Application of the West Coast Floridan Model (WCFM) for the Lower West Coast Water Supply Plan

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EXECUTIVE SUMMARY

The South Florida Water Management District (SFWMD) is required to provide 5-year water supply planning updates for each planning area within its jurisdictional boundaries. The Lower West Coast (LWC) Planning Area encompasses Lee County, most of Collier County, and portions of Charlotte, Glades, Hendry, and Monroe counties. The primary sources of water within the LWC Planning Area are fresh groundwater from the surficial aquifer system (SAS) and portions of the intermediate aquifer system (IAS) as well as surface water bodies, such as the C-43 Canal (Caloosahatchee River) and connected canals. Brackish groundwater from the Floridan aquifer system (FAS) is considered an alternative water supply source option. Based on the 2017 LWC water supply plan update, the permanent resident population in the LWC Planning Area is projected to increase approximately 60% by 2040. Accordingly, public supply demand from the FAS is expected to increase from 43.04 million gallons per day (mgd) in 2014 to 108.17 mgd in 2040, making the FAS the primary source for public supply in the region.

The SFWMD's West Coast Floridan Model (WCFM) was used to evaluate potential changes within the FAS as a result of projected groundwater withdrawals in the LWC Planning Area. The WCFM is a three-dimensional groundwater flow and transport model used to simulate water levels and total dissolved solids concentrations within the FAS for the southwestern coast of Florida. The model was developed using the United States Geological Survey's SEAWAT model code. The WCFM simulates the three primary aquifers in the FAS: the Upper Floridan aquifer, the Avon Park permeable zone, and the first permeable zone of the Lower Floridan aquifer. In the LWC Planning Area, the Avon Park permeable zone and the first permeable zone of the Lower Floridan aquifer generally are too saline and in Collier County the Avon Park permeable zone is not productive enough for water supply. There currently are no users withdrawing water from these aquifers within the planning area.

Model results were analyzed for water level and water quality (total dissolved solids) changes by comparing the 2014 withdrawal quantities to the projected 2040 withdrawal quantities. Although there are some localized areas around wellfields with noticeable drawdowns and water quality degradation, the 2040 model results indicate no significant adverse impact to groundwater levels or water quality. Overall, the model results conclude use of the FAS is sustainable through 2040.

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ACRONYMS AND ABBREVIATIONS

AFSIRS	Agricultural Field-Scale Irrigation Requirements Simulation
APPZ	Avon Park permeable zone
ASR	aquifer storage and recovery
ECFM	East Coast Floridan Model
ECFTX	East-Central Floridan Transient Expanded Model
FAS	Floridan aquifer system
FSAID	Florida Statewide Agricultural Irrigation Demand
ft	foot
IAS	intermediate aquifer system
LF1	Lower Floridan aquifer – first permeable zone
LWC	Lower West Coast
mg/L	milligrams per liter
mgd	million gallons per day
PS	Public Supply
SAS	surficial aquifer system
SFWMD	South Florida Water Management District
SWFWMD	Southwest Florida Water Management District
TDS	total dissolved solids
UFA	Upper Floridan aquifer
WCFM	West Coast Floridan Model

1 INTRODUCTION

The South Florida Water Management District (SFWMD) is required to provide 5-year water supply planning updates for each of the five planning areas within its jurisdictional boundaries. As part of the planning updates, numerical model simulations are conducted in support of the planning objectives to—among other things—identify any potential water supply or environmental issues that may occur during the planning horizon. In general, each planning area identifies existing water demands and projects demands for at least 20 years. Modeling tools are used to assess water supply conditions 20 years into the future using the most recent projected population and demand estimates.

The Lower West Coast (LWC) Planning Area encompasses approximately 5,130 square miles of southwestern Florida, including Lee County, most of Collier County, and portions of Charlotte, Glades, Hendry, and Monroe counties (**Figure 1**). The primary sources of water within the LWC Planning Area are fresh groundwater from the surficial aquifer system (SAS) and portions of the intermediate aquifer system (IAS) as well as surface water bodies, such as the C-43 Canal and connected canals. Brackish groundwater from the Floridan aquifer system (FAS) is considered an alternative water supply source option and is widely used by utilities in the LWC Planning Area, but it requires desalination via reverse osmosis. Based on the 2017 LWC Water Supply Plan Update (SFWMD 2017), the permanent resident population in the LWC Planning Area is projected to increase approximately 60% by 2040. The associated projected increase in public supply (PS) demand is approximately 55%. Most of the increased PS demand is expected to be met through increased use of the FAS. This study evaluated the sustainability of existing and projected future FAS demands in the LWC Planning Area using the West Coast Floridan Model (WCFM) (Giddings et al. 2020) to support the planning process.

The WCFM is a three-dimensional groundwater flow and transport model used to simulate water levels and total dissolved solids (TDS) concentrations (i.e., water quality) within the FAS for the southwestern portion of Florida. The model was developed using the United States Geological Survey SEAWAT model code, version 4.0 (Langevin et al. 2008, United States Geological Survey 2012). The WCFM domain extends from central Florida near Lake Wales to the Florida Keys and from the Dry Tortugas to the approximate center line of the Florida peninsula (**Figure 2**). The active portion of the WCFM domain encompasses this entire area, except for the northwestern corner, which is inactive west of State Road 17. The WCFM has a slight overlap on the eastern border with the East Coast Floridan Model (ECFM), and the portion of the WCFM domain north of the Charlotte County border overlaps with the East-Central Florida Transient Expanded Model (ECFTX). The northern WCFM boundary was extended beyond the LWC Planning Area to include the FAS recharge area in central Florida. The WCFM domain was divided into a uniform grid with spacing of 2,400 feet (ft).

Figure 3 shows a geologic cross-section of the WCFM domain from Fort Myers to Lake Okeechobee. The top layers from the water table aquifer through the Hawthorn Confining Zone are simulated in the Lower West Coast Surficial and Intermediate Aquifer Systems Model (Bandara et al. 2020). Vertically, the WCFM is composed of seven layers, each consisting of a confining unit or primary aquifer (**Table 1**). The WCFM can simulate aquifer response to stresses such as wellfield pumpage, aquifer storage and recovery (ASR) systems, reductions in recharge, and increasing sea level, among others. Additional information on WCFM development and calibration can be found in the model documentation report (Giddings et al. 2020).

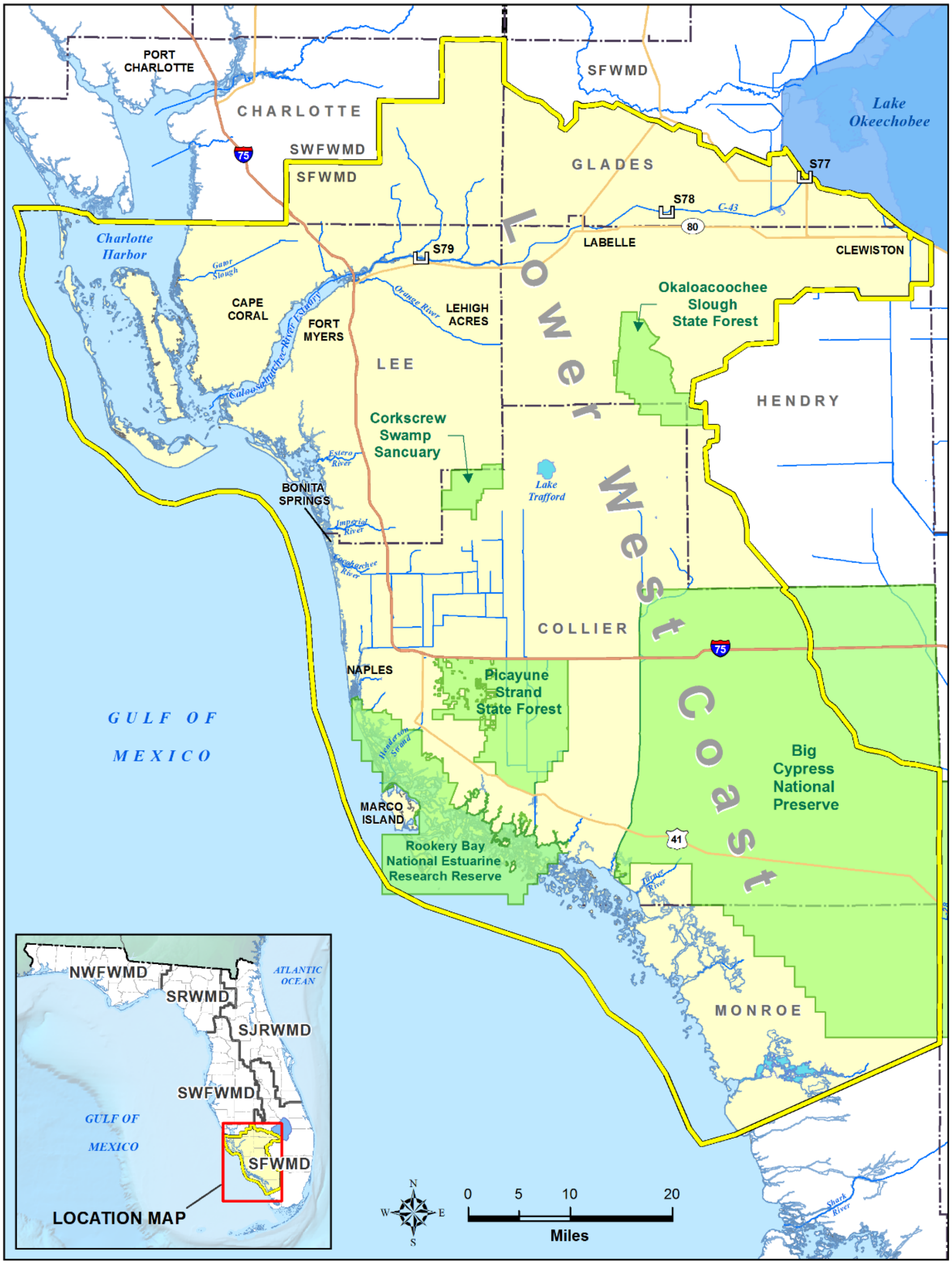

Figure 1. Location of the Lower West Coast Planning Area.

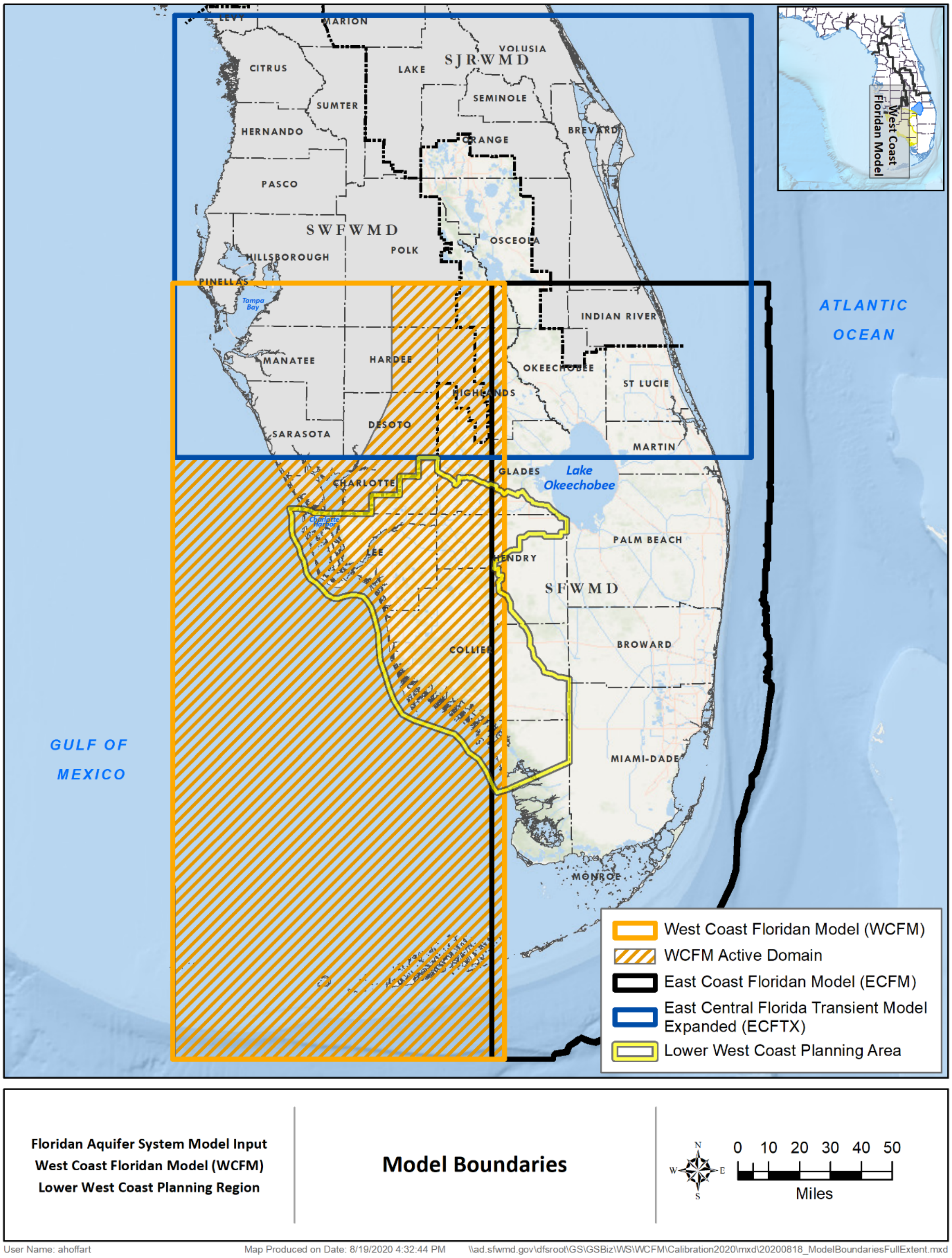

Figure 2. Model boundaries of three regional groundwater models in Central and South Florida.

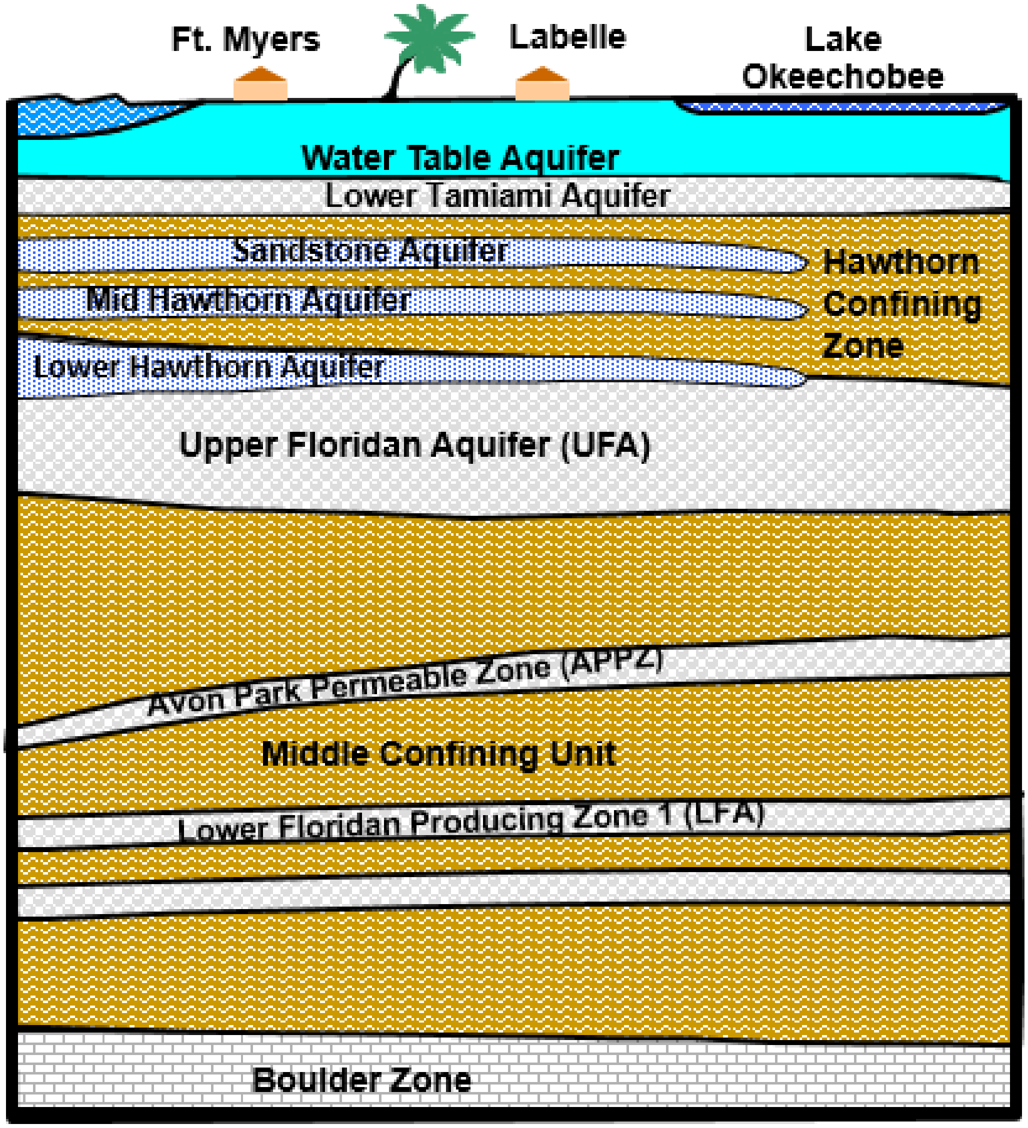

Figure 3. Geologic cross-section through the model domain.

Table 1. Model layers and corresponding hydrogeologic units.

Model Layer	Hydrogeologic Unit	Abbreviation
1	Upper Floridan aquifer	UFA
2	Ocala-Avon Park low-permeability zone	OCAPlpz
3	Avon Park permeable zone	APPZ
4	Middle confining unit	MCU
5	Lower Floridan aquifer – first permeable zone	LF1
6	Boulder Zone confining unit	BC
7	Boulder Zone	BZ

2 WCFM UPDATES FOR THE LWC WATER SUPPLY PLAN

The current version of the WCFM was completed by the SFWMD in 2020. The model originally was developed by Restrepo et al. (2008) to support ongoing water supply management efforts in the LWC Planning Area. The model was revised by Guo et al. (2011) to address the peer-review comments and recommendations. The current version of the model builds upon the work completed by Guo et al. (2011) and incorporates updated information.

The 2020 WCFM was used to develop the initial conditions for the 2014 and future 2040 simulations to support the LWC planning effort. Three main changes were made during development of the input files for the 2014 and 2040 planning simulations:

1) Removal of the ASR wells used in the calibration runs.
2) Incorporation of additional data received from PS utilities in the region. The additional data relate to new wellfields and wells that are permitted but were not yet installed during the calibration period, and therefore not included in the original model calibration.
3) Incorporation of historical and predicted demands developed for the ECFTX.

Within the LWC Planning Area, there are several permitted ASR systems in Lee and Collier counties. Within Lee County, Lee County Utilities and Fort Myers Utility have ASR systems, with Lee County Utilities having two separate permitted systems, one at the Olga water treatment plant and another at the North wellfield. Within Collier County, the City of Naples at Golden Gate and Marco Island Utilities have permitted ASR systems. The WCFM calibration only included operational ASR systems for the City of Naples at Golden Gate and Marco Island Utilities. The Marco Island Utilities ASR system has a maximum capacity of approximately 6 million gallons per day (mgd), and the City of Naples at Golden Gate ASR system has a maximum capacity of approximately 4 mgd. The ASR systems in Lee County Utilities were not simulated in the calibration because the Olga system only has one ASR well which currently is not being used for recovery, and the other permitted ASR wells were not yet built or operational in 2014. The ASR well at Lee County Utilities' North wellfield is being used as a production well; therefore, it was not modeled as an ASR well. The Fort Myers Utility ASR well currently only injects water, but does not withdraw from the FAS; therefore, it was not simulated in the WCFM calibration.

In addition to the differences in modeled ASR systems, each PS utility wellfield underwent review for modifications to the existing calibration data set. Typical modifications included changes to wellfield distribution or incorporation of new wells that came online after the calibration period.

The northern portion of the WCFM domain overlaps with the ECFTX domain. Historical and projected demands for the ECFTX were developed in a collaborative effort between the SFWMD, Southwest Florida Water Management District (SWFWMD), St. Johns River Water Management District, and other stakeholders, including PS utilities in the region. Demands from the ECFTX 2014 and 2040 scenario runs were used in the WCFM.

3 MODEL SCENARIOS

The WCFM (Giddings et al. 2020) was used to evaluate potential changes in the FAS as a result of projected groundwater withdrawals in the LWC Planning Area. The WCFM simulates the three primary aquifers in the FAS: the UFA, the Avon Park permeable zone (APPZ), and the first permeable zone of the Lower Floridan aquifer (LF1). In the LWC Planning Area, the APPZ and LF1 generally are too saline and not productive. There currently are no users withdrawing water from these aquifers within the planning area.

Two scenarios were simulated with the WCFM (**Table 2**). The 2014 base condition was developed as the basis for comparing the results of the 2040 future simulation. The scenario was developed to represent aquifer conditions that would be expected if the modeled 2014 demands were repeatedly realized over the 24-year period. Modeled groundwater withdrawals for the 2014 base condition represent the pumping required to meet the demands for water as they occurred in 2014 given the rainfall that occurred over the period from 1989 through 2012. The modeled groundwater withdrawals for the 2040 future simulation represent the pumping required to meet the demands for water as they are projected for 2040, given the rainfall that occurred over the period from 1989 through 2012. **Table 3** summarizes the demands by use type within the LWC Planning Area for the 2014 base condition and 2040 future simulation. The modeled demands in the WCFM are a portion of the total demands for the LWC Planning Area because surface water and groundwater from the SAS and IAS are the primary sources of water for the region, and only a fraction of demands are met from the FAS.

Table 2. Model scenario descriptions.

Model Run	Description
2014 Base Condition	The WCFM with historical public supply use, permitted allocations for commercial and industrial use, and AFSIRS estimated demands for agriculture and landscape irrigation.
2040 Future Simulation	The WCFM with planning projections for public supply, agriculture, and landscape irrigation and permitted allocations for commercial and industrial use.

AFSIRS = Agricultural Field-Scale Irrigation Requirements Simulation; WCFM = West Coast Floridan Model.

Table 3. Simulated water use demands within the Lower West Coast Planning Area for the 2014 base condition and 2040 future simulation.

Water Use Type	Simulated Average FAS Withdrawals (mgd)	
	2014 Base Condition	2040 Future Simulation
Public Supply	43.04	108.17
Agriculture	16.56	16.56
Landscape/Recreational*	4.25	4.25
Commercial/Industrial	0.02	0.02
Total	**63.87**	**129.00**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes water used for golf courses.

Figure 4 shows the spatial distribution of wells by water use type across the LWC Planning Area. Agricultural wells typically are clustered in the northeastern portion of the planning area, primarily within Glades, Hendry, and Charlotte counties. The western portion of the planning area has predominantly PS wells, with some golf course and landscape irrigation wells within Lee and Collier counties. **Figures 5** and **6** show the spatial distribution of PS wellfields that are simulated in the 2014 base condition and 2040 future simulation, respectively. All PS wells in the LWC Planning Area are completed in the UFA, which generally is productive and has better water quality north of Collier County. Comparing the two figures, the spatial expansion of the Fort Myers Utility wellfield and the new wellfields at Lee County Utilities Green Meadows and Collier County Water Sewer District's Northeast Wellfield (NERWTP) are apparent.

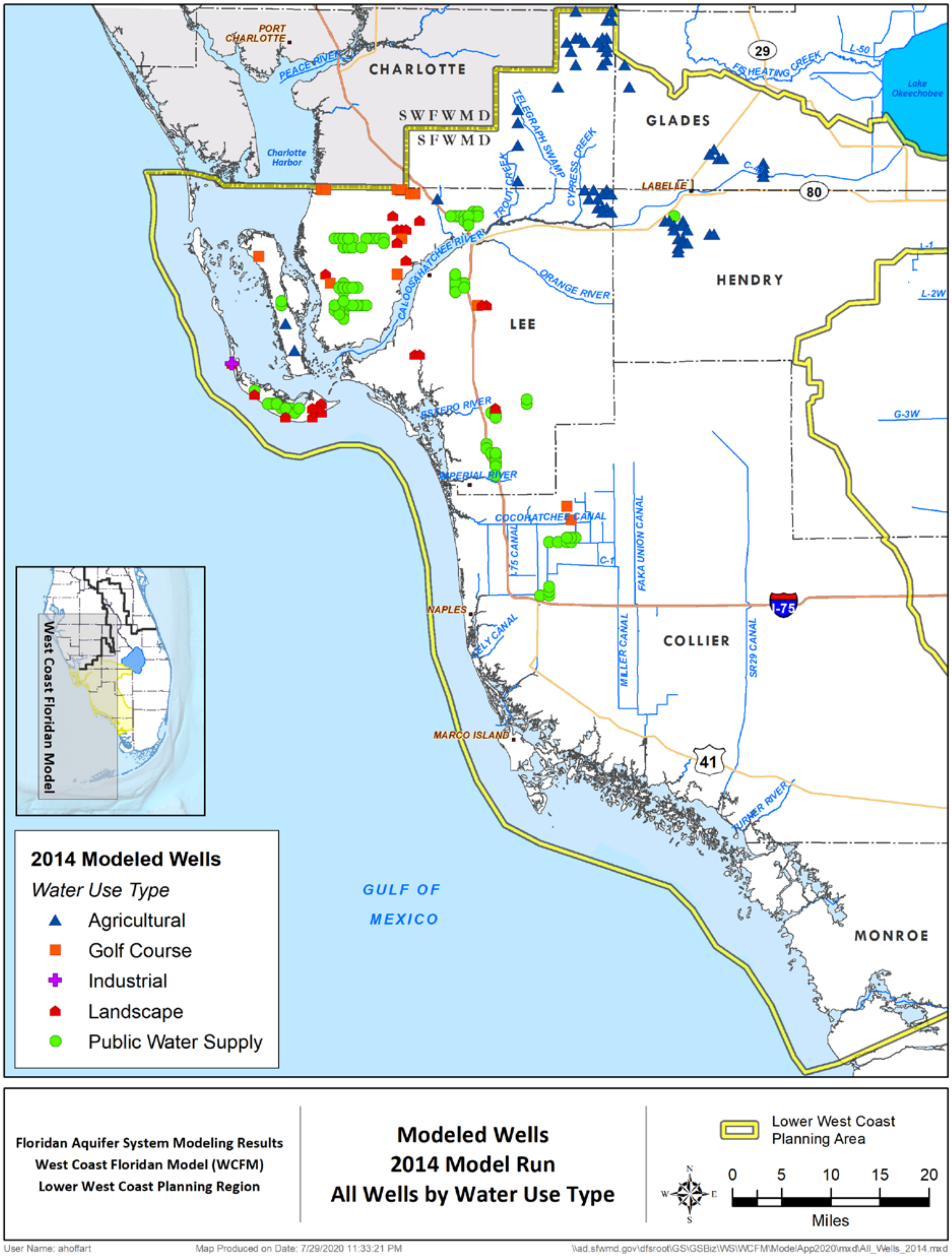

Figure 4. Spatial distribution of modeled wells in the Upper Floridan aquifer by water use type across the Lower West Coast Planning Area.

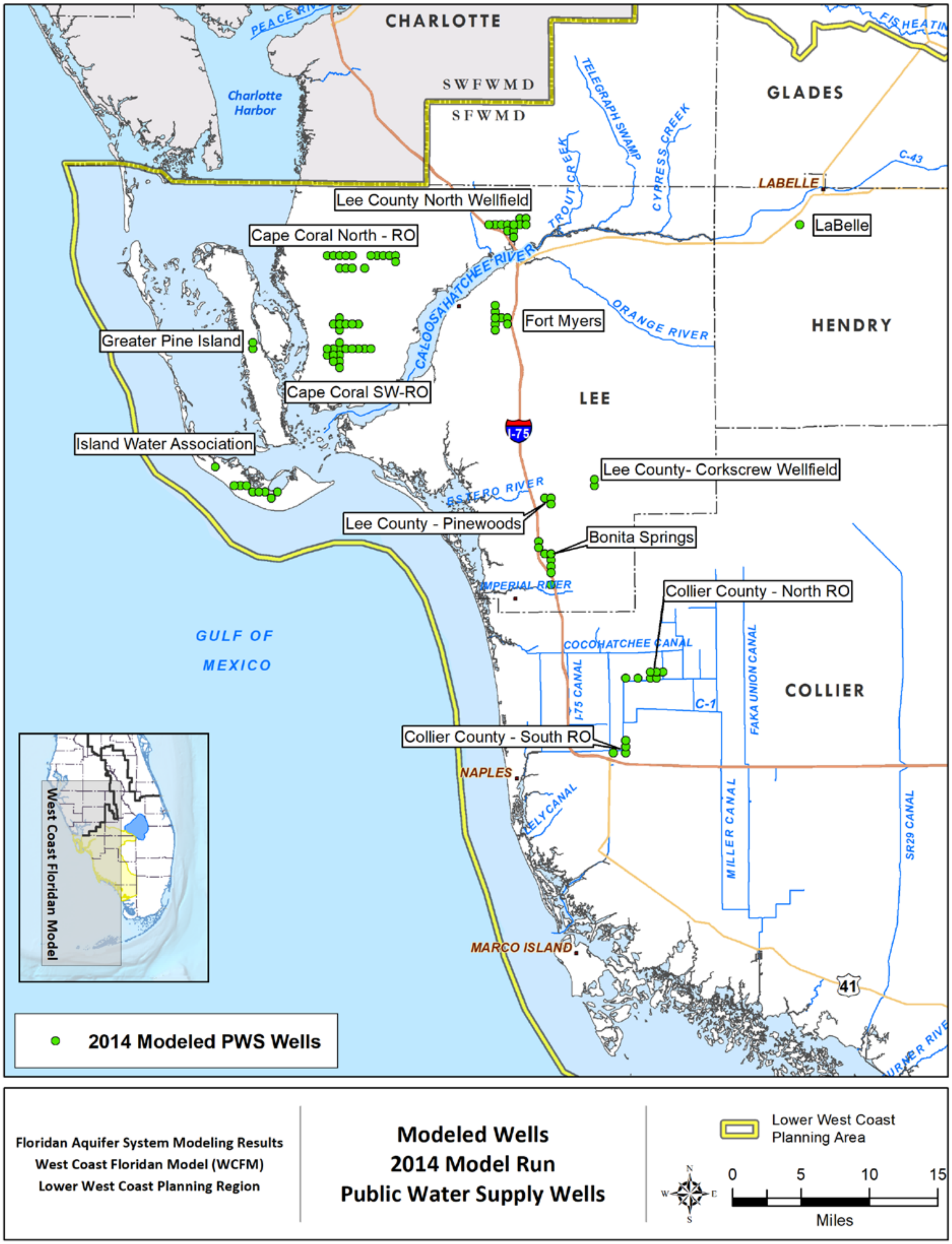

Figure 5. Spatial distribution of public supply wells completed in the Upper Floridan aquifer simulated in the 2014 base condition across the Lower West Coast Planning Area.

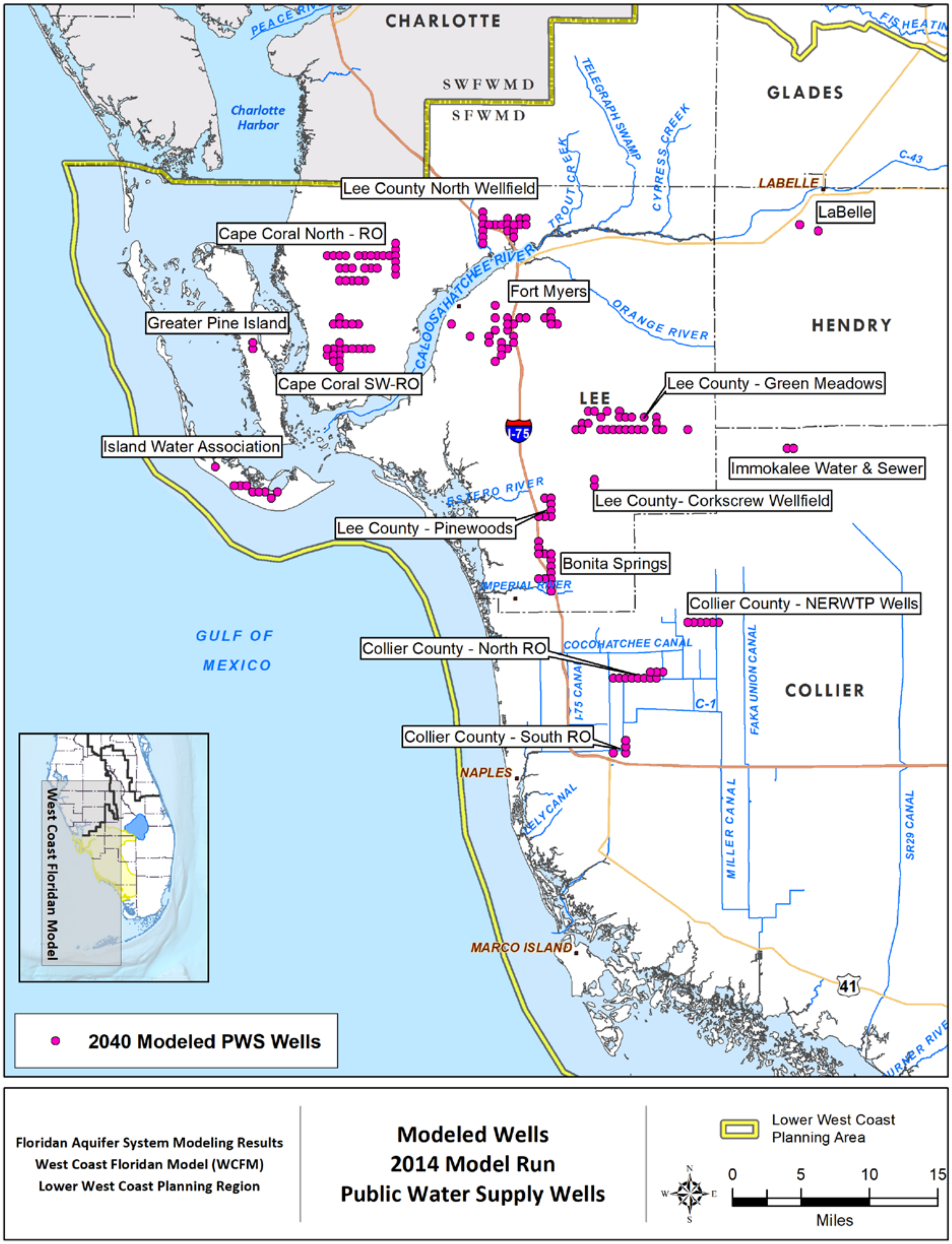

Figure 6. Spatial distribution of public supply wells completed in the Upper Floridan aquifer simulated in the 2040 future simulation within the Lower West Coast Planning Area.

