Appendix 4-2. Groundwater Modeling

1.0 Introduction

For the WRWSA's 2010 Water Supply Plan, The SWFWMD and SJRWMD used regional groundwater flow models to assess the quantity of groundwater that could be developed without causing exceedances of MFL constraints. The SWFWMD used their Northern District model, which covered all of the four-county region except for the portion of Marion County in the SJRWMD. For this area, the SJRWMD used their North-Central Florida groundwater model. Because the models were developed independently, differences in assumptions, aquifer characteristics, grid spacings, and other parameters were incorporated, which caused results to differ.

Following completion of the WRWSA's 2010 Water Supply Plan, the District's agreed to work together to update and expand the SWFWMD's Northern District Groundwater Flow Model (Northern District Model). The expanded boundary included eastern Marion County, with its critical water resources that included the Silver Springs/Silver River system, and parts of Alachua, Levy, Lake, Orange, Polk, Pasco, Pinellas, Putnam, and Hillsborough Counties. Figure 4-2 in the Water Supply Plan shows the domain of the revised model. The update also included a number of refinements, the most important of which was a more sophisticated representation of the Lower Floridan aquifer that represents the current, albeit limited, understanding of the extent and characteristics of the aquifer.

2.0 Description of the Northern District Model

The ND Model is a regional groundwater flow model used to simulate transient conditions. The ND Model utilizes MODFLOW-SURFACT groundwater flow and solute transport modeling code. MODFLOW-SURFACT is an updated version of the USGS Modular three-dimensional groundwater flow code. MODFLOW-SURFACT specializes in saturated and unsaturated conditions in unconfined aquifers and has the ability to simulate groundwater-seepage faces and open-borehole wells that penetrate multiple aquifer units.

The regional model finite-difference grid consists of 212 columns and 275 rows with uniform grid spacing of 2,500 feet. The model extent includes the St. Johns River as the eastern boundary. The western boundary extends approximately five miles offshore in the Gulf of Mexico to be used in future iterations to determine regional salt water intrusion. The model was constructed to contain seven layers to represent the major hydrostratigraphic units.

- Layer 1 – surficial aquifer unit (SAS)
- Layer 2 – intermediate confining unit (ICU)
- Layer 3 – Suwannee Limestone
- Layer 4 – Ocala Limestone
- Layer 5 – Upper Avon Park Formation
- Layer 6 – Middle Confining Unit (MCU) I and II
- Layer 7 – Lower Avon Park Formation or Oldsmar Formation

The Upper Floridan Aquifer System (UFAS) is composed of the Suwannee Limestone, Ocala Limestone and the Upper Avon Park Formation. The Lower Floridan Aquifer System (LFAS) comprises the permeable sections of both Lower Avon Park and the Oldsmar Formation.

In regions where the ICU is missing, layer 2 represents the uppermost portion of the UFAS. The Suwannee Limestone is absent over large sections of the model and in these areas, layers 3 and 4 represent the Ocala Limestone. The Ocala Limestone is absent in localized portions of northern region of the model domain and in this area, model layers 3 to 5 represent the Upper Avon Park Formation. The Oldsmar Formation is assumed to have relatively low permeability similar to the permeability of the overlying MCU II (which includes the Lower Avon Park Formation), except in the eastern portion of the model domain. Therefore, the finite-difference cells representing the LFAS in Layer 7 are active only in this eastern region.

The external boundary conditions used to represent the lateral and lower model boundaries of the model include constant-head, general-head, or no-flow boundary conditions. The SAS (Layer 1) along the southeastern boundary is represented by constant-head boundary conditions of prescribed model heads. The southeastern boundary extends through southwestern Orange, Polk, and Hillsborough Counties. The western boundary of the model was also assigned constant-head boundary conditions to represent the saltwater interface along the gulf coast. Equivalent freshwater heads were assigned for all finite-difference cells located along the Gulf of Mexico for all layers replacing saltwater heads via conversion.

Regional scale modeling results (Sepulveda, 2002) were duplicated to assign general-head boundary conditions along the southeastern section of the model domain in southwestern Orange and northern Polk Counties. The general-head boundary conditions were assigned to the Suwannee Limestone (Layer 3), Ocala Limestone (Layer 4) and the Upper and Lower Avon Park Formations (Layers 5 and 7). The SAS boundary near Keystone Heights was also assigned a general-head boundary condition (HGL, 2013).

The remaining lateral boundaries not defined with constant-head or general-head boundaries were assigned no-flow boundary conditions. This includes the ICU (Layer 2) and MCU I and II (Layer 6) boundaries due to the semi-confining nature of the hydrogeologic units with groundwater flow predominately in the vertical direction. In the western section of the model, no flow-boundaries are assigned to the base of Layer 6 to represent MCU II. This is based on the assumption that the Oldsmar Formation in this area has permeability that is similar to MCU II. In this section of the model, the LFAS is represented by inactive cells and groundwater flow is not simulated (HGL, 2013).

In the ND Model, recharge is calculated through a water-budget methodology that accounts for the major components of the hydrologic cycle: precipitation, evapotranspiration and runoff. Initial Hydraulic parameter values used in the ND Model were taken from previous iterations of the model developed by HGL, LLC. Initial hydraulic parameters for the expanded areas of the model domain were taken from existing models that overlap or are adjacent to the expanded areas. These models include the Volusia County Model, the East Central Model and the North-Central Florida Model (HGL, 2013). Additional transmissivity values for the LFAS in Marion, Sumter, Lake and Orange Counties were collected from other data sources (HGL, 2013)

The ND Model was calibrated to average, steady-state conditions observed in 1995. Once the steady-state ND Model was calibrated, the regional model was calibrated to observed transient conditions from 1996 to 2006. This period encompasses abnormal precipitation conditions including wet (El Nino 1997 to1998) dry (1999 to 2000 drought) and wet (2004) periods (HGL, 2013). The SWFWMD provided the 2035 water demand projections for the entire model boundary; which are detailed in Chapter 3 of the Water Supply Plan.

3.0 Modeling Scenarios

3.1 Scenario 1. Pre-development (No-Pumpage)

The ND model was used to simulate a pre-development or no pumpage scenario. The pre-development scenario used the calibrated transient model removing all groundwater withdrawals (domestic self-supply users and permitted withdrawals). The simulation was run for 365 days to allow water levels to reach equilibrium throughout the model domain. The water levels and spring-flows calculated under the pre-development scenario served as the basis to which all other model scenario results are compared, as described in Chapters 4 and 5 of the Water Supply Plan.

3.2 Scenario 2. 2035 Adjusted Water Use Demand Scenario

The SWFWMD used the ND Model to conduct a comprehensive evaluation of the impacts of projected 2035 groundwater withdrawals from the UFAS and LFAS on MFL waterbodies in the WRWSA region. Groundwater withdraws were set equal to the projected 2035 demand in the model domain, approximately 637 mgd and 6.5 mgd from the UFAS and LFAS, respectively, and distributed throughout the region based on the location of where the demands were projected to occur. The withdrawals were adjusted by the SWFWMD to account for water conservation and use of reclaimed water. The adjustments for water conservation included reductions of 10 percent for public supply, 10 percent for agriculture, and 20 percent for recreational/aesthetic, which were considered to be reasonable targets. The higher percentage allocated to recreation is due to the likely application of reclaimed water to some of the golf courses. The effects of reclaimed water use projected for 2035 were represented in the model as an increase in recharge in the vicinity of reclaimed water facilities (HGL, 2013). The recharge factors chosen were based on those that were published by the Florida Department of Protection (Page 19, FDEP, 2013). The adjusted water demand scenario was simulated for five years to determine the effect of increased recharge on the extent of potential impacts caused by the projected demands.

