FPL.

January 27, 2017

Mr. Wilbur Mayorga, P.E.
Chief, Environmental Monitoring and Restoration Division
Miami-Dade County Department of Regulatory and Economic Resources,
Division of Environmental Resources Management
701 NW 1st Court, 4th Floor
Miami, FL 33136-3912

**RE: Florida Power & Light Company Phase I Remediation Action Plan Submittal**

Dear Mr. Mayorga:

Florida Power & Light Company (FPL) hereby provides you a copy of the Phase I Remediation Action Plan prepared as requested in Paragraph 4 B., of your letter dated September 29, 2016. In addition, attached to this letter please find design drawings and the FDEP UIC injection well permit modification (Permit No. 293962-003-UC/MM) requested under Paragraph 4 A., of your September letter. FPL acknowledges the two groundwater monitoring well clusters and the surface water gauges identified in Paragraph 3a. and d., of the letter in addition to the three additional monitoring well clusters identified in Paragraph 17 d. iv., of the Consent Agreement and would like to discuss these during our meeting on February 8, 2017. Also, during our November 22, 2016 meeting you requested information pertaining to our water use permit application (Application No. 160916-12). All FPL submittals and SFWMD correspondence are available on the District's e-permitting public access website at: http://my.sfwmd.gov/ePermitting/PopulateLOVs.do?flag=1, (enter the application number only and hit the search records prompt).

FPL looks forward to moving forward with the construction and operation of the DERM approved groundwater remediation system as soon as the requisite project permits are issued. Should you have any questions or request additional information, please contact Steve Scroggs at (561) 694-4496 or me at (561) 691-2808 at your convenience.

Sincerely,

Matthew J. Raffenberg
Sr. Director of Environmental Licensing and Permitting

CC: Lee Hefty, MDC DERM
Barbara Brown, MDC DERM
John Truitt, FDEP
Steve Scroggs, FPL
Alan Katz, FPL

Attachments:

- Turkey Point Cooling Canal System Phase I Remediation Action Plan
- UIC extended testing FDEP permits and drawings

# Turkey Point Cooling Canal System
# Phase I Remediation Action Plan

# Turkey Point Cooling Canal System
# Phase I Remediation Action Plan

January 27, 2017

## 1. Introduction

On May 16, 2016, FPL submitted a three-dimensional, variable density dependent transient groundwater flow and transport model (Model) to DERM along with the design and supporting information of a groundwater recovery well system (RWS) in fulfillment of paragraph 17.b. of the October 7, 2015 Consent Agreement (CA) between Miami-Dade County and FPL. On May 23, 2016, June 10, 2016, and July 14, 2016, FPL submitted supplemental information at the request of MDC DERM about the Model and the RWS. On September 29, 2016, MDC DERM provided conditional approval of FPL's groundwater Recovery Well System (RWS). A component of this approval required FPL to submit a Phase I Remedial Action Plan as described in Paragraph 4.B., of the letter.

FPL's responses to the specific elements contained in paragraph 4.B., of the September 29, 2016 letter comprise this Phase I Remedial Action Plan. Since presenting the Model and the proposed groundwater recovery well system in May 2016, FPL has implemented several actions, including construction and operation of the Upper Floridan Aquifer Cooling Canal System (CCS) freshening well system, commencement of the CCS Biscayne aquifer Underground Injection Control extended injection testing program, and filing permit applications for the construction and operation of the RWS and associated monitoring sites. Documentation of FPL's actions in implementing the provisions of the CA is included in the "*Turkey Point Power Plant Consent Agreement 2016 Annual Report*", November, 10, 2016.

As stated in paragraph 1.A., of the September 29, 2016 letter, the MDC technical team identified several areas associated with development of the Model. To date FPL has made several revisions to the Model identified by the MDC technical team. These revisions include 1) implementing a parameter estimation optimization methodology recommended by Miami-Dade County (PEST) to recalibrate the Model, 2) revising the boundary characterization of the Card Sound Canal south of the CCS, 3) revise the L-31E southern boundary characterization, and 4) adding heterogeneous hydraulic parameter layering across the Model domain and re-calibrating the Model again using PEST. These revisions resulted in no substantive changes to the original Model calibration statistics, location and orientation of the hypersaline plume, or predicted plume response to the RWS alternatives. It is FPL's evaluation that the revisions have offered no significant improvement to the Model's predictive responses because they add no new information. This restructuring of existing assumptions in the absence of providing new actual data has not reduced Model uncertainty in the vicinity of the hyper-saline plume. While two site-specific APT and existing lithologic and geophysical data were used in the Model development, in comparison to the size of the model domain there remains a limited amount of site-specific hydrogeologic data along the central and southern portion of the CCS and eastern Model Lands Basin. Improved understanding of the hydrogeology of the plume will be accomplished during the construction and testing of the alternative 3D RWS extraction wells and the three monitor well sites within the Model Lands Basin later this year.

Responses to specific elements in paragraph 4.B. of the September 29, 2016 letter are provided. It is FPL's evaluation that the revisions to the Model have had no significant changes to the Model's predictive responses. Although the revisions may have resulted in a more complex representation of the hydrogeology, the original model was a suitable tool that contributed to the design of the RWS. Consistent with the CA, FPL will improve upon the model as relevant information becomes available.

Improved understanding of the hydrogeology of the plume will be accomplished by the production of new hydrogeologic data resulting from the construction and testing of the alternative 3D RWS extraction wells and the three new monitor well sites within the Model Lands Basin later this year. Construction and operation of the RWS alternative 3D project and associated monitoring wells is necessary for providing new hydrogeologic information capable of reducing the uncertainties inherent in the current version of the Model.

2. **Responses to Paragraph 4B. Phase I Remedial Action Plan**

4B.(i);1A. (ii): The model design shall incorporate significant water features such as quarries as well as significant recreational (e.g. golf courses) and other water users located within the model domain.

**FPL Response: The existing Model addresses land use coverages and consumptive use withdrawals that exist in the area through the calibration period as described in June, 2016 model documentation by TetraTech (provided to MDC RER on June 10, 2016). Agricultural water use and public water supply represent the most significant consumptive uses within the Model domain. There is a single golf course located within the Model domain. Quarries are not explicitly represented in the existing model as they are located several miles west and north of the hypersaline plume (although water use from wells described in the Earthfx Inc., 2012 model are included). As required under the FDEP Consent Order (OGC File No. 16-0241), FPL shall be conducting an evaluation of causal influences on the position and orientation of the saltwater interface in 2018 using the variable density three dimensional groundwater model developed under the MDC CA. In order to complete this evaluation, FPL will be making some revisions to the model to better assess additional factors that could influence the position and orientation of the saltwater interface including impacts of quarries, land use changes, water management/drainage actions, water use withdrawals, sea level rise, and the CCS operations. Explicit representation of quarries and the golf course withdrawals/recharge will be added to the model under this effort.**

4B.(i);1A. (iii): Given the aquifer heterogeneity described in various local and regional studies relating to the Biscayne aquifer in Miami-Dade County, the assumption of aquifer homogeneity with respect to hydraulic parameters across the model domain shall be reevaluated. Available data (e.g. data from the WASD's Newton and Everglades Labor Camp wellfields (copies attached) and the Florida Keys Aqueduct Authority's wellfield) shall be utilized to evaluate and refine assumptions regarding hydraulic parameters within the Model domain.

**FPL Response: FPL conducted an evaluation of lithologic and geophysical data from the deep pilot core bore collected at each of the 14 original 2009 Uprate Monitoring well network sites in order to provide estimates of hydraulic conductivity values and ranges for each of the 11 model layers. These estimated values were regionalized within each model layer via a kriging algorithm and then the model was calibrated using the PEST parameter optimization method as described in Attachment 1. Available data from the Newton and the Everglades Labor Camp (ELC) wellfields were considered however, the values reported for the ELC and FKAA wellfields were composite transmissivity values (11,600,000 and 14,900,000 gpd/ft respectively). Assuming the aquifer is approximately 60 feet thick in the region and not accounting for partial penetration issues, estimated composite hydraulic conductivity values of 26,000 and 33,000 ft/day are calculated. The average horizontal hydraulic conductivity values for model layer 4 (6,398 ft/day) and layer 8 (37,435 ft/day) from the regionalized variable K model calibrated model compare favorably with the reported values for the ELC/FKAA wellfields. As described above, additional model revisions associated with the evaluation of causal influences on the position and orientation of the saltwater interface may further refine the hydraulic conductivity values in the western region of the model domain.**

4B.(i);1A. (iv): Until the SWR package referenced in item 1A above is incorporated into the model, the model simulations using the river package shall properly account for the construction of the L-31E Canal specifically the discontinuity between the northern and southern portions of the canal at the canal's intersection with the Florida City Canal.

