Importance of a Sound Regional Groundwater Flow Model for Water Resource Management

Wakulla & Leon County
Soil and Water Conservation Districts
Natural Resources Conservation Service
January 16, 2014

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GeoHydros, LLC

Problem – *Diminishing Groundwater Flow*

- Diminished Spring Flows
  - Reduced flow to Wakulla & Spring Creek springs
    - Spring Creek is now reversing flow in summers
    - Flow is diverted to Wakulla
    - Diminished water clarity at Wakulla
    - Salt water intrusion at Spring Creek
  - Rapid and pervasive salt water intrusion
    - Spring Creek reversals send salt water at least 3 miles inland via conduits
    - Salt water persists at depth until groundwater levels rise sufficiently to force it back out
    - Duration of salt water intrusions and vertical extent likely increasing
- Failing to recognize and address problems
  - Pumping and sea level rise important factors
- Existing models and modeling approaches incapable of delivering reliable predictions
  - *Cedar Key*

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Problem -

- o Diminish
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  - Rapid
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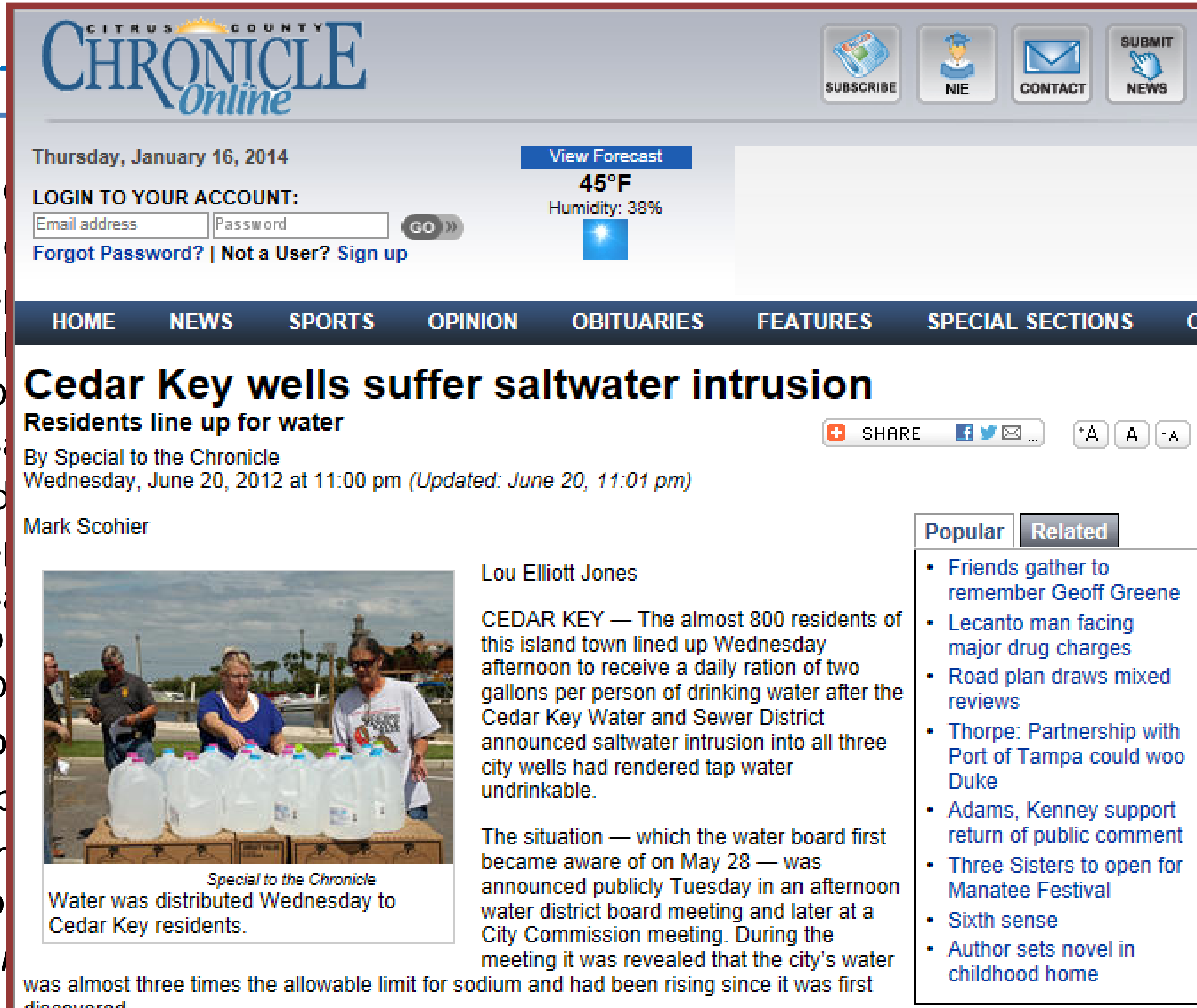
    - D
- o Failing to
  - Pump
- o Existing r predictio
  - *Cedar*



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Cedar Key wells suffer saltwater intrusion

Residents line up for water

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By Special to the Chronicle

Wednesday, June 20, 2012 at 11:00 pm *(Updated: June 20, 11:01 pm)*

Mark Scohier

Special to the Chronicle

Water was distributed Wednesday to Cedar Key residents.

Lou Elliott Jones

CEDAR KEY — The almost 800 residents of this island town lined up Wednesday afternoon to receive a daily ration of two gallons per person of drinking water after the Cedar Key Water and Sewer District announced saltwater intrusion into all three city wells had rendered tap water undrinkable.

The situation — which the water board first became aware of on May 28 — was announced publicly Tuesday in an afternoon water district board meeting and later at a City Commission meeting. During the meeting it was revealed that the city's water was almost three times the allowable limit for sodium and had been rising since it was first discovered.

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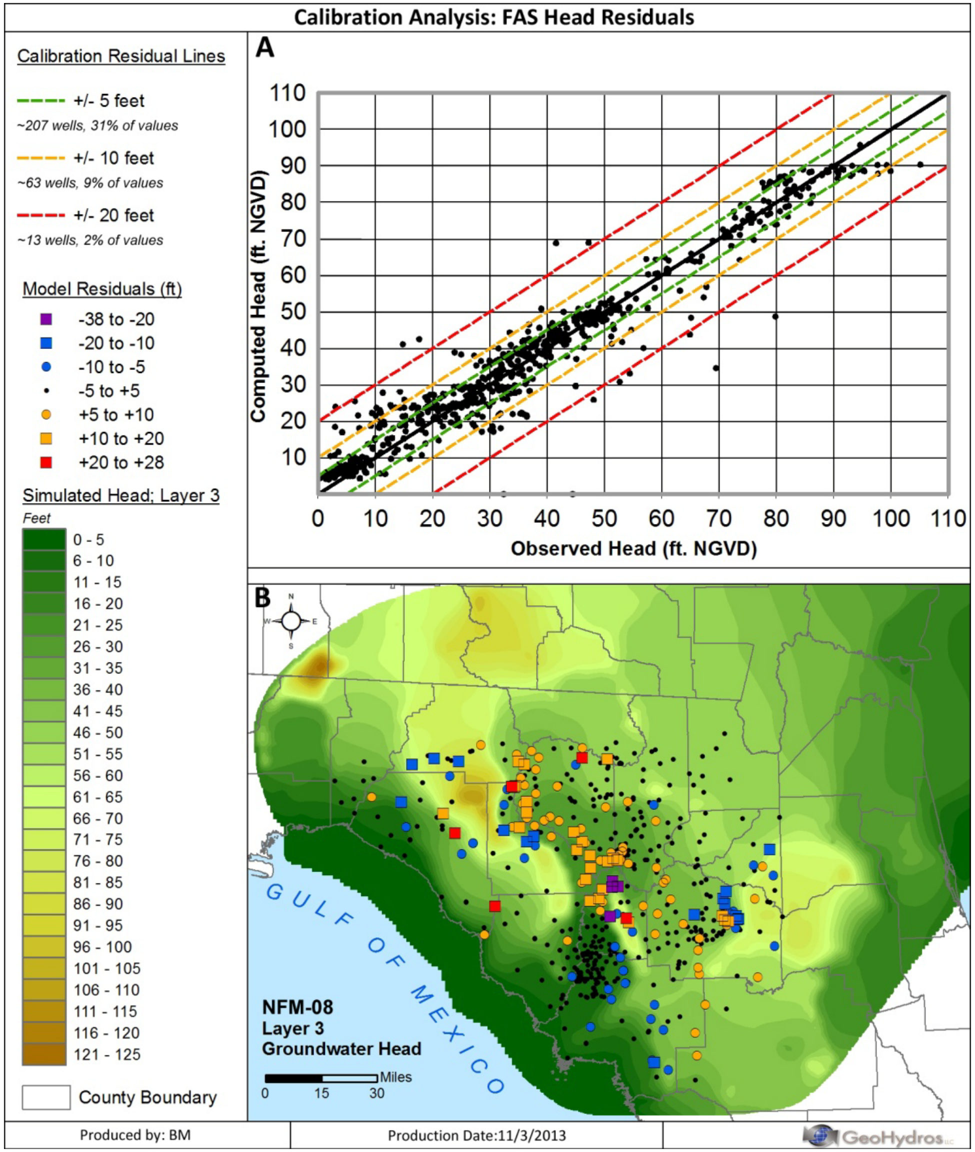
Why are models failing?

