SOUTH FLORIDA WATER MANAGEMENT DISTRICT

East Coast Surficial Model (ECSM)

Peer Review Meeting No. 1

Resource Evaluation Section
September 7, 2022

sfwmd.gov

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Introduction

Pete Kwiatkowski, P.G.

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Agenda

Morning Session:

- Peer Review Process
- Model Overview
- Specialized District Packages
- Hydrostratigraphy
- Saltwater Intrusion Mapping
- SEAWAT Modifications
- Panel Discussion
- Public Comment

Afternoon Session:

- ET-Recharge and Return Flow
- Input Data Sets
- Model Calibration Plan
- Calibration Criteria
- Panel Discussion
- Public Comment

Peer Review Process

Alicia Magloire

Peer Review and Process

- What is Peer Review?
  - An independent evaluation of work products by individuals with similar competencies as the producers of the work products
  - Involves soliciting feedback regarding decisions on input data and assumptions, methodology, and resulting work products
- Peer Review Process
  - The process will be conducted through a dedicated, electronic web board, and all subsequent documents and correspondence will also be available at the SFWMD's web board https://sfwmd.websitetoolbox.com/east-coast-surficial-model-ecsm-peer-review-914820

ECSM Statement of Work for Peer Review

The peer-review panel is tasked with evaluating the overall appropriateness of the model and to answer the following questions:

- Was the model developed using good modeling practices?
- Did the model address peer-review comments to the extent possible?
- Did the model achieve reasonable calibration statistics?
- Can the model be applied for its intended purpose?

Peer Reviewer Scope of Work

Duties of the Peer Review Panel:

- Conduct reviews of the conceptual model, calibration plan, model input datasets, model calibration, sensitivity analysis, and documentation
- Evaluate the suitability of the model for water supply planning, scenario evaluation and groundwater availability
- Participate in meetings and workshops

ECSM Task Timeline

Task	Task Completion Date	Panel Deliverable Date
Model Conceptualization and Calibration Strategy	September 2022	October 2022
Transient Data Sets and Calibration Status	December 2022	January 2023
Final Model Calibration Results	March 2023	April 2023
Model Calibration Report	July 2023	August 2023

Peer Review Panel

- Weixing Guo, Ph.D., P.G. – Panel Chair
- Wendy Graham, Ph.D. – Panelist
- Michael Sukop, Ph.D., P.G. - Panelist

East Coast Surficial Modeling Team

SFWMD Staff:

- Anushi Obeysekera, E.I.T
- Yirgalem Assegid, Ph.D.
- David Butler, P.G.
- Sondipon Paul, Ph.D., E.I.T
- Jagath Vithanage, Ph.D.
- Kevin A. Rodberg
- Brian Moore
- Jose Grisales
- Alicia Magloire
- Stacey Coonts, G.I.T.

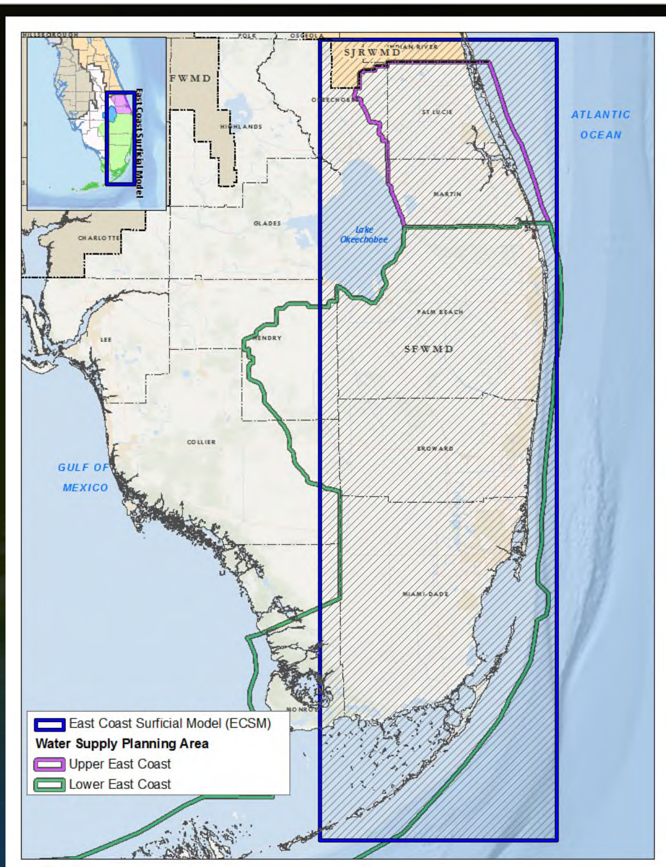
Contract Staff:

Jeff Giddings, Tradewinds Group, LLC

Model Overview

Anushi Obeysekera, E.I.T.

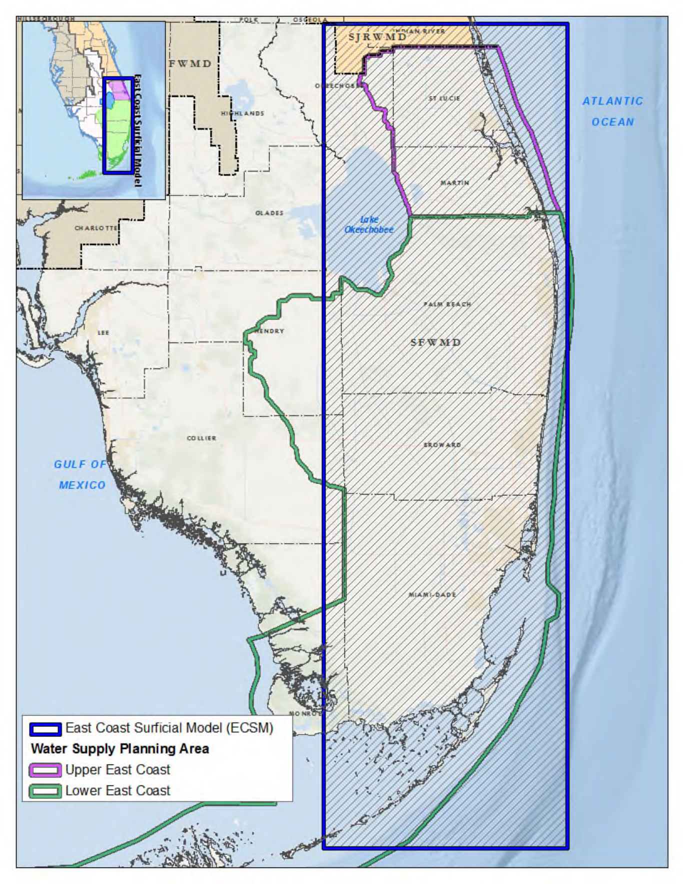
Objectives of ECSM



- Evaluate if the water supply demands within the East Coast water supply planning regions can be met within a 20-year planning horizon without undue effects on existing legal users of water and natural systems
- Simulate and evaluate the effects of sea-level rise and saltwater intrusion on the groundwater system

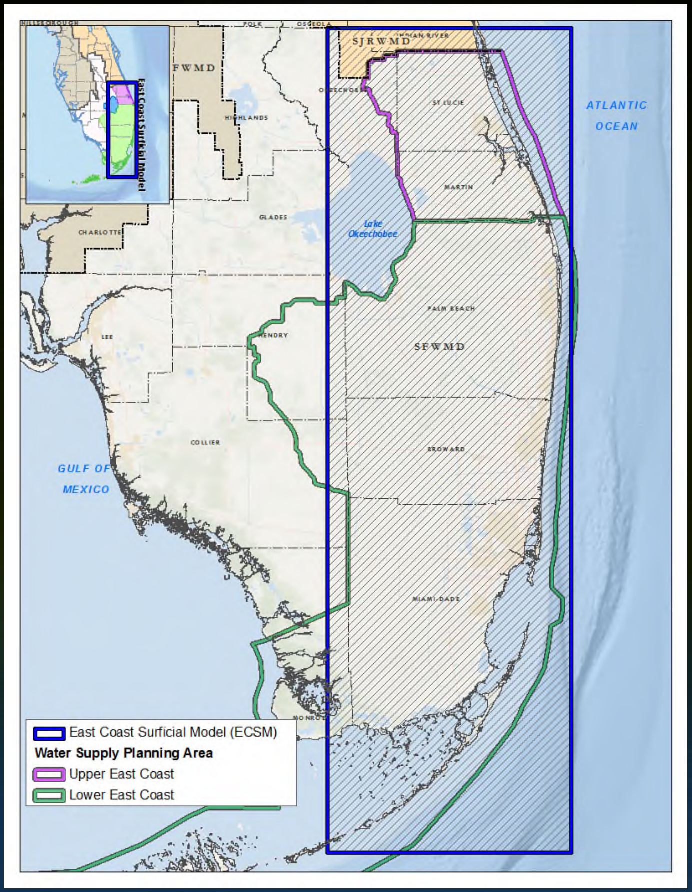
East Coast Surficial Model

- Model Boundaries
  - Northern: Vero Beach
  - Southern: Marathon
  - Eastern: Atlantic Ocean
  - Western: L-2 Canal



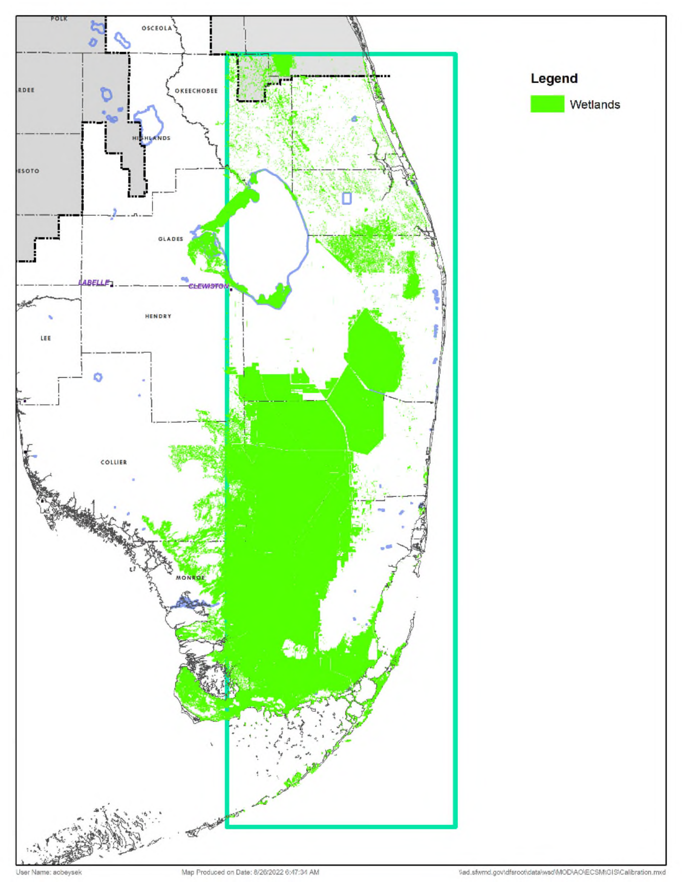
East Coast Surficial Model

- Calibration Period of Record: 1985 – 2012
- Verification Period of Record: 2013 – 2016
- Daily Stress periods
- Cell size: 1,000 ft x 1,000 ft
- 5 model layers
- Calibrated to water levels (daily), water quality (Total Dissolved Solids [TDS]) mg/L (monthly), and structure flows (30-day rolling average)



Code Selection

- Code selection was based on:
  - Ability to simulate contiguous wetlands, and operational rules within canals, stormwater treatment areas (STA) and water conservation areas (WCA)
  - Ability to analyze potential degradation of water quality due to saltwater intrusion and sea level rise
  - Adhere to timeline to meet water supply planning needs (2023)
- Selected Code: SEAWAT v 4.0 (USGS 2008) updated with SFWMD packages

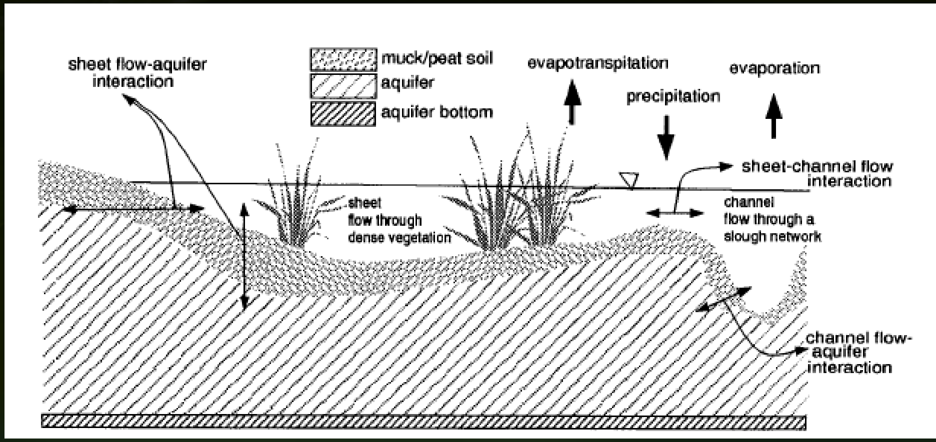


Specialized District Packages

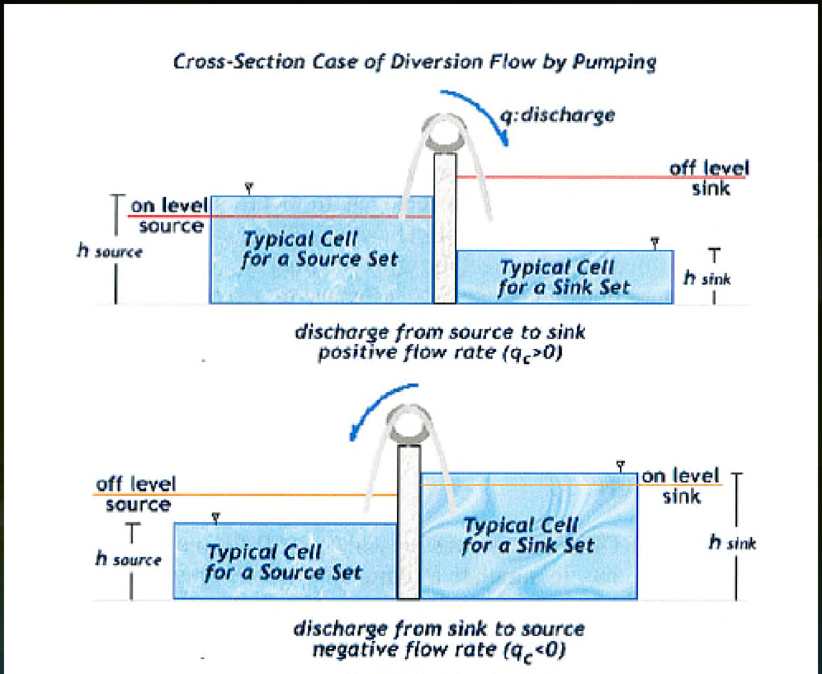
Anushi Obeysekera, E.I.T.

Wetland Package

- The wetland package was developed by Restrepo et al., (1998)
- Simulates surface water flow and surface water/groundwater interaction through wetlands
- Top layer – 2D overland and/or groundwater flow
- When a wetland cell is inundated, flow is governed by Kadlec equation



Routing Packages



- Diversion Package (MDIV)
  - Uses source and sink cells to move water from one location to another
  - Allows the user to set the head upstream and downstream, and manipulate daily flow rates, which is useful in modeling flood protection or areas where flow rates change during the wet and dry seasons
- RDF Package (Reinjection Drainflow)
  - Uses source and sink cells to move water from one location to another
  - Allows the user to change the stage constraints on a daily basis, which is useful in modeling operational schedules
  - Currently implemented to move water between the STAs, WCAs, and ENP

Data Management Packages

Multibud (MBUD) Package

- Post-processing utility
- Creates water budgets for either the entire model domain or specific subregions
- Used especially during structure flow calibration, when water budgets of contributing areas are used to determine flow through structures
- The functionality allows for water budgets to be evaluated without the need for the cell by cell flow file

Utility Generation (UGEN) Package

- Used to generate time-dependent model input
- Links static input parameters with dynamic temporal data
- Increases efficiency because static information is only read once.
- Significantly reduces file size

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Hydrostratigraphy

Stacey Coonts, G.I.T.

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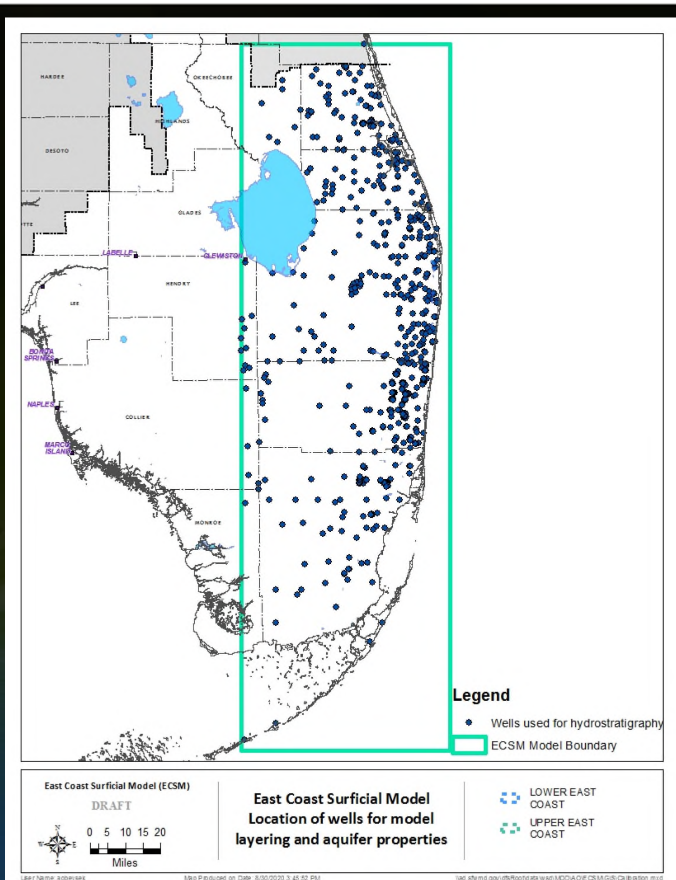
Wells with Hydrogeologic Data



- 702 wells used across the model domain
- Leveraged all data sources (e.g., DBHYDRO, consultant reports, etc.)
- Used to identify hydrostratigraphy, model layering, and aquifer parameters

Hydrostratigraphy

- Based on Q layers described by Perkins (1977) and Tamiami Formation
- Q layers correspond to eustatic sea-level changes during the Pleistocene era
- Subaerial exposures are associated with layers of lower vertical hydraulic conductivity that can be used to delineate hydrostratigraphic layers and therefore model layers

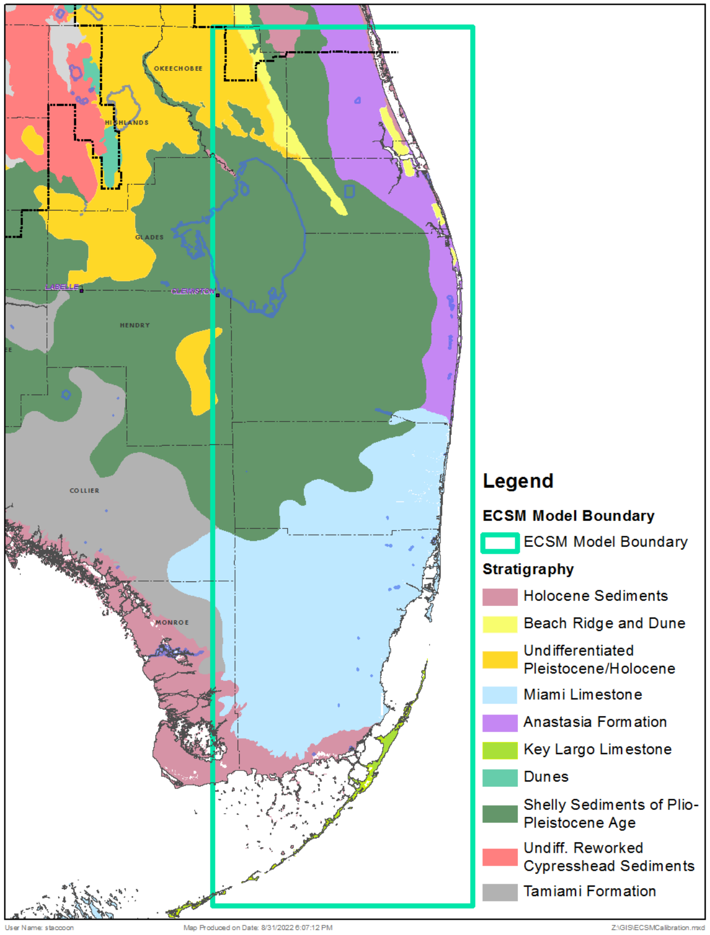
Q Layers

- Q1 through Q5, with Q1 being the oldest
- Signs of low sea-level and subaerial exposures:
  - Root casts and plant remains
  - Freshwater limestone
  - Caliche and laminated crusts
  - Solution surfaces, soil and soil breccias
- Signs of high sea-level
  - Rapid growth of coral reefs, sand bars, and other marine deposits
  - Marine fossils

Model Layers

Age	Model Layer	Q Layer	Stratigraphy		Lithology	Hydrostratigraphy	
Holocene	Layer 1		Lake Flirt Marl, Undifferentiated Soil and Sand		Marl, peat, organic soil, and quartz sand	Surficial Aquifer System	Water Table Aquifer
Pleistocene	Layer 1	Q4, Q5	Pamlico Sand		Quartz sand		Water Table Aquifer / Biscayne Aquifer
	Layer 1	Q4, Q5	Miami Limestone		Oolitic limestone and fossiliferous limestone		Biscayne Aquifer
	Layer 1 / Layer 2	Q4, Q5 / Q2, Q3	Fort Thompson Formation		Marine limestone, gastropod-rich freshwater limestone, sandy limestone, and fossiliferous quartz sandstone		Biscayne Aquifer
	Layer 2	Q2, Q3	Key Largo Limestone		Coralline limestone and minor amounts of sandy limestone		Biscayne Aquifer / Semiconfining Unit
	Layer 3	Q1	Anastasia Formation		Coquina, shell, quartz sand, and sandy limestone		Semiconfining Unit / Biscayne Aquifer
	Layer 3	Q1	Caloosahatchee Formation		Sandy to shelly marl, clay, silt, and quartz sand		Semiconfining Unit
Pliocene	Layer 4		Tamiami Formation	Pinecrest Sand Member	Quartz sand, bivalve-rich quartz sandstone and sandy limestone, shell, mudstone, and minor amounts of phosphate grains		Semiconfining Unit
	Layer 5		Tamiami Formation	Ochopee Limestone Member	Bivalve-rich limestone, bivalve-rich quartz sand and sandstone, and moldic quartz sandstone		Grey Limestone Aquifer

Geologic Map of South Florida



Lithology Photos

Ooids, Miami Limestone (view of ~25X).