**FPL Response: The Model is configured to reflect the L-31E Canal is discontinuous at Palm Drive.**

4B.(i);1A. (v): Re-evaluate the model representation of net recharge, especially during the dry seasons, to properly account for evaporative losses.

**FPL Response: It is recognized that there are a variety of non-unique methods that can be used to estimate recharge and evaporation in the Model, the approached used by FPL is one such accepted method. No information was provided that the approach used by FPL to represent recharge and evaporation was inconsistent with accepted modeling methods or is otherwise incorrect. Compelling technical data is needed in order to support further investment into alternative recharge and evaporation changes and associated model recalibration.**

4B.(i);1A. (vi): Until the SWR package is incorporated into the model, given that the Card Sound Canal is simulated as a drain, address how the model accounts for the canals contribution to the movement of the saltwater interface.

**FPL Response: Revisions to the boundary conditions representing the L-31E Canal south of the S-20 structure and the Card Sound Canal have been completed and are described in Attachment 2. While changes to the boundary conditions in these areas from drains to rivers were made (such that these boundaries can discharge to the aquifer), comparison of Model results show no significant differences in the calibration statistics, location and orientation of the hypersaline plume, or response of the RWS alternative 3D in retracting the plume.**

4B.(i);1B.: In addition to the above the model reevaluation shall incorporate the applicable comments provided by the South Florida Water Management District (SFWMD) during the groundwater modeling review meeting held at the DERM office on July 21, 2016, along with the comments provided by the Florida Keys Aqueduct Authority, included as an attachment to this correspondence.

**FPL Response: Comments provided by the South Florida Water Management District during the groundwater modeling review meeting held at the DERM office on July 21, 2016 have been addressed and documented in a technical memorandum included as Attachment 2. This technical memorandum along with the revised model data sets were provided to the South Florida Water Management District on September 9, 2016 as part of the FPL RWS consumptive use permit application process. While changes to the boundary conditions in these areas were made as recommended, comparison of Model results show no significant differences in the calibration statistics, location and orientation of the hypersaline plume, or response of the RWS alternative 3D in retracting the plume. FPL has also reviewed the comments provided by the Florida Keys Aqueduct Authority and has responded to their comments which is included as Attachment 3 of this report.**

4B.(i) last sentence: In addition, the model shall demonstrate that pursuant to Section 28-48 and Section 24-48.3 of the Code of Miami-Dade County, Florida and paragraph 17.b.i of the CA, that the proposed groundwater recovery system will not create potential adverse environmental impacts on the surrounding wetland areas (hydroperiod or water stage).

**FPL Response: Drawdowns associated with recovery well system Alternative 3D in layer one (wetlands) of the PEST calibrated model with the SFWMD recommended boundary changes are shown on Figure 2 of the TetraTech technical memorandum entitled *"Addendum to Regional Biscayne Aquifer Groundwater Model Report Incorporating Comments from SFWMD"* (Attachment 2). Drawdowns beneath wetlands are less than 0.3 feet. The Model Lands wetlands within the drawdown influence of Alt 3D are predominantly seasonally inundated emergent marshes which are categorized as Category 2 wetlands in the *"Applicants Handbook for Water Use Permit Applications (09/07/2015)"* by the SFWMD. Numeric criteria for Category 2 wetlands in SFWMD water use permit rules state that drawdowns less than one foot beneath wetlands are not considered harmful. Drawdowns resulting from withdrawals associated with Alt 3D are much less than one foot and are therefore considered not to create potential adverse environmental impacts to surrounding wetlands.**

4B.(ii): Copies of any permit, approval, or letter of no objection from SFWMD, Florida Department of Environmental Protection (FDEP) or any other regulatory agency with jurisdiction over the activities related to the design, construction, or operation of any component of the groundwater recovery system.

**FPL Response: On September 15, 2016 FPL filed applications with the USACOE, FDEP, and MDC for impacts to wetlands associated with the RWS extraction well pads, piping lay down, and monitoring well pads. On November 9, 2016 these applications were modified by FPL as a result of RWS well and piping design changes which eliminated impacts to wetlands. Minor impacts associated with two monitoring site well clusters required by Miami-Dade County located within the Model Lands Basin (amounting to 0.006 acres of impact) were unavoidable. On December 19, 2016 FDEP issued Environmental Resource Permit No. 13-0127512-014-EI for wetland impacts associated with the monitor websites TPGW-18 and 19 (copy attached). Applications with the USACOE and MDC DERM remain currently under review.**

**FPL also filed applications for consumptive use and right-of-way permits with the SFWMD. The right-of-way permit application was modified by FPL on November 9, 2016 to realign the piping route along Palm Drive instead of the originally proposed L-31E Levee route which significantly reduced the impacts to the L-31 levee right-of-way and wetlands. The revised piping crossing of the L-31E levee and the associated USACOE 408 authorization are currently under review. The consumptive use application has been deemed complete and the proposed agency action is due by February 15, 2017. Copies of applications and associated data submittals are included in Attachment 5**

4B. (iii): Design details and construction plans of the proposed groundwater recovery system which incorporates the revised groundwater model required in 4B.(i) above and which includes:

a. recovery well construction details
b. recovery well spacing and location was supporting justification
c. flow rate per recovery well
d. pump specifications and supporting calculations, ancillary equipment, etc.
e. piping specifications and layout

**FPL Response: As stated above, revisions to the Model resulted in little appreciable changes to the original calibration statistics, location and orientation of the hypersaline plume, or predicted plume response to the RWS alternatives. Accordingly, there are no significant changes to the July 2016 Alternative 3D design (summarized below). Final detailed designs and construction plans of the proposed groundwater recovery system and the associated monitoring wells will be informed by the issuance of all permits, completion of the analysis of pilot wells bores and engineering design and analysis. Based on our current best available information, the following project design details are provided:**

**Recovery well construction details:**

- **Well depth; base of the Biscayne aquifer (approximately -90 feet to - 120 feet NAVD),**
- **Casing depth; open to lower high flow zone of the Biscayne aquifer (approximately -70 to - 90 feet NAVD)**
- **Well diameter; 24 inches ID**
- **Well completion; open hole**
- **Casing material; PVC**
- **Flow rate; ~ 1,040 GPM per well, 15 MGD total wellfield extraction rate**
- **Pump and piping specifications to be determined by engineering after permits and site data collection are completed.**

**Recovery well location and spacing:**


RWS Well #1
TPGW-19 S,M,D
RWS Well #3
RWS Well #2
RWS Well #4
TPGW-18 S,M,D
Deep Injection Well
RWS Well #5
RWS Well #6
RWS Well #7
TPGW-22M
RWS Well #8
TPGW-17 S,M,D
RWS Well #9
RWS Well #10
Google earth

| | RWS-1 | RWS-2 | RWS-3 | RWS-4 | RWS-5 |
|---|---|---|---|---|---|
| Latitude | 25.445980° | 25.438010° | 25.434370° | 25.422930° | 25.410480° |
| Longitude | -80.352370° | -80.345650° | -80.351340° | -80.354040° | -80.358470° |
| Spacing to next RWS well | 3,650 feet | 2,300 feet | 4,230 feet | 4,740 feet | 4,590 feet |

| | RWS-6 | RWS-7 | RWS-8 | RWS-9 | RWS-10 |
|---|---|---|---|---|---|
| Latitude | 25.398460° | 25.387920° | 25.377250° | 25.368390° | 25.359392° |
| Longitude | -80.362770° | -80.366530° | -80.367530° | -80.367540° | -80.367600° |
| Spacing | 4,580 feet | 4,020 feet | 3,890 feet | 3,200 feet | 3,275 feet |

