APPENDICES

APPENDIX A

EVALUATION OF REQUIRED FLORIDAN WATER FOR SALINITY REDUCTION IN THE COOLING CANAL SYSTEM, TETRA TECH, TECHNICAL MEMORANDUM (5/9/2014)

TETRA TECH

TECHNICAL MEMORANDUM

From: Peter F. Andersen and James L. Ross, Tetra Tech

To: Rory Rahming, Florida Power & Light Company

Date: May 9, 2014

Subject: Evaluation of Required Floridan Water for Salinity Reduction in the Cooling Canal System

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Introduction

This technical memorandum describes the water and salt balance modeling of the proposed salinity reduction in the Florida Power & Light (FPL) Cooling Canal System (CCS), located at the Turkey Point Nuclear Power Plant. The modeling was conducted to provide an assessment of the volume of Floridan water that would be required to add to the CCS in order to reduce the hypersalinity of CCS water to salt concentrations commensurate with seawater.

Two spreadsheet-based water and salt balance models were employed for this analysis: 1) a steady state balance model based on long-term average flows to/from the CCS, and 2) a transient balance model calibrated to 22 months of hydrologic and water quality data collected as a part of FPL comprehensive pre-uprate monitoring (Ecology and Environment, 2012). These models were collectively used to provide estimates of the amount of Floridan water required to achieve the desired CCS salinity reductions and the corresponding changes to canal stage within the CCS.

Background

The CCS is a constructed surface water body that receives heated water from Turkey Point Nuclear Units 3 and 4. As the heated water travels southward along the discharge canals and northward back to the plant along return canals, it is cooled by evaporation and mixing with inflowing water from the Biscayne Aquifer. Due to the evaporative process, which is facilitated by the elevated temperature of the water, a portion of the water from the CCS is lost to the atmosphere, leaving dissolved solids behind in the CCS and producing hypersaline conditions in the CCS. Hypersaline water exhibits salinities greater than that of seawater, which has a salinity of approximately 35 g/L. Salinity in the CCS has ranged between 42 and 69 g/L over the past 10 years.

In order to mitigate the contribution of hypersaline water to the underlying Biscayne Aquifer, FPL has evaluated remedial alternatives to reduce the salinity of water in the CCS to seawater levels. In the course of that evaluation, an inspection of 22 months of pre-uprate monitoring data revealed a correlation between daily rainfall on the CCS and CCS salinity, where rainfall events were generally followed by short term reductions in CCS salinity. The visual comparison between daily precipitation and daily averaged CCS salinities in Figure 1 illustrates this relationship. Two phenomena are evident in this figure: 1) CCS salinities generally reduce during rainy months (June through September); 2) significant rainfall events produce notable reductions in CCS salinity. The latter phenomenon is effectively illustrated by a large (> 7 inches) rainfall event in late-September 2010 that induced an approximate 10 g/L drop in the average CCS salinity.

Because precipitation events are simply freshwater inflows to the CCS, they effectively dilute the water and reduce salinity. Based on the effectiveness of these freshwater inflows in reducing salinity, a remedial alternative was proposed wherein low salinity water would be added to the CCS on a sustained basis. The Floridan Aquifer was identified as the source of added water due to the low salinity and long term availability of groundwater.

Balance Modeling

In order to evaluate the effectiveness of reducing CCS salinity with added Floridan water, as well as the associated volume of water that would be needed, two balance models were employed. First, a simple, uncalibrated water and salt balance model of the CCS was developed. This balance model is based on a conceptual understanding of the inflows to and outflows from the CCS; it was employed as a screening model to provide a broad assessment of the efficacy of the proposed remedial alternative.

Subsequent to analysis with the steady state balance model, a transient water and salt balance model of the CCS system was configured to provide estimates of impacts to the CCS caused by the remedial alternative, including canal stage changes, changes in salinity, and time required to reduce salinity to the desired concentration. This transient model, which has been accepted by South Florida Water Management District, is calibrated to 22 months of CCS hydrologic and water quality data, such that it effectively replicates historical responses of the CCS to changes in inflows and outflow; as such, this transient model is capable of evaluating a wide range of climatic and operational conditions.

Steady State Balance Model

In order to determine the volume of Floridan water required to reduce CCS salinity to approximately 35 g/L, a steady state water and salt balance model of the CCS was developed. This balance model was based on a conceptual model of CCS equilibrium where inflows to the CCS are equal to and offset by outflows from the CCS, such that the volume of water in the CCS is invariant. The components of inflow are:

- Inflow from Nuclear Units 3 and 4,
- Precipitation,
- Seepage of groundwater, and
- Blowdown from other nuclear units.

Outflows from the CCS are comprised of:

- Outflow to nuclear Units 3 and 4 (assumed equal to the inflow from these units),
- Evaporation, and
- Seepage to groundwater.

Based on measurements and estimates of many of the flow components and associated salinities, the steady state water and salt balance effectively defines equilibrium flows into and out of the CCS, as well as the resulting salinity of the water within the CCS (Table 1a).

An additional inflow component was considered in the balance model with an assumed concentration of approximate 2 g/L, based on recent measurements of Floridan water. Using the balance model, the volume of the additional inflow was adjusted until the equilibrium concentration of CCS water reached approximately 35 g/L; the minimum additional inflow was derived to be 14 million gallons per day (mgd), which reduced the CCS salinity to 34.4 g/L (Table 1b).

Transient Balance Model

As a necessary component of FPL’s pre-uprate monitoring, a transient water and salt balance model was constructed for the CCS and calibrated to 22-months of hydrologic and salinity data from September 2010 through May 2012 (Ecology and Environment, 2012). Though the model considers the same CCS inflows and outflows as the steady state model, it calculates these inflows and outflows on a daily basis using 15-minute water level, salinity, and meteorological data measured throughout the Biscayne Aquifer, Biscayne Bay, the CCS, and nearby canals. The model uses these daily inflows and outflows to effectively simulate daily changes in CCS water and salt storage. The quality of the model is illustrated by the accurate simulation of daily changes in average CCS water levels and salinity between over the 22-month period (Figure 1). It should be noted that the model correctly simulates the reduction in salinity resulting from the addition of precipitation. The ability to match the response of salinity to addition of a known quantity and quality of water provides confidence that the model is capable of predicting a similar cause and response situation with the addition of Floridan water.

Transiently modeling the impacts of the proposed remedial alternative was a two-step process, wherein two predictive versions of the transient balance model were configured. The first model configuration, called the *unconstrained* model, predicted water levels in the CCS considering the addition of 14 mgd of Floridan water. This model was used to determine the increase in canal stage that would likely result from the added inflow: an average of 0.25 ft due to the Floridan-based inflow. Salinity changes were not assessed with this model due to the compounding error associated with predicting both hydrologic and water quality data.

The second model configuration, referred to as the *constrained* model, added the calculated 0.25 ft stage increase to the 22 months of observed CCS stages, and predicted the change in CCS salinity likely to result from the contribution of low salinity (2 g/L) Floridan water to the CCS. This model predicted a 41.3% reduction in CCS salinity from 60 g/L to approximately 35 g/L within 1 year of the initiation of the remedial action (Figure 2). Figure 2 also suggests that the quantity of added Floridan water could be optimally managed to obtain CCS salinities that are close to seawater. Note that less than 14 mgd may be required during the wet season while more may be required during the dry season when less precipitation is being added naturally.

The estimated flow of water for salinity reduction (14 mgd) appears low relative to the volume of the CCS (approximately 4.2×10^9 gallons); the key to remedial success, however, is the significantly low salinity in the Floridan relative to the salinity observed in the CCS. This difference between Floridan and CCS salinities may become less pronounced over time as the quality of the Floridan aquifer will likely vary and may degrade with continued stress on the aquifer. As such, two additional evaluations were performed with the transient model in order to determine the requisite increases in Floridan-based inflows to the CCS should the associated salinity increase by 50% (3 g/L) and 100% (4 g/L). Based on these analyses, it was determined that:

- If Floridan water were to degrade to 3 g/L, 14.5 mgd would be required to reduce the CCS salinity to 35.2 g/L; and
- If Floridan water were to degrade to 4 g/L, 15 mgd would be required to reduce the CCS salinity to 35.3 g/L.

As in the base remediation scenario, the relative difference between the CCS and the Floridan aquifer groundwater is critical to successful salinity reduction.

Summary

Changes in salinity in the CCS appear to be strongly correlated to precipitation: large precipitation events are followed by appreciable reductions in the salinity of the CCS. This observation led to exploration of the effect of adding on a continuous basis a source of water with a much lower salinity than the CCS. A simple steady state water balance and a more complex transient water balance were used in this evaluation. In order to abate the hypersaline conditions within the CCS, water and salt balance modeling determined that an average 14 mgd of Floridan water with a salinity of 2 g/L would need to be added to the CCS. Both models estimated that the addition of the Floridan water would reduce CCS concentrations to approximately 35 g/L. The transient model indicates that reduction of CCS salinity to that of seawater will take less than one year using an average addition of 14 mgd. Sensitivity analysis on the salinity of the added water indicates that the required quantities to reduce CCS concentration to approximately 35 g/L are 14.5 and 15 mgd for assumed Floridan aquifer salinities of 3 and 4 g/L, respectively. The transient model also indicates that the added water will raise the average stage in the CCS by 0.25 ft. This rise is accounted for in the water balance that is used for computations of CCS salinity and water budget components.

References

Ecology and Environment, 2012, Turkey Point Plan Comprehensive Pre-Uprate Monitoring Report: Unit 3 & 4 Uprate Project, Prepared for Florida Power & Light, October 2012.

