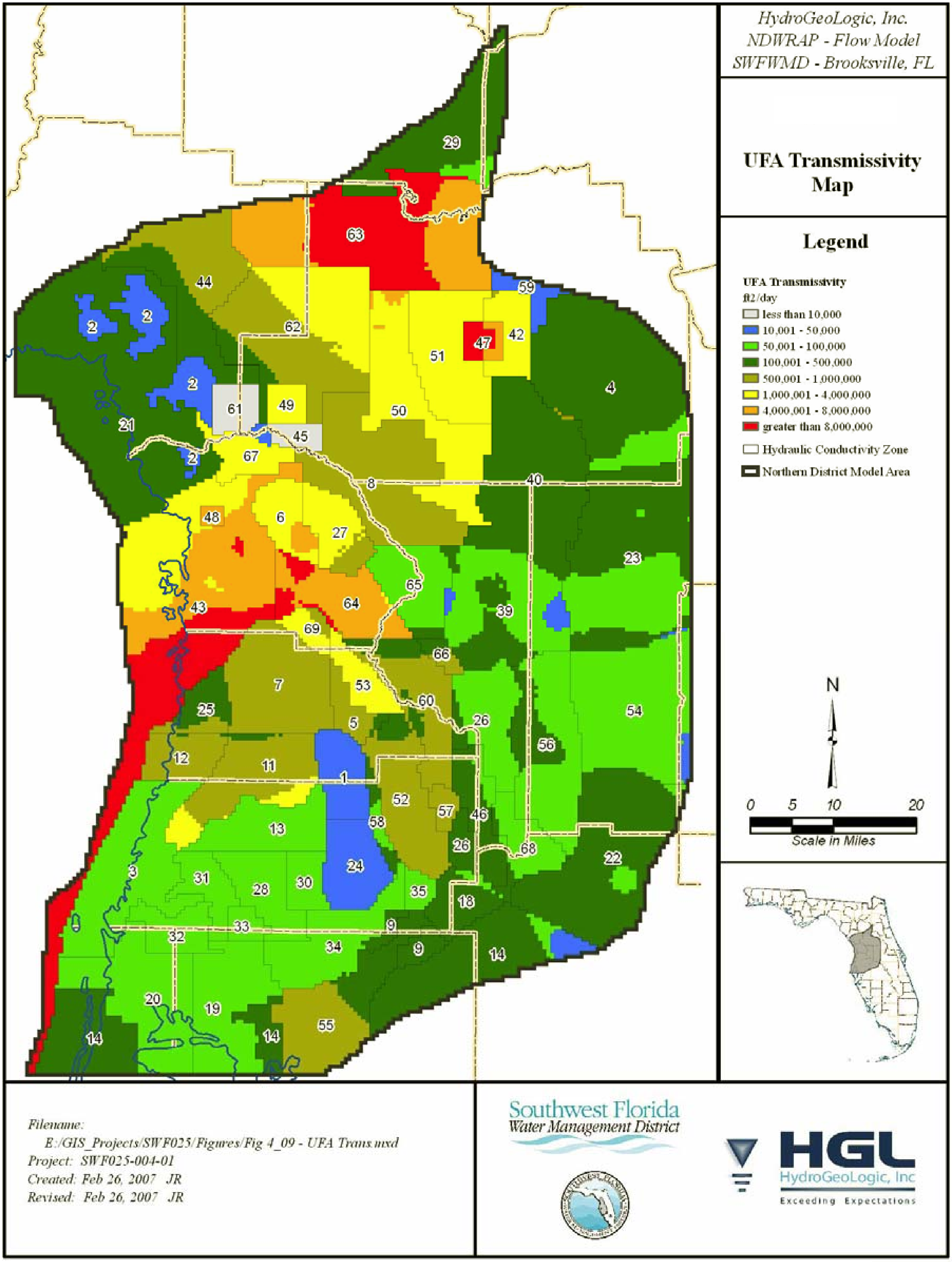

Figure 3-8. UFA Transmissivity Distribution in the ND Model (Hydrogeologic, 2008)

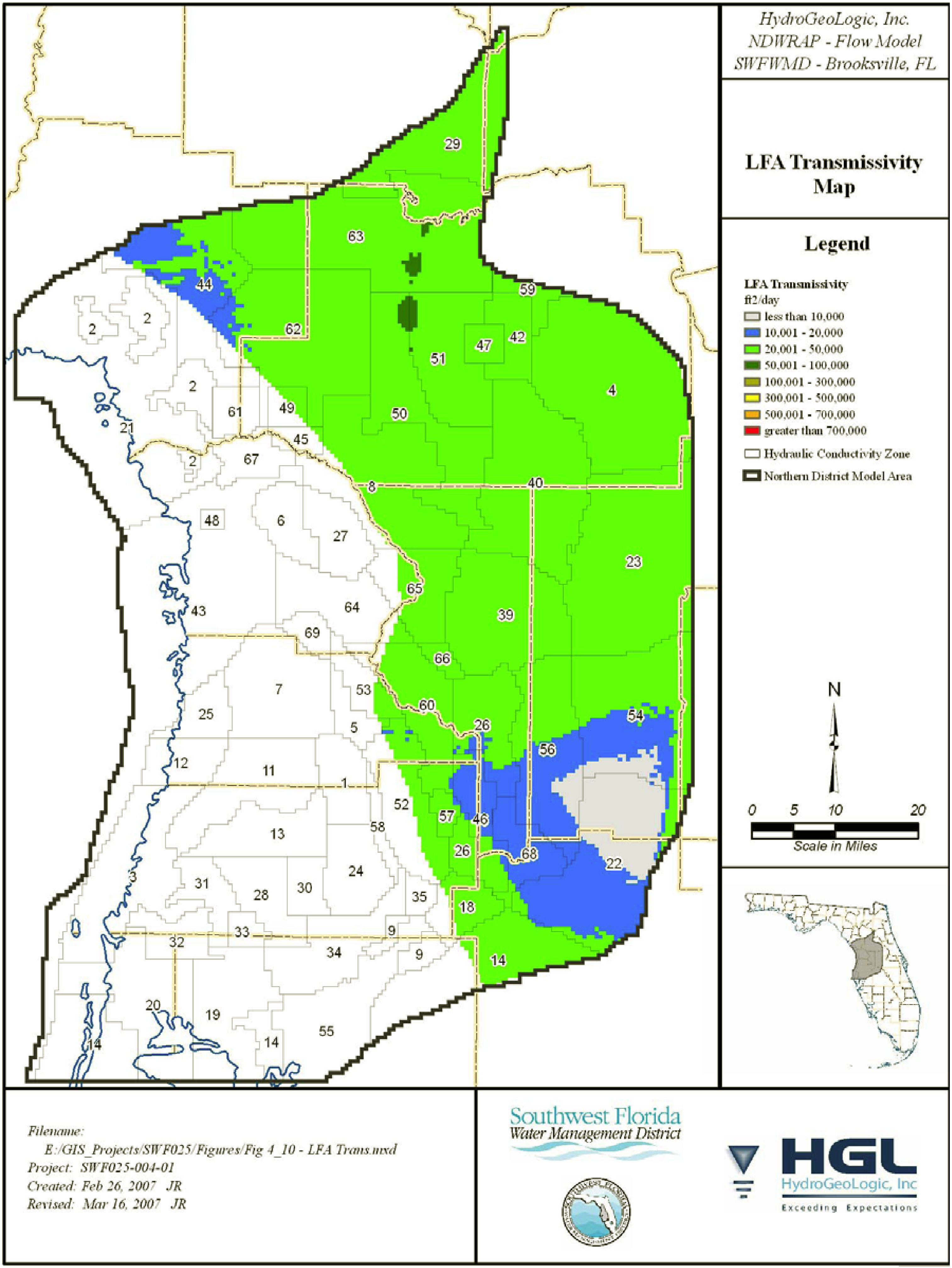

Figure 3-9. LFA Transmissivity Distribution in the ND Model (HydroGeoLogic, 2008)

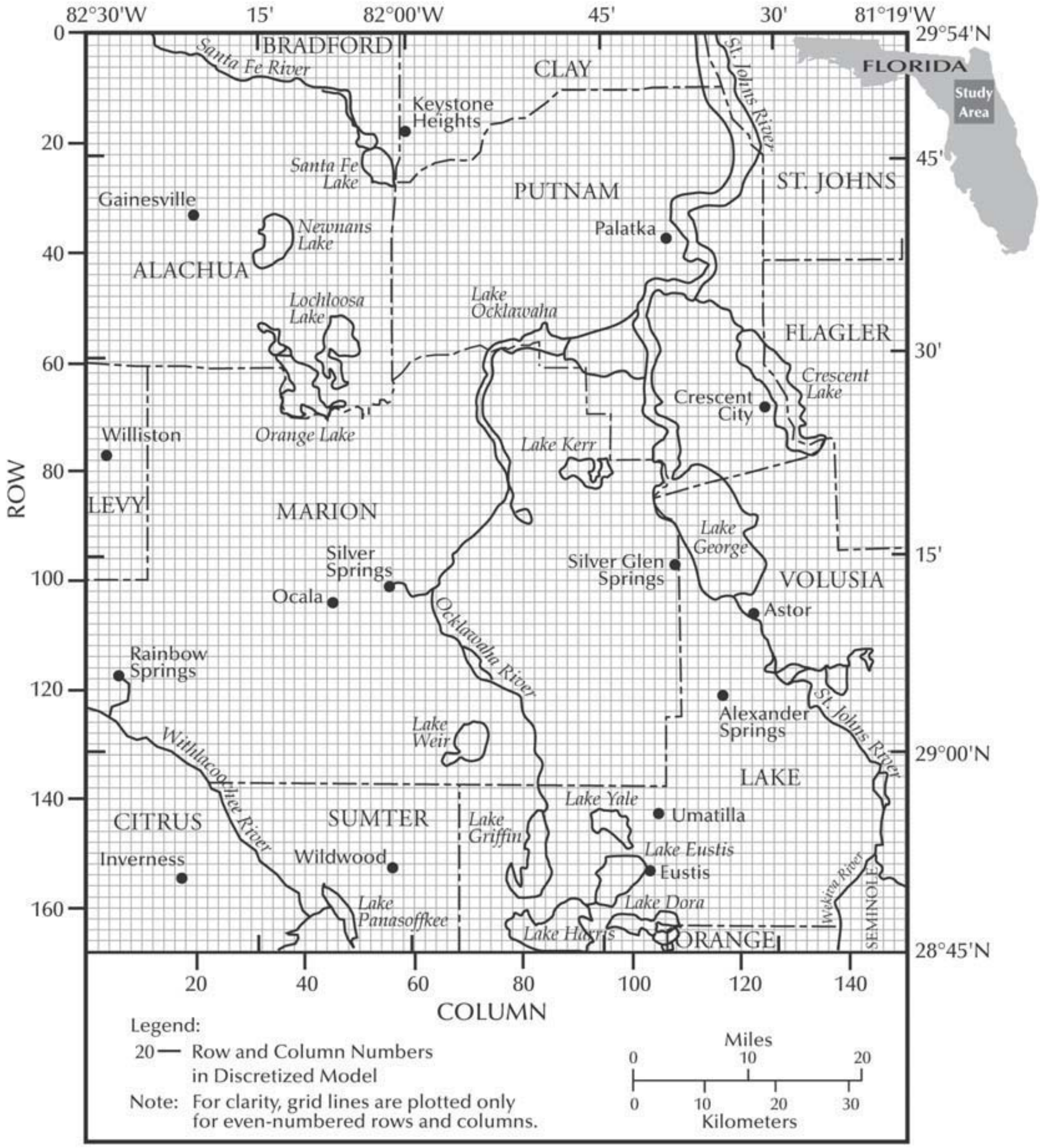

Figure 3-10. The NCF Model Grid (Motz and Dogan, 2004)

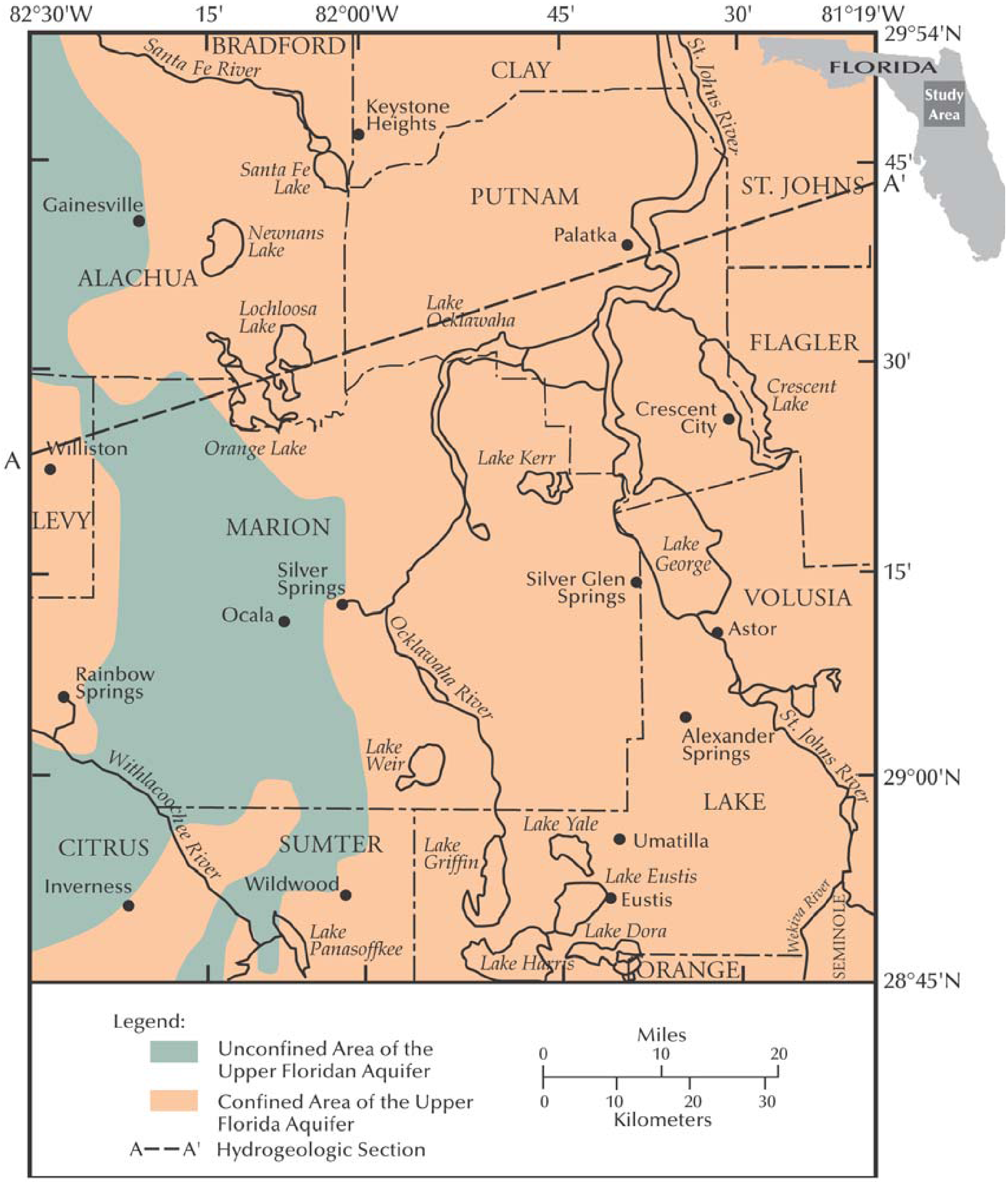

Figure 3-11. Unconfined/Confined Areas in the NCF Model (Motz and Dogan, 2004)