**The locations of the RWS extraction wells were determined based on consideration of several factors including the authorized capacity of the existing underground injection well DW-1 (UIC permit number), minimizing the potential for adverse impacts to wetlands, and the ability of the extraction wells to collectively intercept, capture contain and retract hypersaline groundwater within the Biscayne aquifer west and north of the CCS as demonstrated by the MDC approved (September 29, 2016 letter from Wilbur Mayorga) variable density dependent groundwater model.**

# Attachment 1

## Biscayne Aquifer Groundwater Flow and Transport Model: Heterogeneous Hydraulic Conductivity Analyses, January 2017

### (Text and Tables)

# Biscayne Aquifer Groundwater Flow and Transport Model: Heterogeneous Hydraulic Conductivity Analyses

## Introduction

Florida Power & Light (FPL) and its consultant, Tetra Tech, conceptualized, constructed, and calibrated a variable density groundwater flow and salt transport model of the Biscayne Aquifer in the vicinity of the Turkey Point Power Plant and its Cooling Canal System (CCS). The purpose of this model, presented to Miami Dade County (MDC) Department of Environmental Resource Management (DERM), South Florida Water Management District (SFWMD), and Florida Department of Environmental Protection in May 2016 (Tetra Tech, 2016a), and July 2016 (Tetra Tech, 2016b), is to support the design of the RWS to intercept, capture, and contain the hypersaline plume north and west of the CCS; support authorization through the appropriate regulatory processes; and demonstrate that the RWS will not create adverse impacts to groundwater, wetlands or other environmental resources.

Upon review of the groundwater flow and transport model, MDC and SFWMD recommended certain revisions to the model, including changes to the representation of the L-31E and Card Sound Canal boundary conditions and the representation of variable hydraulic conductivities in key hydrogeologic formations (in lieu of uniform hydraulic conductivity). FPL revised the boundary conditions, with no marked impact on the quality of the model calibration or the simulated effectiveness of selected RWS Alternative 3D, as documented in an attached addendum to the July 2016 technical memorandum (Tetra Tech, 2016b). These boundary revisions are employed herein along with more recent revisions to the model's hydraulic conductivity distributions.

Paragraph 17.b.i. of the October 7, 2015 Consent Agreement (CA) between MDC DERM and FPL required FPL to develop a variable density dependent groundwater model, which was to be informed by an Aquifer Performance Test (APT) conducted at the site (Enercon, 2016) within 180 days of execution of the CA. In developing the model, FPL utilized uniform hydraulic parameters for each model layer which were derived from parameters derived by the APT. The assumption of uniform hydraulic conductivities was later questioned by the MDC, and FPL was required to re-calibrate the model using heterogeneous hydraulic conductivities. This memorandum describes FPL's efforts to address MDC's comments regarding heterogeneous hydraulic conductivity and the associated PEST-based calibration of the model with heterogeneity reflected in key hydrogeologic formations. Multiple calibration efforts were made and are summarized herein, along with assessments of calibration quality and predictive simulation results.

# Calibration Overview

## Heterogeneous Hydraulic Conductivity Definition

In order to establish smoothly varying heterogeneous hydraulic conductivities in individual layers of the numerical flow model, values of this flow parameter are defined at a number of discrete locations (called pilot points) throughout the model layer. Then, based on an estimate of spatial continuity of hydraulic conductivity values, as defined by a semivariogram, the hydraulic conductivities at these discrete locations are spatially interpolated throughout the model layer via kriging, a geostatistical tool.

Heterogeneous hydraulic conductivities were defined in the shallow (model layer 4) and deep (model layer 8) high flow zones, as well as the deepest portion of the model beneath the lower high flow zone (layers 9, 10, 11), for a total of 5 layers with heterogeneous hydraulic conductivities. The high flow zones were selected for the definition of heterogeneity due to the perceived spatial discontinuities in high permeability materials north and west of the CCS. Heterogeneous hydraulic conductivities were defined in the deepest model layers in an effort to improve the match to CSEM survey-based groundwater salt concentrations.

Pilot points are predominantly coincident with the locations of TPGW monitoring wells (TPGW-1 through TPGW-14) that were installed as a part of the Extended Power Uprate monitoring program. As **Figure 1** illustrates, this monitoring network provides a good spatial distribution of locations to represent heterogeneity in hydraulic conductivity throughout the Biscayne Aquifer where hypersaline groundwater is primarily located. Two additional pilot point locations ("Added-1" and "Added-2") were specified immediately west and north of the CCS (**Figure 1**) in order to provide better opportunity to vary hydraulic conductivity, were it necessary for improved calibration quality. Initially, the values at pilot point locations were defined based on interpretation of TPGW well cores by JLA Geosciences (JLA Geosciences, 2016). The hydraulic conductivity values at the two added locations were initially estimated by averaging the hydraulic conductivity estimates from the two closest TPGW monitoring wells. Throughout the course of calibration, the hydraulic conductivity values at the 16 discrete locations were iteratively adjusted and re-interpolated in an effort to reduce model error with respect to groundwater levels and salt concentrations. A model was constructed and simulated using the original estimated hydraulic conductivities provided by JLA Geosciences. The results of this model (referred to as HHC-JLA) are discussed in the following section of this memorandum.

The initial (pre-calibration) hydraulic conductivities at the 14 TPGW well locations were provided by JLA Geosciences after an evaluation of core photographs, lithologic logs, and supporting data (e.g. digital borehole images and acoustic borehole images) collected during the installation of the TPGW wells (JLA Geosciences, 2010). For each layer of the numerical model at a TPGW well location, JLA Geosciences first interpreted the geologic material identified in the core within the layer's vertical thickness. Then, using professional judgment, a geologist estimated the hydraulic conductivities of those materials, and calculated a weighted average hydraulic conductivity based on the thicknesses of the materials within the model layer's vertical profile. This was repeated for each model layer at each TPGW well location. No aquifer testing test was available or developed as a part of this task.

It is important to note that, while more pilot points could have been specified, the configuration discussed above (16 pilot points defined in each of five layers) introduced 80 new adjustable model parameters into the calibration, more than quadrupling the number of parameters in the July 2016 calibration. With model run times varying between 6 and 10 hours, the inclusion of these parameters extends the duration of a single PEST-based calibration (throughout which significant reductions in overall model error are achieved) to between two and three weeks.

Three separate PEST-based calibration efforts were conducted. In each of these calibrations, the pilot point horizontal hydraulic conductivities (in high flow zones and deep model layers), the uniform hydraulic conductivities of other layers, vertical hydraulic conductivities, and the CCS canal boundary condition conductance were iteratively adjusted. Additionally, layer-wide porosities and dispersivity were adjusted. Note that the CCS conductance decreases late in the calibration model's simulation timeframe in order to reflect siltation that is believed to have decreased both the conductance of the CCS canal beds and the thermal efficiency of the CCS. Several cores collected in the CCS bottom sediments are evidence of such siltation. Additionally, the reduction in conductance due to siltation is apparent in the observed salinities directly below the CCS (TPGW-13S and TPGW-13D. The factor by which the conductance decreases late in the simulated timeframe is an adjustable parameter in these analyses; the conductance reduction factor was adjusted from 21 down to approximately 16 in the course of this calibration analysis.

Each of the three calibration analyses was designed using insight gained from earlier calibration exercises, such that refinements were made to adjustable model parameters, initial model parameter values, and calibration target weights from one calibration exercise to the next. For example, horizontal-to-vertical hydraulic conductivity ratios (not vertical hydraulic conductivity) for all model layers (uniform in each layer) were adjusted in the first two calibrations. This meant that in model layers with heterogeneous horizontal hydraulic conductivities, the vertical hydraulic conductivity would also be heterogenous, since vertical hydraulic conductivity is the product of the horizontal hydraulic conductivity and the anisotropy factor. However, based on insight gained during the second calibration analysis, the third calibration analysis, vertical hydraulic conductivity was adjusted independent from the horizontal hydraulic conductivity. This is discussed later in this technical memorandum.

The three separate calibration analyses conducted as a part of this effort, along with associated relevant results, are discussed below.