Table 1a. Steady State Water and Salt Balance Model for the CCS (Base Case)

Inflows	Flow (mgd)	Salinity (g/L)
Precipitation	24.7	0
Blowdown	7.9	7
Groundwater Inflow to CCS	35.9	40
Total Inflow	68.5	

Outflows	Flow (mgd)	Salinity (g/L)
Evaporation	43.7	0
Seepage to Groundwater from CCS	24.8	60
Total Outflow	68.5	
	CCS Salinity (g/L):	**60**

Table 1b. Steady State Water and Salt Balance Model for the CCS (with Added Floridan Water)

Inflows	Flow (mgd)	Salinity (g/L)
Precipitation	24.7	0
Blowdown	7.9	7
Added Water	14	2
Groundwater Inflow to CCS	28.9	35
Total Inflow	75.5	

Outflows	Flow (mgd)	Salinity (g/L)
Evaporation	43.7	0
Seepage to Groundwater from CCS	31.8	34.4
Total Outflow	75.5	
	CCS Salinity (g/L):	**34.4**

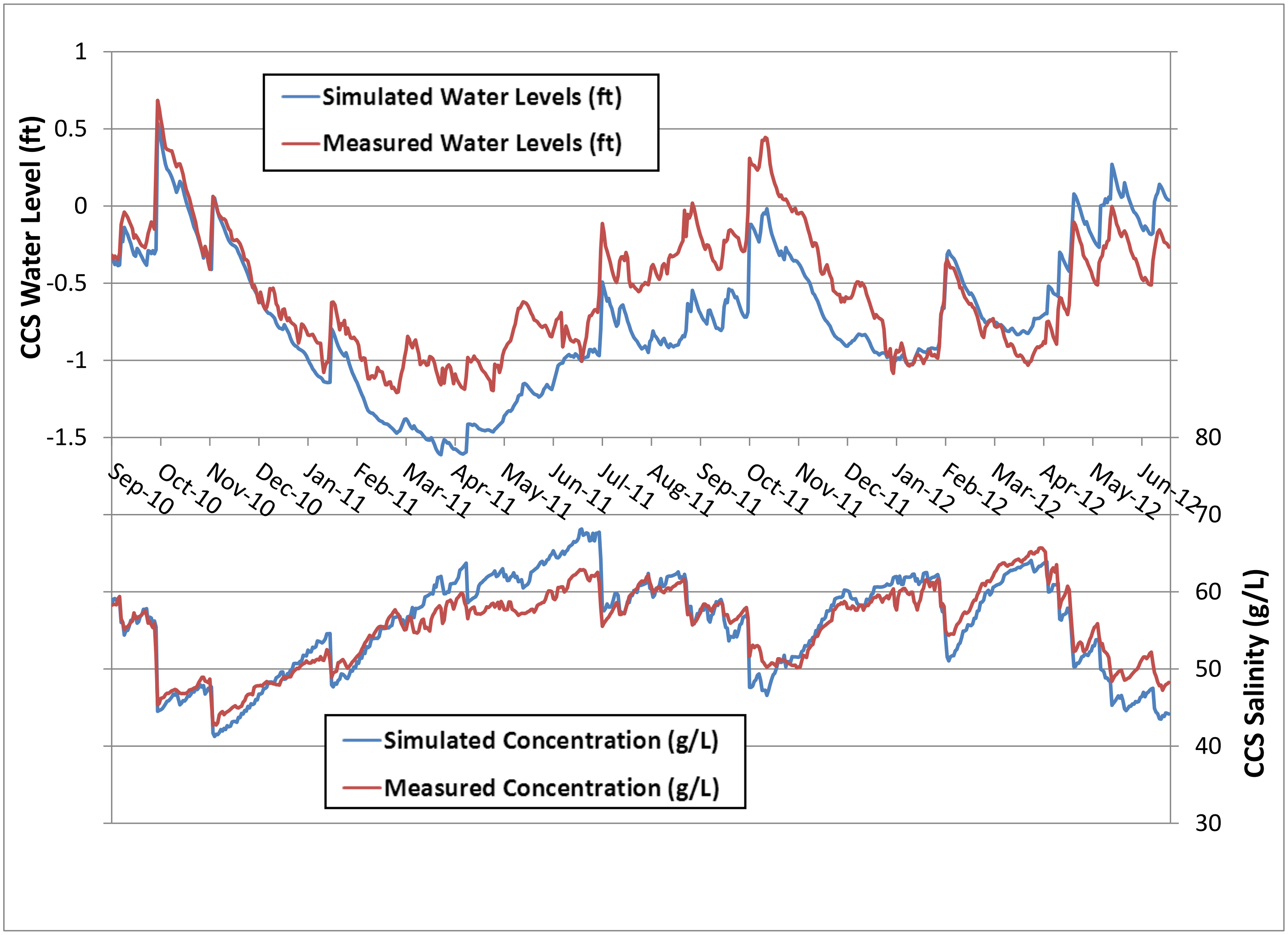

Figure 1. Comparison of observed daily average CCS water levels and salinity to those simulated by the calibrated 22-month transient water and salt balance model

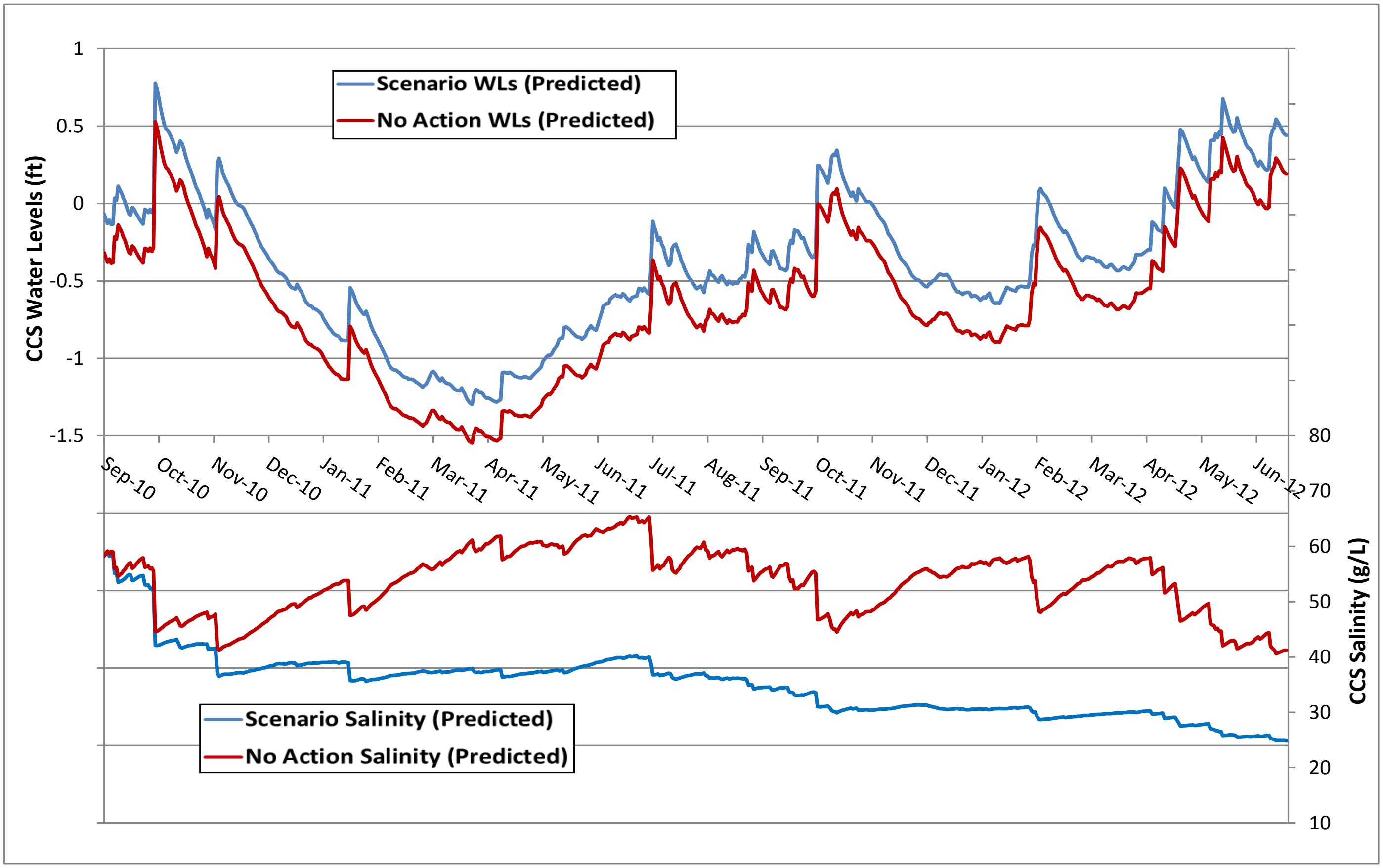

Figure 2. Predicted CCS stage and salinity in response to the additional inflow of Floridan water at a rate of 14 mgd and salinity of 2 g/L

APPENDIX B

EVALUATION OF DRAWDOWN THE UPPER FLORIDAN AQUIFER DUE TO PROPOSED SALINITY REDUCTION-BASED WITHDRAWALS, TETRA TECH, TECHNICAL MEMORANDUM (5/13/2014)

TECHNICAL MEMORANDUM

From: Peter F. Andersen and James L. Ross, Tetra Tech

To: Rory Rahming, Florida Power & Light Company

Date: May 13, 2014

Subject: Evaluation of Drawdown in the Upper Floridan Aquifer Due to Proposed Salinity Reduction-based Withdrawals

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1 INTRODUCTION

1.1 Background

Florida Power & Light Company (FPL) is in the process of applying for a modification to site certification to reflect the proposed reduction of salinity of cooling canal system (CCS) waters at the Turkey Point Power Plant, located near Florida City, Florida. A component of this project is a series of 1000-1200 foot deep wells that will extract low salinity water from the Upper Floridan Aquifer and discharge it into the CCS for the purpose of reducing the salinity of CCS water to levels commensurate with Biscayne Bay. As a step in the site certification process, FPL must demonstrate the feasibility of withdrawing approximately 14 million gallons per day (MGD) of Upper Floridan Aquifer water without adversely impacting the wells of existing legal users of the Floridan Aquifer. This memorandum describes the calibration and simulation of a groundwater flow model of the Floridan Aquifer system that is used to determine potential groundwater level (drawdown) changes resulting from the use of the Floridan Aquifer as a source of water for CCS salinity reduction.

1.2 Scope

The scope of this analysis is to calibrate a regional groundwater flow model of the Upper Floridan Aquifer, as defined from regional hydrogeologic data, including two documented Floridan Aquifer Performance Tests (APTs). The modeling shall meet the minimum requirements of the South Florida Water Management District (SFWMD) Basis of Review (BOR) for water use permitting. Once calibrated, the model will be used to evaluate the anticipated drawdown of the Upper Floridan Aquifer potentiometric surface at the plant site and regional settings. The drawdown information will be used to assess the likely impacts to the wells of existing legal users.

1.3 Report Organization

Following this introduction, the memorandum provides a summary of the existing regional groundwater model developed by the SFWMD that was modified and re-calibrated. This existing model is referred to as the East Coast Floridan Aquifer System Model - Phase 2 (ECFAS2). The calibration to the two APTs is then discussed, including changes that were made to the ECFAS2 model and the resulting quality of calibration. Predictive regional simulations and corresponding results follow.