Miami Limestone
Model Layer 1

Fort Thompson Formation
Model Layers 1-3

Key Largo Limestone
Model Layers 1-3

Caloosahatchee Formation
Model Layers 2-3

Anastasia Formation
Model Layers 1-3

Layer 1

- Holocene Sediment
  - Lake Flirt Marl and undifferentiated soil and sand – marl, peat, organic soil and quartz sand
- Q5 and Q4
  - Pamlico Sand – quartz sand
  - Miami Limestone – oolitic limestone and fossiliferous limestone
  - Fort Thompson Formation – fossiliferous marine limestone, gastropod-rich freshwater limestone, sandy limestone, and fossiliferous quartz sandstone
  - Key Largo Limestone – coralline limestone and minor amounts of sandy limestone
  - Anastasia Formation – coquina, shell, quartz sand, and sandy limestone

Age	Model Layer	Q Layer	Stratigraphy		
Holocene	Layer 1		Lake Flirt Marl, Undifferentiated Soil and Sand		
Pleistocene		Q4, Q5	Pamlico Sand		
			Miami Limestone		
			Fort Thompson Formation	Key Largo Limestone	Anastasia Formation

Layer 2

- Q2 and Q3
  - Fort Thompson Formation – fossiliferous marine limestone, gastropod-rich freshwater limestone, sandy limestone, and fossiliferous quartz sandstone
  - Key Largo Limestone – coralline limestone and minor amounts of sandy limestone
  - Anastasia Formation – coquina, shell, quartz sand, and sandy limestone
  - Caloosahatchee Formation – sandy to shelly marl, clay, silt, and quartz sand

Age	Model Layer	Q Layer	Stratigraphy		
Pleistocene	Layer 2	Q2, Q3	Fort Thompson Formation	Key Largo Limestone	Anastasia Formation
			Caloosahatchee Formation		

Layer 3

- Q1
  - Fort Thompson Formation – fossiliferous marine limestone, gastropod-rich freshwater limestone, sandy limestone, and fossiliferous quartz sandstone
  - Key Largo Limestone – coralline limestone and minor amounts of sandy limestone
  - Anastasia Formation – coquina, shell, quartz sand, and sandy limestone
  - Caloosahatchee Formation – sandy to shelly marl, clay, silt, and quartz sand

Age	Model Layer	Q Layer	Stratigraphy		
Pleistocene	Layer 3	Q1	Fort Thompson Formation	Key Largo Limestone	Anastasia Formation
			Caloosahatchee Formation		

Layer 4

- Pinecrest Sand Member of the Tamiami Formation
  - Quartz sand, bivalve-rich quartz sandstone and sandy limestone, shell, mudstone, phosphate grains

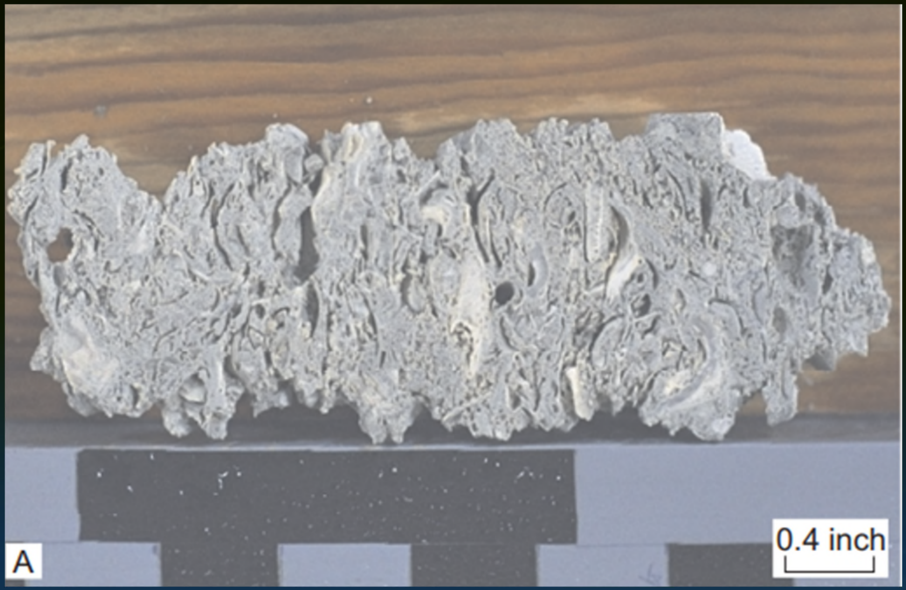
Age	Model Layer	Q Layer	Stratigraphy	
Pliocene	Layer 4		Tamiami Formation	Pinecrest Sand Member


APAC pit photo (Pincrest Sand), Sarasota County.

Layer 5

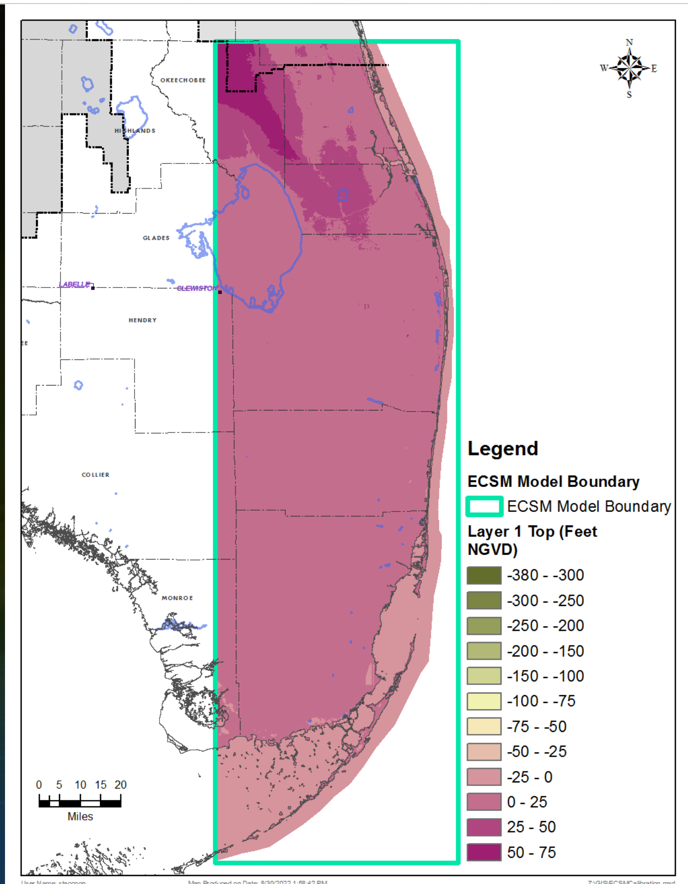
- Ochopee Limestone Member of the Tamiami Formation
  - Locally known as the Grey Limestone aquifer within LEC
  - Bivalve-rich limestone and bivalve-rich quartz sand and sandstone, moldic quartz sandstone

Age	Model Layer	Q Layer	Stratigraphy	
Pliocene	Layer 5		Tamiami Formation	Ochopee Limestone Member

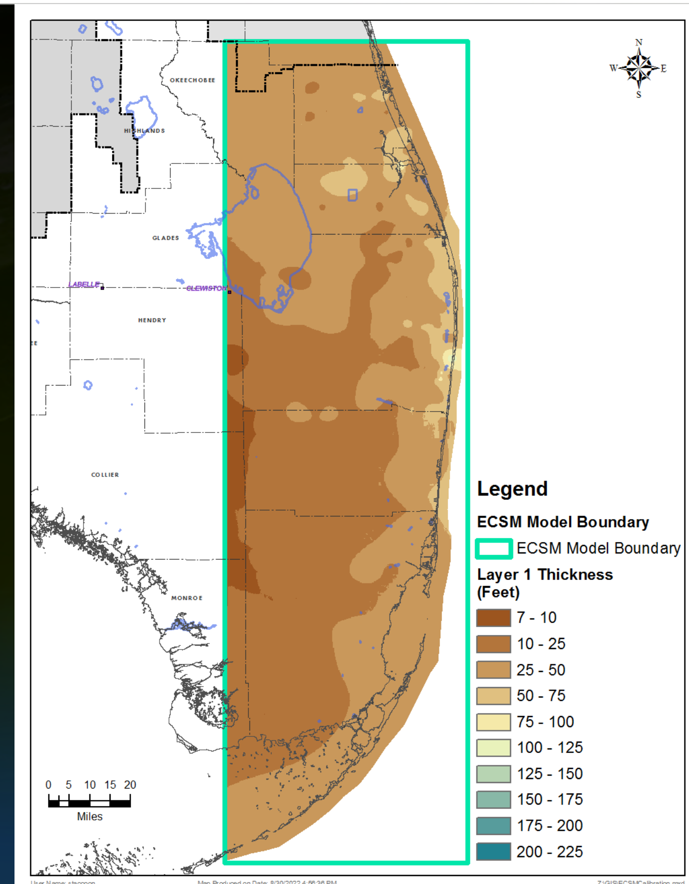


(Reese & Cunningham, 2000)