4 INPUT DATA SETS FOR THE LWC WATER SUPPLY PLAN

4.1 Simulated FAS Demands

Simulated water use demands in the WCFM are divided into four categories: 1) public supply (PS); 2) agricultural irrigation; 3) landscape and golf course irrigation; and 4) commercial and industrial water use. Within the LWC Planning Area, the total demand for all water use categories in 2014 was 63.87 mgd. In 2040, the total demand for all water use categories is projected to be 129.00 mgd (**Table 3**). As shown in **Figure 7**, the model does not simulate a gradual annual demand growth as would realistically occur. Simulated demands in 2014 and projected demands in 2040 are withdrawn from the model instantly, starting at stress period 1, and continued throughout the simulation period. The 2014 base condition simulates aquifer conditions that would occur if the 2014 demands were repeatedly realized every year for the 24-year period of record, with the climatic conditions from 1989 through 2012. The 2040 future condition simulates aquifer conditions that would occur if the projected demands were repeatedly realized every year for the 24-year period of record, with climatic conditions from 1989 through 2012.

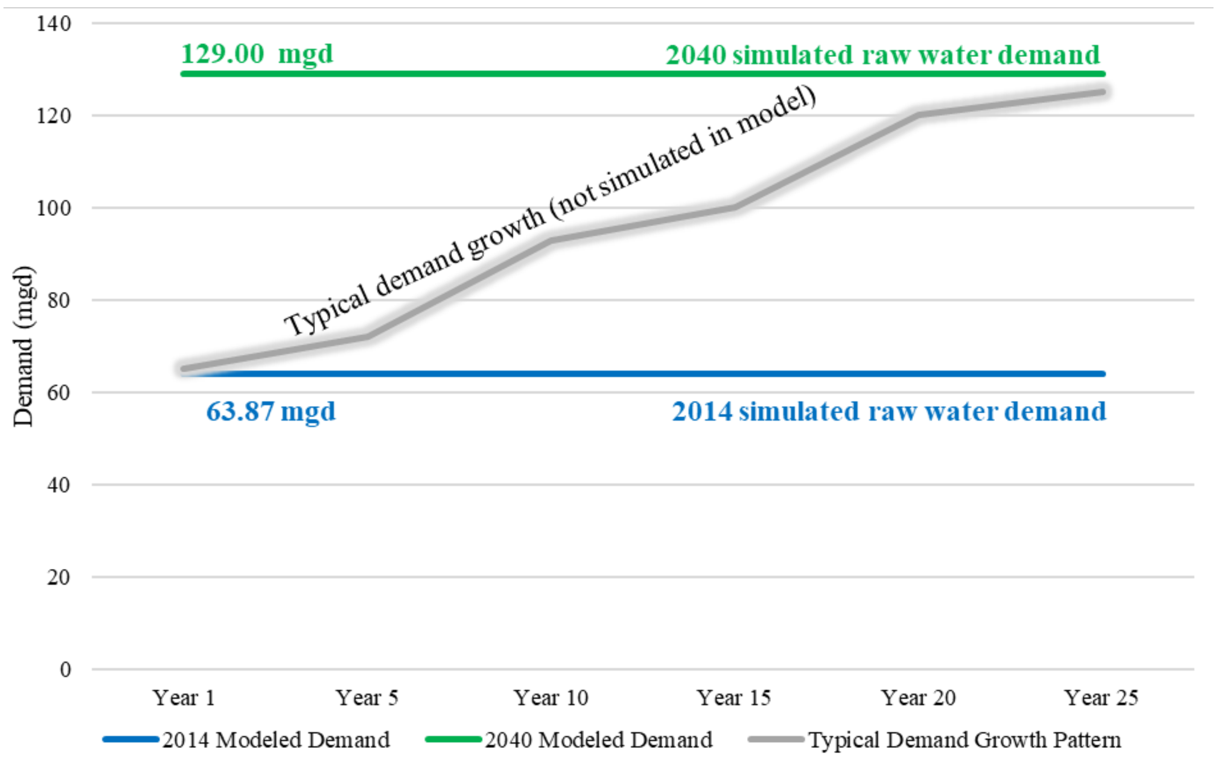

Figure 7. Total demand modeled in 2014 and 2040 within the Lower West Coast Planning Area.

The 2014 modeled PS demands were based on historical water use information collected by the SFWMD's Water Use Bureau. Well ratios (distribution of monthly water use among wells) and monthly variations in pumping volumes were based on 2014 historical data. The modeled 2040 PS demands, as described in the 2017 LWC Water Supply Plan Update (SFWMD 2017), generally were calculated from historical per capita use and projected population estimates by utility service area, which were further adjusted to reflect the SAS/IAS to FAS ratio at the utility level. Monthly variations in simulated demands were based on historical use patterns from all utility sources and reflect variability associated with seasonal climatic conditions. The 2040 PS demand with the monthly seasonal variation was repeated for each year of the 24-year simulation period.

Within the WCFM, three methodologies were used to calculate irrigation demands (**Table 4**). Within the portion of the model domain that is in the SWFWMD boundary, 2014 irrigation demands were based on historical metered data and the 2040 irrigation demands were based on the Florida Department of Agriculture and Consumer Services' Florida Statewide Agricultural Irrigation Demand Report version 5 (FSAID V). The portion of the WCFM domain within the SFWMD boundary includes agricultural and landscape irrigation demands based on estimated total crop acreage, which was modified to reflect the percentage of acreage irrigated with water from the FAS and adjusted for irrigation type. In the northern portion of the model domain, which overlaps with the ECFTX domain (excluding the portion within the SWFWMD), irrigated acres and annual irrigation demands were obtained from FSAID V. LWC Planning Area irrigated acres were obtained from the SFWMD's water use permit database and irrigation demands were based on the University of Florida Agricultural Field-Scale Irrigation Requirements Simulation (AFSIRS) model (Smajstrla 1990). There is an overall decreasing trend in future irrigation demands within the portion of the WCFM domain that overlaps with the ECFTX. Although there an overall increase in agricultural and landscape irrigation demand was projected in the 2017 LWC Water Supply Plan Update (SFWMD 2017), the increase is not expected to be met with water from the FAS; therefore, 2040 modeled demands within the planning area are equal to 2014 estimated demands for agricultural and irrigation use classes.

Table 4. Agricultural irrigation demand estimation methodology by water management district and domain.

District	Domain	2014 Methodology	2040 Methodology
SFWMD	LWC Planning Area	Permitted irrigated acreage and AFSIRS	Permitted irrigated acreage and AFSIRS
SFWMD	ECFTX model domain	FSAID V irrigated acreage and annual irrigation demand	FSAID V irrigated acreage and annual irrigation demand
SWFWMD	ECFTX model domain	Historical metered data	Adjusted FSAID V

AFSIRS = Agricultural Field-Scale Irrigation Requirements Simulation; ECFTX = East-Central Floridan Transient Expanded Model; FSAID = Florida Statewide Agricultural Irrigation Demand; LWC = Lower West Coast; SFWMD = South Florida Water Management District; SWFWMD = Southwest Florida Water Management District.

For agricultural and landscape irrigation permits within the LWC Planning Area, irrigated acreage was obtained from SFWMD permit databases, which include the crop type, acreage, irrigation efficiency, withdrawal facilities, and sources of irrigation water. Acreage and permits were cross-checked against existing land use and land cover maps to verify the irrigated acres and ensure the permit was still active. Improved pasture was only irrigated in the simulations when directly specified in the permit. Otherwise, pasture demands were based on water required per head of livestock, as specified in the permit, and remained fixed with no projected increase or decrease in the herd size.

Within the LWC Planning Area, monthly simulated irrigation demands were calculated using the AFSIRS model. Most agricultural operations in the region use a combination of surface water and groundwater from the SAS, IAS, and FAS to meet crop irrigation needs. The distribution between these sources was estimated from actual operations, site-specific model calibration, water supply plan estimates, and water use permit facility information. Irrigation demands developed from AFSIRS were calculated using actual daily rainfall and evapotranspiration for the simulation period. The monthly simulation period was from January 1989 through December 2012. **Figure 8** shows the mean average rainfall, in inches per day, for the city of Sebring, located in Highlands County. June is the wettest month, and average annual rainfall was approximately 48.8 inches from 1989 through 2012. Monthly demand variability for agricultural irrigation and PS in the LWC Planning Area is shown in **Figure 9**. As expected, there was more variability in agricultural demand compared to PS demand. This is due to agricultural irrigation depending on climatic conditions, with lowest demands occurring during the wet season. **Figure 10** shows the monthly demand variability for landscape and golf course irrigation (recreational use) and commercial/industrial use. Recreational demands also heavily depend on climatic conditions, with drier months having significantly higher demand than wet season months.

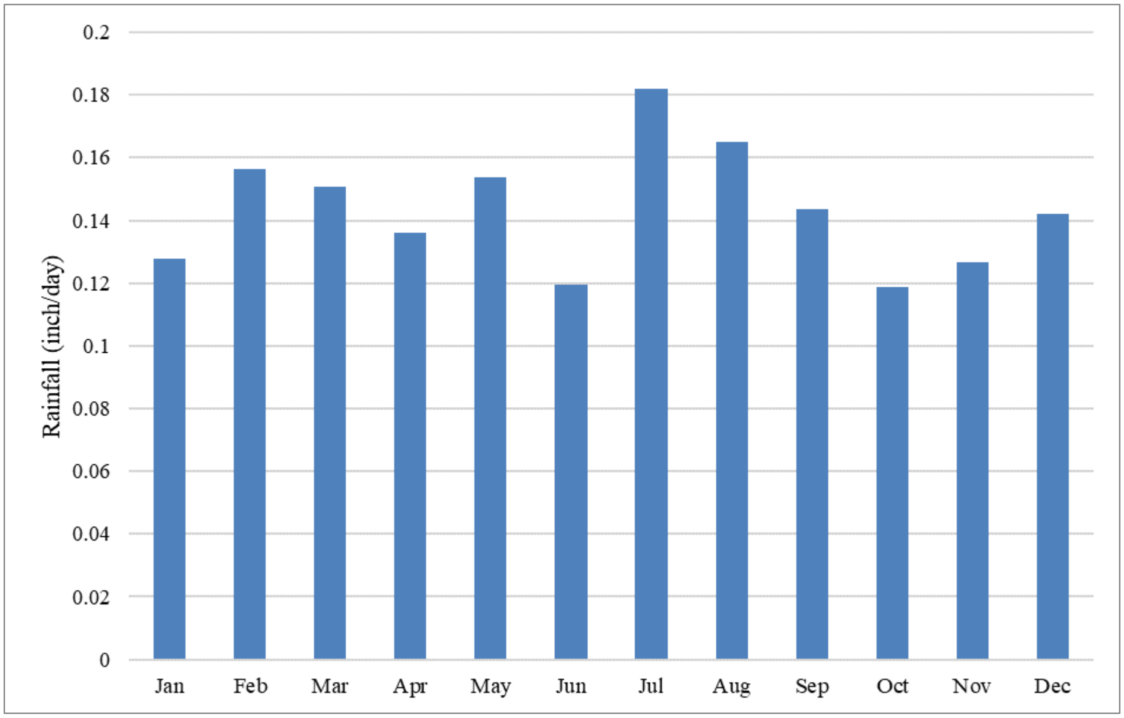

Figure 8. Average monthly rainfall for the city of Sebring in Highlands County, Florida.

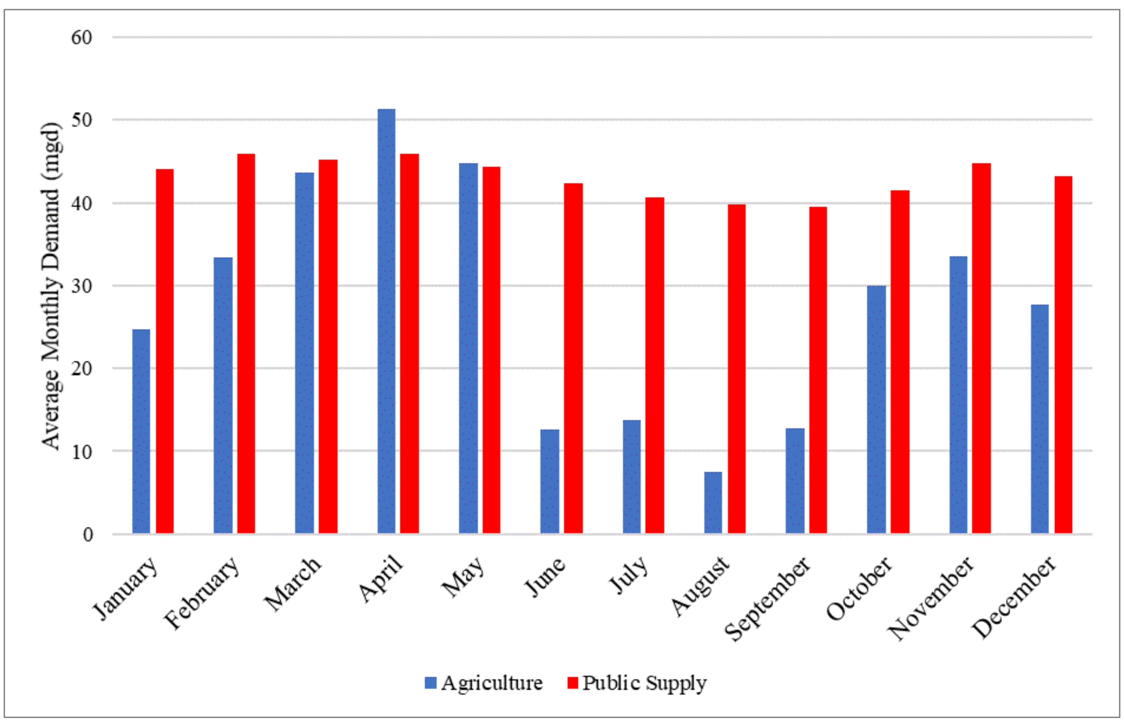

Figure 9. Monthly demand variability for agricultural irrigation and public supply in 2014 and 2040 within the Lower West Coast Planning Area.

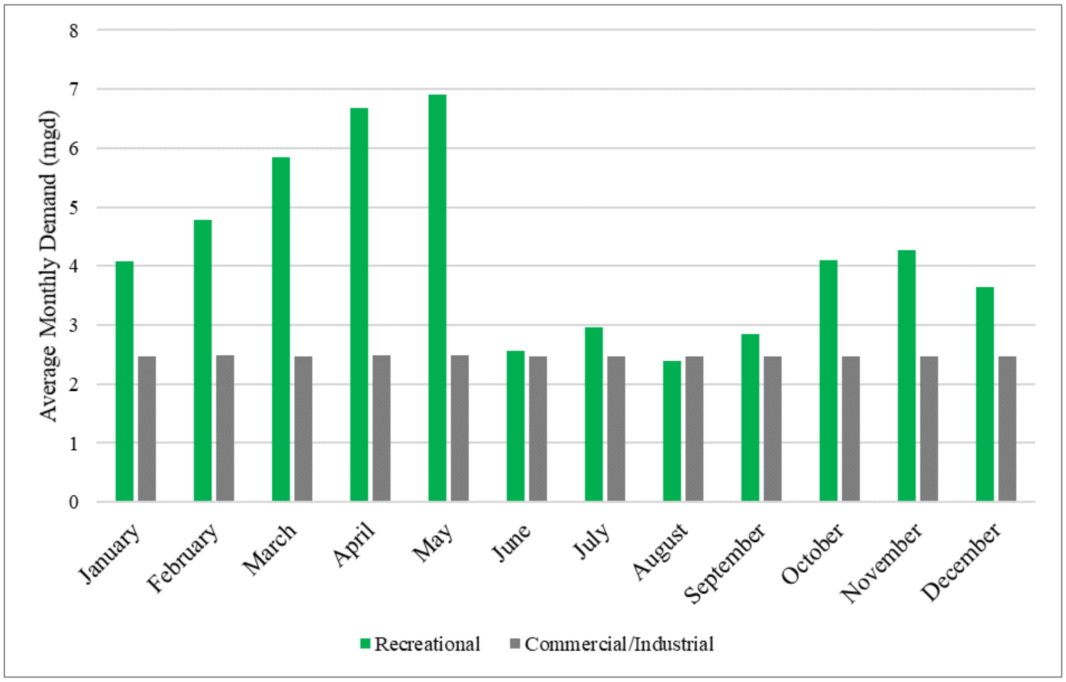

Figure 10. Monthly demand variability for landscape/recreational irrigation and commercial/industrial use in 2014 and 2040 within the Lower West Coast Planning Area.

The ECFTX data set used for the SWFWMD portion of the model domain was developed by SWFWMD staff. For the 2040 future simulation, FSAID V was reviewed and modified to better represent historical water use patterns in the SWFWMD (Kiger et al. 2019). The finalized 2040 projected FAS demands for the ECFTX were implemented in the WCFM.

Commercial and industrial water users typically do not use the FAS as a source of water; however, within the LWC Planning Area, there are a few permits that pump water from the UFA. Demands for those permits were set at the current water use permit FAS source allocation, or a ratio was developed based on individual permit facility information to determine the amount of water that would be withdrawn from the FAS. Demands were not projected to increase between the 2014 and 2040 modeled simulations.

Table 5 shows the total demand for each water use category across the model domain, including demands developed for the ECFTX and areas within the WCFM domain that are not within the LWC Planning Area. Across the model domain, the total demand in 2014 for all water use categories was 120.86 mgd. In 2040, the total demand for all water use categories is projected to be 186.20 mgd.

Table 5. Simulated water use demands within the model domain for the 2014 base condition and 2040 future simulation.

Water Use Type	Simulated Average FAS Withdrawals (mgd)	
	2014 Base Condition	2040 Future Simulation
Public Supply	53.45	120.91
Agriculture	57.94	57.38
Landscape/Recreational*	7.00	5.44
Commercial/Industrial	2.47	2.47
Total	**120.86**	**186.20**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes water used for golf courses.

4.1.1 Lee County

Water use demands from the FAS in Lee County are met through use of the UFA and are predominantly related to PS. Agricultural and landscape irrigation demands from the FAS are limited due to the brackish water quality and the cost related to constructing wells and treating the water. There is also a very small industrial demand of 0.02 mgd. **Table 6** shows the agricultural and landscape irrigation demands from the FAS for the 2014 base condition and 2040 future simulation.

Table 6. Water supply demands in Lee County for the 2014 and 2040 model simulations.

Use Type	Simulated Average FAS Withdrawals (mgd)	
	2014	2040
Agriculture	0.26	0.26
Landscape/Recreational*	3.82	3.82
Commercial/Industrial	0.02	0.02
Total	**4.10**	**4.10**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes water used for golf courses.

Table 7 shows the Lee County PS demands for the 2014 and 2040 simulations. The following utilities in Lee County withdraw from the FAS: Bonita Springs Utilities, Cape Coral Utilities, Fort Myers Utility, Greater Pine Island Water Association, Lee County Utilities, and Island Water Association. **Figure 11** shows the monthly variability in FAS demand from PS utilities in Lee County. The Lee County Utilities wellfields were combined. There was only a slight variation in average monthly demand among the utilities.

Bonita Springs Utilities has one main FAS wellfield, with some expansion projected by 2040. All wells are pumping water from the UFA. The 2014 base condition has eight wells simulated with a historical demand of 5.61 mgd. In 2040, the wellfield is projected to expand to 16 wells, with a projected demand of 10.69 mgd.

Table 7. Public supply demands in Lee County for the 2014 and 2040 model simulations.

Utility	Simulated FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
Bonita Springs Utilities, Inc.	5.61	10.69	5.09
Cape Coral Utilities	11.32	27.60	16.28
Fort Myers Utility	8.93	17.49	8.56
Greater Pine Island Water Association	1.54	2.24	0.70
Lee County Utilities Corkscrew and Green Meadows Wellfields	0.27	13.57	13.29
Lee County Utilities North Wellfield	5.00	10.98	5.98
Lee County Utilities Pinewoods Wellfield Public Water Supply	2.24	6.15	3.91
Island Water Association Inc.	4.43	4.70	0.27
Total	**39.34**	**93.42**	**54.08**

FAS = Floridan aquifer system; mgd = million gallons per day.

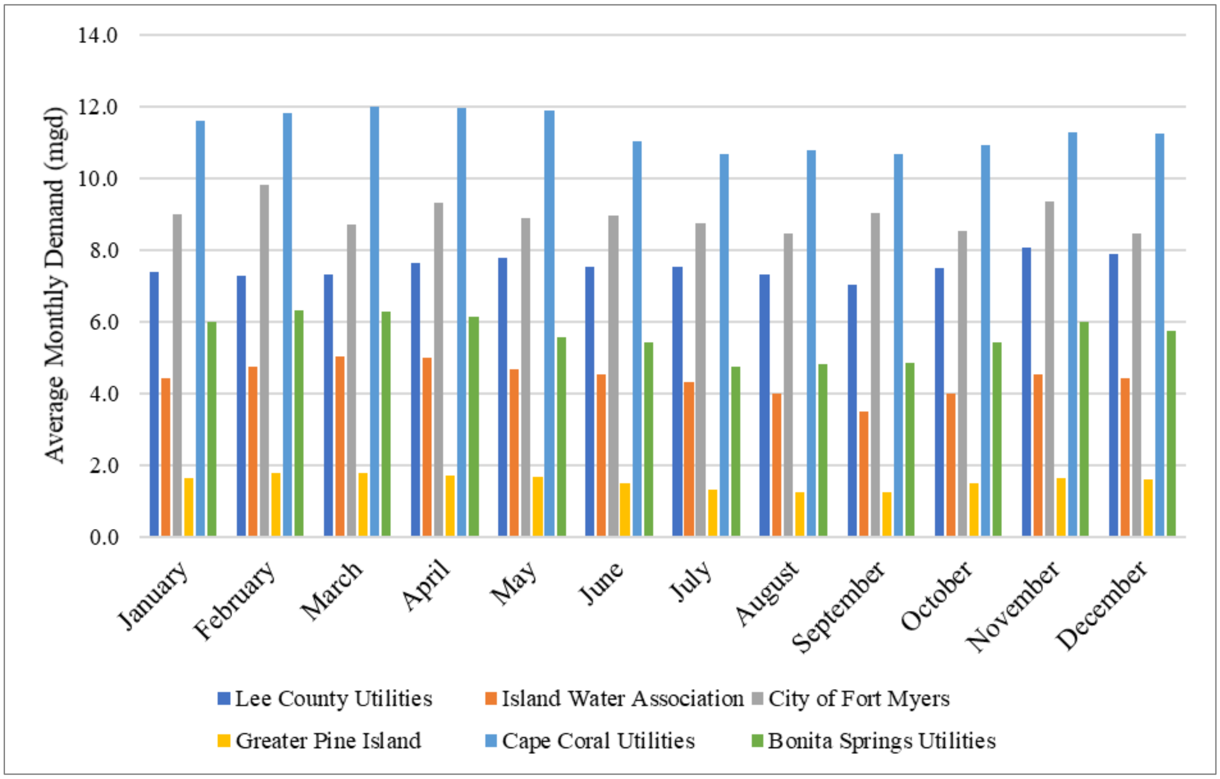

Figure 11. Monthly demand variability for public supply utilities in Lee County.

Cape Coral Utilities has two wellfields: south and north. The 2014 demand was 11.32 mgd, with a projected increase to 27.60 mgd by 2040. There are 34 wells in the south wellfield; however, two wells are not used due to historical issues with high chloride concentrations. The south wellfield is not projected to expand (i.e., it is considered built out). The north wellfield has 24 wells simulated in the 2014 base condition. The north wellfield is projected to expand, adding 18 new wells by 2040, for a total of 42 wells; however, two wells will not be used due to predicted high chloride concentrations. Historically, 60% of the utility's total demand came from the south wellfield and 40% came from the north wellfield. In the 2040 future simulation, total demand is evenly distributed among 72 wells.

Fort Myers Utility has 18 wells in the 2014 base condition and is projected to expand its wellfield to 41 wells by 2040. All existing and proposed wells will pump water from the UFA. The utility's 2014 demand was 8.93 mgd, increasing to 17.49 mgd in 2040.

Greater Pine Island Water Association is a small utility that serves Pine Island. The 2014 demand was 1.54 mgd, and the utility's demand is projected to increase 0.70 mgd by 2040. There are five active pumping wells in the 2014 and 2040 model simulations. The main difference between the two model runs is the change in demand and wellfield distribution, evenly distributing the total 2.24 mgd in 2040.

Lee County Utilities has several wellfields and water use permits for different wellfields and water treatment plants. The main utility wellfields simulated in the WCFM are: North, Green Meadows, Corkscrew, and Pinewoods. The North and Pinewoods wellfields have their own historical data and projections, while water use from the Green Meadows and Corkscrew wellfields is combined in the main Lee County Utilities permit and projections. The North wellfield had 17 active FAS wells in the 2014 model simulation, with a demand of 5.00 mgd. The wellfield is projected to expand to 25 wells by 2040, with a 5.98 mgd increase in demand. The Pinewoods wellfield had five active FAS wells in 2014, with a demand of 2.24 mgd. In 2040, the wellfield is expected to have five additional wells and demand is projected to increase to 6.15 mgd, which is more than the currently permitted FAS allocation. The Corkscrew wellfield only has two active FAS wells, and the wellfield is not projected to expand by 2040. The Green Meadows wellfield currently is proposed and projected to come online by 2040. It is expected to consist of 29 UFA wells. Historically, 0.27 mgd of demand was pumped from the two Corkscrew FAS wells, but in the 2040 model simulation, when the Green Meadows wellfield is online, 0.82 mgd will be pumped from the Corkscrew wellfield, and the remaining 12.75 mgd will be pumped from the Green Meadows wellfield.

Island Water Association, Inc. is a small utility that serves Sanibel Island. The 2014 demand was 4.43 mgd, and there are no projected expansions to the wellfield. With 22 active UFA wells, the wellfield is considered built out. The utility is expected to increase its demand by 0.27 mgd.

4.1.2 Collier County

Water use demands from the FAS in Collier County are predominantly related to PS. Within Collier County, the APPZ is saline and not productive; therefore, FAS demands in Collier County are met by the UFA. The only irrigation demands from the FAS are for golf courses, and they are very limited due to the brackish water quality and the cost related to constructing wells and treating the water. **Table 8** shows the landscape irrigation demands from the FAS for the 2014 base condition and 2040 future simulation.

Table 8. Irrigation demands in Collier County for the 2014 and 2040 model simulations.

Use Type	Simulated Average FAS Withdrawals (mgd)	
	2014	2040
Recreational*	0.42	0.42
Total	**0.42**	**0.42**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes water used for golf courses.

Table 9 shows the Collier County PS demands for the 2014 and 2040 simulations. Only two utilities in Collier County use the UFA: Collier County Water Sewer District and Immokalee Water and Sewer District. Although Collier County has other PS utilities, they do not have current or projected demands from the FAS.

Table 9. Public supply demands in Collier County for the 2014 and 2040 model simulations.

Utility	Simulated FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
Collier County Water Sewer District	3.42	14.12	10.70
Immokalee Water and Sewer District	0.0	0.002	0.002
Total	**3.42**	**14.122**	**10.702**

FAS = Floridan aquifer system; mgd = million gallons per day.

Collier County Water Sewer District has three main wellfields simulated in the WCFM: north, south, and NERWTP. The north and south wellfields were active in the 2014 base condition. The NERWTP wellfield is a proposed wellfield projected to be active by 2040; therefore, it is only included in the 2040 future simulation. The north wellfield has 19 active UFA wells and pumped 68% of the 3.42 mgd historical demand. The south wellfield has seven active wells and pumped the remaining 32% of historical demand in the 2014 base condition. The utility is expected to experience significant growth by 2040, with a projected demand increase of 10.70 mgd. The south wellfield will have two new wells, and the NERWTP wellfield, which has 14 proposed wells, will be operational. In the 2040 future simulation, the north wellfield pumps 43% of the projected demand, the south wellfield pumps 7%, and the NERWTP wellfield pumps 50%.

Immokalee Water and Sewer District currently uses the SAS and IAS to meet demands, but the utility has one proposed UFA wellfield with four wells that is projected to be active by 2040. Because the wellfield is proposed, the 2014 base condition did not simulate any wells for the utility. The 2040 future simulation included the 0.002 mgd projected demand distributed equally among the four proposed wells.

4.1.3 Hendry County

Water use demands in Hendry County are predominantly related to agriculture, which irrigates with surface water and groundwater from the SAS. The amount of water withdrawn from the UFA is small because of its brackish water quality. **Table 10** shows the agricultural irrigation demands from the FAS for the 2014 base condition and 2040 future simulation.

Table 10. Irrigation demands in Hendry County for the 2014 and 2040 model simulations.

Use Type	Simulated Average FAS Withdrawals (mgd)	
	2014	2040
Agriculture	1.49	1.49
Total	**1.49**	**1.49**

FAS = Floridan aquifer system; mgd = million gallons per day.

Table 11 shows the Hendry County PS demands for the 2014 and 2040 simulations. The City of LaBelle is the only Hendry County utility simulated in the WCFM. The utility has one main wellfield with two UFA wells, and some expansion is projected by 2040. The 2014 base condition had a demand of 0.33 mgd. In 2040, the wellfield is projected to expand to three wells, with a projected demand of 0.74 mgd.

Table 11. Public supply demands in Hendry County for the 2014 and 2040 model simulations.

Utility	Simulated FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
City of LaBelle	0.33	0.74	0.41
Total	**0.33**	**0.74**	**0.41**

FAS = Floridan aquifer system; mgd = million gallons per day.

4.1.4 Charlotte County

Water use demands in Charlotte County from the FAS are only for agricultural irrigation needs. Although Charlotte County has an SFWMD water use permit for a backup PS wellfield in the FAS, because of its intermittent and short-term potential use, it was not included in the simulation. Historical data were obtained and used to determine agricultural water use for the portion of Charlotte County within the SWFWMD. AFSIRS was used to determine historical agricultural irrigation demands for the SFWMD's portion of the county. **Table 12** shows the total agricultural irrigation demand from the FAS for the 2014 base condition and 2040 future simulation. Agricultural demands from the FAS in Charlotte County are not projected to increase by 2040.

Table 12. Irrigation demands in Charlotte County for the 2014 and 2040 model simulations.

Use Type	Simulated Average FAS Withdrawals (mgd)	
	2014	2040
Agriculture	16.98	16.98
Total	**16.98**	**16.98**

FAS = Floridan aquifer system; mgd = million gallons per day.

4.1.5 Glades County

Water use demands in Glades County are based on agricultural irrigation and commercial/industrial demands. AFSIRS was used to determine historical agricultural irrigation demands for Glades County. Industrial demands were set to the permitted allocation. **Table 13** shows the total FAS demand for the 2014 base condition and 2040 future simulation. FAS demands in Glades County are not projected to increase by 2040.

Table 13. Water supply demands in Glades County for the 2014 and 2040 model simulations.

Use Type	Simulated Average FAS Withdrawals (mgd)	
	2014	2040
Agriculture	7.18	7.18
Commercial/Industrial	2.45	2.45
Total	**9.63**	**9.63**

FAS = Floridan aquifer system; mgd = million gallons per day.

4.1.6 Highlands County

A portion of Highlands County is simulated in the WCFM. Agricultural irrigation is the largest user of water within Highlands County, followed by PS, then landscape/recreational irrigation use. Part of Highlands County is within the SWFWMD and part is within the SFWMD. In order to combine the best information available from both water management districts, the ECFTX's historical water use data and 2040 projections were used for Highlands County. **Table 14** shows the total FAS irrigation demand in both water management districts for the 2014 base condition and 2040 future simulation. Agricultural irrigation demands are projected to decrease approximately 30% by 2040. Landscape/recreational demand is projected to decrease by 85% in 2040. **Table 15** shows the total PS demand in Highlands County. There is a slight increase in PS demand projected by 2040.

Table 14. Irrigation demands in Highlands County for the 2014 and 2040 model simulations.

Use Type	Simulated Average FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
Agriculture	67.40	45.10	-22.30
Landscape/Recreational*	2.03	0.34	-1.69
Total	**69.43**	**45.44**	**-23.99**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes water used for golf courses.

Table 15. Public supply demands in Highlands County for the 2014 and 2040 model simulations.