2 METHODOLOGY

2.1 General

The methodology for conducting this study follows standard groundwater modeling protocols. As outlined in Anderson and Woessner (1992) the steps involved with model application include:

- Definition of purpose
- Conceptual model development
- Code selection
- Model design
- Calibration / verification
- Prediction
- Presentation of results

2.2 Regional Model

The primary purpose of the regional model analysis is to assess potential regional drawdown resulting from pumping water from the Upper Floridan Aquifer as a source of low-salinity water for the CCS. Some of the early steps in the modeling process, most notably conceptual model development, model design, and, to some degree, calibration, were abbreviated in this application because the ECFAS2 model (Golder Associates, 2008) was available to use as the framework for the analysis. The abbreviated relevant steps are summarized in this section. The resulting revised model marks an FPL adaptation to the ECFAS2 model, and is herein referred to as the Adapted Floridan model.

The conceptual model of the natural system is consistent with that described in the existing ECFAS2 model documentation (Golder Associates, 2008). Additional data to modify the hydraulic parameters are available from site specific data collection and testing. Two APTs performed at the site are documented in JLA Geosciences (2006) and Dames and Moore (1975) and serve to supplement the conceptual model presented in the existing ECFAS2 model documentation (Golder Associates, 2008).

The design of the original model was generally unchanged. However, the modeled domain was truncated in the north such that the longitudinal extent of the revised model is less than that of the original. Additionally, the finite difference grid spacing was modified to account for well locations used in the APTs that are simulated in the model re-calibration. Grid modifications are described in Section 3.2. Additionally, since relative changes in flow conditions (i.e. drawdowns) are the focus of both model calibration and predictions, only the groundwater flow component of the original model is evaluated and employed, herein. Logistically, this decision facilitated efficient model calibration and predictive simulations, as consideration of density-dependent flow and transport resulted in very long run times. The original groundwater flow and transport model was calibrated to regional water levels and saltwater concentrations. To account for site-specific conditions, the model was re-calibrated to two APTs conducted at the site.

3 Regional Model Simulations

3.1 ECFAS2 Model

The SFWMD, through contractors, developed a density-dependent groundwater flow and saltwater transport model of the East Coast of Florida in two phases. The first phase, ECFAS1 (HydroGeologic, 2006), simulated the southern half of the study area (the Lower East Coast of Florida); the second phase (ECFAS2) expanded the model domain northward to include more of the East Coast of Florida (Golder Associates, 2008). Both phases of the ECFAS model are available from the SFWMD; only the former has been peer-reviewed. Nevertheless, these models represent the best available framework from which to base a permitting-level analysis of regional Floridan Aquifer impacts resulting from pumping.

The ECFAS2 model encompasses the ECFAS1 region and represents a revision to the earlier work. Consequently, the ECFAS2 model was used as the framework for this analysis. The ECFAS2 model covers the much of the East Coast of Florida, from southern Indian River County to the Florida Keys. This area is discretized into uniform 2400 by 2400 ft cells. Vertically, the model extends from land surface to the Boulder Zone, a depth of approximately 3000 ft. The vertical section is discretized into 14 layers, with the Upper Floridan Aquifer represented as 2 layers. Boundary conditions are specified to represent flow into and out of the model domain, usually along the perimeter of the study area. Both flow (hydraulic heads) and saltwater transport (TDS concentrations) are simulated and are dependent upon one another (density-dependent flow and transport). Field data from numerous borings were used to establish the structure of the model layering, which represents the hydrostratigraphic layers. In addition, field data from APTs were used to guide the initial choice of hydraulic parameters that were used in the model calibration. The model was calibrated to both hydraulic heads and concentrations. Even though the model was calibrated, Golder Associates (2008) found that the model's size resulted in exceptionally long run times such that the scope of the calibration had to be reduced from what was originally envisioned.

3.2 Adapted Floridan Model

The ECFAS2 model was not usable in its available state because it covers a very large area and does not provide the resolution required to accurately assess site-specific features and impacts. Several structural modifications were made to the model and are described herein. Modifications to the calibration of the model are discussed in this section. As previously mentioned, only the groundwater flow capabilities of the ECFAS2 model were germane to the analyses of drawdown described herein, as regional changes in water quality attributable to the proposed wells, as well as the impact of such changes on drawdown, are anticipated to be negligible. Moreover, model run times were dramatically reduced by eliminating the density-dependence.

Since the Adapted Floridan model simulates groundwater flow and is adapted from the SEAWAT-based ECFAS2 model, the USGS simulation software MODFLOW-2000 (Harbaugh, et al, 2000), a commonly applied groundwater flow model, was used to simulate the regional model. MODFLOW-2000 is capable of addressing the requirements of the SFWMD BOR inasmuch as it:

- simulates groundwater flow,

- is capable of addressing multiple hydrostratigraphic layers and subdividing these layers such that drawdown can be computed at multiple levels within each layer, and
- is in the public domain, peer-reviewed, and widely used.

The most significant structural change to the model was the grid spacing, which was originally set at 2400 ft. For calibration purposes, the grid was refined in the immediate vicinity of the Turkey Point APTs, such that the well spacing for the APTs could be accurately represented and changes in head over small distances resolved. The revised grid spacing in the model for the calibration is shown in **Figure 1a**. The minimum grid spacing used in the Adapted Floridan model, near pumping and monitoring wells, is as little as 1.5 ft. The original model grid spacing, shown in **Figure 1b**, was used in subsequent predictive runs because it was adequate for assessment of impacts at the desired scale and was practical from a run-time perspective.

The original model layering was retained because it appeared to be generally appropriate for the level of detail required. The Intermediate Confining Unit (ICU), which overlies the Upper Floridan, was represented using a single layer.

The additional pumping wells that were included as a part of the calibration of the Adapted Floridan model also represent modifications to ECFAS2. The well locations and rates are described in the calibration and model results sections below. The time stepping of the models was also modified to provide adequate resolution for the duration of the APTs and to account for intermittent pumping (Section 3.2.1.1 and 3.2.1.2).

3.2.1 Additional calibration of model

Although the ECFAS2 model may represent the regional conditions fairly well, it may not represent site-specific conditions particularly well. This hypothesis was tested by running the model using documented pumping stresses on the system and comparing the modeled response to that which was observed during the test. In general, as discussed below, the comparison was not good. In order to obtain a reasonable representation of site-specific conditions, two additional calibrations, one to a short-term APT and another to a longer term APT, were performed. The ability to match aquifer system response to these APTs provides confidence that the model can predict the response to future proposed pumping. Modeled water levels were checked to ensure that the match to regional calibration targets had not been degraded as a result of the local changes. The methodology and results of each of the additional calibrations are described below.

3.2.1.1 <u>JLA APT</u>

JLA Geosciences (2006) conducted an APT in support of the Unit 5 site certification. Floridan water supply well PW-1 was pumped for 72 hours and drawdown was measured in two other water supply wells and a shallow observation well. The drawdown response documented during this test was believed to represent a good series of targets to match as a part of a calibration because it was local to the area of proposed pumping and was conducted under quality-controlled conditions. However, it was recognized that the short duration of the test and extent of monitoring points would provide data that may only be representative of a relatively small area.

Simulation of the APT was accomplished using the revised model grid. Well PW-1 was represented with a single well pumping at a rate of 4500 gpm in model layers 3 and 4, which represent the Upper Floridan Aquifer, in the cell at row 166, column 143 Timestepping ranged from a minimum of 5 to a maximum of 567 minutes,   Drawdown response was noted in wells PW-3 (layers 3 and 4, row 168, column 171), PW-4 (layers 3 and 4, row 180, column 157), and OBS-1 (layer 2, row 166, column 143) at distances of 3036, 1686, and 0 feet, respectively from the pumped well. Note that OBS-1 is co-located with the pumping well, but is screened near the base of the Biscayne Aquifer and did not experience drawdown in response to the APT.

Comparison of modeled to observed conditions for the original model, prior to adjustment, was not good, with a residual standard deviation of greater than 100 ft. However, as shown in **Figure 2**, this match improved considerably (residual standard deviation of 0.36 ft) after adjustment of hydraulic parameters as a part of the calibration. In general, hydraulic conductivities were increased from their original values during calibration. Goodness-of-fit calibration metrics are shown in **Table 1** and indicate that the model provides a reasonable fit to observed data.

Table 1. Goodness of fit metrics for the JLA APT calibration.

Metric	Numerical Value
Mean Error, ft	0.22
Mean Absolute Error, ft	0.33
Residual Standard Deviation, ft	0.36
Range of Targets, ft	6.36
Residual Standard Deviation / Range *100	5.6%

Note that this calibration was conducted iteratively with the Dames and Moore APT described below and hence the calibrations strike a balance between matching the results of both APTs with the same set of parameters.

3.2.1.2 Dames and Moore APT

Dames and Moore (1975) conducted an APT in support of a feasibility study for using Floridan Aquifer water to cool the original Turkey Point nuclear units. Floridan Aquifer production test well (PTW) was pumped for 90 days and drawdown was measured in eight monitoring wells at various distances from the pumped well and depths in the aquifer. The drawdown response documented during this test was believed to represent a good series of targets to match as a part of a calibration because of its long duration and use of monitoring points that were distant from the pumping well. Thus, this test was complementary to the shorter duration, more local JLA APT described above.

As in the simulation of the JLA APT, the simulation of the Dames and Moore APT was accomplished using the refined model grid. Well PTW was represented with a single well pumping at a rate of 5000 gpm in cell layers 3 and 4, row 220, and column 97. Timestepping ranged from a minimum of 73 minutes to a maximum of 11.8 days. Drawdown response was noted in wells OW-A (row 229, column 108), OW-B (row 238, column 120), OW-C (row 207,column 82), and OW-D (row 258, column 181) at distances of 100 feet, 500 feet, 2000 feet, and 48,000 feet, respectively from the pumped well. Drawdown was recorded in the Upper and Middle Floridan aquifers at each of the four observation well sites, which are represented by layers 3 and 4, and 7 and 8, respectively

Comparison of modeled to observed conditions for the original model, prior to adjustment, was not good (residual standard deviation in excess of 10 ft), as was the case for the JLA APT. As shown in **Figure 3**, this match also improved considerably (with a residual standard deviation of

0.77 ft) after adjustment of hydraulic parameters as a part of the calibration. Goodness-of-fit calibration metrics are shown in **Table 2** and indicate that the model provides a reasonable fit to observed data.

Table 2. Goodness of fit metrics for the Dames and Moore APT calibration

Metric	Numerical Value
Mean Error, ft	-0.30
Mean Absolute Error, ft	0.66
Residual Standard Deviation, ft	0.77
Range of Targets, ft	11.8
Residual Standard Deviation / Range * 100	6.5%

Though the wells shown in **Figure 3** are not an exhaustive representation of the calibration targets, they are a microcosm of the quality of the model match to this APT. The lateral and vertical proximity to the pumping well precluded a reasonable match to the observed drawdown at well OW-A (Upper); as such, this well was omitted from the calibration.