Layer 1 Top Elevation and Thickness

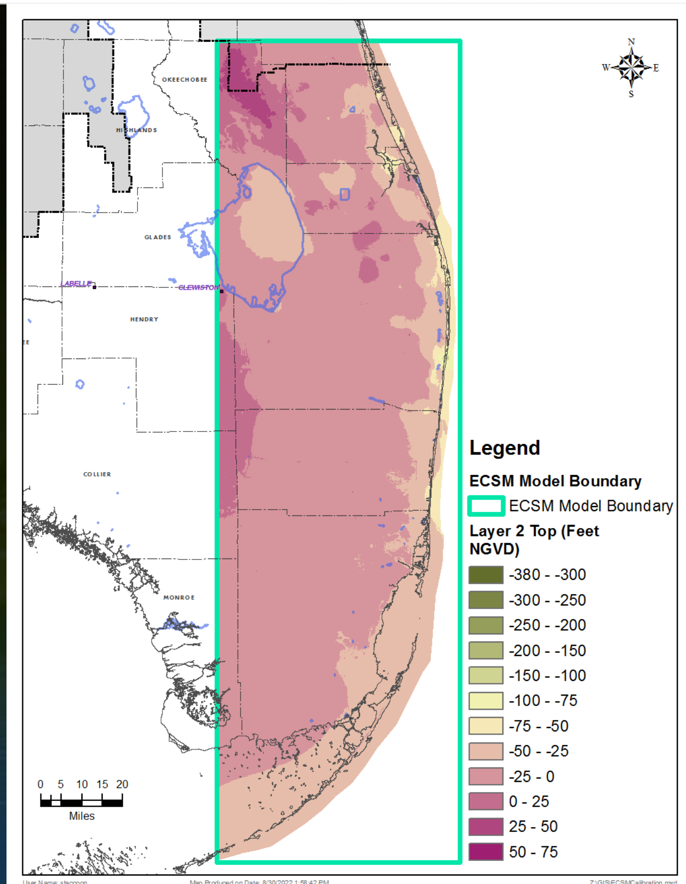


Top of Layer 1

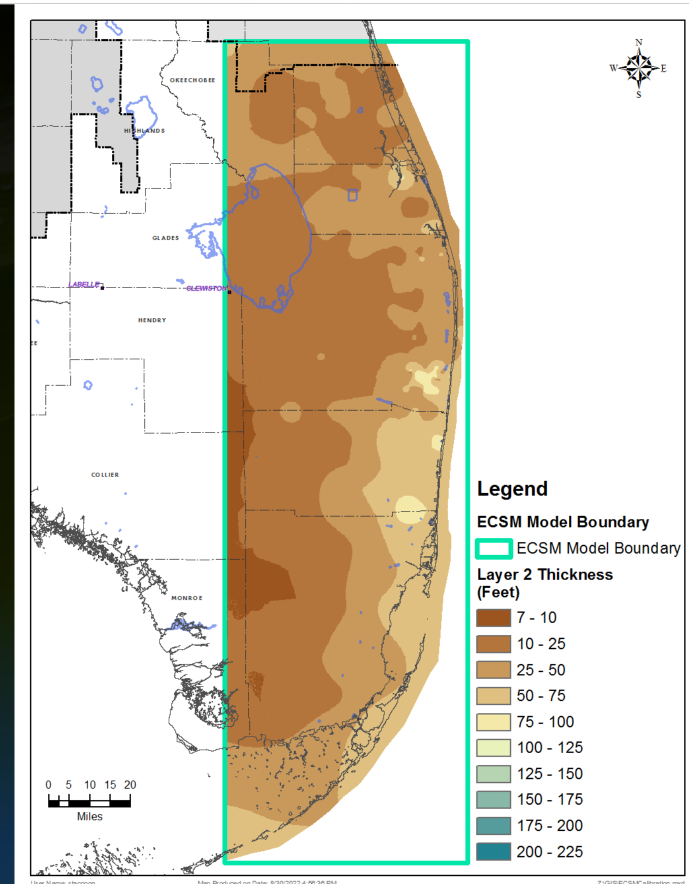


Thickness of Layer 1

Layer 2 Top Elevation and Thickness

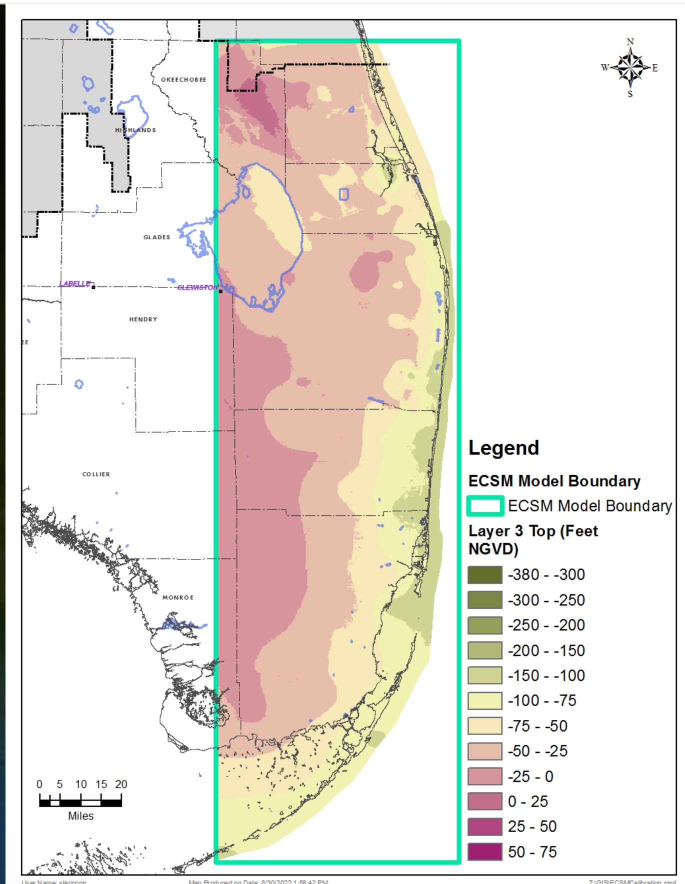


Top of Layer 2

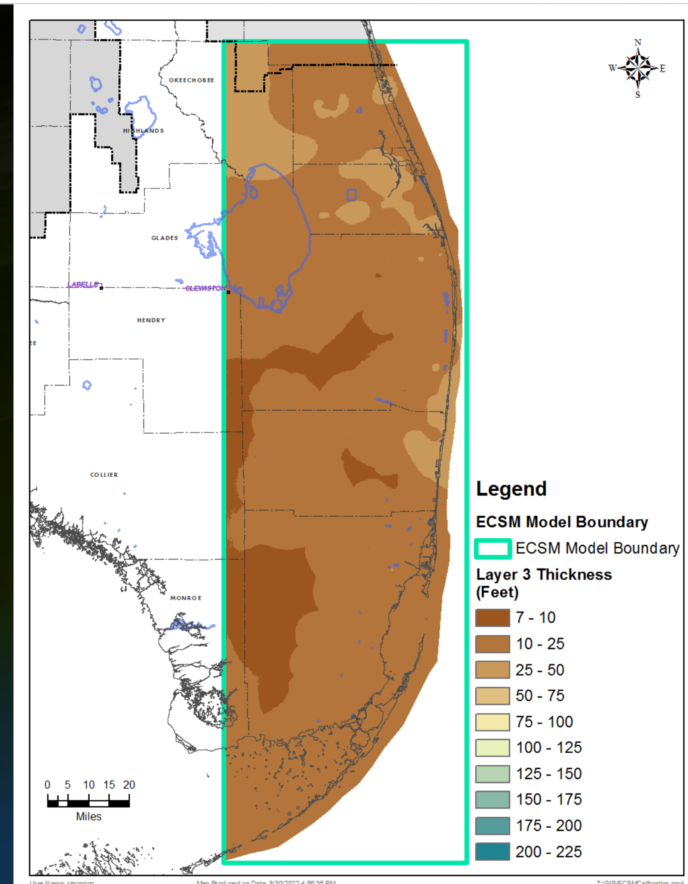


Thickness of Layer 2

Layer 3 Top Elevation and Thickness

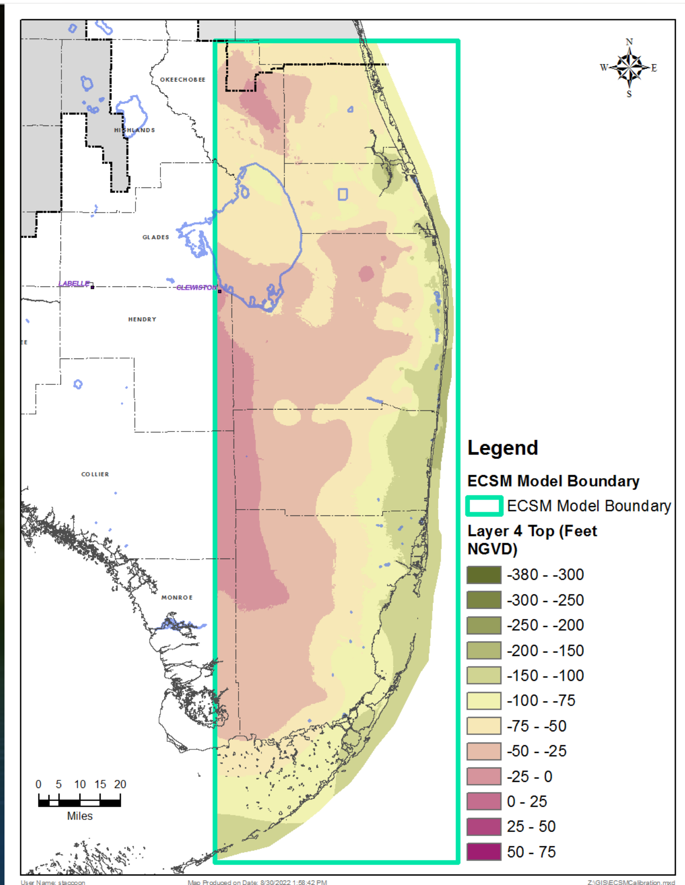


Top of Layer 3

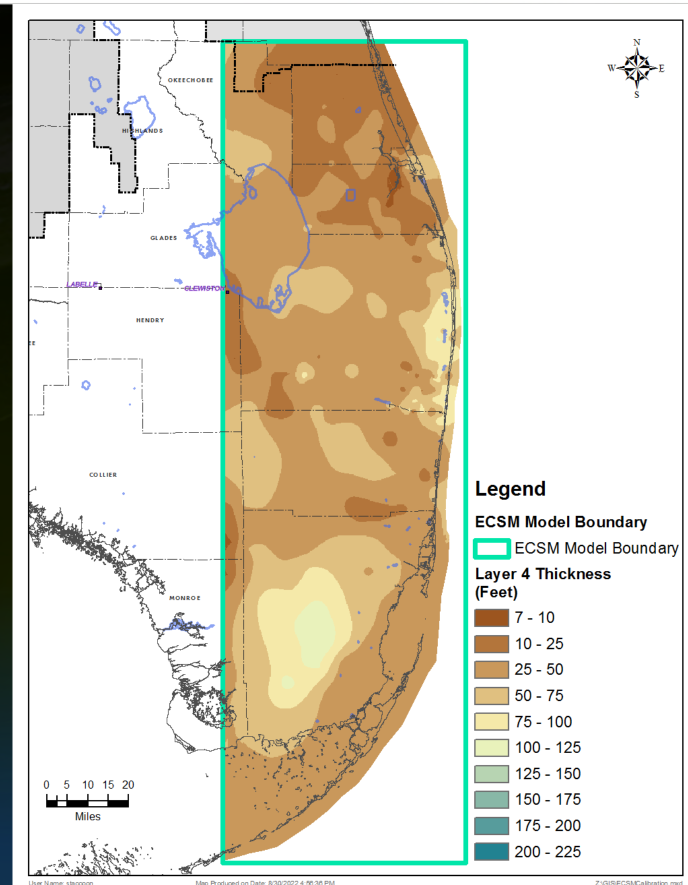


Thickness of Layer 3

Layer 4 Top Elevation and Thickness

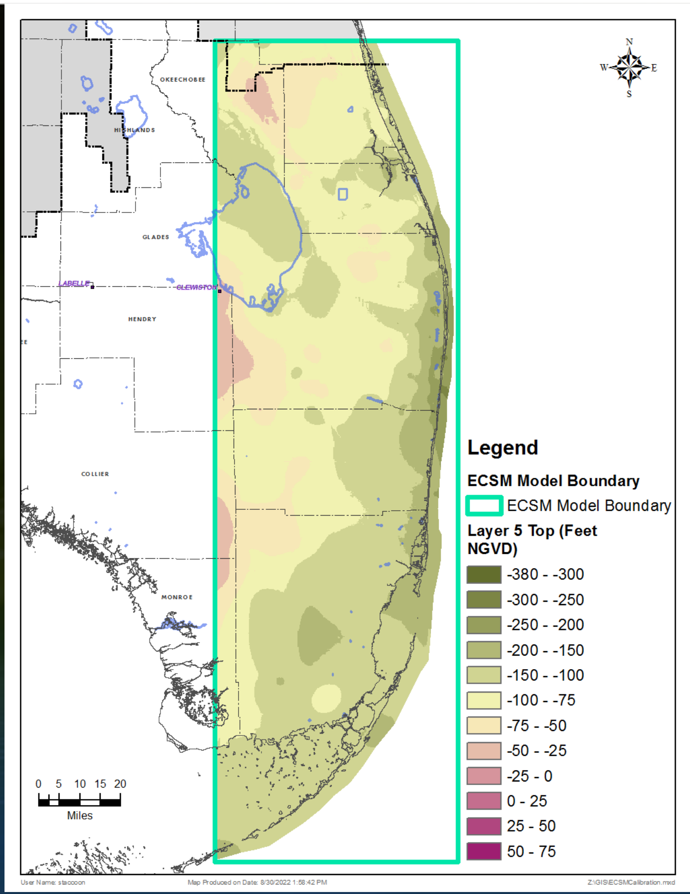


Top of Layer 4

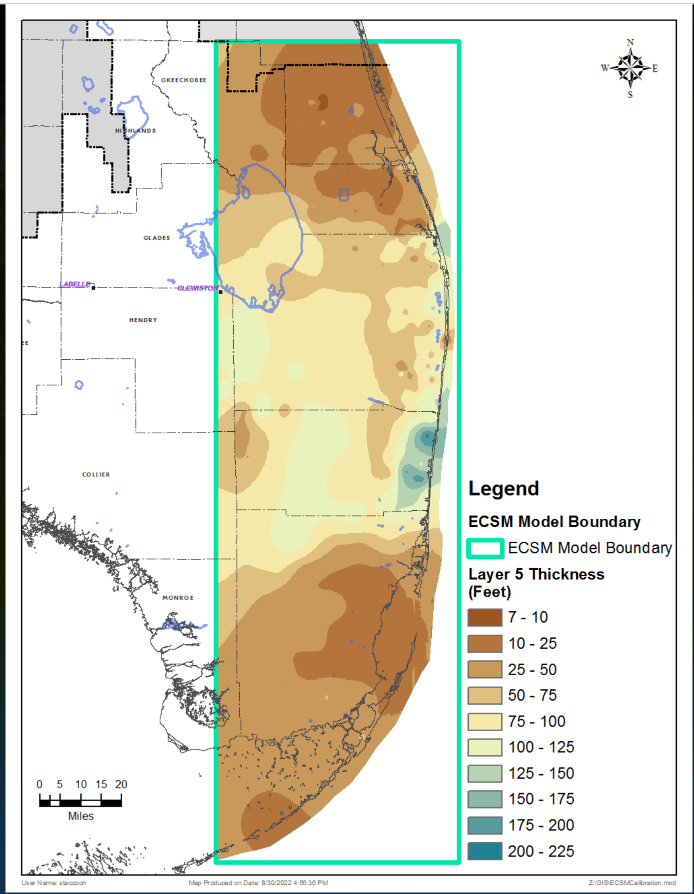


Thickness of Layer 4

Layer 5 Top Elevation and Thickness

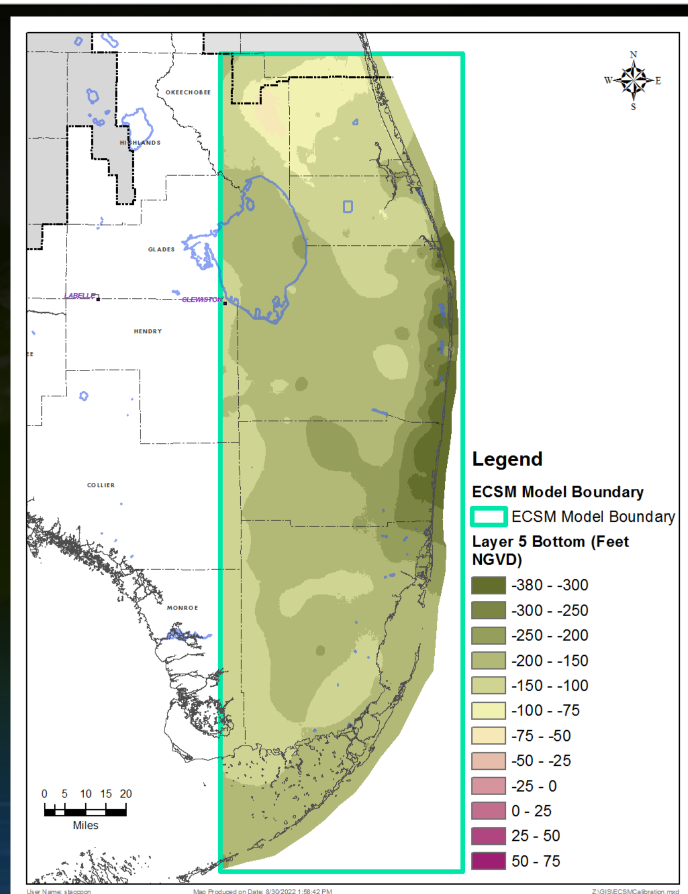


Top of Layer 5



Thickness of Layer 5

Layer 5 Bottom Elevation



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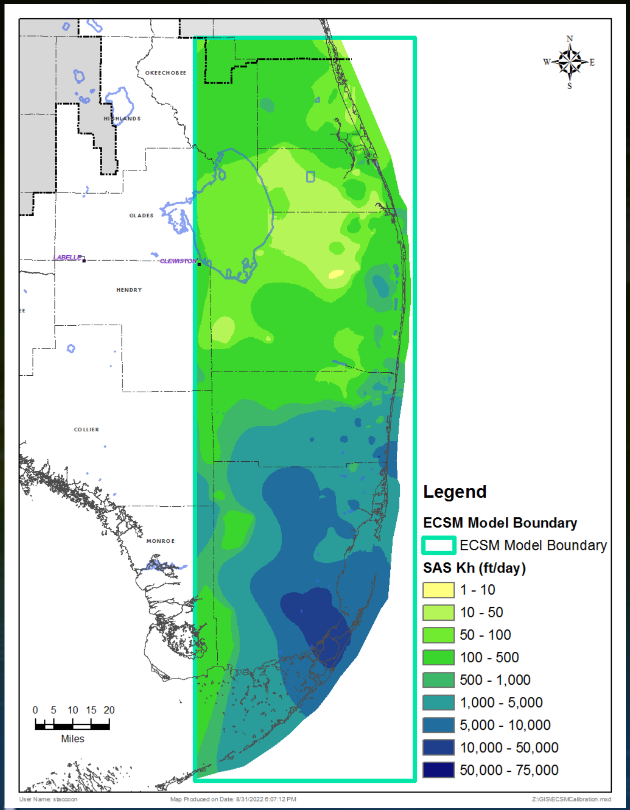
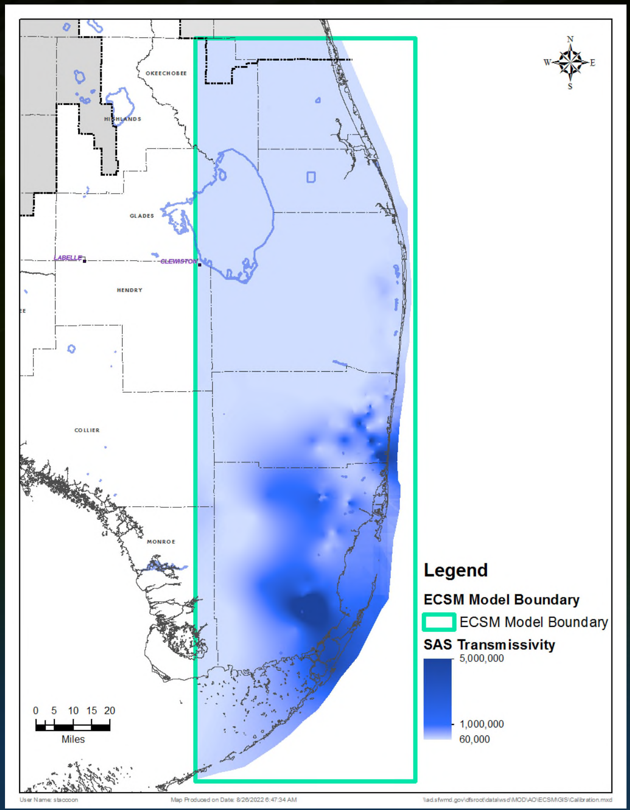
Composite Hydraulic Properties of the Surficial Aquifer System

Hydraulic Conductivity



Transmissivity



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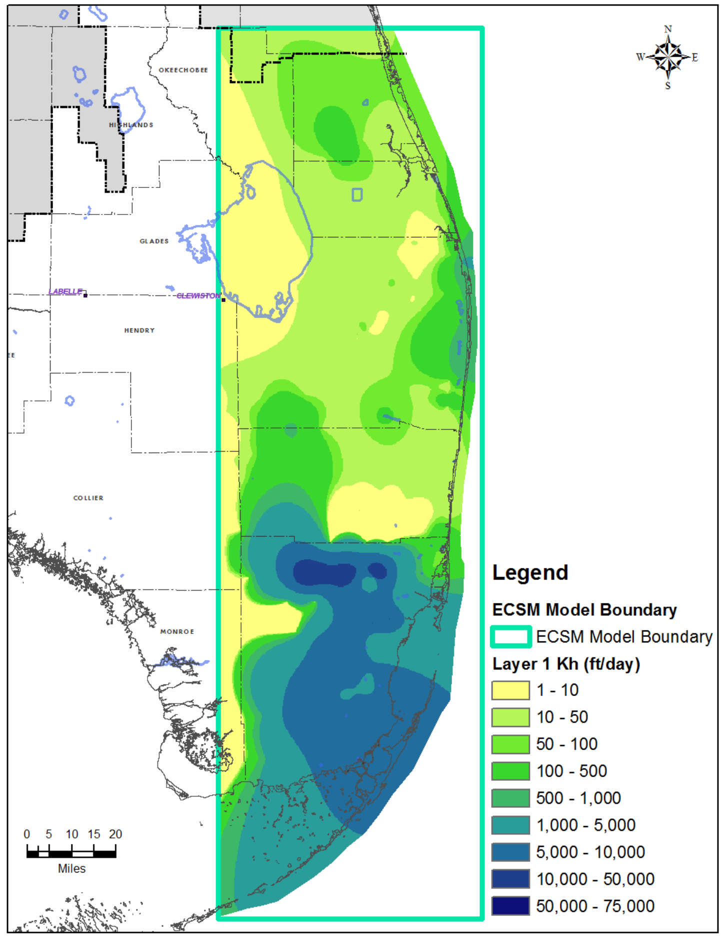
Hydraulic Conductivity of Layer 1



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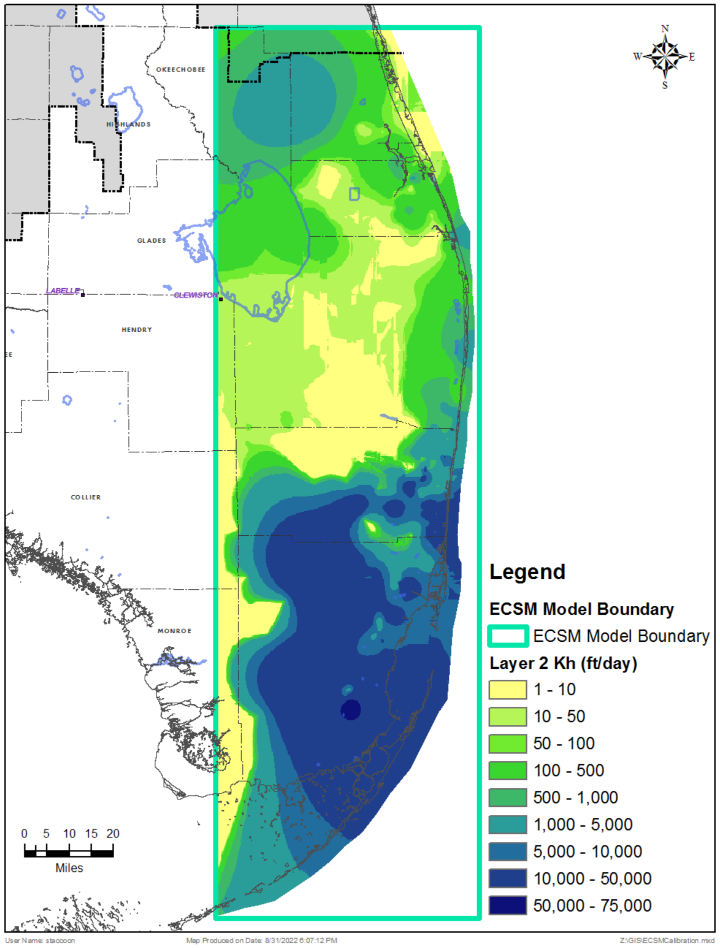
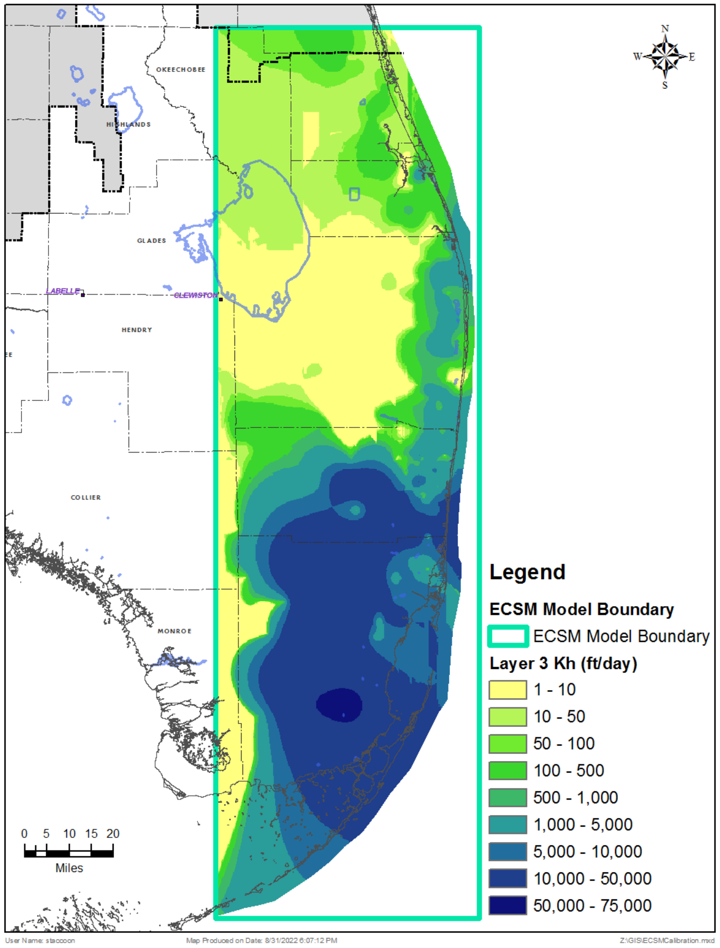
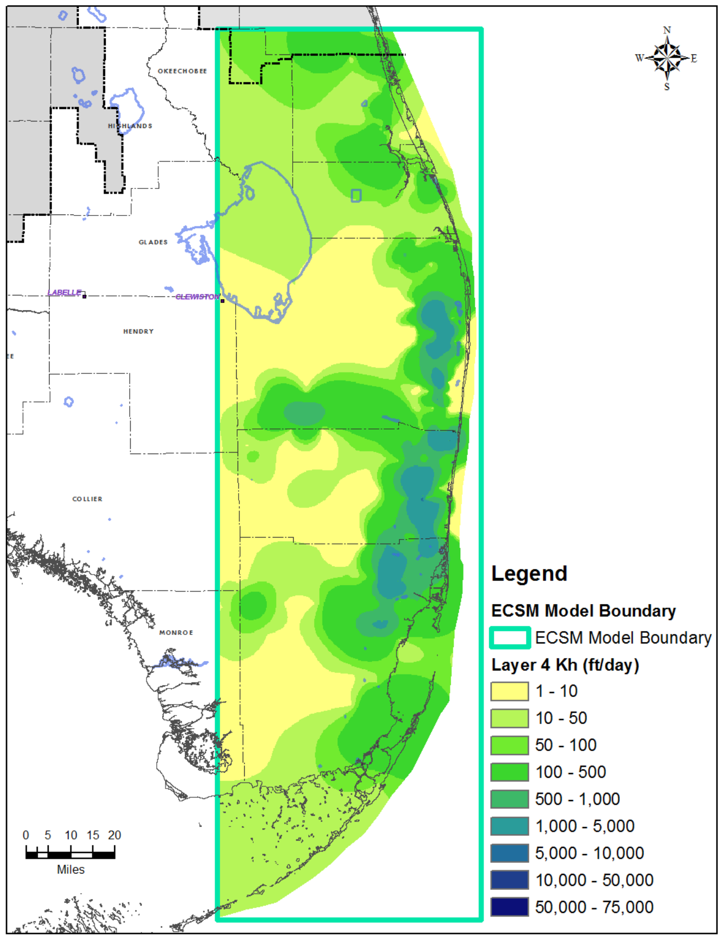
Hydraulic Conductivity of Layer 2



Hydraulic Conductivity of Layer 3



Hydraulic Conductivity of Layer 4



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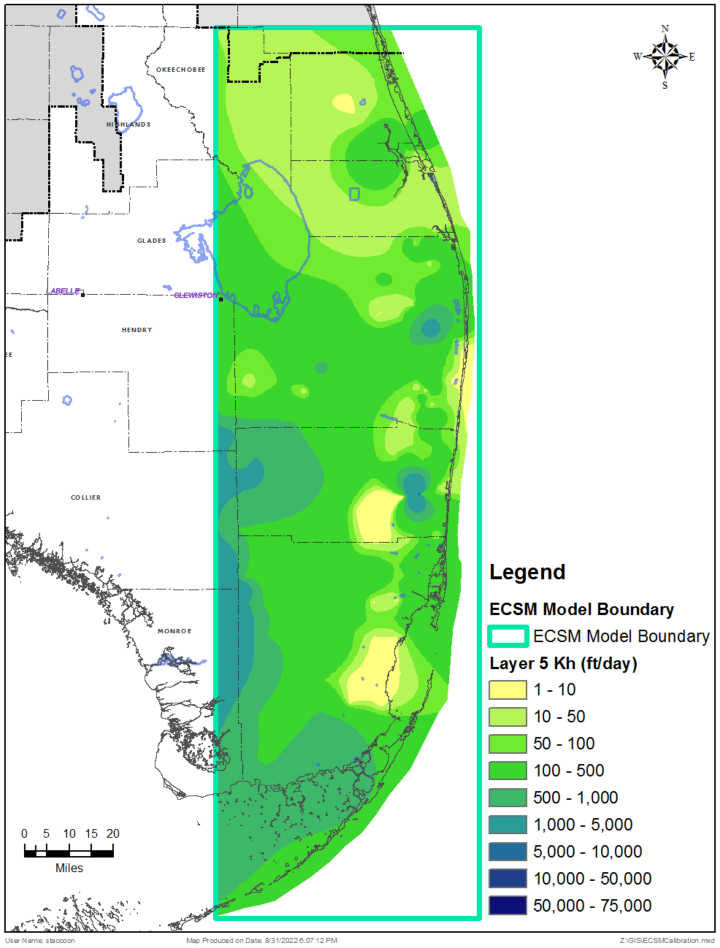
Hydraulic Conductivity of Layer 5



Saltwater Intrusion Mapping

Pete Kwiatkowski, P.G.

SFWMD Saltwater Interface Mapping Project

- Strategy -- Compare interface positions (i.e., 2009, 2014, 2019), note areas of concern, adjust monitoring, and adapt as necessary
- Update maps every 5 years
- Use all available data (USGS, SFWMD, Counties, Water Use Permittees)
- Furthest inland extent – dry season
- 250 milligrams per liter (mg/L) chlorides (isochlor)
- Coastal aquifers except Miami-Dade (USGS)

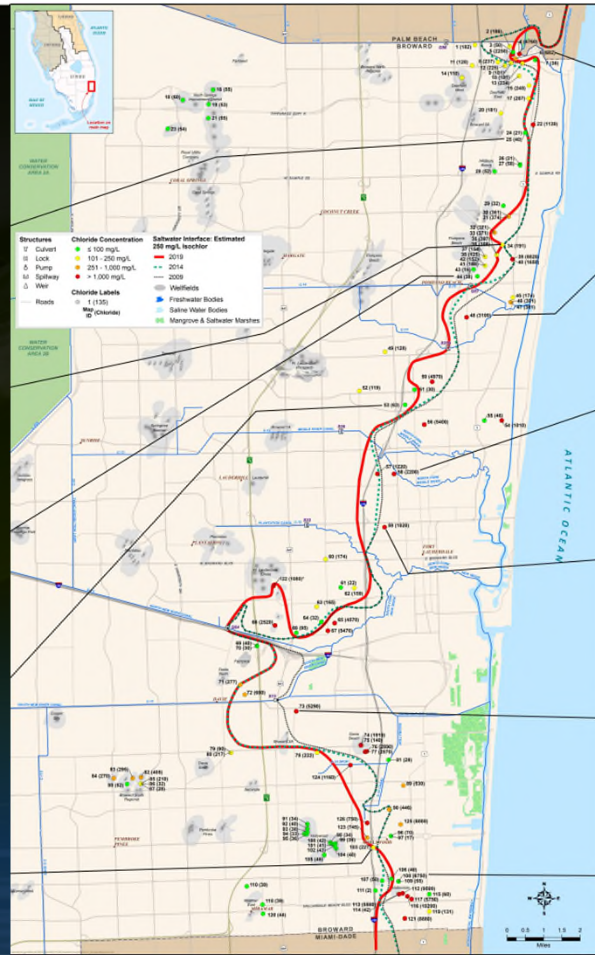
Data

Map ID	SFWMD Facility ID	Project Name	Well Name	XCOORD	YCOORD	Cased Depth (feet lbs)	Total Depth (feet lbs)	Chloride (mg/L)
1	115935	DEERFIELD BEACH PUBLIC WATER SUPPLY	D1-A (G2718)	944746	725422	100	150	182
2	149498	DEERFIELD BEACH PUBLIC WATER SUPPLY	D11 (G2729)	949765	725218	20	180	186
3	115984	DEERFIELD BEACH PUBLIC WATER SUPPLY	CWI	950221	724407	150	160	50
4	115976	DEERFIELD BEACH PUBLIC WATER SUPPLY	D12 (G2730)	951147	724120	20	180	4760
5	115985	DEERFIELD BEACH PUBLIC WATER SUPPLY	CWD	950198	724065	190	200	2250
6	115978	DEERFIELD BEACH PUBLIC WATER SUPPLY	D13 (G2731)	950594	723439	20	170	682
7		BROWARD COUNTY / USGS	FP MW-1 (G-2892)	953429	723245	108	155	36
8	149548	DEERFIELD BEACH PUBLIC WATER SUPPLY	D10 (2728)	948052	722957	20	180	237
9	115943	DEERFIELD BEACH PUBLIC WATER SUPPLY	D7 (G2725)	949933	722800	60	170	181
10	115979	DEERFIELD BEACH PUBLIC WATER SUPPLY	D14-A (G2733)	951596	722753	100	150	181
11	115936	DEERFIELD BEACH PUBLIC WATER SUPPLY	D2-A (G2719)	944329	722439	100	150	128
12	115982	DEERFIELD BEACH PUBLIC WATER SUPPLY	D17 (G2737)	949053	722435	100	150	225
13	115980	DEERFIELD BEACH PUBLIC WATER SUPPLY	D15-A (G2735)	951110	720940	100	150	234
14	115983	DEERFIELD BEACH PUBLIC WATER SUPPLY	DR-1 (G2738)	942847	720664		170	110
15	115981	DEERFIELD BEACH PUBLIC WATER SUPPLY	D16 (G2736)	952549	719549	10	260	245
16	6428	NORTH SPRINGS IMPROVEMENT DISTRICT	4	906867	718939	80	130	55
17	115942	DEERFIELD BEACH PUBLIC WATER SUPPLY	D6 (G2724)	952492	717676	60	180	207
18	6431	NORTH SPRINGS IMPROVEMENT DISTRICT	9	902493	717446	80	130	60
19	6424	NORTH SPRINGS IMPROVEMENT DISTRICT	6	906227	716828	80	130	53
20	115973	DEERFIELD BEACH PUBLIC WATER SUPPLY	D9 (G2727)	948468	715524	80	180	181
21	6425	NORTH SPRINGS IMPROVEMENT DISTRICT	7	906186	714820	80	130	55
22	136498	BROWARD COUNTY 2A/NORTH REGIONAL P W S	G-2893	953145	713873	167	177	1130
23	6423	NORTH SPRINGS IMPROVEMENT DISTRICT	2A	900319	713297	80	130	54
24	136493	BROWARD COUNTY 2A/NORTH REGIONAL P W S	G-2694	952025	712690	85	125	21
25	136492	BROWARD COUNTY 2A/NORTH REGIONAL P W S	G-2693	953145	712686	200	229	40
26		USGS	G-2752	951245	708113	250	255	21
27	136873	TOWN OF HILLSBORO BEACH	HBBSW1(39th Street)	951253	707989		257	58
28	136872	TOWN OF HILLSBORO BEACH	HBBMP1 (plant 110)	947573	707104		110	52
29		BROWARD COUNTY / USGS	FP MW-3 (G-2277)	948831	702139	131	131	31.6
30	136306	POMPANO BEACH PUBLIC WATER SUPPLY	SWI4-D	949590	700570		200	361
31	136307	POMPANO BEACH PUBLIC WATER SUPPLY	SWI4-S	949590	700570		120	374
32	136193	POMPANO BEACH PUBLIC WATER SUPPLY	SWI1D	947553	698254		200	371
33	136299	POMPANO BEACH PUBLIC WATER SUPPLY	SWI1-S	947553	698253		120	371
34		USGS	G-2445	948675	696456	117	132	255
35	136326	POMPANO BEACH PUBLIC WATER SUPPLY	SWI6-D	947869	695024		200	397
36	136327	POMPANO BEACH PUBLIC WATER SUPPLY	SWI6-S	947869	695024		120	108
37	136308	POMPANO BEACH PUBLIC WATER SUPPLY	SWI5-D	946184	694743		200	154
38	136325	POMPANO BEACH PUBLIC WATER SUPPLY	SWI5-S	946184	694743		120	125
39	136304	POMPANO BEACH PUBLIC WATER SUPPLY	SWI3-D	950151	694392		180	8820
40	136305	POMPANO BEACH PUBLIC WATER SUPPLY	SWI3-S	950151	694392		120	1650

Broward County
Estimated Position of the Saltwater Interface

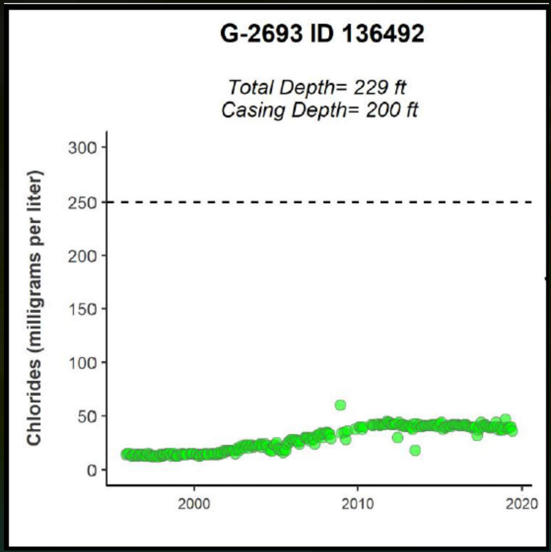
Surficial Aquifer System

March/April/May 2019

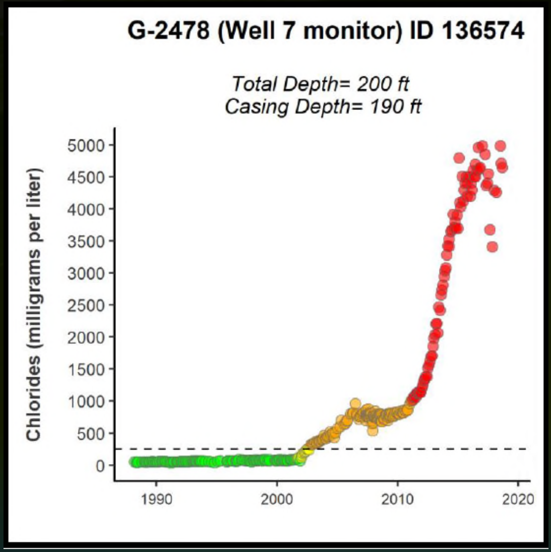


Chloride Time-Series Graphs West and East of the Interface

West



East



SOUTH FLORIDA WATER MANAGEMENT DISTRICT

SEAWAT2022

Kevin A. Rodberg

Enhancements to SEAWAT-2000WMD
Variable Density Flow (VDF) and Integrated MT3DMS Transport Processing (IMT)
with the District "WMD packages" including:
-- Reinjection Drainflow (RDF)
-- Multi-Operation Diversion (MDIV)
-- Block Centered Flow Wetlands (BCF_WTL)
-- and a new Layer Property Flow Wetlands (LPF_WTL)

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SEAWAT Background and How is it Related to MODFLOW?