## Model Calibration Analyses

### First Calibration (HHC-V1 Model)

#### *First Calibration Setup*

As mentioned above, the first set of pre-calibration horizontal hydraulic conductivities were provided by JLA Geosciences, based on a review of geologic and geophysical data from the construction of the TPGW monitoring wells. Inspection of **Table 1** reveals that in nearly all of the key model layers these values of horizontal hydraulic conductivity at TPGW well locations were considerably greater than the existing calibrated values presented to MDC and SFWMD in July 2016 (Tetra Tech, 2016b). This is particularly evident in layers 9 through 11, where the uniform calibrated value of hydraulic conductivity (389 ft/day) is less than nearly all of the core-based estimated hydraulic conductivities by at least an order of magnitude. The relatively low calibrated horizontal hydraulic conductivity in the July 2016 model was necessary in order to limit the westward extent of hypersaline water in the deepest model layers. Nevertheless, the July 2016 calibrated flow and transport model still over-simulated the westward extent of hypersaline water in the deepest model layers. This over-simulation was one of the motivations the calibration analyses described in this memorandum.

The first heterogeneous hydraulic conductivity PEST-based calibration (denoted herein as HHC-V1) began with a simulation of a model using the JLA estimates of hydraulic conductivity (HHC-JLA), results of which are discussed below. The calibration required over 500 model runs and 5 iterations, during which the model error reduced. By the fifth iteration, reductions in model error had begun to plateau and continued calibration beyond the fifth iteration was believed to produce diminishing returns in terms of calibration quality.

### *First Calibration Results*

**Table 2** summarizes the normalized mean absolute errors for the different categories of calibration targets for the initial model (JLA-estimated hydraulic conductivities, HHC-JLA), HHC-V1, and the July 2016 calibrated model. Note that a target normalized mean absolute error of less than 10% is often used as a criteria for a calibrated model. In this memorandum, the July 2016 calibrated model refers to that which includes the revisions to certain boundary conditions as documented in the addendum to the July 2016 memorandum (Tetra Tech, 2016c). The statistics summarized in **Table 2** illustrate that, though the significant errors associated with the pre-calibration model (HHC-JLA) were reduced in the HHC-V1 model, the July 2016 calibrated model is a generally better calibrated model, particularly with respect to the match to CSEM survey-based data (salt concentrations measured via a CSEM survey in January 2016). Reductions in model error were achieved by generally reducing the magnitude of horizontal hydraulic conductivities. However, the extent of these reductions was not sufficient to eliminate the model's over-simulation of saline and hypersaline conditions in the Biscayne Aquifer. The variably accurate match to CSEM survey salt concentrations for the July 2016, HHC-JLA, and HHC-V1 models are shown in **Figure 2**. Comparison of the July 2016 model results to the models associated with HHC-V1 elucidates the general over-simulation in both the HHC-JLA and HHC-V1 models. The simulated breakthrough of the saltwater wedge at the shallow and deep depths of wells G-21 and G-28 (**Figure 3**) also illustrate the general over-simulation of groundwater salt concentrations in HHC-V1. Essentially, the HHC-V1 model-simulated saltwater and hypersaline water moving westward at a significantly greater-than-observed rate.

Upon conclusion of the fifth iteration, the PEST-based calibration was terminated, and a new approach to calibration with heterogeneous hydraulic conductivities was designed, set up, and conducted. This second calibration analysis, described below, endeavored to initialize the PEST-based calibration procedure with better calibrated model parameter values than those with which the first calibration analysis was initialized. The purpose of better initializing the second calibration was to start the calibration with a more accurate simulated representation of the saline and hypersaline salt concentrations in the Biscayne Aquifer in an effort to focus the calibration process on refining these already-reasonable model results.

## Second Calibration (HHC-V2 Model)

### *Second Calibration Setup*

As described in the July 2016 modeling memorandum, automated calibration with PEST is an optimization-based procedure wherein reductions in model error are iteratively reduced by adjusting the values of sensitive model parameters. This process can be viewed as a multi-dimensional solution surface defined by the independent variables (adjustable model parameters) and the dependent variable (model error). The optimization-based calibration process endeavors to locate the area of the solution surface where the model error is the lowest (the globally minimum error); the associated set of model parameter values constitutes the best calibrated model. In calibrations where the initial (pre-calibration) model result is located on the solution surface significantly distant from the globally minimum error, it can be very difficult and/or time-consuming for the optimization to identify the globally minimum error.

Based on a review of the error statistics in **Table 2** and simulation results in **Figures 2 and 3**, FPL and Tetra Tech believed that:

1) The first heterogeneous hydraulic conductivity calibration, described above, would not improve upon the July 2016 model without significant time and effort;
2) The difficulty in achieving an improved model was likely attributable to the values of the pilot point hydraulic conductivities (core-based estimates) in the HHC-JLA model. It is recognized that the pilot point values were estimates from visual inspections of cores and geophysical logs and accordingly are subject to a degree of uncertainty; and
3) Calibration targets associated with the salt breakthrough at wells G-21 and G-28, as well as the CSEM survey-based salt concentration targets (particularly in deeper portions of the aquifer) should be emphasized by attributing those targets greater weight in the calculation of overall model error.

In order to improve upon the first calibration effort, FPL and Tetra Tech recognized that a more efficient calibration, that would potentially improve upon the July 2016 model, should initialize pre-calibration pilot point hydraulic conductivities for model layers 4, 8, and 9 to 11 to the calibrated values in the July 2016 model (Tetra Tech, 2016b).

Hence, this second calibration attempt was initialized to aquifer properties consistent with the July 2016 calibrated model and also employed the pilot point methodology to facilitate the definition of heterogeneous hydraulic conductivity in model layers 4, 8, and 9 to 11. In addition, calibration target weights were revised from the first calibration attempt, described above, in order to elevate the importance of matching 1) the saltwater breakthrough at wells G-21 and G-28, and 2) the orientation of saline and hypersaline water in deep model layers (as define by the CSEM survey). The changes to the weights attributed to these calibration targets from the first calibration attempt to the second calibration attempt are summarized in **Table 3**.

The second heterogeneous hydraulic conductivity calibration analysis (HHC-V2) was terminated after three iterations and over 300 model simulations due to diminishing reductions in overall model error by the last iteration. The same parameters that were adjusted in the first calibration attempt (above) were adjusted in this calibration analysis (uniform hydraulic conductivities, pilot point hydraulic conductivities, vertical hydraulic conductivity anisotropies, CCS canal bed conductance, dispersivity, and aquifer porosities).

### *Second Calibration Results*

The adjustments made to the horizontal hydraulic conductivities (both uniform values and pilot point values) to produce the HHC-V2 calibrated model are summarized in **Table 4**. On average, the pilot point hydraulic conductivity values did not vary significantly from the uniform pre-calibration values in the five model layers that were now represented as having heterogeneous hydraulic conductivity distributions:

- Upper High Flow Zone (Layer 4) – Average pilot point horizontal hydraulic conductivity value calibrated from 6030 ft/day to 6398 ft/day
- Lower High Flow Zone (Layer 8) – Average pilot point horizontal hydraulic conductivity value calibrated from 35980 ft/day to 37435 ft/day
- Deeper Model Layers (Layer 9) – Average pilot point horizontal hydraulic conductivity value calibrated from 389 ft/day to 397 ft/day
- Deeper Model Layers (Layer 10) – Average pilot point horizontal hydraulic conductivity value calibrated from 389 ft/day to 410 ft/day
- Deeper Model Layers (Layer 11) – Average pilot point horizontal hydraulic conductivity value calibrated from 389 ft/day to 362 ft/day

However, inspection of **Table 4** shows that, while the *average* pilot point values did not change significantly (which gives credence to the July 2016 calibrated hydraulic conductivities), there is notable variability in hydraulic conductivity value across the pilot points in each layer. This is particularly true in the high flow zones. For instance, hydraulic conductivity varies from approximately 14,000 ft/day to 100,000 ft/d in the lower high flow zone. This variability in hydraulic conductivity values is illustrated in **Figures 4 through 8** for layers 4, 8, and 9 to 11. Whereas layer 4 is relatively conductive, the greatest horizontal hydraulic conductivities are located west of the CCS, with lower hydraulic conductivities north and southwest of the CCS. Likewise, layer 8 is highly conductive, and most conductive west of the CCS. While layers 9 through 11 are less conductive than other layers, relatively low hydraulic conductivities north of the CCS are evident in the calibration model and imply an effort to curb the model's over-simulation of salt concentrations north and northwest of the CCS in the deeper portions of the groundwater flow model.