- Inaccurate conceptualization
  - Assume "Equivalent Porous Media" – Aquifer is a sand box
  - Reality – Aquifer is karst where conduit flow is dominant
- Inaccurate water budget
  - Let models dictate how much water flows through the aquifer
    - Coastal boundaries are not constrained
    - Assume large diffuse flow to Gulf of Mexico *(no data)*
  - Reality – Spring flows represent majority of flow to Gulf of Mexico
- Do not incorporate all of the key factors affecting flow
  - Not large enough *(political vs. natural boundaries)*
  - Overly simplified spatial and magnitude assignments *(i.e. pumping)*
  - Lack of data – *(can usually be overcome with enough work)*

Modeling Problem Examples



North Florida Model (SRWMD)

- Presented as "well calibrated"
- Closer inspection – big errors
  - error > 5 feet: 207 wells
  - error > 10 feet: 63 wells
  - error > 20 feet 13 wells

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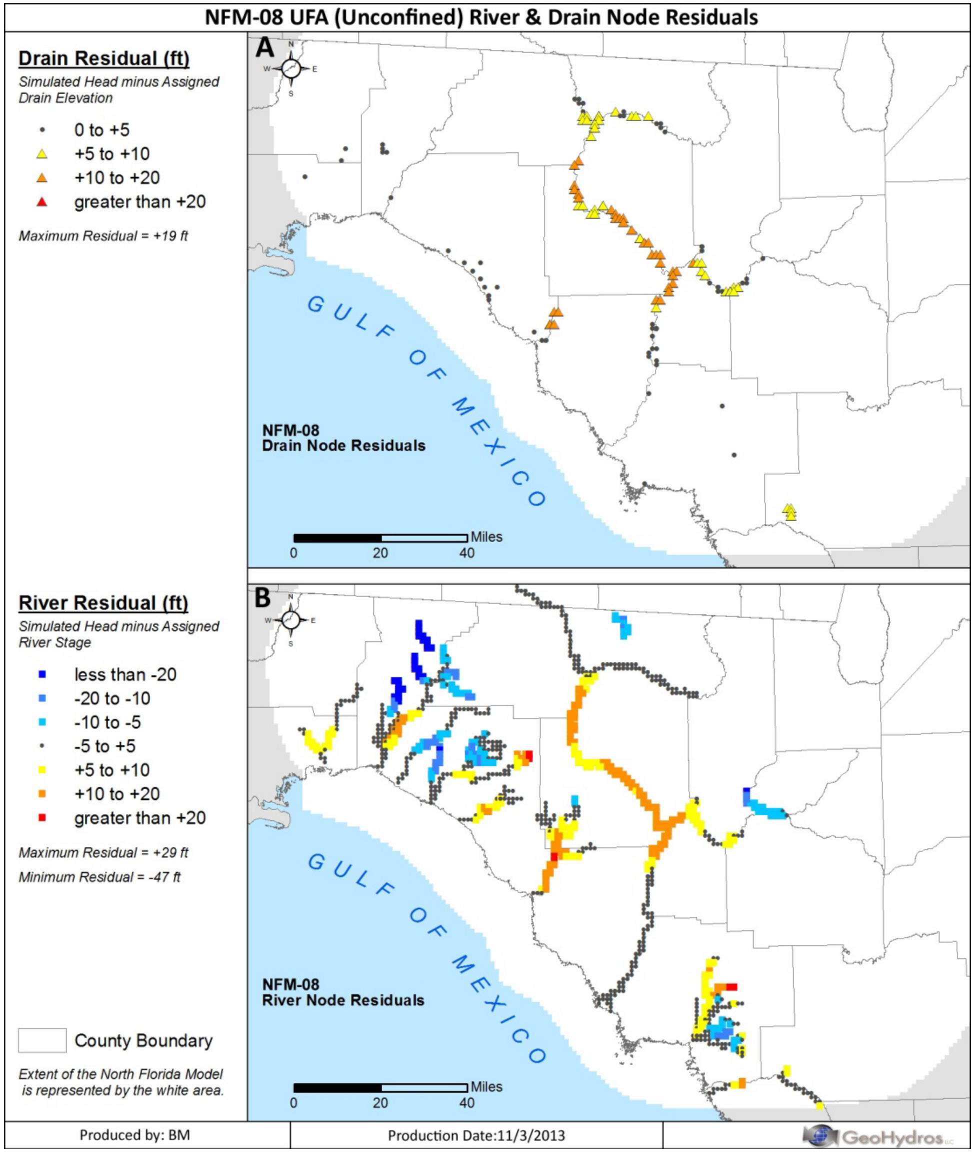
Modeling Problem Examples



Inaccurate simulation of spring and river flows

- Flows simulated at expense of head
- Over-estimates head in rivers by 5 – 20+ feet

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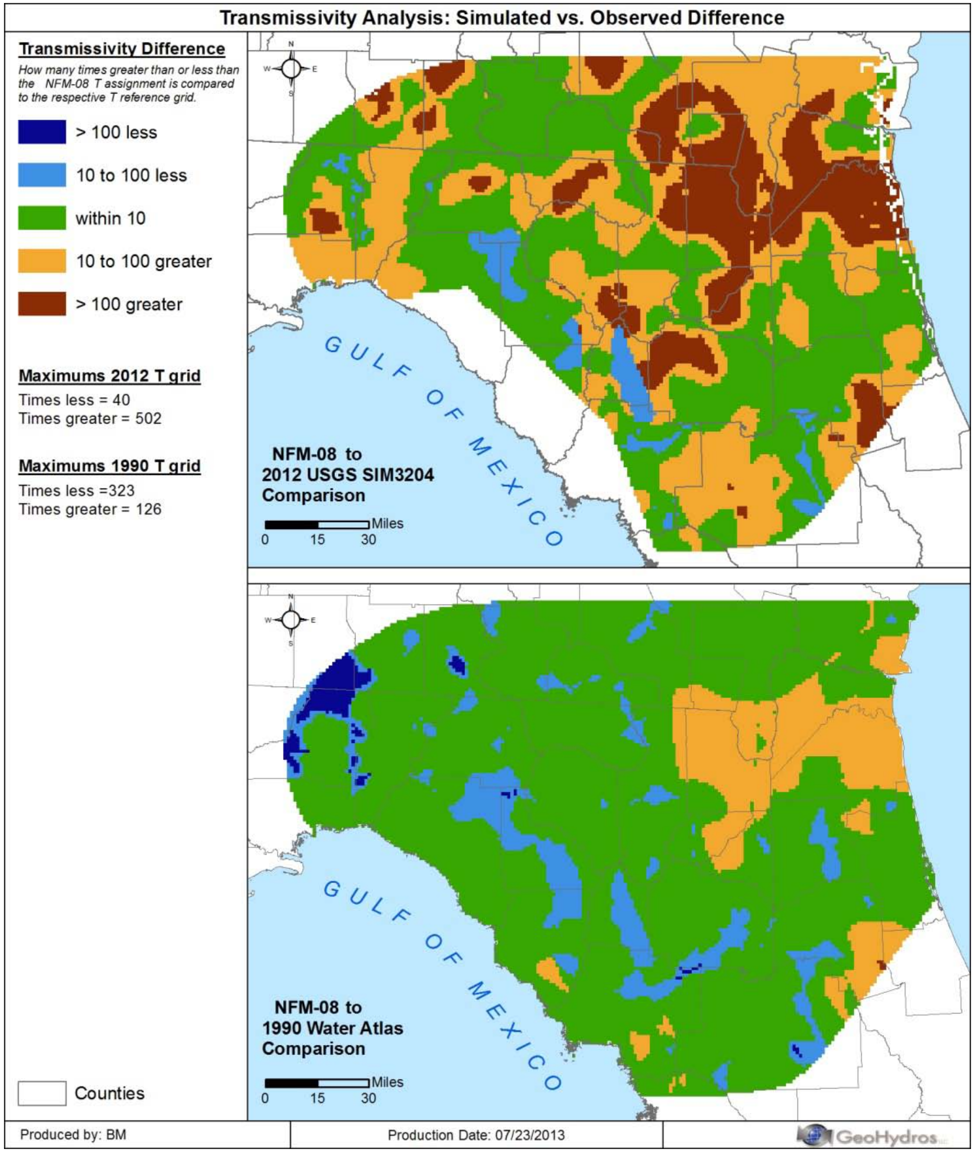
Modeling Problem Examples