Utility	Simulated FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
City of Sebring	3.38	3.91	0.53
Silver Lake Utilities	0.01	0.00	-0.01
Spring Lake Improvement District	0.19	0.26	0.07
Town of Lake Placid	0.56	0.66	0.10
Other Public Supply*	3.67	4.41	0.75
Total	**7.81**	**9.25**	**1.44**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes churches, parks, condominiums, and commercial properties that have some public water use.

4.1.7 Polk County

A portion of Polk County is simulated in the WCFM. Agricultural irrigation is the largest water user in Polk County. PS and landscape/recreational uses are not significant within the simulated areas of Polk County. Part of Polk County is within the SWFWMD and part is within the SFWMD. In order to combine the best information available from both water management districts, the ECFTX's historical water use data and 2040 projections were used for Polk County. **Table 16** shows the total FAS irrigation demand in both water management districts for the 2014 base condition and 2040 future simulation. There is very little change in agricultural irrigation demand from 2014 to 2040, and landscape/recreational demand is projected to remain constant through 2040. **Table 17** shows the total PS demand in Polk County. PS demands are projected to increase approximately 40% by 2040.

Table 16. Irrigation demands in Polk County for the 2014 and 2040 model simulations.

Use Type	Simulated Average FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
Agriculture	30.02	29.47	-0.55
Landscape/Recreational*	0.37	0.43	0.06
Total	**30.39**	**29.90**	**-0.49**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes water used for golf courses.

Table 17. Public supply demands in Polk County for the 2014 and 2040 model simulations.

Utility	Simulated FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
City of Fort Meade	0.24	0.16	-0.07
City of Frostproof	0.30	0.43	0.13
Polk County Utilities	0.52	0.62	0.10
Other Public Supply*	0.50	0.98	0.49
Total	**1.55**	**2.20**	**0.65**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes churches, parks, condominiums, and commercial properties that have some public water use.

4.1.8 DeSoto County

A portion of DeSoto County is simulated in the WCFM. DeSoto County is located within the SWFWMD; therefore, historical data and projections for the 2040 future simulation that were developed for the ECFTX by SWFWMD planners and modelers were utilized for the WCFM. **Tables 18** and **19** show the historical and projected FAS demands for the portion of DeSoto County that is simulated in the model. Agricultural irrigation demands are the biggest water use type in DeSoto County but are projected to decrease slightly by 2040. Landscape irrigation is projected to remain the same. PS demands in the City of Arcadia are projected to increase slightly from 0.57 mgd in 2014 to 0.77 mgd in 2040.

Table 18. Irrigation demands in DeSoto County for the 2014 and 2040 model simulations.

Use Type	Simulated Average FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
Agriculture	33.16	32.92	-0.24
Landscape/Recreational*	0.08	0.13	0.05
Total	**33.24**	**33.05**	**-0.19**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes water used for golf courses.

Table 19. Public supply demands in DeSoto County for the 2014 and 2040 model simulations.

Utility	Simulated FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
City of Arcadia	0.57	0.77	0.20
Total	**0.57**	**0.77**	**0.20**

FAS = Floridan aquifer system; mgd = million gallons per day.

4.1.9 Hardee County

A portion of Hardee County is simulated in the WCFM. Hardee County is located within the SWFWMD; therefore, historical data and projections for the 2040 future simulation that were developed for the ECFTX by SWFWMD planners and modelers were utilized for the WCFM. **Tables 20** and **21** show the historical and projected FAS demands for the portion of Hardee County that is simulated in the model. Agricultural irrigation demands are the biggest water use type in Hardee County but are projected to decrease slightly by 2040. Overall, landscape irrigation and PS demands are projected to remain the same.

Table 20. Irrigation demands in Hardee County for the 2014 and 2040 model simulations.

Use Type	Simulated Average FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
Agriculture	18.81	17.09	-1.72
Landscape/Recreational*	0.26	0.29	0.03
Total	**19.07**	**17.38**	**-1.69**

FAS = Floridan aquifer system; mgd = million gallons per day.
* Includes water used for golf courses.

Table 21. Public supply demands in Hardee County for the 2014 and 2040 model simulations.

Utility	Simulated FAS Withdrawals (mgd)		
	2014	2040	Difference (2040 – 2014)
City of Wauchula	0.34	0.38	0.04
Town of Zolfo Springs	0.14	0.14	0.00
Total	**0.48**	**0.52**	**0.04**

FAS = Floridan aquifer system; mgd = million gallons per day.

4.2 Simulation Results

The simulation results are presented in three ways: 1) changes to water levels between simulations; 2) changes in water quality, including horizontal or vertical movement (upconing) of poorer quality water within or between aquifers; and 3) an evaluation of changes in horizontal flow direction and magnitude within a single aquifer layer. Potential areas of concern were identified based on groundwater level drawdown and water quality degradation between the 2014 base condition and 2040 future simulation. Simulated water levels (in feet National Geodetic Vertical Datum of 1929 [NGVD29]) and water quality (as TDS in milligrams per liter [mg/L]) by county and utility for individual monitor wells can be found in **Appendices A** and **B**, respectively. The results discussion is focused on the area of interest simulated by the WCFM for the LWC Planning Area, primarily Lee and Collier counties where demands are higher. When reviewing the graphics in this section, the UFA maps show PS wells as green circles for the 2014 base condition and pink circles for the 2040 future simulation.

4.2.1 Water Level Variations

Figures 12 and **13** show the spatial distribution of water levels in the UFA for the 2014 and 2040 model runs, respectively. Across the LWC Planning Area, UFA water levels typically are between +10 and +50 ft of head, with some localized low areas around large wellfields. The spatial distribution of UFA water level differences between the 2014 base condition and 2040 future simulation is shown in **Figure 14**. Although water level changes are mostly related to differences in withdrawal quantities, some are due to changes in the locations of withdrawal points and distribution of demands within individual utility wellfields. Changes in water levels compare the final condition (stress period 288, representing December 2012) of the 2040 future simulation minus the final condition of the 2014 base condition. In **Figure 14**, differences in yellow and red colors represent a drawdown effect, with water levels in 2040 being lower than the water level in the 2014 base condition. Differences shown in green represent an increase in water level for the 2040 final condition compared to the 2014 final condition.

Overall, there is 1 to 10 ft of additional drawdown in the simulated 2040 water levels compared to the 2014 water levels (**Figure 14**). The largest observed head differences in the UFA are within Lee County near Cape Coral Utilities' South wellfield, Fort Myers Utility's wellfield, and Lee County Utilities' Pinewoods wellfield, which is expected due to the significant increase in PS demands from 2014 to 2040. The head differences at Cape Coral Utilities' South wellfield are a direct result of the close proximity of the wells to each other, with multiple wells occurring in a single model cell. Generally, the model exaggerates drawdowns when multiple wells are located in a single model cell because the model assumes withdrawals from all the wells occur at the center of the cell. Additionally, the wellfield demand doubles between 2014 and 2040, which puts additional stress on the aquifer. This results in a maximum additional drawdown of approximately 36 ft within the wellfield. Fort Myers Utility's wellfield has maximum additional drawdown of approximately 26 ft. This most likely is attributed to the 8.56 mgd increase in PS demands from 2014 to 2040. The spatial extent and expansion of the Fort Myers Utility wellfield in 2040 is expected to reduce the potential for the extreme drawdown currently predicted by the model.

The third and most significant additional drawdown is within the Lee County Utilities' Pinewoods wellfield. The Pinewoods wellfield has 10 wells, 5 of which are simulated to come online in 2040, and all the wells, including the proposed wells, are within close proximity to each other, which results in two wells in each of three model cells. Additionally, within this small wellfield, there is a 3.91 mgd increase in pumpage from 2014 to 2040. This results in two model cells having a significant additional drawdown of more than 60 ft. Water levels in these cells go from +34 ft of head in the final condition of 2014 to -30 ft of head in the final condition of 2040. The surrounding cells also have a significant amount of additional drawdown, ranging between 20 and 40 ft. Drawdown of this magnitude is a direct result of the projected increase in demand from the 10 wells in the center of 2 model cells. There are two additional wellfields that are predicted to have additional drawdown between 10 and 15 ft: Collier County Water Sewer District North and NERWTP. The additional drawdown at Collier County Water Sewer District's NERWTP wellfield is a direct result of the wellfield becoming operational in 2040, which results in an average of 12 ft of additional drawdown within the immediate vicinity of the wellfield. Drawdowns of this magnitude are not uncommon when new wellfields become operational. The additional drawdown at Collier County Water Sewer District's North wellfield most likely is due to the increase in demand between 2014 and 2040 (3.7 mgd) and the placement of new wells within the same model cell as existing wells, which results in an average of 11 ft of additional drawdown.

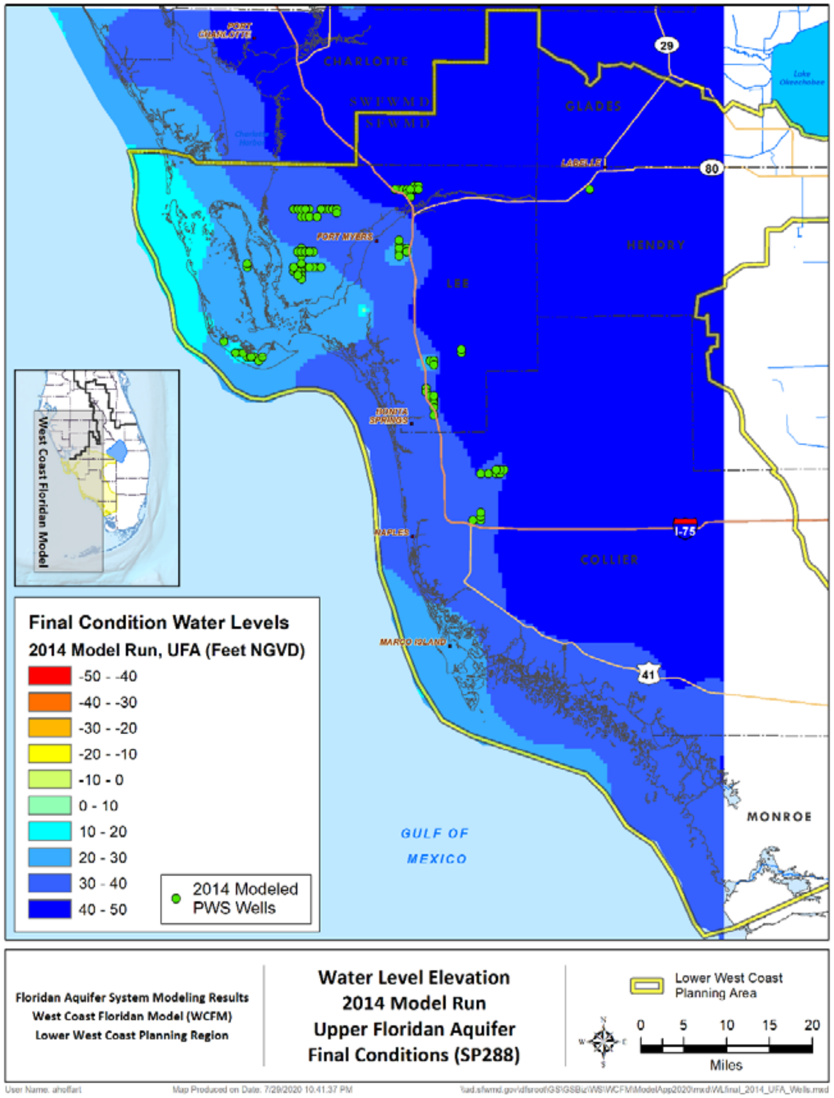

Figure 12. Upper Floridan aquifer water levels for the final condition of the 2014 model run.

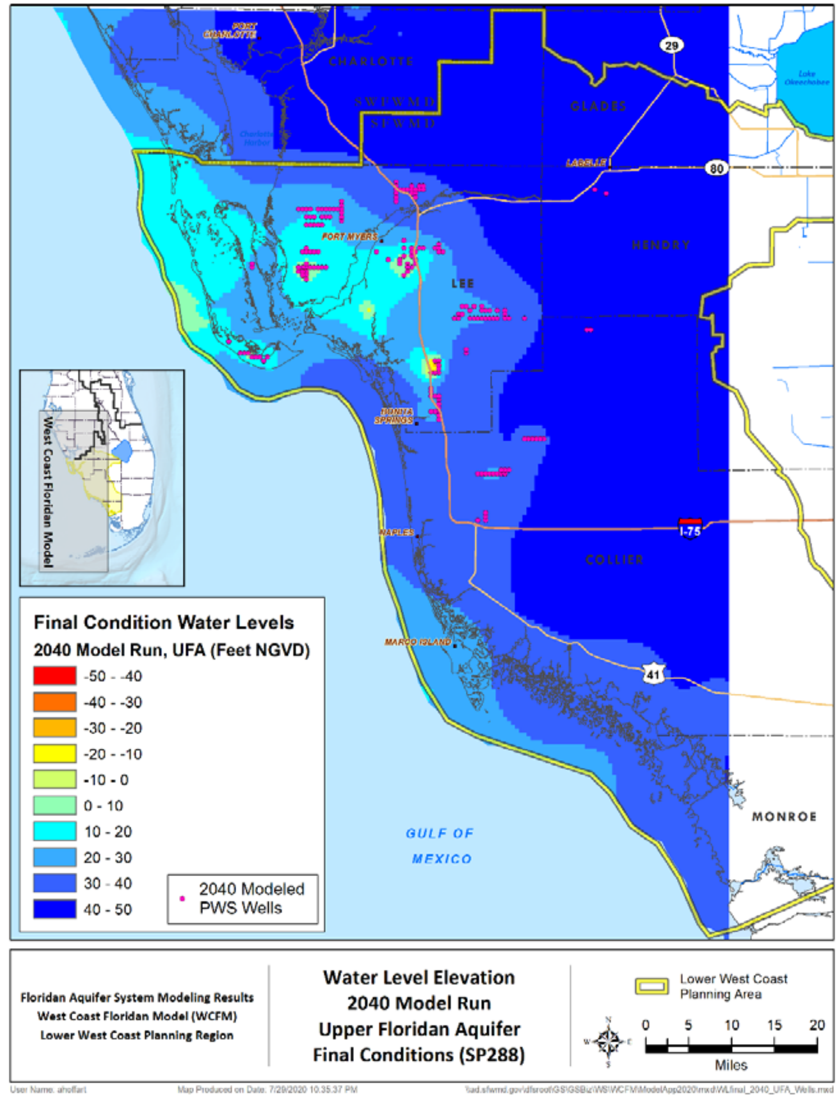

Figure 13. Upper Floridan aquifer water levels for the final condition of the 2040 model run.

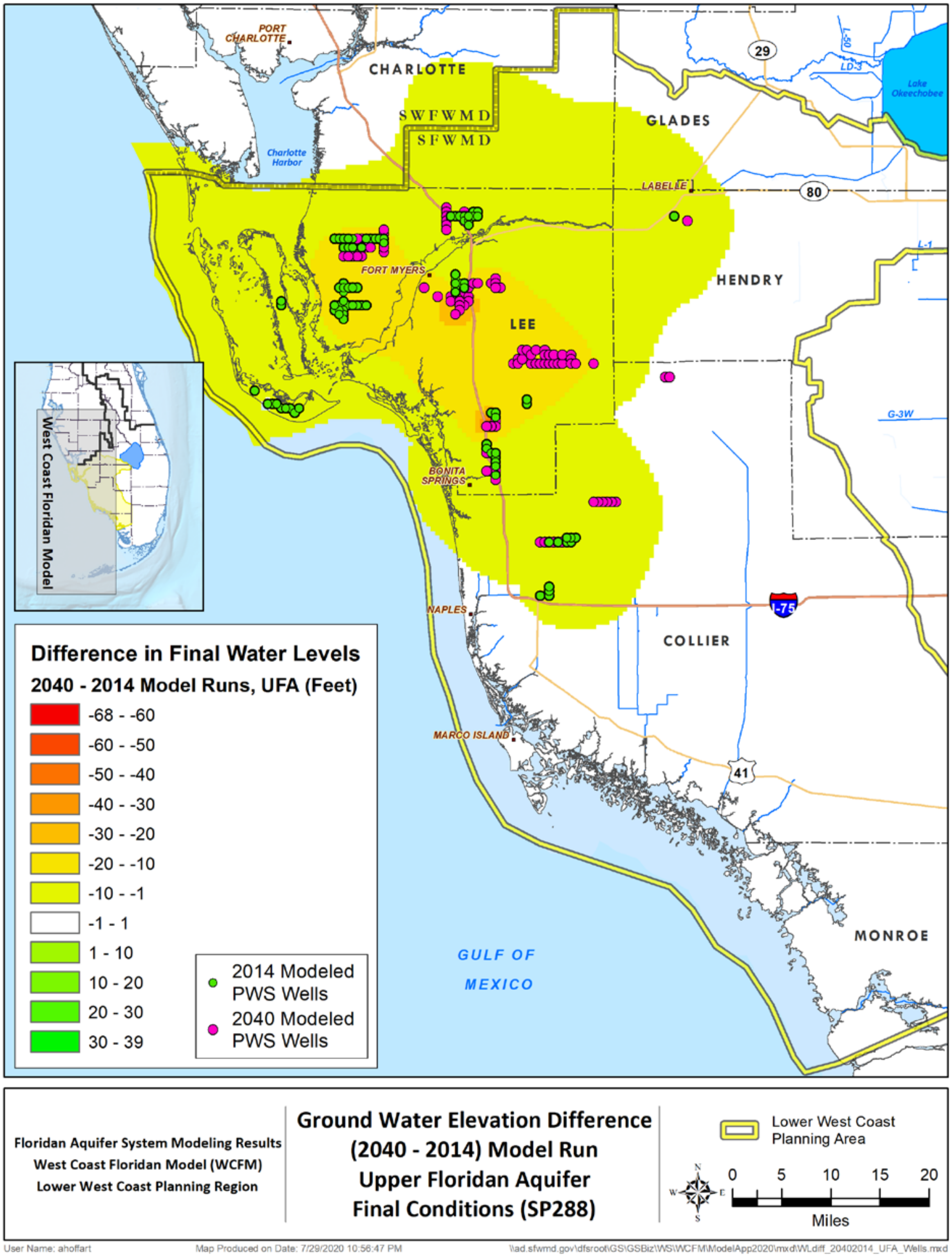

Figure 14. Upper Floridan aquifer water level differences between 2014 and 2040.

Figures 15 and **16** show the spatial distribution of water levels in the APPZ for the 2014 and 2040 model runs, respectively. Across the LWC Planning Area, APPZ water levels typically are between -20 and +50 ft of head, with some localized low areas around large wellfields. **Figure 17** shows the APPZ water level differences between the 2040 future simulation and 2014 base condition. In **Figure 17**, differences in yellow and red colors represent a drawdown effect, with water levels in 2040 being lower than the water level in the 2014 base condition. Differences shown in green represent an increase in water level for the 2040 final condition compared to the 2014 final condition. There is less than 10 ft of additional drawdown between the two model scenarios. Two main areas have apparent increases in additional drawdowns: Cape Coral Utilities' South wellfield and Fort Myers Utility's wellfield. Both areas of increased additional drawdown are a direct result of the significant increase in pumping from the overlying UFA. Near the Cape Coral Utilities wellfield, the 2014 final condition water level is -17 ft of head, and the 2040 final condition water level is -41 ft of head, resulting in -24 ft of additional drawdown. The water level difference in the Fort Myers Utility wellfield is 26 ft of additional drawdown, with water levels going from +7 ft of head in 2014 to -19 ft of head in 2040.

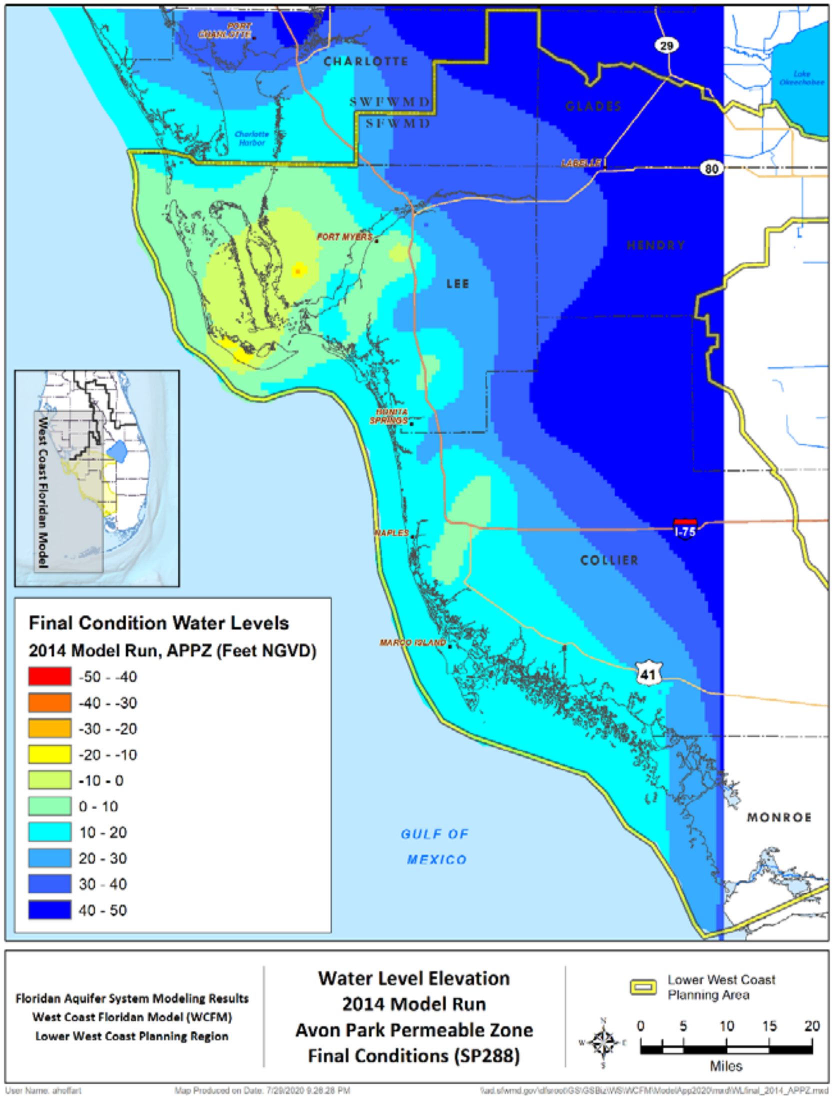

Figure 15. Avon Park permeable zone water levels for the final condition of the 2014 model run.

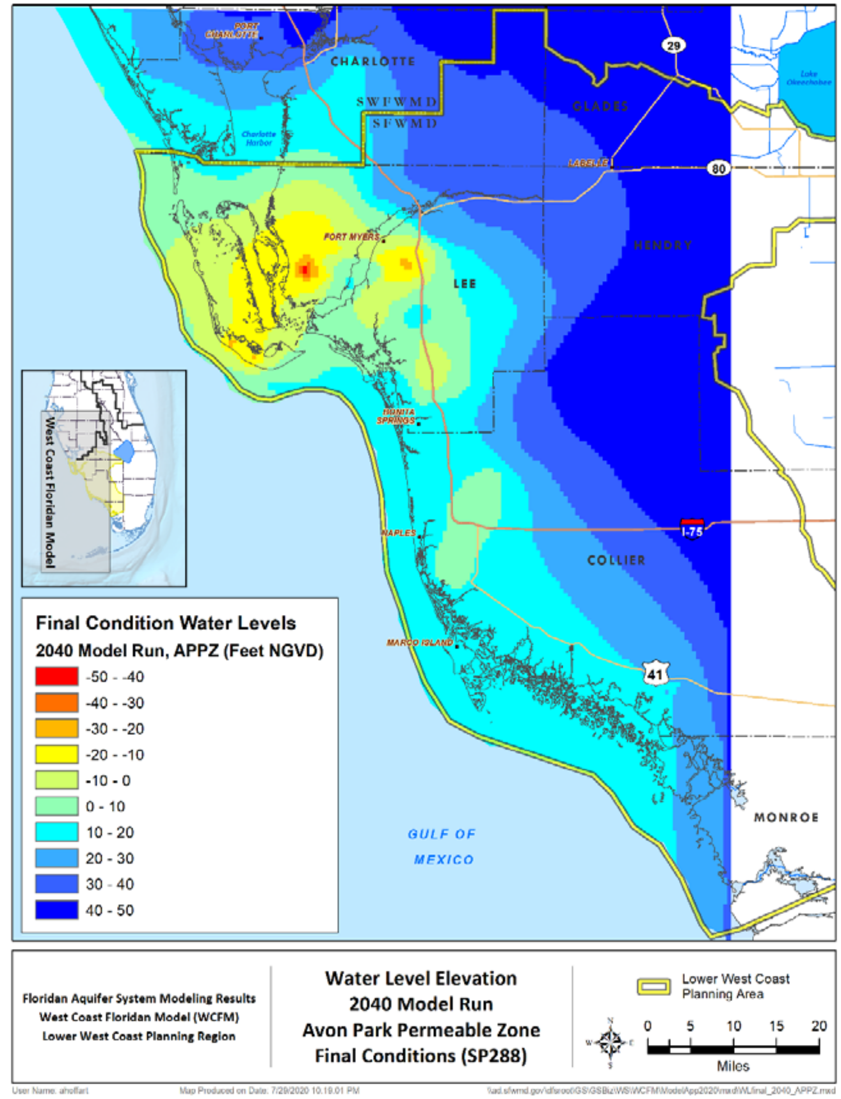

Figure 16. Avon Park permeable zone water levels for the final condition of the 2040 model run.

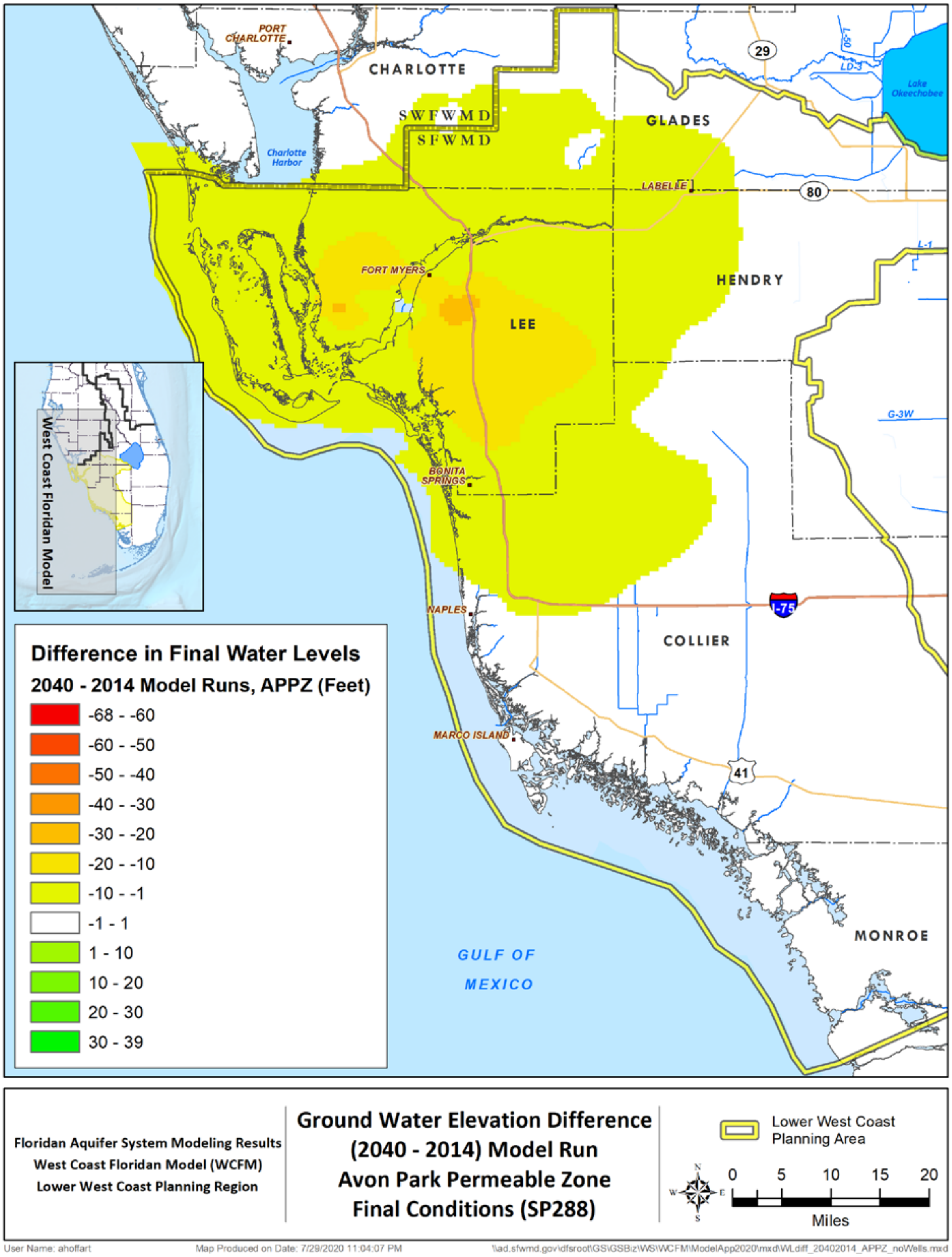

Figure 17. Avon Park permeable zone water level differences between 2014 and 2040.

4.2.2 Water Quality Variations

Figures 18 and **19** show the spatial distribution of UFA water quality (represented by TDS concentrations) for the 2014 and 2040 model runs, respectively. Across the LWC Planning Area, TDS concentrations in the UFA vary between 1,000 and 30,000 mg/L (in coastal areas). The spatial distribution of UFA water quality differences for the 2014 base condition and 2040 future simulation is shown in **Figure 20**, respectively. PS wells that were simulated in the WCFM are shown in green for the 2014 base condition and in pink for the 2040 future simulation. In general, the simulated TDS concentrations remain steady throughout the model domain, except in Lee County where there are slight increases associated with the projected 2040 demands. Changes in water quality compare the final condition (stress period 288, representing December 2012) of 2040 to the final condition of 2014. As a reminder, the future condition assumes pumping the full 2040 demands continuously for 24 years. Differences in gray and purple colors represent a degradation in water quality, with TDS concentrations in 2040 being higher than in 2014. Differences shown in green represent improvements in water quality for the 2040 final condition compared to the 2014 final condition. Water quality changes of less than 200 mg/L were predicted in most counties, suggesting no major issues with water quality for the planning area, even with the significant increase in demand.

Figure 20 shows the UFA water quality difference between the 2040 final condition and the 2014 final condition. Overall, there is very little difference in TDS concentrations across the LWC Planning Area. There is one area of noticeable water quality degradation around the Bonita Springs Utilities wellfield, and there are several areas of slight water quality degradation near all Lee County Utilities' wellfields, Island Water Association's wellfield, and Cape Coral Utilities' wellfield. Bonita Springs Utilities is close to the saltwater interface along the west coast of Florida, and just north of the Collier-Lee county line, where water quality in the UFA starts to noticeably degrade. With an increase in demand of 5.1 mgd from 2014 to 2040, there is lateral flow of water from the coast towards the wellfield and lateral movement of water from northern Collier County towards the wellfield. This results in a water quality degradation maximum of 1,800 mg/L within the vicinity of the wellfield. Water quality degradation near the Pinewoods wellfield is between 200 and 1,000 mg/L and is a result of the significant increase in demand, which almost triples from 2014 to 2040. Water quality degradation near the Green Meadows wellfield is between 200 and 700 mg/L and is a result of the new wellfield coming online in the 2040 future simulation with an average demand of 12.7 mgd. Water quality degradation within the Cape Coral Utilities and Fort Myers Utility wellfields are on the order of 200 to 500 mg/L, which is a result of the increase in water use in these areas.

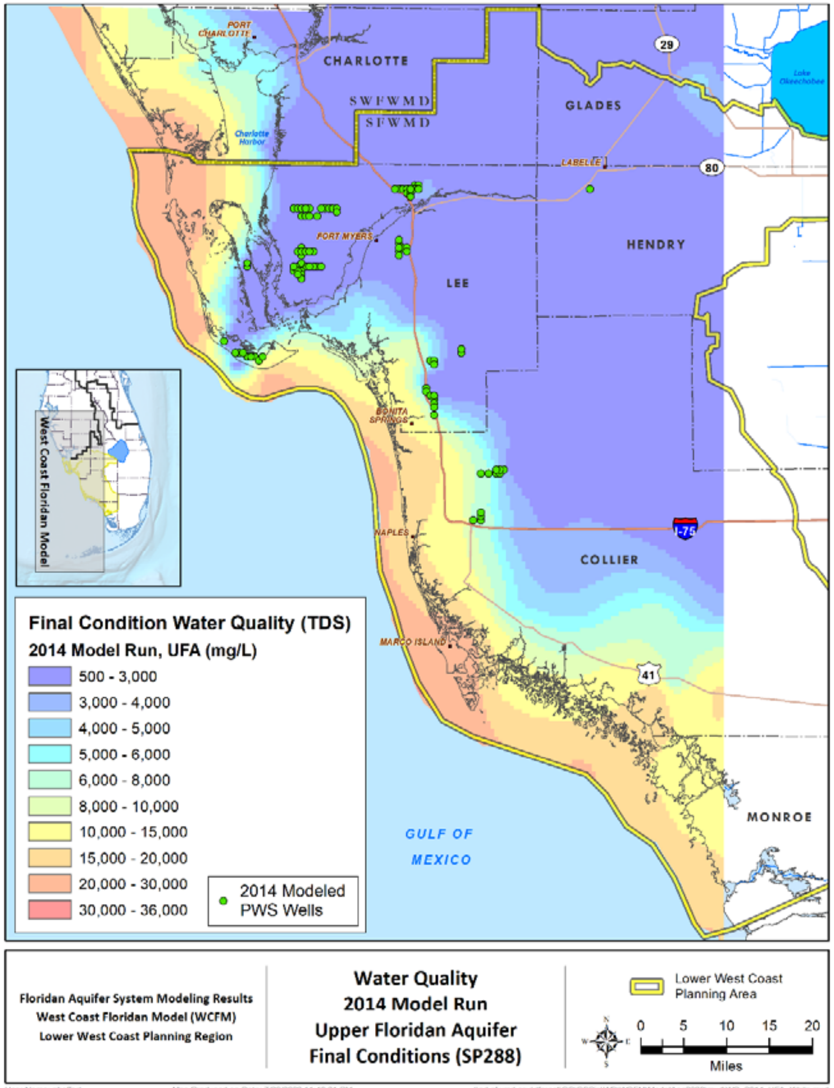

Figure 18. Upper Floridan aquifer water quality (total dissolved solids concentrations) for the final condition of the 2014 model run.