3.2.1 Aquifer Drawdowns

Aquifer drawdown was predicted by calculating the difference in surficial and UFAS water levels from pre-pumping conditions to 2035. Drawdowns predicted by the model in the surficial and Upper Floridan aquifer varied across the WRWSA and are shown in Figures 1 through 3. The range-of-drawdowns in each county were as follows: Citrus County, 0.0 to 0.5 feet, Hernando County, 0.0 to 3.0 feet, Sumter County, 0.0 to 4.0 feet and Marion County 0.0 to 4.0 feet. The largest drawdowns were located in the vicinity of concentrated centers of groundwater withdrawals.

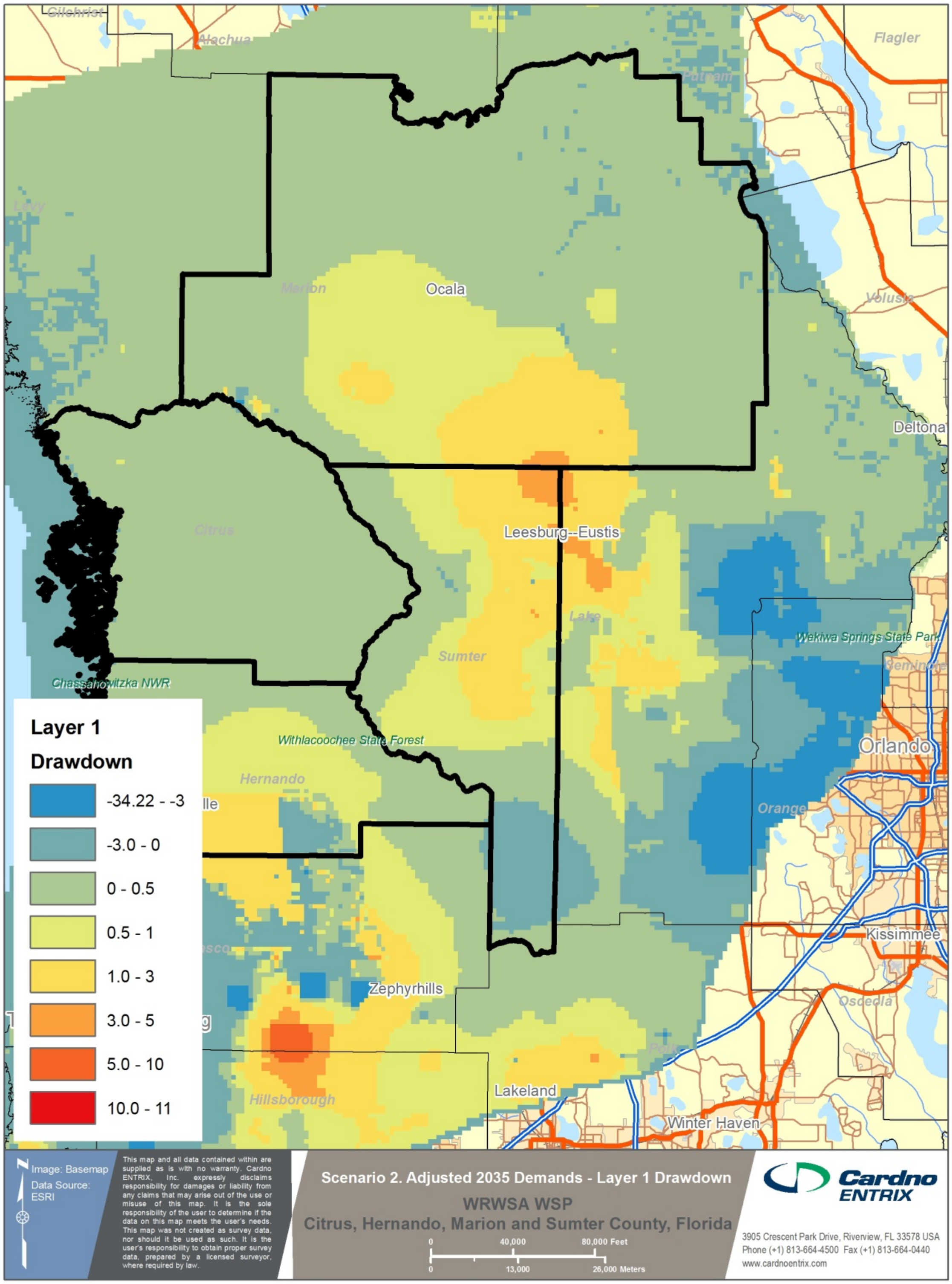

Figure 1. Scenario 2 Predicted 2035 Drawdown in Layer 1.

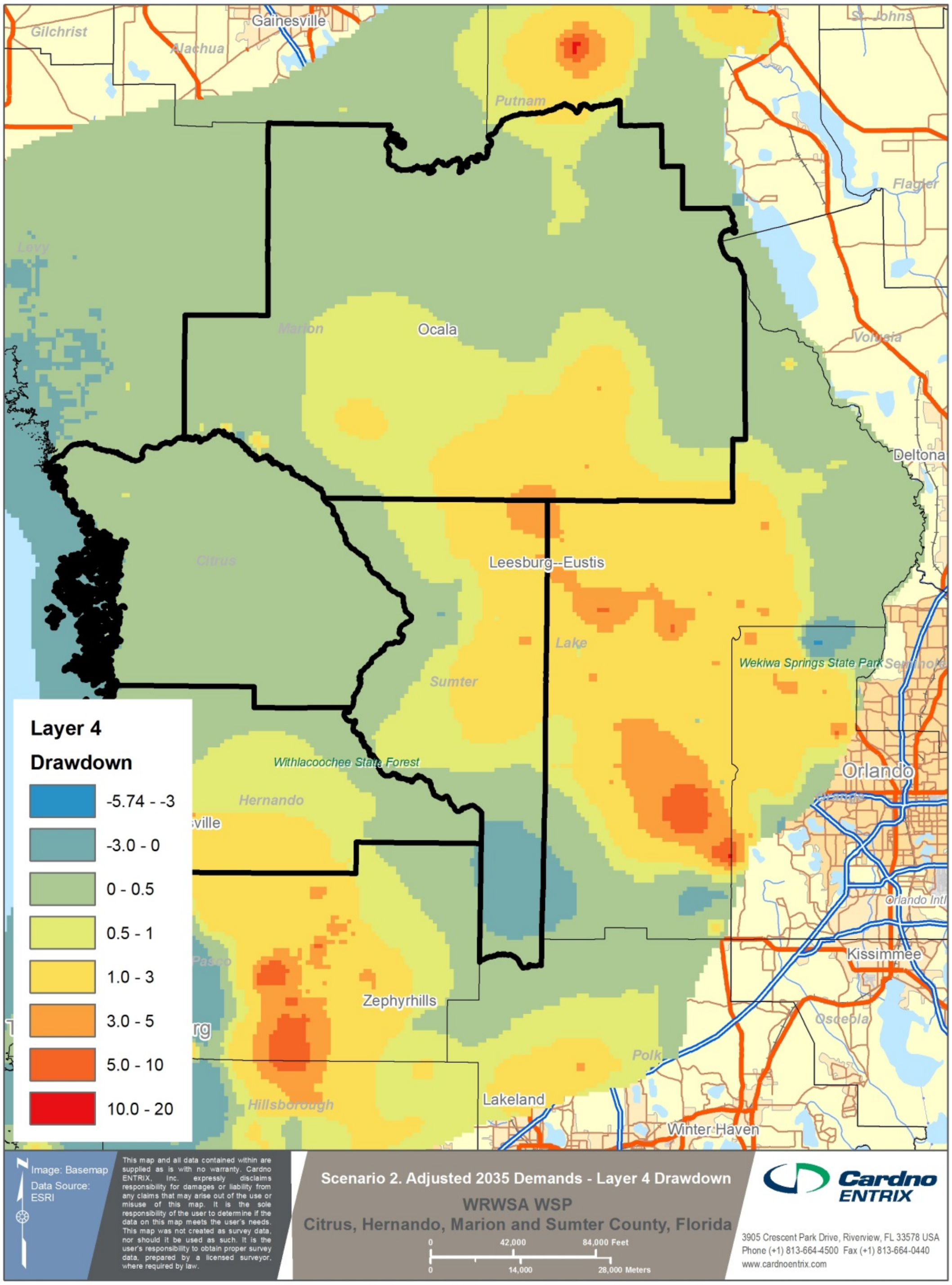

Figure 2. Scenario 2 Predicted 2035 Drawdown in Layer 4.