Simulated permeabilities too high

- Elevated permeabilities required because conduits not simulated
- 10 – 100+ times higher than observed and published values
- Distribution not geologically defensible

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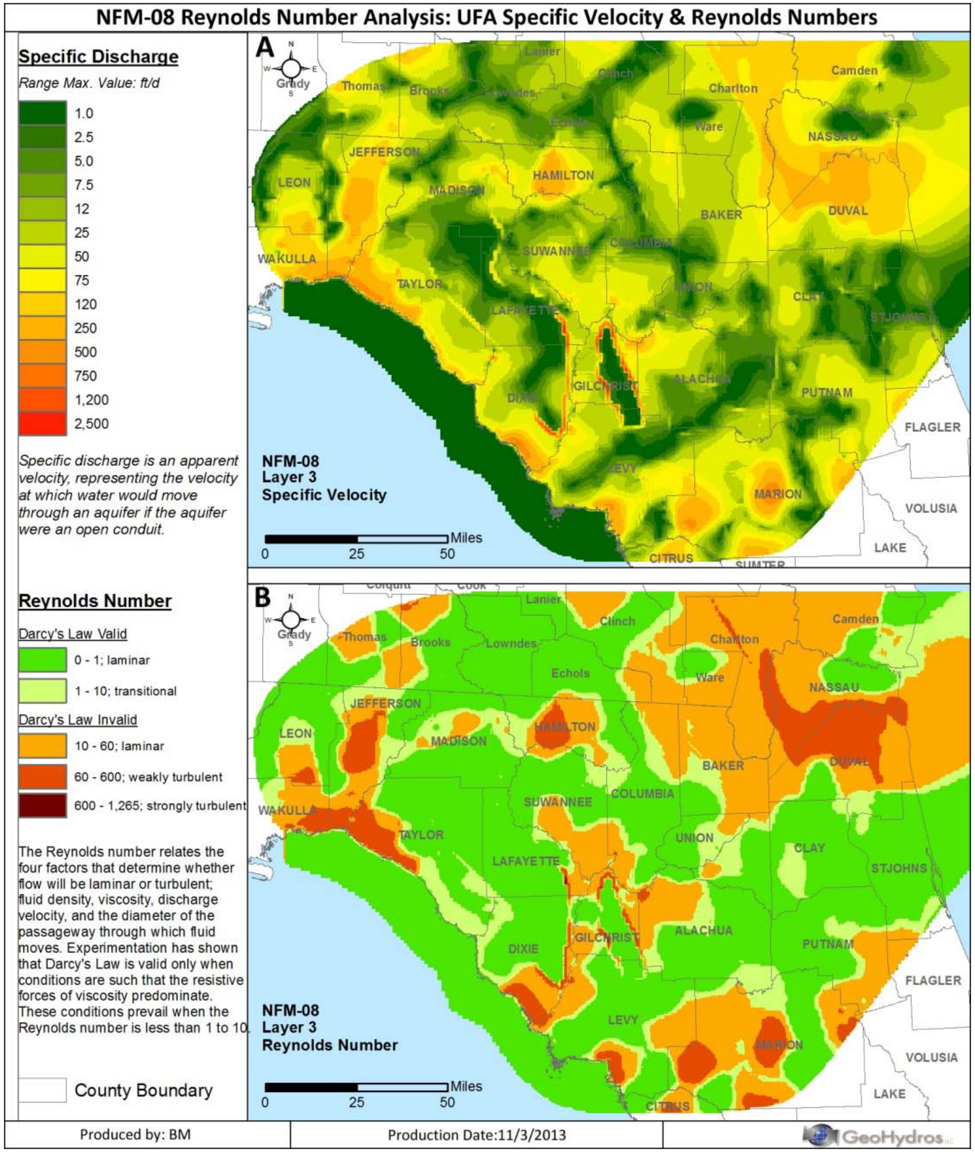
Modeling Problem Examples - *Result*



Mathematics invalid over half of model domain

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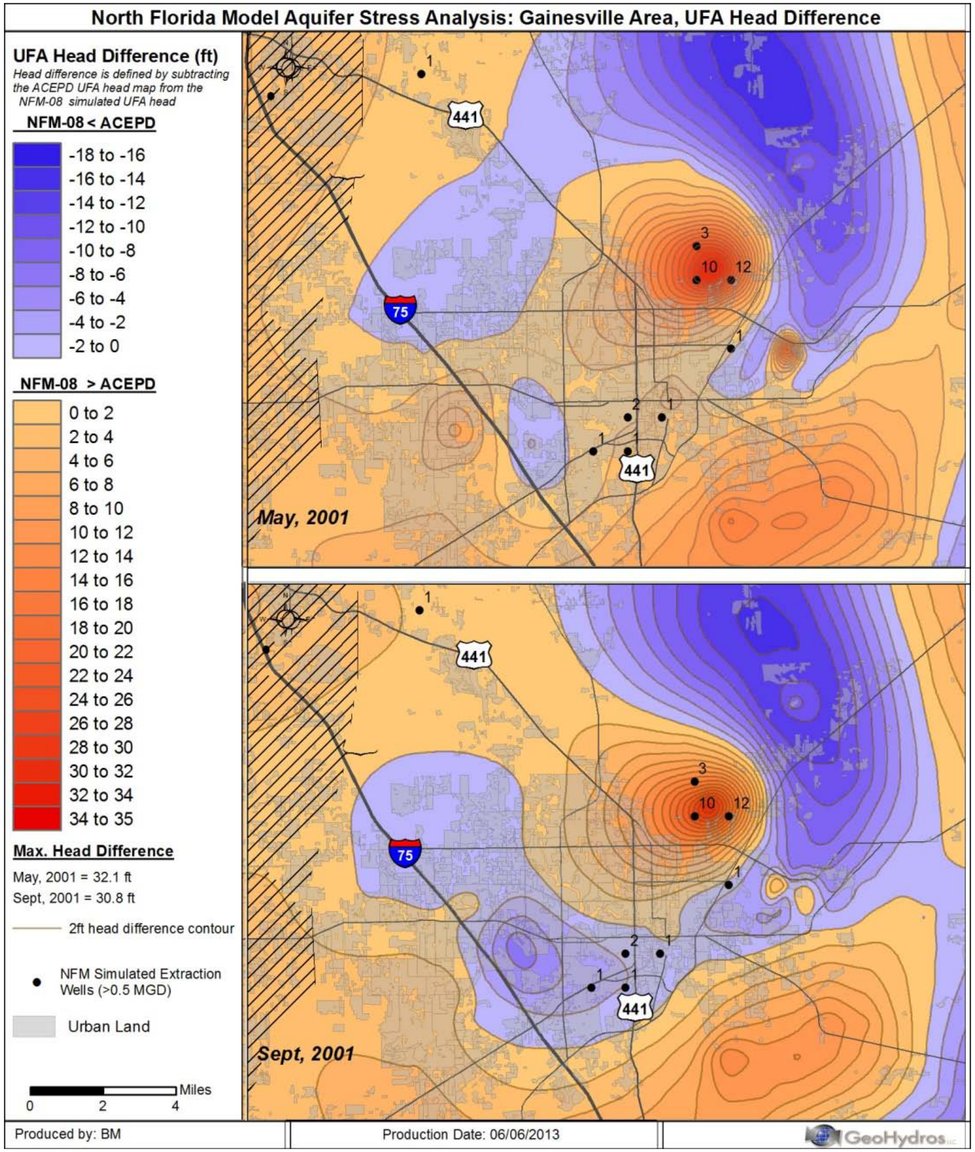
Modeling Problem Examples - *Result*