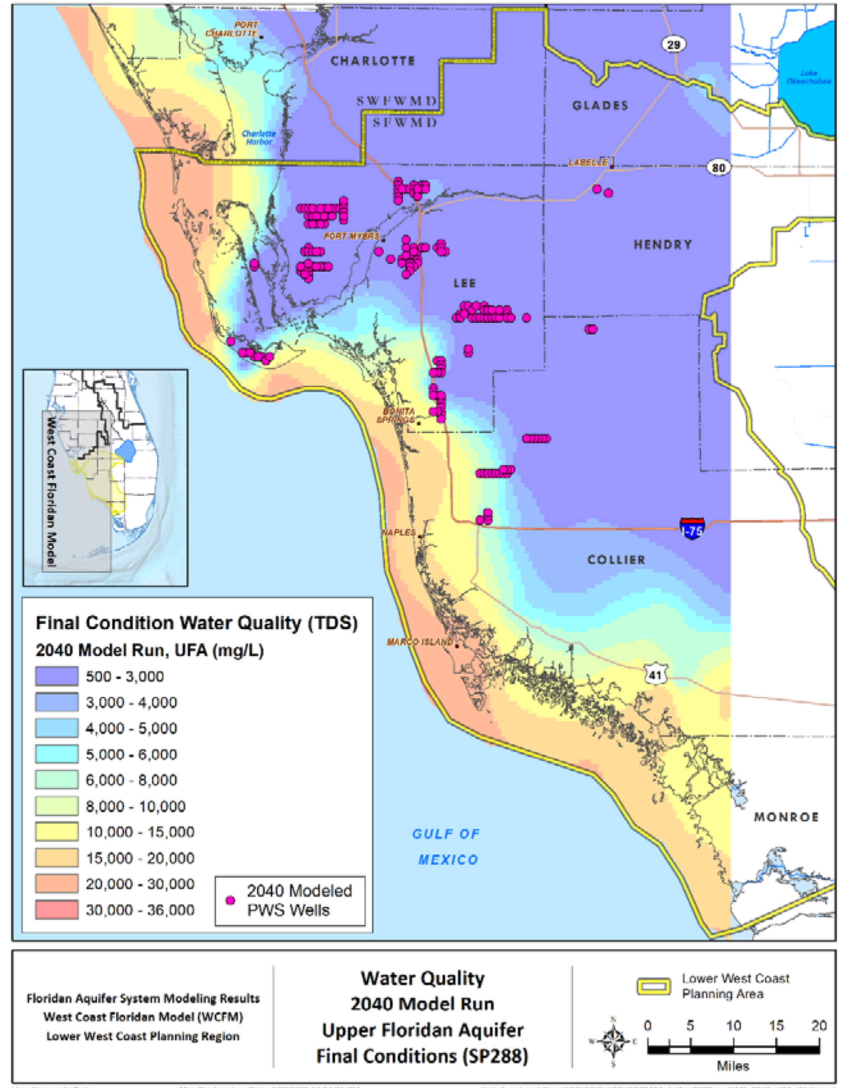

Figure 19. Upper Floridan aquifer water quality (total dissolved solids concentrations) for the final condition of the 2040 model run.

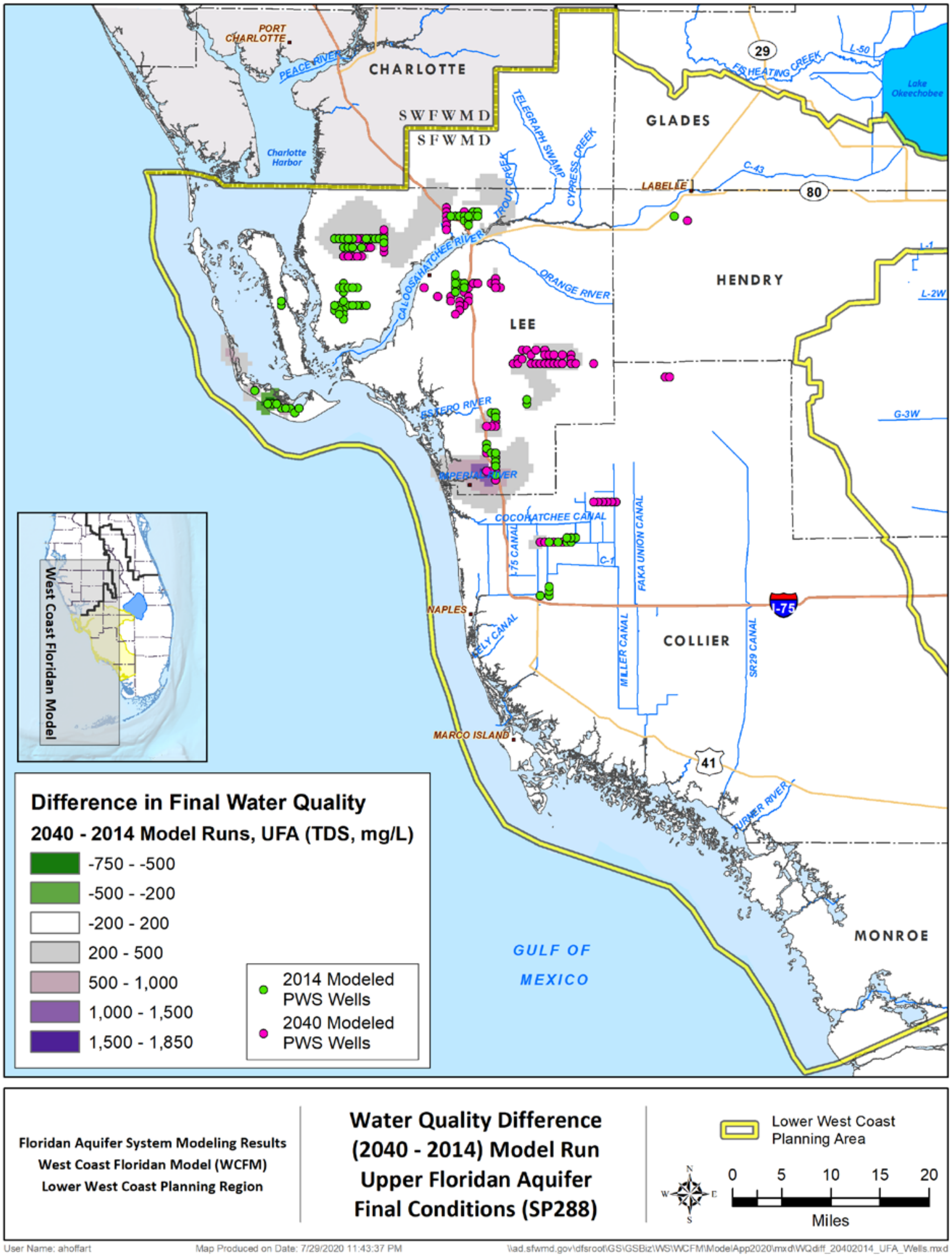

Figure 20. Upper Floridan aquifer water quality (total dissolved solids concentration) difference between 2014 and 2040.

Figures 21 and **22** show the spatial distribution of APPZ water quality for the 2014 and 2040 model runs, respectively. Across the LWC Planning Area, TDS concentrations in the APPZ vary between less than 3,000 mg/L in northeastern Collier County to more than 30,000 mg/L near the coast. **Figure 23** shows the APPZ water quality difference between the 2040 final condition and 2014 final condition. Overall, there is very little difference in TDS concentrations across the LWC Planning Area, largely because no PS wellfields withdraw from the APPZ. There is one area of noticeable water quality degradation near Lee County Utilities' new Green Meadows wellfield, and there are three areas of slight water quality improvement: east of Lee County Utilities' Pinewoods wellfield and on either side of Lee County Utilities' North wellfield. The area of water quality degradation is a direct result of the new Green Meadows wellfield coming online in the 2040 future simulation. Although the demand will be met with water from UFA wells, water quality degradation is seen in the APPZ due to an increase in lateral flow from the south. The area south of the Green Meadows wellfield has slightly higher TDS concentrations, resulting in a maximum water quality degradation of 1,000 mg/L. Water quality improvement near the Pinewoods wellfield, on the order of 300 to 600 mg/L, is a result of lateral flow in the APPZ from the east, where there is noticeably fresher water. Water quality improvement east and west of Lee County Utilities' North wellfield is on the order of 200 to 500 mg/L and is a result of lateral water movement from the northern portion of the model domain, which is the known FAS recharge area for the LWC Planning Area and has significantly fresher water.

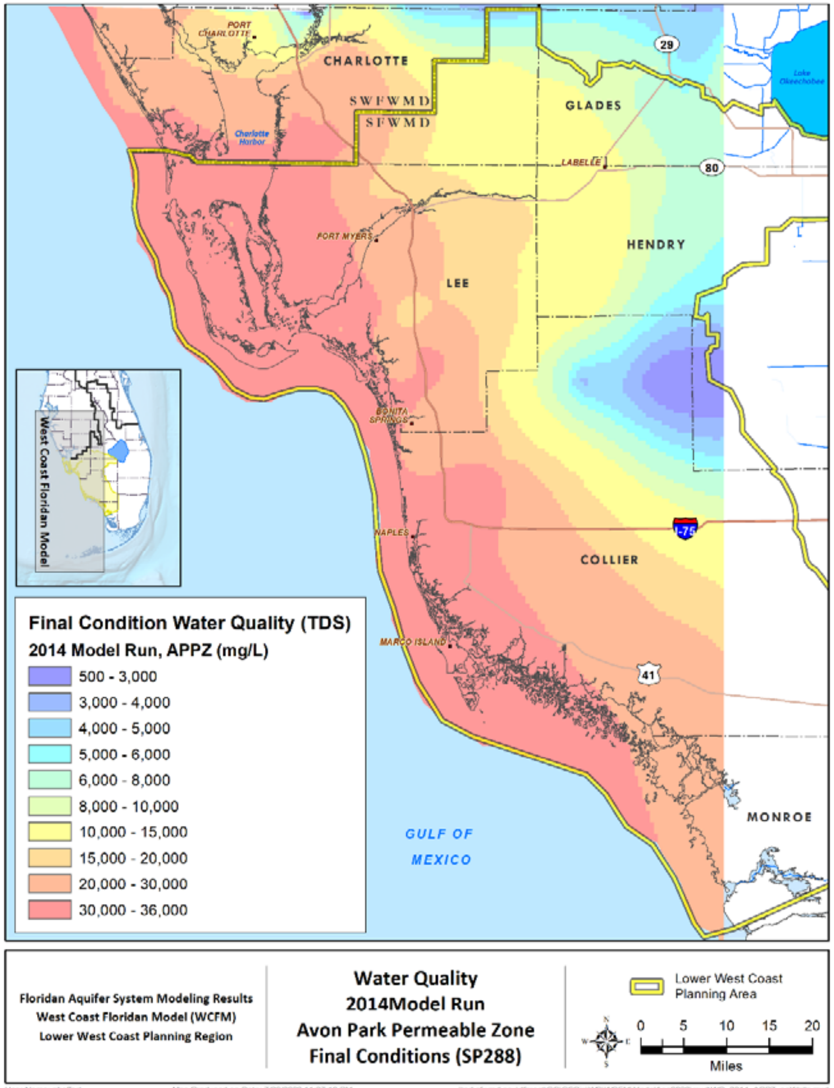

Figure 21. Avon Park permeable zone water quality (total dissolved solids concentrations) for the final condition of the 2014 model run.

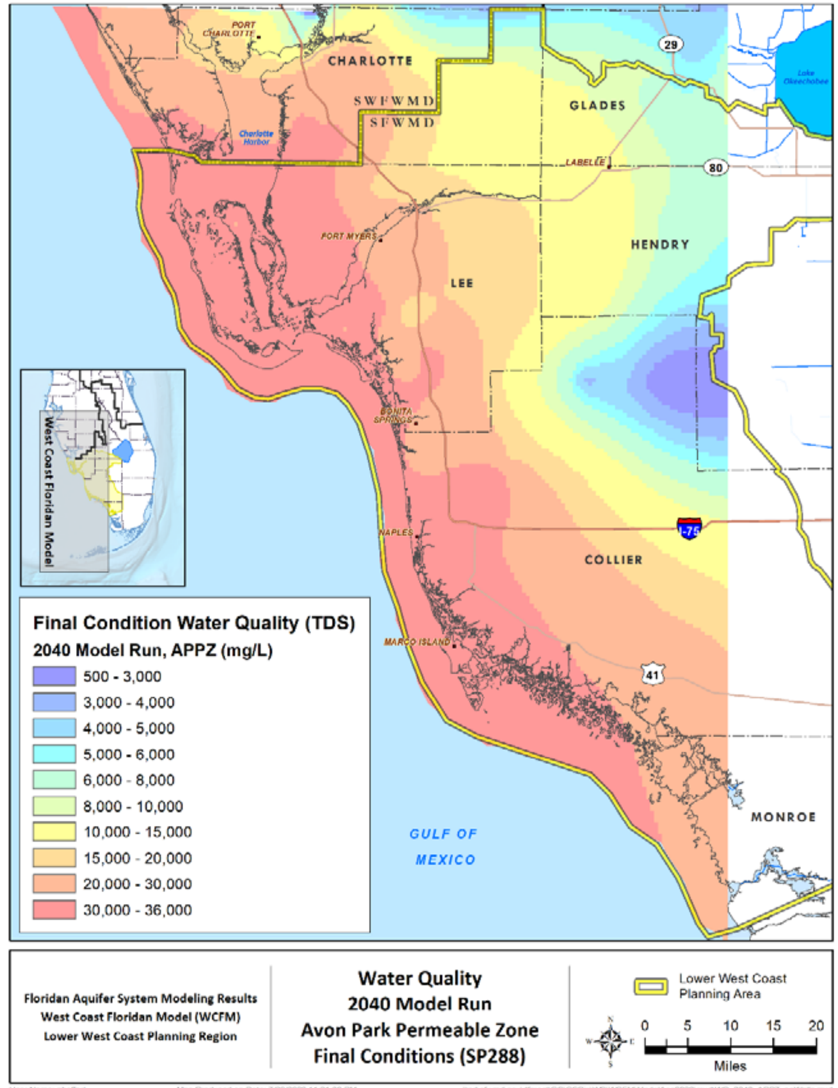

Figure 22. Avon Park permeable zone water quality (total dissolved solids concentrations) for the final condition of the 2040 model run.

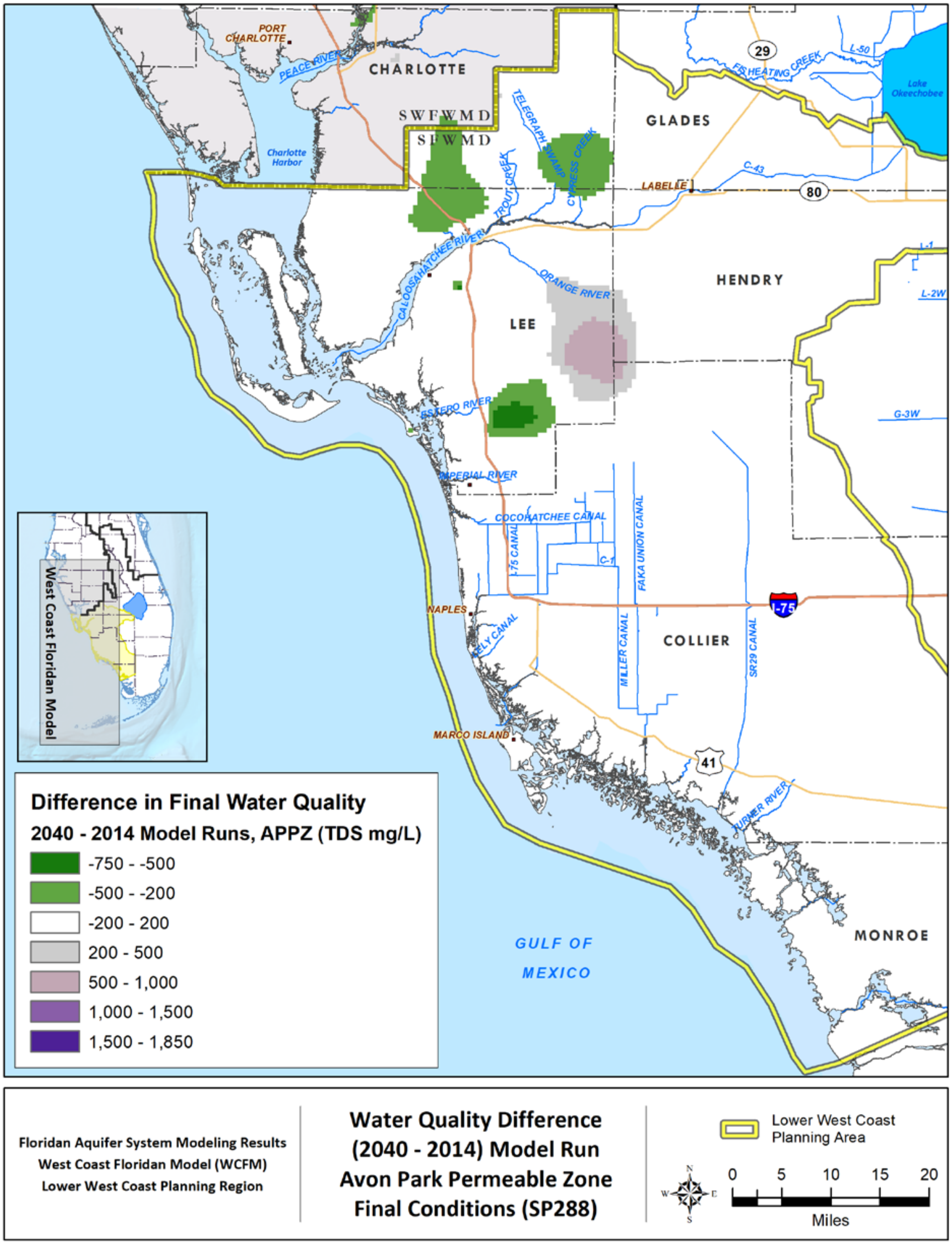

Figure 23. Avon Park permeable zone water quality (total dissolved solids concentration) difference between 2014 and 2040.

4.2.3 Flow Vectors

Horizontal flow vectors show the magnitude and direction of lateral flow for the final condition (stress period 288, which represents December 2012) for the 2014 and 2040 simulations. A side-by-side comparison of the flow vectors is necessary to understand changes in the magnitude and direction of flow resulting from the difference in water use demand. The horizontal flow vectors shown in **Figures 24** to **27** represent a resampling of five model cells by five model cells. The vectors represent the average conditions for the specific grouping of 25 cells. **Figures 24** and **26** show the resampled horizontal flow vectors for the 2014 base condition in the UFA and APPZ, respectively, and **Figures 25** and **27** show the resampled horizontal flow vectors for the 2040 future simulation in the UFA and APPZ, respectively. As illustrated in each figure, water moves into the model domain from the northern recharge area located along the Lake Wales Ridge and the potentiometric high in Polk County, which provide the only FAS recharge in South Florida. Overall, the flow pattern in the graphics has a general northeast to southwest flow, as expected based on historical, regional potentiometric levels (Meyer 1989, Miller 1990).

Comparing **Figures 24** and **25**, which show the horizontal flow vectors for 2014 and 2040 in the UFA, there are some apparent differences in magnitude and direction of flow. There is a distinct increase in the magnitude of lateral flow from the northern recharge area into the vicinity of Fort Myers Utility's wellfield and Lee County Utilities' North wellfield. This increase in flow from an area of higher head and fresher water could help minimize potential drawdown and water quality degradation that would occur due to the increased PS demand. There also is a change in flow direction near the new Green Meadows wellfield that is simulated in the 2040 future condition. In **Figure 25**, the 2040 flow vectors north of the wellfield are higher in magnitude but have the same direction as the 2014 flow vectors. However, south of the wellfield, the flow vectors change direction, with vectors that were moving from east to west in the 2014 simulation now moving south to north towards the wellfield. The increase in horizontal flow from the south can cause water quality degradation because the southern portion of the model domain tends to have higher TDS concentrations. Near the Pinewoods wellfield, more flow vectors turn towards the wellfield from the south and the magnitude of the flow vectors increases, indicating some movement of poor-quality water into the wellfield from the south. This observation is consistent with the water quality difference maps, which indicate additional water quality degradation in the area. Near the Bonita Springs Utilities wellfield, there is a noticeable increase in the magnitude and number of flow vectors coming from the Gulf of Mexico towards the wellfield, indicating a potential lateral saltwater intrusion issue. Additionally, there is an increase in the magnitude of lateral water movement from northern Collier County, which has higher salinity. These observations are consistent with the water quality difference results discussed above, which showed noticeable water quality degradation near the Bonita Springs Utilities wellfield.

Changes in the flow vectors between the 2014 base condition and 2040 future simulation are less apparent in the APPZ. Comparing **Figures 26** and **27**, there is a slight increase in the magnitude of horizontal flow from the north due to additional UFA withdrawals near the Lee County Utilities North wellfield. The magnitude of flow increases from north to south towards the Green Meadows wellfield. The new wellfield also causes a change in the direction of southern flow vectors, which moved from east to west in 2014, and move from south to north at a larger magnitude in 2040.

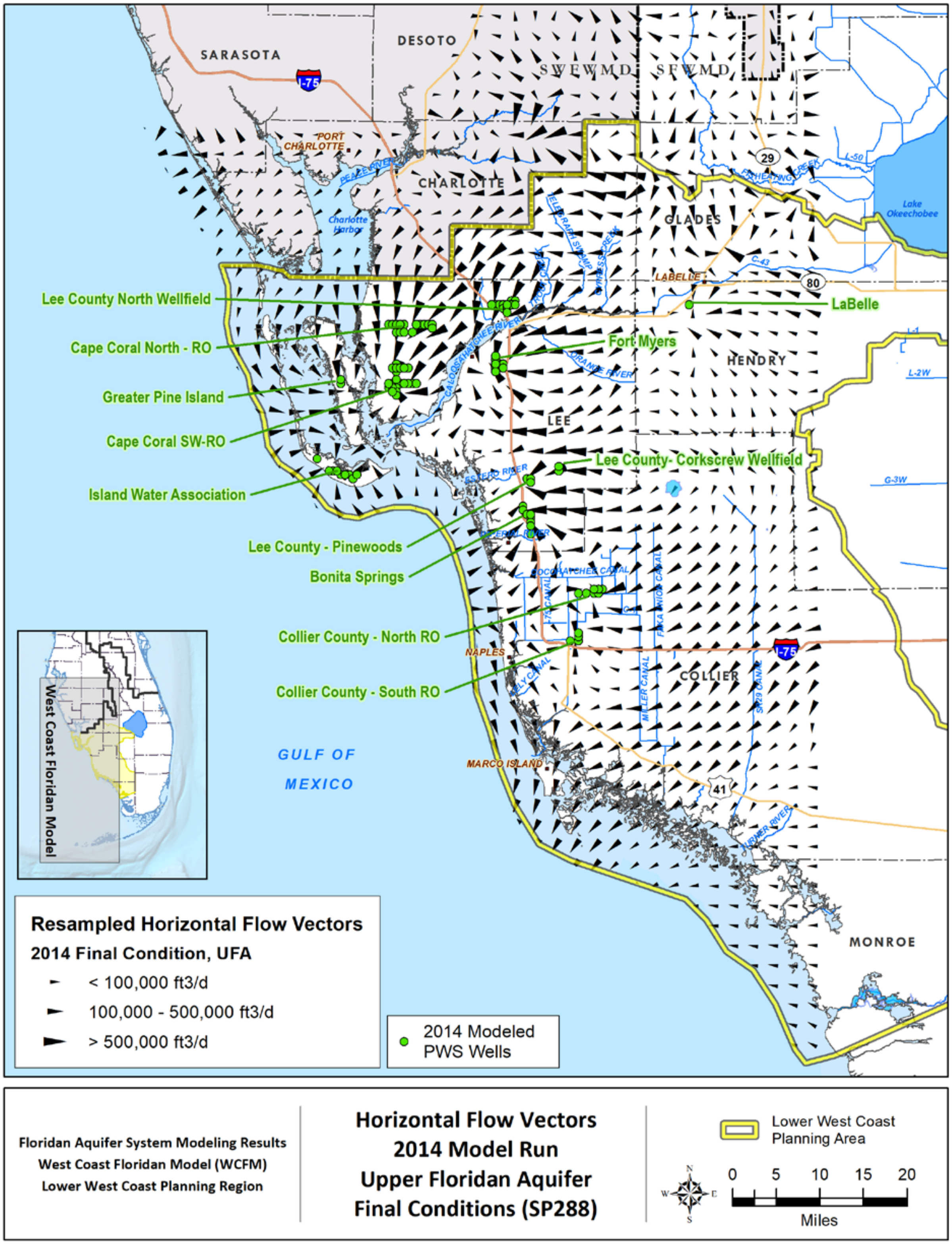

Figure 24. Resampled horizontal flow vectors for the final condition of the 2014 model simulation in the Upper Floridan aquifer.

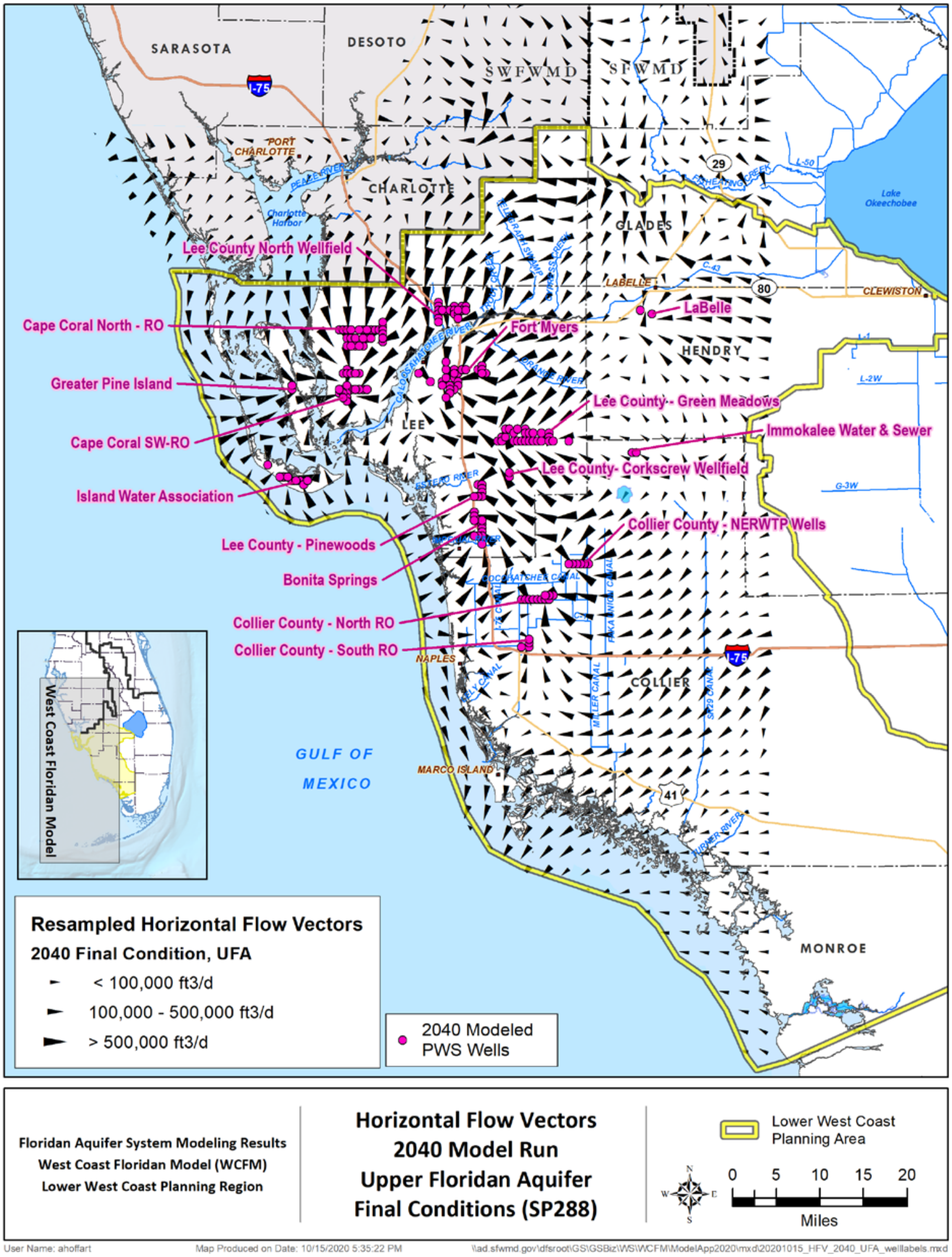

Figure 25. Resampled horizontal flow vectors for the final condition of the 2040 model simulation in the Upper Floridan aquifer.

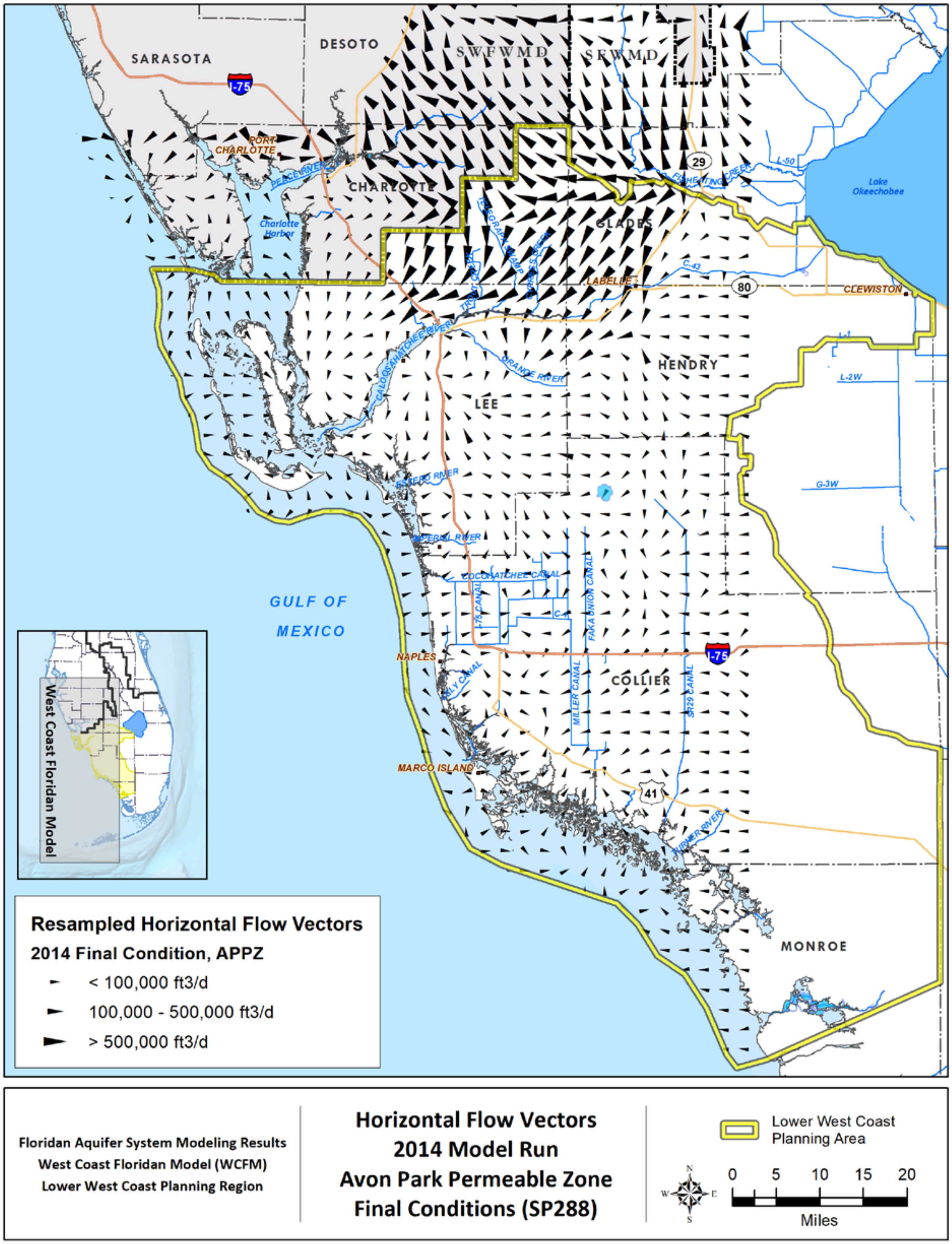

Figure 26. Resampled horizontal flow vectors for the final condition of the 2014 model simulation in the Avon Park permeable zone.