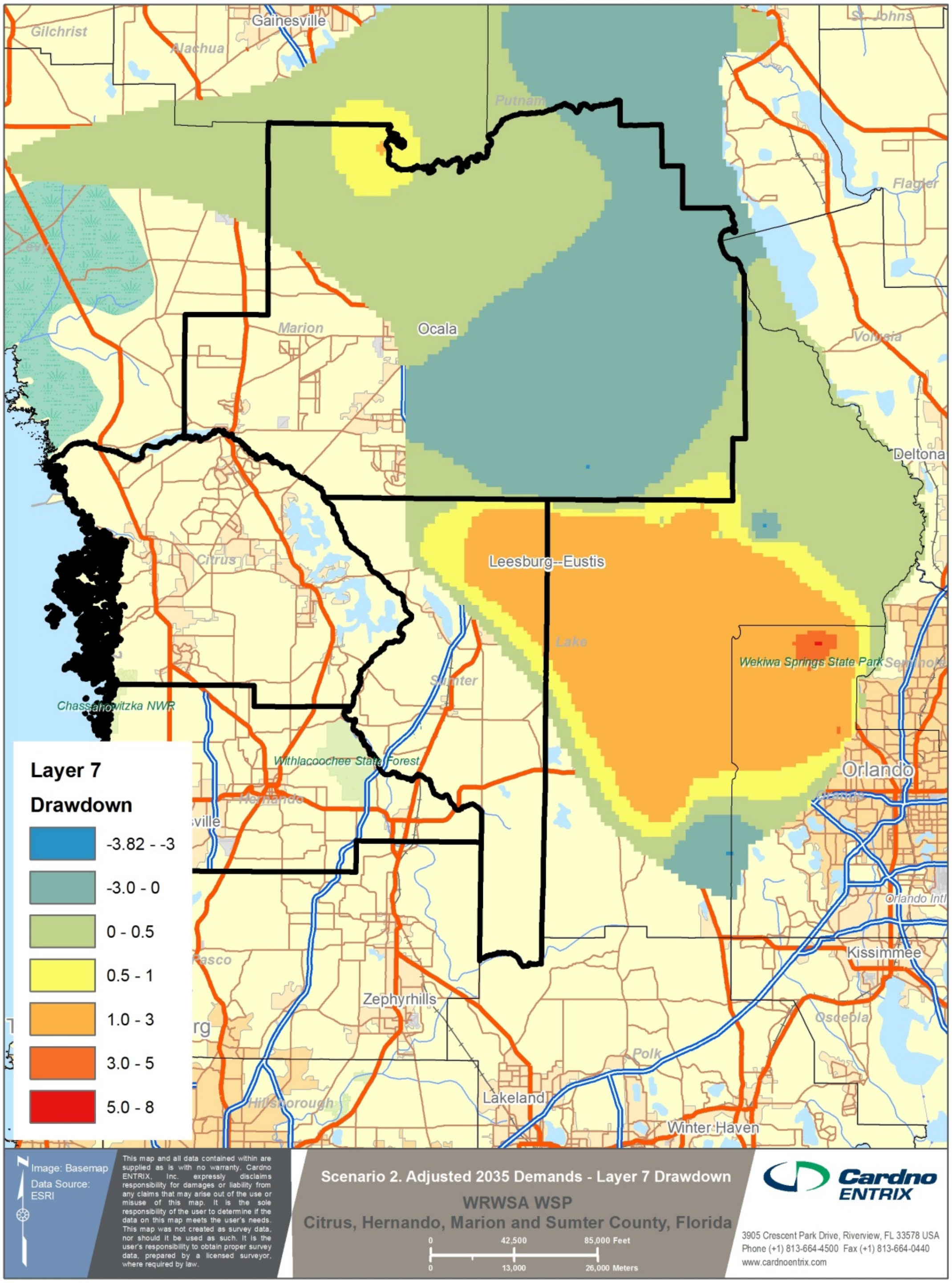

Figure 3. Scenario 2 Predicted 2035 Drawdown in Layer 7.

3.2.2 Spring Flow

Reductions in the flow of springs from pre-pumping conditions to 2035 that would result from projected groundwater withdrawals are shown in the following tables.

Weeki Wachee Spring System - The minimum flow adopted for the Weeki Wachee Springs System allows for a 10 percent reduction in flow. The table shows that the predicted decline for the system of 6.5 percent, resulting from projected 2035 groundwater withdrawals, does not exceed the allowable 10 percent reduction.

Weeki Wachee Springs System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Weeki Wachee Spring	157.2	145.7	7.3
Jenkins Creek Spring	18.0	17.4	3.0
Mud Spring	8.6	7.9	7.7
Salt Spring	22.4	21.8	2.7
Weeki Wachee River and Spring System	**206.1**	**192.8**	**6.5**

Chassahowitzka Springs System - The minimum flow adopted for the Chassahowitzka Springs System allows for a 3 percent reduction in flow. The table shows that the predicted decline for the system of 1.9 percent, resulting from projected 2035 groundwater withdrawals, does not exceed the allowable 3 percent reduction.

Chassahowitzka Springs System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Chassahowitzka Main Spring	65.7	64.1	2.3
Crab Spring	33.8	32.8	2.9
Potter Creek	14.7	14.4	2.2
Blind Spring	42.8	42.7	0.4
Chassahowitzka River and Spring System	**157.0**	**154.0**	**1.9**

Homosassa Springs System - The minimum flow adopted for the Homosassa Springs System allows for a 3 percent reduction in flow. The table shows that the predicted decline for the system of 2.9 percent, resulting from projected 2035 groundwater withdrawals, does not exceed the allowable 3 percent reduction.

Homosassa Springs System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Homosassa 1 Spring	85.0	82.9	2.5
SE Fork Homosassa Spring	36.5	35.6	2.4
Halls River Head Main Spring	99.6	96.8	2.8
Halls River 1 Spring	6.3	6.1	2.4
Hidden River Head Spring	5.8	5.1	11.5
Trotter Spring	4.9	4.8	2.5
Belcher Spring	4.8	4.5	6.7
Abdoney Spring	5.6	5.5	2.5
McClain Spring	5.6	5.5	2.5
Pumphouse Spring	4.2	4.1	2.4
Homosassa River and Spring System	**258.4**	**250.9**	**2.9**

Gum Slough and Springs System - The minimum flow proposed for the Gum Slough Springs System allows for a 9 percent reduction in flow. The table shows that the predicted decline for the group of 6.3 percent, resulting from projected 2035 groundwater withdrawals, does not exceed the allowable 9 percent reduction.

Gum Slough and Spring System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Gum Springs 1	89.5	83.7	6.5
Alligator Spring	5.8	5.6	2.6
Gum Slough and Spring System	**95.3**	**89.3**	**6.3**

King's Bay Springs System - The SWFWMD has not yet proposed minimum flows for the King's Bay Springs System. The table shows that the predicted decline for the system resulting from projected 2035 groundwater withdrawals is 2.2 percent.

Kings Bay Springs System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Tarpon Spring	4.1	4.0	2.6
House Spring	2.5	2.3	6.0
Hunter's Spring	3.7	3.6	0.2
Manatee Sanctuary Spring	98.7	96.6	2.2
Three Sister's Run Spring 2	3.7	3.6	0.2
Three Sister's Run Spring	3.7	3.6	0.2
Idiot's Delight Spring	3.7	3.6	0.2
Crystal Spring	345.7	338.0	2.2
Kings Bay	**465.5**	**455.4**	**2.2**

Rainbow Springs System – The SWFWMD has not yet proposed minimum flows for the Rainbow Springs System. The table shows that the predicted decline for springs in the system resulting from projected 2035 groundwater withdrawals is 2.6 percent.