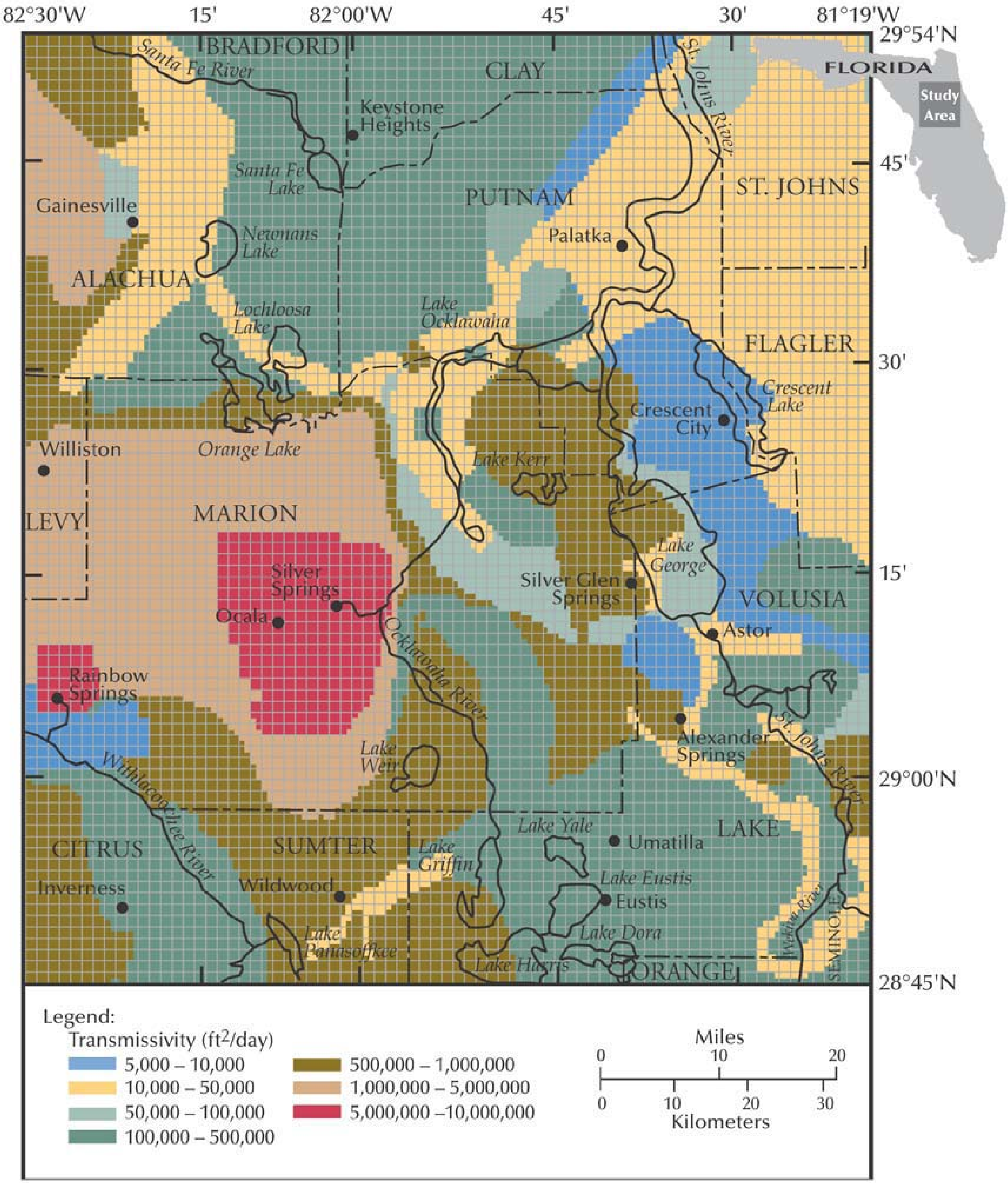

Figure 3-12. UFA Transmissivity in the NCF Model (Motz and Dogan, 2004)

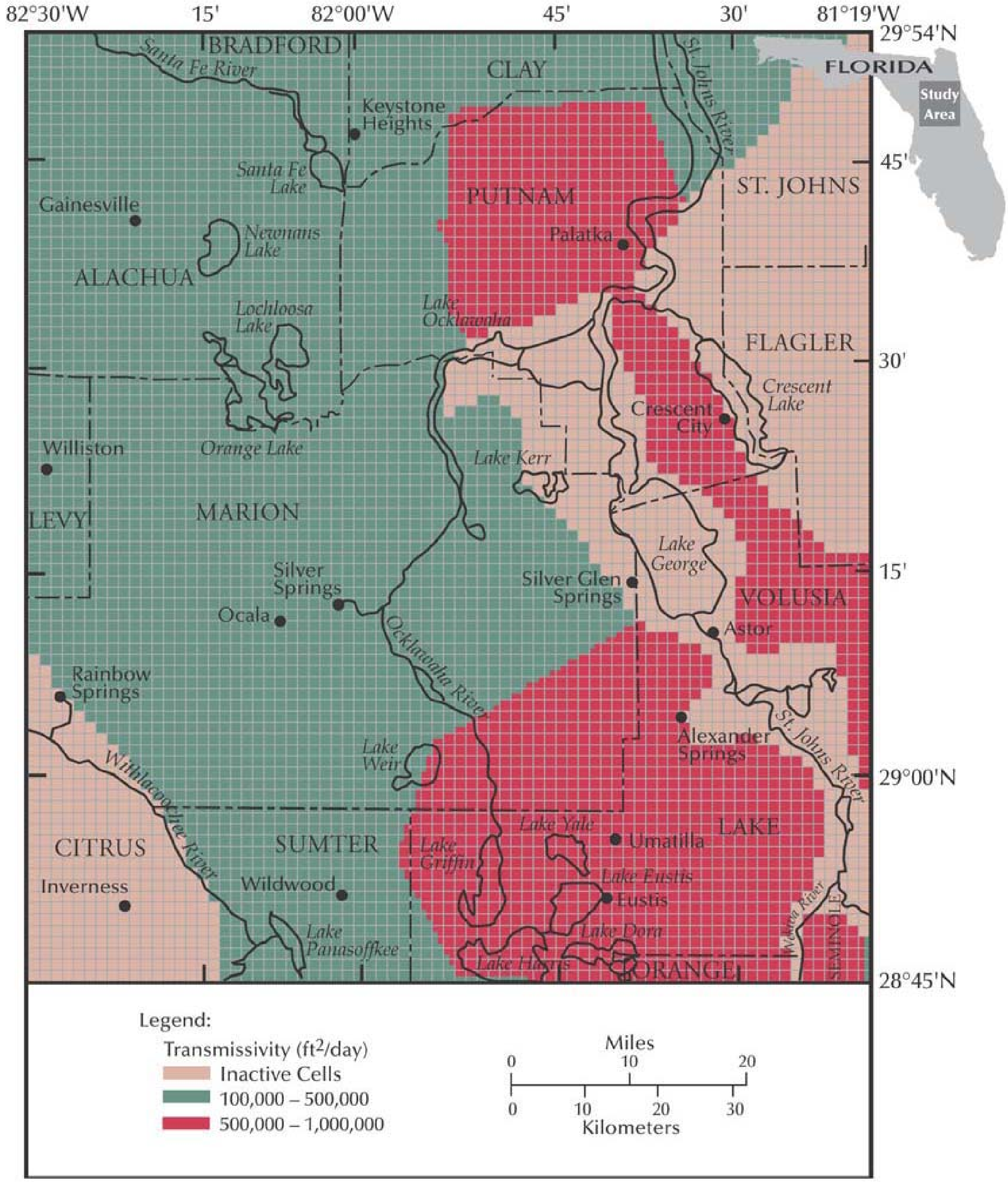

Figure 3-13. LFA Transmissivity in the NCF Model (Motz and Dogan, 2004)

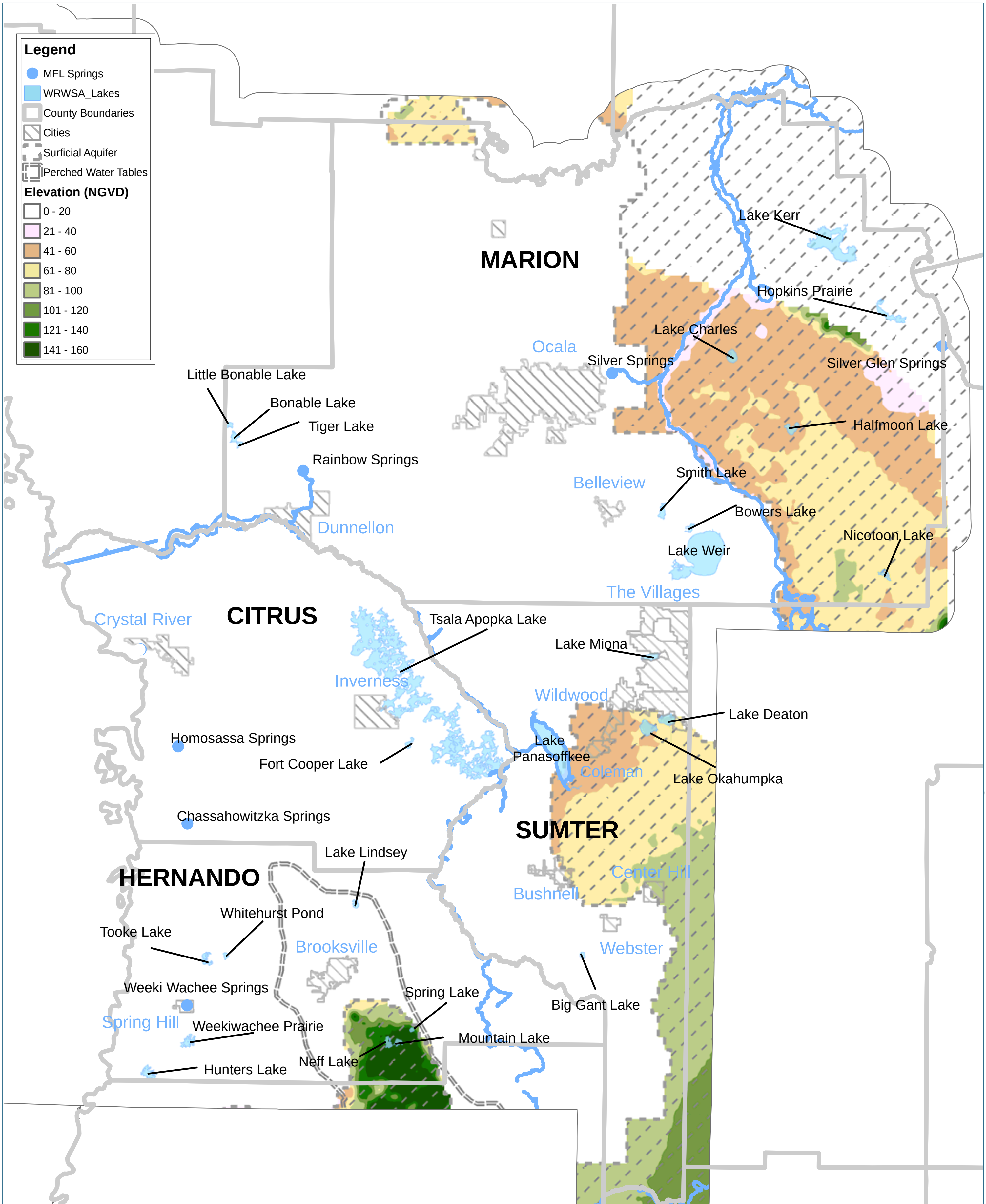

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Figure 3-14
ND Model Potentiometric Surface Distribution at Predevelopment: SA