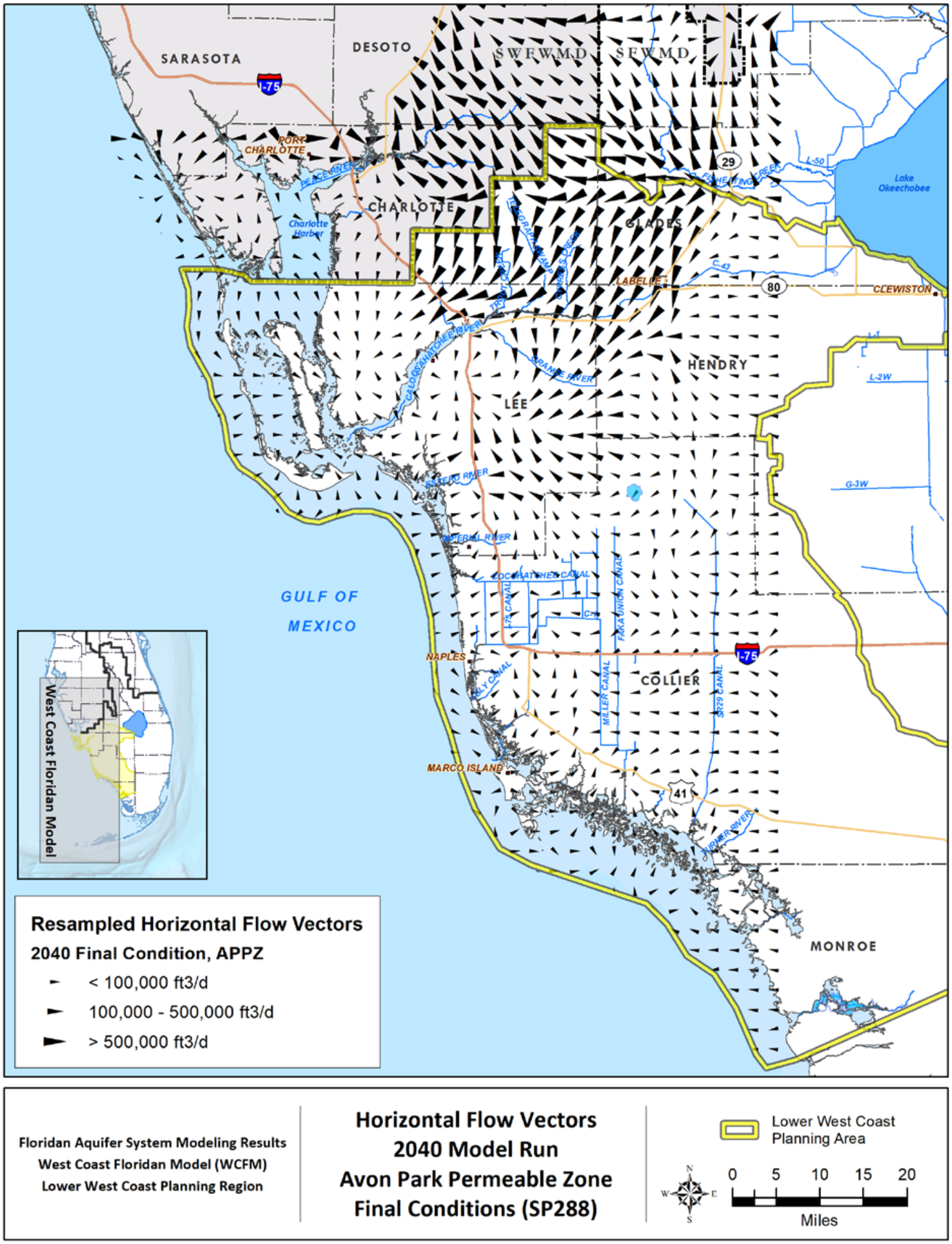

Figure 27. Resampled horizontal flow vectors for the final condition of the 2040 model simulation in the Avon Park permeable zone.

5 MODEL INTERPRETATION

The 2020 WCFM is a significant improvement over previous model versions, including the most recent version (2011), which addressed comments from the 2008 peer review. Much has been learned from peer reviews of other regional FAS models adjacent to the LWC Planning Area, including improved hydrogeologic conceptualization based on data from new well installations, increased water use information, increased water level and TDS data from production and monitor wells, and more stringent calibration criteria. Overall, these improvements provide greater confidence in model applications and associated interpretations.

Understanding the WCFM's limitations is important when interpreting the model results, especially given its regional nature. The model cell size is 2,400 ft by 2,400 ft; as such, when wells are close together, multiple wells are simulated in a single model cell. In these cases, the model assumes all withdrawals occur from the center of the model cell, which tends to exaggerate water level drawdowns and water quality degradation impacts. The WCFM also may not capture local heterogeneity in the FAS or the response at individual wells. Additionally, the model does not simulate gradual annual demand growth as would realistically occur. Simulated demands in 2014 and projected demands in 2040 are withdrawn from the model instantly, starting at stress period 1, and continued throughout the simulation period. The 2014 base condition simulates aquifer conditions that would occur if the 2014 demands were repeatedly realized every year for the 24-year period of record, with the climatic conditions from 1989 through 2012. The 2040 future condition simulates aquifer conditions that would occur if the projected demands were repeatedly realized every year for the 24-year period of record, with climatic conditions from 1989 through 2012. Therefore, the results of the 2040 simulation are considered conservative. The WCFM should be used as an overall planning tool, and the results and conclusions should not be considered absolutes.

6 CONCLUSIONS

Numerical modeling was conducted using the WCFM to simulate the 2014 and projected 2040 FAS demands to support water supply planning in the LWC Planning Area. Agricultural and landscape irrigation demands in the region are projected to remain constant; however, PS demands are projected to significantly increase, from 68.1 mgd in 2014 to 108.2 mgd in 2040. Review and analysis of water levels, water quality (represented by TDS concentrations), and flow vectors showed the WCFM is performing as expected, given current understanding of water demands and the regional groundwater system.

Groundwater model simulations were conducted to evaluate changes in water levels and water quality as a result of the net increase in FAS demand. The primary findings, with recommendations when appropriate, are as follows:

- On a local scale, spatial expansion of wellfields in Fort Myers Utility and Cape Coral Utilities, combined with the lateral recharge from the northeast, tended to minimize potential drawdown impacts despite a significant increase in demands. Expansion of the spatial extent of the wellfields (i.e., spreading out withdrawals with an increased number of wells over a larger footprint) also minimized potential water quality degradation.
- Around Lee County Utilities' Pinewoods wellfield, there is an increase in the number of production wells in 2040, but the well locations are relatively clustered, which causes 20 to 68 ft of additional drawdown compared to 2014 water levels. The additional drawdown is a result of a predicted wellfield demand increase of 3.91 mgd.
- Water quality degradation near Bonita Springs Utilities' wellfield is a result of lateral saltwater intrusion from the west (i.e., the Gulf of Mexico) and lateral water movement from northern Collier County, which has a higher salinity than water in Bonita Springs. Spatial expansion of the wellfield towards the northeast, farther from the coast and Collier County, should be considered.

Although there are localized areas of noticeable drawdowns and water quality degradation, based on planning projections, with wellfield management, the 2040 model results do not indicate a significant adverse impact to groundwater levels or water quality, which indicates that prolonged use of the FAS is sustainable for the 20-year planning horizon.

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APPENDIX A: SIMULATED VERSUS OBSERVED WATER LEVEL HYDROGRAPHS

Lee County

Cape Coral Utilities

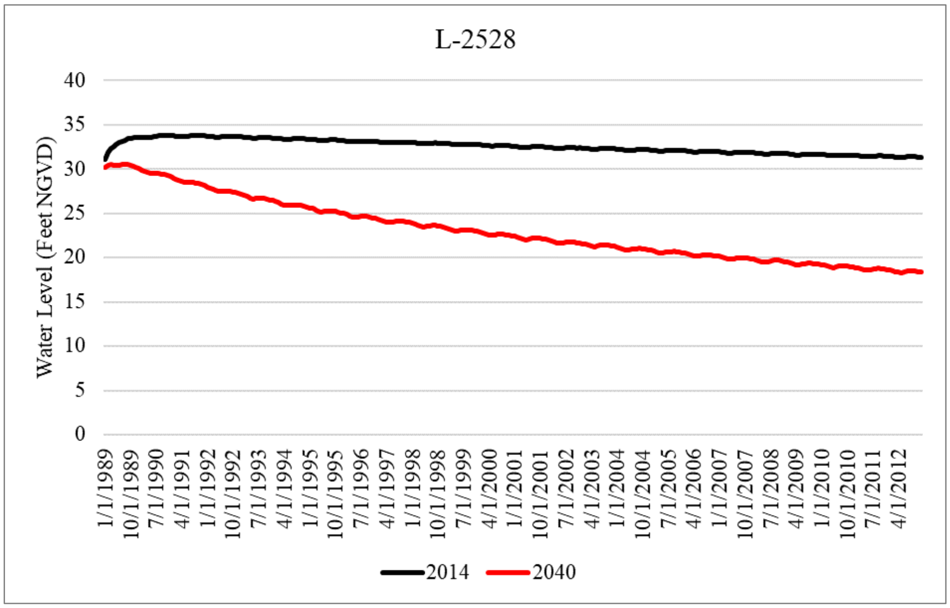

Figure A-1. Simulated water levels within the Upper Floridan aquifer for the 2014 and 2040 model runs at L-2528 in Lee County.

Fort Myers Utility

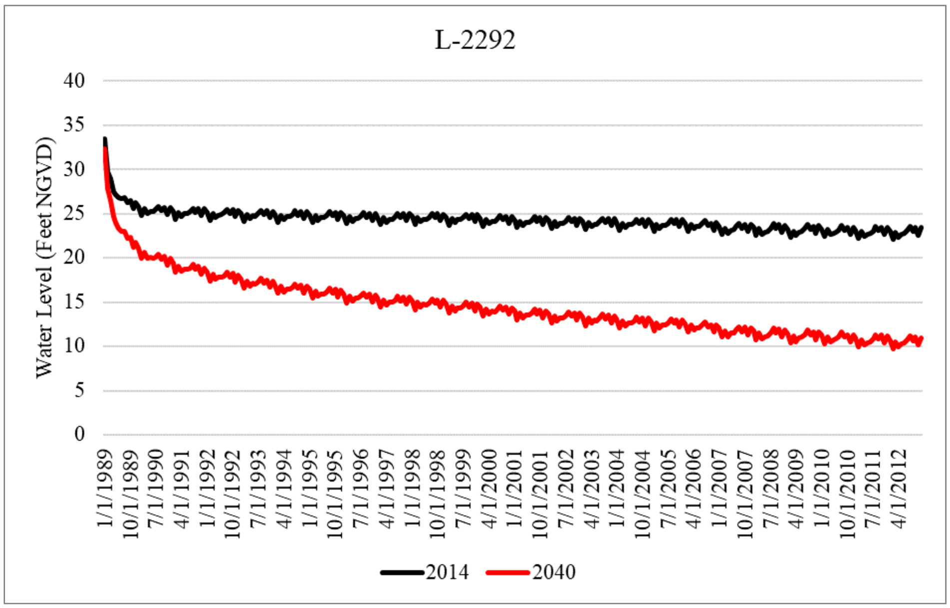

Figure A-2. Simulated water levels within the Upper Floridan aquifer for the 2014 and 2040 model runs at L-2292 in Lee County.

Island Water Association

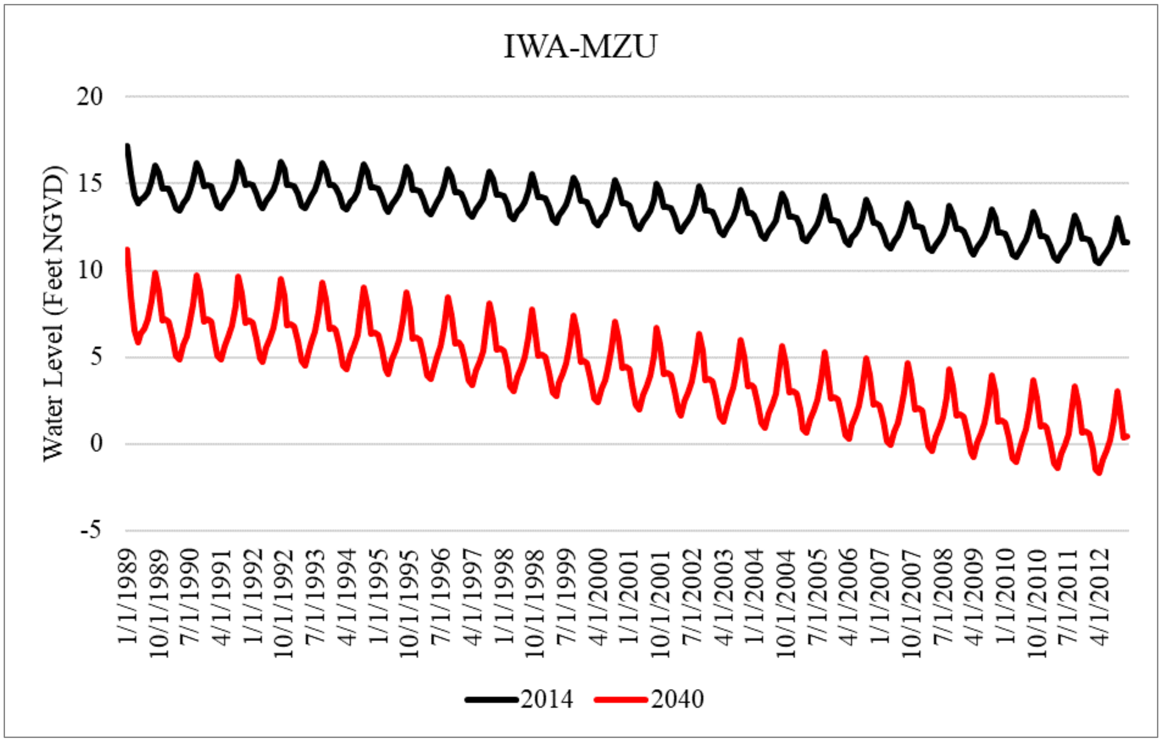

Figure A-3. Simulated water levels within the Upper Floridan aquifer for the 2014 and 2040 model runs at IWA-MZU in Lee County.

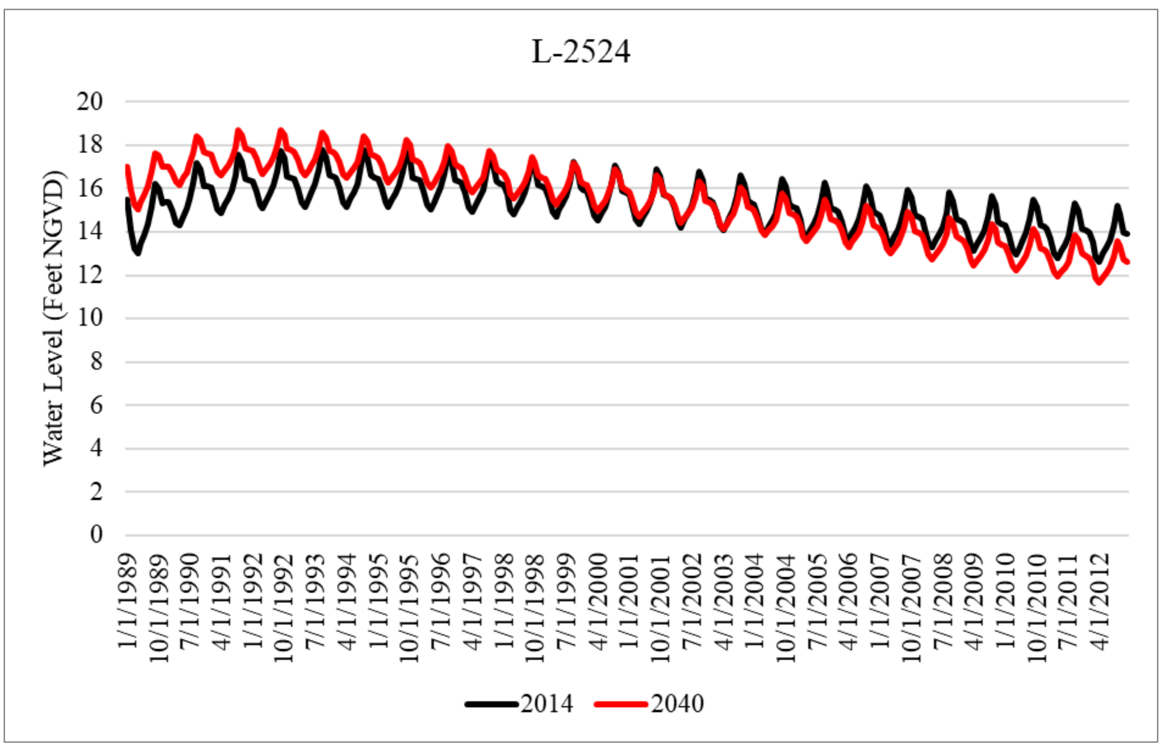

Figure A-4. Simulated water levels within the Upper Floridan aquifer for the 2014 and 2040 model runs at L-2524 in Lee County.

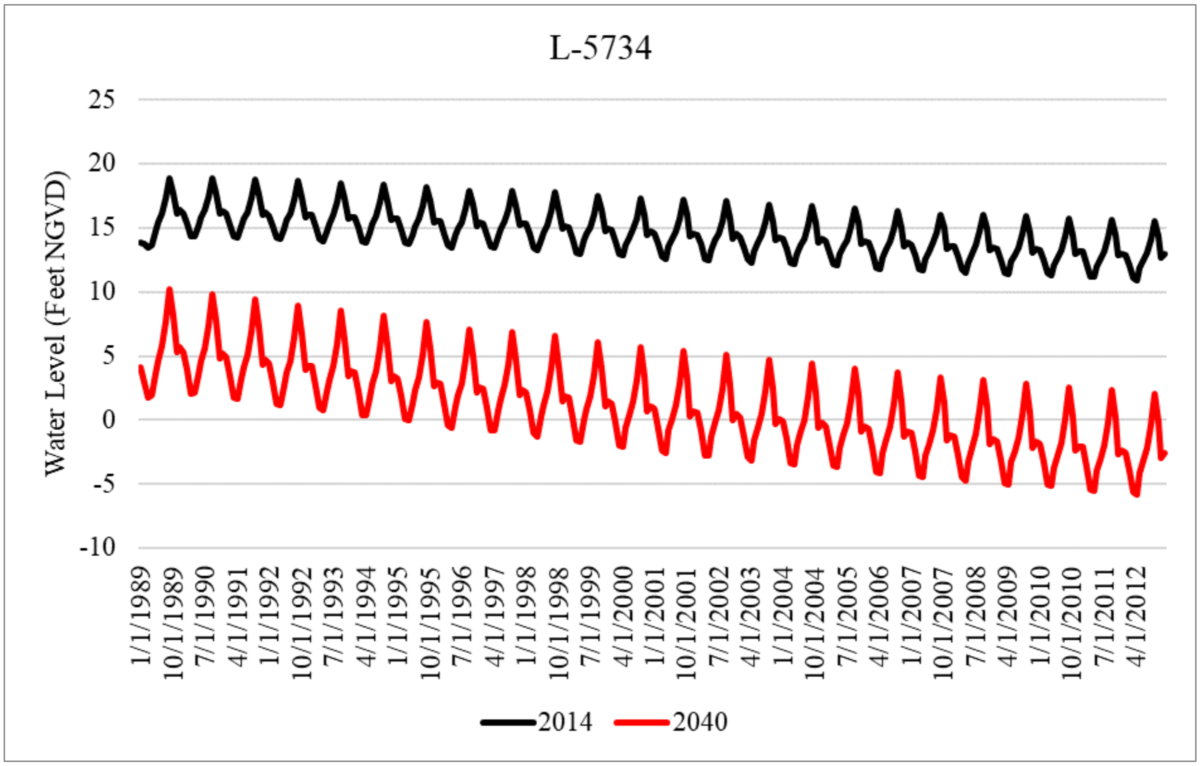

Figure A-5. Simulated water levels within the Upper Floridan aquifer for the 2014 and 2040 model runs at L-5734 in Lee County.

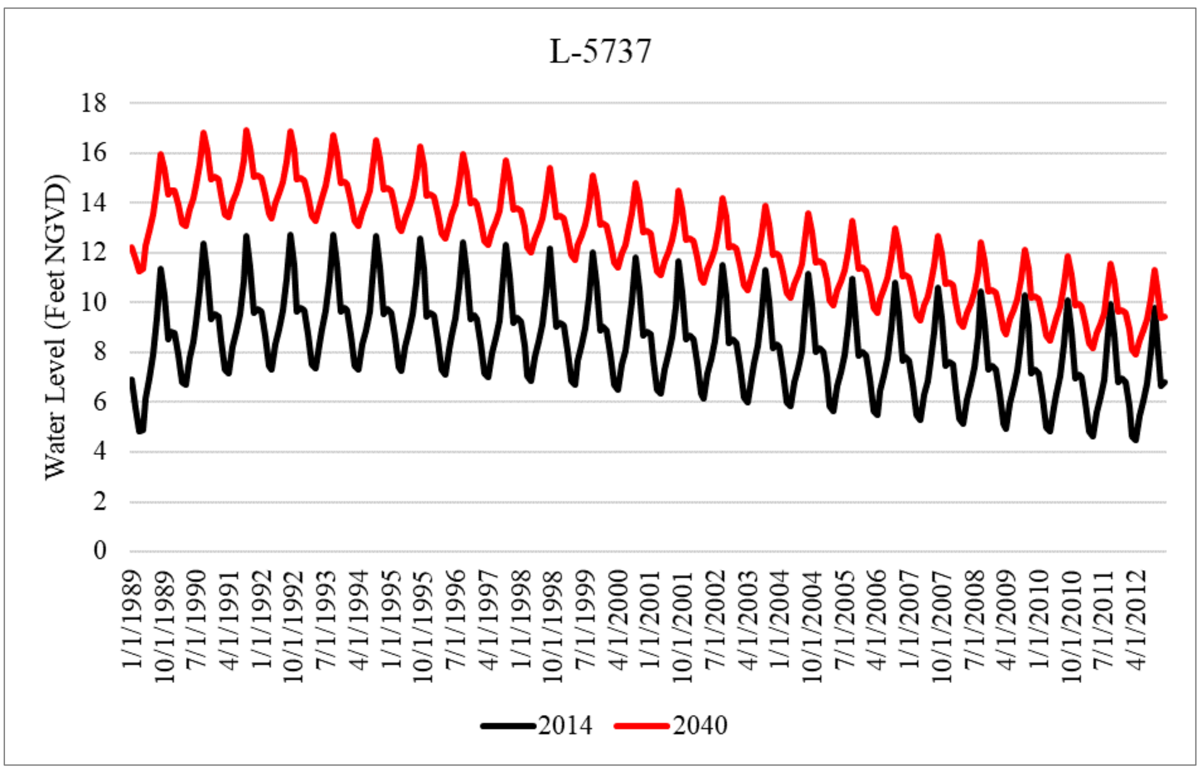

Figure A-6. Simulated water levels within the Upper Floridan aquifer for the 2014 and 2040 model runs at L-5737 in Lee County.

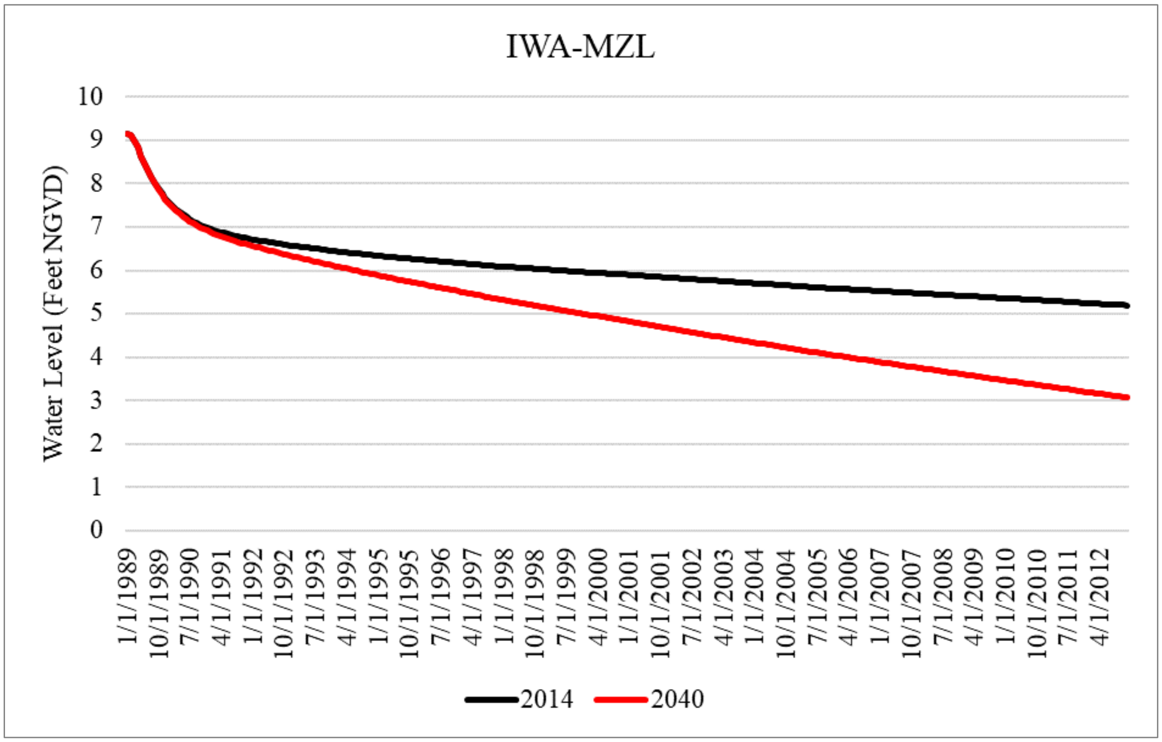

Figure A-7. Simulated water levels within the Lower Floridan aquifer – first permeable zone for the 2014 and 2040 model runs at IWA-MZL in Lee County.

Lee County Utilities – North Wellfield

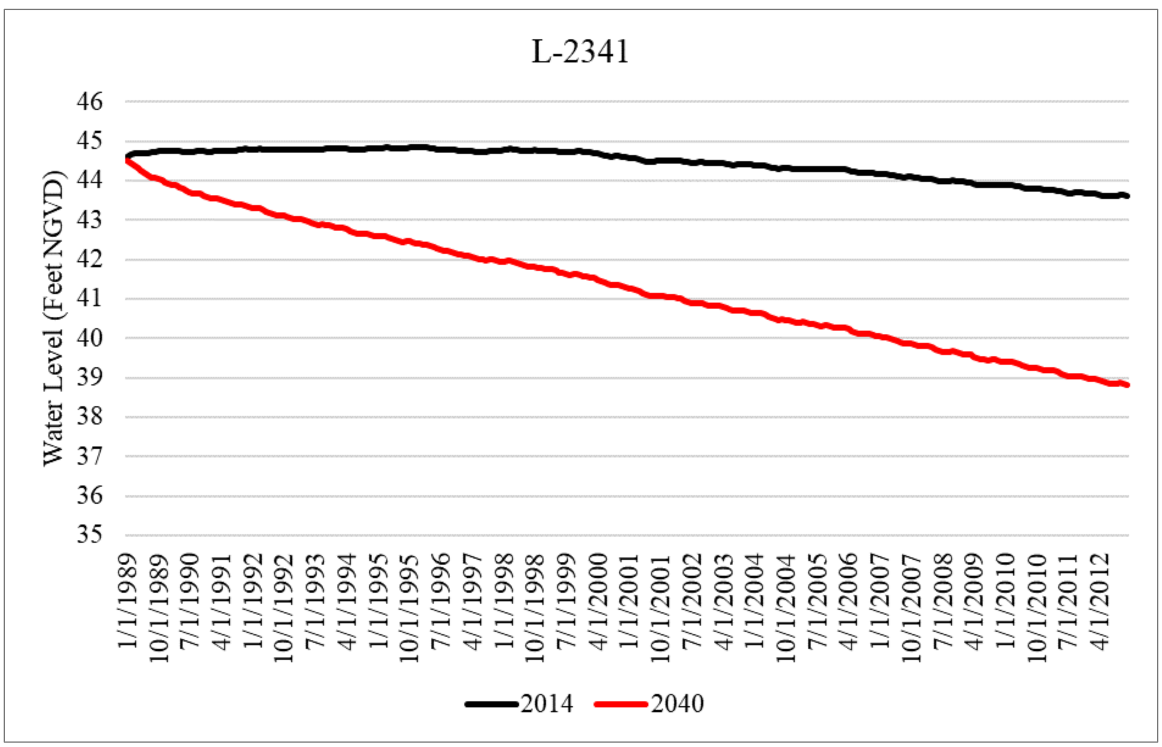

Figure A-8. Simulated water levels within the Upper Floridan aquifer for the 2014 and 2040 model runs at L-2341 in Lee County.

Collier County

Collier County Water Sewer District – South Wellfield

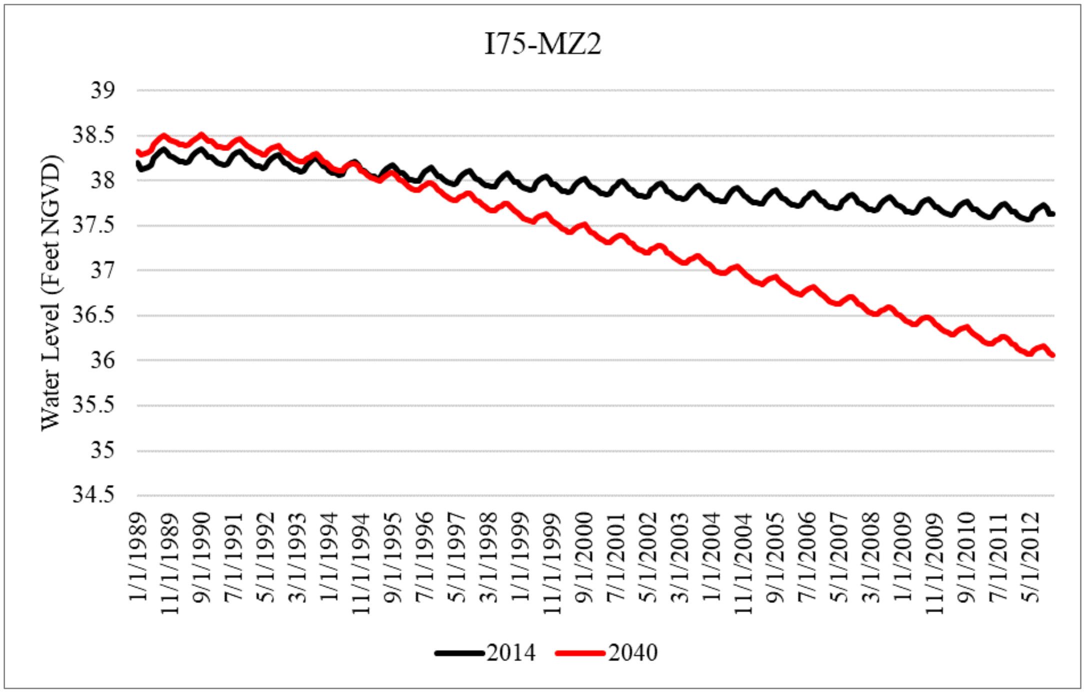

Figure A-9. Simulated water levels within the Upper Floridan aquifer for the 2014 and 2040 model runs at I75-MZ2 in Collier County.

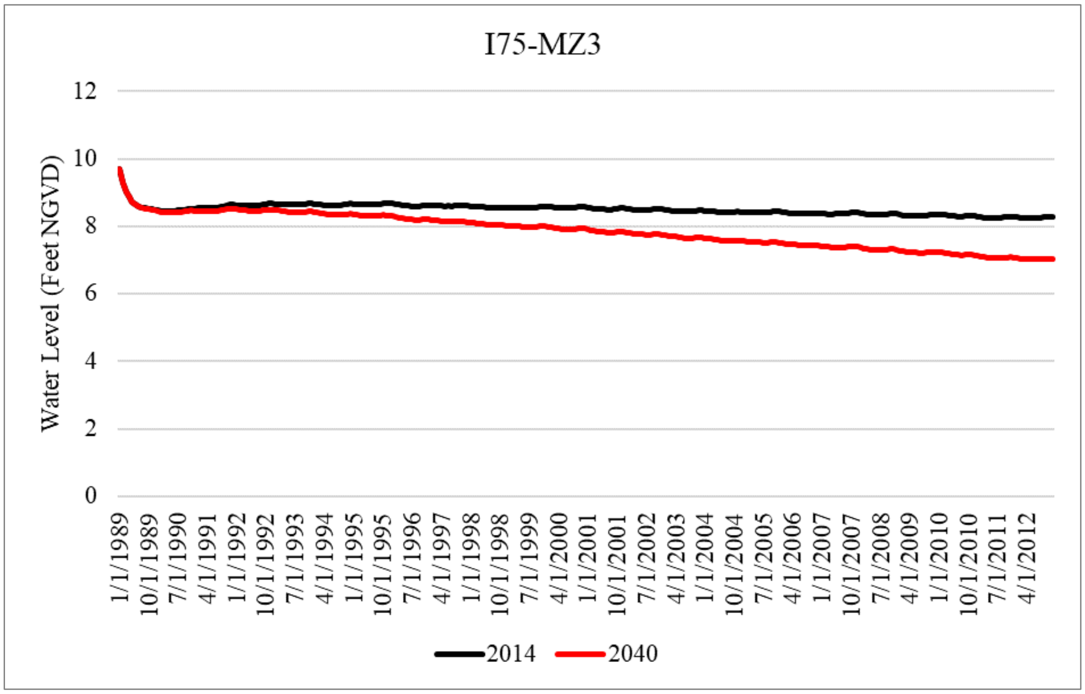

Figure A-10. Simulated water levels within the Lower Floridan aquifer – first permeable zone for the 2014 and 2040 model runs at I75-MZ3 in Collier County.