Rainbow Springs System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Rainbow 1 Spring	643.1	626.5	2.6
Bubbling Spring	1.7	1.7	2.4
Waterfall Spring	4.5	4.4	1.3
Rainbow Springs System	**649.3**	**632.6**	**2.6**

Silver Springs System – The table shows that the predicted decline for the springs resulting from projected 2035 groundwater withdrawals is 7.0 percent. As discussed previously, MFLs for Silver Springs/Silver River are being developed by the SJRWMD and will likely impact resource availability. Based on current analyses, the current draft MFLs would not be met under 2035 projected demand. The SJRWMD is working on tools to assist in the development of a prevention/recovery strategy.

Silver Springs.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Silver Springs	**683.45**	**635.38**	**7.0**

Silver Glen Springs - The SJRWMD has not yet proposed a minimum flow for Silver Glen Springs. The table shows that the predicted decline for the spring resulting from projected 2035 groundwater withdrawals is 0.1 percent.

Silver Glen Springs.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flow (cfs)	2035 Percent Change
Silver Glen Springs	108.0	107.9	0.1

3.2.3 River Flow

River systems in the WRWSA four-county region include the Withlacoochee and Ocklawaha Rivers. Draft minimum flows have been developed for the rivers by the Districts. The following is a discussion of how the predicted changes in the baseflow of the rivers resulting from projected 2035 groundwater withdrawals affect their proposed minimum flows.

Withlacoochee River – The table below shows that the predicted decline in baseflow for the Withlacoochee River at Croom and Holder, resulting from projected 2035 groundwater withdrawals, is 4.5 percent and 10.3 percent, respectively.

Predicted Reduction in Baseflow in 2035 for the Withlacoochee River at Croom and Holder.

River Segment	Pre-Pumpage Flow (cfs)	Predicted 2035 Flow (cfs)	Percent Flow Reduction
Withlacoochee at Croom	77.6	74.1	4.5
Withlacoochee near Holder	315.2	282.7	10.3

The following procedure was used to determine whether the predicted reductions in baseflow of the Withlacoochee River resulted in exceedences of the draft minimum flows at Croom and Holder. Figures 4 and 5 are graphs for the Croom and Holder locations that show the historic median daily flow (blue line) and the draft minimum flow (black line), which is the historic median daily flow reduced by the allowable reductions for each seasonal flow block.

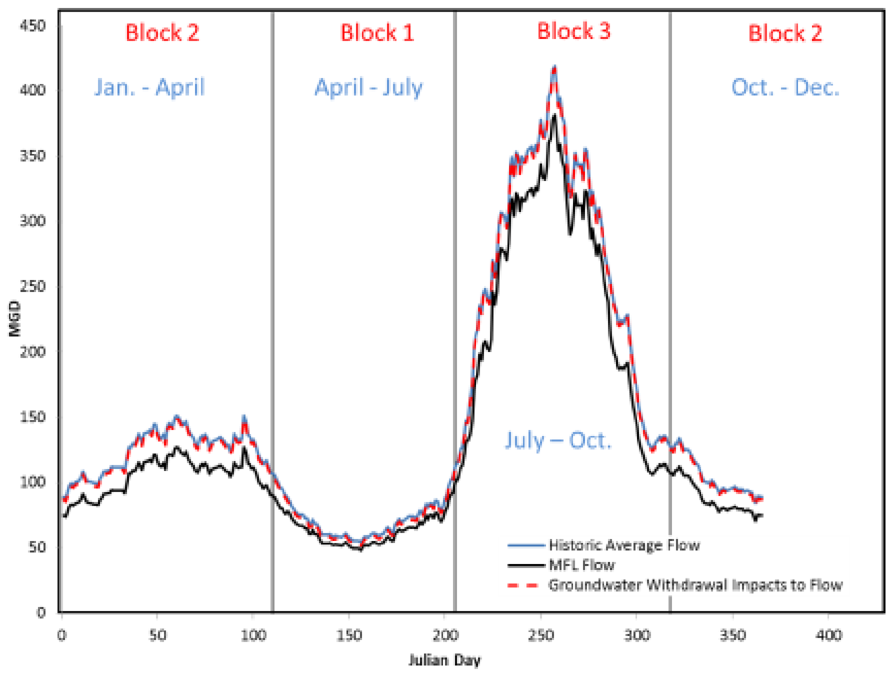

Figure 4. Predicted Reduction in Baseflow for the Withlacoochee River at Croom Resulting from Projected 2035 Groundwater Withdrawals, Relative to the Historic Median Daily Flow and the Draft Minimum Flow.

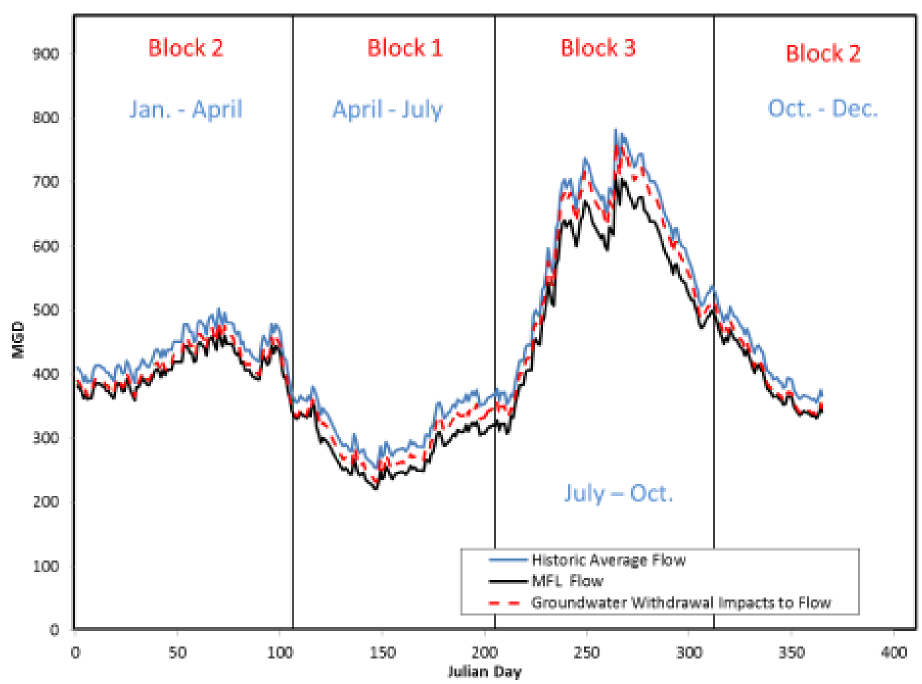

Figure 5. Predicted Reduction in Baseflow for the Withlacoochee River at Holder Resulting from Projected 2035 Groundwater Withdrawals, in Relation to the Historic Median Daily Flow and the Draft Minimum Flow.

The predicted baseflow reductions were subtracted from the historic median daily flows at Croom and Holder and the resulting flow was plotted on the graphs (dashed red line). If the line representing the predicted baseflow reduction was above the draft minimum flow line, the minimum flow was not exceeded. The figure shows that this was always the case and therefore, the predicted reduction in groundwater baseflow resulting from the projected 2035 groundwater withdrawals, does not cause the Withlacoochee River to exceed the draft minimum flows at Croom or Holder.

Ocklawaha River – The table below shows the predicted percent reduction in baseflow for the Ocklawaha River at Moss Bluff, Conner, and Eureka.

Predicted Reduction in Baseflow in 2035 for the Ocklawaha and Silver Rivers.