SEAWAT-2000[1] is a coupled version of MODFLOW-2000[2] and MT3DMS[3] [as published by the USGS] designed to simulate three-dimensional, variable density groundwater flow and multi-species transport.

SEAWAT is generally divided into 3 processes: [GWF, VDF, IMT] + LMT

- "Variable Density Flow" (VDF) process in SEAWAT is based on the constant density "Ground Water Flow" (GWF) process of the MODFLOW packages.
- The VDF process uses the MODFLOW and MT3DMS methodologies to solve the variable density groundwater flow with variable density versions of the GWF packages.
- Integrated MT3DMS Transport (IMT) process code provides the solute transport equations.
- Linked Mass Transport (LMT) is the coupling of Modflow and MT3DMS passing data between GWF or VDF and IMT processes

[1] SEAWAT-2000 [ver 4.00.05] Langevin et al., 2003

[2] MODFLOW-2000 [ver 1.18.01 06/20/2008 w/Bug fixes added thru 01/09/2012] Harbaugh et al., 2000

[3] MT3DMS [ver 5.20 10/30/2006] Zheng and Wang, 1999; Zheng, 2006

To Meet the Objectives of the ECSM

New MODFLOW and SEAWAT
Features were Needed:

Combine Groundwater Flow [GWF] processes
supported in SEAWAT-2000WMD by "WMD packages"
with SEAWAT's Variable Density Flow [VDF] and
Integrated Mass Transport [IMT] processing

The Original "WMD Packages"

Were enhancements to MODFLOW 96 and SEAWAT-2000 code
implemented as MODFLOW Packages
were developed as GWF

The "WMD packages" needed for ECSM

WTL, RDF, UGEN, MDIV

Features Needed for ECSM Were the Primary Focus of the SEAWAT2022 Development

ECSM required variable density [VDF] and

solute transport [IMT]

… so these packages required SEAWAT enhancements:

- Re-injection Drainflow (RDF)
- Multi-operation Diversion (MDIV)
- New Layer Property Flow Wetlands (LPF_WTL)
  - LPF provides a more robust approach to vertical conductance compared to BCF's VCONT approach

Focus of the SEAWAT2022 Development - Continued

Enhancements to Transport packages

To properly simulate open water conditions in wetland areas required adjusted porosity, diffusion and dispersivity equations

Due to ECSM's large domain, specialized subroutines facilitate:

- Reading ET and Recharge from binary input
- Saving concentration as monthly binary rather than daily
- Efficient management of transport source and sinks

SEAWAT2022 Code Development Phases

Phase	Base	+	=	Description
0	SEAWAT-2000wmd	SEAWATv4 [2012]	SEAWAT-2012wmd	Merge Code
1	SEAWAT-2012wmd	LPF Wetland Package	SEAWAT-2020wmd	LPF Wetlands
2	SEAWAT-2020wmd	VDF Wetlands VDF WMD Packages	SEAWAT-2020vdf	VDF Wetlands
3	SEAWAT-2020vdf	Transport Wetlands	SEAWAT-2020mt3d	Transport Wetlands
4	SEAWAT-2020mt3d	Transport WMD pkgs Openwater Transport	SEAWAT2022	OW Transport with Transport WMD

Phase 0 – Merge Code

SEAWAT-2000wmd + SEAWATv4 [2012] = SEAWAT-2012wmd

Merge Code

SEAWAT-2000WMD code was updated
to be consistent with USGS SEAWATv4 2008
including the USGS bug fixes through 2012

Phase 1 – LPF Wetlands Package

SEAWAT-2012wmd + LPF Wetland Package = SEAWAT-2020wmd

LPF Wetlands

Provides a Groundwater Flow [GWF] version

of the LPF wetlands package

added to SEAWAT 2012 code with WMD packages

SEAWAT Main Subroutines Called for LPF Wetlands

wtl6_2000.f:: SUBROUTINE WTL6LPFRS New "Read and Prepare"

Purpose: Read the wetland input data and call SGWF1LPF1N_WTL

LPF uses HK instead of HY

wtl6_2000.f:: SUBROUTINE SGWF1LPF1N_WTL New "Initial Vertical Conductance"

Purpose: Calculate initial Vertical Conductance and Storage Terms

LPF uses HK instead of HY

LPF uses LAYWET from COMMON instead of BCF IWDFLG

gwflpf1_wtl.F:: SUBROUTINE GWF1LPF1FM_WTL New "Formulate and Solve"

Purpose: add leakage correction and storage to HCOF and RHS; and calculate conductance.

or convertible layers, vertical and horizontal conductance is recalculated w/ SGWF1LPF1HCOND_WTL and SGWF1LPF1VCOND_WTL with each LPF call vs just horizontal w/ SGWF1BCF6H_WTL for BCF.

Key Logic for Wetland Package code:

```
IF (LAYTYP.EQ.1) THEN ! [unconfined necessary for wetlands]
  IF (LAYER.EQ.1 .AND. IBND_WTL.GT.0) THEN
```

Wetland leakage & storage are handled w/2 storage capacities just as confined and unconfined aquifers, except that wetland specific yield is substituted for the secondary storage capacity (SC2)

```
  ELSE ! [outside wetlands in unconfined layer 1]
```

Leakage and storage are handled with two storage capacities (SC1 and SC2)

```
ELSE IF (LAYTYP.NE.0 .AND. LAYTYP.NE.1) THEN
```

Normal LPF for LAYTYP >0 Included to simplify differences in previous code.

LAYTYP .EQ. 3 w/BCF wetlands runs for layer 2 & 3 = convertible confined/unconfined

Leakage and storage are handled with two storage capacities (SC1 and SC2)

```
ELSE IF (LAYTYPE .EQ. 0) THEN ! [non-convertible aka confined]
```

A single/primary storage capacity (SC1) is used.

gwflpf1_wtl.F:: SUBROUTINE SGWF1LPF1S_WTL New "Compute Storage Budget"

Purpose: Computes Storge budget flow term.

Key Logic for Wetland Package vs. LPF code:

```
IF (LAYER.EQ.1) THEN
  IF (IBND_WTL.GT.0) THEN !(within the wetland boundary)
```

wetland storage is handled w/ two storage capacities in the same manner as confined and unconfined aquifers, except the wetland specific yield (SYWTL) is used instead of secondary storage capacity (SC2).

```
  ELSE !(Outside the wetland boundary in layer 1) (SC1 and SC2 ) are used.
ELSE IF LAYTYP.NE.0 !(convertible) two storage capacities (SC1 And SC2) are used.
ELSE ! (confined) a single, primary storage capacity. (SC1)
```

gwflpf1_wtl.F:: SUBROUTINE SGWF1LPF1HCOND_WTL New "Horizontal Branch Conductance"

Purpose: Computes Horizontal Conductance

Key Logic for Wetland Package vs. LPF code:

```
IF (THCK.LE. .000005) THEN ! [if sat thickness of layer 1 wetland is very, very thin]
  CC= 0.0 ![transmissivity = 0.0]
ELSE IF (LAYER.EQ.1 .AND. IBND_WTL.GT.0) THEN
  IF (LAYAVG .EQ. 2) THEN
```

[UNTESTED: arithmetic mean of saturated thickness & log mean hydraulic conductivity (for unconfined aquifers with gradually varying Transmissivities]

```
  ELSE
```

[TESTED: layavg .eq. 0 for harmonic mean & UNTESTED layavg .eq 1 for Log mean]

convert BCF equation CC (transmissivity) to Branch Conductance value needed by LPFHARM equation

```
CC(J,I,KB)=(THCK1**BETA(J,I))*HK(J,I,KB)+ZTHCK*HYMUC(J,I)
CC(J,I,KB)=CC(J,I,KB)/HK(J,I,KB)
```

gwflpf1_wtl.F:: SUBROUTINE SGWF1LPF1VCOND_WTL New "Vertical Branch Conductance"

Purpose: Computes Vertical Conductance

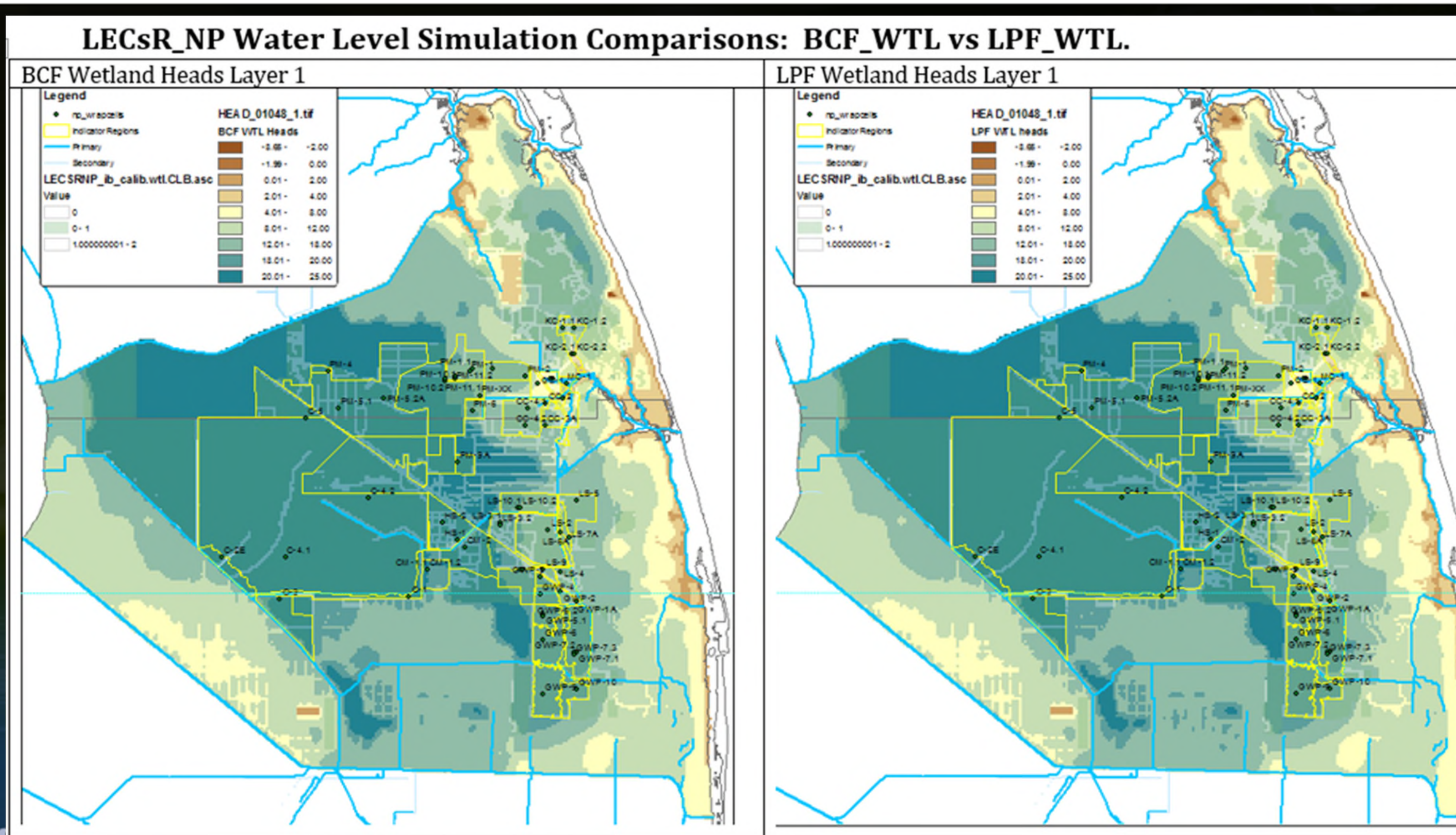
Key Logic for Wetland Package vs. LPF code:

```
IF LAYER.EQ.1 .AND. IBND_WTL.GT.0
```

Calculate sat thickness in wetland cell and for cell below and then calculate vertical hydraulic conductivity

```
CV(J,I,K)=((THCKW*.5/HYC1)+(THCK2*.5/HYC2))+(ZTHCK/VHYM)
CV(J,I,K)= DELR(J)*DELC(I) / CV(J,I,K)
```

Head Difference Map Comparing BCF vs. LPF Within the Wetland Boundary Showing Nearly Identical Heads



Phase 2 – Variable Density Wetland and "WMD packages"

SEAWAT-2020wmd + VDF Wetlands / VDF WMD Packages = SEAWAT-2020vdf

VDF Wetlands

Provides variable density [VDF] versions of:

- Wetland packages
- "WMD packages" needing VDF [RDF, MDIV, UGEN]

Example Code Comparisons Highlight Code for the New Subroutines for WMD Packages

Compare pre-2020 BCF GWF1 with VDF1 subroutines:

GWF1BCF6FM	VDF1BCF6FM
GWF1BCF6H	VDF1BCF6H
GWF1BCF6S	VDF1BCF6S
GWF1BCF6F	VDF1BCF6F
GWF1BCF6B	VDF1BCF6B

Compare pre-2020 LPF GWF1 with VDF1 subroutines:

GWF1LPF1FM	VDF1LPF1FM
SGWF1LPF1S	SGWF1LPF1S
SGWF1LPF1F	SVDF1LPF1F
SGWF1LPF1B	SVDF1LPF1B
SGWF1LPF1HCOND	SVDF1LPF1HCOND
SGWF1LPF1HHARM	SVDF1LPF1HHARM
SGWF1LPF1HLOG	SVDF1LPF1HLOG
SGWF1LPF1HUNCNF	SVDF1LPF1HUNCNF
SGWF1LPF1VCOND	SVDF1LPF1VCOND

Comparing pre-2020 GWF and VDF process for Rivers and GHB

VDF1RIV6SSMDENSE	VDF1GHB6SSMDENSE
GWF1RIV6BD	VDF1RIV6BD
GWF1RIV6FM	VDF1RIV6FM
GWF1GHB6FM	VDF1GHB6FM
GWF1GHB6BD	VDF1GHB6BD
GWF1DRT1FM	VDF1DRT1FM
GWF1DRT1BD	VDF1DRT1BD
GWF1RDF6FM	GWF1DRT1FM
GWF1RDF6BD	VDF1DRT1BD

Example Code Comparison

GWF1LPF1FM (Clean up DO Loops and GOTOs)

```
      SUBROUTINE GWF1LPF1FM(HCOF,RHS,HOLD,SC1,HNEW,IBOUND,CR,CC,CV,HK,
     1      HANI,VKA,BOTM,SC2,DELR,DELC,DELT,ISS,KITER,KSTP,KPER,NCOL,
     2      NROW,NLAY,IOUT,WETDRY,WETFCT,IWETIT,IHDWET,HDRY,NBOTM,VKCB)
```

```
      DOUBLE PRECISION HNEW
```

```
C------FOR EACH LAYER: IF CONVERTIBLE, CALCULATE CONDUCTANCES.
      DO 100 K=1,NLAY
        KK=K
        IF(LAYTYP(K).NE.0) THEN
          CALL
SGWF1LPF1HCOND(HNEW,IBOUND,CR,CC,HK,HANI,DELR,DELC,BOTM,
     1      NBOTM,KK,KITER,KSTP,KPER,NCOL,NROW,NLAY,IOUT,WETDRY,
     2      WETFCT,IWETIT,IHDWET,HDRY)
        END IF
      END DO
      DO K=1,NLAY
        KK=K
        IF(K.NE.NLAY) THEN
         IF(LAYTYP(K).NE.0 .OR. LAYTYP(K+1).NE.0)
     1      CALL SGWF1LPF1VCOND(CV,HK,VKA,VKCB,IBOUND,BOTM,NBOTM,KK,
     2         NCOL,NROW,NLAY,HNEW,DELR,DELC,IOUT)
        END IF
      END DO
```

```
C------SEE IF THIS LAYER IS CONVERTIBLE OR NON-CONVERTIBLE.
         IF(LAYTYP(K).EQ.0) THEN
C------NON-CONVERTIBLE LAYER, SO USE PRIMARY STORAGE
            DO I=1,NROW
              DO J=1,NCOL
                IF(IBOUND(J,I,K).GT.0) THEN
                  RHO=SC1(J,I,K)*TLED
                  HCOF(J,I,K)=HCOF(J,I,K)-RHO
                  RHS(J,I,K)=RHS(J,I,K)-RHO*HOLD(J,I,K)
                END IF
              END DO
            END DO
```

VDF1LPF1FM (Clean up DO Loops and GOTOs)

```
      SUBROUTINE VDF1LPF1FM(HCOF,RHS,HOLD,SC1,HNEW,IBOUND,CR,CC,CV,HK,
     1      HANI,VKA,BOTM,SC2,DELR,DELC,DELT,ISS,KITER,KSTP,KPER,NCOL,
     2      NROW,NLAY,IOUT,WETDRY,WETFCT,IWETIT,IHDWET,HDRY,NBOTM,VKCB,
     3      INVSC)
```

```
      USE VDFMODULE,   ONLY: DENSEREF,PS,ELEV,HSALT,MFNADVFD
```

```
      DOUBLE PRECISION HNEW,HTMP
```

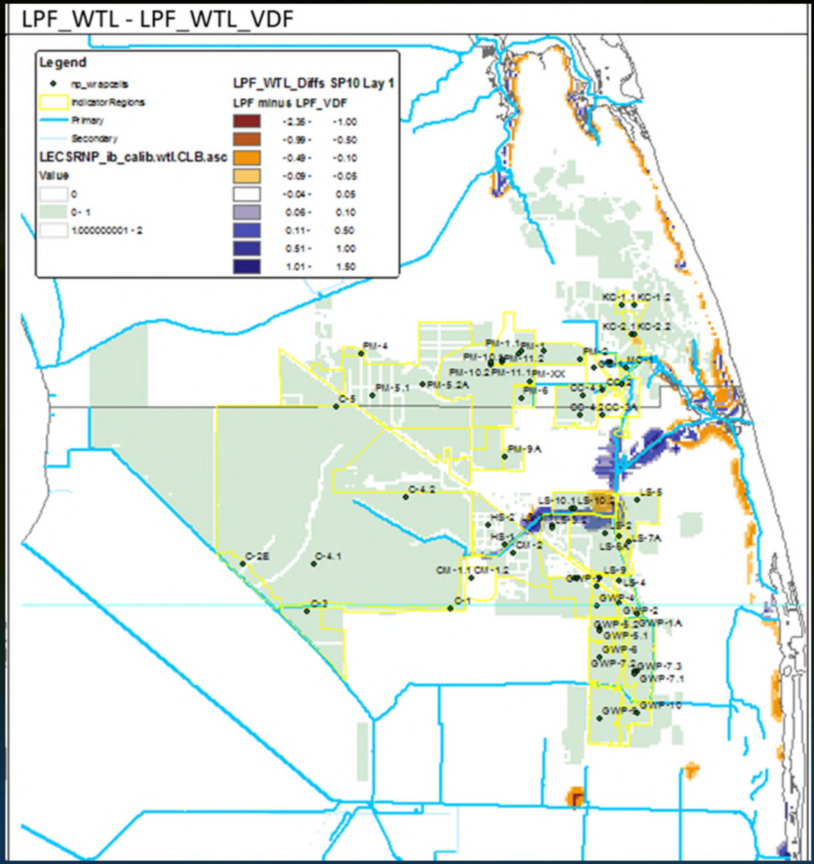
```
C------FOR EACH LAYER: IF CONVERTIBLE, CALCULATE CONDUCTANCES.
      DO K=1,NLAY
        KK=K
C--SEAWAT: THE FOLLOWING ROUTINE ALWAYS NEEDS TO BE CALLED IF VARIABLE
C--SEAWAT: VISCOSITY IS ACTIVE AND IT IS THE FIRST ITERATION
C--SEAWAT:      IF(LAYTYP(K).NE.0)
        IF (INVSC.GT.0.AND.KITER.EQ.1 .OR. LAYTYP(K).NE.0) THEN
            CALL
SVDF1LPF1HCOND(HNEW,IBOUND,CR,CC,HK,HANI,DELR,DELC,BOTM,
     1      NBOTM,KK,KITER,KSTP,KPER,NCOL,NROW,NLAY,IOUT,WETDRY,
     2      WETFCT,IWETIT,IHDWET,HDRY,HSALT,INVSC)
        END IF
      END DO
      DO K=1,NLAY
        KK=K
        IF(K.NE.NLAY) THEN
C--SEAWAT: THE FOLLOWING ROUTINE ALWAYS NEEDS TO BE CALLED IF VARIABLE
C--SEAWAT: VISCOSITY IS ACTIVE AND IT IS THE FIRST ITERATION
C--SEAWAT:         IF(LAYTYP(K).NE.0 .OR. LAYTYP(K+1).NE.0)
C--SEAWAT: PASSING IN HSALT INSTEAD OF HNEW (04/13/2007)
         IF(INVSC.GT.0.AND.KITER.EQ.1)
     2      CALL SVDF1LPF1VCOND(CV,HK,VKA,VKCB,IBOUND,BOTM,NBOTM,KK,
     3         NCOL,NROW,NLAY,HSALT,DELR,DELC,IOUT)
         IF(INVSC.EQ.0 .AND. (LAYTYP(K).NE.0 .OR. LAYTYP(K+1).NE.0))
     2      CALL SGWF1LPF1VCOND(CV,HK,VKA,VKCB,IBOUND,BOTM,NBOTM,KK,
     3         NCOL,NROW,NLAY,HSALT,DELR,DELC,IOUT)
        END IF
      END DO
```

```
C------SEE IF THIS LAYER IS CONVERTIBLE OR NON-CONVERTIBLE.
         IF(LAYTYP(K).EQ.0) THEN
C------NON-CONVERTIBLE LAYER, SO USE PRIMARY STORAGE
            DO I=1,NROW
              DO J=1,NCOL
                IF(IBOUND(J,I,K).GT.0) THEN
                  RHO=SC1(J,I,K)*TLED
C--SEAWAT: CONSERVE MASS
                  HCOF(J,I,K)=HCOF(J,I,K)-RHO*PS(J,I,K)
                  RHS(J,I,K)=RHS(J,I,K)-RHO*HOLD(J,I,K)*PS(J,I,K)
                END IF
              END DO
            END DO
```

Head Difference Map GWF - VDF

Nearly identical heads are shown in areas within the wetland boundary [pale green area] as expected, since WQ was fresh in the wetland areas.

Differences in this comparison highlight coastal salinity effects on heads.