Under-predicts Gainesville cone of depression by 30+ feet

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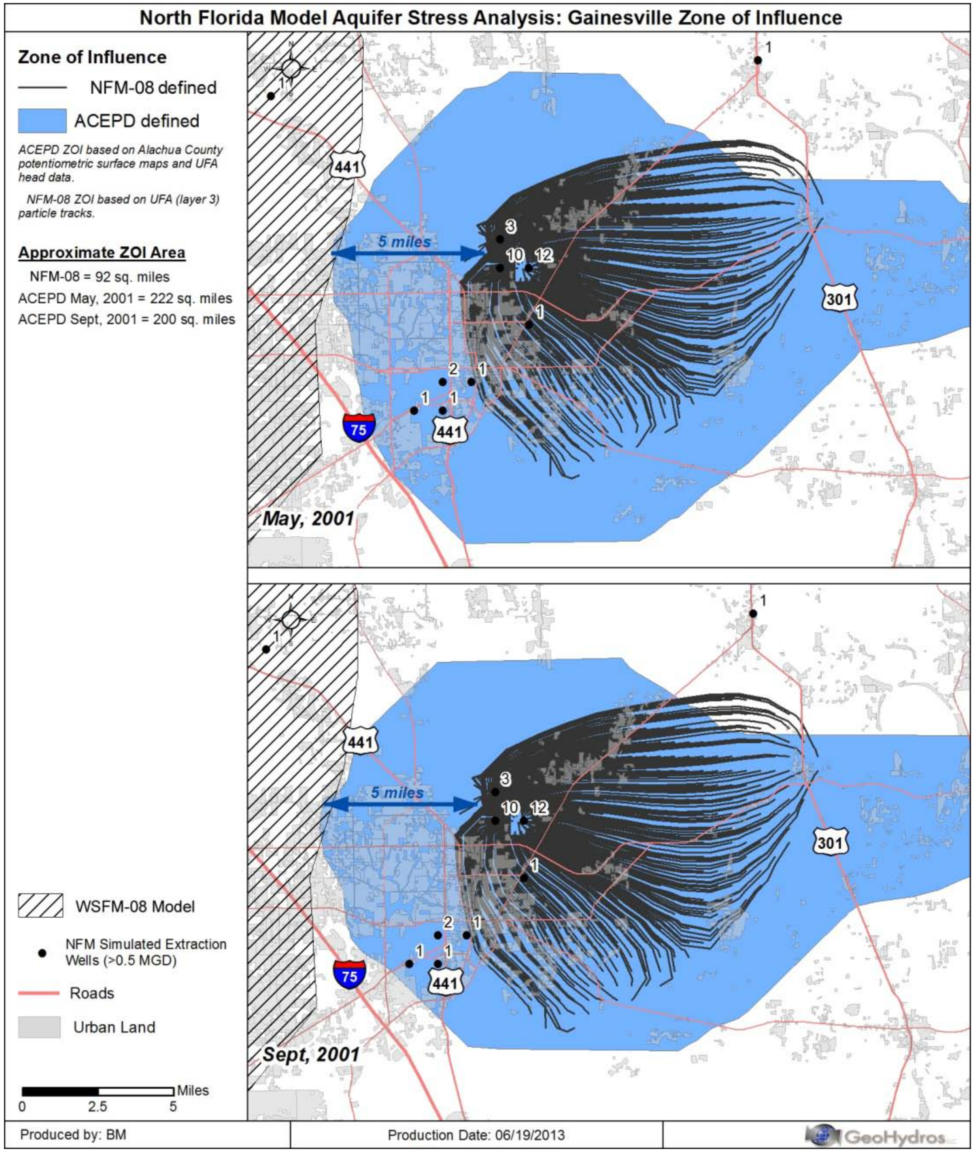
Modeling Problem Examples - *Result*



Under-predicts Gainesville zone of influence by 100+ square miles

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Modeling Problem Examples - *Result*

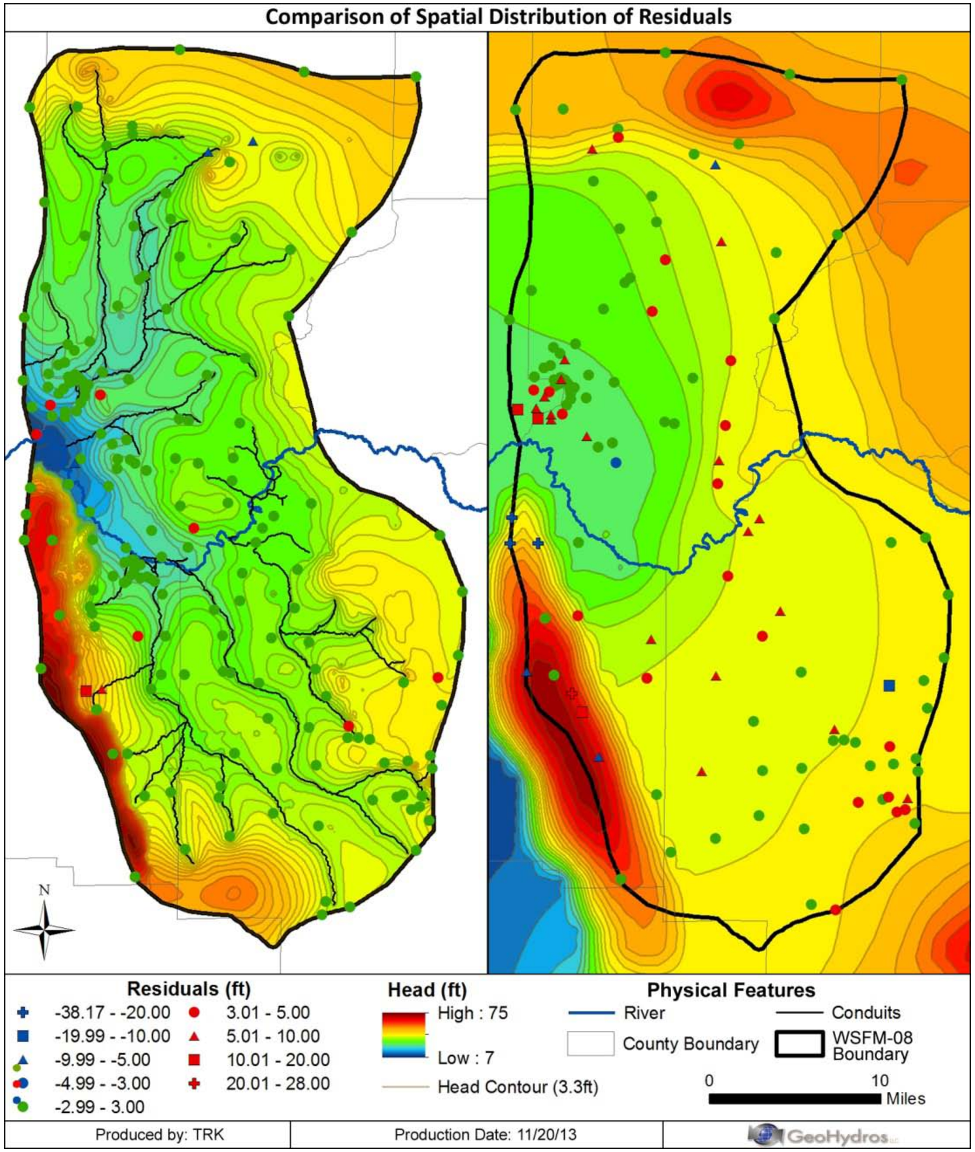
	CFS	*%*
Total Simulated UFA Flux	**13,130**	
Rivers & Springs	7,163	55%
Wells	1,005	8%
Coastal Boundaries	1,809	14%
Non-coastal Boundaries	3,153	24%

Non-verifiable Boundaries = 38% of Total UFA Flux

Over-estimates total flow through aquifer

Under-estimates impacts of pumping

Improved Modeling Approach – *Hybrid Model*



Simulates Conduit & Matrix Flow

- Darcy flow in matrix
- Pipe flow in conduits
- Conduit locations and dimensions estimated through model calibration
- Dramatic improvement in calibration