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-14.mxd
GIS OPERATOR: DR

1 Inch = 9.5 Miles

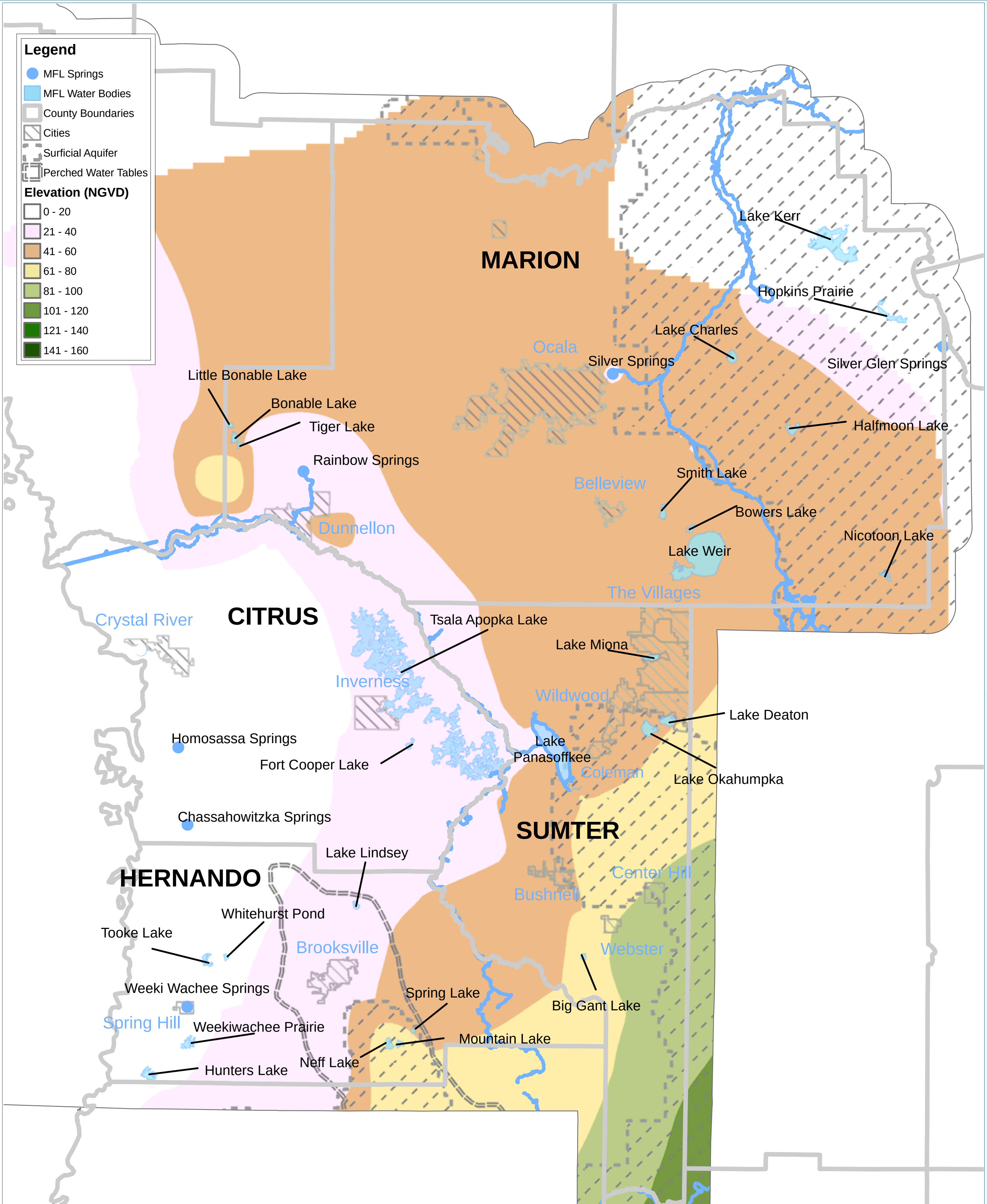

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Figure 3-15
ND Model Potentiometric Surface Distribution at Predevelopment: UFA

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-15.mxd
GIS OPERATOR: DR

N W E S
1 Inch = 9.5 Miles

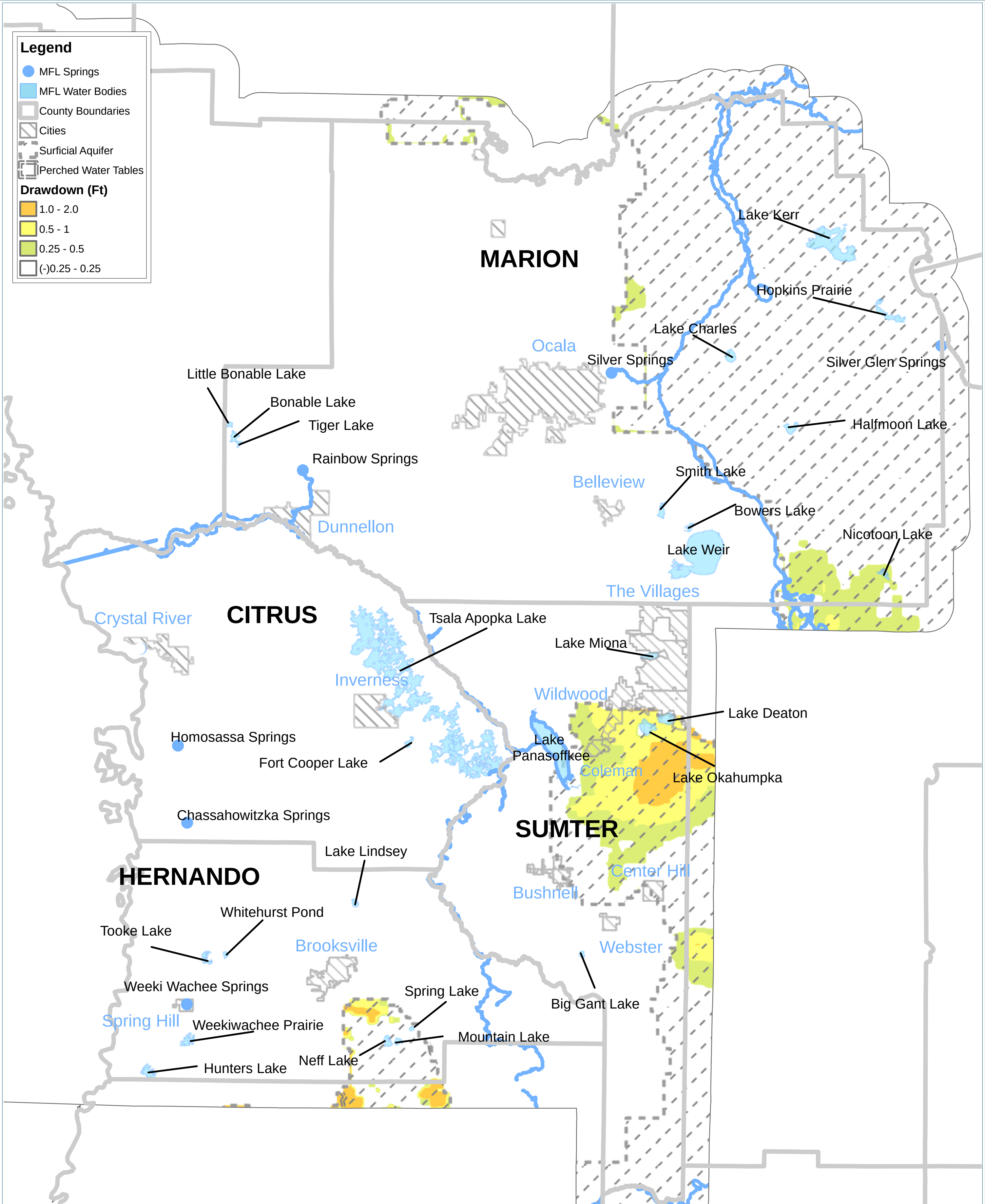

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Figure 3-16
ND Model Cumulative Drawdown Distribution in 2030: Surficial Aquifer, High Withdrawal Simulation

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-16.mxd
GIS OPERATOR: DR

N W E S
1 Inch = 9.5 Miles

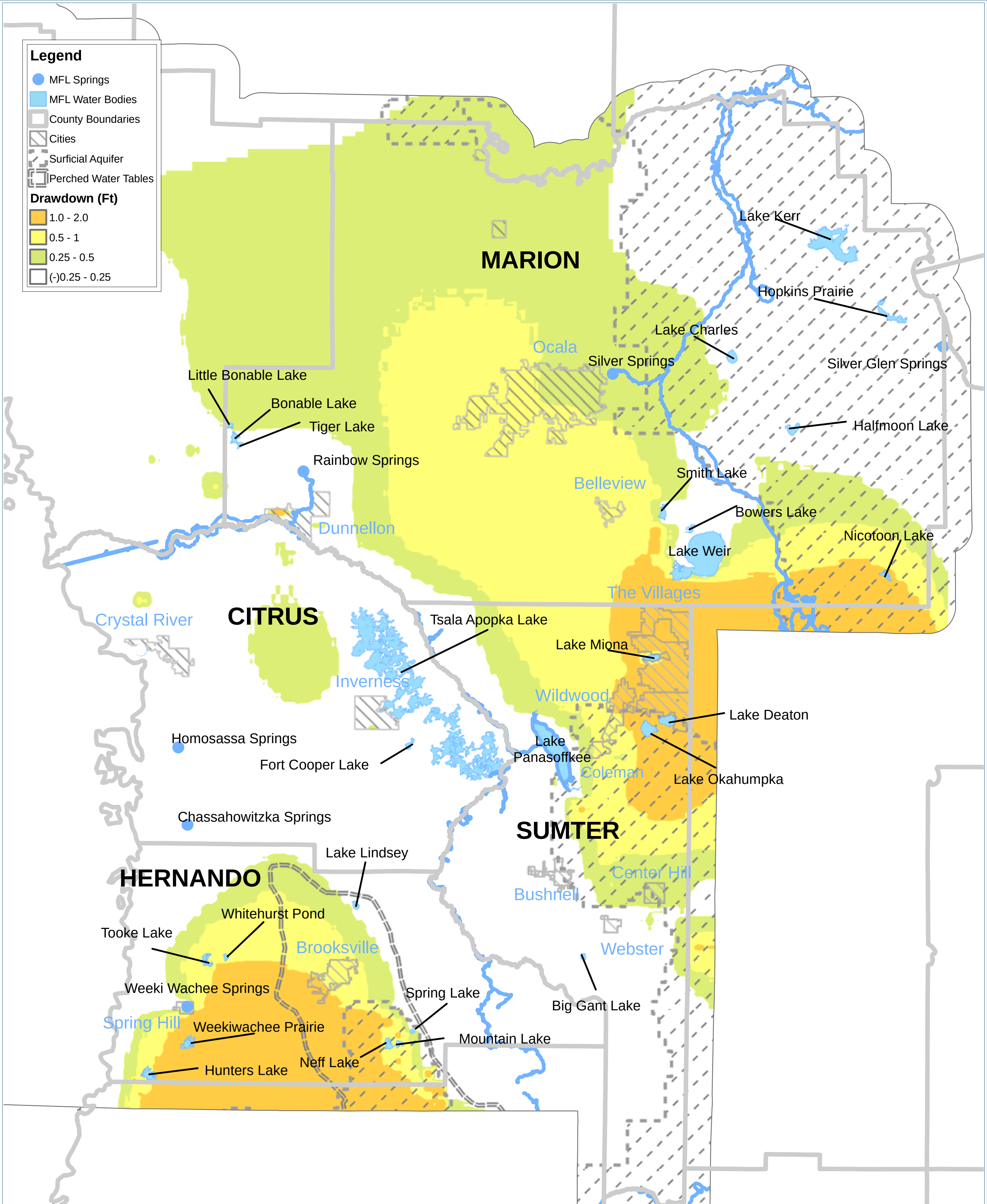

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Figure 3-17
ND Model Cumulative Drawdown Distribution in 2030: Upper Floridan Aquifer, High Withdrawal Simulation

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-17.mxd
GIS OPERATOR: DR

N W E S

1 Inch = 9.5 Miles

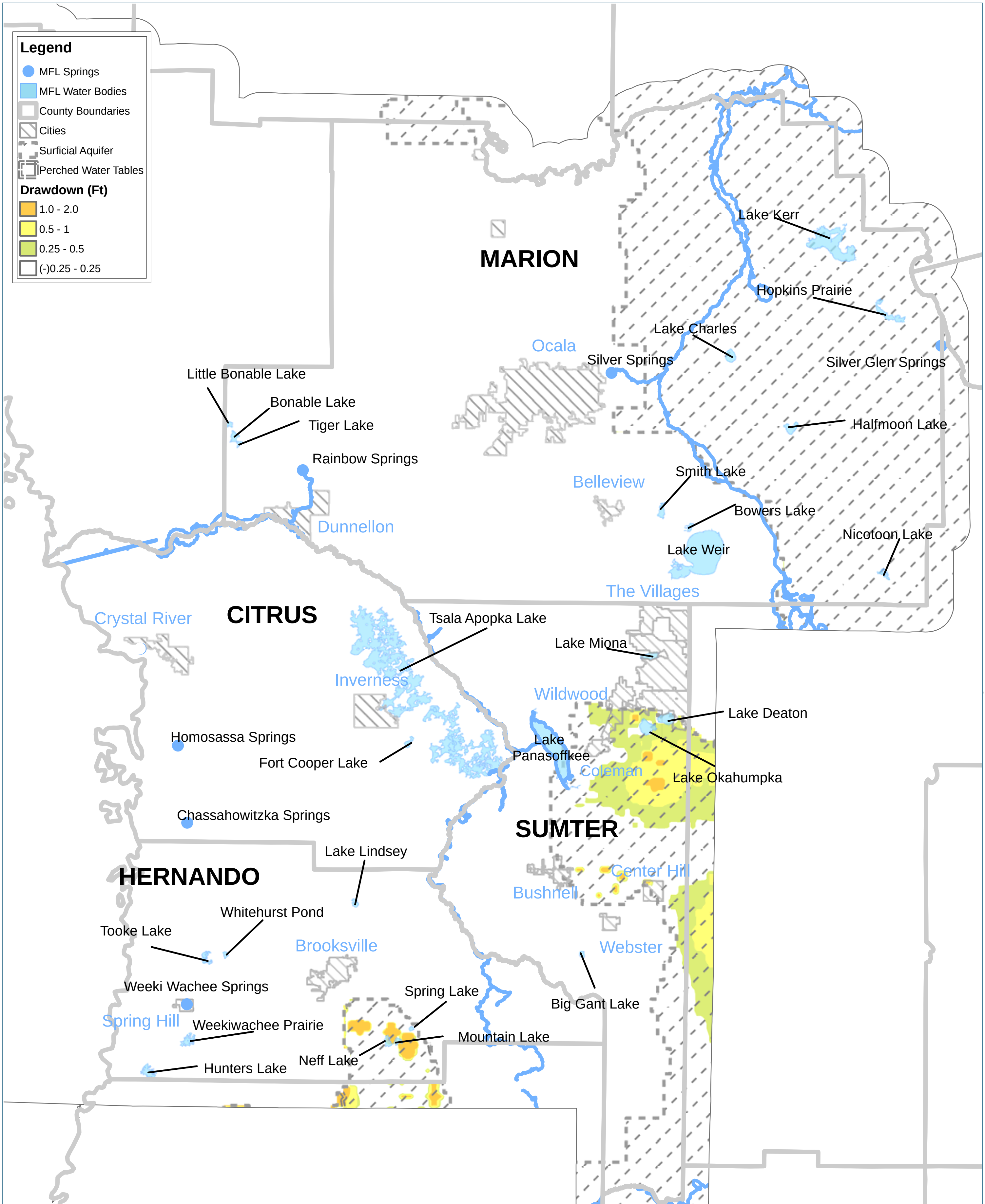

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Figure 3-18
ND Model Cumulative
Drawdown Distribution in 2030: Surficial Aquifer, Medium Withdrawal Simulation