River Segment Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flow (cfs)	Percent Reduction
Ocklawaha River near Moss Bluff	46.5	33.7	27.5
Ocklawaha River at Conner	806.5	741.5	8.1
Ocklawaha River at Eureka	811.9	746.7	8.0

The SJRWMD's draft District Water Supply Plan states that preliminary estimates indicate that up to 30 mgd may be available from the river in the District's Planning Region 2 (which includes Marion County) depending on how much is withdrawn in the District's other planning regions. This estimate will be refined once MFLs are adopted for the river.

3.2.4 Lakes and Wetlands

The impacts on lakes and wetlands from predicted declines in aquifer levels resulting from the 2035 projected groundwater withdrawals were not included in this analysis. This is because the ND Model could not accurately assess impacts to relatively small-scale features such as lakes and wetlands. The SWFWMD undertakes a separate analysis of lakes to determine compliance each year. The MFL lakes in the SWFWMD portion of the WRWSA Region are currently meeting their levels.

SJRWMD uses regional groundwater models in conjunction with surface water models to predict drawdown impacts to lakes and wetlands that have significant connection to the Floridan aquifer. There are eight MFL lakes and wetlands within the SJR portion of Marion County. Of those eight, six are predicted to meet their MFLs based on 2035 projected demand, one has no significant Floridan aquifer connection, and the other is being reevaluated.

3.2.5 Scenario 2 Summary

The results of the modeling investigation discussed above demonstrate that in the SWFWMD portion of the WRWSA region, 2035 demands for all use categories can be met with groundwater with no exceedances to springs and rivers for which MFLs have been proposed or adopted. However, this result was achieved by reducing demand through water conservation and mitigating aquifer drawdowns to some degree by recharge from the use of reclaimed water. The implication of this is that groundwater from the Upper Floridan aquifer may be limited in certain areas by 2035.

In the SJRWMD portion of the WRWSA region, MFLs for Silver Springs/Silver River are currently being developed by the SJRWMD and will likely impact resource availability. An analysis by SJRWMD staff indicates that the current draft MFLs would not be met under 2035 projected demands. The SJRWMD is working on tools to assist in the development of a prevention/recovery strategy.

3.3 Scenario 3. Simulation of Proposed Wellfield Project Options

The locations of the projected 2035 groundwater withdrawals were redistributed to simulate withdrawals from the wellfields proposed as project options in Chapter 5 of the Water Supply Plan. The proposed project options included the following:

- Option 1 – WRWSA Charles A. Black Wellfield Expansion, Central Citrus County;
- Option 2 – City of Wildwood Lower Floridan Aquifer Well, City of Wildwood's Southern Wellfield, Sumter County;
- Option 3 – Marion County Utilities Marion Oaks Upper Floridan Aquifer Wellfield, Southwest-Central Marion County; and
- Option 4 – Marion County Utilities, Lower Floridan Aquifer Wellfield, Near Silver Springs, Southeast-Central Marion County.

For the entire model domain, the simulation included approximately 637.6 mgd of withdrawals from the UFAS and 6.5 mgd from the LFAS. Approximately 16.7 mgd of the 2035 withdrawals were redistributed from the service areas where the deficits of permitted quantities discussed above were identified, to the locations of the proposed groundwater project options. The table below shows the quantities of water redistributed to each project option location. Scenario 3 was simulated for a period of 5 years to determine the effect caused by the redistribution of quantities to the UFAS and LFAS.

Location and Quantity of Redistributed Water Supply Demands

Utility Source	Redistributed Quantity (mgd)	Redistribution Location	Model Layer
Citrus County Utilities (20002842.01 & 20007879.003)	2.08	Charles A.Black UFA Wellfield	4
City of Wildwood (20008135.009)	4.08	Wildwood Southern LFA Wellfield	7
Marion County Utilities (SWFWMD) (20006151.01)	5.43	Marian Oaks UFA Wellfield	4
Marion County Utilities (SJRWMD)(Cup No. 4578)	5.10	Marion County LFA Wellfield	7

3.3.1 Aquifer Drawdown

Aquifer drawdown was predicted by calculating the difference in surficial and UFAS water levels from pre-pumping conditions to 2035. Drawdowns predicted by the model in the surficial and Upper Floridan aquifer varied across the WRWSA and are shown in Figures 6 through 8. The range-of-drawdowns in each county were as follows: Citrus County, 0.0 to 0.5 feet, Hernando County, 0.0 to 3.0 feet, Sumter County, 0.0 to 4.0 feet and Marion County 0.0 to 4.0 feet. The largest drawdowns were located in the vicinity of concentrated centers of groundwater withdrawals.

3.3.2 Spring Flow

Reductions in the flow of springs from pre-pumping conditions to 2035 that would result from projected groundwater withdrawals are shown in the following tables.

Weeki Wachee Spring System - The minimum flow adopted for the Weeki Wachee Springs System allows for a 10 percent reduction in flow. The table shows that the predicted decline for the system of 6.5 percent, resulting from projected 2035 groundwater withdrawals, does not exceed the allowable 10 percent reduction.

Weeki Wachee Springs System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Weeki Wachee Spring	157.2	145.7	7.3
Jenkins Creek Spring	18.0	17.4	3.0
Mud Spring	8.6	7.9	7.7
Salt Spring	22.4	21.8	2.7
Weeki Wachee River and Spring System	**206.1**	**192.8**	**6.5**

Chassahowitzka Springs System - The minimum flow adopted for the Chassahowitzka Springs System allows for a 3 percent reduction in flow. The table shows that the predicted decline for the system of 1.9 percent, resulting from projected 2035 groundwater withdrawals, does not exceed the allowable 3 percent reduction.

Chassahowitzka Springs System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Chassahowitzka Main Spring	65.7	64.1	2.4
Crab Spring	33.8	32.8	3.0
Potter Creek	14.7	14.4	2.2
Blind Spring	42.8	42.7	0.4
Chassahowitzka River and Spring System	**157.0**	**154.0**	**1.9**