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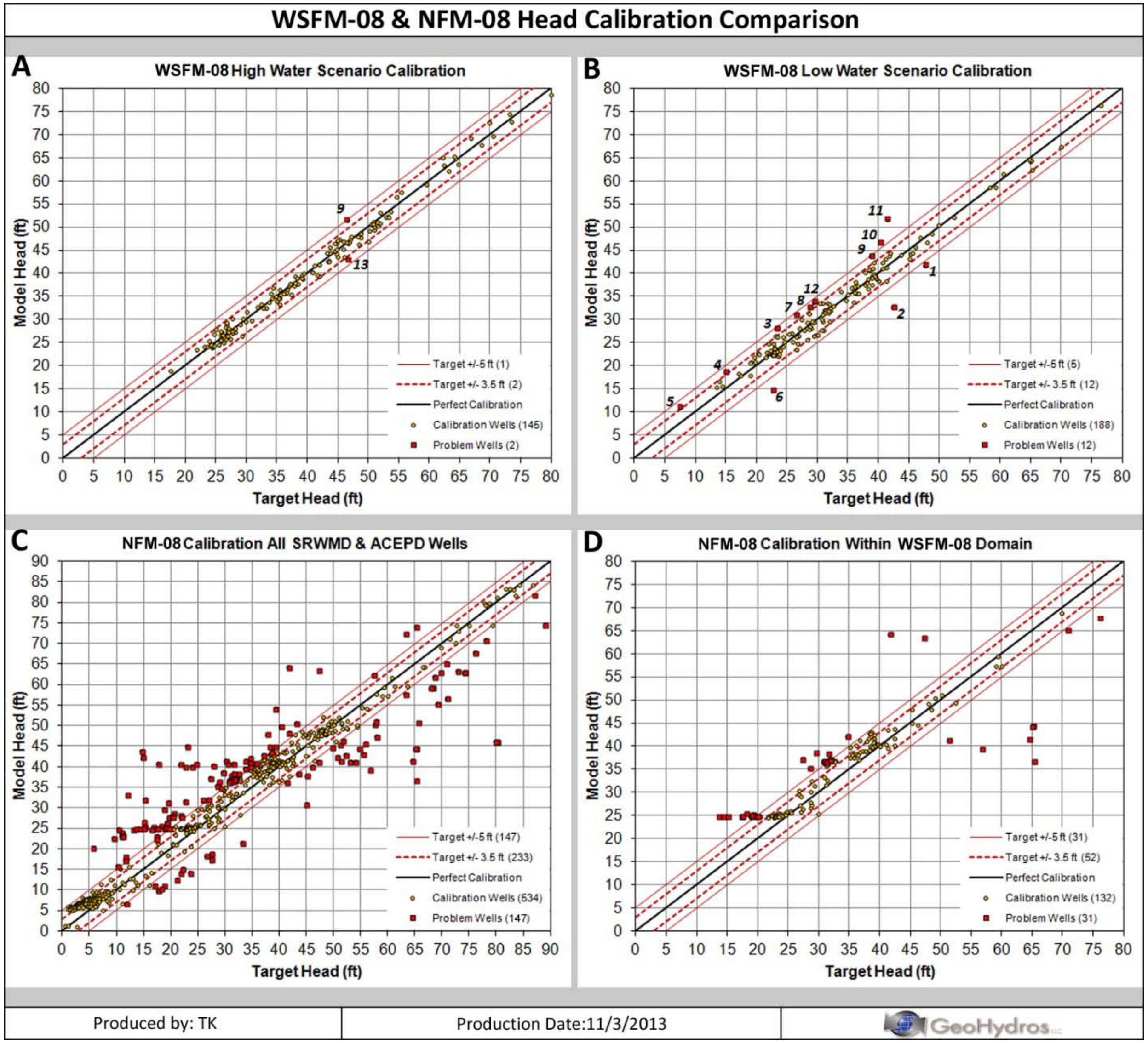
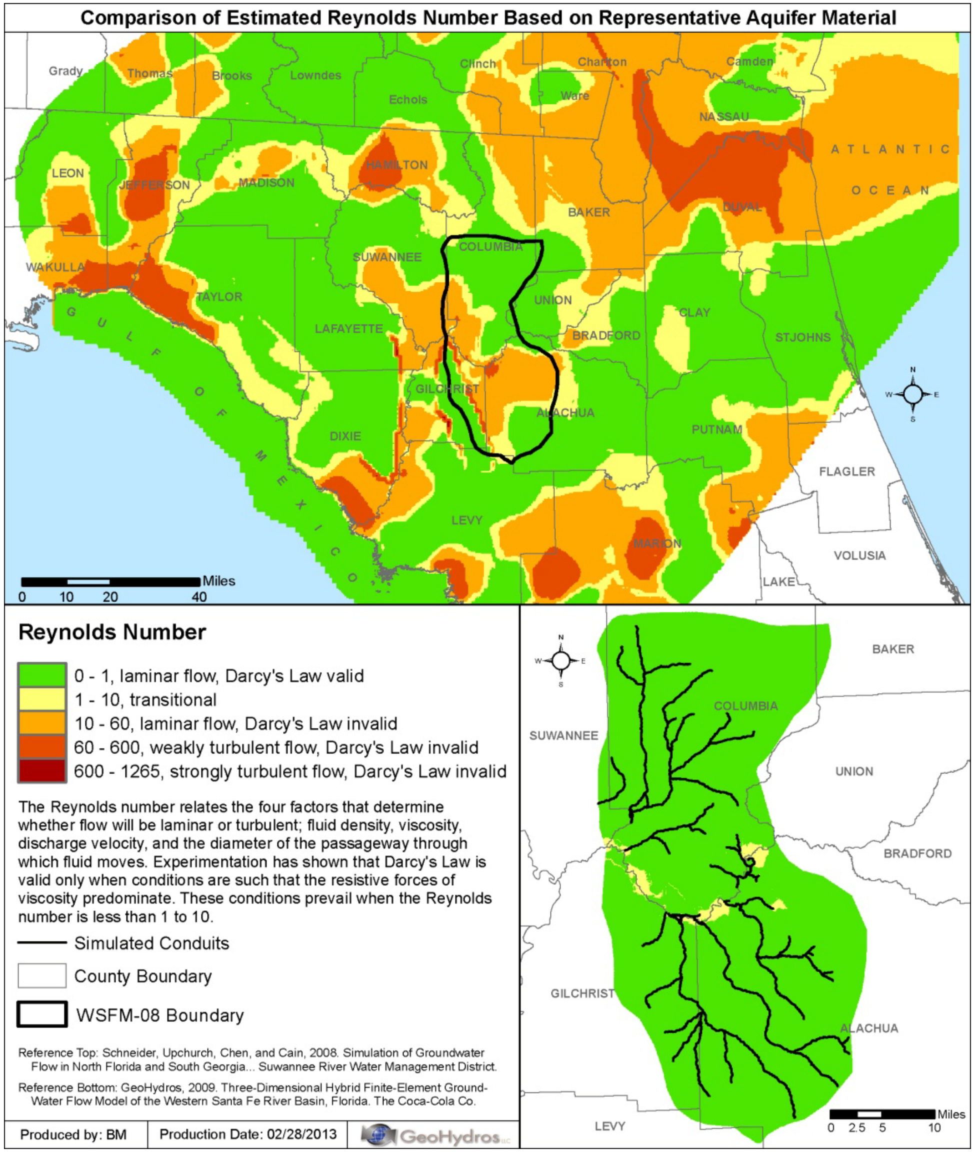
Improved Modeling Approach – *Hybrid Model*



Hybrid Model

EPM Model

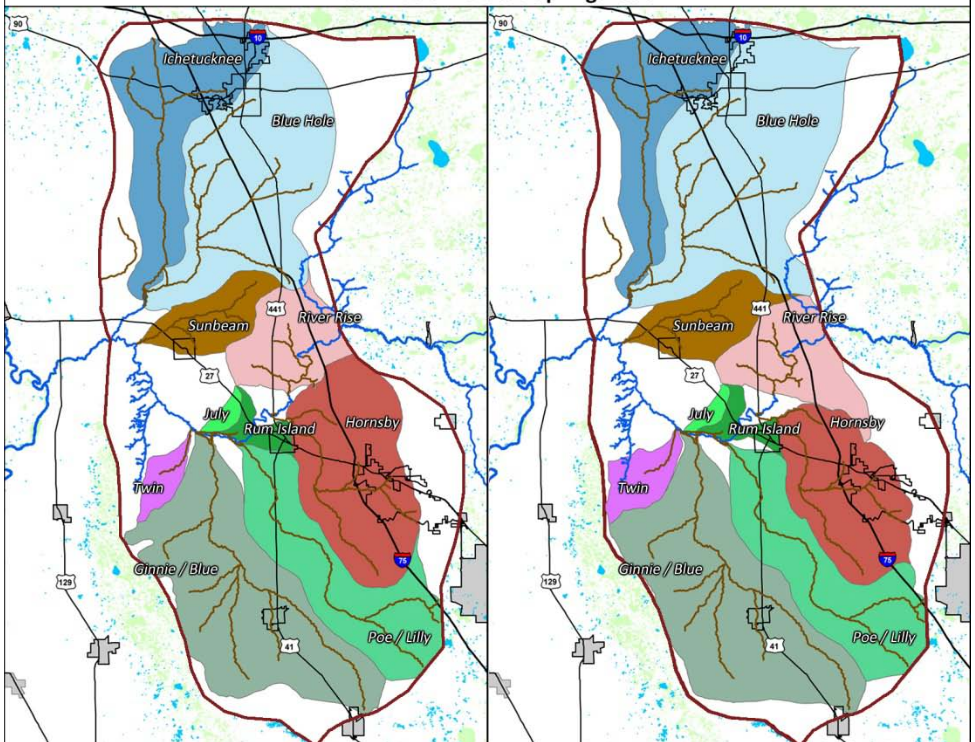
Improved Modeling Approach – *Hybrid Model*