**Table 5** summarizes the normalized mean absolute errors for the different categories of calibration targets for the initial model and calibrated HHC-V2 model. Note that since the initial model is the same as the July 2016 model (with uniformly valued pilot point hydraulic conductivities), its error statistics are the same as those presented in **Table 2** for the July 2016 model. Errors associated with water level targets were only marginally improved over the course of this second calibration analysis, whereas errors in the simulation of salt concentrations improved. This is most evident in the match to CSEM targets, which improved in all individual CSEM categories (e.g. Layers 5 to 7) and the overall match to CSEM data. Improvement in the match to salt concentration targets is further elucidated in the simulated match to the saltwater breakthrough at wells G-21 and G-28 (**Figure 9**), where the HHC-V2 model better matches the observed saltwater breakthrough at most of the well screens. Additionally, comparison of the observed versus simulated CSEM survey salt concentration data for the initial and HHC-V2 models (**Figure 10**) shows that for most of the model layers, the density of the data clusters moves closer to the 45° line of perfect match. This is particularly evident for layers 4 to 8 and, to a lesser degree, layers 9 to 11.

While this second calibration analysis improved the calibration quality of the model, there appeared some clear areas that warranted improvement, namely the match to deeper model layers' salt concentration data. In an effort to reconcile this match, FPL and Tetra Tech configured and conducted a third calibration analysis that revised 1) the manner in which vertical hydraulic conductivity was conceptualized and calibrated, and 2) the weighting of calibration targets to add greater import to salt concentration targets in the bottommost portions of the Biscayne Aquifer.

## Third Calibration (HHC-V3 Model)

### *Third Calibration Setup*

The third and final calibration analysis with heterogeneous hydraulic conductivities refined the second calibration analysis in three key ways:

1) CSEM survey-based salt concentrations target weights in the deeper model layers were increased relative to the second calibration (**Table 3**);
2) Vertical hydraulic conductivities were decoupled from horizontal hydraulic conductivities by eliminating the anisotropy factor and adjusting vertical conductivities for all layers independent from the horizontal conductivities;
3) A pilot point-based methodology to vertical hydraulic conductivity calibration in model layers 9 through 11 was employed, using a subset of pilot point locations (TPGW-1, -4, -5, -6, -12, -13); modelers determined that simulated results would be insensitive to heterogeneity in the high flow zones (layers 4 and 8).

Vertical hydraulic conductivity was adjusted independent from the horizontal hydraulic conductivity in the following manner:

- Uniform (layer-wide) vertical hydraulic conductivities were calibrated in layers with uniform (layer-wide) horizontal hydraulic conductivities (i.e. model layers 1 to 3 and 5 to 7);
- Heterogeneous, pilot point-based vertical hydraulic conductivities were adjusted independent from the heterogeneous horizontal hydraulic conductivities in the deep model layers (i.e. model layers 9 to 11) using vertical hydraulic conductivity pilot points located coincident with a subset of the TPGW monitoring wells (i.e. TPGW-1, -4, -5, -6, -12, -13); and
- Uniform vertical hydraulic conductivities were defined for the high flow zones (i.e. model layers 4 and 8).

The latter revision introduced a total of 18 additional adjustable parameters to the calibration, which would notably increase calibration timeframes. However, based on calibration results to date, and in an effort to mitigate the added calibration times, the pilot point horizontal hydraulic conductivities in layer 4 were fixed at their second calibration values and unchanged during the third calibration. Thus, a net of two model parameters were added to the calibration analysis. As in the case of the prior calibration, the HHC-V3 calibration analysis was terminated after three iterations and over 300 model simulations due to diminishing reductions in overall model error by the last iteration.

### *Third Calibration Results*

The calibrated horizontal hydraulic conductivities (uniform layer values and pilot points) for the pre-calibration and HHC-V3 models are provided in **Table 6**, where it is evident that values were not significantly adjusted during the third calibration. The heterogeneous hydraulic conductivity fields for Layers 4, 8, and 9 to 11 are illustrated in **Figures 11 to 15**. The heterogeneities illustrated in these figures are slightly different than those shown for the HHC-V2 model (**Figures 4 to 8**), though the general model-wide variability is consistent between both calibrated models. As in the case of horizontal hydraulic conductivities, the values of vertical hydraulic conductivity varied only slightly over the course of the calibration (**Table 7**); the heterogeneous vertical hydraulic conductivity for layers 9, 10, and 11 are illustrated in **Figures 16 through 18**.

Over the course of the three iterations of this calibration, the overall model error decreased, such that the overall HHC-V3 model error is lower than that of the July 2016 model. During this third calibration the normalized absolute mean error decreased for both the water level and salt concentration targets between 1972 and 2015 (**Table 8**). Plots of observed versus simulated water levels and relative salt concentrations in **Figures 19 and 20**, respectively, illustrate the overall good match to those observed conditions. The simulated breakthrough of saltwater at wells G-21 and G-28 was not impacted by this third calibration effort, and is nearly identical to those shown for the HHC-V2 model.

Overall, the match to the CSEM survey-based concentrations degraded slightly (**Table 8**), due to slight increases in error associated with salt concentrations in layers 1 to 4, 8, and 9. However, reductions in error associated with CSEM survey-based salt concentration targets in Layers 5 to 7 and, most notably, Layers 10 and 11, are relatively significant. Inspection of the plots in **Figure 21** illustrates this improvement in the match to the deeper model salt concentrations, as the cloud of green data points becomes more densely located about the line of perfect match over the course of calibration. Though there still remain some key elements of the HHC-V3 that warrant improvement, as a result of the overall and targeted improvements in the model simulation, this is deemed the best calibrated version of the Biscayne Aquifer Groundwater Flow and Transport Model to date.

## Model Predictions

Simulations of RWS alternative 3D were made using the HHC-V3 model. The simulated effectiveness of this RWS alternative in retracting hypersaline water from areas west of the CCS in the deepest portions of the groundwater flow model (model layers 8 to 11) are of particular interest and have been a motivation for reducing model errors through continued calibration analyses and model enhancements.

**Figures 22 through 25** compare the retraction of saline and hypersaline groundwater in model layers 8 through 11 due to RWS alternative 3D over a 10-year period as simulated by the HHC-V3 model and that simulated by the July 2016 model. In each of these figures, the left panels illustrate the 10-year changes in groundwater salt concentrations simulated by the July 2016 model, and the right panels simulate results for the HHC-V3 model. The color flood represents varying relative saltwater concentrations, and the hypersaline interface is defined by the rounded black contour that surrounds the CCS. In each of the layers, the initial conditions (top row) are generally different between the two models, due to the different calibrated aquifer conditions and representation of hydraulic conductivity. Conversely, the 10-year location of the hypersaline interface is similarly simulated by both models, with one key exception. Both models simulate retraction in layers 8 and 9, and no retraction in layer 11; however, unlike the July 2016 model (which does not simulate retraction of the hypersaline interface in layer 10), the HHC-V3 model simulates slight retraction of the interface northwest of the CCS in layer 10. The relevance of this change is discussed in the Conclusions below.

## Conclusions

In response to a request by MDC DERM and SFWMD, FPL and Tetra Tech conducted a rigorous and increasingly informed calibration of the Biscayne Aquifer Groundwater Flow and Transport model, wherein a heterogeneous representation of hydraulic conductivity was incorporated into the model's high flow zones and deepest model layers. The calibration analyses described herein ultimately produced a model that improves upon the July 2016 model in a number of ways:

- The representation of hydraulic conductivity as a spatially varying aquifer parameter is more realistic than uniformly specified layer-wide hydraulic conductivity
- Overall model error statistics are lower;
- The simulation of historical water levels and salt concentrations is more accurate;
- Normalized absolute mean error for water levels and salt concentrations (1972 to 2015) are well below the 10% threshold used to distinguish a calibrated model;
- The match to CSEM survey-based concentrations is notably improved, as the normalized absolute mean errors for seven layers, as well as the aggregate model, now fall at or below the 10% threshold;
- The match to deep aquifer CSEM salt data is significantly improved; and
- The simulation of RWS alternative 3D now shows some retraction in layer 10, whereas the July 2016 model simulation did not.