Hendry County

City of LaBelle

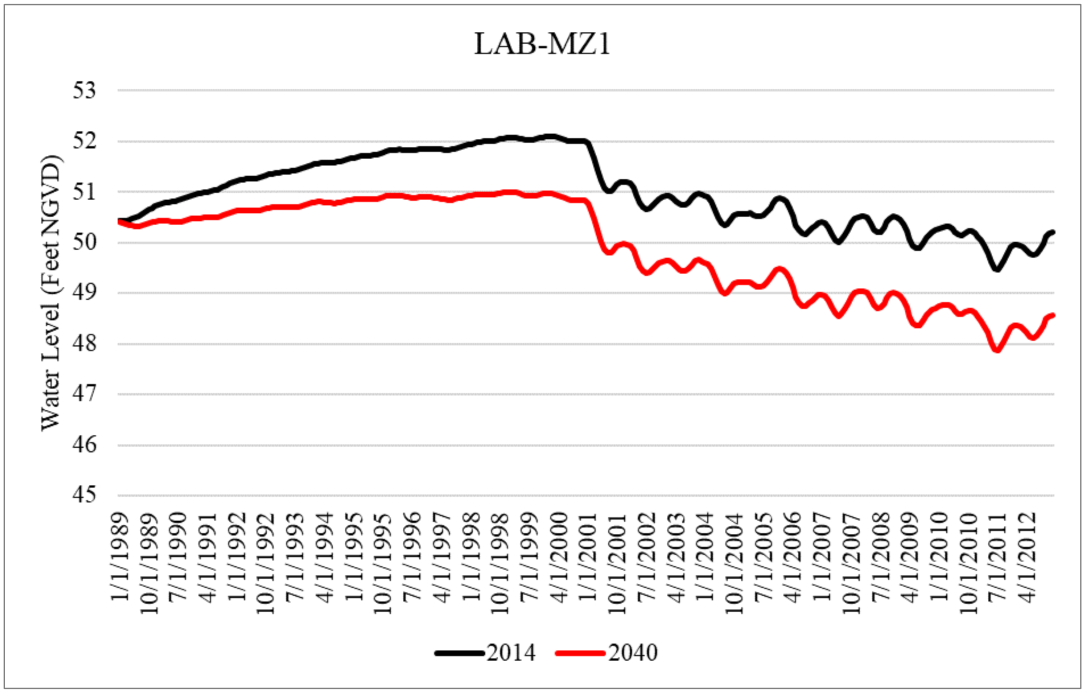

Figure A-11. Simulated water levels within the Upper Floridan aquifer for the 2014 and 2040 model runs at LAB-MZ1 in Hendry County.

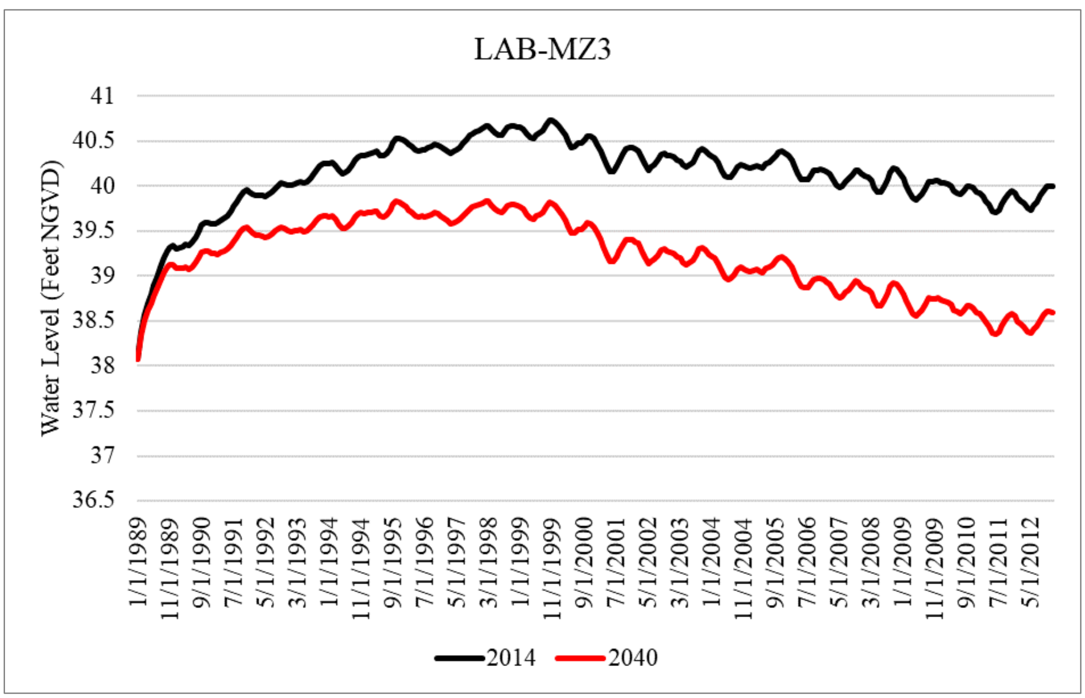

Figure A-12. Simulated water levels within the Avon Park permeable zone for the 2014 and 2040 model runs at LAB-MZ3 in Hendry County.

APPENDIX B: SIMULATED VERSUS OBSERVED TOTAL DISSOLVED SOLIDS

Lee County

Bonita Springs Utilities

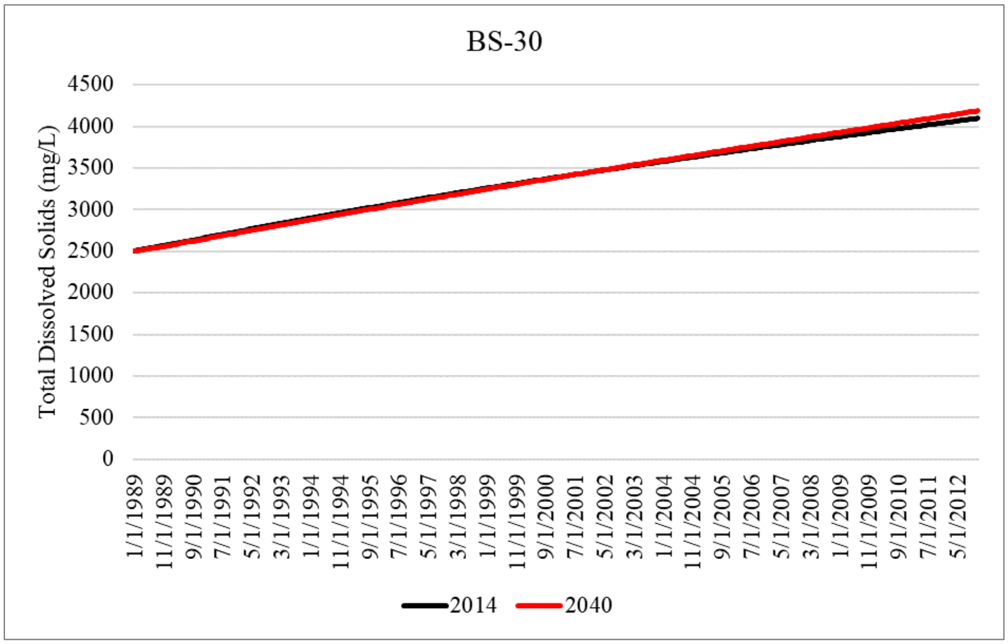

Figure B-1. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at BS-30 in Lee County.

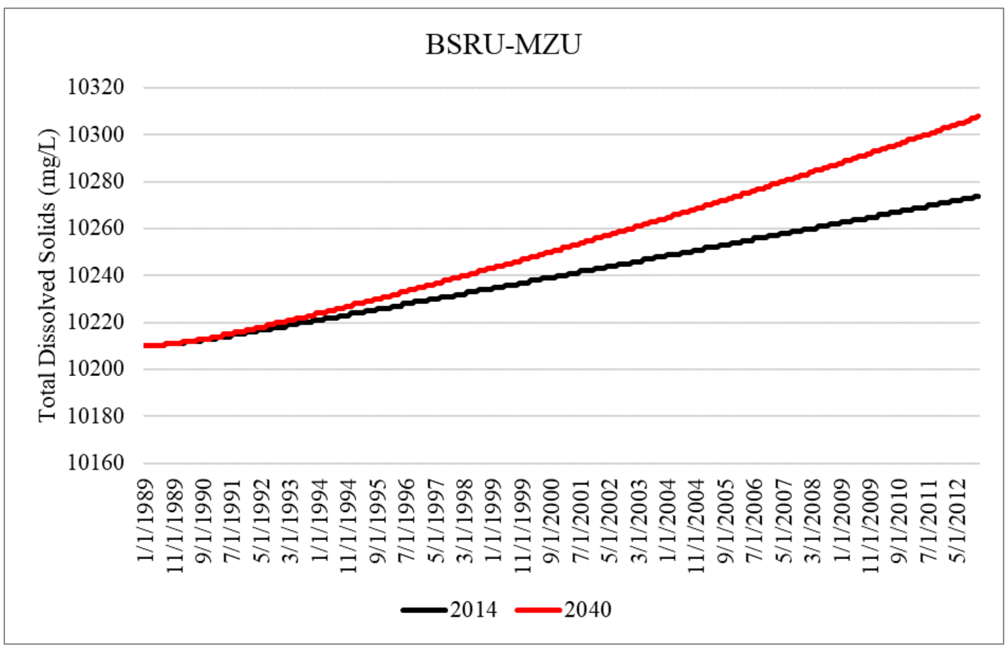

Figure B-2. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at BSRU-MZU in Lee County.

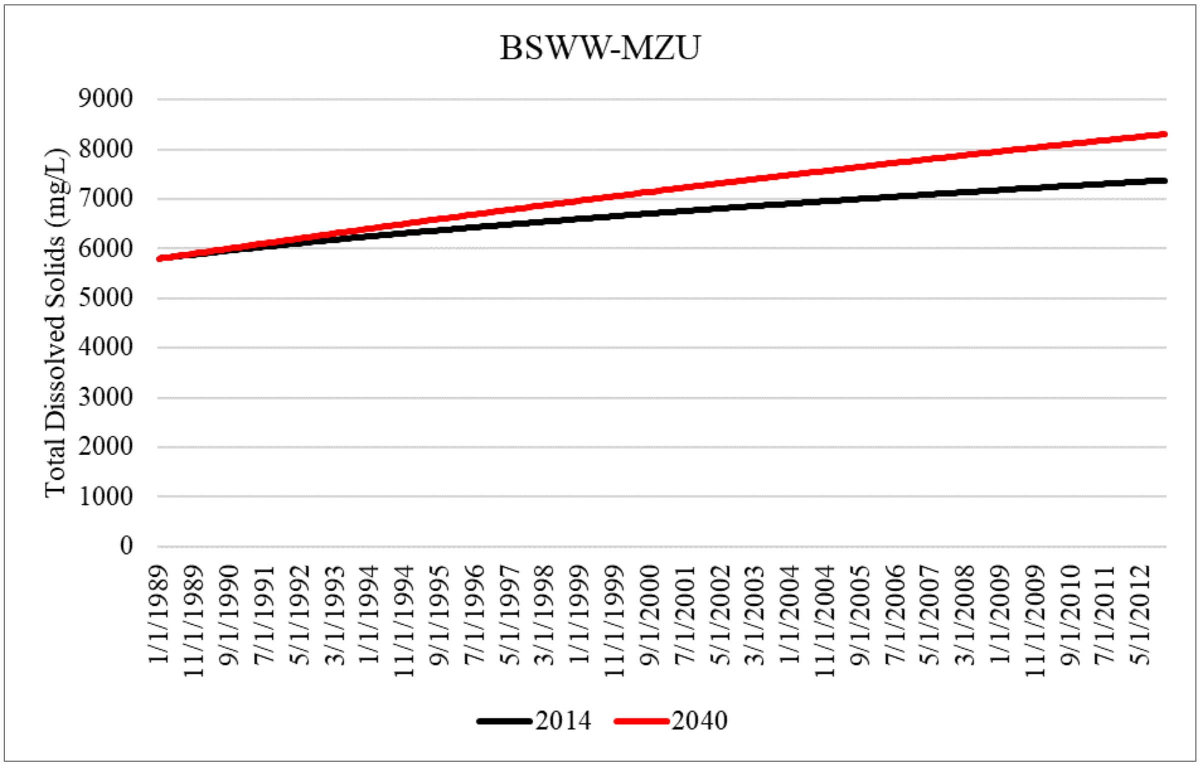

Figure B-3. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at BSWW-MZU in Lee County.

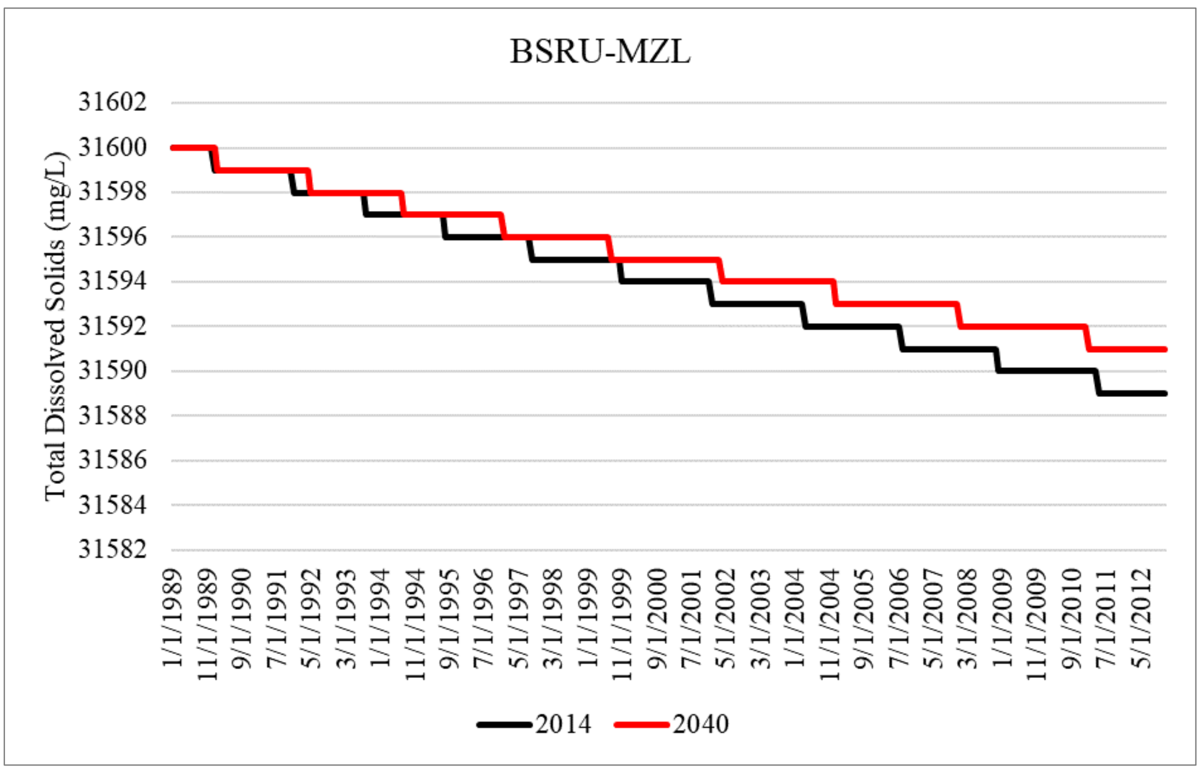

Figure B-4. Simulated total dissolved solids concentrations within the Avon Park permeable zone for the 2014 and 2040 model runs at BSRU-MZL in Lee County.

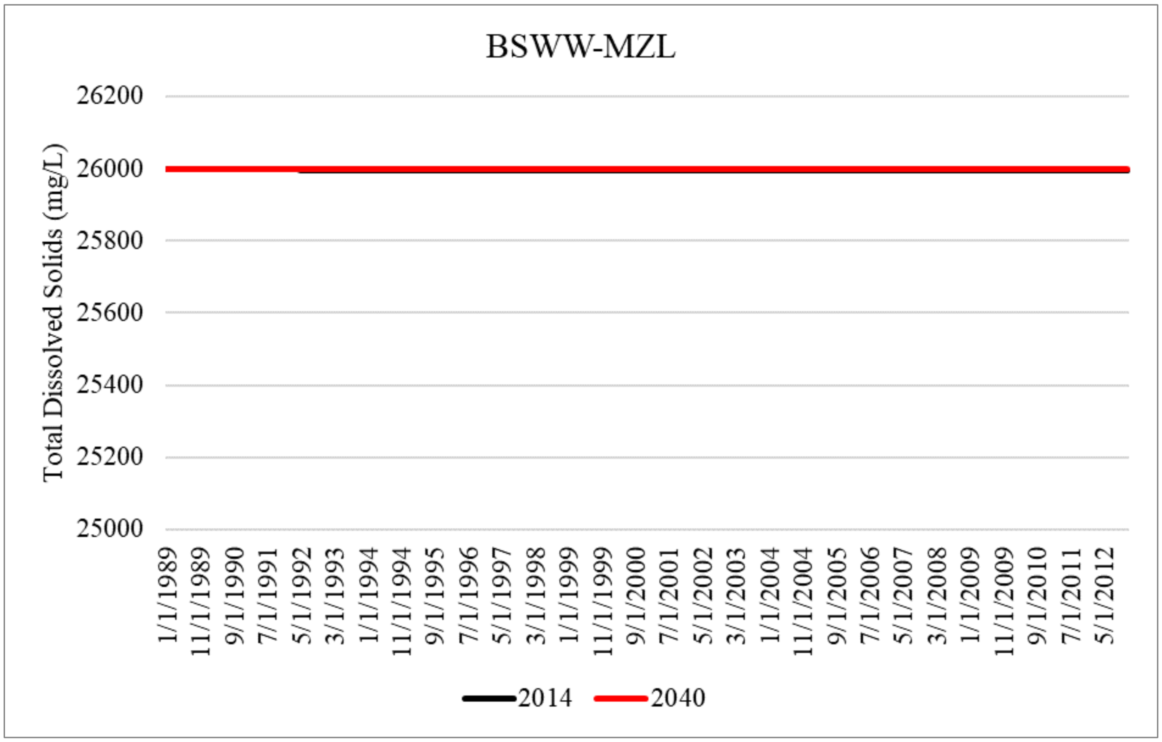

Figure B-5. Simulated total dissolved solids concentrations within the Avon Park permeable zone for the 2014 and 2040 model runs at BSWW-MZL in Lee County.

Cape Coral Utilities

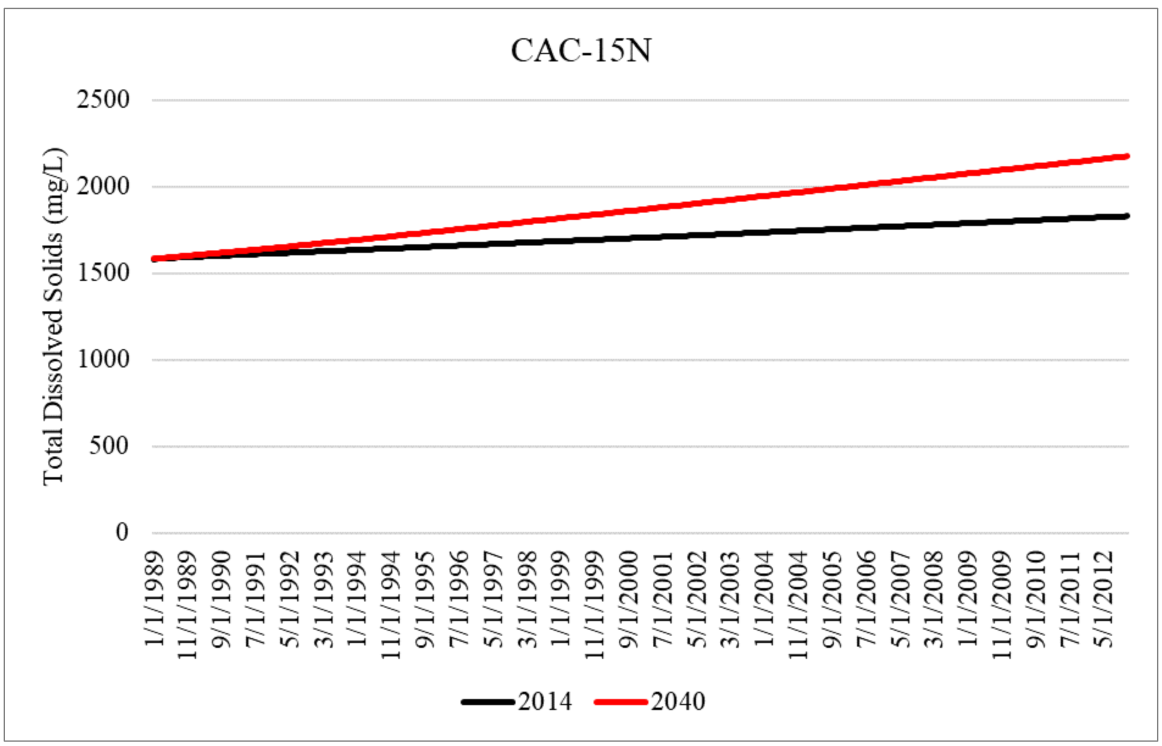

Figure B-6. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at CAC-15N in Lee County.

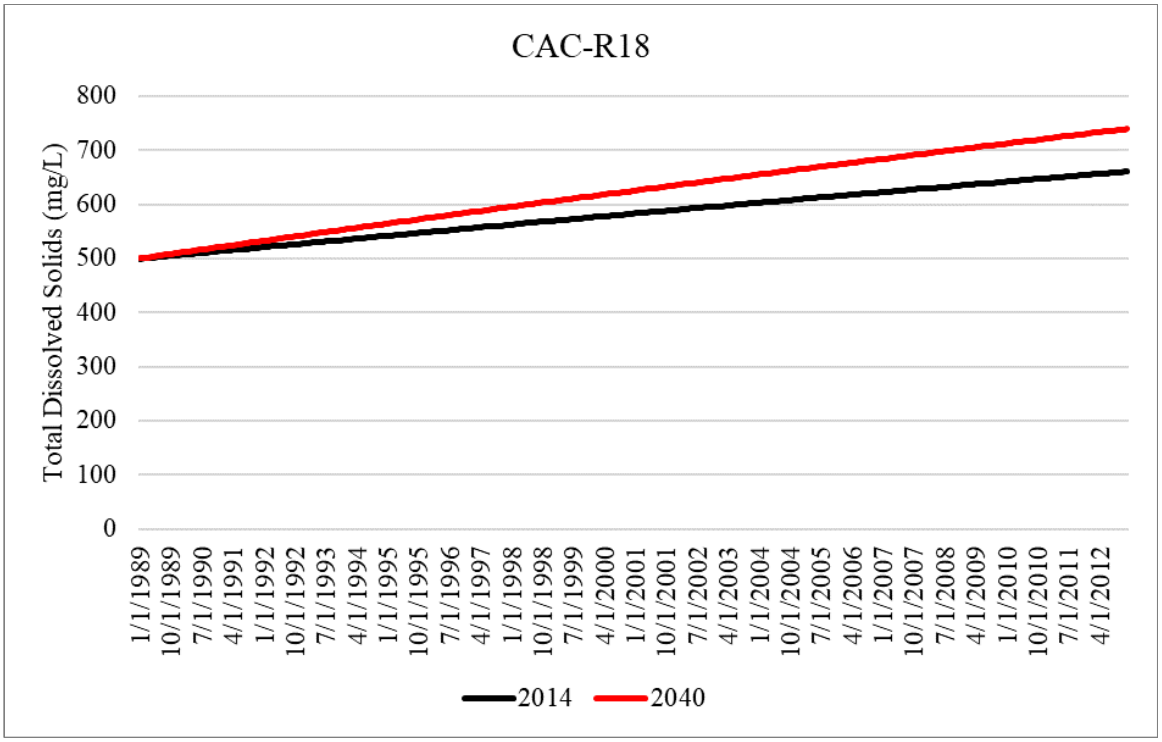

Figure B-7. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at CAC-R18 in Lee County.

Fort Myers Utility

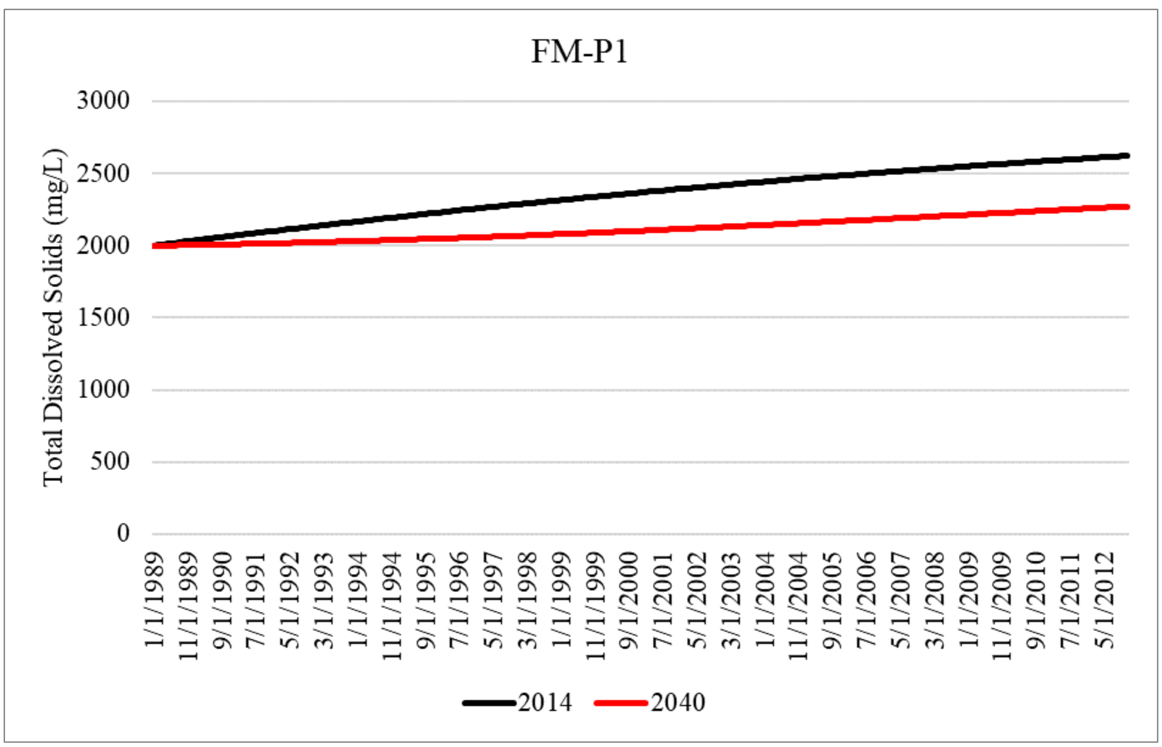

Figure B-8. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at FM-P1 in Lee County.

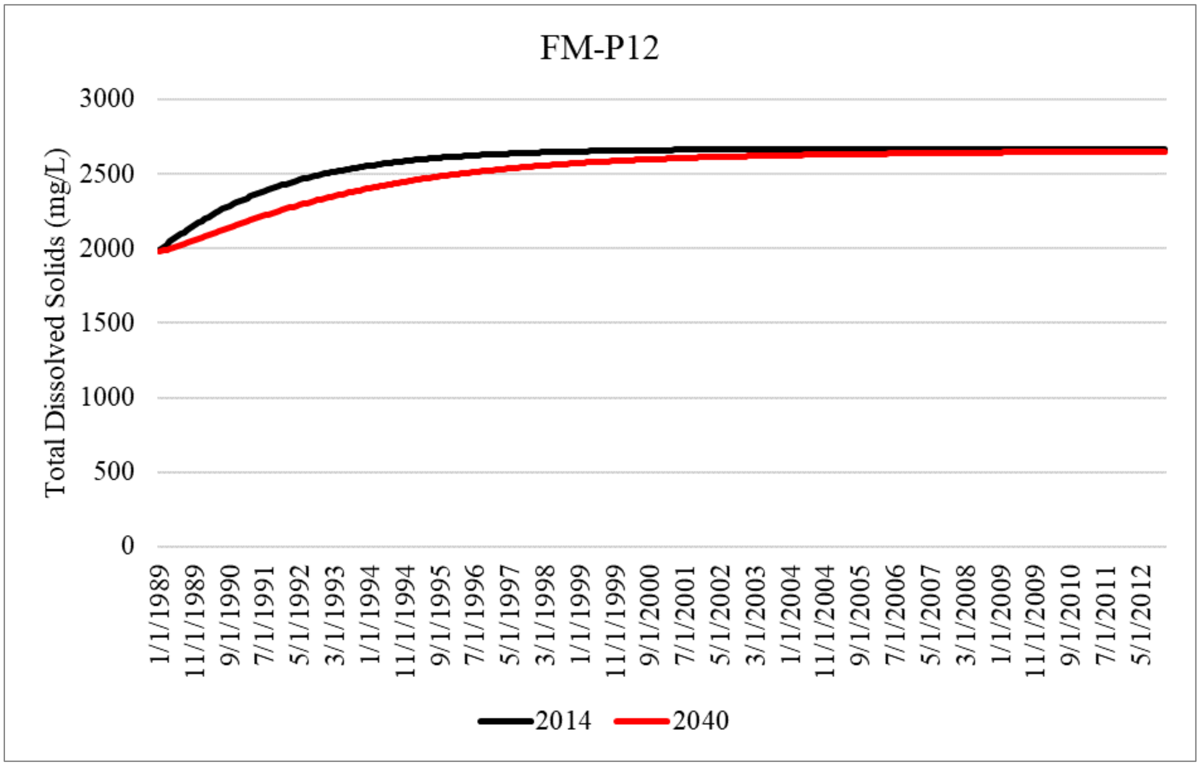

Figure B-9. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at FM-P12 in Lee County.

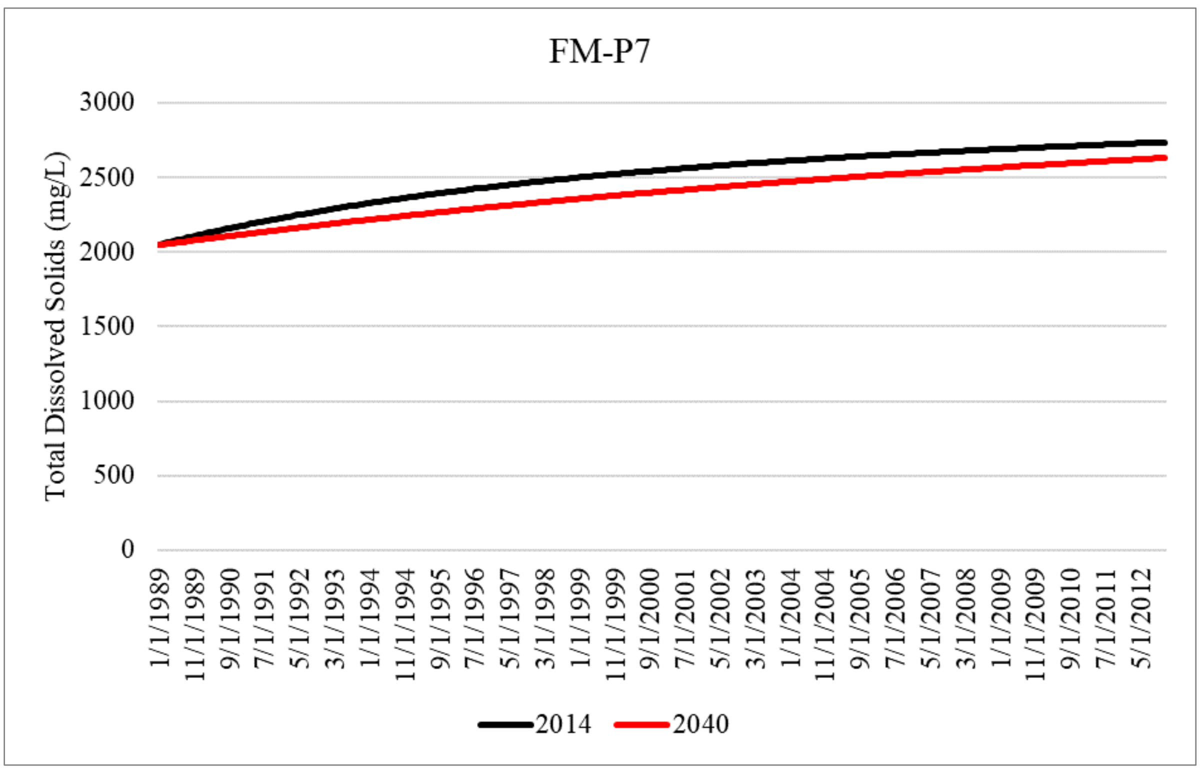

Figure B-10. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at FM-P7 in Lee County.