Substantially more reliable mathematics

Improved Modeling Approach – *Hybrid Model*

WSFM-08 Simulated Springsheds



High Water Simulation

	km^2	mi^2		km^2	mi^2
Ichetucknee	248	96	July	12	5
Blue Hole	377	146	Twin	29	11
Sunbeam	80	31	Ginnie	395	152
River Rise	116	45	Poe / Lilly	237	91
Rum Island	24	9	Hornsby	274	106

Low Water Simulation

	km^2	mi^2		km^2	mi^2
Ichetucknee	222	86	July	11	4
Blue Hole	488	188	Twin	49	19
Sunbeam	103	40	Ginnie	414	160
River Rise	134	52	Poe / Lilly	241	93
Rum Island	26	10	Hornsby	210	81

Physical Features

River
Conduits
County Boundary
WSFM-08 Boundary

N

0 2.5 5 10 Miles

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Reasonably Simulate Springsheds

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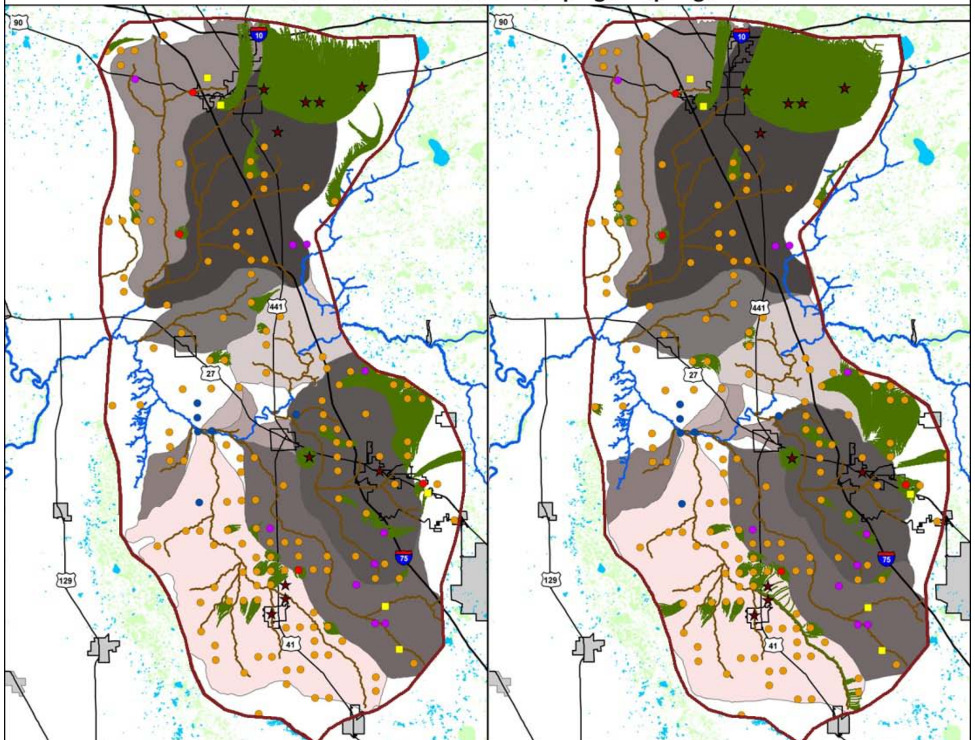
Improved Modeling Approach – *Hybrid Model*

WSFM-08 Simulated Effects of Pumping on Springsheds



High Water Simulation	*Low Water Simulation*

Example: Lake City Pumping = 4.5 MGD (High Water Simulation)

	Ichetucknee	Blue Hole
No Pumping	248 km^2	347 km^2
Pumping	245 km^2	316 km^2
Reduction	-1%	-19%

Example: Lake City Pumping = 4.5 MGD (Low Water Simulation)

	Ichetucknee	Blue Hole
No Pumping	222 km^2	488 km^2
Pumping	222 km^2	377 km^2
Reduction	0%	-30%

Extraction Wells

- water bottling
- golf course
- industrial & mining
- irrigation & livestock
- nursery
- public supply

N

0 2.5 5 10 Miles

Physical Features

- River
- County Boundary
- Conduits
- WSFM-08 Boundary

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Reasonably Simulate Impacts of Groundwater Pumping

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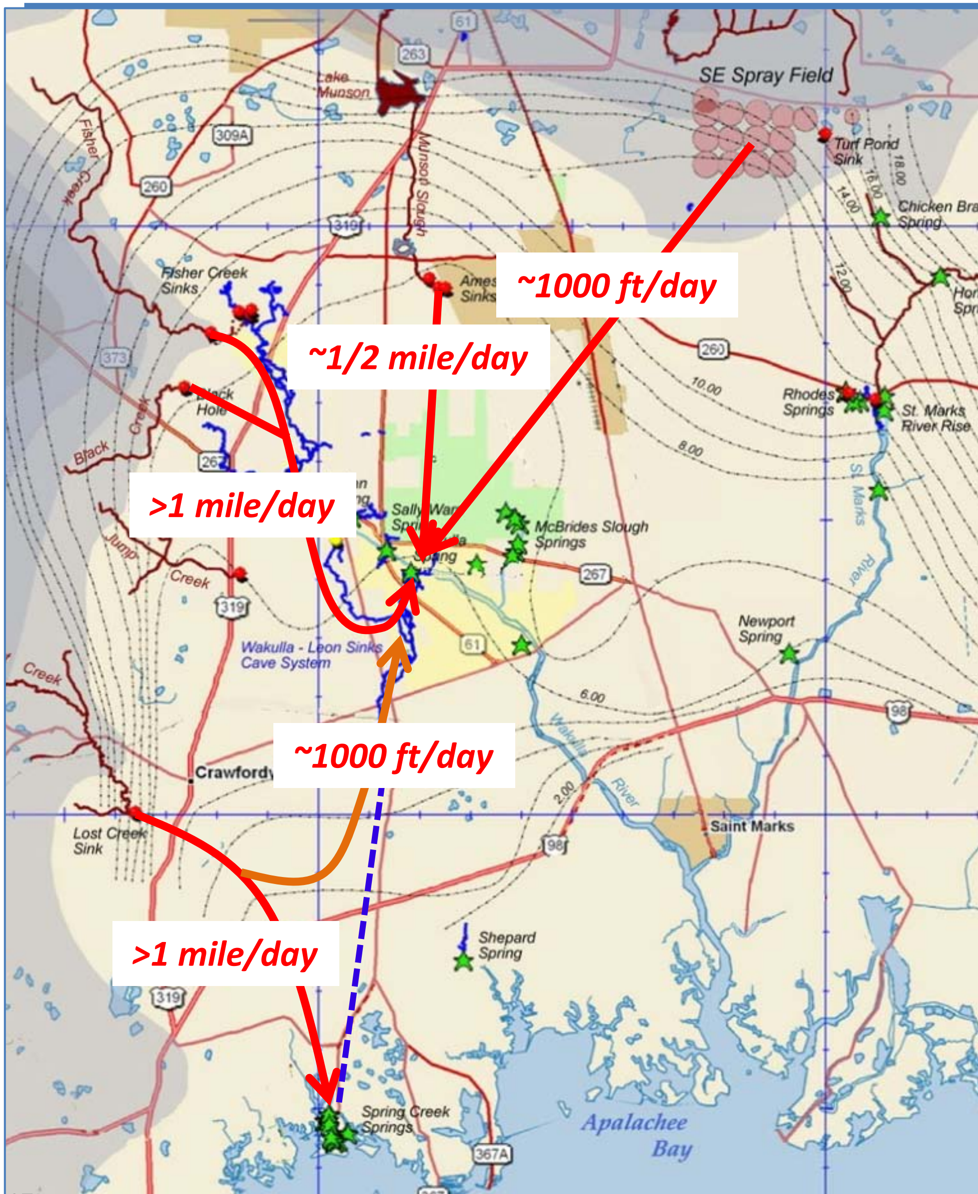
Wakulla Area Hydrogeology – KARST CONDUITS