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-18.mxd
GIS OPERATOR: DR

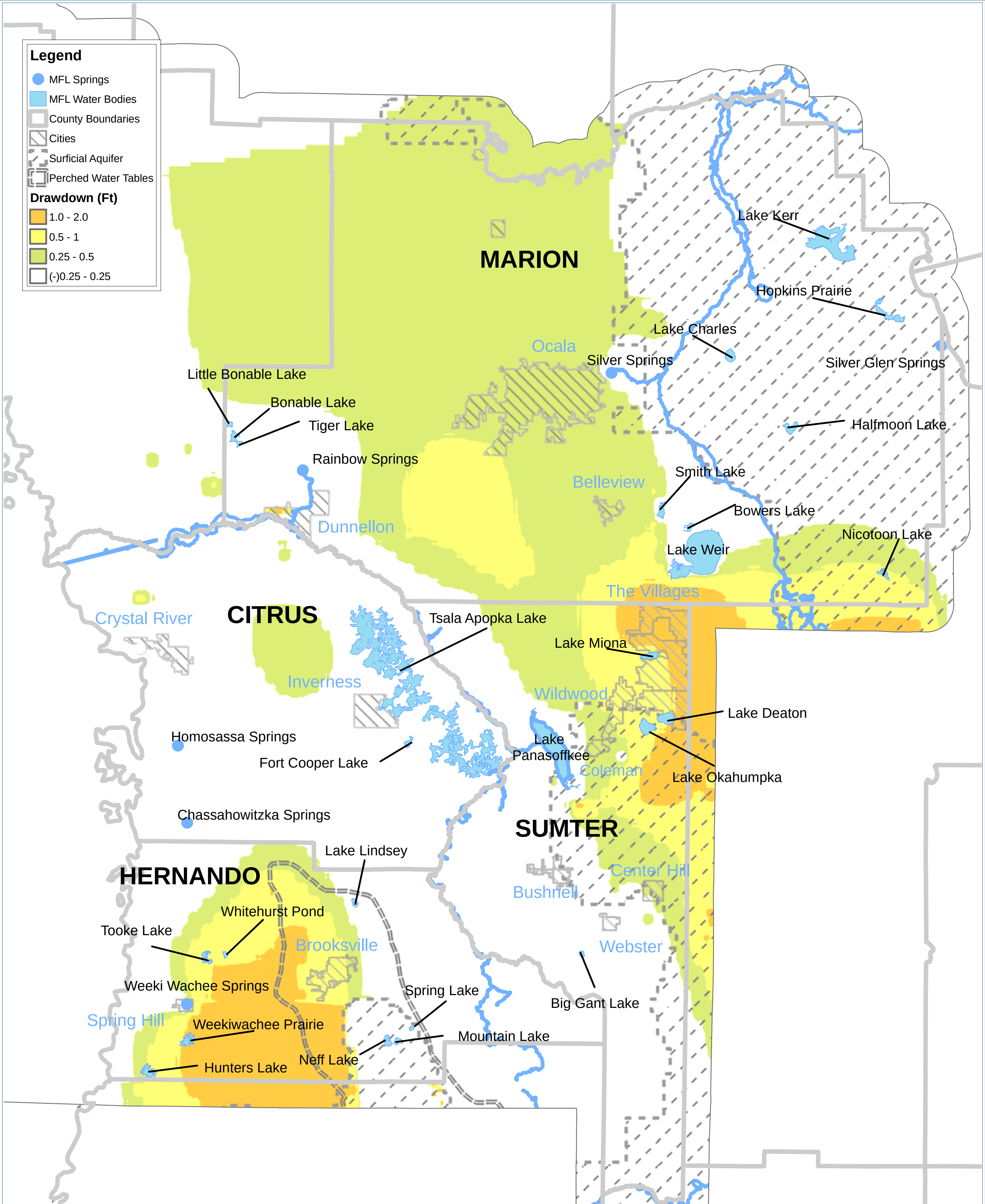

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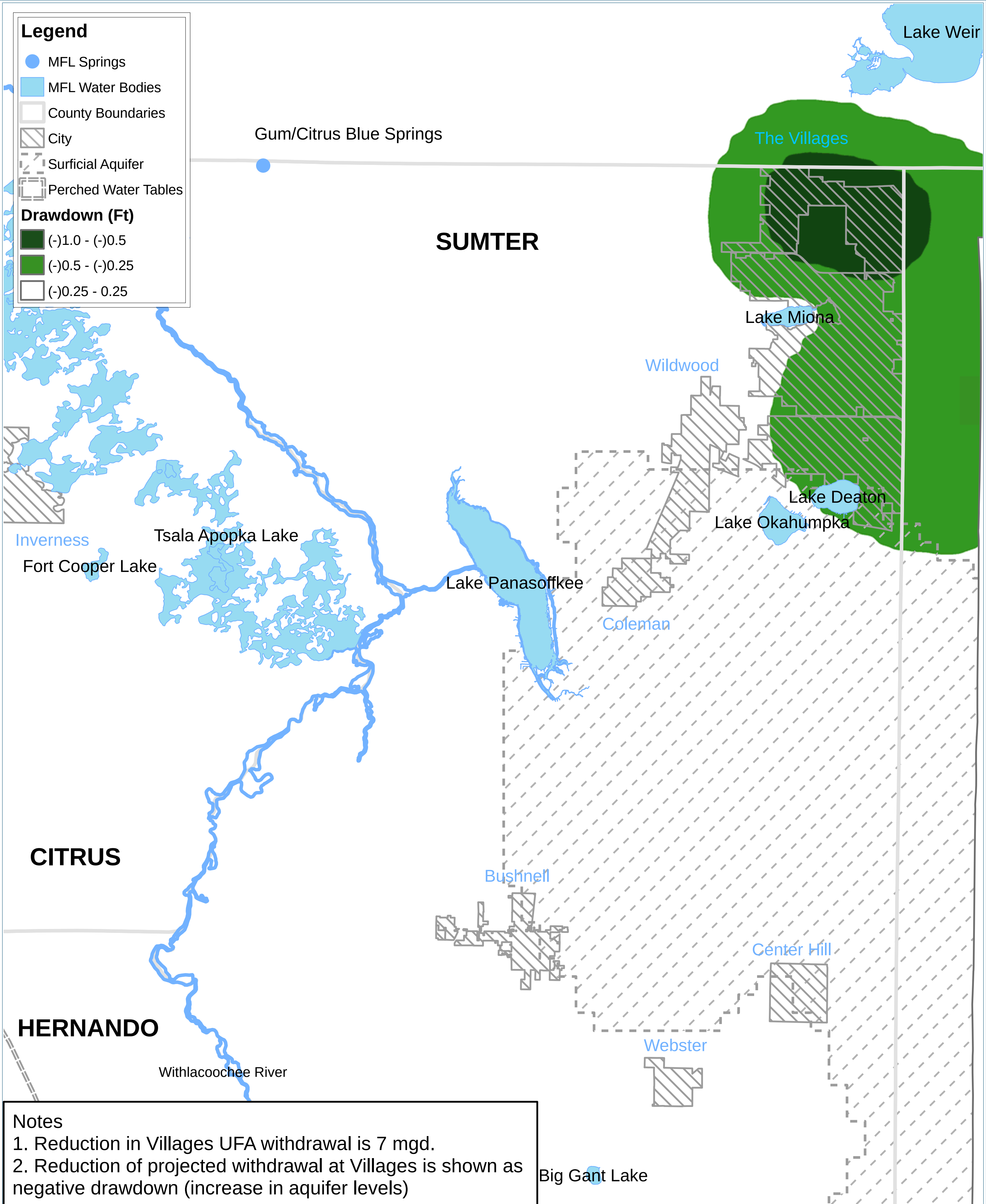
Figure 3-19
ND Model Cumulative Drawdown Distribution in 2030: Upper Floridan Aquifer, Medium Withdrawal Simulation

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-19.mxd
GIS OPERATOR: DR

1 Inch = 9.5 Miles



Notes
1. Reduction in Villages UFA withdrawal is 7 mgd.
2. Reduction of projected withdrawal at Villages is shown as negative drawdown (increase in aquifer levels)

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Figure 3-20
ND Model 7 MGD
Sensitivity Analysis UFA Response

ORIGINAL DATE: 06-26-08
REVISION DATE: 12-29-09
JOB NUMBER: 0468
FILE NAME: Figure 3-20.mxd
GIS OPERATOR: DR

1 Inch = 4.75 Miles

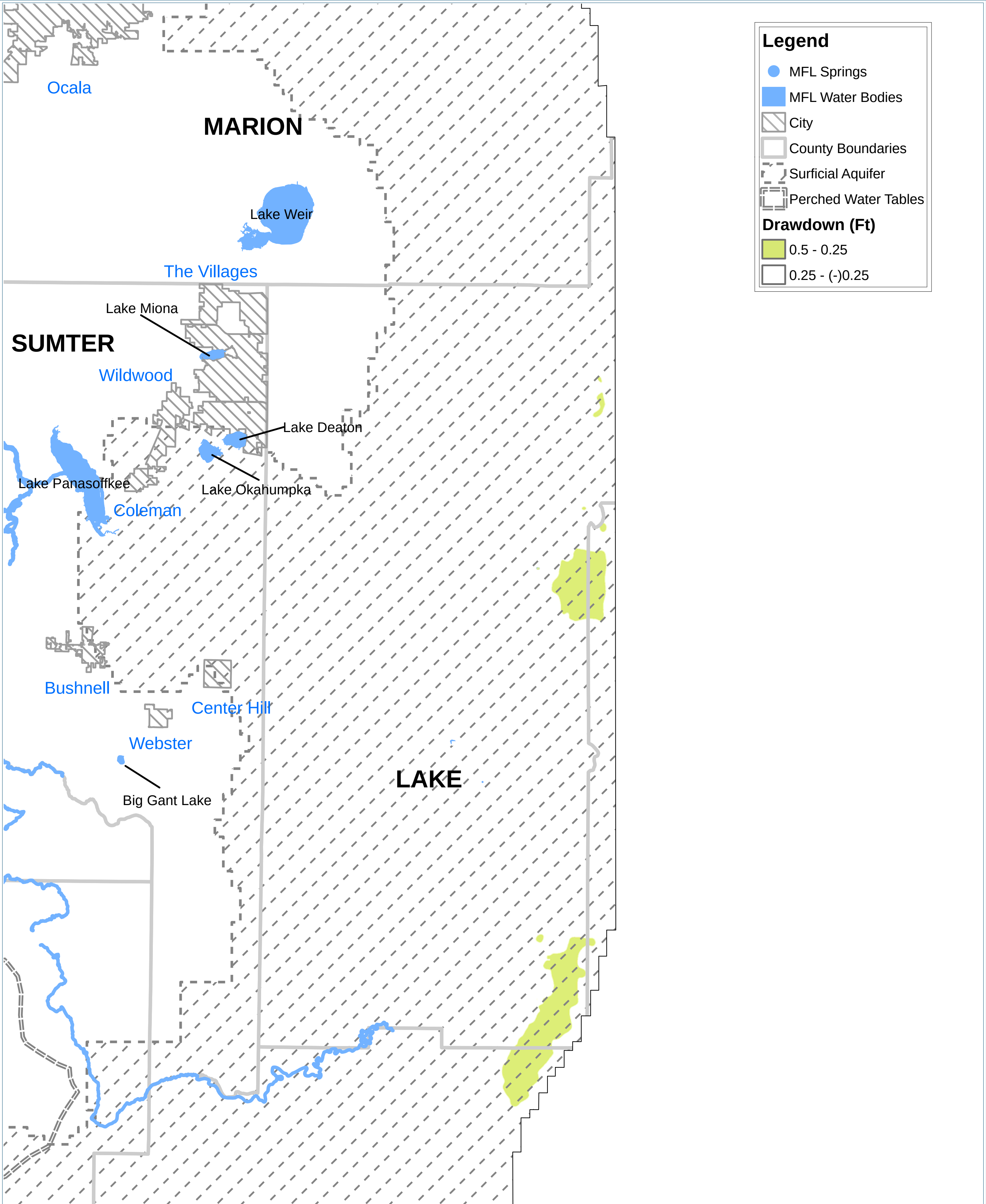

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Figure 3-21
ND Model SA Drawdown Due to Eastern Boundary Condition Withdrawals 1995 - 2013