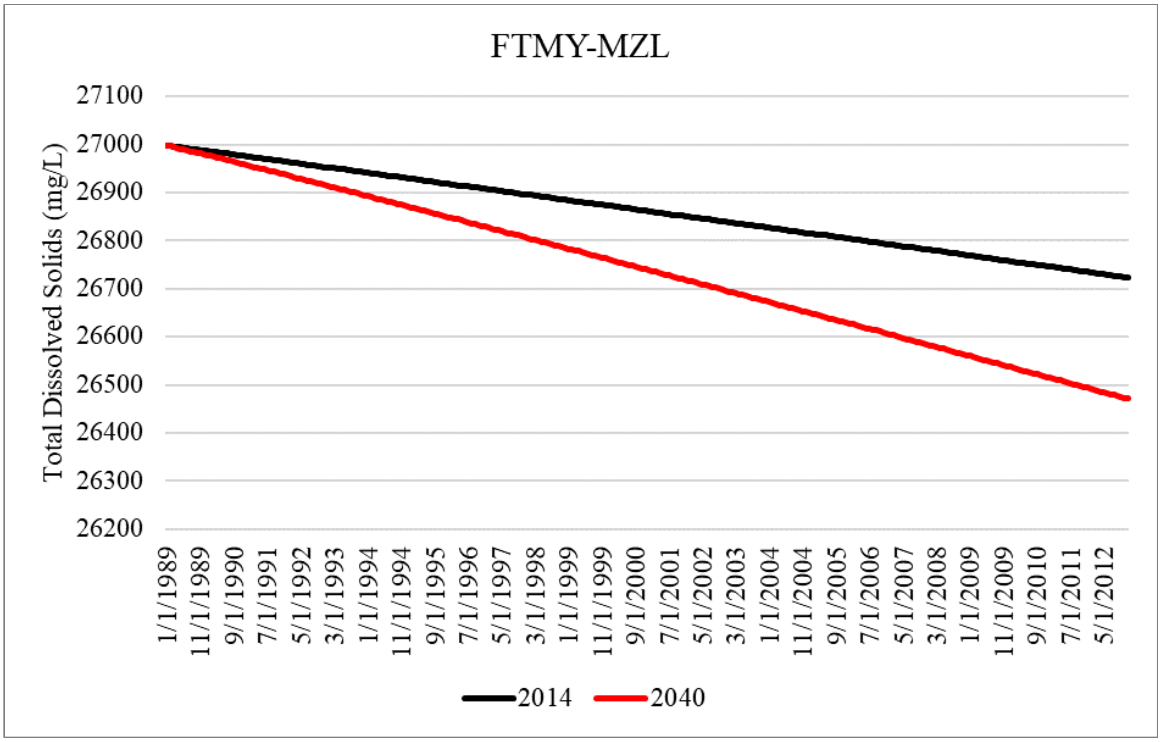

Figure B-11. Simulated total dissolved solids concentrations within the Avon Park permeable zone for the 2014 and 2040 model runs at FTMY-MZL in Lee County.

Greater Pine Island Water Association

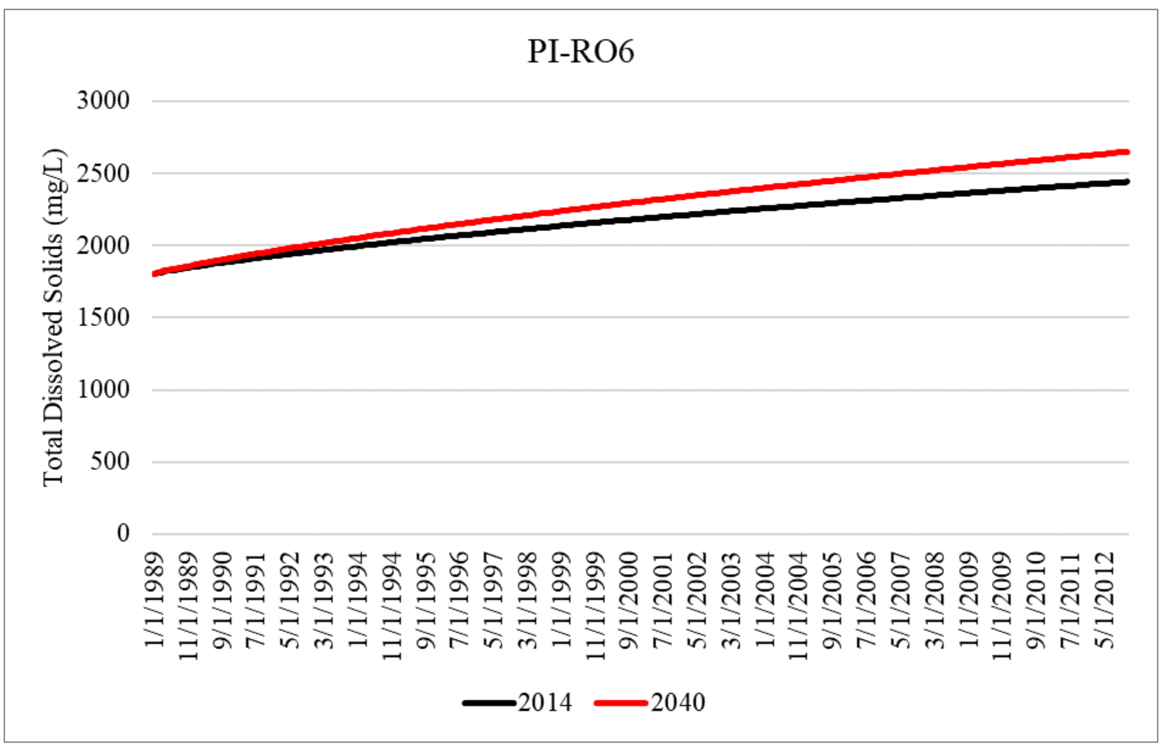

Figure B-12. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at PI-RO6 in Lee County.

Island Water Association

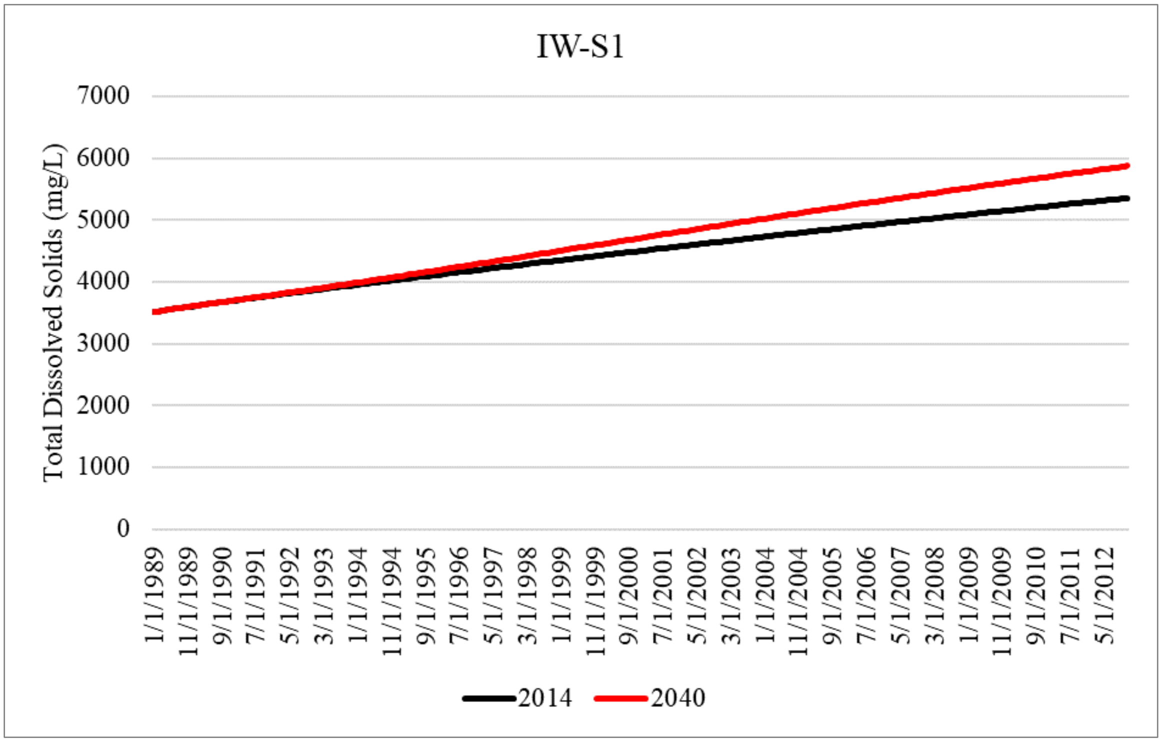

Figure B-13. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at IW-S1 in Lee County.

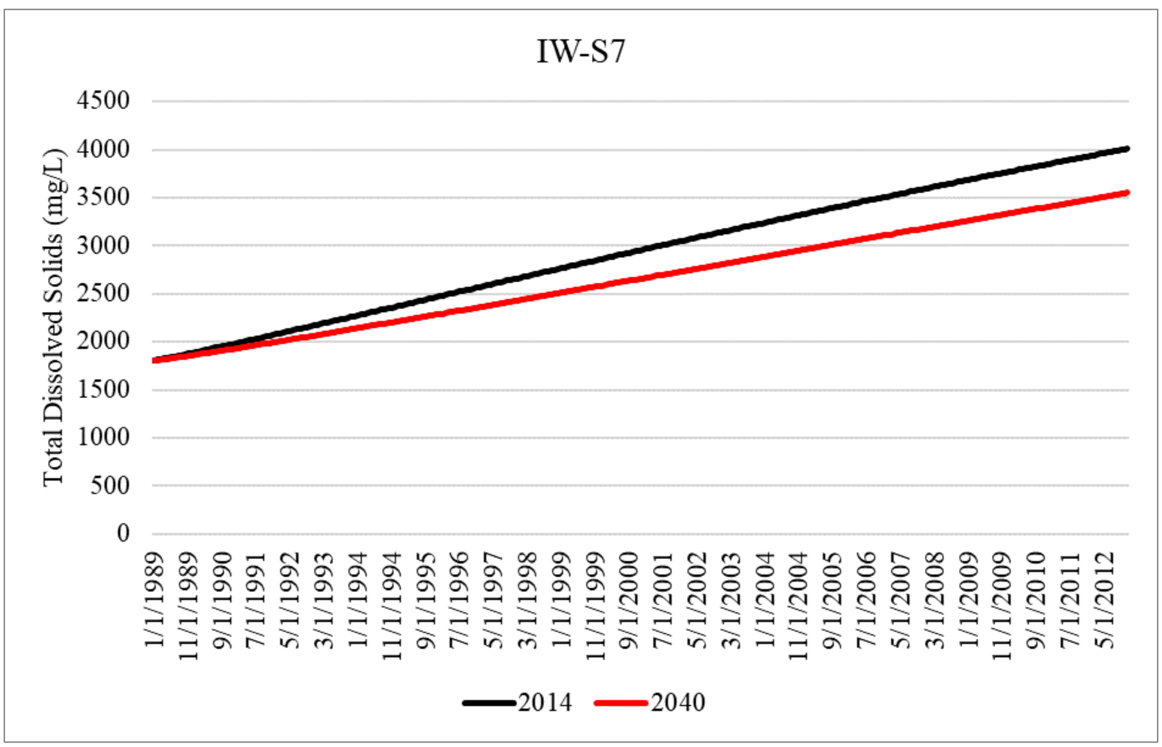

Figure B-14. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at IW-S7 in Lee County.

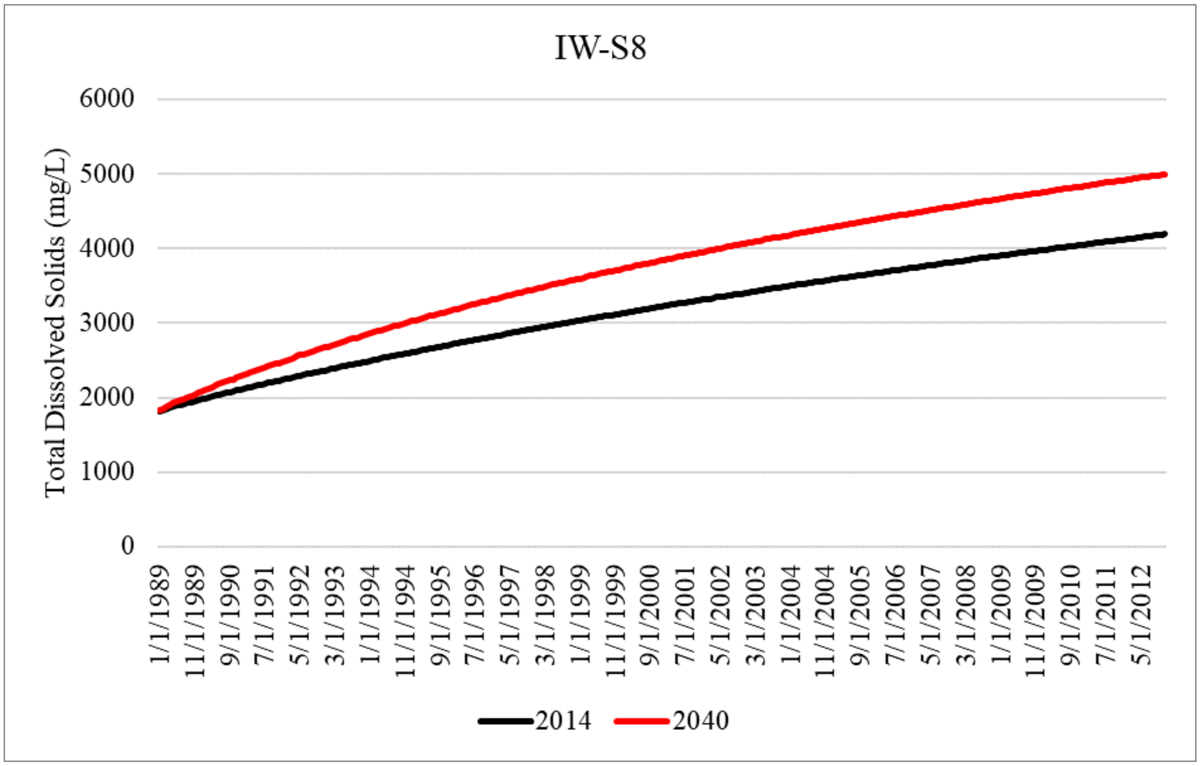

Figure B-15. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at IW-S8 in Lee County.

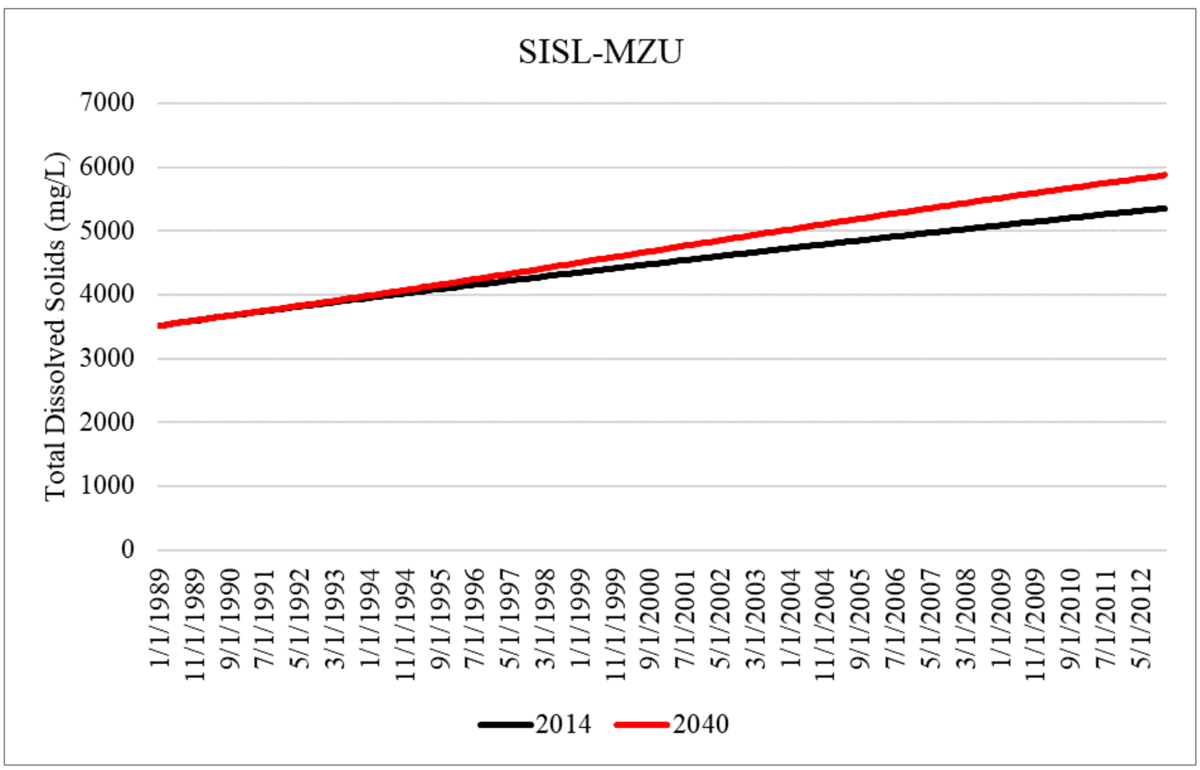

Figure B-16. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at SISL-MZU in Lee County.

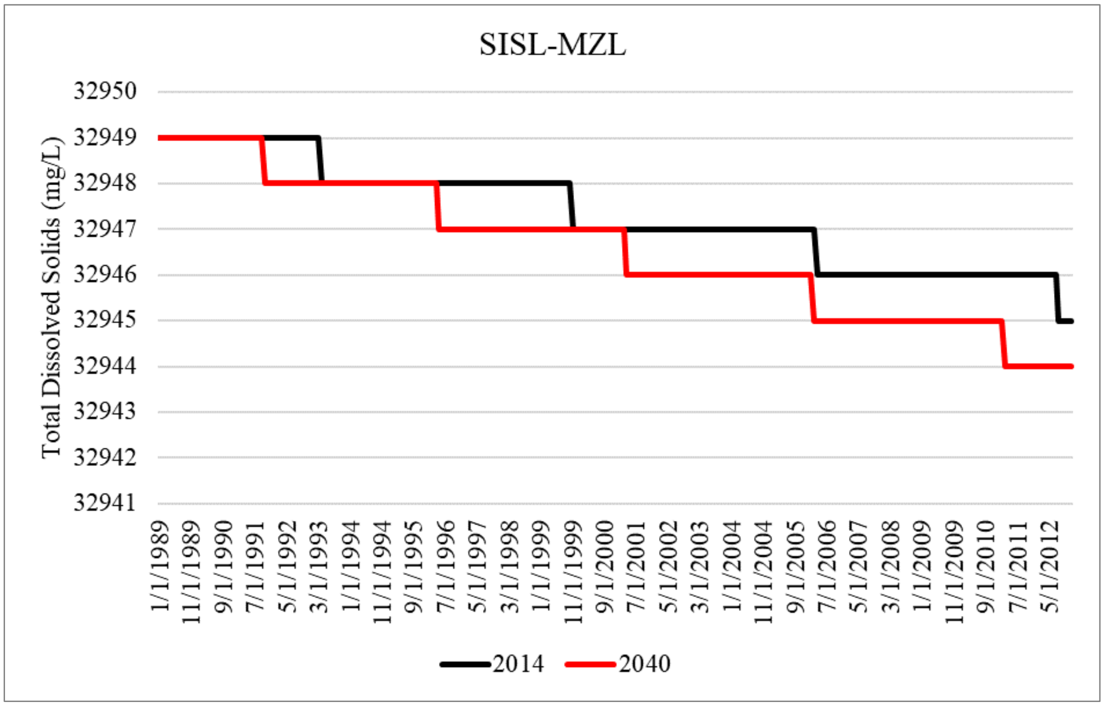

Figure B-17. Simulated total dissolved solids concentrations within the Avon Park permeable zone for the 2014 and 2040 model runs at SISL-MZL in Lee County.

Lee County Utilities

Corkscrew Wellfield

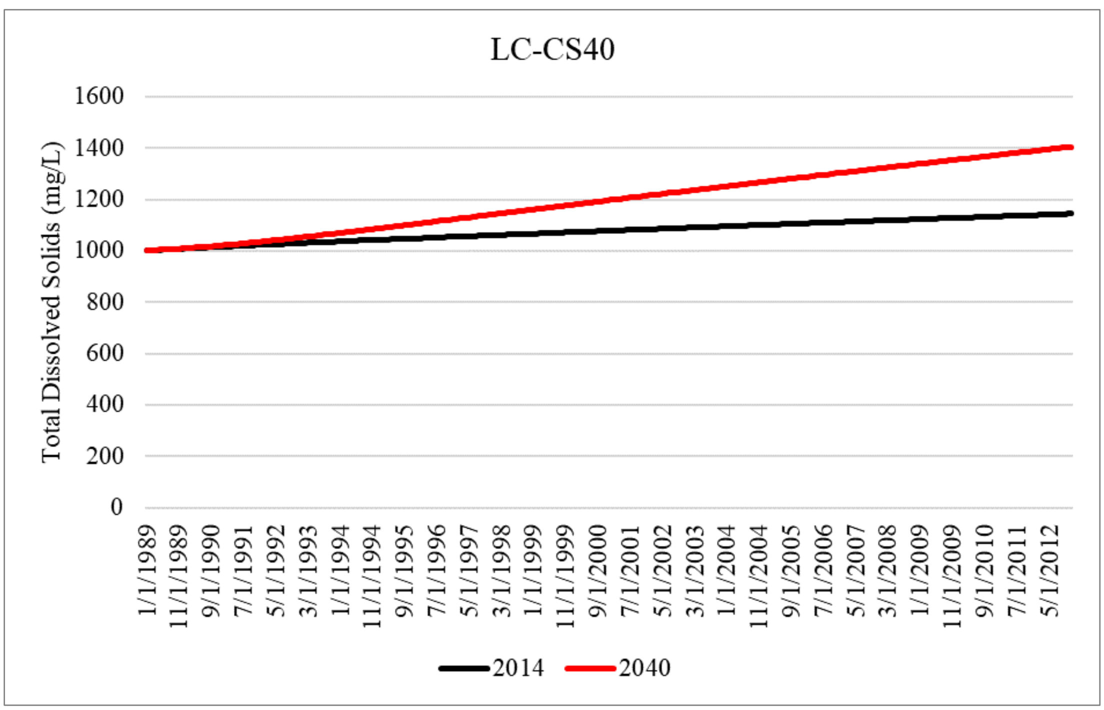

Figure B-18. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at LC-CS40 in Lee County.

Pinewoods Wellfield

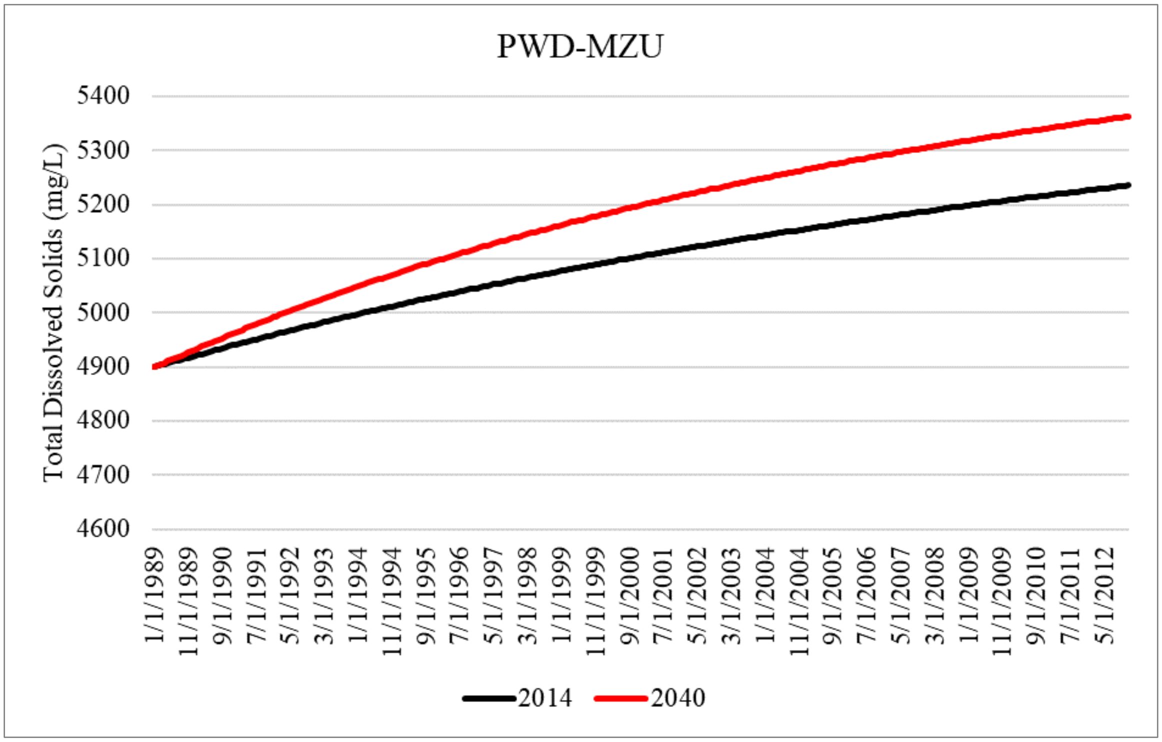

Figure B-19. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at PWD-MZU in Lee County.

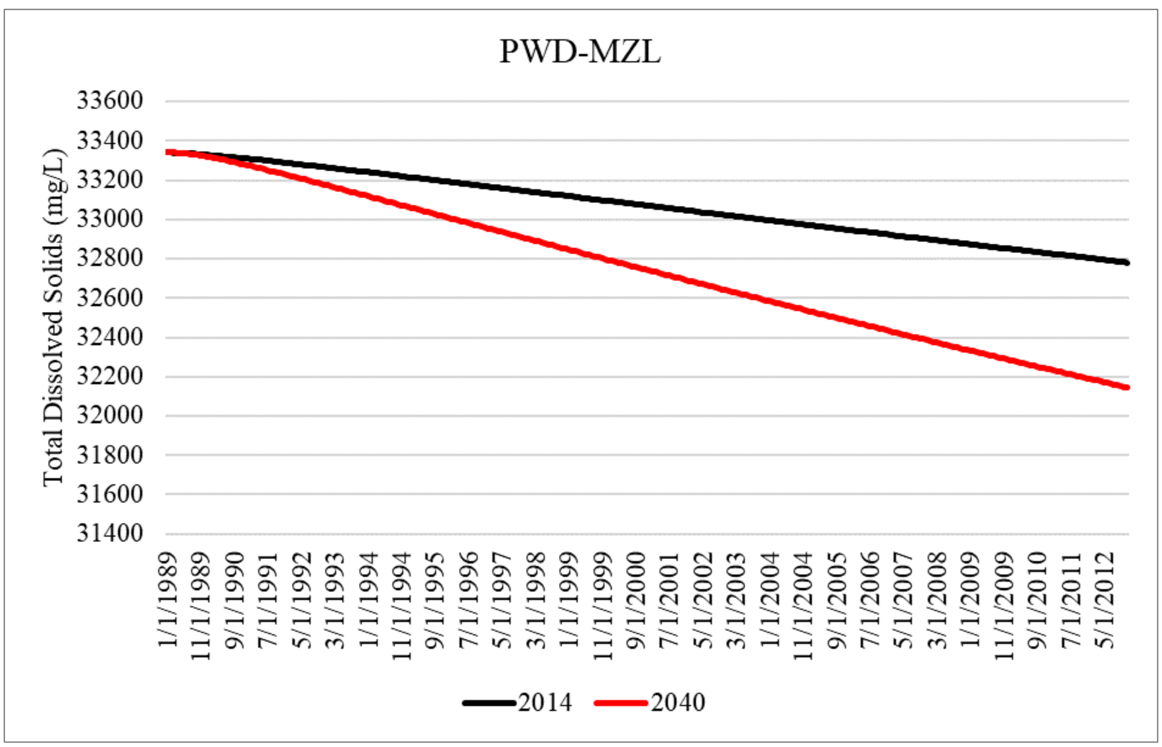

Figure B-20. Simulated total dissolved solids concentrations within the Avon Park permeable zone for the 2014 and 2040 model runs at PWD-MZL in Lee County.

Collier County

Collier County Water Sewer District

North Wellfield

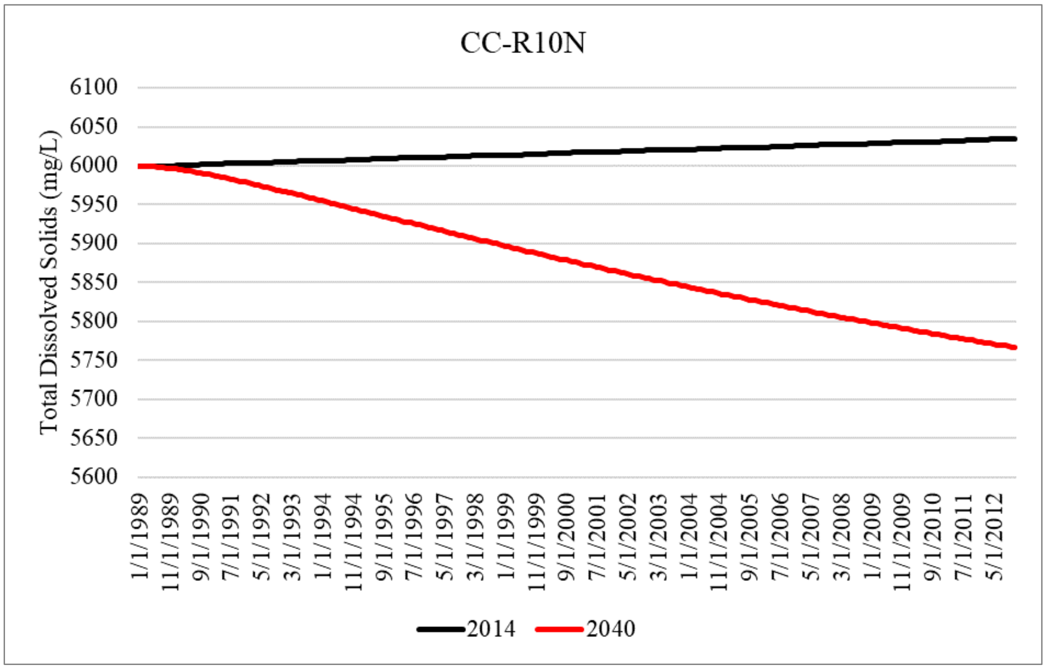

Figure B-21. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at CC-R10N in Collier County.

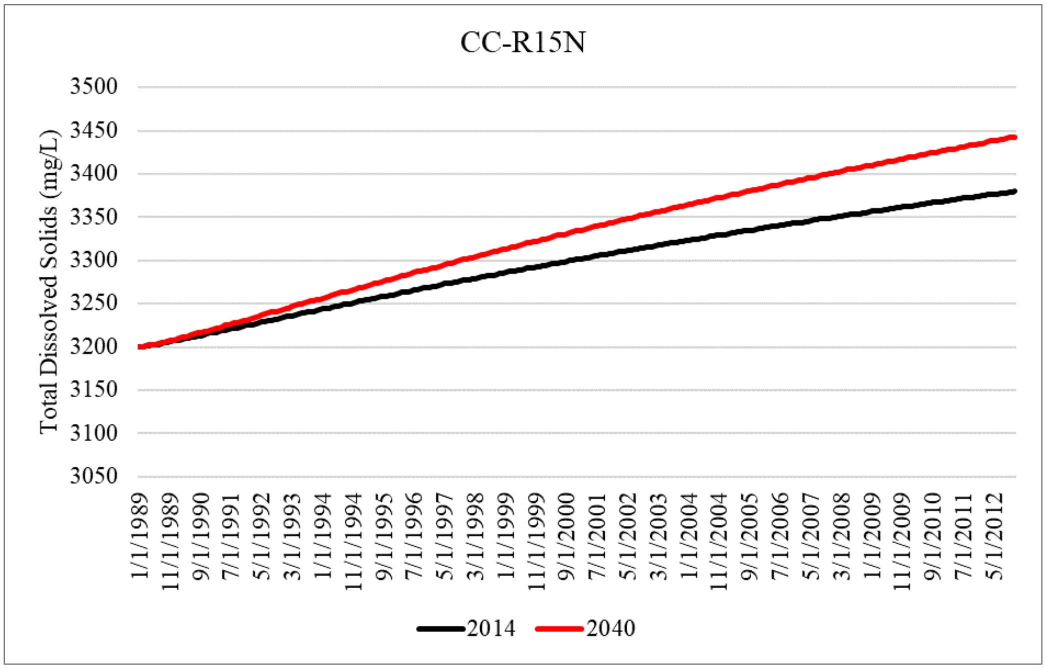

Figure B-22. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at CC-R15N in Collier County.