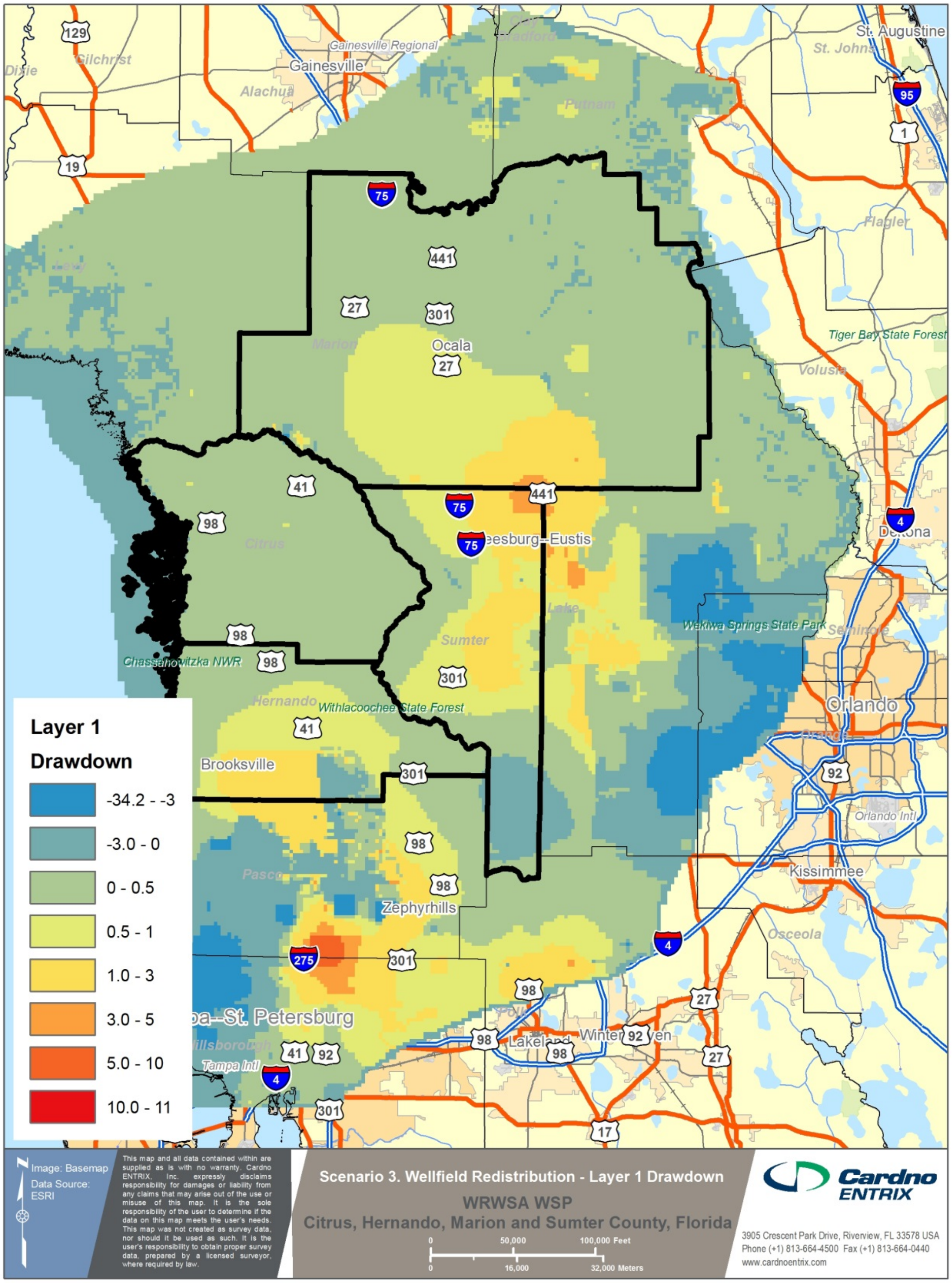

Figure 6. Scenario 3 Predicted 2035 Drawdown in Layer 1.

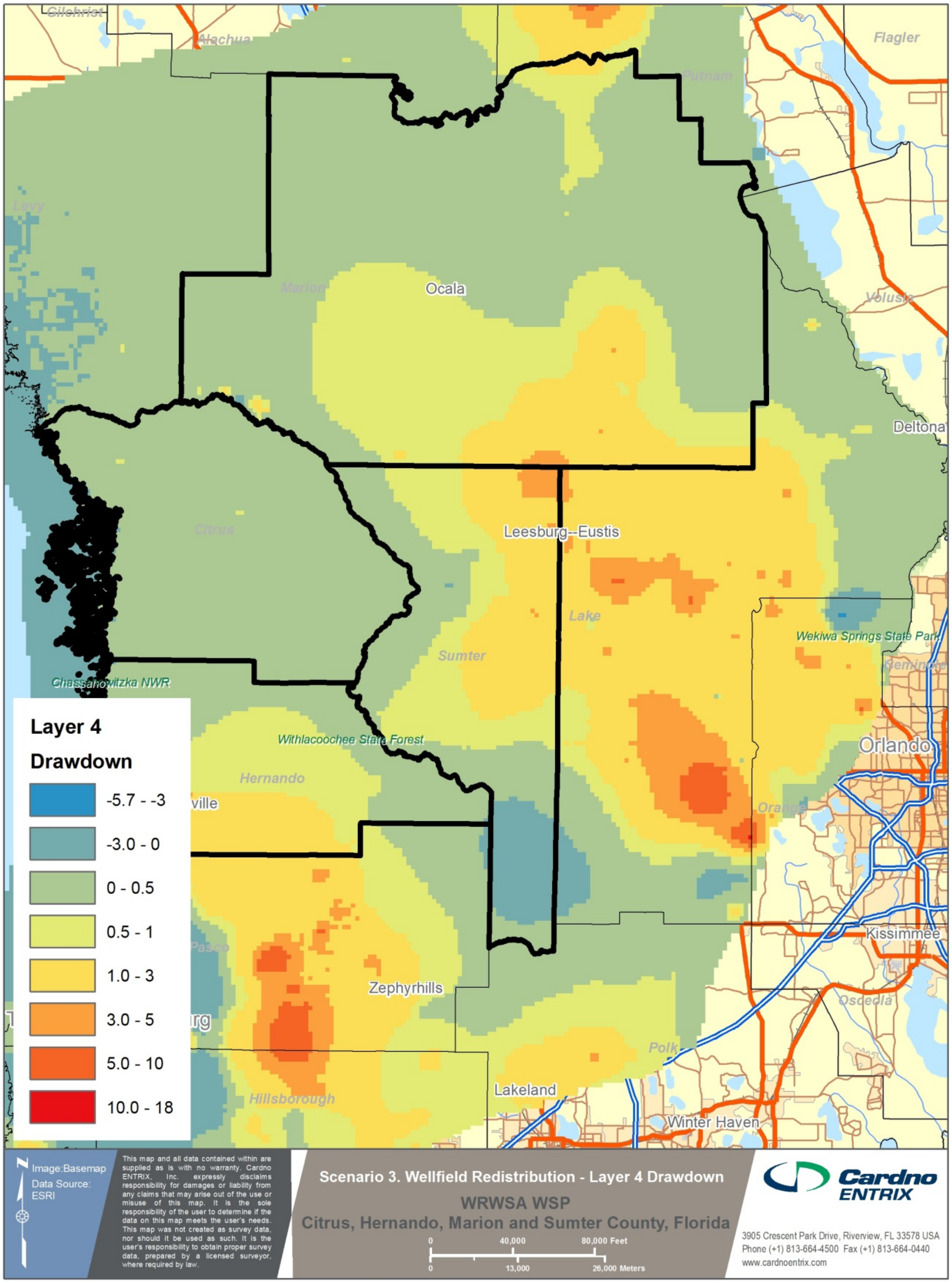

Figure 7. Scenario 3 Predicted 2035 Drawdown in Layer 4.