3.2.1.3 Adjustments to the calibration

The primary parameters that were changed as a result of the additional calibration were hydraulic conductivities of the Upper Floridan Aquifer (UFA), ICU, Middle Confining Unit (MCU), and the Middle Floridan Aquifer (MFA). These parameters were all raised from their original values, as shown in **Table 3**.

Note that the parameter changes were made within zones that were near the Turkey Point site and mostly in areas potentially affected by drawdown from proposed salinity reduction wells, as shown in **Figure 4**, **5**, and **6**.

The changes made to the hydraulic properties in the Adapted Floridan model are not expected to significantly impact the quality of the model match to the water level and water quality targets employed in the calibration of the ECFAS2 model. The changes made to the Adapted Floridan model were generally minor, and the preponderance of the ECFAS2 model calibration targets are located outside of the Adapted Floridan model domain.

Table 3. Parameter changes resulting from calibration of the Adapted Floridan model.

Hydrologic Unit	Model Layers	Aquifer Parameter	ECFAS2 model (original)	FPL Floridan Model (recalibrated)
			magnitude	magnitude
ICU	2	Kz (ft/d)	0.0006	0.001
			0.000075	0.001
		Kh (ft/d)	0.000075	0.001
UFA	3,4	Kz (ft/d)	5.2	100
			9	15
			72.5	225
			0.33	225
		Kh (ft/d)	52	100
			90	150
			725	330
			3.33	330
		Ss	5.25E-07	8.00E-07
MCU	5,6	Kz (ft/d)	0.000002	0.004 0.003 0.08 0.4
			0.002	0.003 0.08
		Kh (ft/d)	0.00001	0.02 0.08 0.4 0.03
MFA	7,8	Kz (ft/d)	5.2	30
		Kh (ft/d)	450	900
			300	600
			180	1200
			52	600
MC2	9,10,11	Kz (ft/d)	0.0015	0.01
			0.0002	0.02

3.3 Predictive Simulations

Once calibration of the regional Floridan model was confirmed, equilibrium flow conditions were established by running the model, holding all flow boundaries (e.g. specified heads, pumping) constant until changes in the simulated flow field in the Floridan Aquifer System were negligible. This equilibrated state formed the initial conditions for ensuing predictive simulations. Equilibrated regional water levels, especially near Turkey Point, were generally lower than observed water levels; this is due to the exclusion of salt transport and the associated density-dependent flow. However, given that purpose of this model is to provide estimates of *relative* changes in water level, the low simulated water levels were deemed irrelevant. Since the focus of the salinity reduction well evaluation is regional drawdown, the original 2400-ft grid spacing was employed for predictive simulations.

According the SFWMD BOR, predictive evaluations made with the calibrated model must be conducted using monthly stress periods that simulate average annual groundwater withdrawals subject to rainfall that alternates between average and 1-in-10 year draught conditions. Given that the model simulates groundwater withdrawals from the Upper Floridan Aquifer and evaluates *relative* water level changes (i.e. drawdown) at nearby Floridan users, the consideration of drought conditions would have no impact on results. As such, the predictive models are conducted using annual stress periods and simulate permitted groundwater withdrawals without any variation in rainfall.

Additionally, the BOR stipulates that the 1-ft drawdown contour associated with the proposed pumping be simulated and the impacts to existing legal users' wells within that contour be evaluated. The process by which this was accomplished is described below.

3.3.1 Proposed Salinity Reduction Well Operation

There are six proposed salinity reduction wells. At any one time, five of these wells will collectively pump 14 MGD of low salinity water from the Upper Floridan aquifer. The six wells will be spaced approximately 1900 ft apart, along the northernmost canal of the Cooling Canal System and along the Interceptor Ditch (**Figure 7**). In the model, the 14 MGD of pumping is distributed evenly amongst the five active wells and is assumed to be a constant rate of pumping over the course of the 25-year simulation. Two alternative pumping scenarios are considered in this modeling analysis and differ in the allocation of pumping to wells F-2 and F-6. The base scenario simulates pumping at wells F-1 through F-5 (no pumping at F-6); the alternative scenario simulates pumping at wells F-1 and F-3 through F-6 (no pumping at F-2).

The salinity reduction wells were simulated, starting from an equilibrium flow field, in which nearby legal users' wells were simulated at their permitted withdrawals. Their operation over a period of 25 years encompasses the time from which the wells are anticipated to begin pumping through to the time 5 years beyond the decommissioning of Turkey Point Power Plant Nuclear Units 3 and 4 (at which point the CCS would no longer function in its current capacity). At the conclusion of the 25-year simulation, the simulated drawdowns in the regional model are those attributable only to the five proposed salinity reduction wells. **Figure 8a** illustrates these regional drawdowns associated with the base pumping scenario. In this base simulation, the drawdowns at a distance from the site are affected by variations in hydraulic conductivity; this is evident upon inspection of the 1-ft drawdown contour, which generally has an oblong shape, whose major axis is oriented north-to-south. Nearer to the site, the drawdown contours radiate outward from the wells in a more uniform manner, where the maximum drawdown is approximately 15.1 ft, near well F-3. In the alternative scenario, the maximum drawdown is approximately 14.4 ft, near well F-5.

As previously mentioned, the SFWMD BOR dictates that drawdown at permitted users' wells encircled by the 1-ft drawdown contour be determined. As illustrated in **Figure 8a,** the following permitted users fall within the 1-ft drawdown contour:

- Card Sound Golf Club,
- Ocean Reef Club,
- the Floridan Keys Aqueduct Authority (FKAA),
- Miami-Dade Water and Sewage Department South Miami Heights Wellfield, and
- FPL Unit 5 Wells.

Predicted drawdowns at Floridan wells of these existing legal users are presented in **Table 4**. These drawdowns are calculated at the center of the model grid cells in which the respective wells are simulated. In addition to drawdowns attributable to the proposed wells for the base pumping allocation scenario, cumulative drawdowns at nearby wells due to both pumping at permitted and proposed wells are provided in **Table 4.** These cumulative drawdowns are also illustrated in **Figure 8b** for the base pumping scenario. Withdrawals by nearby users were simulated at their respective permitted rates.

Table 4. Predicted drawdown at nearby users for the proposed Salinity Reduction Wells due to the base pumping scenario.

Facility	Location (L,R,C)	Permitted Withdrawal (MGD)	Distance from well F-2 (miles)	Base Scenario Drawdown at 25 Years (ft)	Base Scenario Cumulative Drawdown (ft)
Card Sound Golf Club (WUP 44-00001)	(3-4,173,93)	0.58	8.8	2.22	9.79
Ocean Reef Club (WUP 44-00002)	(3-4,173,93)	1.42	8.8	2.22	9.79
FKAA (WUP 13-00005)	(3-4,155,61)	9.70	10.3	2.16	15.06
South Miami Hts (WUP 13-00017)	(3-4,133-135,79)	3.00	10.3	2.27	11.39
FPL Unit 5 Well (PW-1)	(3-4,156,85)	14.3	< 1.0	11.87	32.61

A second evaluation was conducted in which the alternative pumping allocation (wells F-1 and F-3 through F-6) for the salinity reductions wells was simulated. The resulting simulated drawdowns at legal users within the 1-ft drawdown contour are provided in **Table 5**; cumulative drawdowns are also tabulated. Inspection of the drawdowns in **Table 5** reveals that they are not significantly different from those produced by the base pumping allocation.

In addition to the above two evaluations, the cumulative drawdown solely due to permitted pumping by existing legal Floridan water users (i.e. no pumping was simulated at the proposed salinity reduction wells) was also assessed. The cumulative drawdown due to permitted pumping is illustrated in **Figure 9**. The cumulative drawdowns in this figure are not significantly different than those produced by the combination of proposed and permitted withdrawals (**Figure 8b**). This suggests that the proposed pumping of Floridan water by the salinity reduction wells will not significantly exacerbate drawdowns in the Upper Floridan aquifer beyond those induced by existing permitted pumping.

Table 5. Predicted drawdown at nearby users for the proposed Salinity Reduction Wells due to the alternative pumping scenario.

Facility	Location (L,R,C)	Distance from well F-2 (miles)	Alternative Scenario Drawdown at 25 Years (ft)	Alternative Scenario Cumulative Drawdown (ft)
Card Sound Golf Club (WUP 44-00001)	(3-4,173,93)	8.8	2.23	9.80
Ocean Reef Club (WUP 44-00002)	(3-4,173,93)	8.8	2.23	9.80
FKAA (WUP 13-00005)	(3-4,155,61)	10.3	2.19	15.09
South Miami Hts (WUP 13-00017)	(3-4,133-135,79)	10.3	2.25	11.37
FPL Unit 5 Well (PW-1)	(3-4,156,85)	< 1.0	10.36	31.10

4 Conclusions

The evaluation of drawdown due to pumping at the proposed salinity reduction wells is based on the ECFAS2 model developed for the SFWMD. This model was subsequently adapted to site-specific conditions and re-calibrated to two APTs performed at Turkey Point. The resulting regional calibrated groundwater flow model provides assessment of drawdown at nearby existing Floridan water users.

In a regional sense, the proposed pumping of 14 MGD is projected to result in a maximum Upper Floridan Aquifer drawdown ranging between 14.4 ft (alternative scenario) and 15.1 ft (base scenario) at the Turkey Point site; simulated drawdowns at a distance from Turkey Point are not significantly different between the two pumping scenarios. The extent of drawdown, as defined by the 1-ft drawdown contour encompasses four existing legal users. Overall, the impacts to off-site permitted wells are minor. The maximum drawdown due to the proposed salinity reduction wells experienced by the nearest (non-FPL) users is 2.23 ft and occurs at the Card Sound Golf Club and Ocean Reef Club wells, located approximately 8.8 miles away. The drawdown at these wells is approximately equal to that estimated by SFWMD (2013) and comprises approximately 23% of the cumulative drawdown simulated at this site. The drawdown contribution by the proposed salinity reduction wells is a conservative estimate (greater than would actually be experienced), since the drawdown in the wellbore at each nearby user due to localized pumping is undersimulated by the coarse-gridded regional model.

In addition to a demonstration of minimal drawdown induced at wells of permitted users within the 1-ft drawdown contour, the BOR also stipulates that the proposed pumping not impact the saltwater interface, as defined by the 250 mg/L isochlor. As the quality of Upper Floridan Aquifer water in this area already exceeds such a concentration, and no saltwater interface exists, this stipulation does not apply to the proposed project. Moreover, the operation of the salinity reduction well is not expected impact Upper Floridan water quality in a regional sense. Local changes in water quality are expected to be minor, as demonstrated by other Upper Floridan water users in the region (SFWMD, 2012).