The final improvement listed above is a small, yet important, revision to the simulation of RWS alternative 3D, as it demonstrates some success in retracting the hypersaline interface in the deep layers of the model. This improvement is likely attributable to the more appropriate heterogeneous representation of hydraulic conductivity in the deep model layers and the better calibration quality of the model.

It is important to note that, while some improvements were made based on estimated values of aquifer characteristics from the 2010 monitoring network pilot wells, these locations are regional and not well aligned with the location of the hypersaline plume in many cases. It is anticipated that further improvements to the model performance in retracting the plume will be informed by the data collection associated with the construction of the RWS extraction wells themselves as wells as the three monitoring well sites in the Model Lands (to be installed per the conditions of the CA).

While this calibrated model marks a step forward in the simulation of Biscayne Aquifer hydrologic and water quality conditions, there remain facets of the model that warrant refinement. Among these include the simulation of the deep aquifer salt concentrations and the simulated location of the hypersaline interface. It is anticipated that the incorporation of additional hydrogeological and observational data in the calibration process and an increased robustness and realistic representation of aquifer parameters throughout the entire model (rather than in a limited number of layers) may be two of the keys to producing a more accurate simulation of aquifer water quality and the effectiveness of RWS alternative 3D.

# References

JLA Geosciences, 2010, Geology & Hydrogeology Report for FPL, Turkey Point Plant Groundwater, Surface Water, & Ecological Monitoring Plan, FPL, Turkey Point Plant, Homestead, Florida. Prepared for Florida Power and Light Company, October 2010.

JLA Geosciences, 2016, Summary of Hydraulic Conductivity Estimation, Technical Memorandum provided to Florida Power & Light, August 16, 2016.

Tetra Tech, 2016a, A Groundwater Flow and Salt Transport Model of the Biscayne Aquifer, Technical Memorandum provided to Florida Power & Light, June 10, 2016.

Tetra Tech, 2016b, Application of Parameter Estimation Techniques to Simulation of Remedial Alternatives at the FPL Turkey Point Cooling Canal System, Technical Memorandum provided to Florida Power & Light, July 14, 2016.

Tetra Tech, 2016c, Addendum to Regional Biscayne Aquifer Model Report (Tetra Tech, 2016), Technical Memorandum provided to Florida Power & Light, October 12, 2016.

Table 1. Horizontal hydraulic conductivity values (in feet per day) derived from TPGW well geologic assessment (JLA Geosciences, 2016)

| Well Name | Upper High Flow Zone – Layer 4 | Lower High Flow Zone – Layer 8 | Deep Model Layers – Layer 9 | Deep Model Layers – Layer 10 | Deep Model Layers – Layer 11 |
|---|---|---|---|---|---|
| TPGW-1 | 2500 | 55000 | 13240 | 430 | 3160 |
| TPGW-2 | 62160 | 39520 | 45860 | 31770 | 46500 |
| TPGW-3 | 45810 | 480 | 31270 | 44130 | 24020 |
| TPGW-4 | 4270 | 78400 | 12910 | 4350 | 2460 |
| TPGW-5 | 49120 | 6230 | 54720 | 30280 | 8670 |
| TPGW-6 | 26800 | 380 | 38350 | 33550 | 4890 |
| TPGW-7 | 68280 | 7230 | 6130 | 15900 | 5000 |
| TPGW-8 | 14830 | 340 | 5090 | 4440 | 5570 |
| TPGW-9 | 16470 | 660 | 8430 | 29570 | 25650 |
| TPGW-10 | 6060 | 9100 | 7510 | 7350 | 2880 |
| TPGW-11 | 44330 | 6870 | 10320 | 20100 | 35070 |
| TPGW-12 | 48420 | 2510 | 11150 | 5290 | 4120 |
| TPGW-13 | 8530 | 10370 | 16660 | 12700 | 19590 |
| TPGW-14 | 12730 | 6010 | 4620 | 4050 | 5950 |
| July 2016 Calibrated Value | 6030 | 35980 | 389 | 389 | 389 |

Table 2. Normalized mean absolute errors (%) for the HHC-JLA model, the calibrated HHC-V1 model, and July 2016 calibrated model

| Target Type | HHC-JLA | HHC-V1 | July 2016 |
|---|---|---|---|
| Water Levels (1972 to 2010) | 6.4 | 6.3 | 6.8 |
| Salt Concentrations (1972 to 2010) | 14.0 | 10.2 | 9.9 |
| Water Levels (2010 to 2015) | 6.5 | 6.6 | 6.4 |
| Salt Concentrations (2010 to 2015) | 14.9 | 8.7 | 8.2 |
| CSEM Salt Concentrations (Layers 1 to 3) | 17.8 | 10.5 | 5.4 |
| CSEM Salt Concentrations (Layer 4) | 26.7 | 15.3 | 10.9 |
| CSEM Salt Concentrations (Layers 5 to 7) | 25.5 | 13.3 | 10.4 |
| CSEM Salt Concentrations (Layer 8) | 15.7 | 11.7 | 12.6 |
| CSEM Salt Concentrations (Layers 9 to 11) | 24.8 | 17.0 | 13.9 |
| CSEM Salt Concentrations (All Layers) | 22.7 | 13.6 | 10.0 |

Table 3. Calibration target weights for all calibration target types in the three heterogeneous hydraulic conductivity calibration analyses (HHC-V1, -V2, -V3)

| Target Type | HHC-V1 | HHC-V2 | HHC-V3 |
|---|---|---|---|
| Water Levels (1972 to 2010) | 2 | 1.5 | 1 |
| Salt Concentrations (1972 to 2010) | 2 | 2 | 2 |
| Water Levels (2010 to 2015) | 1.75 | 1 | 1.25 |
| Salt Concentrations (2010 to 2015) | 3 | 3 | 3.5 |
| Salt Concentrations (wells G-21, G-28) | 5 | 10 | 10 |
| CSEM Salt Concentrations (Layer 1) | 1 | 1 | 1 |
| CSEM Salt Concentrations (Layer 2) | 1 | 1 | 1 |
| CSEM Salt Concentrations (Layer 3) | 1 | 1 | 1 |
| CSEM Salt Concentrations (Layer 4) | 1 | 1.25 | 1 |
| CSEM Salt Concentrations (Layer 5) | 1 | 1 | 1 |
| CSEM Salt Concentrations (Layer 6) | 1 | 1 | 1 |
| CSEM Salt Concentrations (Layer 7) | 1 | 1 | 1 |
| CSEM Salt Concentrations (Layer 8) | 4.25 | 4.25 | 4 |
| CSEM Salt Concentrations (Layer 9) | 1.25 | 1.6 | 3.5 |
| CSEM Salt Concentrations (Layers 10) | 1.25 | 1.6 | 4 |
| CSEM Salt Concentrations (Layers 11) | 1.25 | 1.6 | 4 |

Table 4. Initial (July 2016) model and calibrated HHC-V2 model horizontal hydraulic conductivities (ft/day)

| Aquifer Zone | Pilot Point Name (or Uniform Value) | Initial (July 2016) Model | Calibrated HHC-V2 Model |
|---|---|---|---|
| Miami Limestone | Uniform Value | 100 | 121 |
| Upper High Flow Zone | TPGW-1 | 6030 | 4478 |
| Upper High Flow Zone | TPGW-2 | 6030 | 5635 |
| Upper High Flow Zone | TPGW-3 | 6030 | 8413 |
| Upper High Flow Zone | TPGW-4 | 6030 | 3613 |
| Upper High Flow Zone | TPGW-5 | 6030 | 9795 |
| Upper High Flow Zone | TPGW-6 | 6030 | 6858 |
| Upper High Flow Zone | TPGW-7 | 6030 | 6945 |
| Upper High Flow Zone | TPGW-8 | 6030 | 9003 |
| Upper High Flow Zone | TPGW-9 | 6030 | 4942 |
| Upper High Flow Zone | TPGW-10 | 6030 | 5407 |
| Upper High Flow Zone | TPGW-11 | 6030 | 5224 |
| Upper High Flow Zone | TPGW-12 | 6030 | 7913 |
| Upper High Flow Zone | TPGW-13 | 6030 | 6656 |
| Upper High Flow Zone | TPGW-14 | 6030 | 4407 |
| Upper High Flow Zone | Added-1 | 6030 | 4747 |
| Upper High Flow Zone | Added-2 | 6030 | 8324 |
| Shallow Ft. Thompson | Uniform Value | 3710 | 3793 |
| Lower High Flow Zone | TPGW-1 | 35980 | 21405 |