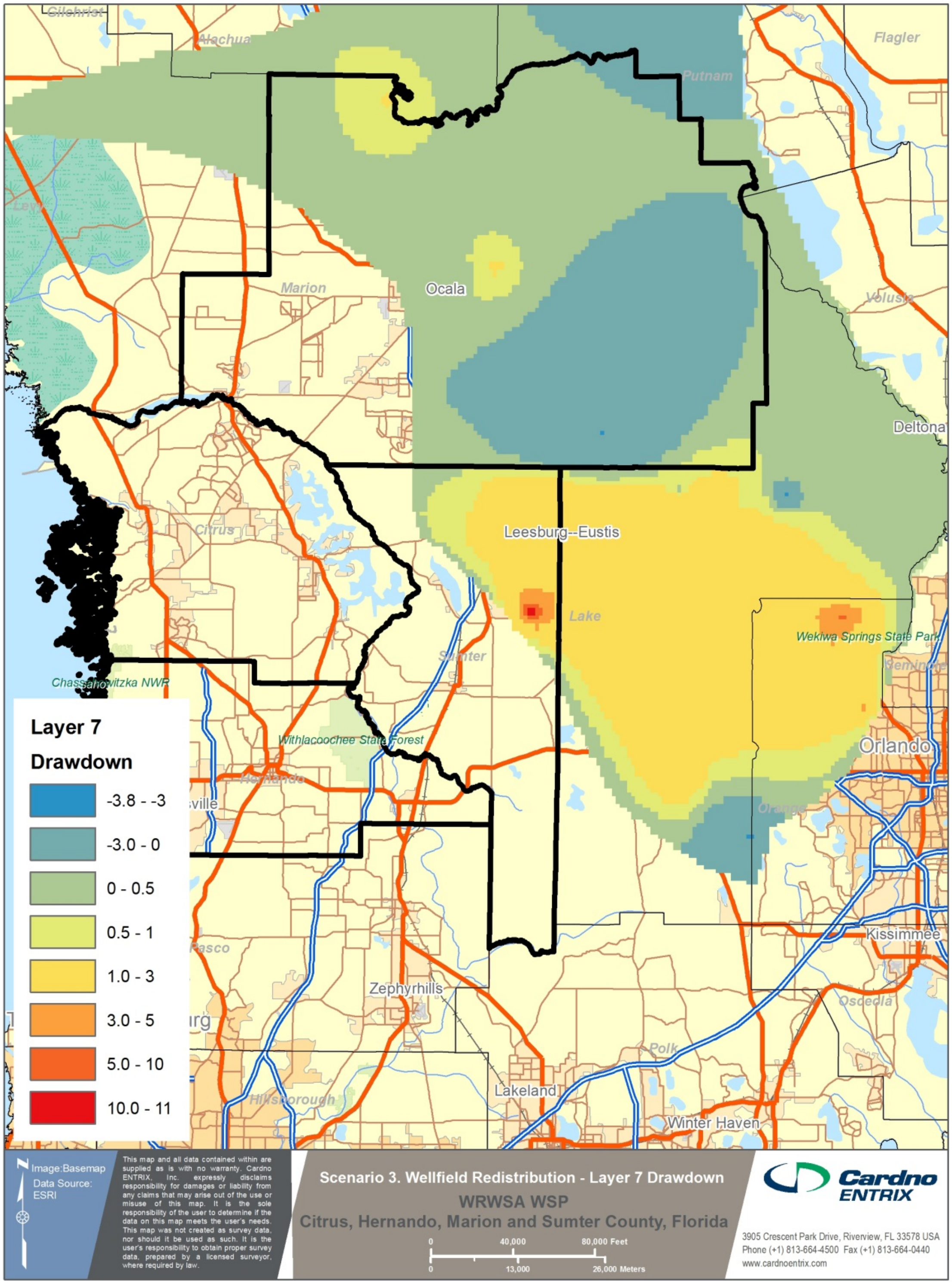

Figure 8. Scenario 3 Predicted 2035 Drawdown in Layer 7.

Homosassa Springs System - The minimum flow adopted for the Homosassa Springs System allows for a 3 percent reduction in flow. The table shows that the predicted decline for the system of 2.9 percent, resulting from projected 2035 groundwater withdrawals, does not exceed the allowable 3 percent reduction.

Homosassa Springs System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Homosassa 1 Spring	85.0	82.8	2.5
SE Fork Homosassa Spring	36.5	35.6	2.5
Halls River Head Main Spring	99.6	96.8	2.9
Halls River 1 Spring	6.3	6.1	2.4
Hidden River Head Spring	5.8	5.1	11.7
Trotter Spring	4.9	4.8	2.5
Belcher Spring	4.8	4.5	6.8
Abdoney Spring	5.6	5.5	2.5
McClain Spring	5.6	5.5	2.5
Pumphouse Spring	4.2	4.1	2.5
Homosassa River and Spring System	**258.4**	**250.8**	**2.9**

Gum Slough and Springs System - The minimum flow proposed for the Gum Slough Springs System allows for a 9 percent reduction in flow. The table shows that the predicted decline for the group of 7.6 percent, resulting from projected 2035 groundwater withdrawals, does not exceed the allowable 9 percent reduction.

Gum Slough and Spring System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Gum Springs 1	89.5	82.5	7.9
Alligator Spring	5.8	5.6	3.2
Gum Slough and Spring System	**95.3**	**88.1**	**7.6**

King’s Bay Springs System - The SWFWMD has not yet proposed minimum flows for the King’s Bay Springs System. The table shows that the predicted decline for the system resulting from projected 2035 groundwater withdrawals is 2.2 percent.

Kings Bay Springs System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Tarpon Spring	4.1	4.0	2.5
House Spring	2.5	2.3	5.9
Hunter's Spring	3.7	3.6	0.2
Manatee Sanctuary Spring	98.7	96.6	2.2
Three Sister's Run Spring 2	3.7	3.6	0.2
Three Sister's Run Spring	3.7	3.6	0.2
Idiot's Delight Spring	3.7	3.6	0.2
Crystal Spring	345.7	338.0	2.2
Kings Bay	**465.5**	**455.4**	**2.2**

Rainbow Springs System – The SWFWMD has not yet proposed minimum flows for the Rainbow Springs System. The table shows that the predicted decline for springs in the system resulting from projected 2035 groundwater withdrawals is 2.4 percent.

Rainbow Springs System.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Rainbow 1 Spring	643.1	627.7	2.4
Bubbling Spring	1.7	1.7	2.3
Waterfall Spring	4.5	4.4	1.2
Rainbow Springs System	**649.3**	**633.8**	**2.4**

Silver Springs System – The table shows that the predicted decline for the springs resulting from projected 2035 groundwater withdrawals is 6.6 percent. As discussed previously, MFLs for Silver Springs/Silver River are being developed by the SJRWMD and will likely impact resource availability. Based on current analyses, the current draft MFLs would not be met under 2035 projected demand. The SJRWMD is working on tools to assist in the development of a prevention/recovery strategy.

Silver Springs.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flows (cfs)	2035 Percent Change
Silver Springs	**683.45**	**638.7**	**6.6**

Silver Glen Springs - The SJRWMD has not yet proposed a minimum flow for Silver Glen Springs. The table shows that the predicted decline for the spring resulting from projected 2035 groundwater withdrawals is 0.1 percent.

Silver Glen Springs.

Spring Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flow (cfs)	2035 Percent Change
Silver Glen Springs	108.0	107.9	0.1

3.3.3 River Flow

River systems in the WRWSA four-county region include the Withlacoochee and Ocklawaha Rivers. Draft minimum flows have been developed for the rivers by the Districts. The following is a discussion of how the predicted changes in the baseflow of the rivers resulting from projected 2035 groundwater withdrawals affect their proposed minimum flows.

Withlacoochee River – The table below shows that the predicted decline in baseflow for the Withlacoochee River at Croom and Holder, resulting from projected 2035 groundwater withdrawals, is 4.5 percent and 10.0 percent, respectively.

Predicted Reduction in Baseflow in 2035 for the Withlacoochee River at Croom and Holder.

River Segment	Pre-Pumpage Flow (cfs)	Predicted 2035 Flow (cfs)	Percent Flow Reduction
Withlacoochee at Croom	77.6	74.1	4.5
Withlacoochee near Holder	315.2	283.5	10.0

The following procedure was used to determine whether the predicted reductions in baseflow of the Withlacoochee River resulted in exceedances of the draft minimum flows at Croom and Holder. Figures 9 and 10 are graphs for the Croom and Holder locations that show the historic median daily flow (blue line) and the draft minimum flow (black line), which is the historic median daily flow reduced by the allowable reductions for each seasonal flow block. The predicted baseflow reductions were subtracted from the historic median daily flows at Croom and Holder and the resulting flow was plotted on the graphs (dashed red line). If the line representing the predicted baseflow reduction was above the draft minimum flow line, the minimum flow was not exceeded. The figure shows that this was always the case and therefore, the predicted reduction in groundwater baseflow resulting from the projected 2035 groundwater withdrawals, does not cause the Withlacoochee River to exceed the draft minimum flows at Croom or Holder.

Ocklawaha River – The table below shows the predicted percent reduction in baseflow for the Ocklawaha River at Moss Bluff, Conner, and Eureka.

Predicted Reduction in Baseflow in 2035 for the Ocklawaha and Silver Rivers.