5 References

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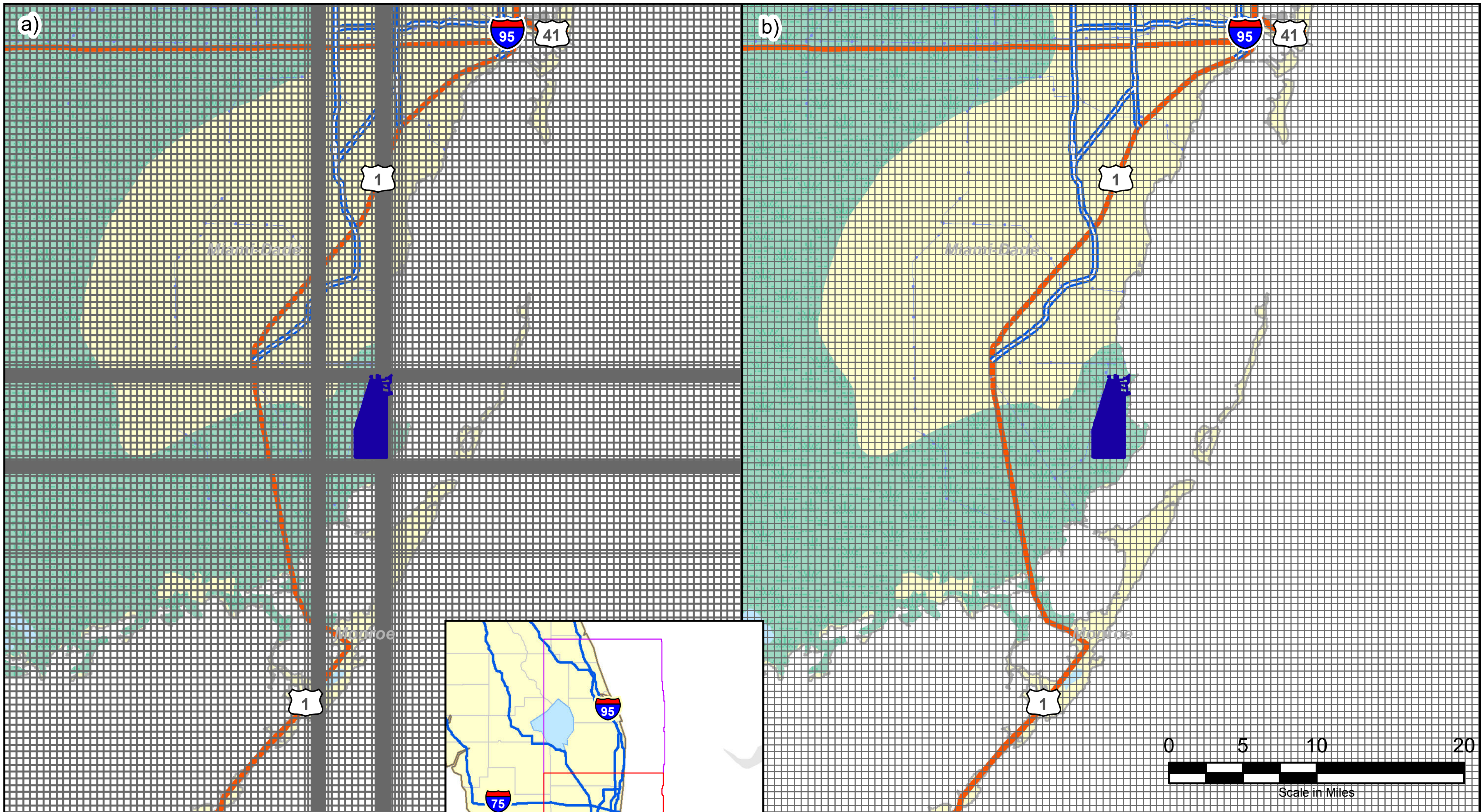

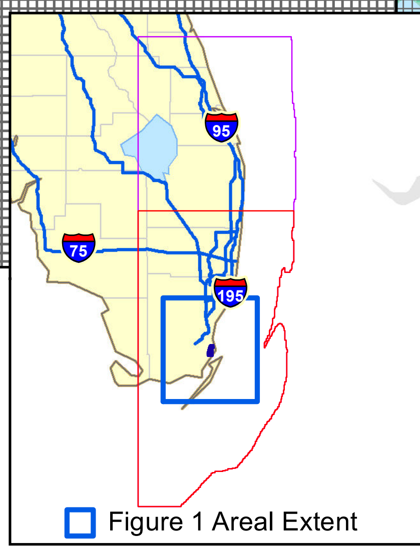

Legend

- Calibration Model Extent
- Original Model Extent
- Cooling Canals
- Model Grid

TITLE: Model Grid Spacing in the Vicinity of Turkey Point for a) Calibration Model and b) Predictive Models

LOCATION: Turkey Point, Florida

TETRA TECH

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DATE	03/10/2014	

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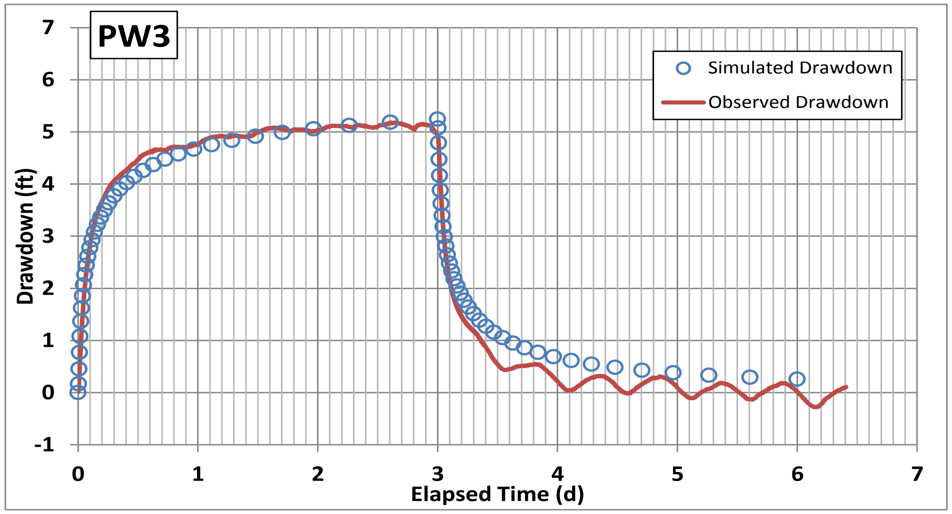

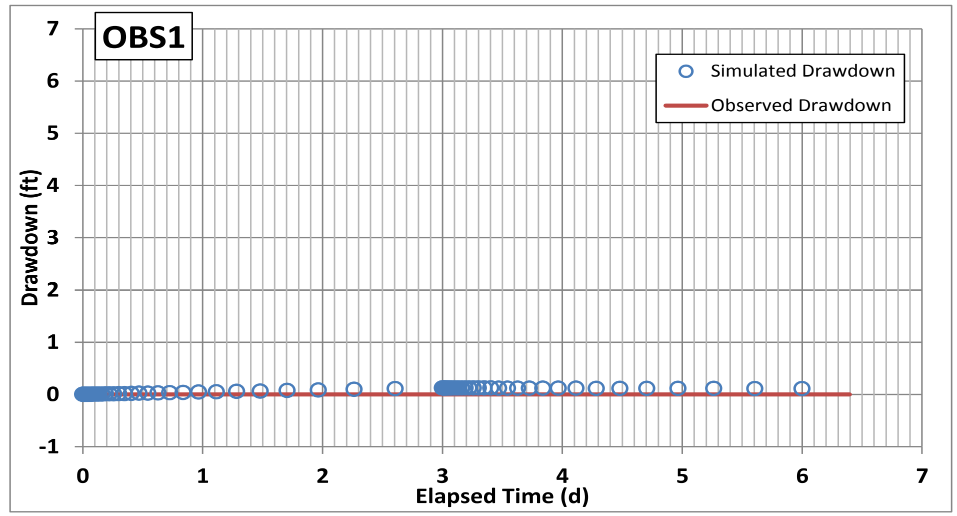

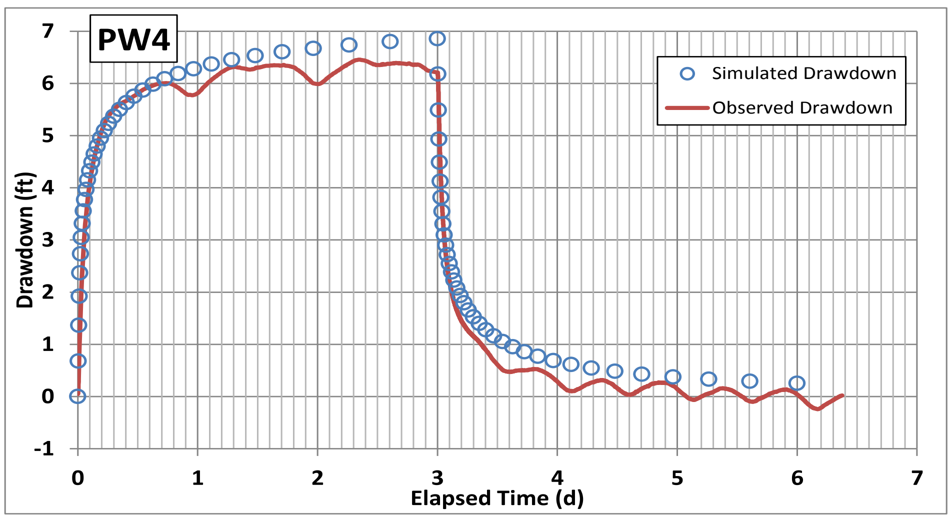

TITLE: **Modeled vs observed drawdown for the JLA APT - Calibrated Adapted Floridan Model**

LOCATION: **Turkey Point, Florida**

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FILE:	117-2826019	
DATE:	03/09/2014	