| Aquifer Zone | Pilot Point Name (or Uniform Value) | Initial (July 2016) Model | Calibrated HHC-V2 Model |
|---|---|---|---|
| Lower High Flow Zone | TPGW-2 | 35980 | 100000 |
| Lower High Flow Zone | TPGW-3 | 35980 | 31839 |
| Lower High Flow Zone | TPGW-4 | 35980 | 69679 |
| Lower High Flow Zone | TPGW-5 | 35980 | 14372 |
| Lower High Flow Zone | TPGW-6 | 35980 | 25395 |
| Lower High Flow Zone | TPGW-7 | 35980 | 30687 |
| Lower High Flow Zone | TPGW-8 | 35980 | 63371 |
| Lower High Flow Zone | TPGW-9 | 35980 | 14011 |
| Lower High Flow Zone | TPGW-10 | 35980 | 33635 |
| Lower High Flow Zone | TPGW-11 | 35980 | 37607 |
| Lower High Flow Zone | TPGW-12 | 35980 | 43384 |
| Lower High Flow Zone | TPGW-13 | 35980 | 34835 |
| Lower High Flow Zone | TPGW-14 | 35980 | 32780 |
| Lower High Flow Zone | Added-1 | 35980 | 23601 |
| Lower High Flow Zone | Added-2 | 35980 | 22354 |
| Deep Model (Layer 9) | TPGW-1 | 389 | 474 |
| Deep Model (Layer 9) | TPGW-2 | 389 | 384 |
| Deep Model (Layer 9) | TPGW-3 | 389 | 494 |
| Deep Model (Layer 9) | TPGW-4 | 389 | 492 |
| Deep Model (Layer 9) | TPGW-5 | 389 | 261 |
| Deep Model (Layer 9) | TPGW-6 | 389 | 459 |
| Deep Model (Layer 9) | TPGW-7 | 389 | 420 |
| Deep Model (Layer 9) | TPGW-8 | 389 | 427 |
| Deep Model (Layer 9) | TPGW-9 | 389 | 353 |
| Deep Model (Layer 9) | TPGW-10 | 389 | 424 |
| Deep Model (Layer 9) | TPGW-11 | 389 | 378 |
| Deep Model (Layer 9) | TPGW-12 | 389 | 403 |
| Deep Model (Layer 9) | TPGW-13 | 389 | 330 |
| Deep Model (Layer 9) | TPGW-14 | 389 | 334 |
| Deep Model (Layer 9) | Added-1 | 389 | 391 |
| Deep Model (Layer 9) | Added-2 | 389 | 326 |
| Deep Model (Layer 10) | TPGW-1 | 389 | 447 |
| Deep Model (Layer 10) | TPGW-2 | 389 | 411 |
| Deep Model (Layer 10) | TPGW-3 | 389 | 523 |
| Deep Model (Layer 10) | TPGW-4 | 389 | 336 |
| Deep Model (Layer 10) | TPGW-5 | 389 | 529 |
| Deep Model (Layer 10) | TPGW-6 | 389 | 349 |
| Deep Model (Layer 10) | TPGW-7 | 389 | 378 |
| Deep Model (Layer 10) | TPGW-8 | 389 | 533 |
| Deep Model (Layer 10) | TPGW-9 | 389 | 407 |
| Deep Model (Layer 10) | TPGW-10 | 389 | 313 |
| Deep Model (Layer 10) | TPGW-11 | 389 | 399 |
| Deep Model (Layer 10) | TPGW-12 | 389 | 339 |

| Aquifer Zone | Pilot Point Name (or Uniform Value) | Initial (July 2016) Model | Calibrated HHC-V2 Model |
|---|---|---|---|
| Deep Model (Layer 10) | TPGW-13 | 389 | 454 |
| Deep Model (Layer 10) | TPGW-14 | 389 | 359 |
| Deep Model (Layer 10) | Added-1 | 389 | 301 |
| Deep Model (Layer 10) | Added-2 | 389 | 478 |
| Deep Model (Layer 11) | TPGW-1 | 389 | 234 |
| Deep Model (Layer 11) | TPGW-2 | 389 | 353 |
| Deep Model (Layer 11) | TPGW-3 | 389 | 432 |
| Deep Model (Layer 11) | TPGW-4 | 389 | 433 |
| Deep Model (Layer 11) | TPGW-5 | 389 | 374 |
| Deep Model (Layer 11) | TPGW-6 | 389 | 505 |
| Deep Model (Layer 11) | TPGW-7 | 389 | 345 |
| Deep Model (Layer 11) | TPGW-8 | 389 | 424 |
| Deep Model (Layer 11) | TPGW-9 | 389 | 381 |
| Deep Model (Layer 11) | TPGW-10 | 389 | 312 |
| Deep Model (Layer 11) | TPGW-11 | 389 | 388 |
| Deep Model (Layer 11) | TPGW-12 | 389 | 265 |
| Deep Model (Layer 11) | TPGW-13 | 389 | 294 |
| Deep Model (Layer 11) | TPGW-14 | 389 | 429 |
| Deep Model (Layer 11) | Added-1 | 389 | 342 |
| Deep Model (Layer 11) | Added-2 | 389 | 285 |

Table 5. Normalized mean absolute errors (%) for the initial (July 2016) model and calibrated HHC-V2 model

| Target Type | Initial (July 2016) Model | Calibrated HHC-V2 Model |
|---|---|---|
| Water Levels (1972 to 2010) | 6.8 | 6.7 |
| Salt Concentrations (1972 to 2010) | 9.9 | 8.3 |
| Water Levels (2010 to 2015) | 6.4 | 6.3 |
| Salt Concentrations (2010 to 2015) | 8.2 | 7.7 |
| CSEM Salt Concentrations (Layers 1 to 3) | 5.4 | 5.5 |
| CSEM Salt Concentrations (Layer 4) | 10.9 | 9.6 |
| CSEM Salt Concentrations (Layers 5 to 7) | 10.4 | 9.1 |
| CSEM Salt Concentrations (Layer 8) | 12.6 | 9.7 |
| CSEM Salt Concentrations (Layers 9 to 11) | 13.9 | 12.8 |
| CSEM Salt Concentrations (All Layers) | 10.0 | 9.1 |

Table 6. Initial and calibrated HHC-V3 model horizontal hydraulic conductivities (ft/day)