Phase 3 – LPF Wetland Transport

SEAWAT-2020vdf + Transport Wetlands = SEAWAT-2020mt3d Transport Wetlands

Provides solute transport processes (IMT) for Wetland packages

- Implemented in new LMT subroutines

Code Comparisons for New Code

For example:

- LMT6LPF1 vs LMT6LPF1_WTL
- LMT6LPF1VD vs LMT6LPF1VD_WTL
- LMT6LPF1_WTL vs LMT6LPF1VD_WTL

Variable Density Transport Code Comparisons

LMT6LPF1VD

```
C--CALCULATE AND SAVE SATURATED THICKNESS
      TEXT='THKSAT'

      DO K=1,NLAY
        IF(LAYTYP(K).EQ.0) CYCLE
        DO I=1,NROW
          DO J=1,NCOL
            IF(IBOUND(J,I,K).NE.0) THEN
              TMP=HNEW(J,I,K)
              BUFF(J,I,K)=TMP-BOTM(J,I,LBOTM(K))
              THKLAY=BOTM(J,I,LBOTM(K)-1)-BOTM(J,I,LBOTM(K))
              IF(BUFF(J,I,K).GT.THKLAY) BUFF(J,I,K)=THKLAY

            END IF
          END DO
        END DO
      END DO

C--SAVE THE CONTENTS OF THE BUFFER
      IF(ILMTFMT.EQ.0) THEN
        IF (IOUT.EQ.INUHF) THEN
C          WRITE(IOUT) BUFF
          DH=BUFF

        ELSE
```

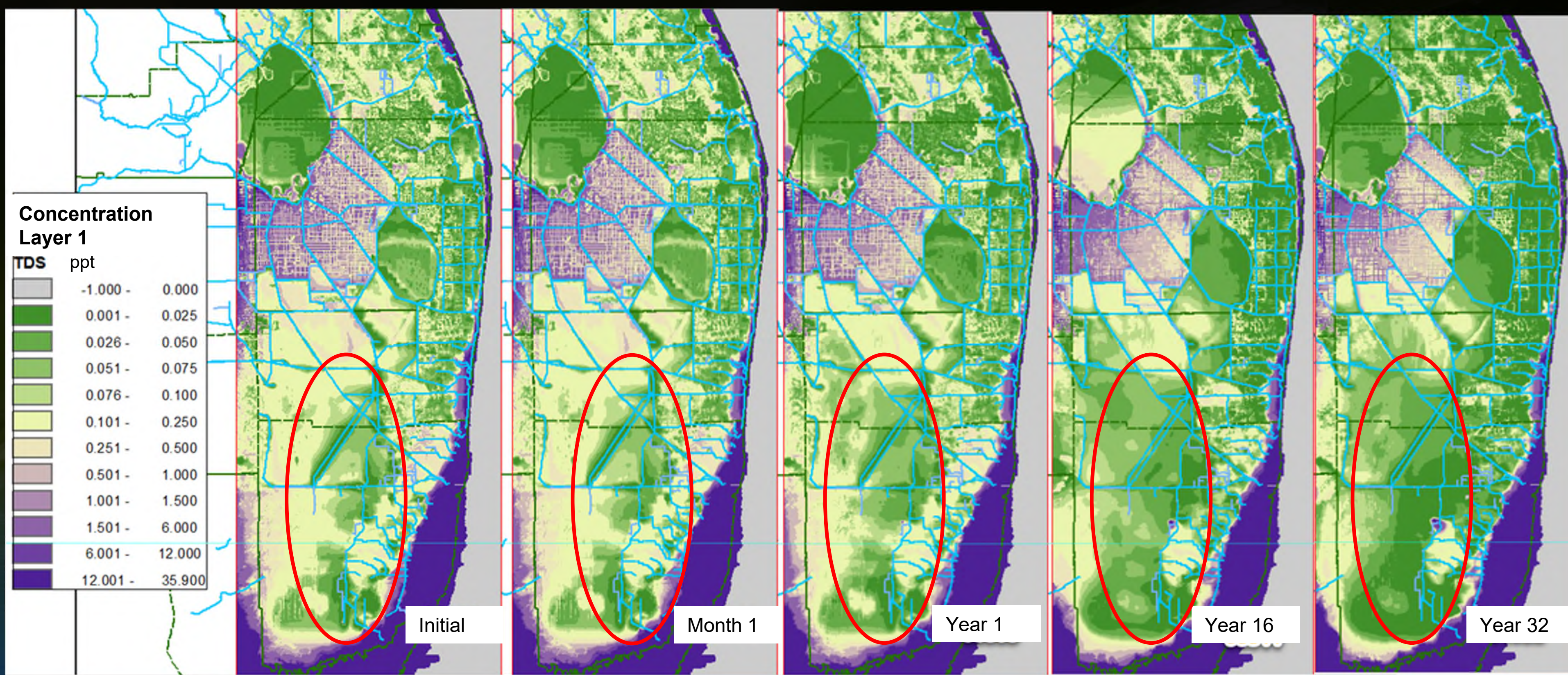
LMT6LPF1VD_WTL

```
C--CALCULATE AND SAVE SATURATED THICKNESS
      TEXT ='THKSAT'
      TEXT2='THKOPENWAT'                                   !WTL Open Water Transport

      DO K=1,NLAY
        IF(LAYTYP(K).EQ.0) CYCLE
        DO I=1,NROW
          DO J=1,NCOL
            IF(IBOUND(J,I,K).NE.0) THEN
              HHD=HNEW(J,I,K)
              BBOT=BOTM(J,I,LBOTM(K))                      !WTL
              TTOP=BOTM(J,I,LBOTM(K)-1)                    !WTL
              IF(LAYTYP(K).NE.0) THEN                      !WTL
                IF (HHD.LT.TTOP) TTOP=HHD                  !WTL
              END IF                                       !WTL
              THCK=TTOP-BBOT                               !WTL
              IF (THCK .LT.0) THEN                         !WTL
                  THCK = 0.0                               !WTL
              END IF                                       !WTL
              BUFF(J,I,K)=THCK                             !WTL
              THKLAY=BOTM(J,I,LBOTM(K)-1)-BOTM(J,I,LBOTM(K))
              IF(BUFF(J,I,K).GT.THKLAY) BUFF(J,I,K)=THKLAY
              BUFF2(J,I)= 0.0
            END IF
            IF((THCK.GT.0.000005) .and.                    !WTL
     &           (K.EQ. 1 .AND. IBND_WTL(J,I).GT.0)) THEN  !WTL
                HHD=HNEW(J,I,K)                            !WTL
                THCK=HHD-BOTM(J,I,K)                       !WTL
                ZTHCK = 0.0                                !WTL
                ZZBOTT = BOTM(J,I,0)                       !WTL
                IF (ZZBOTT.gt.HHD) ZZBOTT=HHD              !WTL
                ZTHCK = ZZBOTT - BOTM(J,I,K)               !WTL
                THCKMAX =  3.0                             !WTL
                THCK1 = THCK - ZTHCK                       !WTL
                IF(THCK1.lt.0.0) THCK1=0.0                 !WTL
                IF(THCK1.gt.THCKMAX) THCK1=THCKMAX         !WTL
C               head above muck (max=3)+ sat muck thickness
                BUFF(J,I,K)= THCK1  + ZTHCK                !WTL
C               head above muck
                BUFF2(J,I) = THCK1                         !WTL
            END IF
          END DO
        END DO
      END DO

C--SAVE THE CONTENTS OF THE BUFFER
      IF(ILMTFMT.EQ.0) THEN
        IF (IOUT.EQ.INUHF) THEN
C          WRITE(IOUT) BUFF
          DH=BUFF
          OW=BUFF2                                         !WTL Open Water Transport
        ELSE
```

Transport Concentrations Vary Over 32 Years Show Noticable Change in the Wetland Areas as Circled



Phase 4 – Transport for "WMD packages" and Adjustments for Open Water Wetlands

SEAWAT-2020mt3d + Transport WMD pkgs / Openwater Transport = SEAWAT2022

OW Transport with Transport WMD

- Integrate solute transport IMT processes for WMD packages

  RDF, MDIV, UGEN

- Porosity, Diffusion, and Dispersion to support OW Wetlands

Layer 0 Porosity Affects Most of the Transport Code

IMT Subroutine	Purpose
Blue indicates code with Adjustments for Open water Green indicates New subroutine	
IMT1BTN5DF	Dimension and simulation options
IMT1BTN5AL	Allocate Arrays
IMT1BTN5RP	Read and Prepare (Constant for Simulation)
IMT1BTN5ST	Stress Timing
IMT1BTN5AD	Advance Timestep and set next step size
IMT1BTN5SV	Formulate and Solve Transport Equation
IMT1BTN5FM	Formulate Matrix Coefficients
IMT1BTN5BD	Calculate Mass Budgets
IMT1BTN5OT	Save Outputs
IMT1FMI5AL	IF BTN Determine Flow Components Active
IMT1FMI5RP2A	Initialize SS array to 0.0
IMT1FMI5AL	Second call for Allocate Arrays
IMT1FMI5RP1	Calc Sat Thickness, fluxes, and flow rates
IMT1FMI5RP2	Read and process SS terms
IMT1ADV5AL	Allocate Space for Advection Array
IMT1ADV5RP	Reads Advection Input
IMT1ADV5SV SADV5M VRK4 SADV5B VRK4 PARMGR GENPTR GENPTN SADV5Q SADV5U CFACE	Calculates concentration at intermediate time level due to advection with the mixed Eulerian-Lagrangian schemes. Several subroutines and functions, specific to IMT1ADV5SV, required modifications to support appropriate handling of the OW and porosity adjustments.

IMT Subroutine	Purpose
IMT1ADV5FM	Formulate Matrix Coefficients
IMT1ADV5BD	Calculate Budget of Constant Concentration
IMT1TOB5AL	Allocate Space for Transport Observation Package
IMT1TOB5RP	Read Input data for TOB package
IMT1DSP5AL	Allocate Space for Dispersivity arrays
IMT1DSP5RP	Reads Dispersivity & Ratios as Well as Diffusion info
IMT1DSP5OW	Calculates open water adjusted longitudinal dispersion & diffusion
IMT1DSP5CF	Calculates components of DISP using DARCY w/porosity
IMT1DSP5FM	Formulate Matrix Coefficients for Dispersivity
IMT1DSP5BD	Calculates Mass Budget for Constant Concentration
IMT1SSM5AL	Allocate space for Source and Sink Mixing
IMT1SSM5RP	Read & Prepare concentration of source and sinks each SP
IMT1SSM5FM	Formulate Matrix Coefficients
IMT1SSM5BD	Calculate Budgets (Mass) all source & sinks terms
IMT1SSM5OT	Saves info for multi-node wells
IMT1RCT5AL	Allocate Space for chemical reaction arrays
IMT1RCT5RP SRCT5R	Read & Prepare input for reactions Calculates retardation factor and concentration of sorbed
IMT1RCT5CF SRCT5R	Update Reaction Coefficients Calculates retardation factor and concentration of sorbed
IMT1RCT5FM	Formulate Matrix Coefficients
IMT1RCT5BD SRCT5R	Calculate Mass Budget associated with reactions. Calculates retardation factor and concentration of sorbed
IMT1GCG5AL	Allocate Storage for Solver
IMT1GCG5RP	Read gcg input for solver package
IMT1GCG5AP	Generalized Conjugate Gradient Solver

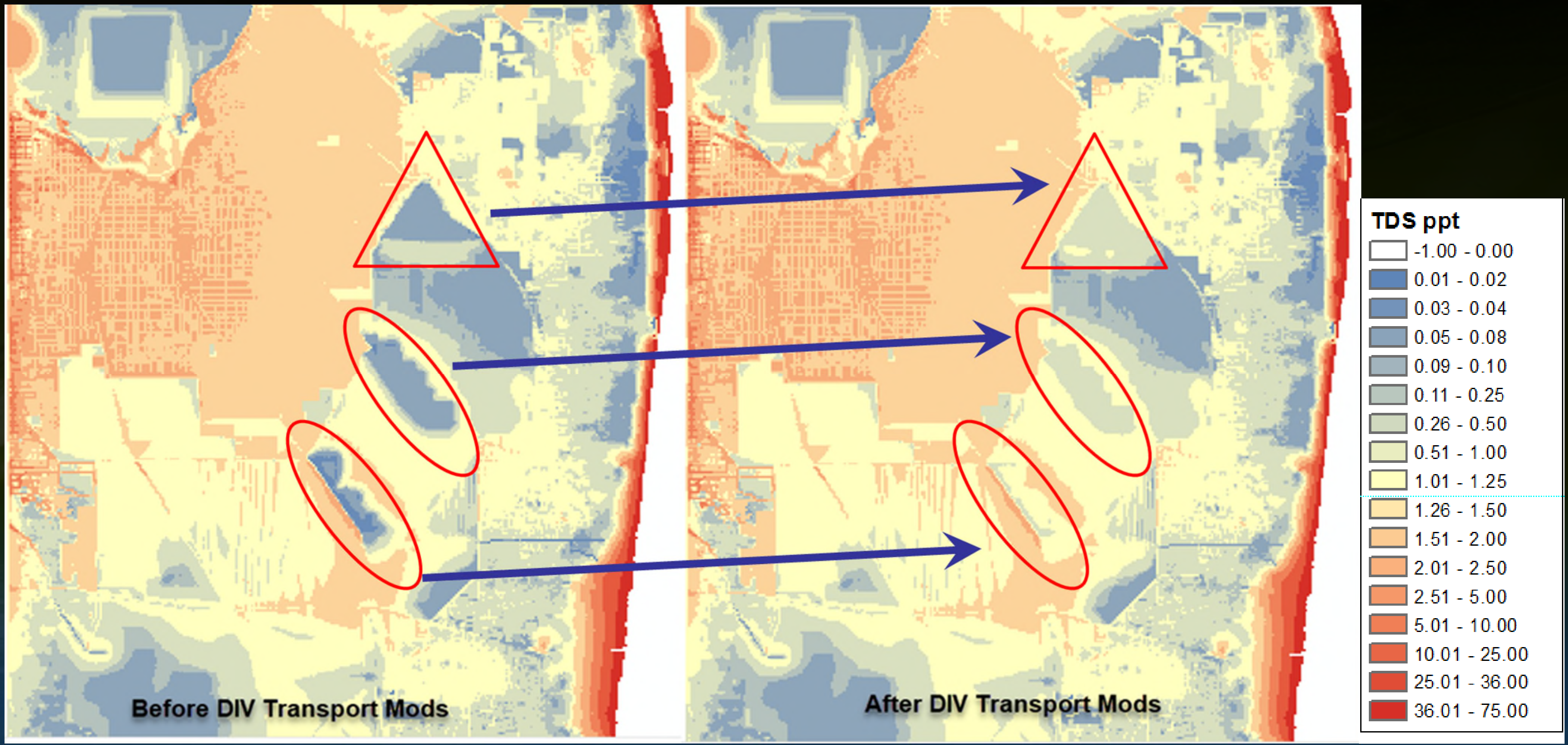
Porosity for Layer 0

```
      DIMENSION DELR(NCOL),DELC(NROW),DH(NCOL,NROW,NLAY),
     & OW(NCOL,NROW),RHOB(NCOL,NROW,NLAY),
     & SRCONC(NCOL,NROW,NLAY,NCOMP),PRSITY(NCOL,NROW,1-IWTL:NLAY)
----------------------------------------------------------------------
        IF (IWTL.EQ.1 .and. K.eq.1) THEN
CKAR-2021       ! Recalc Layer 1 Porosity as weighted Ratio of
CKAR-2021       ! Open Water to Saturated Muck Thickness
          PRSITY(J,I,1) = (PRSITY(J,I,0)*OW(J,I)/DZ(J,I,1))+
     &                    (PRSITYL1(J,I)*(1-(OW(J,I)/DZ(J,I,1))))
----------------------------------------------------------------------
        L0=0.0
        IF(K.EQ.1) L0=OW(J,I)
        DMSTRG=(CNEW(J,I,K,ICOMP)-COLD(J,I,K,ICOMP))
     &                   *DELR(J)*DELC(I)*(DH(J,I,K)+L0)*PRSITY(J,I,K)
```

Specialized Transport Handling for WMD Packages

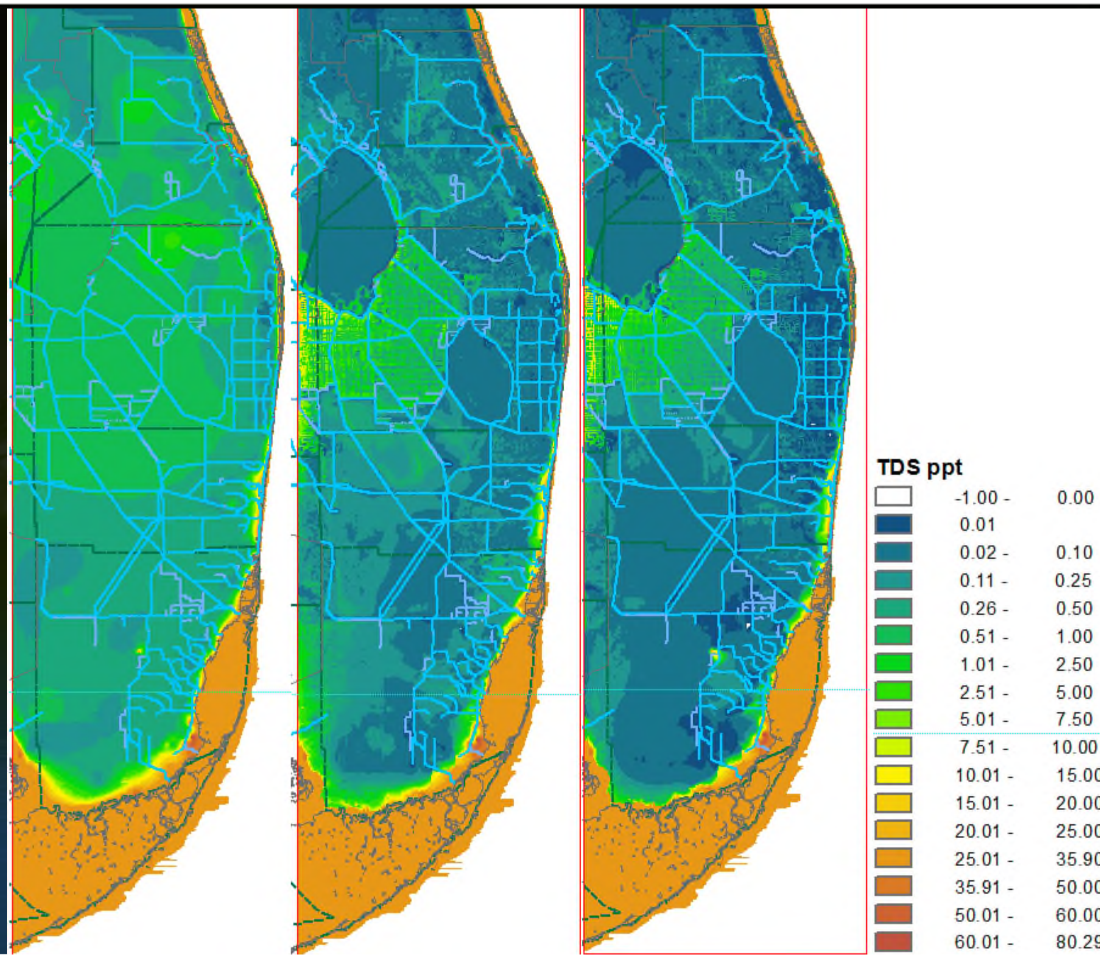
- Transport source WQ defaults to reference WQ for SEAWAT
- Source and Sink WQ may be defined using the SSM or AUX parameters
- RDF and MDIV now use source WQ to mix with sink WQ

Concentrations Before and After Transport Enhancement to Use Source WQ



Transient WQ Incorporating All WMD Packages with Transport

[Initial] [year 32] [year 64]



Example Problems with SEAWAT2022

20 example cases or problems were run with SEAWATv4 and SEAWAT2022

Heads and Concentrations were post processed, compared and found to show identical in most cases or virtually no differences

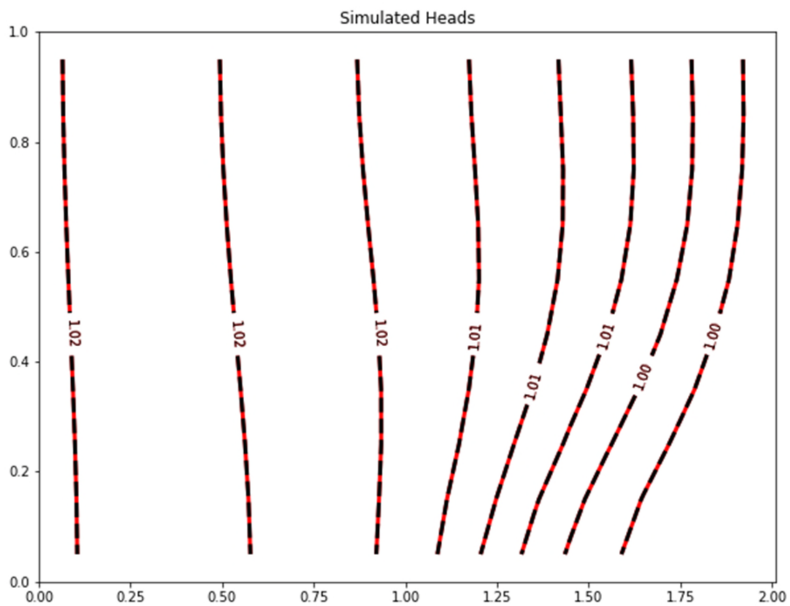
Example problems and cases:

Box	
	case1
	case2
Henry	
	classic case1
	classic case2
	VDF no Trans
	VDF uncpl Trans
	VDF DualID Trans
	age simulation
Elder	
	case1
hydrocoin	
	case1

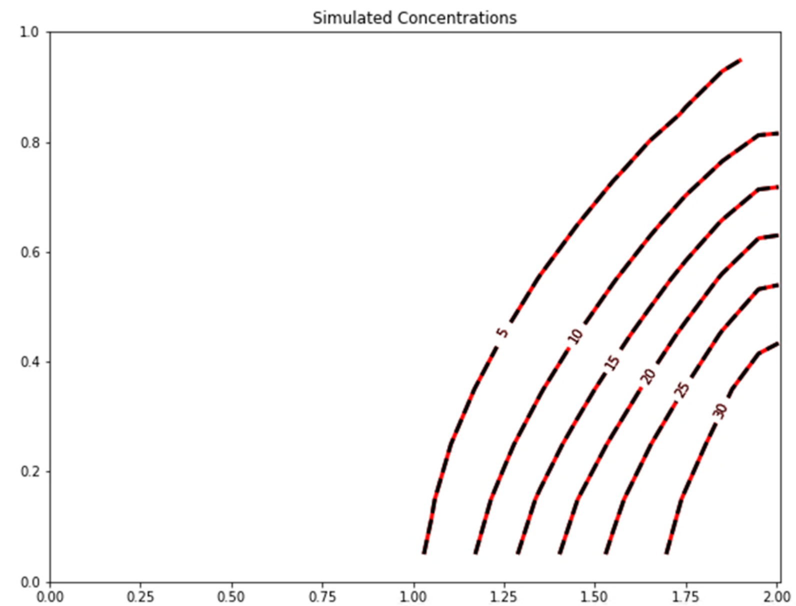
saltlake	
	case1
rotatation	
	symmetric
	asymmetric
swtv4_ex	
	case1
	case2
	case3
	case4
	case5
	case6
	case7

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Henry Problem Comparison



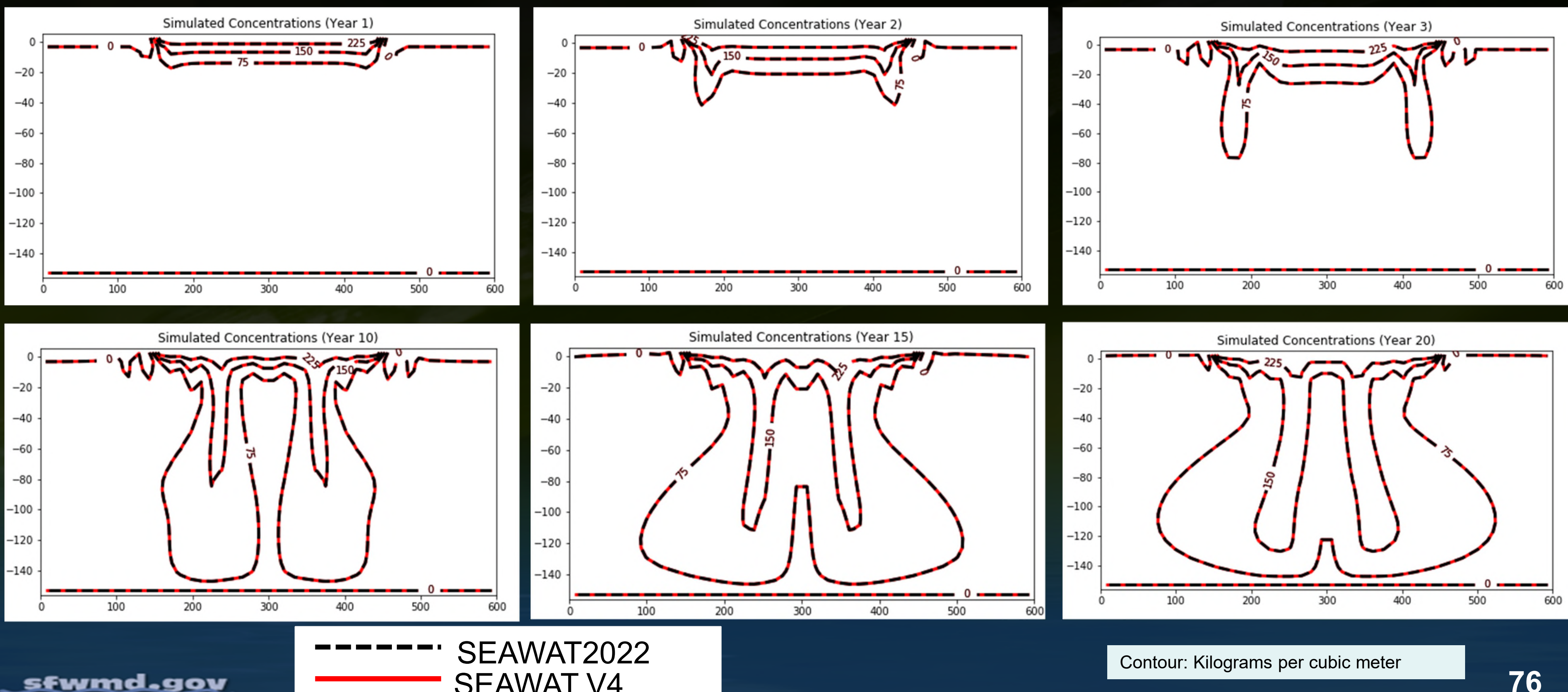
Contour: Meter



Contour: Kilograms per cubic meter

SEAWAT2022
SEAWAT V4

Elder Problem Comparison



Contour: Kilograms per cubic meter

Conclusions

- SEAWAT2022 created using SEAWAT2000 and existing WMD MODFLOW packages to achieve desired functionality
- Phased approach to code modifications ensured functionality and performance at each step
- Using existing MODFLOW model over portion of ECSM model domain, favorably compared performance of new LPF wetlands package (Phase 1) and VDF package (Phase 2)
- Successfully demonstrated code's ability to account for water quality changes over time
- Published example problems replicated to demonstrate SEAWAT2022 achieves virtually identical performance compared to SEAWAT2000
- SEAWAT2022 has therefore been demonstrated to function as designed and is the basis for use in ECSM – documentation to be provided to Panel via webboard