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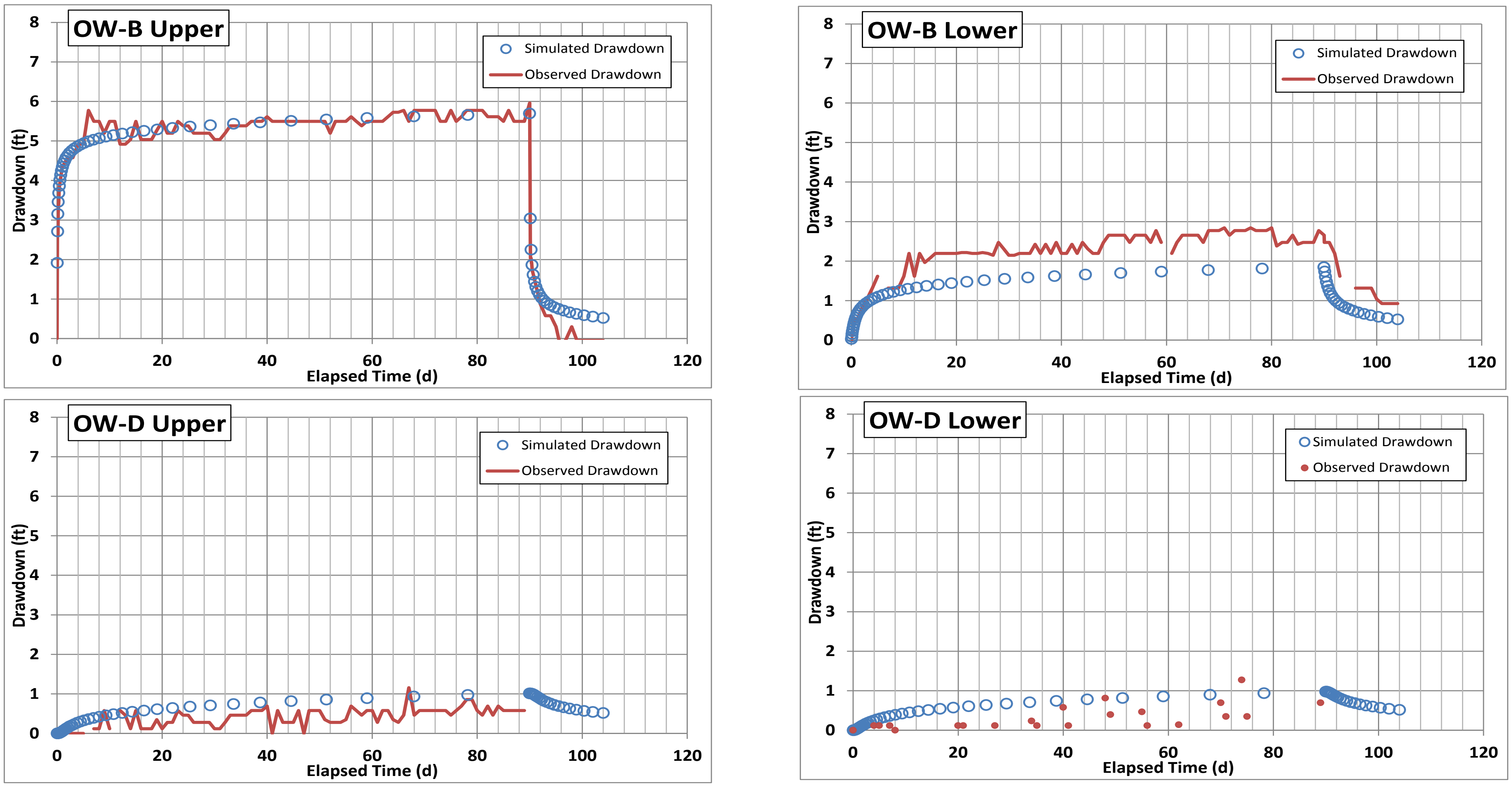

TITLE: **Modeled vs observed drawdown for the Dames and Moore APT - Adapted Floridan Model**

LOCATION: **Turkey Point, Florida**

TETRA TECH

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FILE:	117-2826019	
DATE:	03/09/2014	

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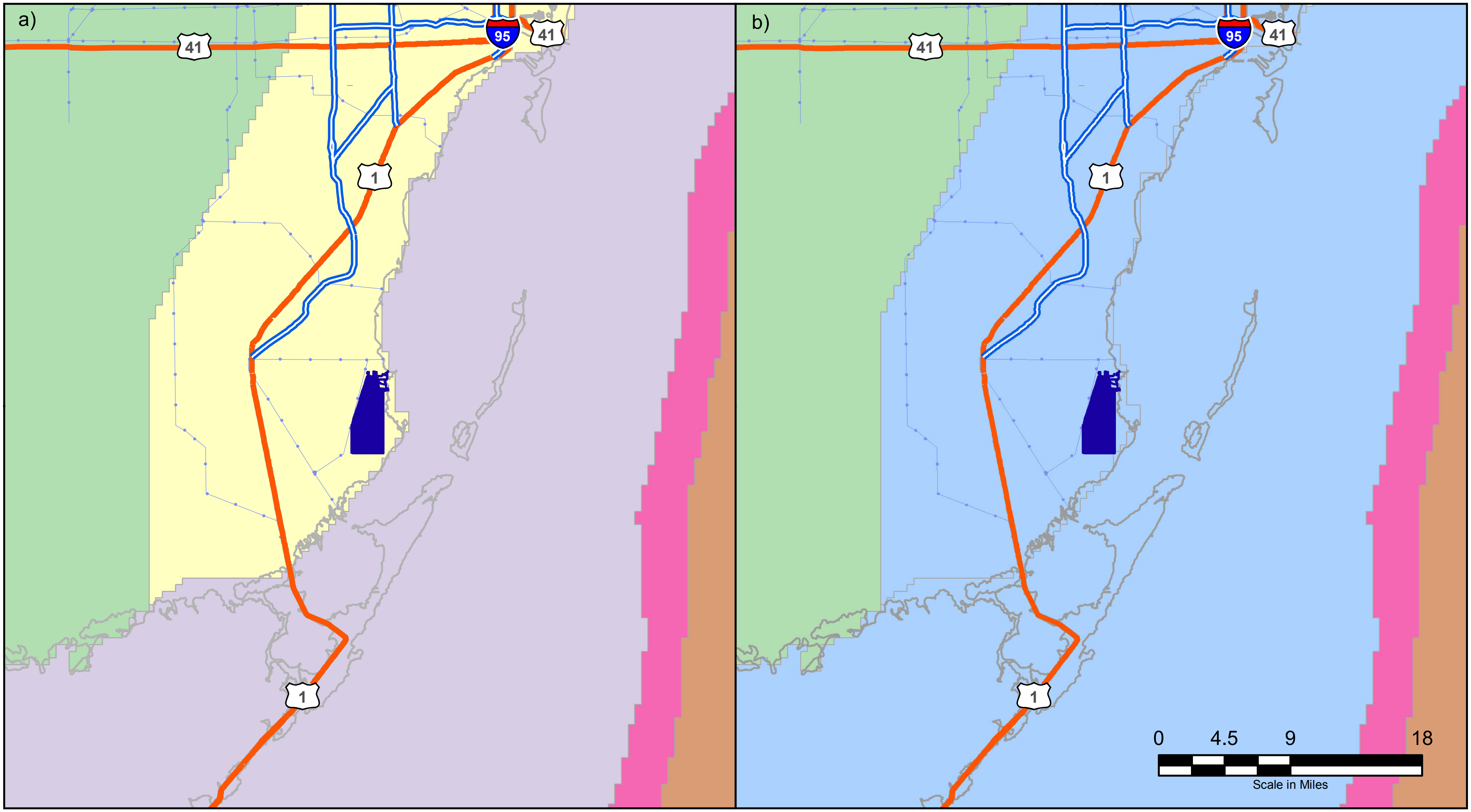

Legend

Original Conductivity — Cooling Canals

- 3.0E-06 ft/d
- 7.5E-05 ft/d
- 6.0E-04 ft/d
- 2.5E-03 ft/d
- 9.5E-03 ft/d

Calibrated Conductivity

- 3.0E-06 ft/d
- 6.0E-04 ft/d
- 1.0E-03 ft/d
- 2.5E-03 ft/d
- 9.5E-03 ft/d

TITLE: Distribution of Vertical Hydraulic Conductivity in the Intermediate Confining Unit a) Original Model, Prior to Additional Calibration and b) After Additional Calibration

LOCATION: Turkey Point, Florida

TETRA TECH

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FIGURE: 4

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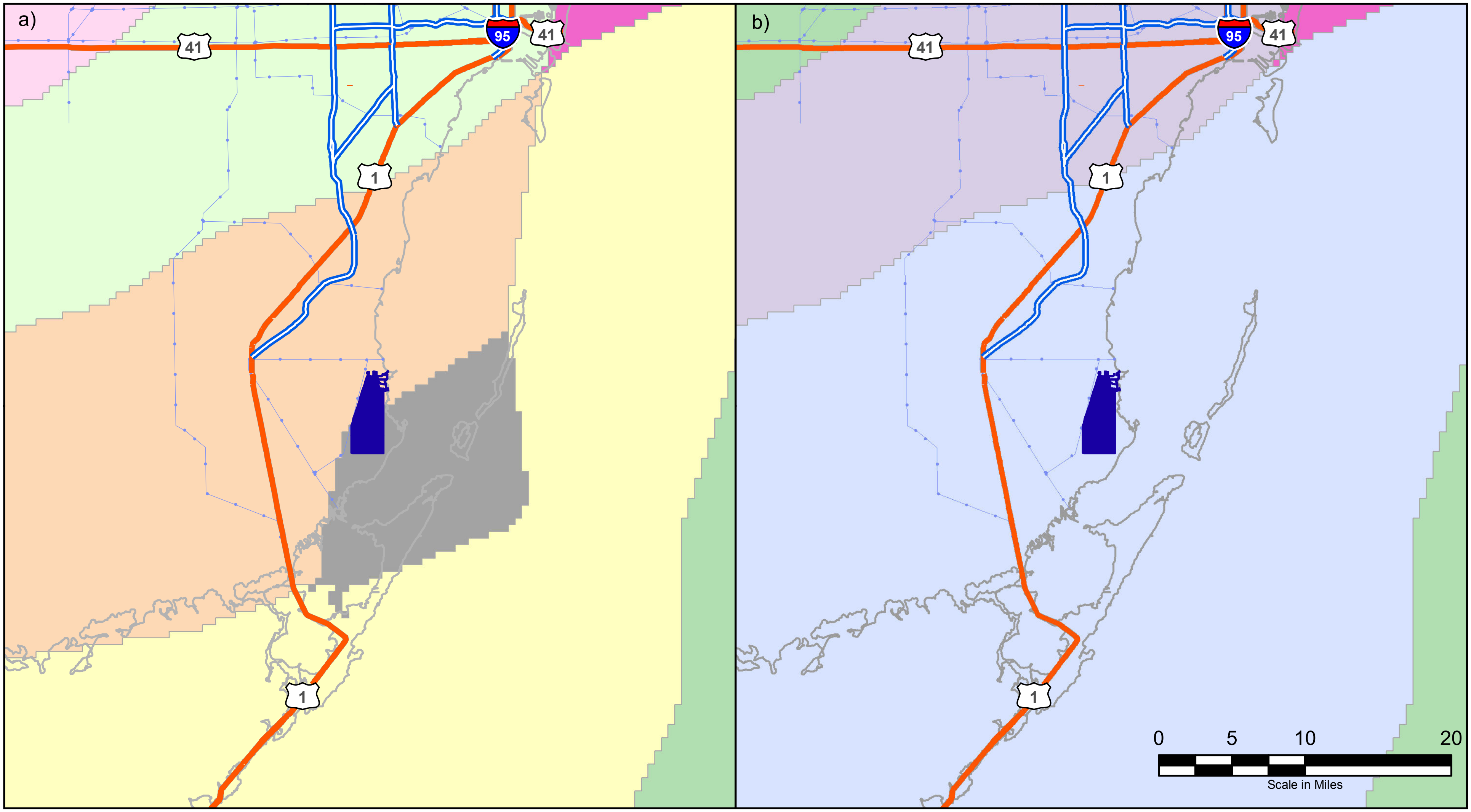