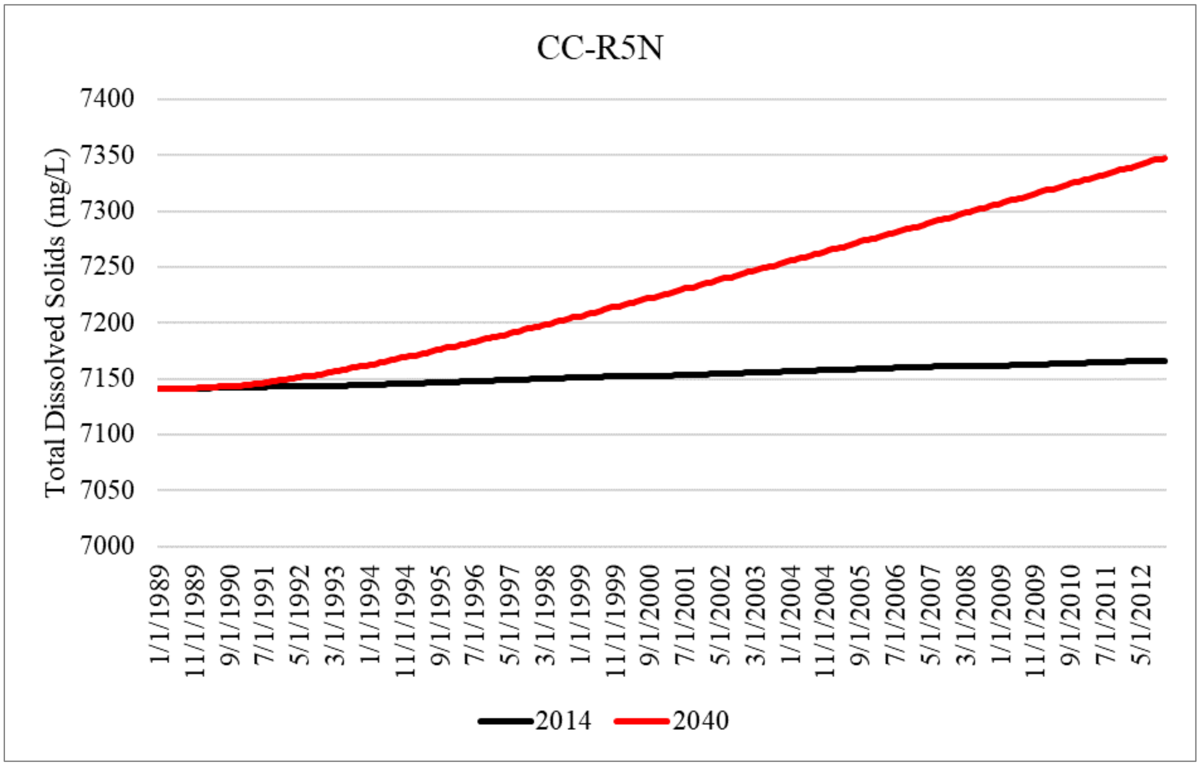

Figure B-23. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at CC-R5N in Collier County.

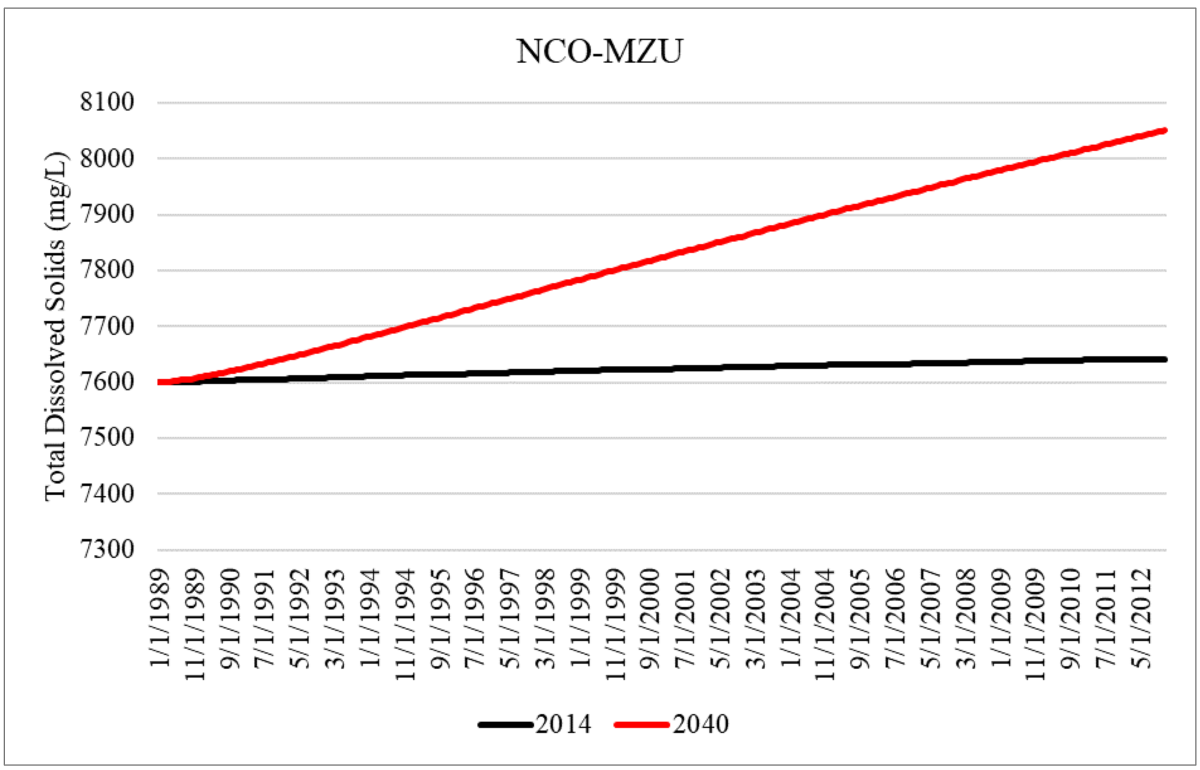

Figure B-24. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at NCO-MZU in Collier County.

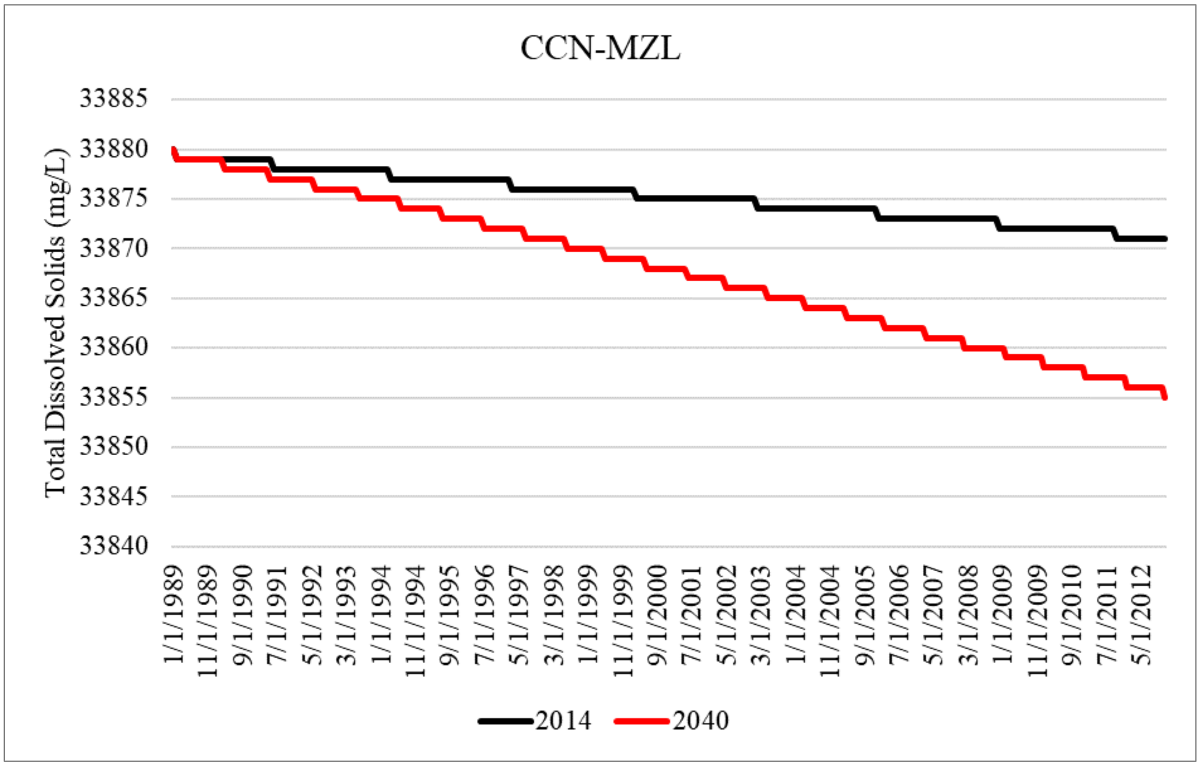

Figure B-25. Simulated total dissolved solids concentrations within the Avon Park permeable zone for the 2014 and 2040 model runs at CCN-MZL in Collier County.

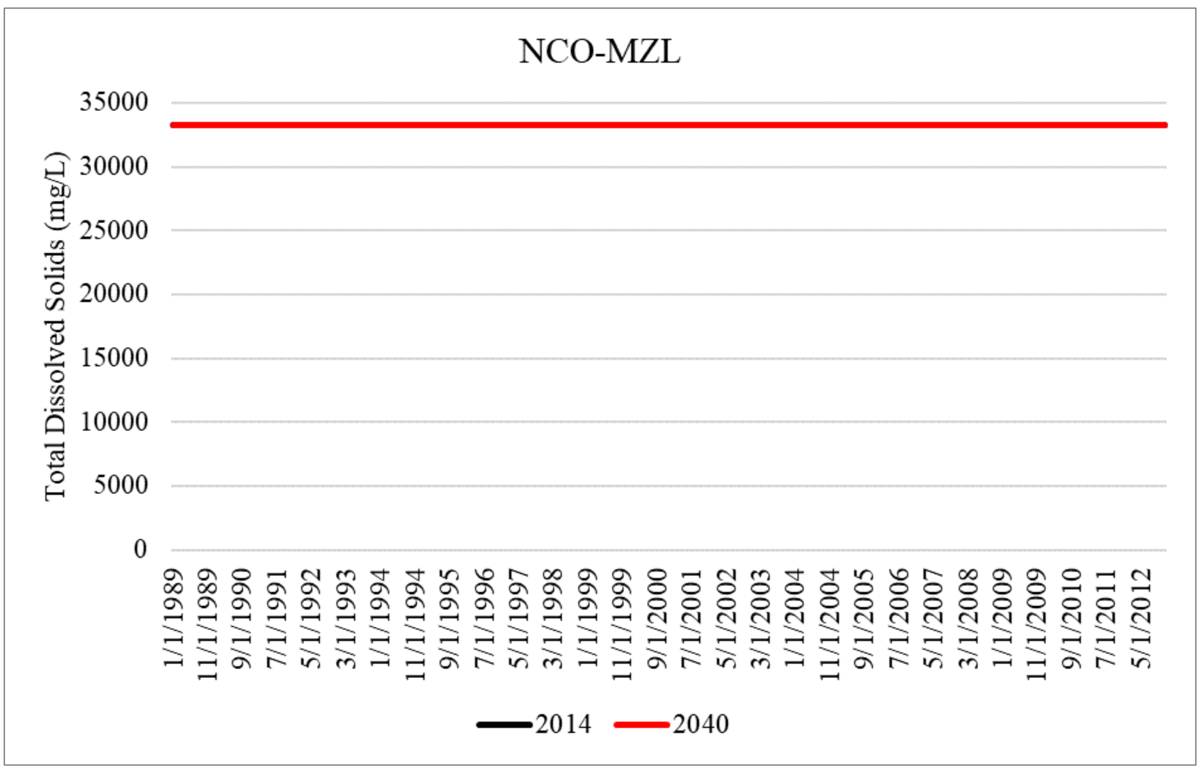

Figure B-26. Simulated total dissolved solids concentrations within the Avon Park permeable zone for the 2014 and 2040 model runs at NCO-MZL in Collier County.

South Wellfield

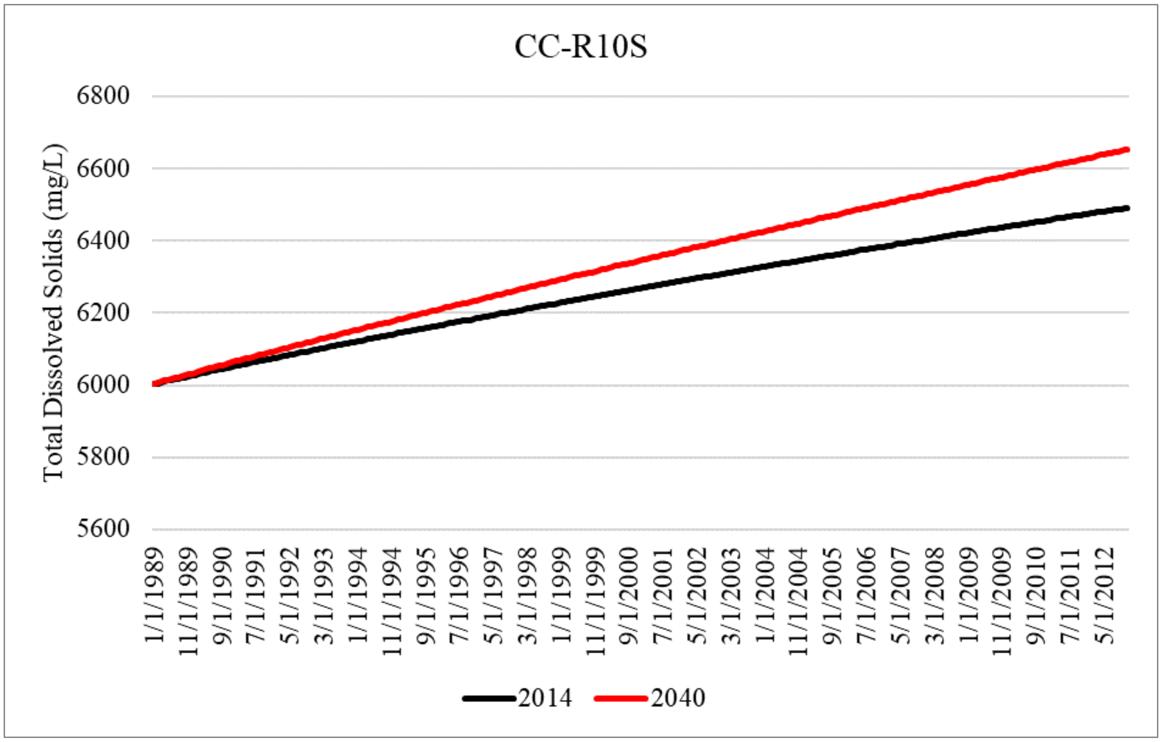

Figure B-27. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at CC-R10S in Collier County.

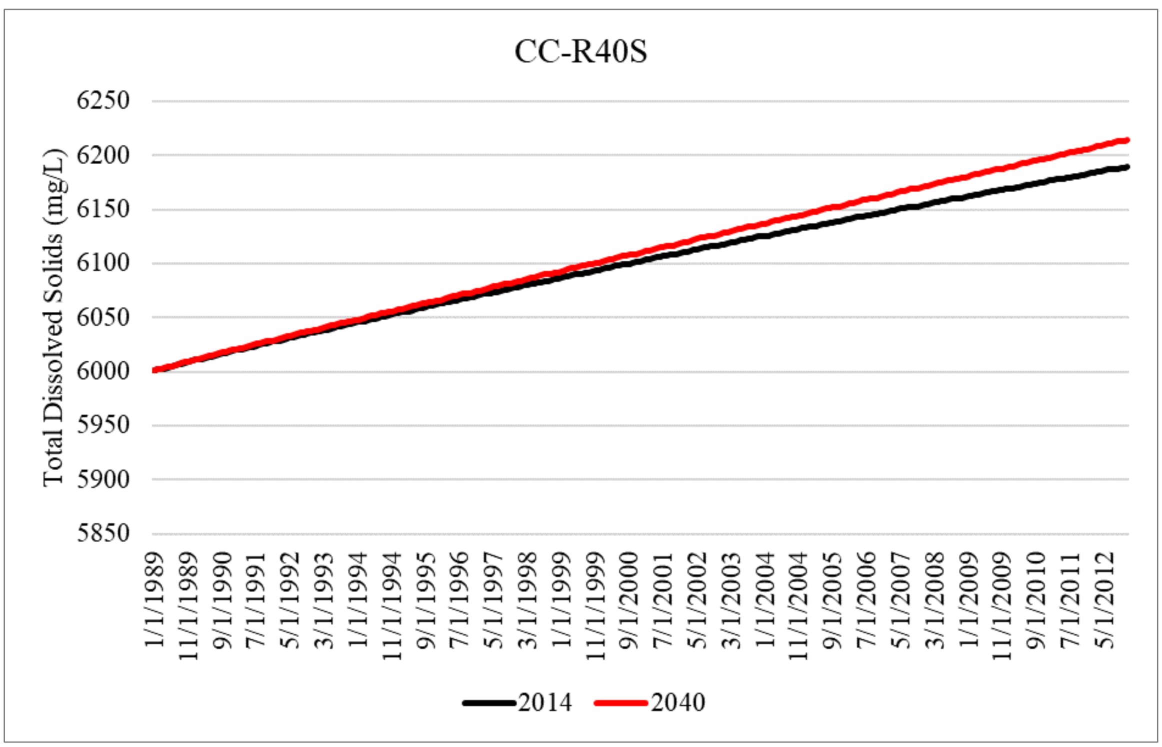

Figure B-28. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at CC-R40S in Collier County.

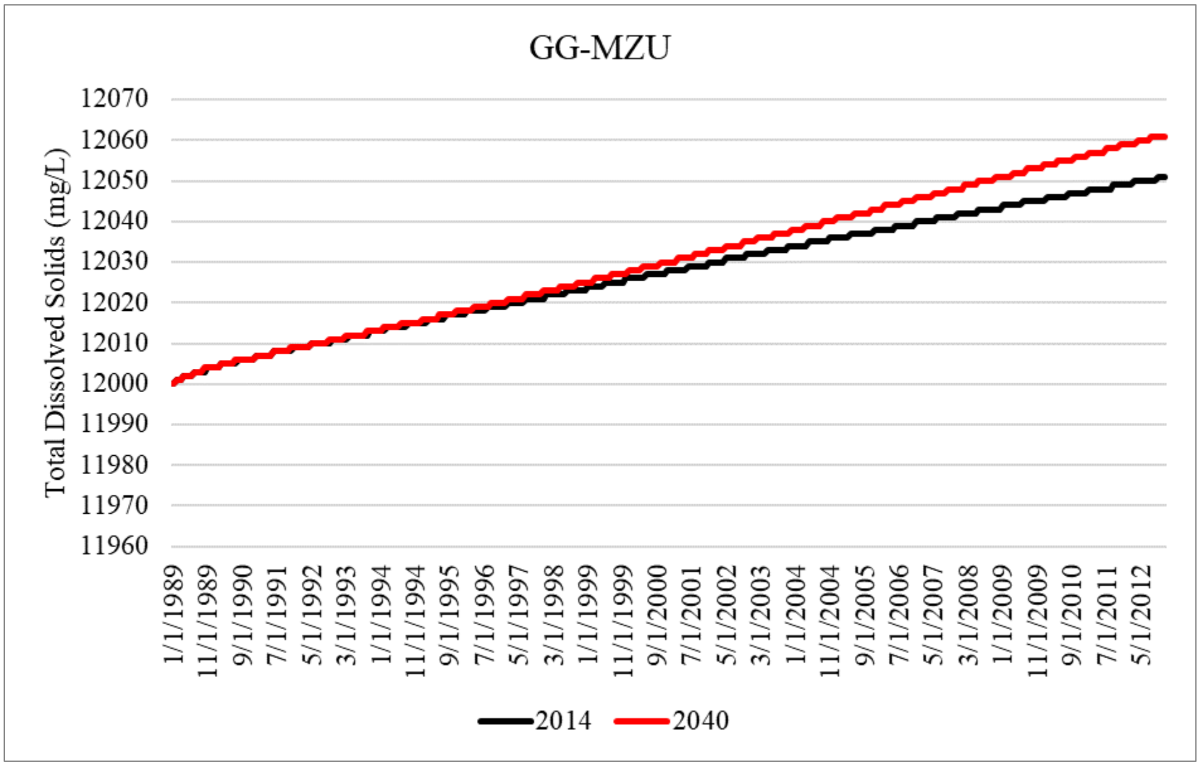

Figure B-29. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at GG-MZU in Collier County.

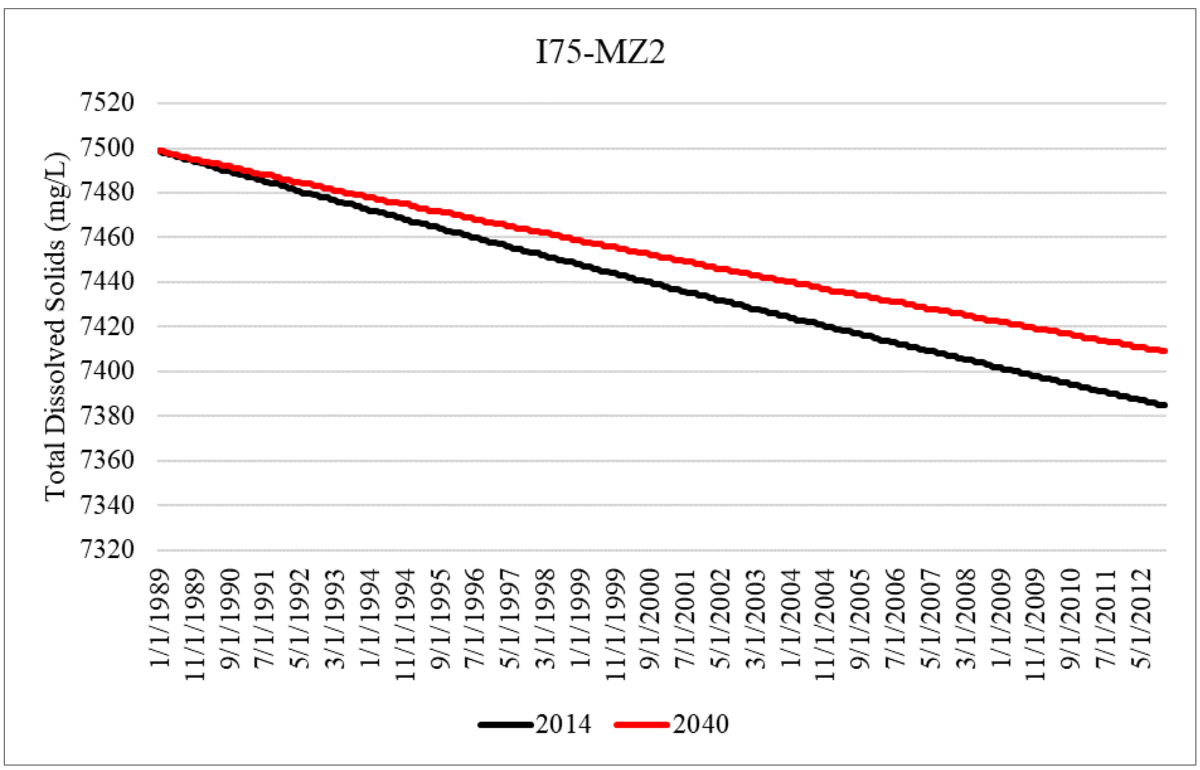

Figure B-30. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at I75-MZ2 in Collier County.

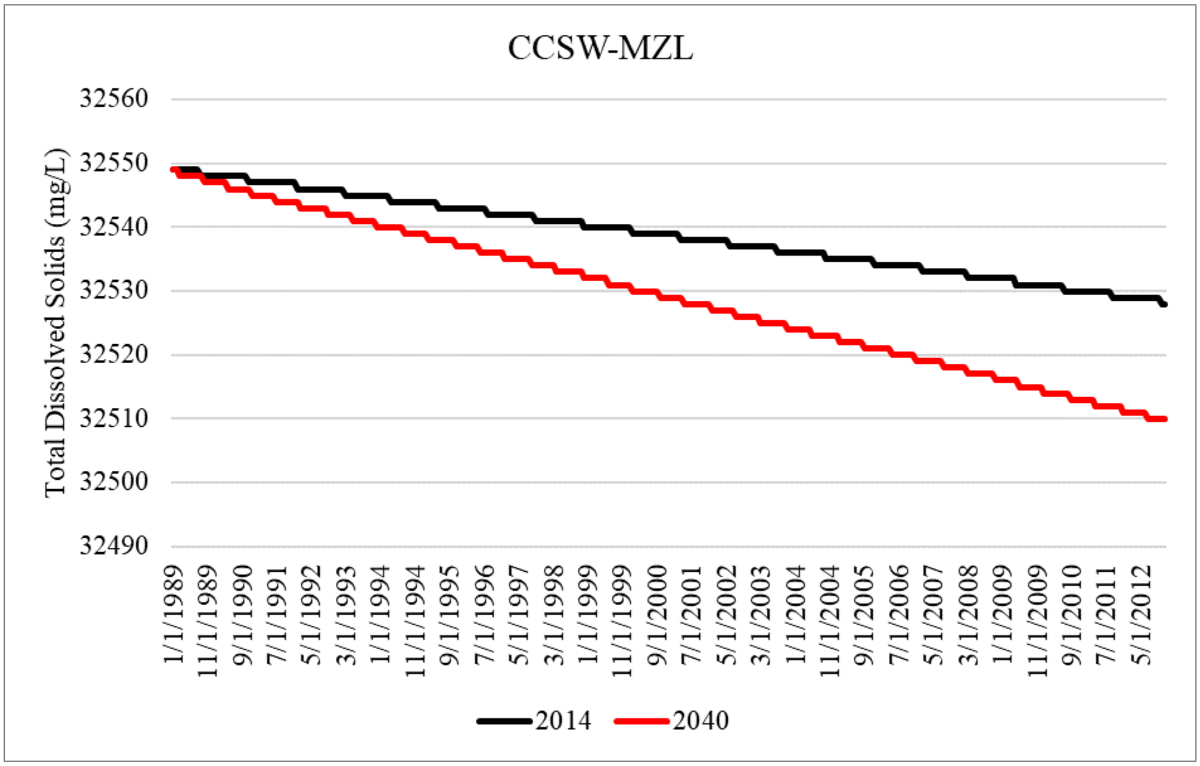

Figure B-31. Simulated total dissolved solids concentrations within the Avon Park permeable zone for the 2014 and 2040 model runs at CCSW-MZL in Collier County.

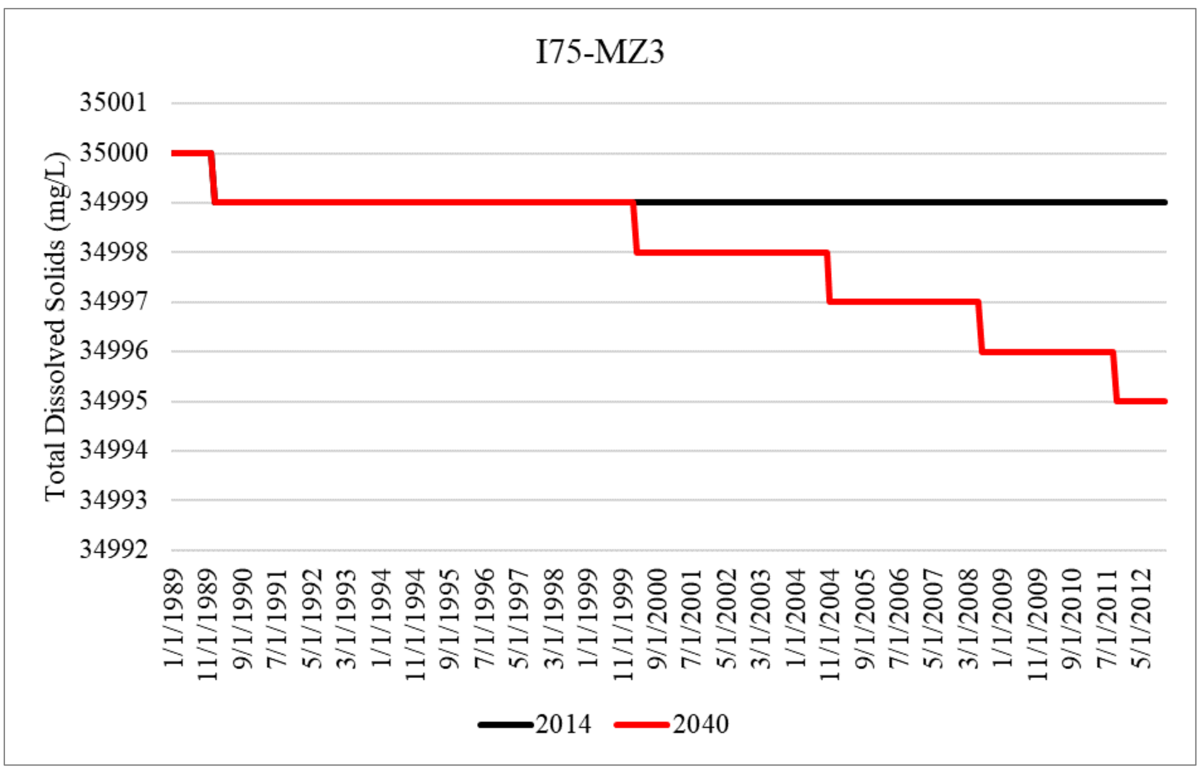

Figure B-32. Simulated total dissolved solids concentrations within the Lower Floridan aquifer – first permeable zone for the 2014 and 2040 model runs at I75-MZ3 in Collier County.

Hendry County

City of LaBelle

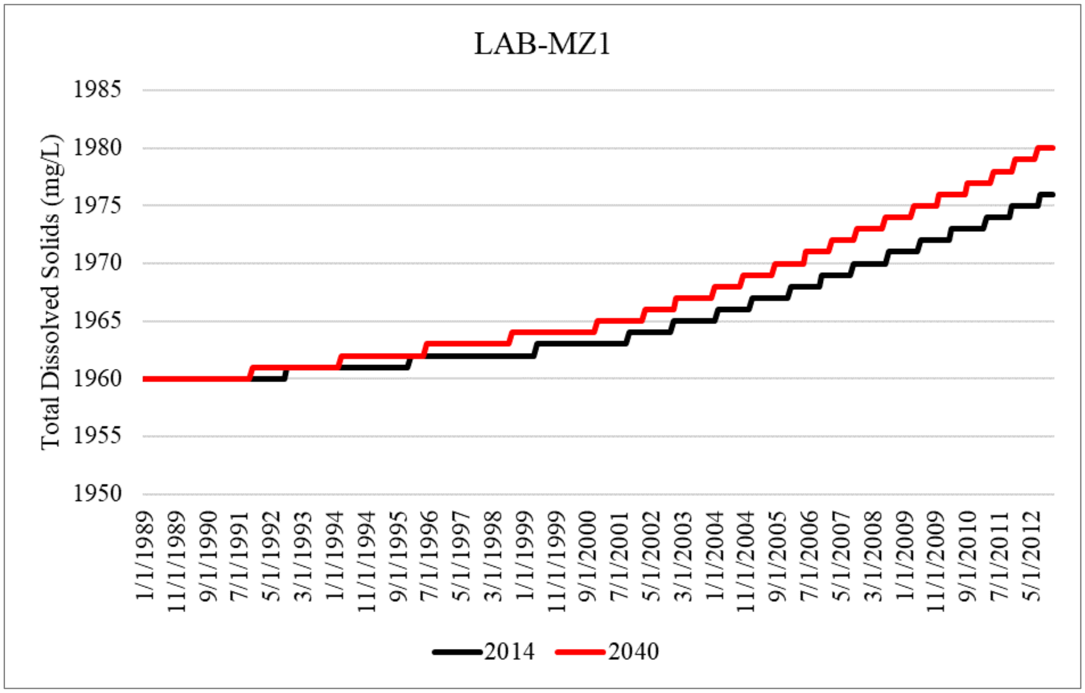

Figure B-33. Simulated total dissolved solids concentrations within the Upper Floridan aquifer for the 2014 and 2040 model runs at LAB-MZ1 in Hendry County.

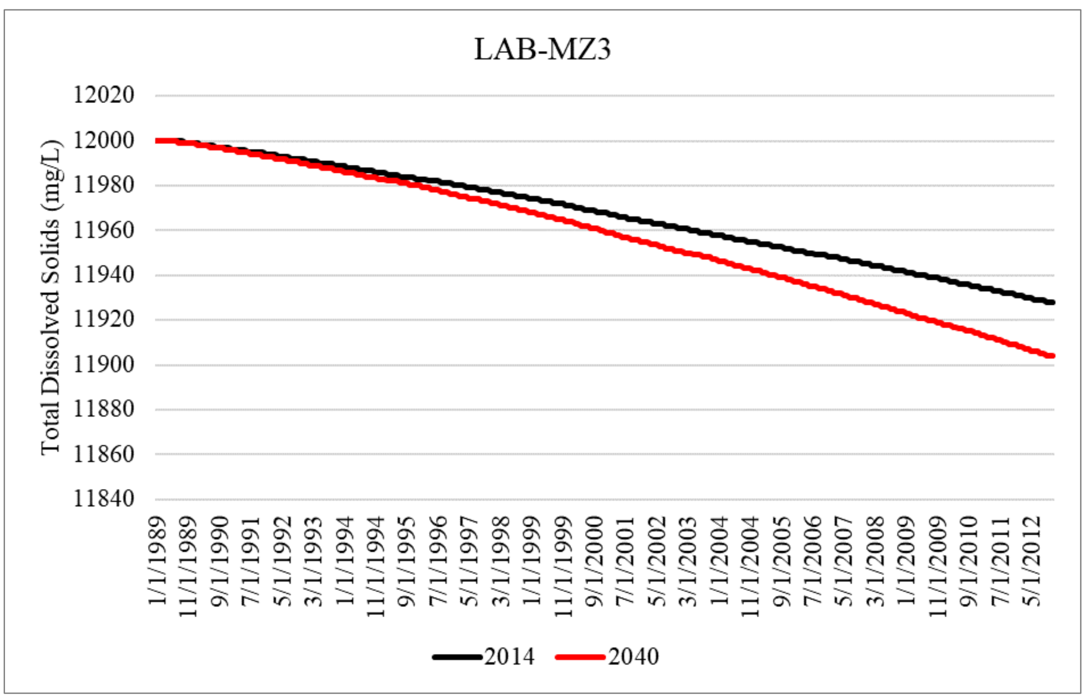

Figure B-34. Simulated total dissolved solids concentrations within the Avon Park permeable zone for the 2014 and 2040 model runs at LAB-MZ3 in Hendry County.