Panel Discussion

Biscayne Bay, Miami

Public Comment

Boca Chita, Biscayne Bay

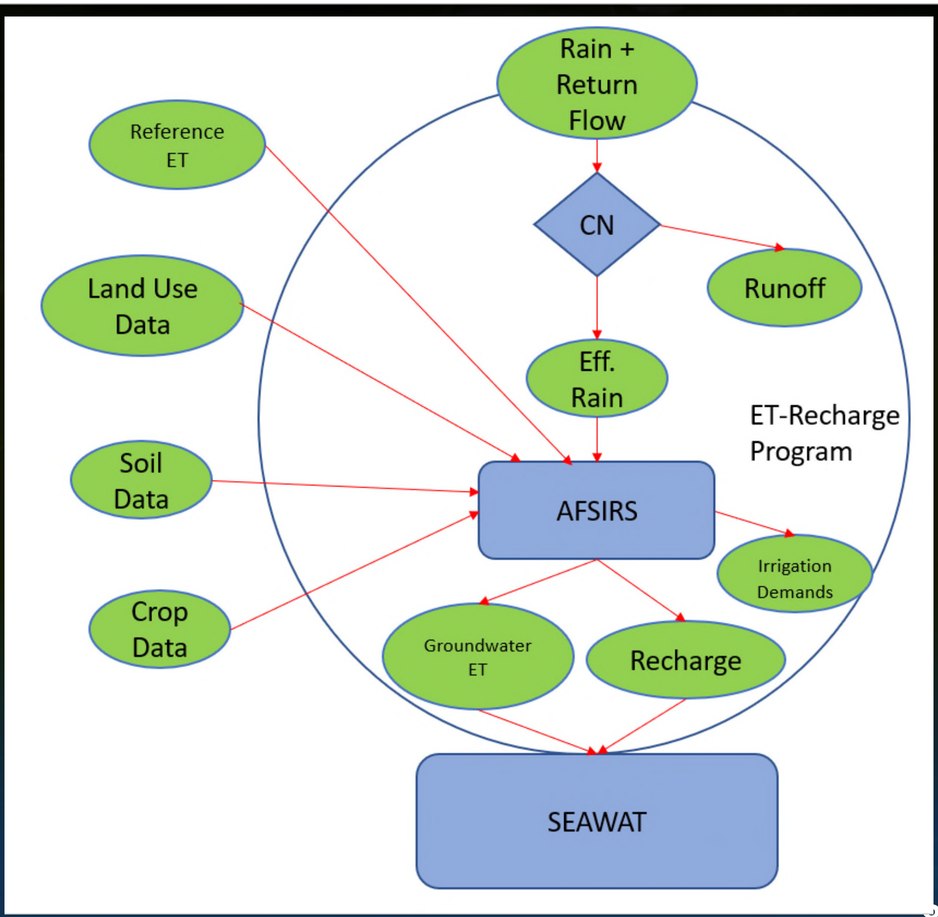
- If you are participating via <u>Zoom</u>:
  - Use the Raise Hand feature
- If you are participating via <u>phone</u>:
  - *9 raises hand
  - *6 mutes/unmutes your line
- When you are called on, please state your full name and affiliation prior to providing comments.

ET-Recharge Program and Return Flow

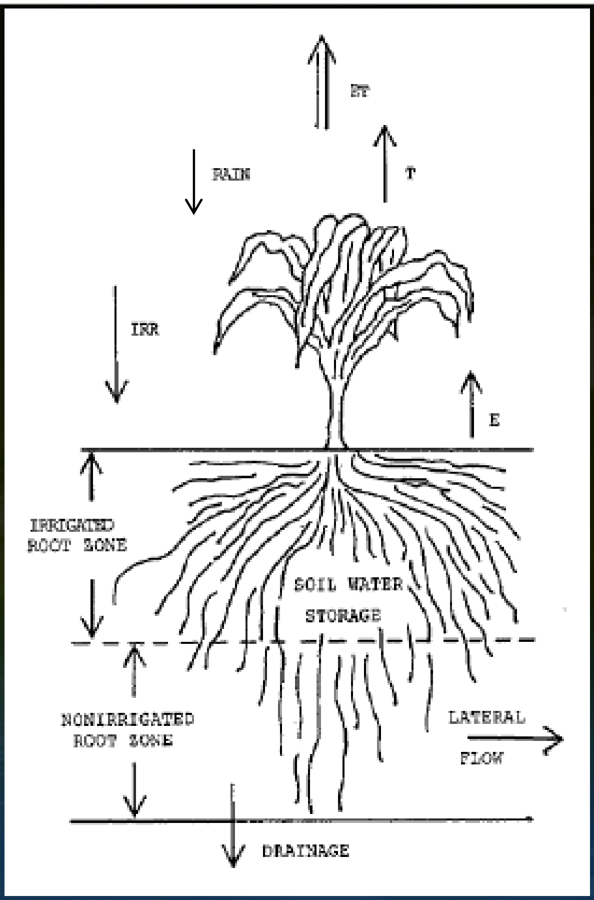
Yirgalem Assegid, Ph.D.
Alicia Magloire
Anushi Obeysekera, E.I.T.

ET-Recharge Program

- The ET-Recharge program is a pre-processing tool that estimates Evapotranspiration (ET) and Recharge that will be used as input into the groundwater model (Restrepo and Giddings, 1994)
- The ET-Recharge program incorporates the Agricultural Field-Scale Irrigation Requirement Simulation (AFSIRS; Smajstrla, 1990) method and the Curve Number Method (NRCS) to estimate runoff



General Information on AFSIRS



- AFSIRS is a root-zone daily water balance model
- Uses daily rainfall and ET, soil type, crop coefficients, irrigation types/efficiencies
- Calculates drainage (DR) and ET deficit from root zone (NIR)
- Drainage (DR) term is the recharge
- Non-irrigated areas
  - Total ET demand PET=RET*Kc (Kc=Crop Coeff.)
  - Potential groundwater ET=PET-unsaturated zone ET
- Irrigated areas
  - Assumes ET demand is met by the irrigation
- AFSIRS is not applied to saturated conditions, i.e. lakes, inundated wetlands, and rivers. In these areas
  - Recharge=Rainfall
  - ET=PET

Incorporation of Return Flow into ECSM

- Return flow to the Surficial Aquifer System (SAS), as applied to ECSM, is herein defined as anthropogenic-derived water being re-introduced to the saturated zone of the aquifer
- The primary mechanisms related to this process are:

    1) excess irrigation from agricultural, golf course and landscaping needs

    2) discharge from septic tank system drain fields

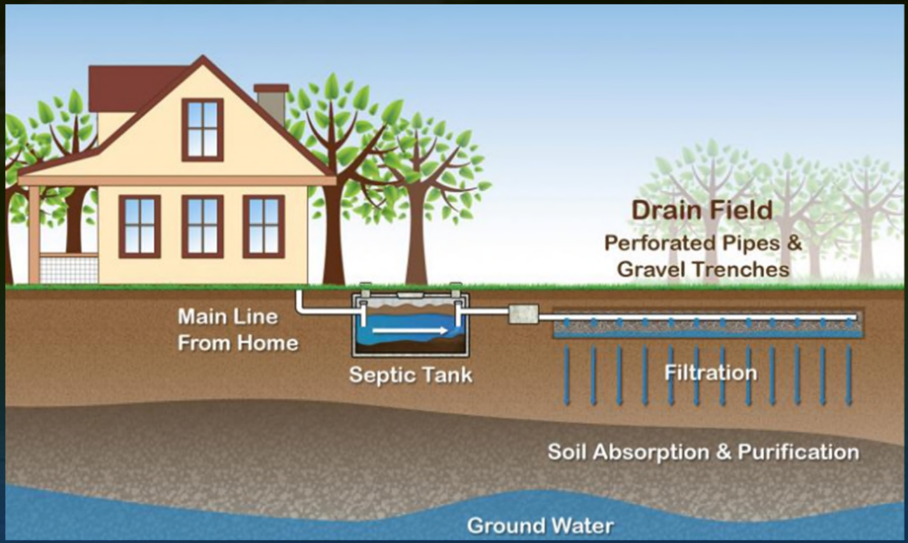
    3) disposal of treated wastewater to wetlands

ECSM Implementation of Return Flow for Irrigation Needs

- AFSIRS is used to calculate saturated zone ET and recharge rates for the model as well as irrigation demands that are then implemented into the model via the well file
- AFSIRS allows the user to specify the efficiency of the irrigation method, thereby allowing for the calculation of how much water re-enters the top model layer as return flow for irrigation
- As land development occurs through the calibration period, crop types, land use type and other conditions change, and irrigation demands are recalculated to account for this
- Other changes considered include:
  - Greater use of reclaimed water for landscape irrigation in the later part of the calibration period
  - Increased conversion of residential, domestic self-supply wells to public supply for irrigation associated with urbanization

ECSM Implementation of Return Flow for Residential Septic Tanks

- Some septic tank systems still occur within the model domain
- Return flow for septic is calculated using the population at each land use type, which is then multiplied by the indoor per capita use and estimated percent fraction returned to the unsaturated zone



Source: Minnesota Pollution Control Agency

ECSM Implementation of Return Flow for Supplemented Surface Water System

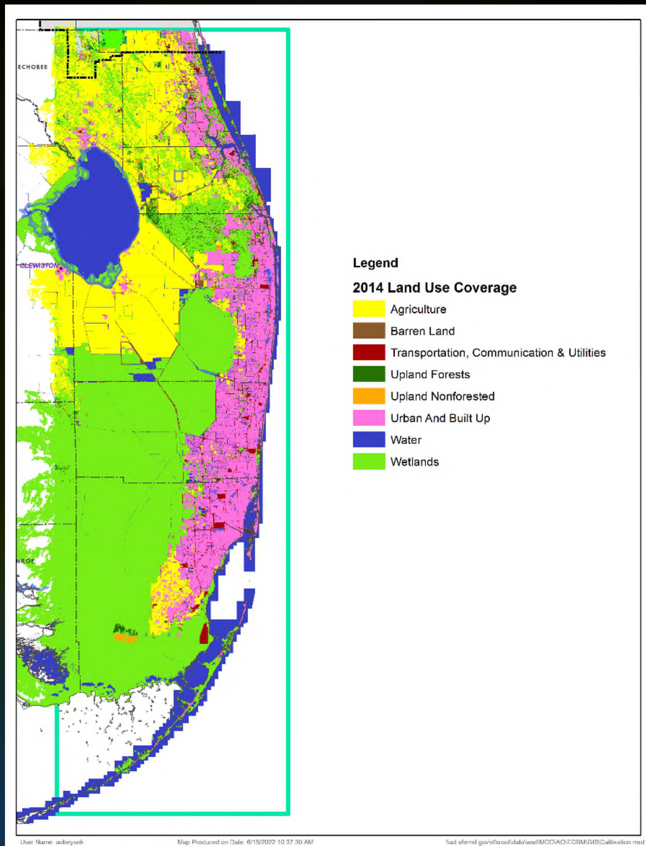
- The final form of return flow implemented in the model is that of reclaimed water applied to surface water bodies. Some examples include lake systems and wetland restoration projects being supplied water from wastewater treatment plants or from another alternative water supply source like the Floridan aquifer.
  - Depending upon the size and type, these systems will be simulated using:
    - The standard river and drain cell approach with the budget calculated to ensure correct seepage rates if the system is or acting like a canal recharge system
    - Large created wetland systems will be simulated using the wetlands package with water inflow into the system coming from observed values and as an outside source
    - Smaller lake systems are simulated by adjusting the layer 1 hydraulic conductivity at the site and applying the observed flow volumes from the outside source

QA/QC Check for Return Flows

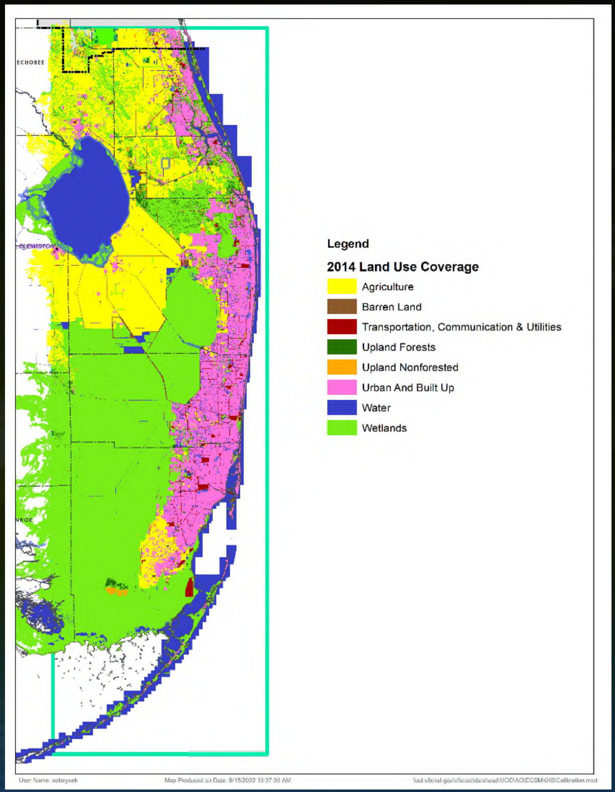
- QA/QC Check: All return flow volumes calculated by the methods discussed above will be summed up at the utility service area level and compared back against the difference between the Utility's treated public supply flow and subsequent waste-water return flows to determine if reasonable
- The primary calibration parameters will be the assumption of the areas being irrigated with public supply and the volume of irrigation and other forms of reuse simulated compared to the observed waste-water reuse plant flows

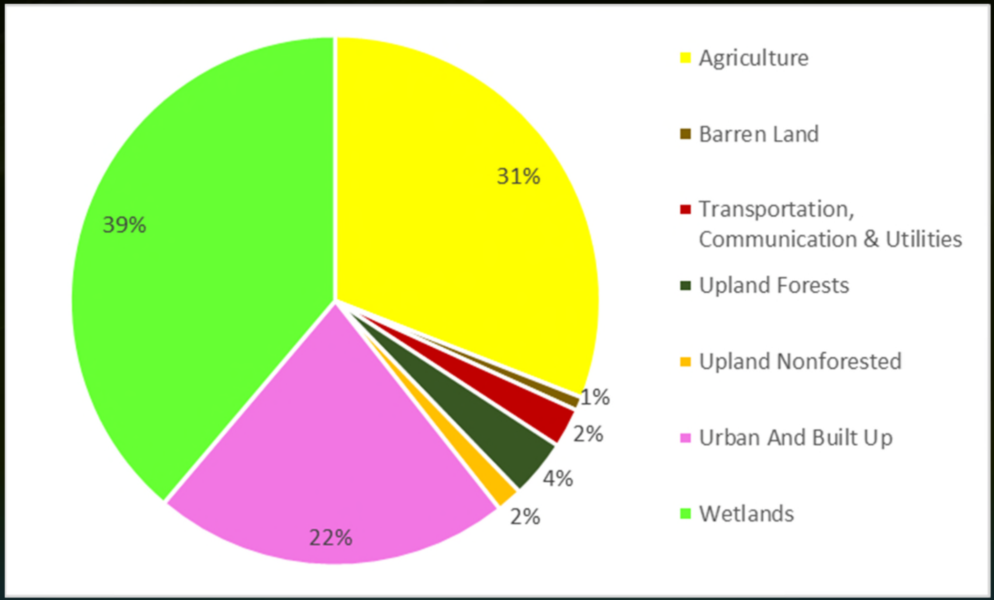
Land Use

- Model Calibration will use 6 land use maps
  - 1988 map for 01/01/1985 – 12/31/1993
  - 1995 map for 01/01/1994 – 12/31/1997
  - 1999 map for 01/01/1998 – 12/31/2002
  - 2004 map for 01/01/2003 – 12/31/2006
  - 2009 map for 01/01/2007 – 12/31/2012
  - 2014 map for 01/01/2013 – 12/31/2016



2014 Land Use

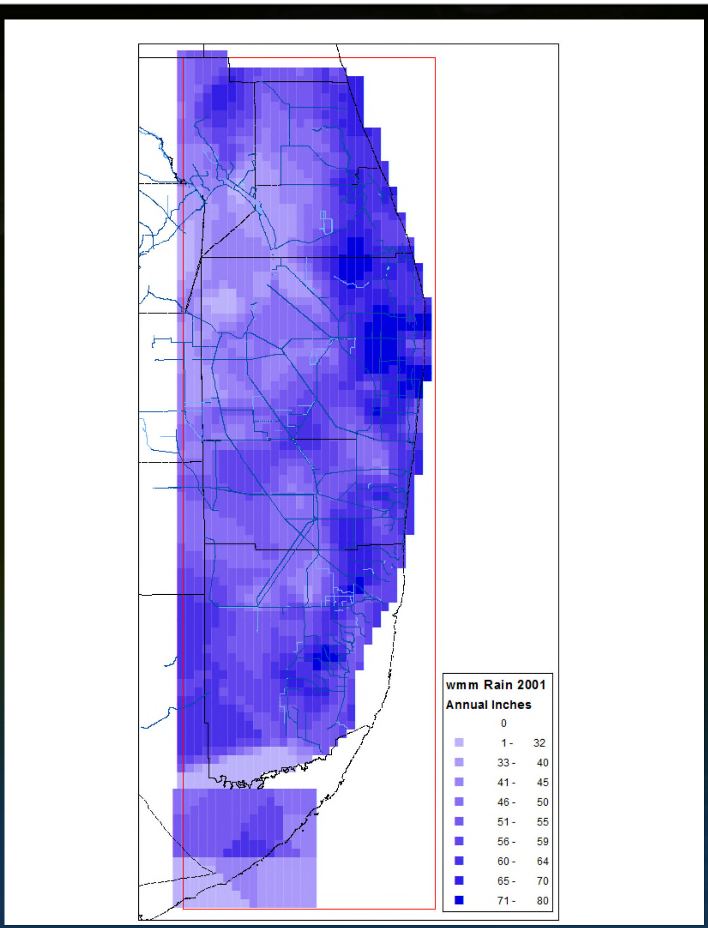




<u>NOTE:</u> Open water (e.g., Lake Okeechobee) was not included in percent calculations

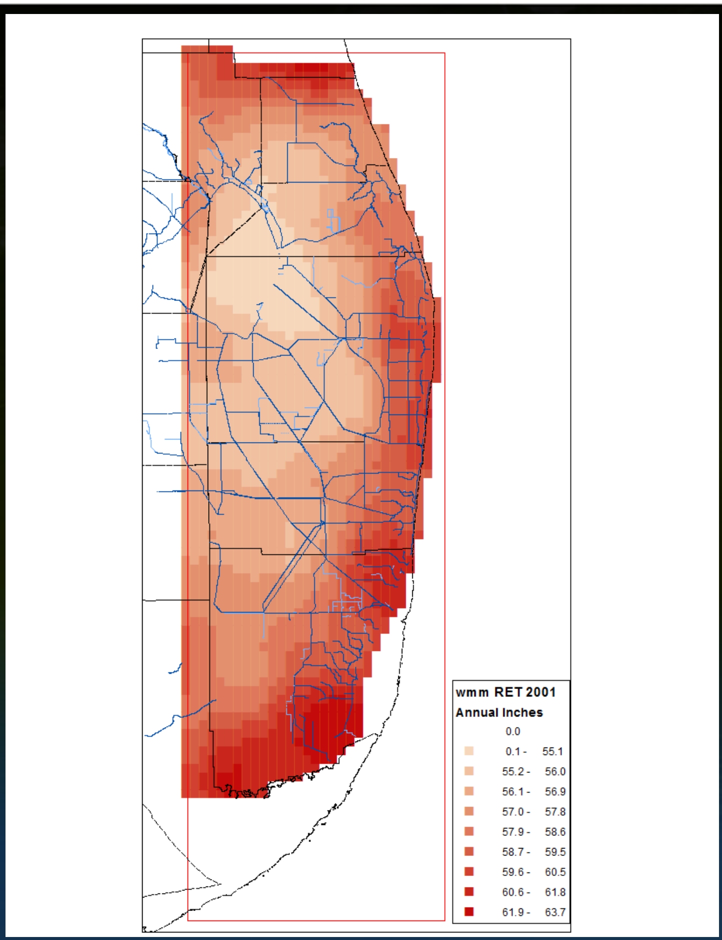
Rainfall

- District's rainfall dataset
- Spatial Variation of Rainfall for 2001 across ECSM
- Transient calibration period uses rainfall from 1985 – 2016
- Data derived from gauged values (1965 – April 2002); uses TIN-10 interpolation
- NEXRAD data (May 2002 – December 2016); averages values to get gridded values
- Nearest neighbor was used to proceed from Water Management Model (2 mi X 2 mi) to ECSM (1,000 ft X 1,000 ft)
- South of Key Largo, rain gage data was used with Thiessen polygons and Inverse Distance Weighting interpolation

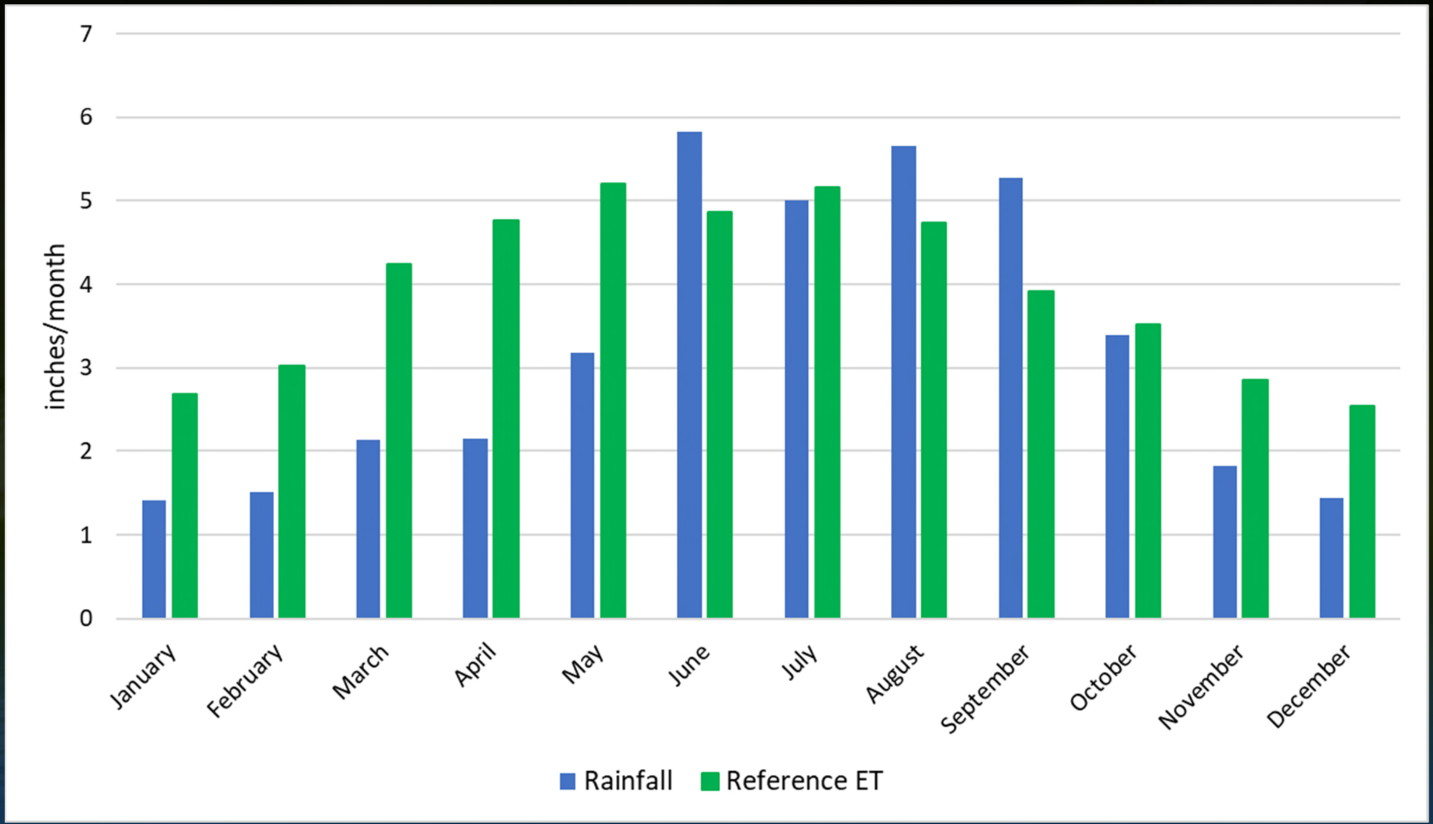


Reference ET (ET_{REF})