Legend

Original Conductivity

- 725 ft/d
- 224.995 ft/d
- 100 ft/d
- 90 ft/d
- 55 ft/d
- 52 ft/d
- 3.33 ft/d
- Cooling Canals

Calibrated Conductivity

- 330 ft/d
- 150 ft/d
- 100 ft/d
- 55 ft/d

TITLE:
Distribution of Hydraulic Conductivity in the Upper Floridan Aquifer
a) Original Model, Prior to Additional Calibration and b) After Additional Calibration

LOCATION:
Turkey Point, Florida

TETRA TECH

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PROJ	117-2826019
DATE	03/10/2014

FIGURE: 5

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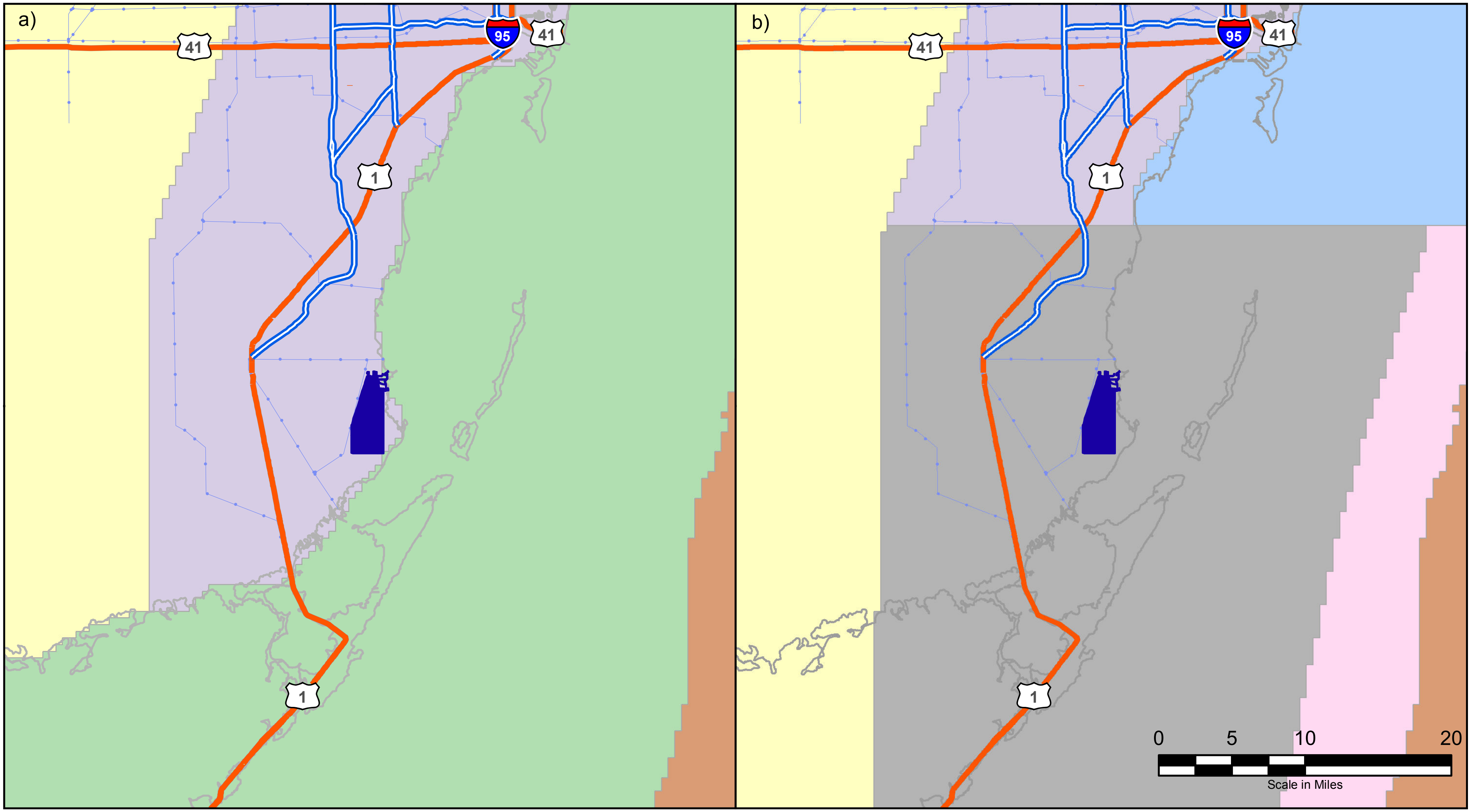

Legend

Original Conductivity — Cooling Canals

- 2.0E-06 ft/d
- 2.0E-03 ft/d
- 4.0E-03 ft/d
- 5.0E-03 ft/d
- 1.5E-02 ft/d

Calibrated Conductivity

- 2.0E-03 ft/d
- 3.0E-03 ft/d
- 4.0E-03 ft/d
- 1.5E-02 ft/d
- 8.0E-02 ft/d
- 4.0E-01 ft/d

TITLE: Distribution of Vertical Hydraulic Conductivity in the Middle Confining Unit a) Original Model, Prior to Additional Calibration and b) After Additional Calibration

LOCATION: Turkey Point, Florida

TETRA TECH

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PROJ	117-2826019
DATE	03/10/2014

FIGURE: 6

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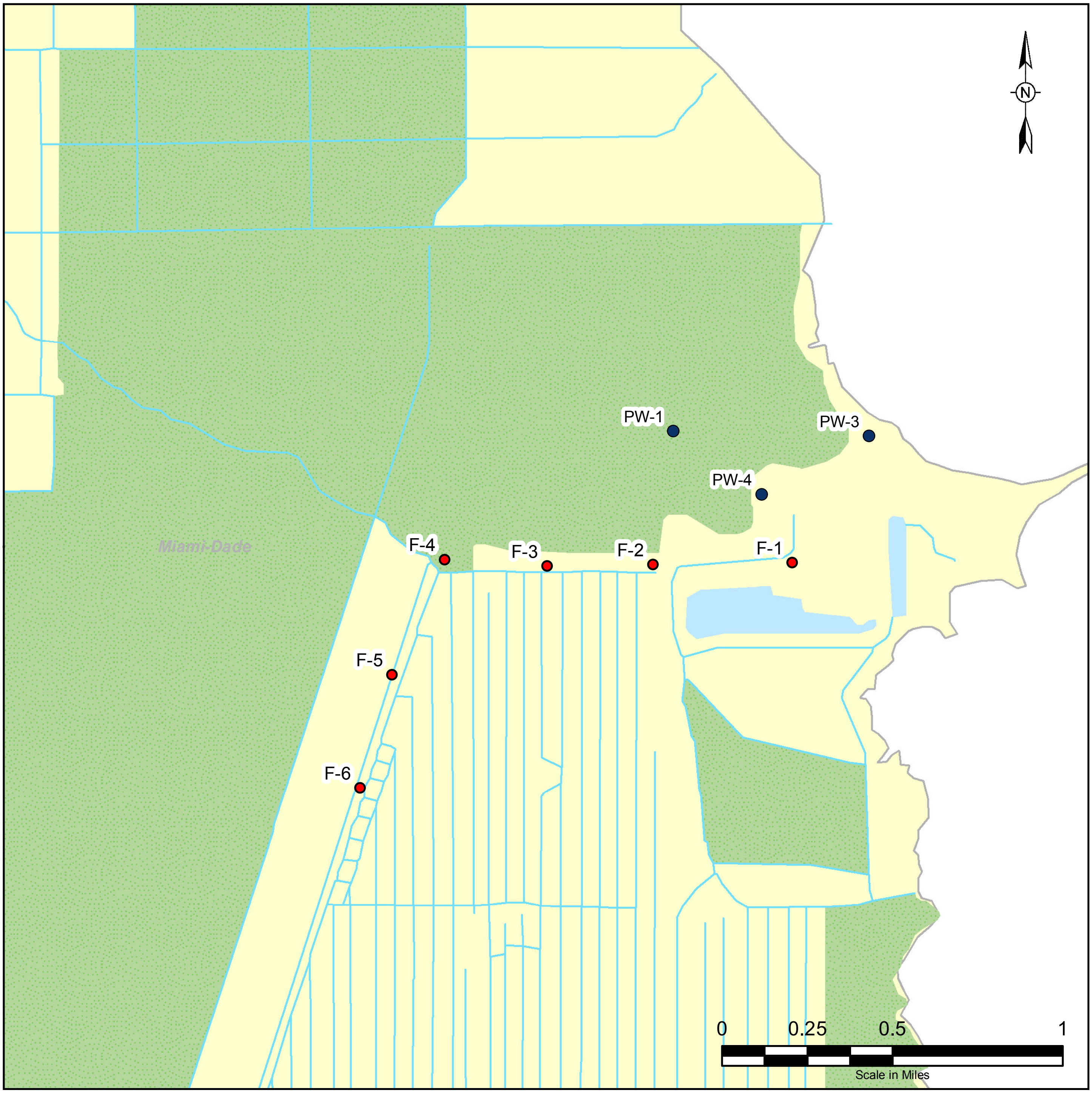

Legend

- Proposed Wells
- Existing Unit 5 Wells

TITLE:	Location of Proposed Salinity Reduction Wells Screened in the Upper Floridan Aquifer
LOCATION:	Turkey Point, Florida