ORIGINAL DATE: 06-26-08
REVISION DATE: 12-29-09
JOB NUMBER: 0468
FILE NAME: Figure 3-21.mxd
GIS OPERATOR: DR

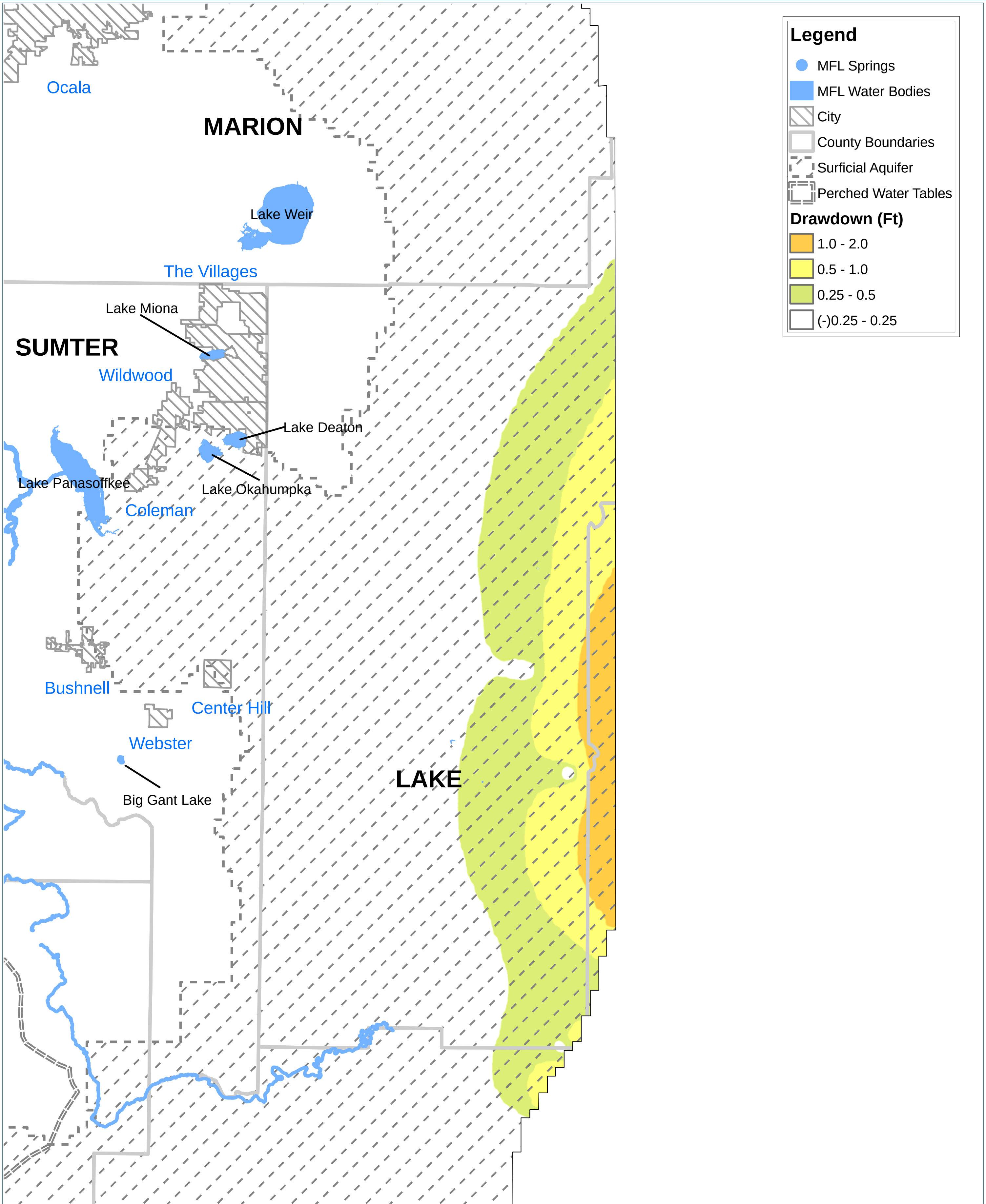

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Figure 3-22
ND Model UFA Drawdown Due to Eastern Boundary Condition Withdrawals 1995 - 2013

ORIGINAL DATE: 06-26-08
REVISION DATE: 12-29-09
JOB NUMBER: 0468
FILE NAME: Figure 3-22.mxd
GIS OPERATOR: DR

N W E S
1 Inch = 4.75 Miles

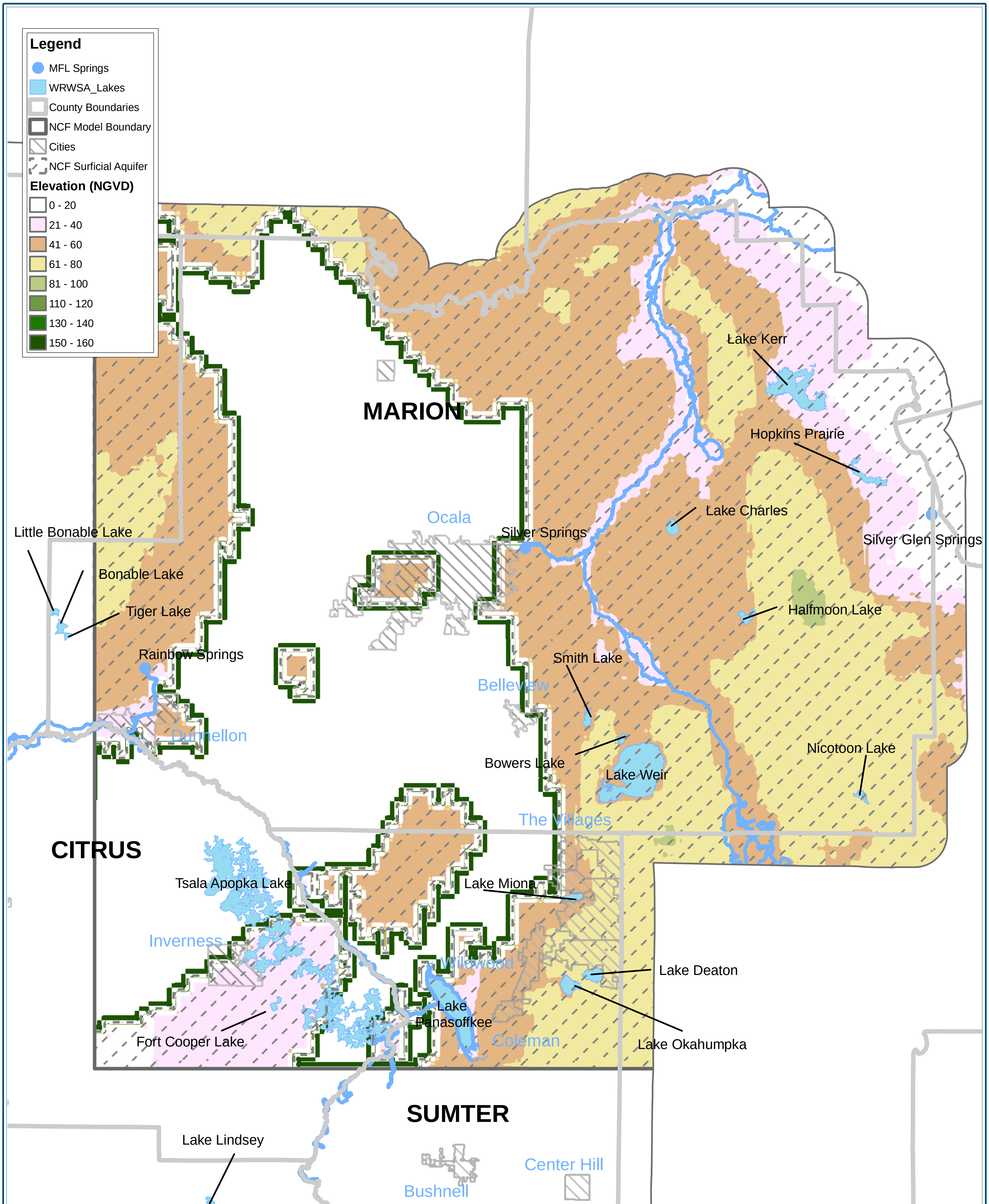

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Figure 3-23
NCF Model Potentiometric Surface Distribution at 1995: SA

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-23.mxd
GIS OPERATOR: DR

N W E S
1 Inch = 9.5 Miles

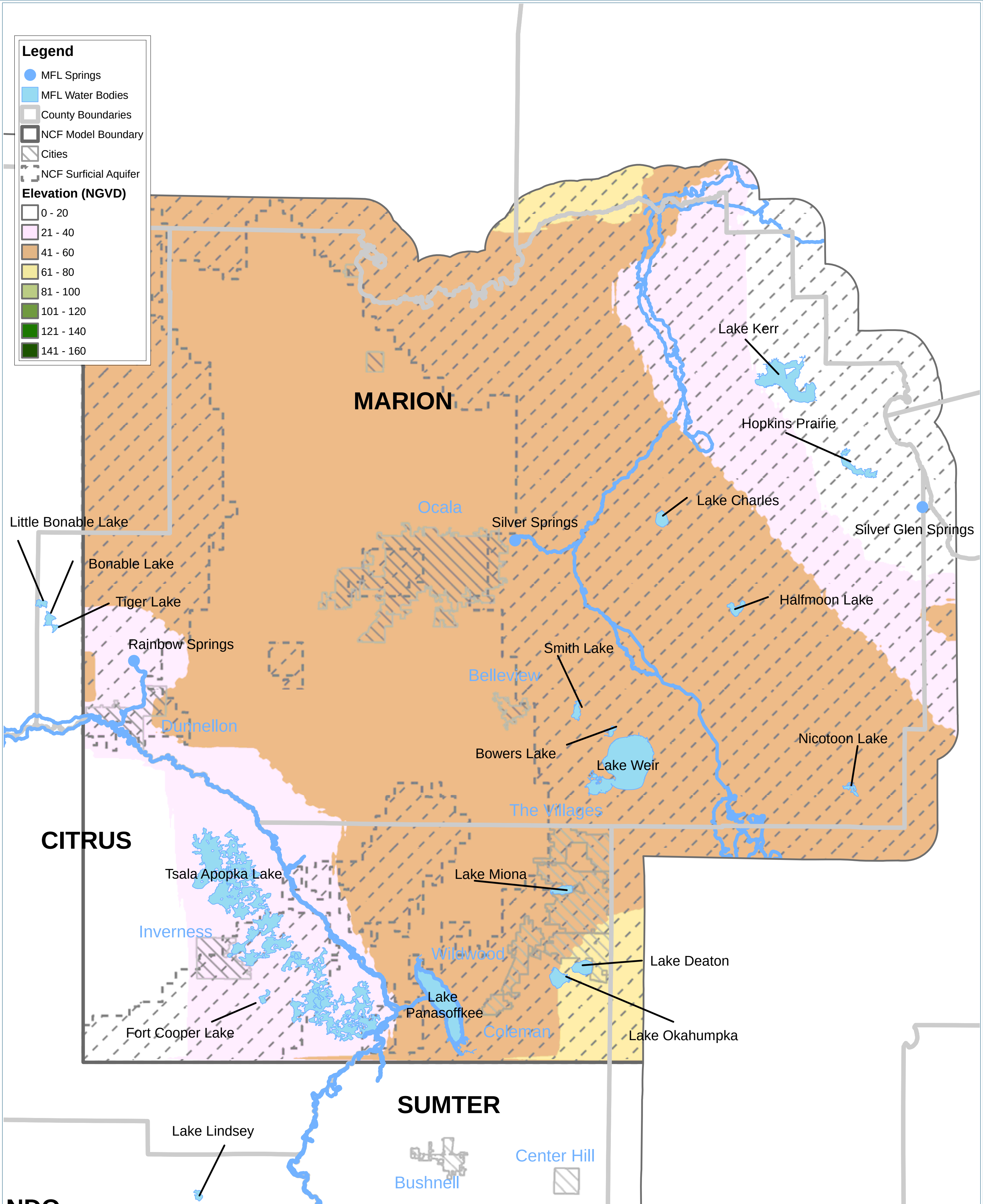

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Figure 3-24
NCF Model Potentiometric Surface Distribution at 1995: UFA

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-24.mxd
GIS OPERATOR: DR

1 Inch = 9.5 Miles

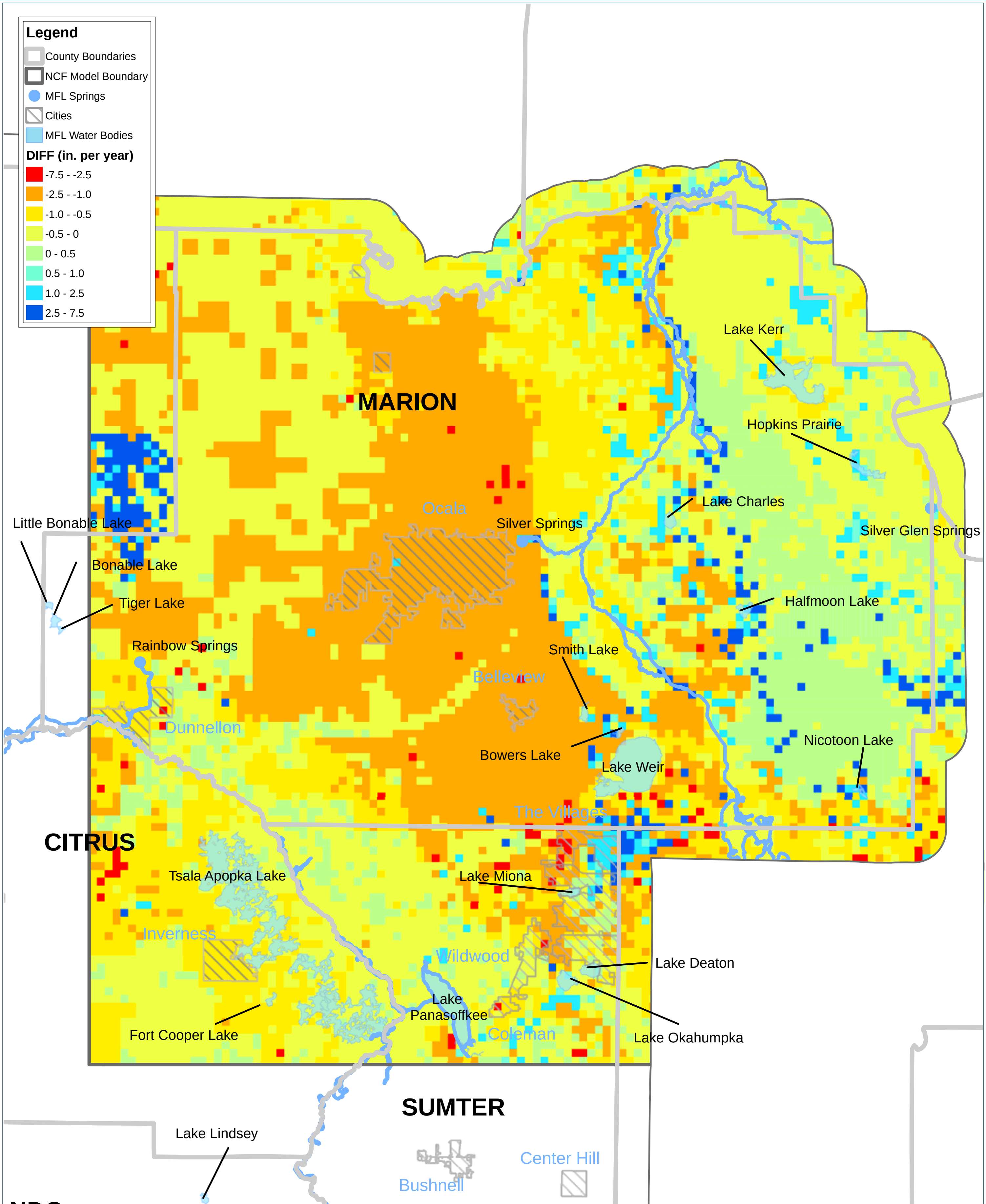

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Figure 3-25
NCF Model Change in Recharge 1995-2030