- District's Reference ET dataset
- Reference crop is green grass with 0.12 m height, actively growing, well-watered, completely shading the ground, fixed surface resistance of 70 $\frac{s}{m}$ and albedo of 0.23
- Based on two meteorological datasets
  - NARR & Hydro51
  - Utilized Multiquad Interpolation
- ET_{REF} computed using Penman-Monteith Equation
- Nearest neighbor was used to proceed from Water Management Model (2 mi X 2 mi) to ECSM (1,000 ft X 1,000 ft)

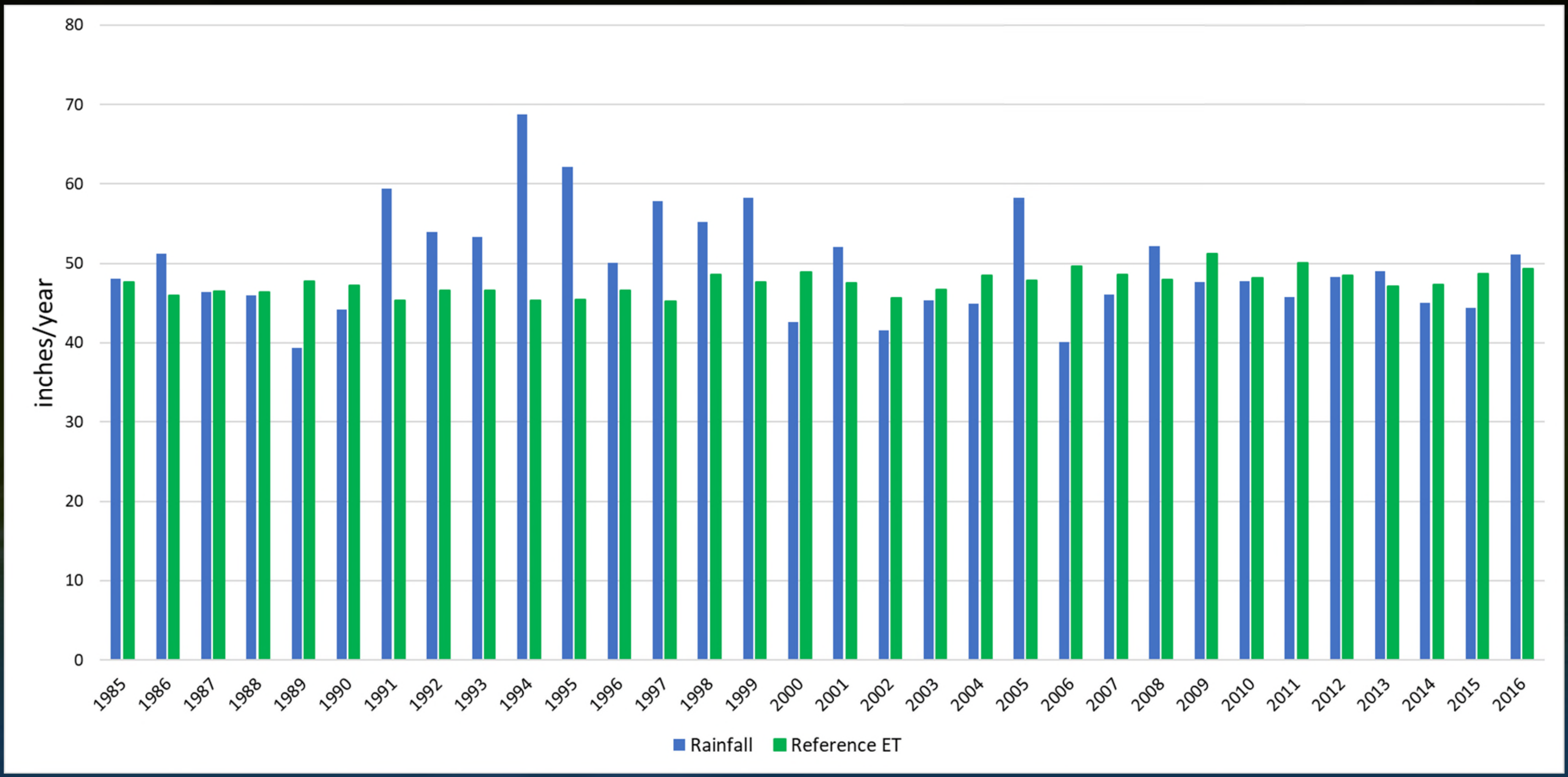


Monthly Distribution of Rainfall and Reference ET



Average monthly distribution over the calibration period of 1985 - 2016

Annual Distribution of Rainfall and Reference ET

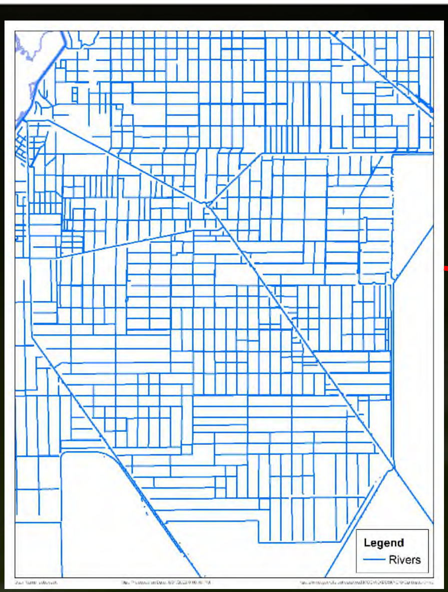


Average Rainfall = 50 in
Average Reference ET = 48 in

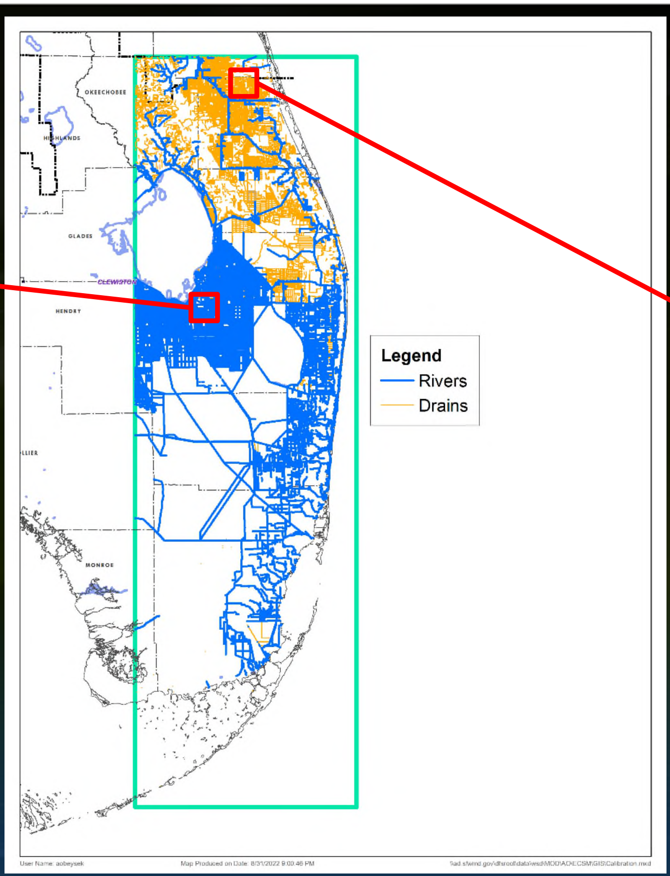
Input Data Sets

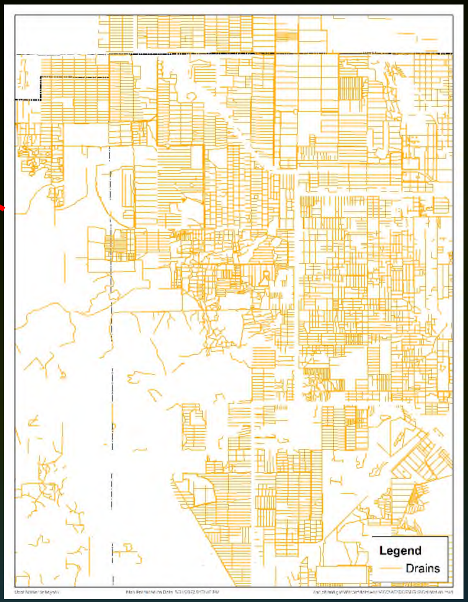
Anushi Obeysekera, E.I.T.

River and Drain Coverage



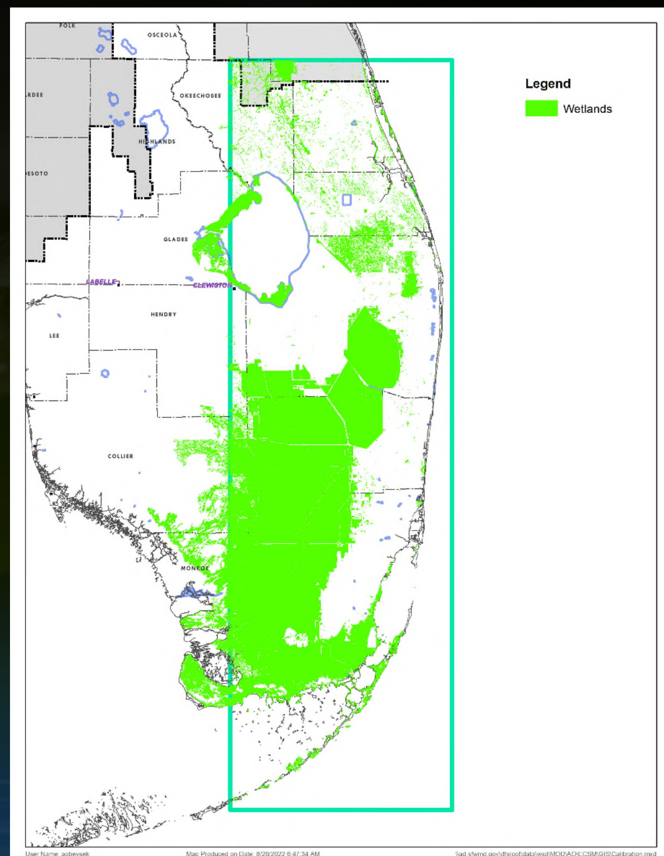
Everglades Agricultural Area



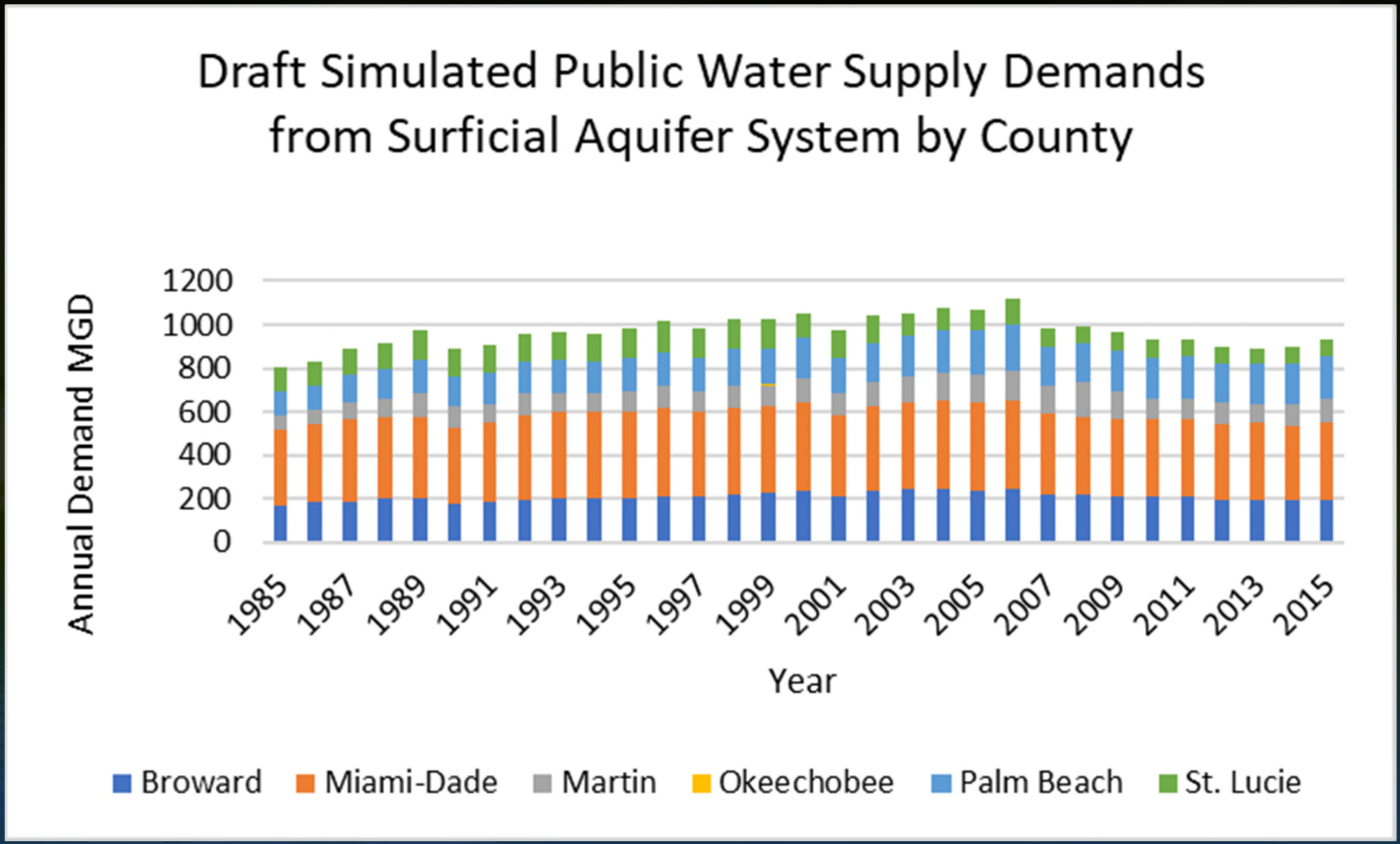


Northern St. Lucie County

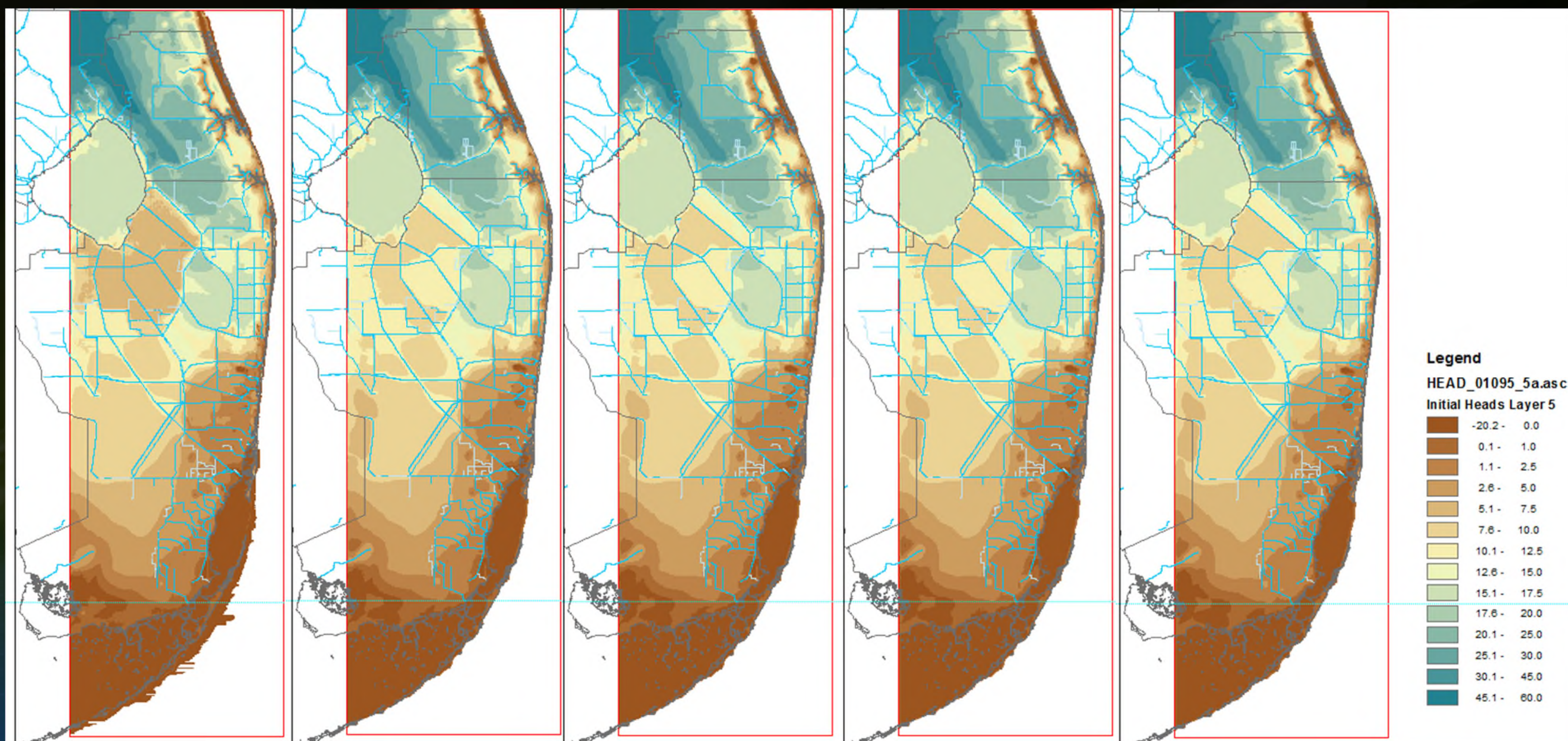
Wetland Coverage



Public Supply Demands

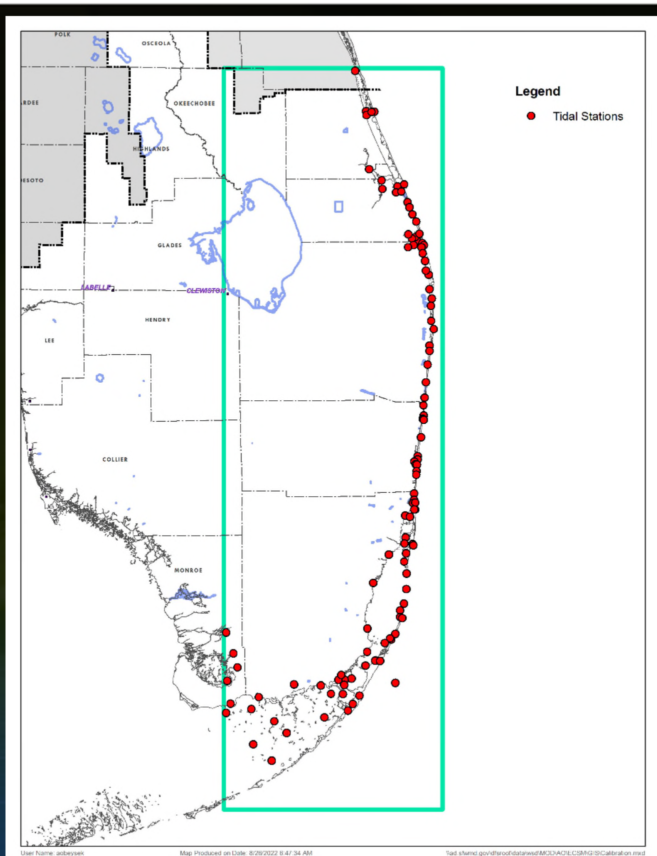


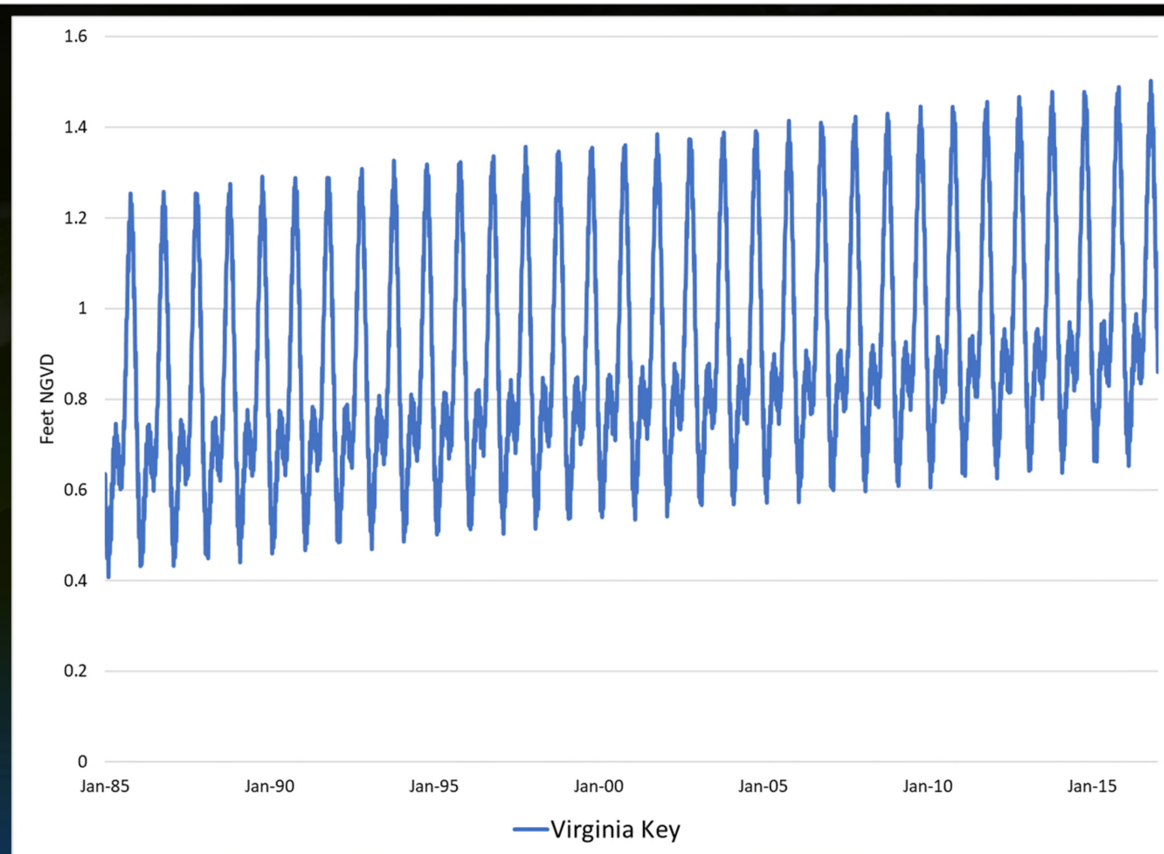
Initial Head Arrays



Layer 1 Layer 2 Layer 3 Layer 4 Layer 5

Tidal Boundary Condition





Development of Initial Water Quality Arrays

- Sources
  - SFWMD's Regulatory Database
  - DBHYDRO
  - USACE Chloride data from USGS wells
  - FPL Turkey Point water quality data
  - FIU database for Shark River Slough and Florida Bay
  - USGS reports
  - C-51 Phase 1 Studies
  - SFWMD WCA-2A Studies
- Strategy: Convert all data to a common parameter (TDS)

Conversion: Chloride to Specific Conductance

- 3658 historical data pairs across the model domain in various layers
- The data pairs were separated into 37 bins (i.e., groupings of similar values)
- Average chloride and average specific conductance value was taken for each bin
- Averages were used to develop the regression lines
- Based on the data, it was determined that one regression equation should not be utilized for the entire range of chlorides. Regression equations were developed for chlorides less than 250 mg/L and between 250 mg/L and 8,300 mg/L
- Chlorides greater than 8,300 mg/L use a conversion factor straight to TDS