TETRA TECH

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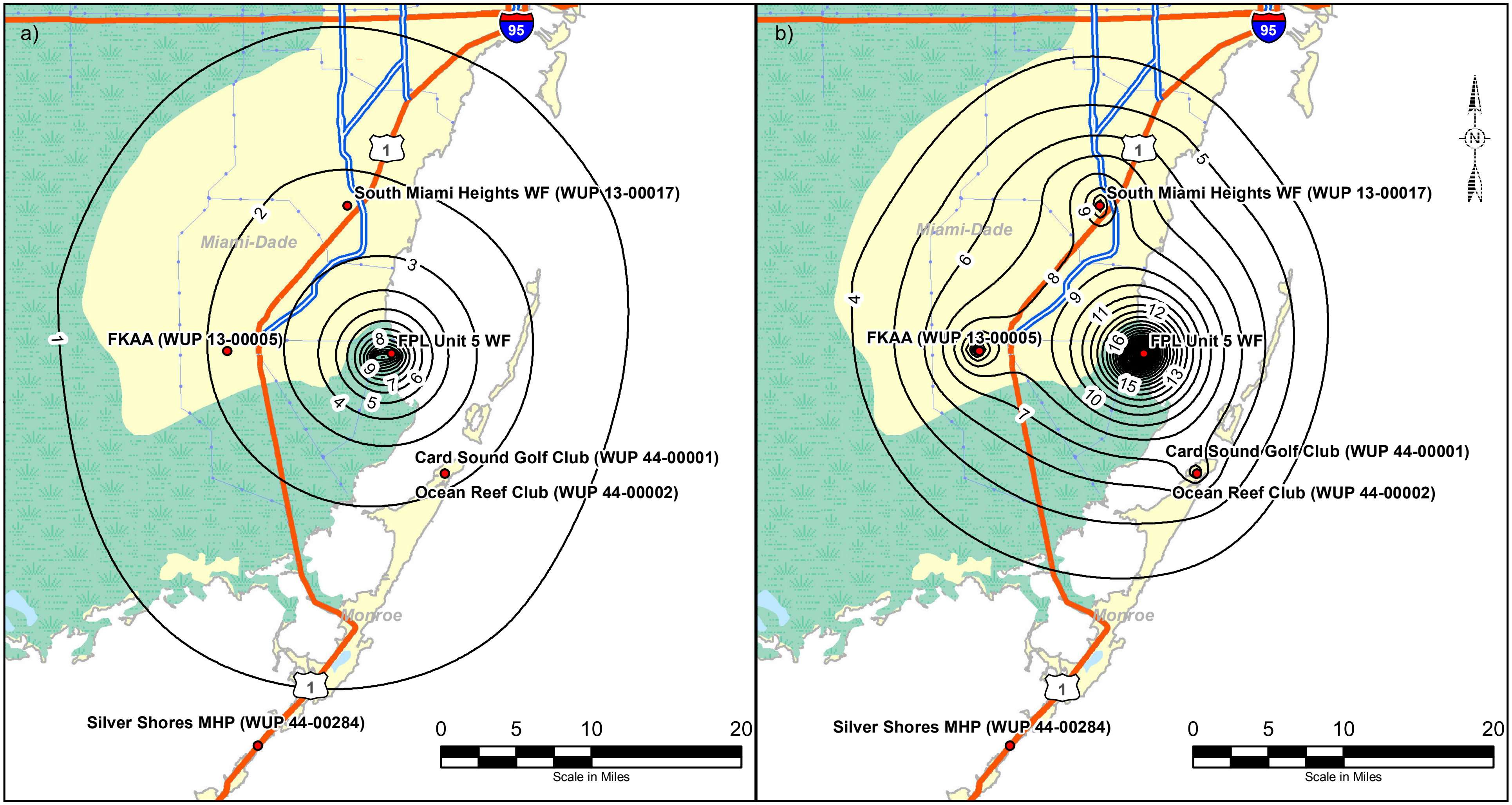

Legend

- Existing User Wells
- Drawdown Contours (1 ft)

TITLE:	a) Predicted UFA Drawdown Due to Proposed Wellfield, and b) Cumulative UFA Drawdown Due to Permitted and Proposed Wellfields
LOCATION:	Turkey Point, Florida

TETRA TECH

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PROJ	117-2826019	
DATE	05/13/2014	

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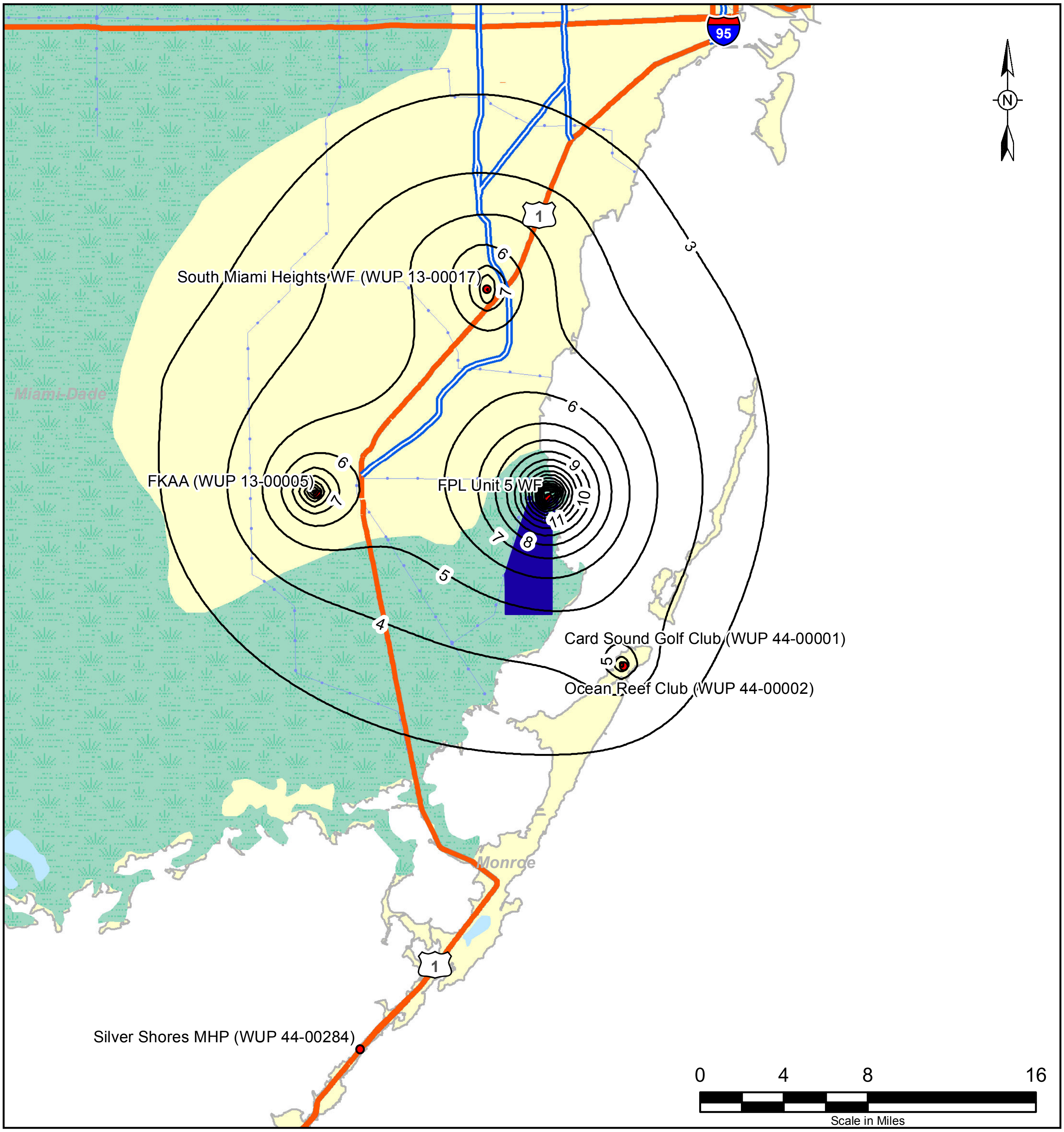

Legend

- Drawdown Contours
- Cooling Canals
- Existing User Wells

TITLE:	Simulated Equilibrium Drawdown in Upper Floridan Aquifer due to Permitted Pumping
LOCATION:	Turkey Point, Florida

TETRA TECH

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PROJ	117-2826019	
DATE	05/13/2014	

APPENDIX C

WATER CONSERVATION PLAN

Water Conservation Plan
Turkey Point Power Plant

The existing Turkey Point Power Plant facility is located near Homestead, Florida. There are currently five operating units at the site. The two existing 400 MW (nominal) fossil fuel fired steam electric generation units have been in service since 1967 (Unit 1) and 1968 (Unit 2). Unit 2 is currently operating in a synchronous condenser mode (to provide voltage support for the transmission system). The two existing 800 MW (nominal) nuclear units have been in service since 1972 (Unit 3) and 1973 (Unit 4). These units use water from the onsite closed loop cooling canal system (CCS). They do not operate under a consumptive use permit, and therefore do not have a formal water conservation plan associated with them. However, all stormwater from these facilities is directed to the CCS for treatment and reuse as cooling water makeup.

Unit 5 has four combustion turbines, four heat recovery steam generators, and a steam turbine creating a "four-on-one" combined cycle unit. Commercial operation started in May 2007. Unit 5 uses a closed-cycle recirculating cooling tower system for heat dissipation. Floridan Aquifer water, obtained from three pumping wells, is used as makeup water for the cooling towers to replace evaporation and blowdown. The heat dissipation system has been designed and constructed to minimize the unnecessary loss of water, including the use of highly efficient mist eliminators in the cooling towers. Blowdown from the cooling towers and other industrial wastewaters, including stormwater from equipment areas, are routed through an oil-water separator and released to the CCS for further treatment and reuse. The wells are designed, constructed, and piped to operate efficiently. Process water for Unit 5 (combustion turbine inlet air evaporative cooling, NOx injection water, power augmentation, and steam cycle make-up) and Units 1 and 2 is supplied from the Floridan Aquifer wells. An in-service leak test of the system was performed during commissioning.

Service water is supplied from the Miami-Dade potable water supply, and the existing Turkey Point facility does not exceed the capacity of the potable water system.

All systems at the Turkey Point Power Plant facility that involve the use of water are designed and commissioned to minimize water losses. This includes an in-service leak test, inspection, or hydrostatic test to ensure the system is leak tight. Other features of the water system design include, when practical:

- Automatic shutoff valves,
- Use of flow restrictors,
- Use of low volume sanitary facilities, and
- Use of low maintenance landscape designs.

After the new wells that are requested by this modification are commissioned, procedures will be in place to ensure that the well systems are inspected on a regular basis and that a repair program is in place to repair leaks in an appropriately timely manner.

The plant will implement an awareness program for operations employees at the time of commercial operation (when construction and testing is complete and FPL begins to operate the unit) which is expected in the second quarter of 2015. The awareness program will educate employees on water conservation methods, techniques and the requirements of In-place construction and operation procedures.

Procedures will be reviewed on an annual basis, with the first review occurring in approximately June 2016, one year after expected commercial operation date. In accordance with South Florida Water Management District (SFWMD) Basis of Review Section 2.4.1, an audit of the amount of water needed in the operational processes will be conducted and submitted to the SFWMD during the second year of operations.

The Water Conservation Plan will be updated as necessary.