Western Woodville Karst Plain

- Flow is fast in caves and in surrounding aquifer (caves too small to map)
- Large part of Wakulla's discharge is inflow from swallets (surface water)
- Wakulla & Spring Creek are connected
- Spring Creek began reversing for appreciable durations in 2006
- Spring Creek reverses now every summer for weeks - months
- We're loosing the largest spring in Florida & the associated fresh water that flows to the Gulf of Mexico estuaries

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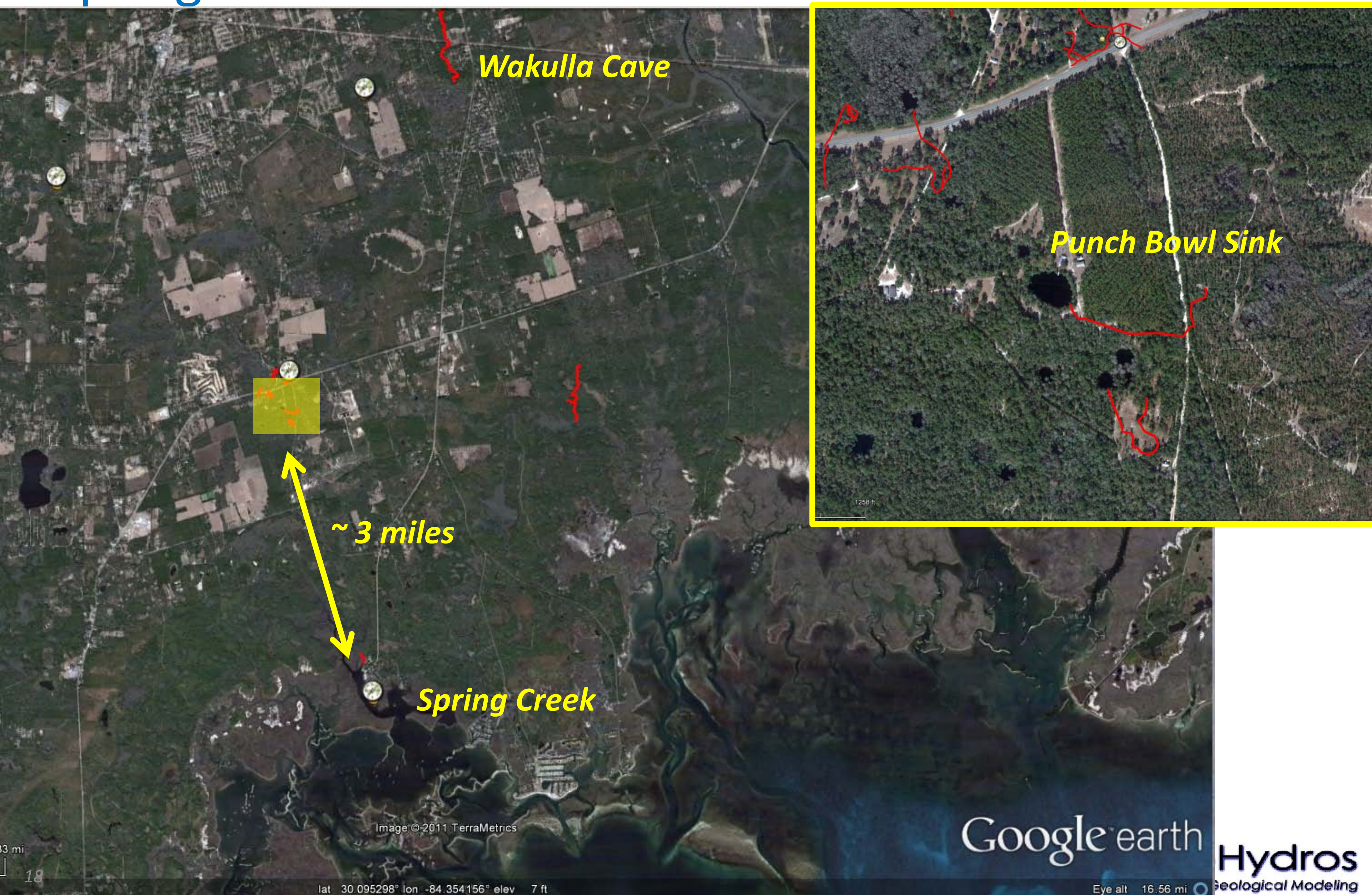
Spring Creek – Saltwater Intrusion



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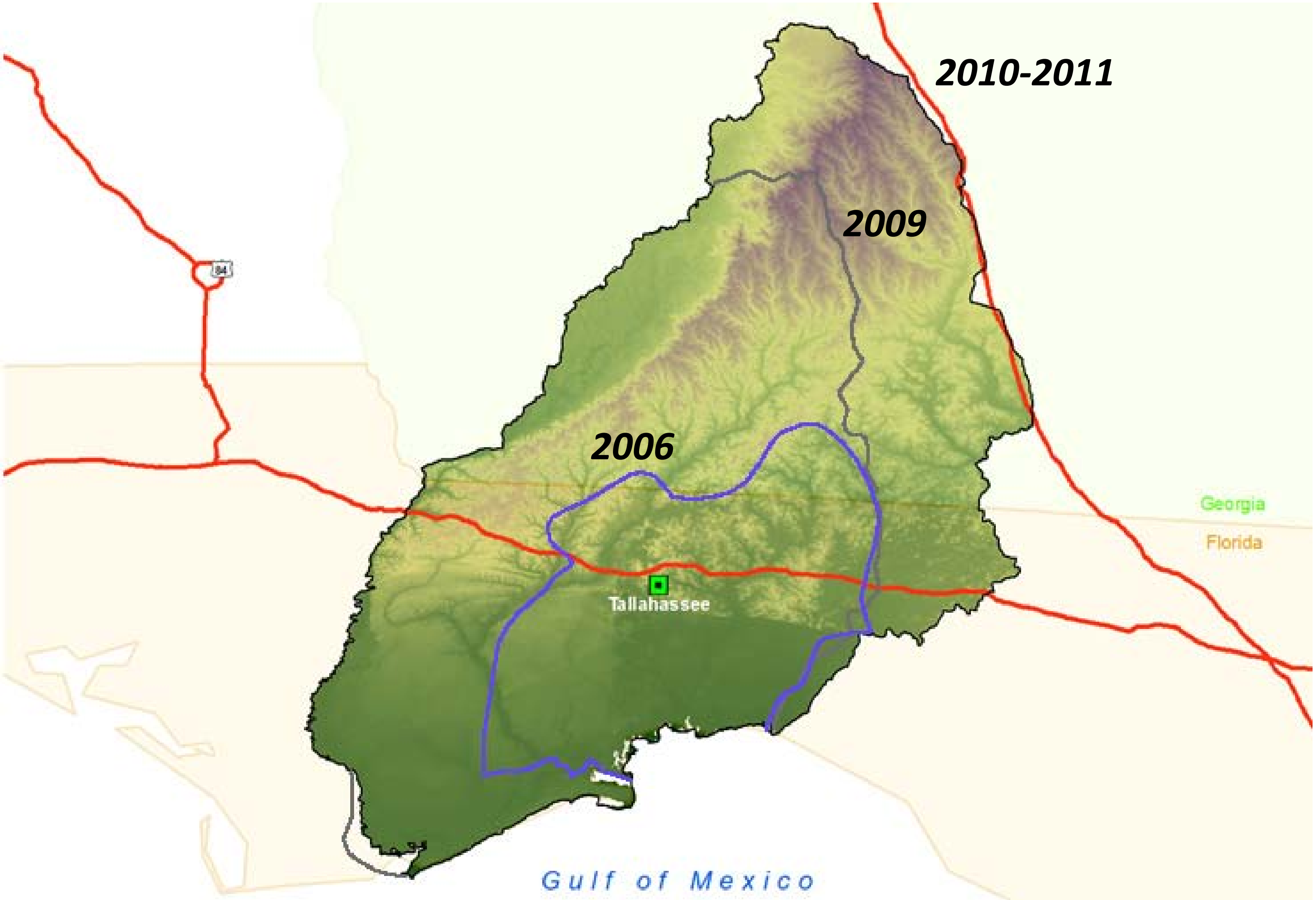
Wakulla – Regional Groundwater Flow Model