| Aquifer Zone | Pilot Point Name (or Uniform Value) | Initial HHC-V3 Value | Calibrated HHC-V3 Value |
|---|---|---|---|
| Miami Limestone | Uniform Value | 121 | 128 |
| Upper High Flow Zone | TPGW-1 | 4478 | 4478 |
| Upper High Flow Zone | TPGW-2 | 5635 | 5635 |
| Upper High Flow Zone | TPGW-3 | 8413 | 8413 |
| Upper High Flow Zone | TPGW-4 | 3613 | 3613 |
| Upper High Flow Zone | TPGW-5 | 9795 | 9795 |
| Upper High Flow Zone | TPGW-6 | 6858 | 6858 |
| Upper High Flow Zone | TPGW-7 | 6945 | 6945 |
| Upper High Flow Zone | TPGW-8 | 9003 | 9003 |
| Upper High Flow Zone | TPGW-9 | 4942 | 4942 |
| Upper High Flow Zone | TPGW-10 | 5407 | 5407 |
| Upper High Flow Zone | TPGW-11 | 5224 | 5224 |
| Upper High Flow Zone | TPGW-12 | 7913 | 7913 |
| Upper High Flow Zone | TPGW-13 | 6656 | 6656 |
| Upper High Flow Zone | TPGW-14 | 4407 | 4407 |
| Upper High Flow Zone | Added-1 | 4747 | 4747 |
| Upper High Flow Zone | Added-2 | 8324 | 8324 |
| Shallow Ft. Thompson | Uniform Value | 3793 | 4092 |
| Lower High Flow Zone | TPGW-1 | 21405 | 20784 |
| Lower High Flow Zone | TPGW-2 | 100000 | 102905 |
| Lower High Flow Zone | TPGW-3 | 31839 | 25805 |
| Lower High Flow Zone | TPGW-4 | 69679 | 72660 |
| Lower High Flow Zone | TPGW-5 | 14372 | 15932 |
| Lower High Flow Zone | TPGW-6 | 25395 | 24846 |
| Lower High Flow Zone | TPGW-7 | 30687 | 28851 |
| Lower High Flow Zone | TPGW-8 | 63371 | 67411 |
| Lower High Flow Zone | TPGW-9 | 14011 | 10740 |
| Lower High Flow Zone | TPGW-10 | 33635 | 30440 |
| Lower High Flow Zone | TPGW-11 | 37607 | 42203 |
| Lower High Flow Zone | TPGW-12 | 43384 | 44952 |
| Lower High Flow Zone | TPGW-13 | 34835 | 34694 |
| Lower High Flow Zone | TPGW-14 | 32780 | 27147 |
| Lower High Flow Zone | Added-1 | 23601 | 20506 |
| Lower High Flow Zone | Added-2 | 22354 | 23230 |
| Deep Model (Layer 9) | TPGW-1 | 474 | 479 |
| Deep Model (Layer 9) | TPGW-2 | 384 | 336 |
| Deep Model (Layer 9) | TPGW-3 | 494 | 507 |
| Deep Model (Layer 9) | TPGW-4 | 492 | 499 |
| Deep Model (Layer 9) | TPGW-5 | 261 | 256 |
| Deep Model (Layer 9) | TPGW-6 | 459 | 517 |
| Deep Model (Layer 9) | TPGW-7 | 420 | 439 |
| Deep Model (Layer 9) | TPGW-8 | 427 | 503 |

| Aquifer Zone | Pilot Point Name (or Uniform Value) | Initial HHC-V3 Value | Calibrated HHC-V3 Value |
|---|---|---|---|
| Deep Model (Layer 9) | TPGW-9 | 353 | 321 |
| Deep Model (Layer 9) | TPGW-10 | 424 | 426 |
| Deep Model (Layer 9) | TPGW-11 | 378 | 345 |
| Deep Model (Layer 9) | TPGW-12 | 403 | 341 |
| Deep Model (Layer 9) | TPGW-13 | 330 | 355 |
| Deep Model (Layer 9) | TPGW-14 | 334 | 298 |
| Deep Model (Layer 9) | Added-1 | 391 | 388 |
| Deep Model (Layer 9) | Added-2 | 326 | 323 |
| Deep Model (Layer 10) | TPGW-1 | 447 | 434 |
| Deep Model (Layer 10) | TPGW-2 | 411 | 460 |
| Deep Model (Layer 10) | TPGW-3 | 523 | 548 |
| Deep Model (Layer 10) | TPGW-4 | 336 | 322 |
| Deep Model (Layer 10) | TPGW-5 | 529 | 650 |
| Deep Model (Layer 10) | TPGW-6 | 349 | 340 |
| Deep Model (Layer 10) | TPGW-7 | 378 | 420 |
| Deep Model (Layer 10) | TPGW-8 | 533 | 533 |
| Deep Model (Layer 10) | TPGW-9 | 407 | 394 |
| Deep Model (Layer 10) | TPGW-10 | 313 | 353 |
| Deep Model (Layer 10) | TPGW-11 | 399 | 424 |
| Deep Model (Layer 10) | TPGW-12 | 339 | 274 |
| Deep Model (Layer 10) | TPGW-13 | 454 | 486 |
| Deep Model (Layer 10) | TPGW-14 | 359 | 338 |
| Deep Model (Layer 10) | Added-1 | 301 | 293 |
| Deep Model (Layer 10) | Added-2 | 478 | 500 |
| Deep Model (Layer 11) | TPGW-1 | 234 | 172 |
| Deep Model (Layer 11) | TPGW-2 | 353 | 333 |
| Deep Model (Layer 11) | TPGW-3 | 432 | 399 |
| Deep Model (Layer 11) | TPGW-4 | 433 | 460 |
| Deep Model (Layer 11) | TPGW-5 | 374 | 327 |
| Deep Model (Layer 11) | TPGW-6 | 505 | 575 |
| Deep Model (Layer 11) | TPGW-7 | 345 | 350 |
| Deep Model (Layer 11) | TPGW-8 | 424 | 446 |
| Deep Model (Layer 11) | TPGW-9 | 381 | 345 |
| Deep Model (Layer 11) | TPGW-10 | 312 | 274 |
| Deep Model (Layer 11) | TPGW-11 | 388 | 397 |
| Deep Model (Layer 11) | TPGW-12 | 265 | 297 |
| Deep Model (Layer 11) | TPGW-13 | 294 | 305 |
| Deep Model (Layer 11) | TPGW-14 | 429 | 410 |
| Deep Model (Layer 11) | Added-1 | 342 | 310 |
| Deep Model (Layer 11) | Added-2 | 285 | 250 |

Table 7. Vertical hydraulic conductivities (ft/day) for the HHC-V2 and HHC-V3

| Aquifer Zone | Pilot Point Name (or Uniform Value) | HHC-V2 Value | HHC-V3 Value |
|---|---|---|---|
| Miami Limestone | Uniform Value | 20.1 | 19.6 |
| Upper High Flow Zone | Uniform Value | 504 | 570 |
| Shallow Ft. Thompson | Uniform Value | 1710 | 1908 |
| Lower High Flow Zone | Uniform Value | 2015 | 2264 |
| Deep Model (Layer 9) | TPGW-1 | 84.2 | 89.7 |
| Deep Model (Layer 9) | TPGW-4 | 84.2 | 91.8 |
| Deep Model (Layer 9) | TPGW-5 | 84.2 | 90.3 |
| Deep Model (Layer 9) | TPGW-6 | 84.2 | 85.9 |
| Deep Model (Layer 9) | TPGW-12 | 84.2 | 80.6 |
| Deep Model (Layer 9) | TPGW-13 | 84.2 | 84.4 |
| Deep Model (Layer 10) | TPGW-1 | 82.2 | 84.3 |
| Deep Model (Layer 10) | TPGW-4 | 82.2 | 84.1 |
| Deep Model (Layer 10) | TPGW-5 | 82.2 | 81.8 |
| Deep Model (Layer 10) | TPGW-6 | 82.2 | 74.8 |
| Deep Model (Layer 10) | TPGW-12 | 82.2 | 73.2 |
| Deep Model (Layer 10) | TPGW-13 | 82.2 | 64.3 |
| Deep Model (Layer 11) | TPGW-1 | 78.7 | 72.1 |
| Deep Model (Layer 11) | TPGW-4 | 78.7 | 75.7 |
| Deep Model (Layer 11) | TPGW-5 | 78.7 | 72.8 |
| Deep Model (Layer 11) | TPGW-6 | 78.7 | 89.0 |
| Deep Model (Layer 11) | TPGW-12 | 78.7 | 86.2 |
| Deep Model (Layer 11) | TPGW-13 | 78.7 | 83.9 |

Table 8. Normalized mean absolute errors (%) for the initial and calibrated HHC-V3

| Target Type | Initial (July 2016) Model | HHC-V3 |
|---|---|---|
| Water Levels (1972 to 2010) | 6.8 | 6.6 |
| Salt Concentrations (1972 to 2010) | 9.9 | 8.0 |
| Water Levels (2010 to 2015) | 6.4 | 6.1 |
| Salt Concentrations (2010 to 2015) | 8.2 | 7.6 |
| CSEM Salt Concentrations (Layers 1 to 3) | 5.5 | 6.1 |
| CSEM Salt Concentrations (Layer 4) | 9.7 | 9.8 |
| CSEM Salt Concentrations (Layers 5 to 7) | 9.1 | 8.9 |
| CSEM Salt Concentrations (Layer 8) | 9.7 | 10.0 |
| CSEM Salt Concentrations (Layer 9) | 11.0 | 11.5 |
| CSEM Salt Concentrations (Layer 10) | 10.7 | 10.2 |
| CSEM Salt Concentrations (Layer 11) | 17.7 | 16.5 |
| CSEM Salt Concentrations (All Layers) | 9.1 | 9.2 |