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-25.mxd
GIS OPERATOR: DR

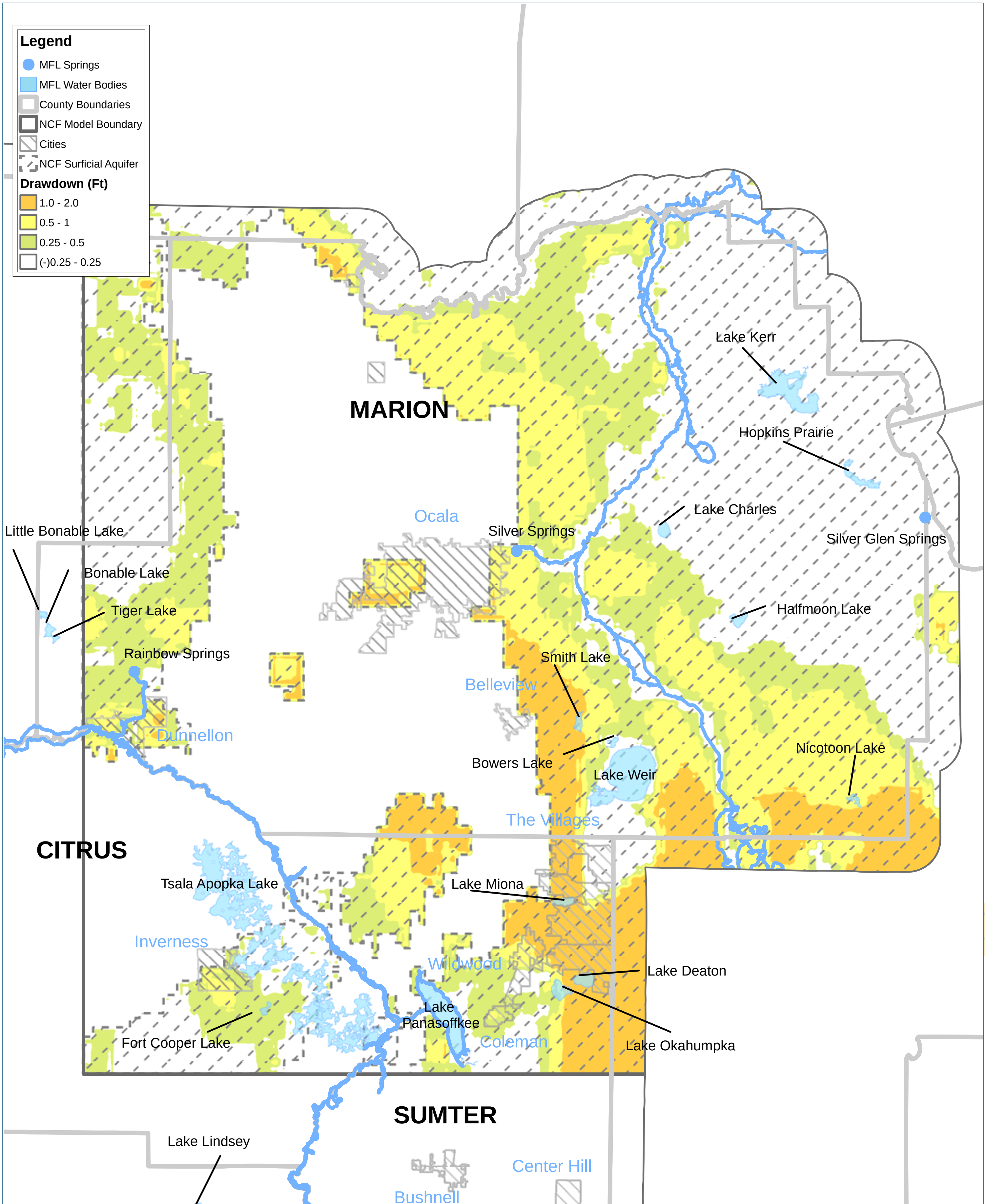

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Figure 3-26
NCF Model 1995 Drawdown Distribution in 2030: Surficial Aquifer

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-26.mxd
GIS OPERATOR: DR

N W E S

1 Inch = 7.7 Miles

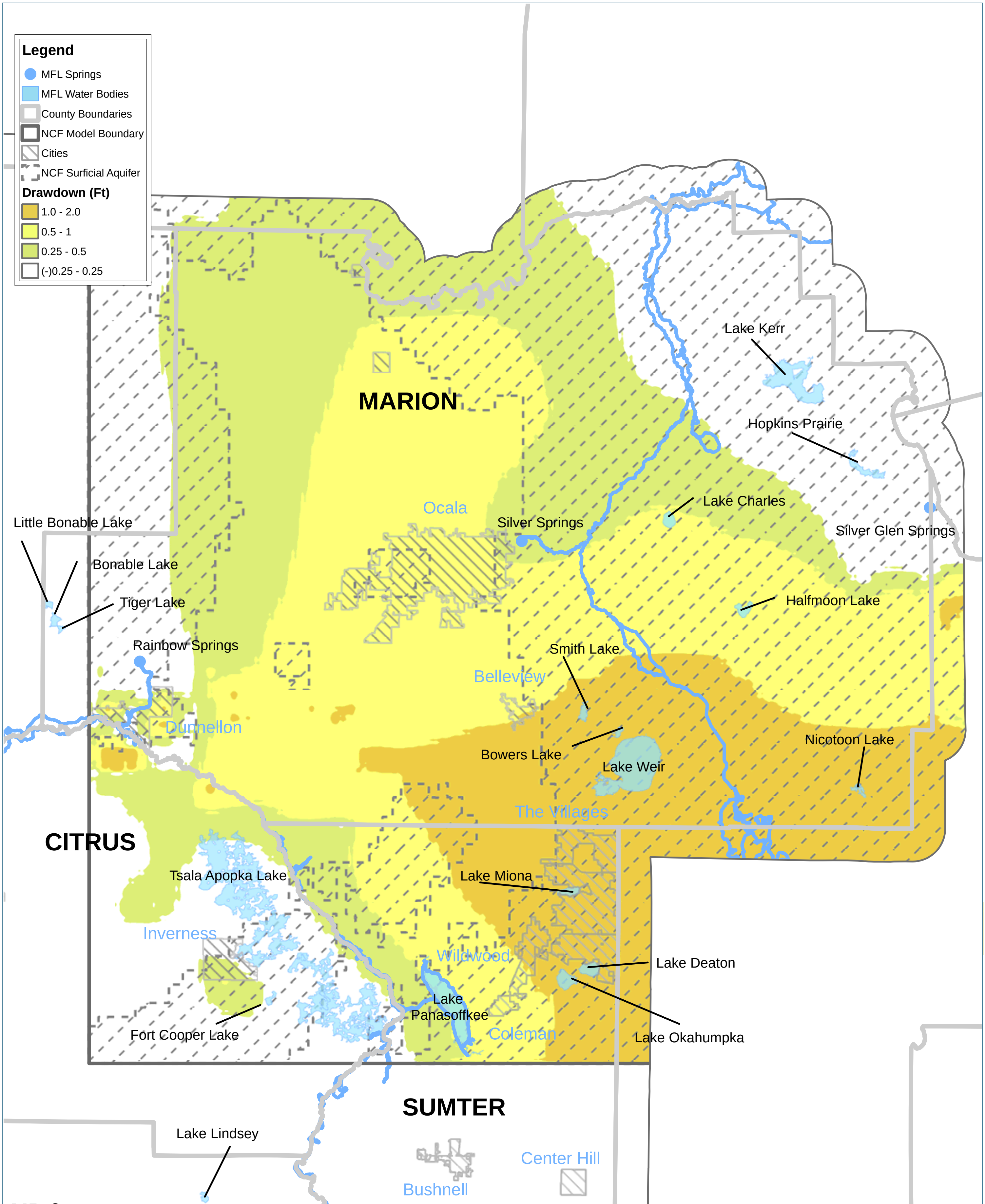

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Figure 3-27
NCF Model 1995 Drawdown Distribution in 2030: Upper Floridan Aquifer

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-27.mxd
GIS OPERATOR: DR

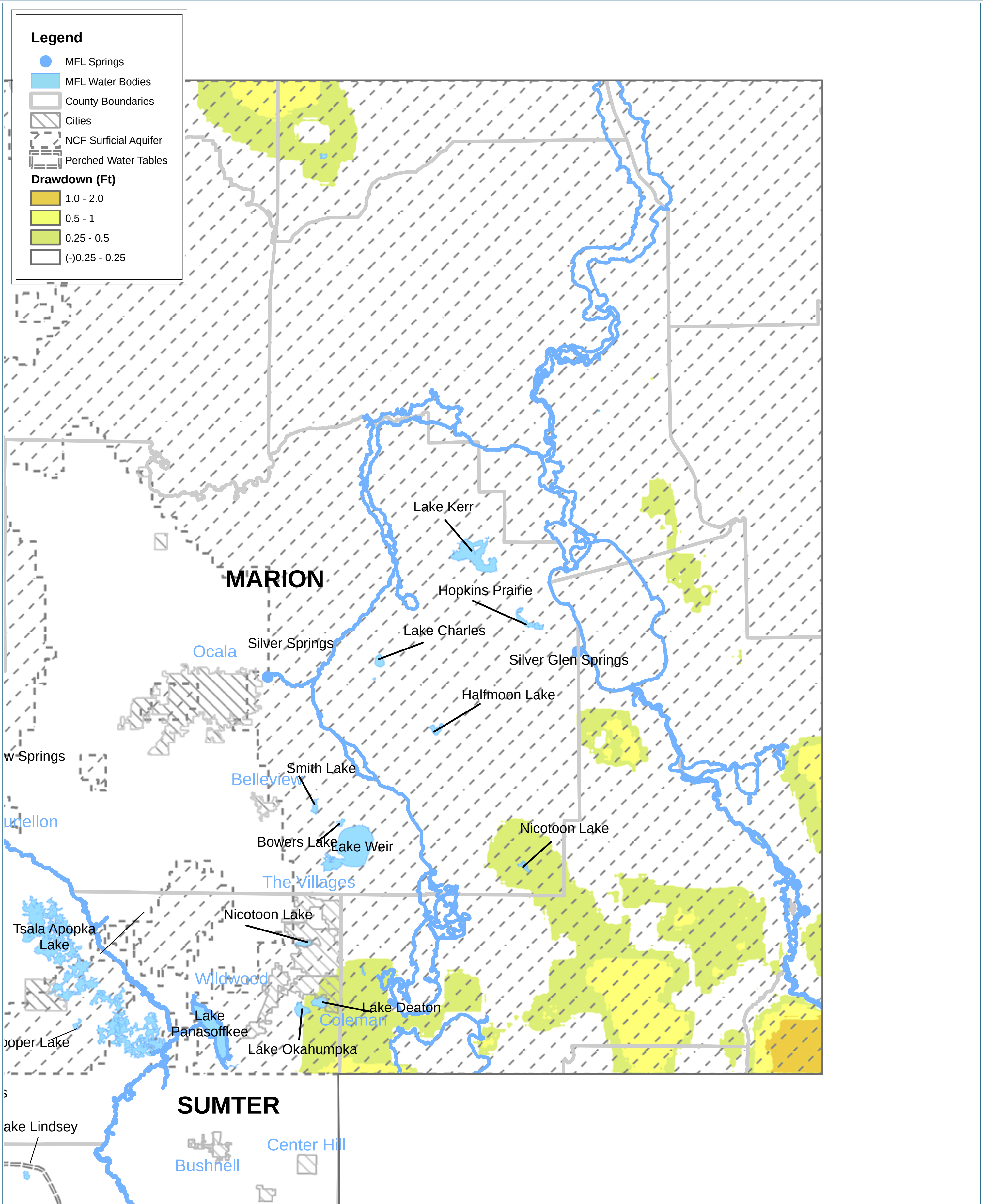

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Figure 3-28
NCF Model SA Drawdown Due to Boundary Condition Withdrawals 1995-2013