Conversion: Specific Conductance to TDS

- 2,954 historical data pairs across the model domain in various layers
- Specific Conductance to TDS ratio was calculated using historical data
- The data pairs were separated into bins
- Range of specific conductance values were developed for each bin and the average ratio was calculated for each bin
- Average ratios were the conversion factors utilized for converting specific conductance to TDS

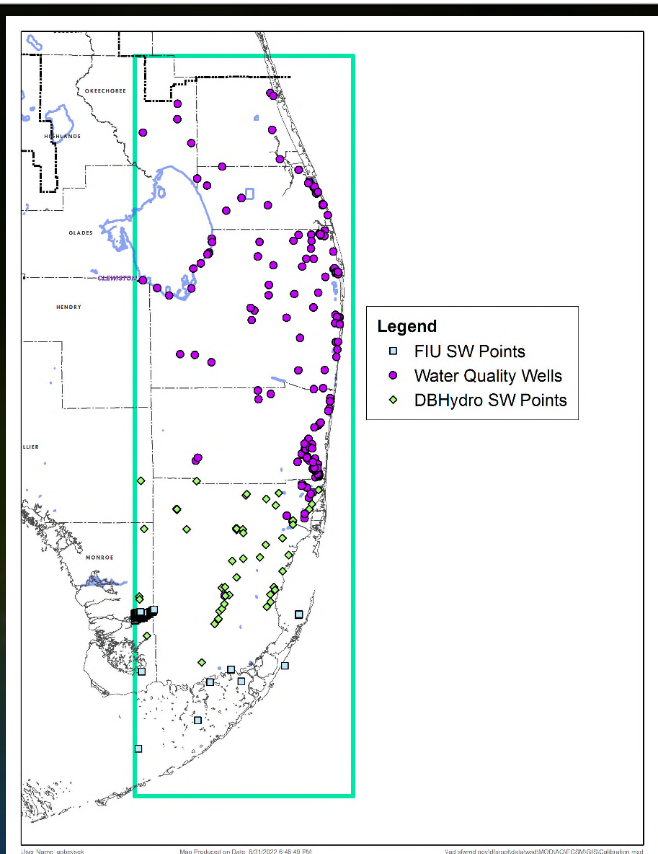
Equation Verification

- FPL Turkey Point site has historical chlorides, specific conductivity and TDS data from 2011 through 2019
- Data ranges from 12 mg/L – 39,800 mg/L (chlorides)

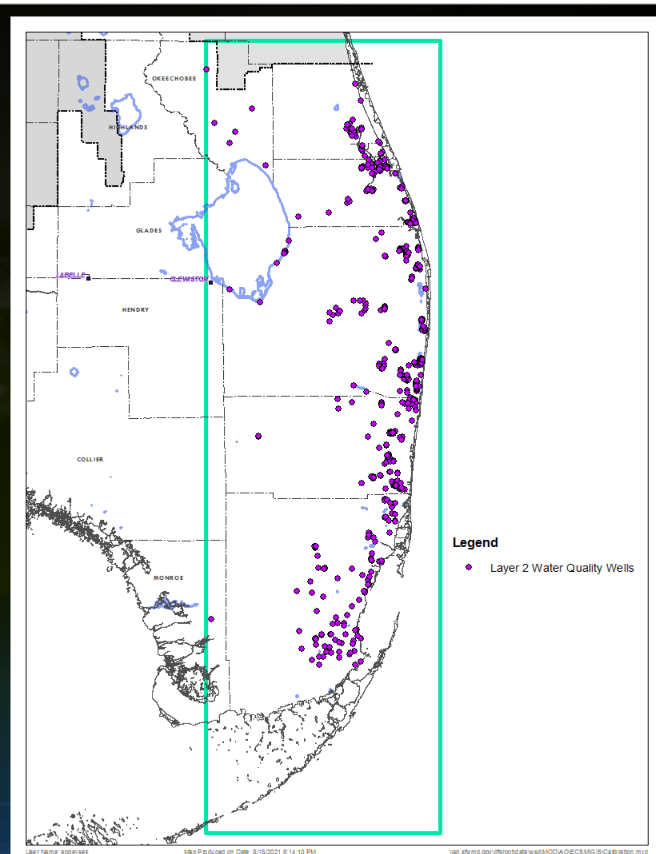
  455 us/cm – 86,709 us/cm (specific conductance)

  210 mg/L – 71,900 mg/L (TDS)

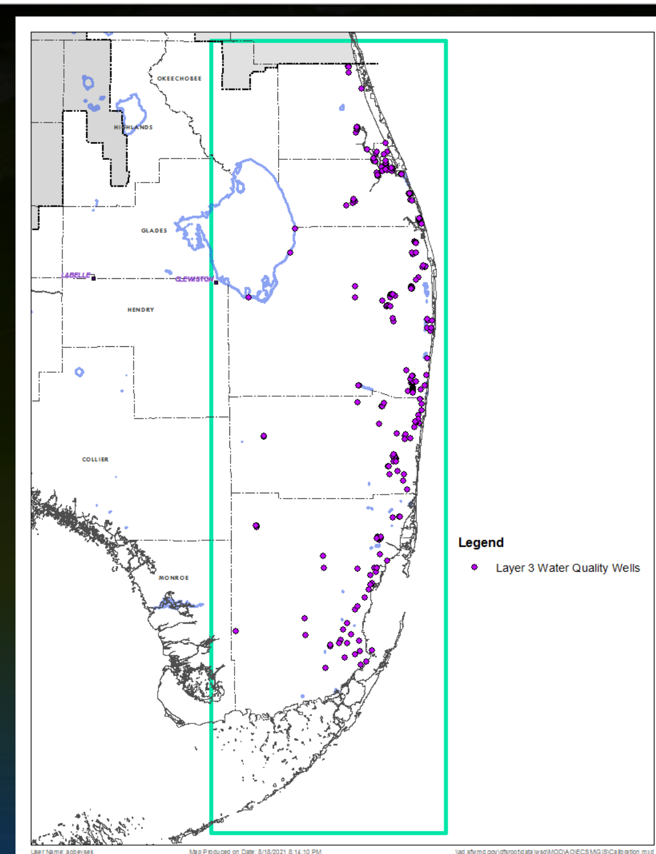
Historical Water Quality Data Points



Layer 1

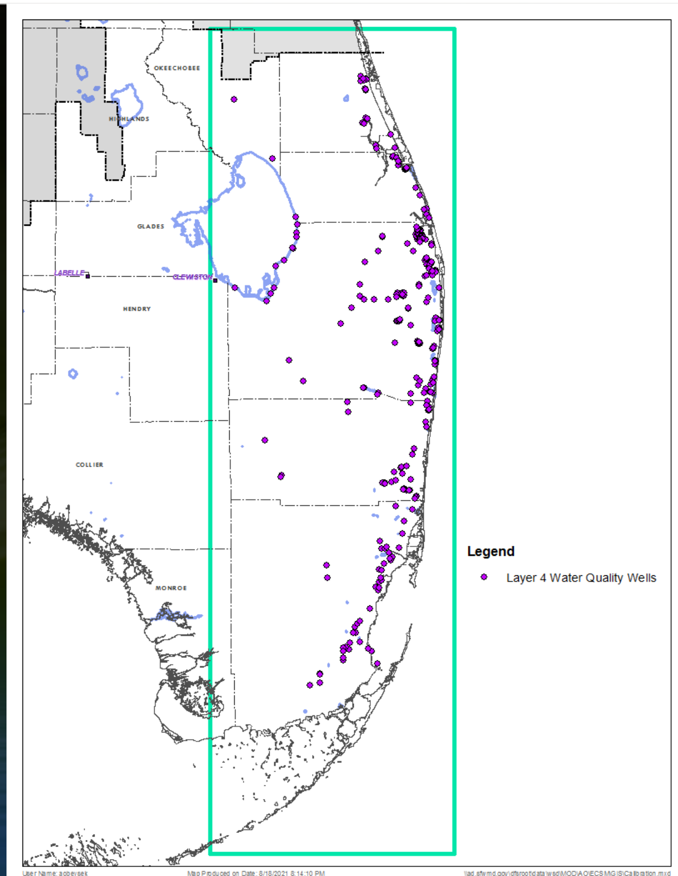


Layer 2

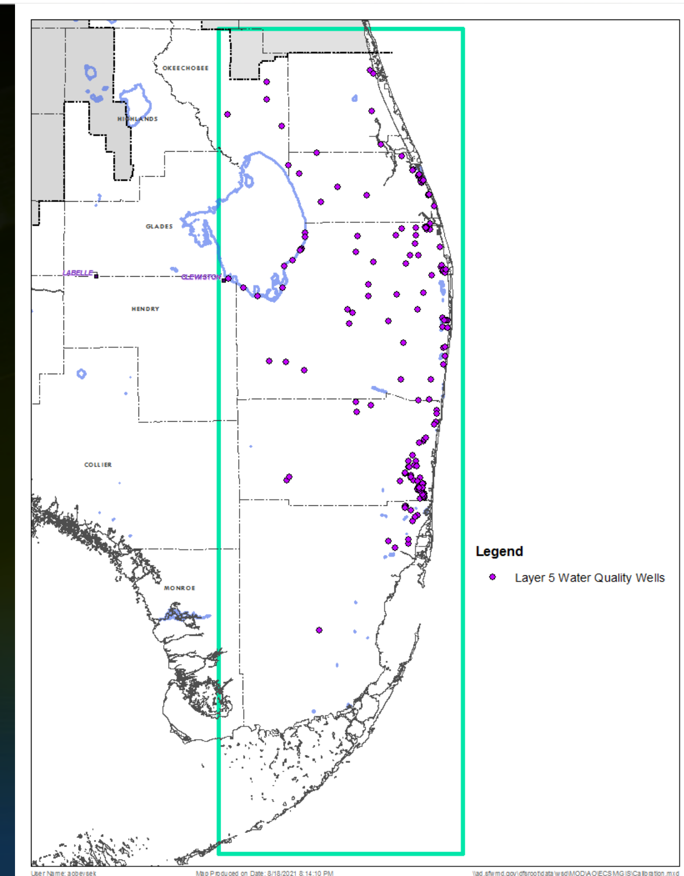


Layer 3

Historical Water Quality Data Points

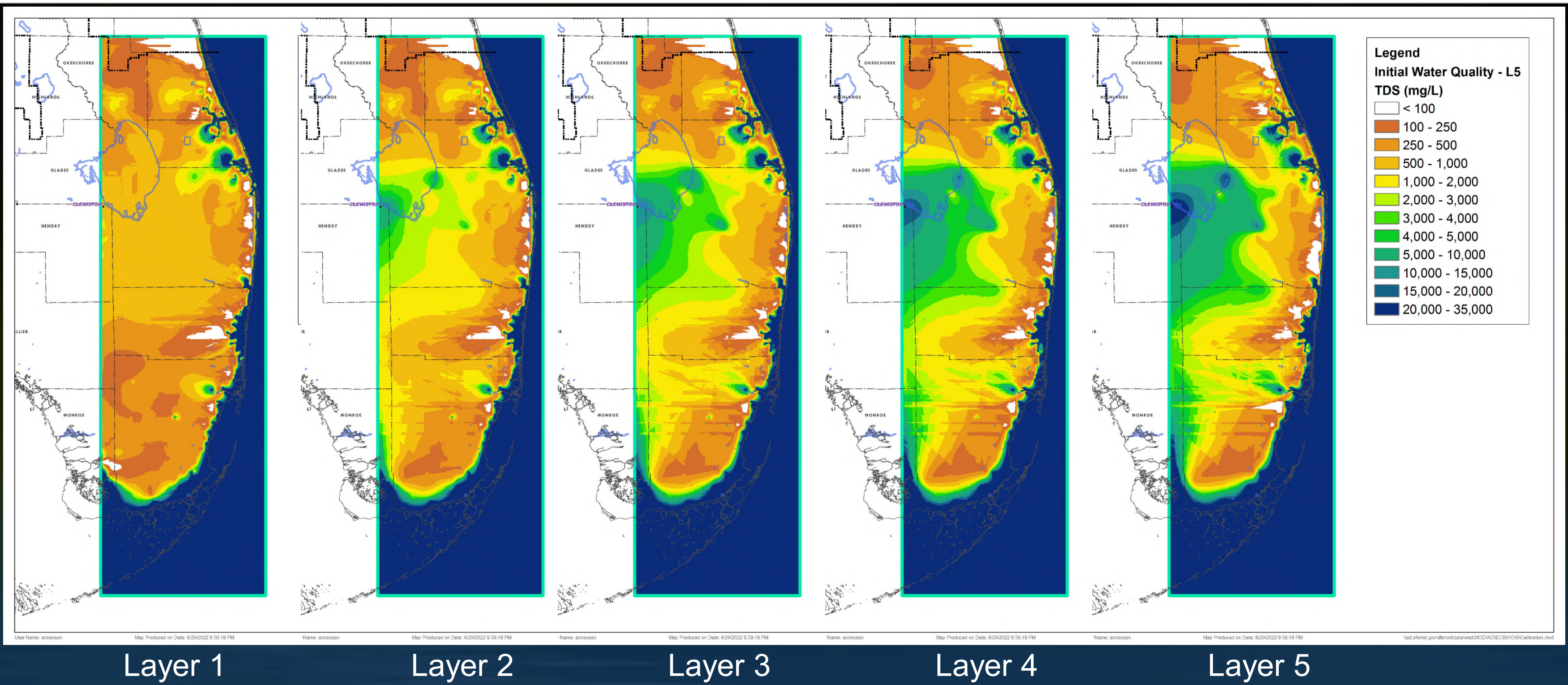


Layer 4



Layer 5

Initial Water Quality Array (1985)



NOTE: Poor water quality in inland areas associated with connate water

Model Calibration Plan

Anushi Obeysekera, E.I.T.

Proposed Calibration Procedure

- Calibration of the ECSM will be undertaken with a two-phased approach:
  - Phase I: manual calibration with initial sensitivity approach
  - Phase II: utilizing PEST to evaluate final model performance
- Phase I – Primary Calibration
  - Calibration parameters for water levels
    - Both static and dynamic parameters are included in the process and examples include aquifer horizonal and vertical hydraulic conductivities; variations in recharge and ET rates; pumpage distribution by source and wellfield; and other variables depending upon the results of the preliminary sensitivity runs

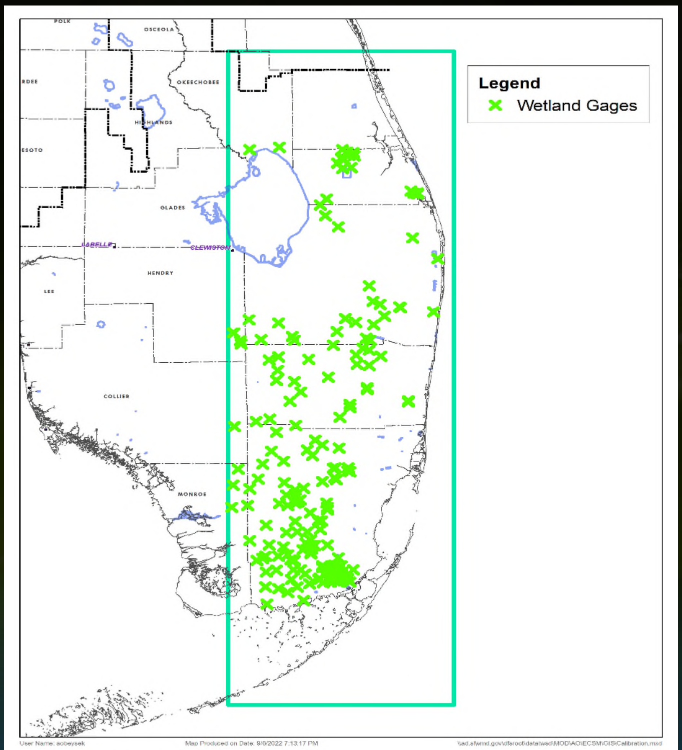
Proposed Calibration Procedure - Continued

- Calibration parameters for water quality
  - In addition to the parameters used to calibrate water levels, additional parameters are horizonal and transverse dispersivity values, boundary conditions including tidal variations, the sink/source mixing package and initial water quality arrays to account for the trapped connate water beneath the Everglades Agricultural Areas, Water Conservation Areas, and Lake Okeechobee
- Calibration parameters for structure flows:
  - control elevations of secondary and tertiary canals; river and drain conductance; diversion and RDF operational rules for water movement; curve numbers and the Muskingum delay function coefficients

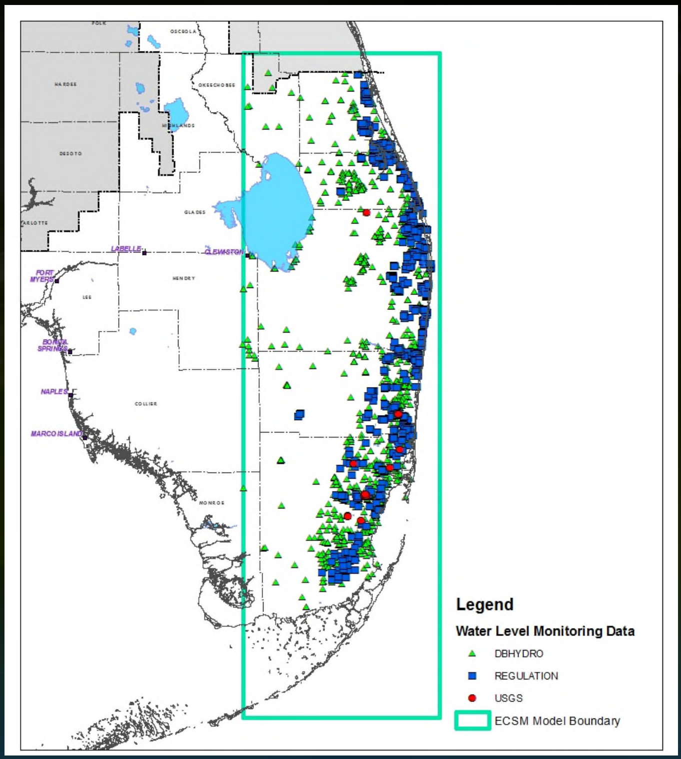
Phase II - Global Sensitivity Analysis

- Use of PEST to run a global sensitivity analysis via Method of Morris to determine if the results of manual calibration result in a well-calibrated model

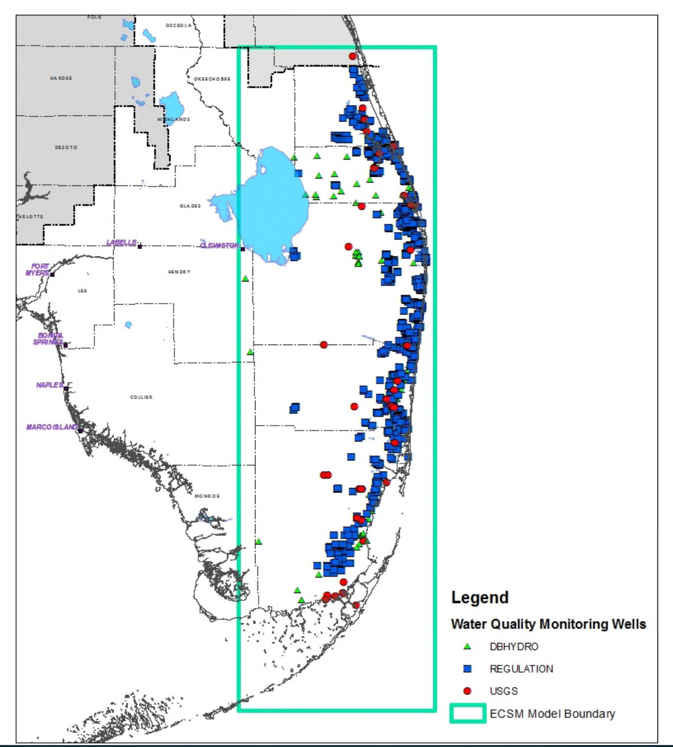
Monitoring Locations



Wetland Gages
(Water Levels)



Groundwater Wells and
Surface Water Stations
(Water Levels)



Groundwater Monitoring Wells
(Water Quality)

Proposed Water Level Calibration Criteria

- Mean error (ME): ±1 ft
- Mean absolute error (MAE): <1 ft
  - 50% of wells with MAE < 1 ft
  - 80% of wells with MAE < 1.5 ft

Proposed Water Quality Calibration Criteria

Water quality calibration criteria determined by salinity, as set forth in Jacobs et al. (2011), based on averaged monthly values

	Fresh to Brackish Water		Moderately Saline	Saline Water
Total Dissolved Solids (mg/L)	0 – 4,000	4,000 – 10,000	10,000 – 18,000	>18,000
Calibration Error Band (mg/L)	±500	±750	±3,000	±4,000

Calibration Target: 80% of all water quality monitor wells will simulate total dissolved solids concentration within its individual calibration error band

Jacobs, B., M. Stewart, R. Therrien, and C. Zheng, 2011. Peer Review Report – East Coast Floridan Aquifer System Model Phase II Project, South Florida Water Management District, West Palm Beach, FL.

Proposed Water Quality Calibration Criteria

	Fresh to Brackish Water				Moderately Saline	Saline Water
Total Dissolved Solids (mg/L)	0 – 1,000	1,000 – 2,000	2,000 – 4,000	4,000 – 10,000	10,000 – 18,000	>18,000
Calibration Error Band (mg/L)	±500	±750	±1,000	±2,000	±3,000	±4,000

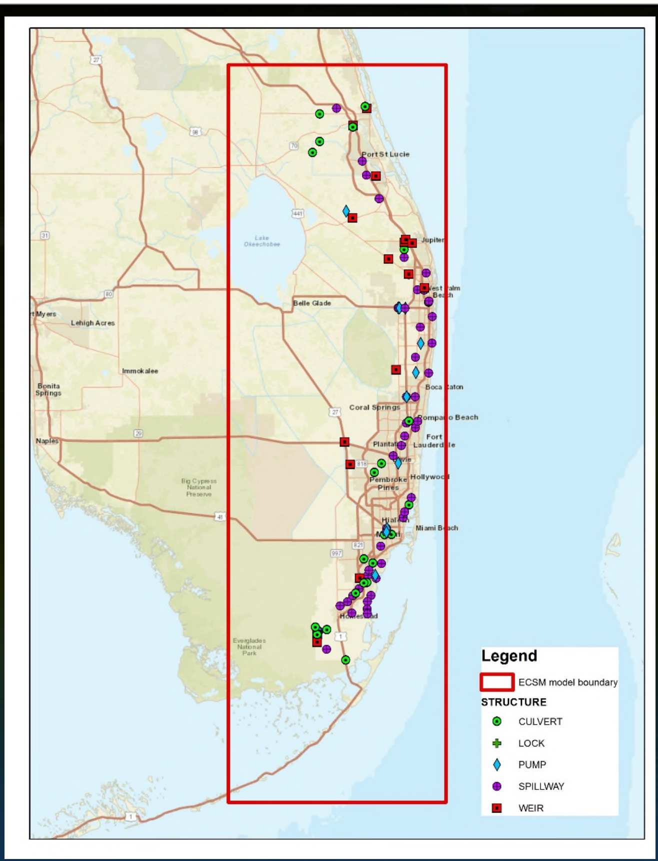
Calibration Target: 80% of all water quality monitor wells will simulate total dissolved solids concentration within its individual calibration error band

Proposed Structure Flow Calibration Criteria

- Coefficient of Determination: $R^2 > 0.4$
- Nash – Sutcliffe: NS > 0.4
- Deviation of Volume: DV $\pm$ 15%

NOTE: These criteria were successfully used for the groundwater model associated with CERP Loxahatchee River Restoration Project

Description
Coefficient of determination measures the goodness of fit.
Nash-Sutcliffe is a model efficiency coefficient that indicates the predictive power of models.
Deviation of volume measures the difference between historical and simulated flow volumes. Positive values indicate that the model is underpredicting, negative values indicate that the model is overpredicting.



Soft Calibration Metrics

- Water Budgets
- Transient model response, evaluating wet vs. dry season statistics
- Reviewing direction and quantity of flux across model boundaries
- Reviewing historical saltwater interface maps to ensure the model spatially simulates position of saltwater front

Path Forward

Finalizing Input Data → Model Calibration → Model Application

Peer Review Process

Panel Discussion

Biscayne Bay, Miami

Public Comment

Boca Chita, Biscayne Bay

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  - Use the Raise Hand feature
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  - *9 raises hand
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