River Segment Name	Pre-Pumpage Flow (cfs)	Predicted 2035 Flow (cfs)	Percent Reduction
Ocklawaha River near Moss Bluff	46.5	34.0	26.8
Ocklawaha River at Conner	806.5	745.4	7.6
Ocklawaha River at Eureka	811.9	750.6	7.6

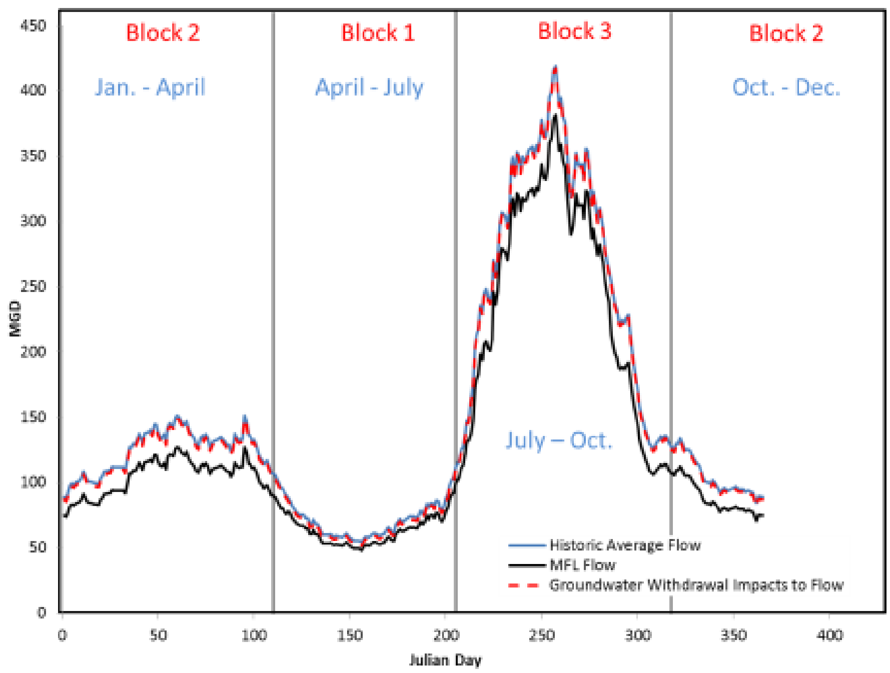

Figure 9. Predicted Reduction in Baseflow for the Withlacoochee River at Croom Resulting from Projected 2035 Groundwater Withdrawals, Relative to the Historic Median Daily Flow and the Draft Minimum Flow.

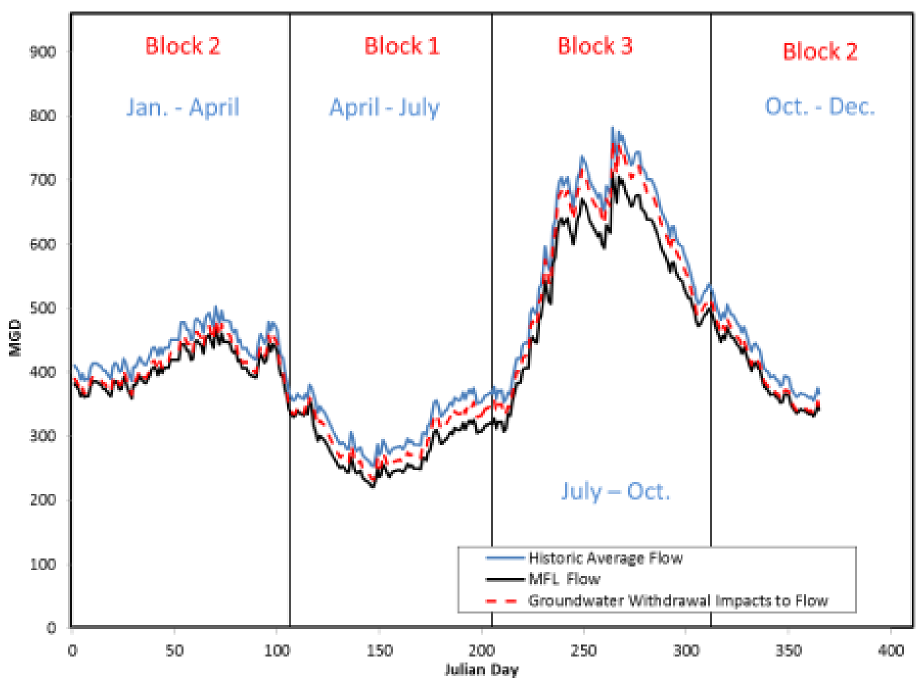

Figure 10. Predicted Reduction in Baseflow for the Withlacoochee River at Holder Resulting from Projected 2035 Groundwater Withdrawals, in Relation to the Historic Median Daily Flow and the Draft Minimum Flow.

The SJRWMD's draft District Water Supply Plan states that preliminary estimates indicate that up to 30 mgd may be available from the river in the District's Planning Region 2 (which includes Marion County) depending on how much is withdrawn in the District's other planning regions. This estimate will be refined once MFLs are adopted for the river.

3.4.4 Lakes and Wetlands

The impacts on lakes and wetlands from predicted declines in aquifer levels resulting from the 2035 projected groundwater withdrawals were not included in this analysis. This is because the ND Model could not accurately assess impacts to relatively small-scale features such as lakes and wetlands. The SWFWMD undertakes a separate analysis of lakes to determine compliance each year. The MFL lakes in the SWFWMD portion of the WRWSA Region are currently meeting their levels.

SJRWMD uses regional groundwater models in conjunction with surface water models to predict drawdown impacts to lakes and wetlands that have significant connection to the Floridan aquifer. There are eight MFL lakes and wetlands within the SJR portion of Marion County. Of those eight, six are predicted to meet their MFLs based on 2035 projected demand, one has no significant Floridan aquifer connection, and the other is being reevaluated.

3.4.5 Scenario 3 Summary

The results of the modeling investigation for scenario 3 were similar to those of Scenario 2 with a few notable exceptions. In the SWFWMD portion of the WRWSA region, the only major difference was a reduction in spring flow for the Gum Slough Spring System from 6.3 percent to 7.6 percent. This decline, which probably resulted from concentrating withdrawals at the proposed Marion Oaks Upper Floridan aquifer wellfield, does not exceed the 9 percent reduction allowed by the proposed minimum flow. Therefore, the 2035 demands for all use categories can be met with groundwater with no exceedences to springs and rivers for which MFLs have been proposed or adopted. However, similar to Scenario 2, groundwater supplies will be sufficient to meet demands through 2035 only if demand is reduced significantly by water conservation and aquifer drawdowns are offset to some degree by recharge from the use of reclaimed water.

In the SJRWMD portion of the WRWSA region, there were slight improvements in the predicted flow of Silver Springs and the Ocklawaha and Silver Rivers, which resulted from moving approximately 9.2 mgd of groundwater withdrawals in Marion and Sumter counties from the UFAS to the LFAS. The predicted flow reduction at Silver Springs declined from 7.0 percent to 6.6 percent and the predicted flow reductions at the Ocklawaha River near Moss Bluff, at Conner, and at Eureka declined by 0.7, 0.5, and 0.4 percent, respectively.

MFLs for Silver Springs/Silver River are being developed by the SJRWMD and will likely impact resource availability. Based on current analyses, the current draft MFLs would not be met under 2035 projected demand. The SJRWMD is working on tools to assist in the development of a prevention/recovery strategy.

Prior to the implementation of any of the groundwater project options, extensive testing and evaluation would be required at each site to determine whether the withdrawals would cause exceedances of proposed or adopted MFLs. Testing would likely include construction of test wells, aquifer performance testing, and water quality evaluations and groundwater modeling.

References

Florida Department of Environmental Protection, 2013. *2012 Reuse Inventory*. Water Reuse Program Florida, Florida Department of Environmental Protection, Tallahassee, Florida.

HGL, 2013. *North District Groundwater Flow Model Version 4.0*. Report submitted to the Southwest Florida Water Management District.

Sepulveda, N., 2002 *Simulation of Ground-Water Flow in the Intermediate and Floridan Aquifer Systems in Peninsular Florida*. U.S. Geological Survey Water-Resources Investigations Report 02-4009.