ORIGINAL DATE: 07-08-08
REVISION DATE: 1-2-10
JOB NUMBER: 0468
FILE NAME: Figure 3-28.mxd
GIS OPERATOR: DR

1 Inch = 7.1 Miles

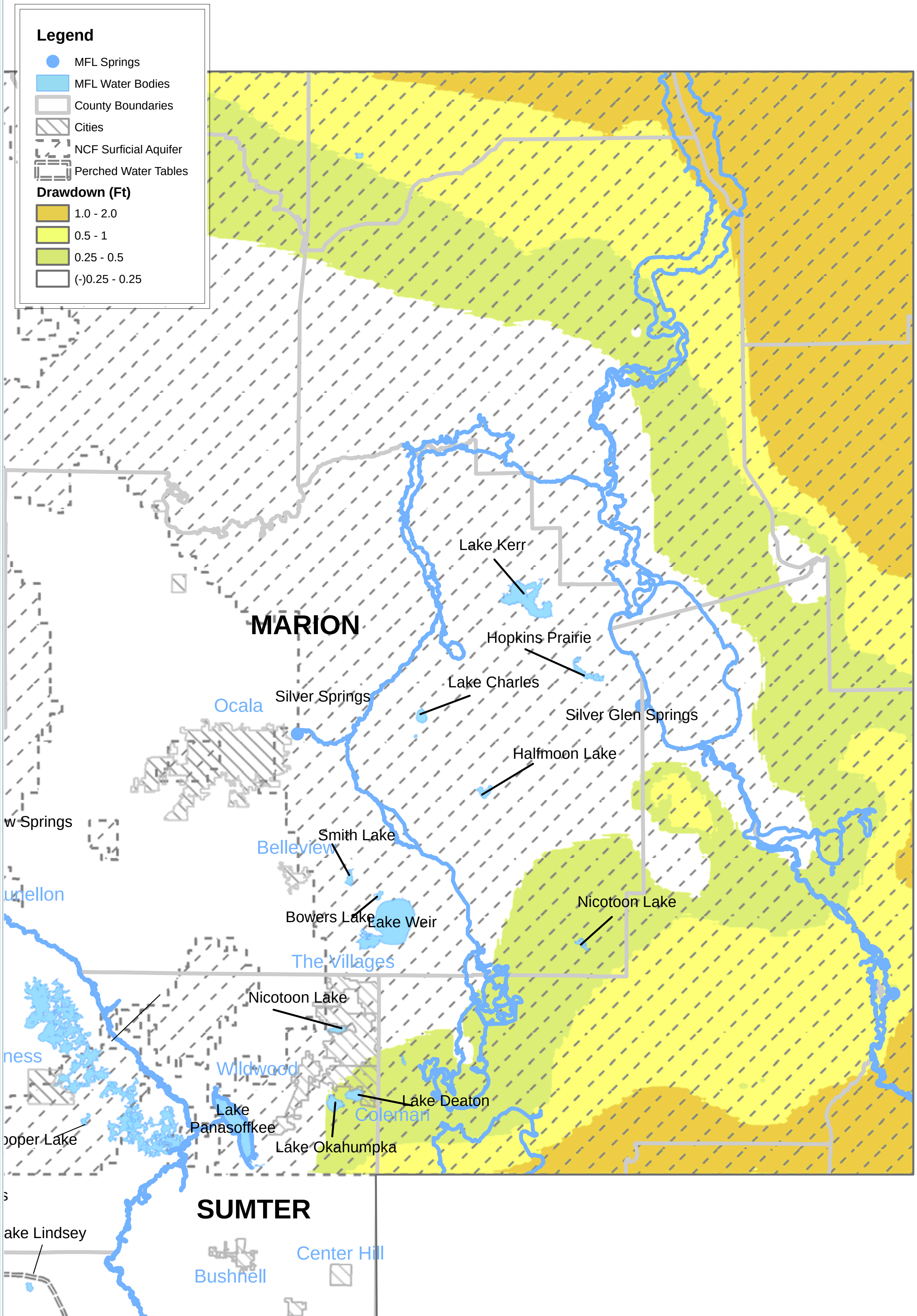

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Figure 3-29
NCF Model UFA Drawdown Due to Boundary Condition Withdrawals 1995-2013

ORIGINAL DATE: 07-08-08
REVISION DATE: 1-2-10
JOB NUMBER: 0468
FILE NAME: Figure 3-29.mxd
GIS OPERATOR: DR

1 Inch = 7.1 Miles

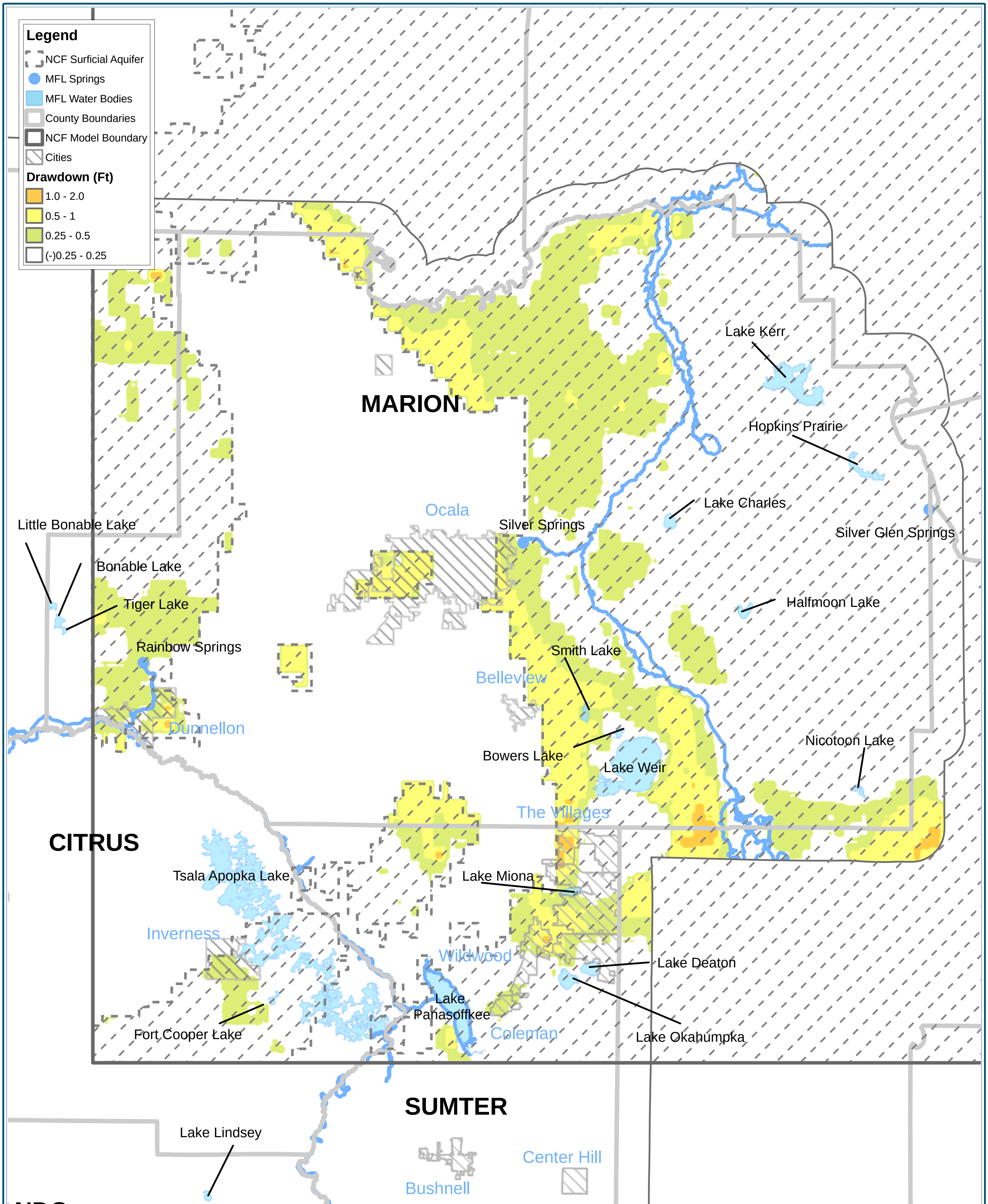

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Figure 3-30
NCF Model SA Change Due to Recharge 1995-2030

ORIGINAL DATE: 07-08-08
REVISION DATE: 2-10-10
JOB NUMBER: 0468
FILE NAME: Figure 3-29.mxd
GIS OPERATOR: DR

N W E S
1 Inch = 7.7 Miles

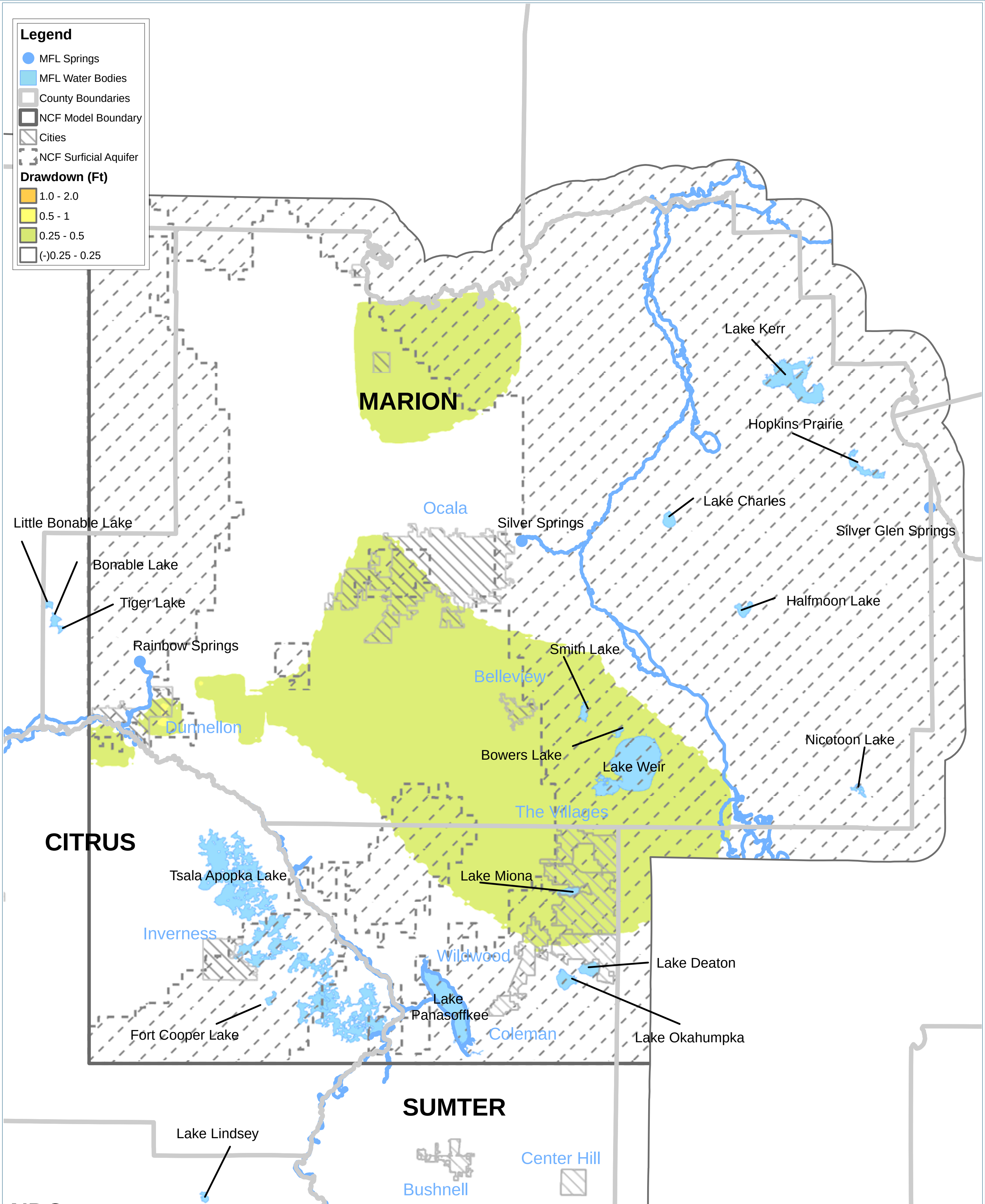

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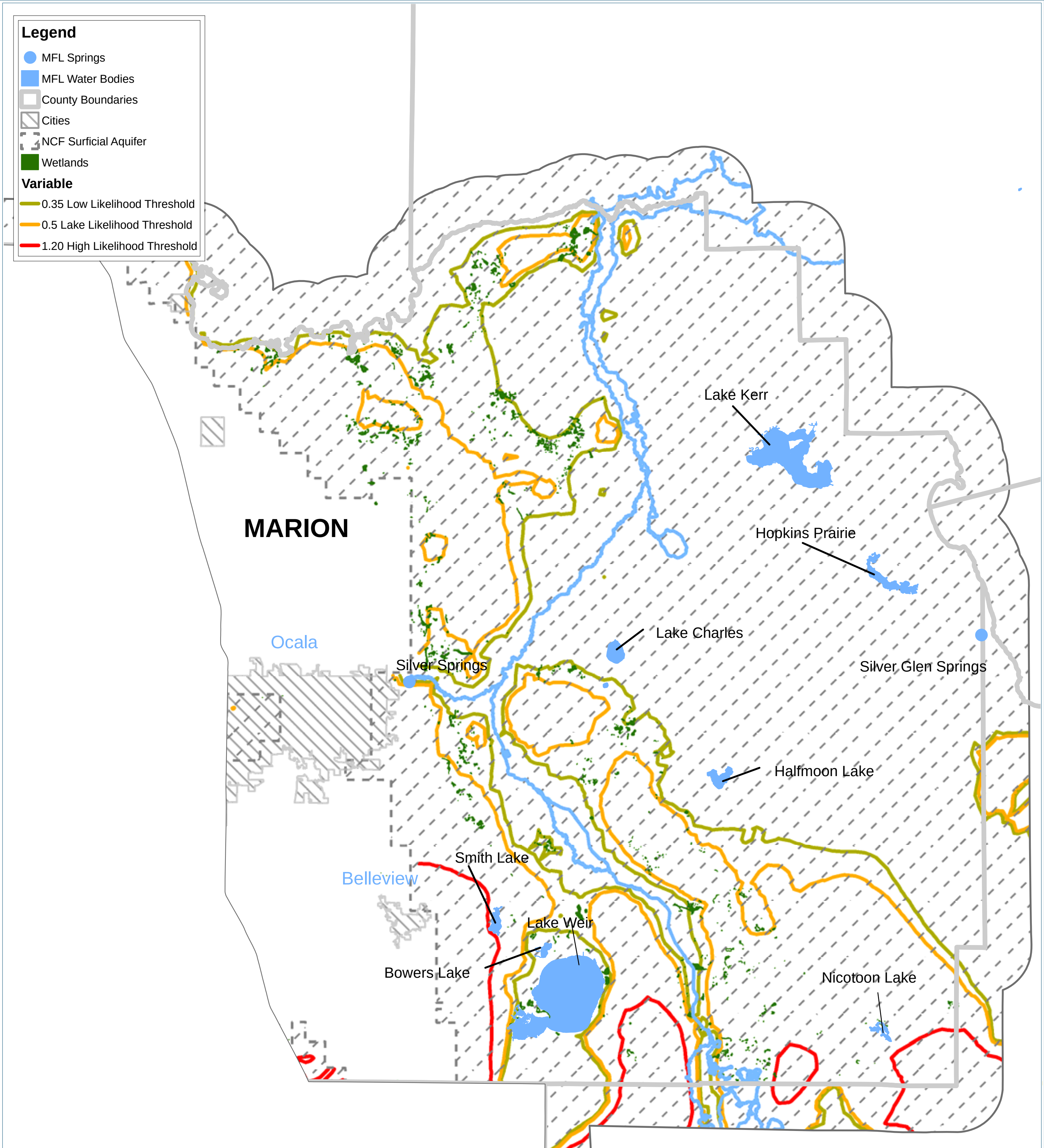
Figure 3-31
NCF Model UFA Change Due to Recharge 1995-2030

ORIGINAL DATE: 01-05-10
REVISION DATE: NA
JOB NUMBER: 0468
FILE NAME: Figure 3-31.mxd
GIS OPERATOR: DR

N W E S

1 Inch = 7.7 Miles



Notes:
1. SWFWMD does not employ likelihood of harm analysis.
2. Likelihood of harm thresholds are not applicable to MFL water bodies, which have separate criteria.

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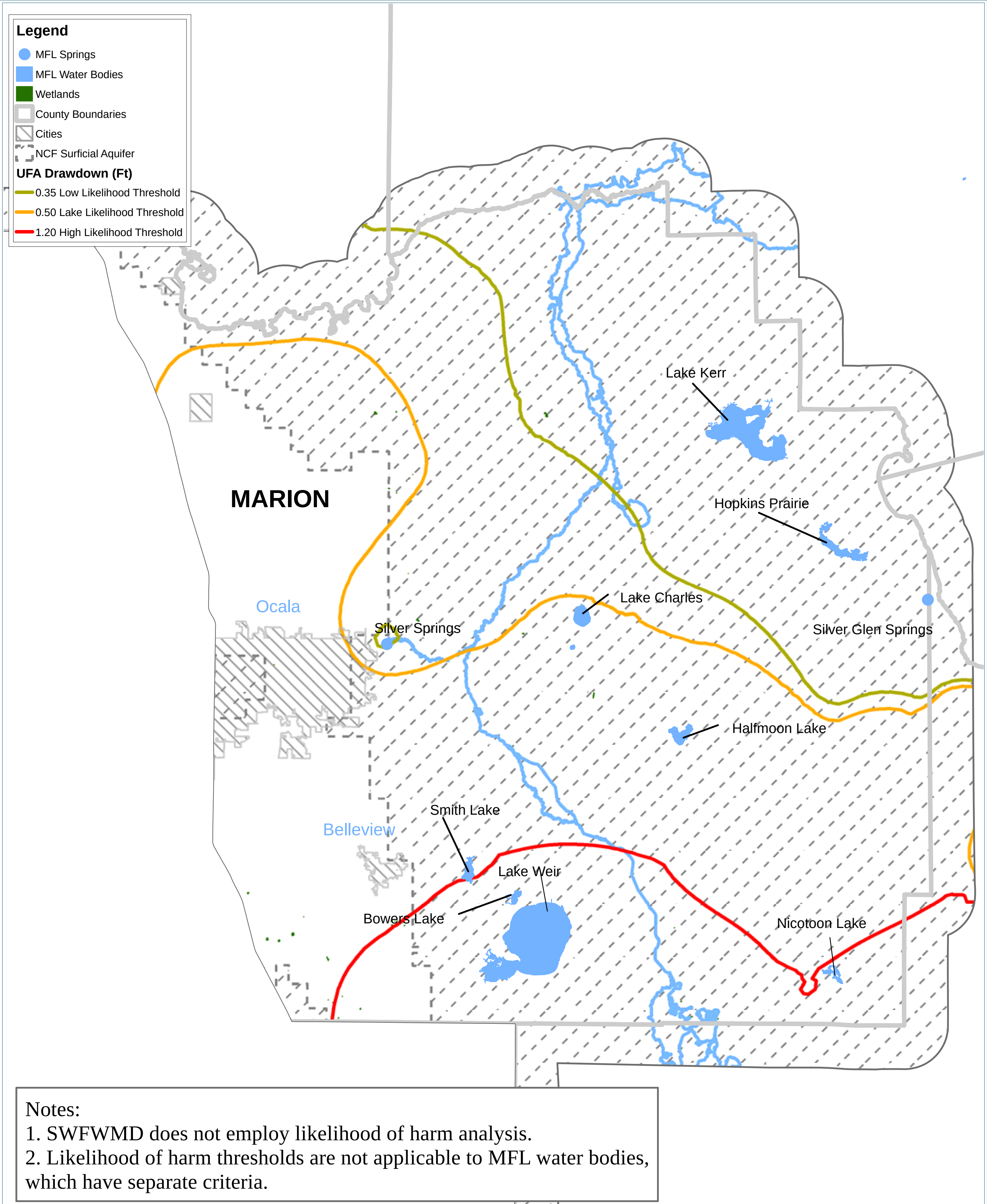
Figure 3-32
NCF Model SA
Likelihood of Harm Analysis

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-32.mxd
GIS OPERATOR: DR

N W E S

1 Inch = 5.8 Miles



Notes:
1. SWFWMD does not employ likelihood of harm analysis.
2. Likelihood of harm thresholds are not applicable to MFL water bodies, which have separate criteria.

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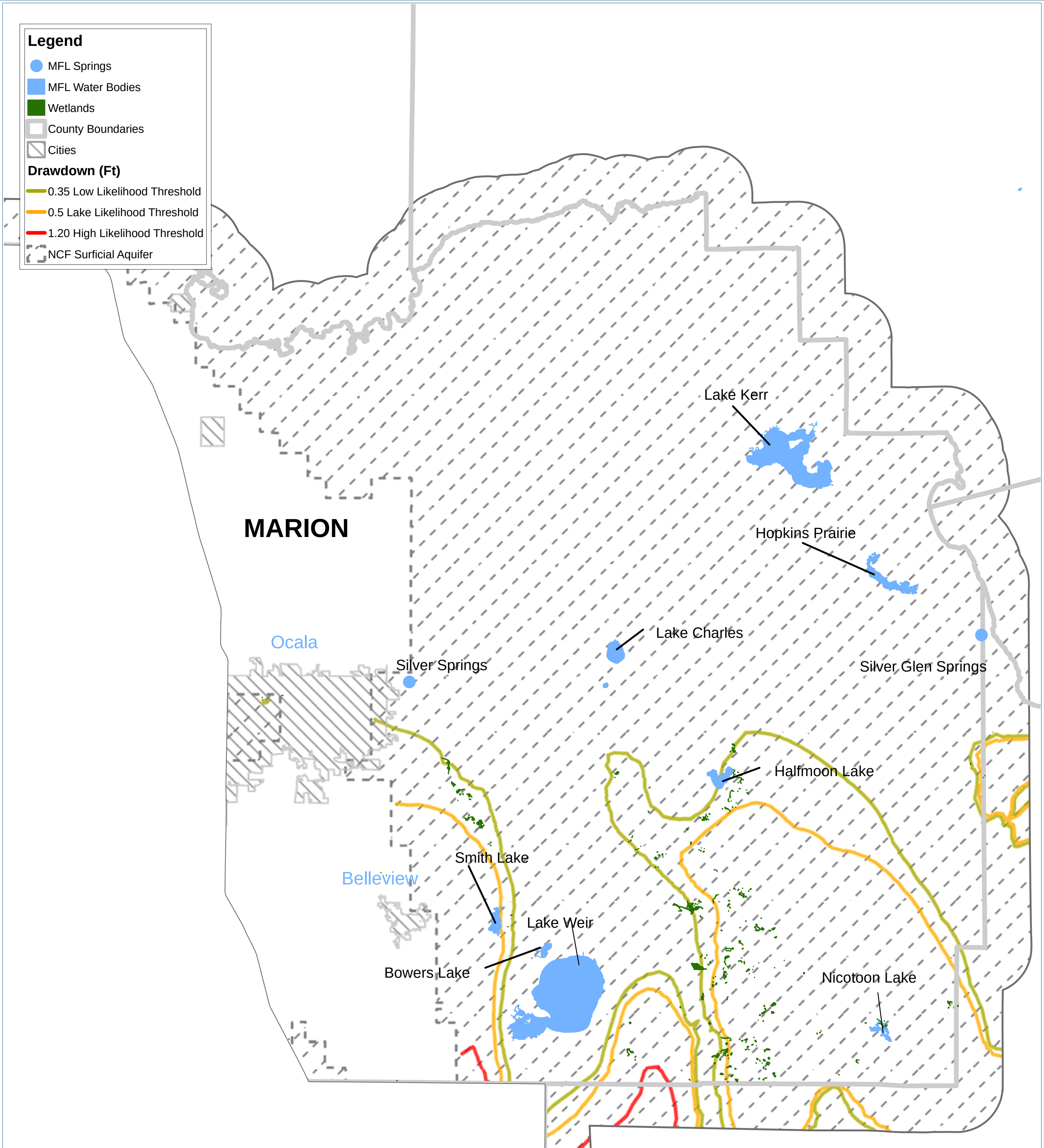
Figure 3-33
NCF Model Unconfined UFA Likelihood of Harm Analysis

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-33.mxd
GIS OPERATOR: DR

N W E S
1 Inch = 5.8 Miles



Notes:
1. SWFWMD does not employ likelihood of harm analysis.
2. Likelihood of harm thresholds are not applicable to MFL water bodies, which have separate criteria.

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Figure 3-34
NCF Model SA Likelihood of Harm Analysis
Sensitivity to Constant Recharge

ORIGINAL DATE: 07-08-08
REVISION DATE: 12-17-09
JOB NUMBER: 0468
FILE NAME: Figure 3-34.mxd
GIS OPERATOR: DR

N W E S
1 Inch = 5.8 Miles

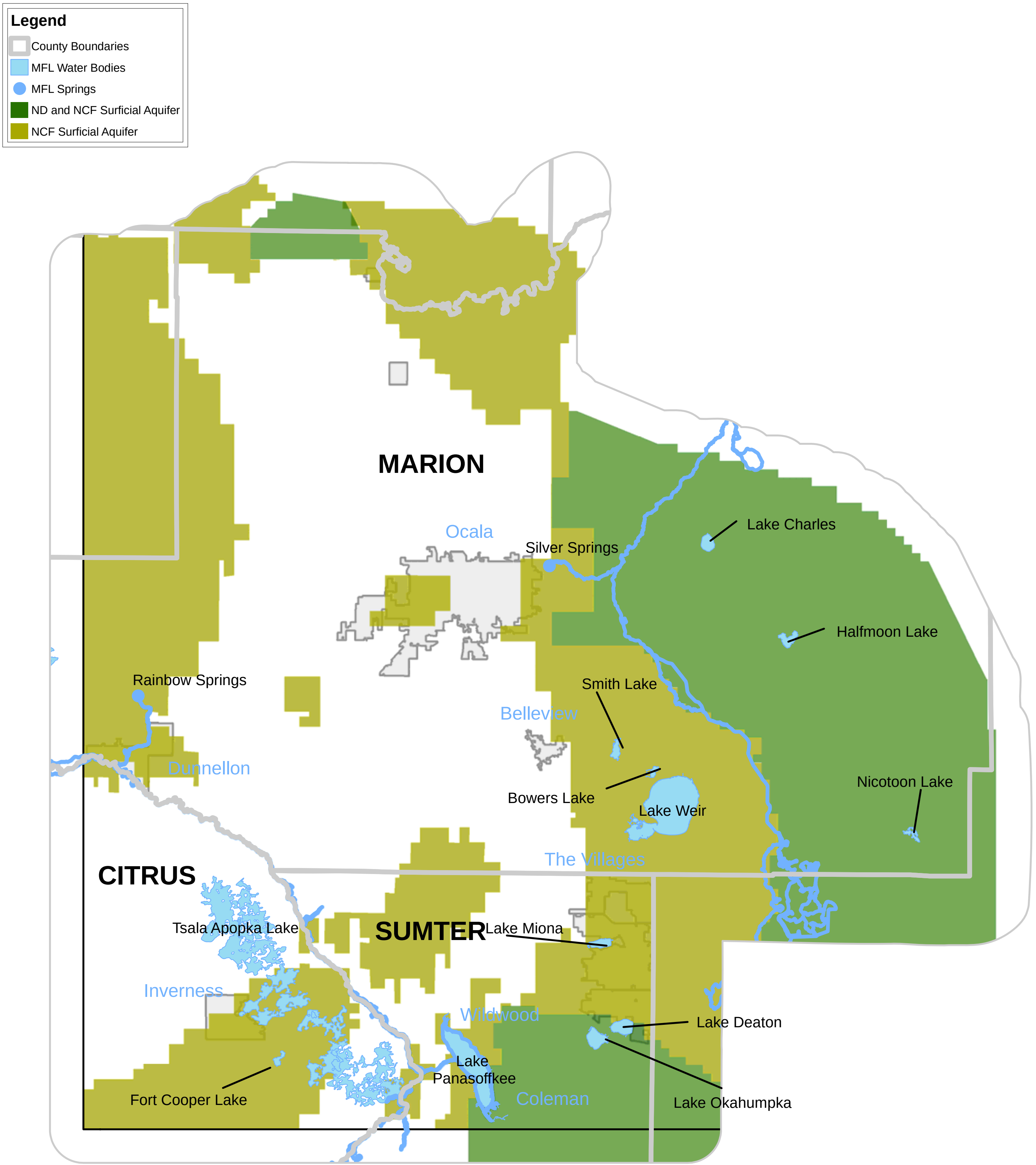

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Figure 3-35
Variation in NCF and ND Model Conceptualization of SA

ORIGINAL DATE: 01-05-10
REVISION DATE: 02-11-10
JOB NUMBER: 0468
FILE NAME: Figure 3-35.mxd
GIS OPERATOR: DR

1 Inch = 9.5 Miles