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Wakulla Model - History

- Began in 2002 with Rodney DeHan and FGS
  Can we build a better mouse trap?
- Identify technologies that would accommodate conduit flow
  Hybrid Modeling Technology – established in early 1990's
- Built on existing models
  largely limited to Florida – Woodville Karst Plain
- Expanded regional scope in 2009
  Allow model to define springshed boundaries internally
  Used compiled pumping and geologic datasets
- 2011 - Learned of much more pumping
  compiled all pumping data from Florida & Georgia
  forced reinterpretation of geology – compiled from more available data
- 2012 – new datasets compiled and presented
  model needs to be revised
  should address technologies developed for the Santa Fe Model

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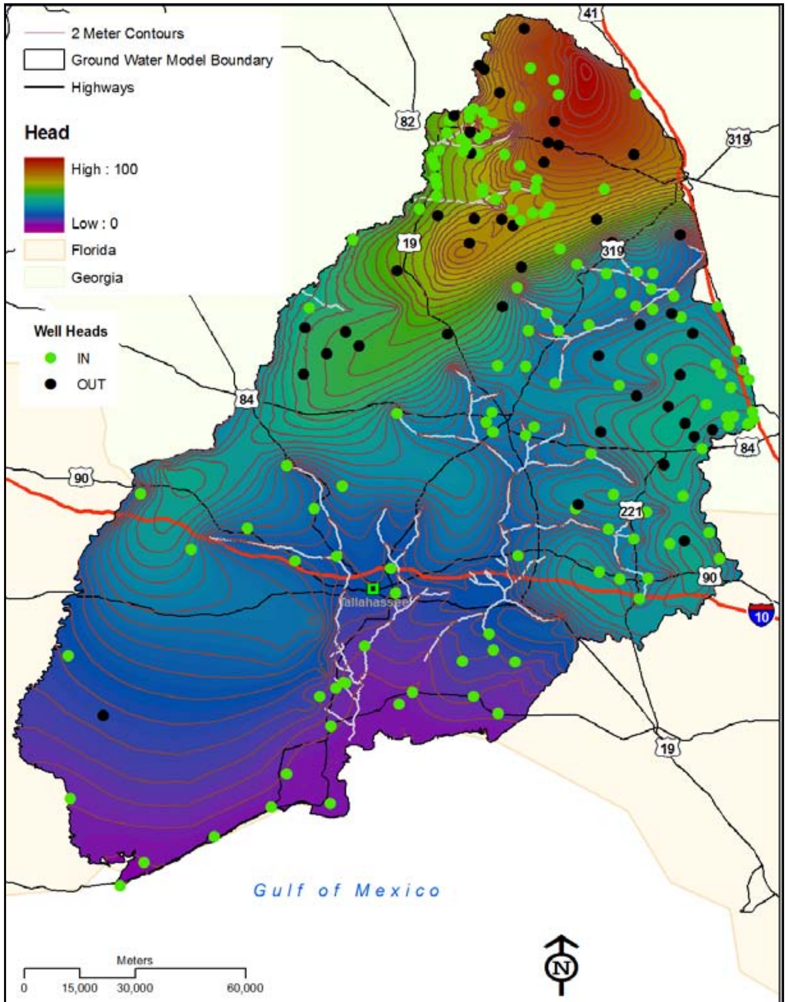
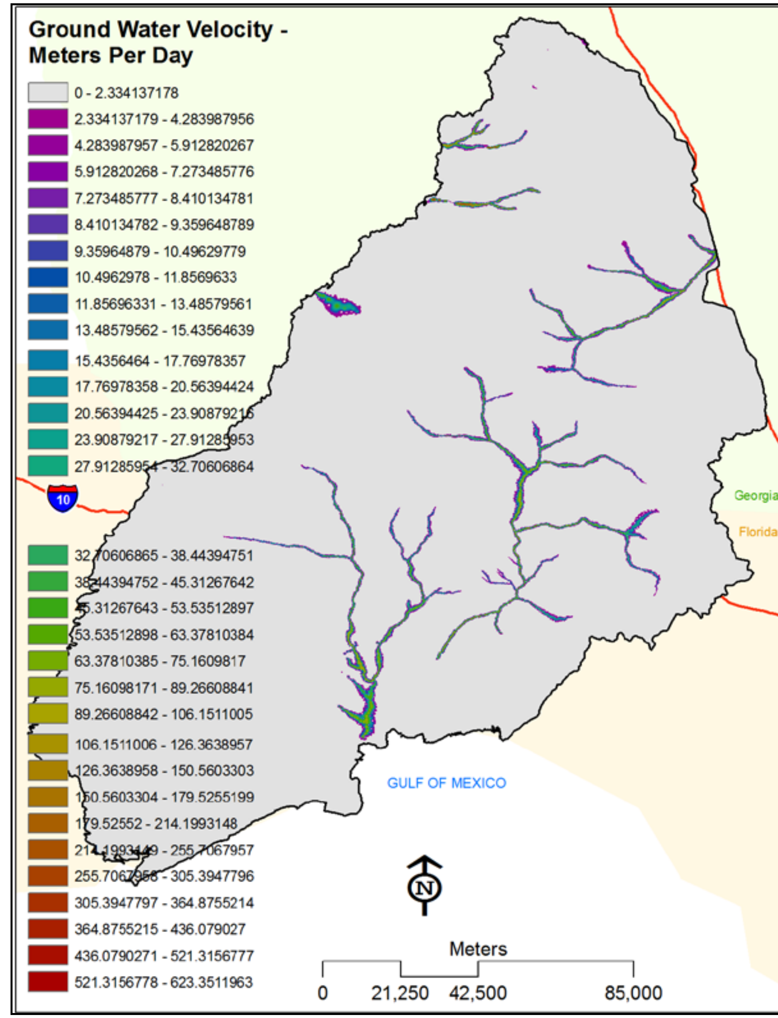
2010 Model Results

Potentiometric Surface



Velocities



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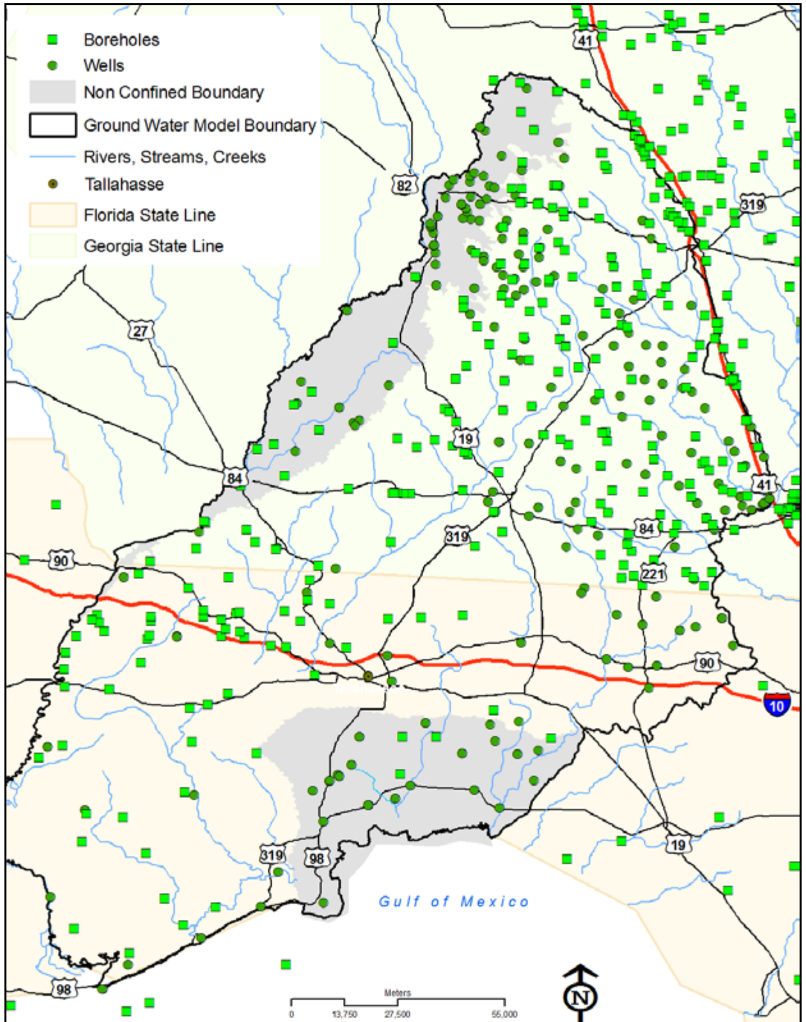
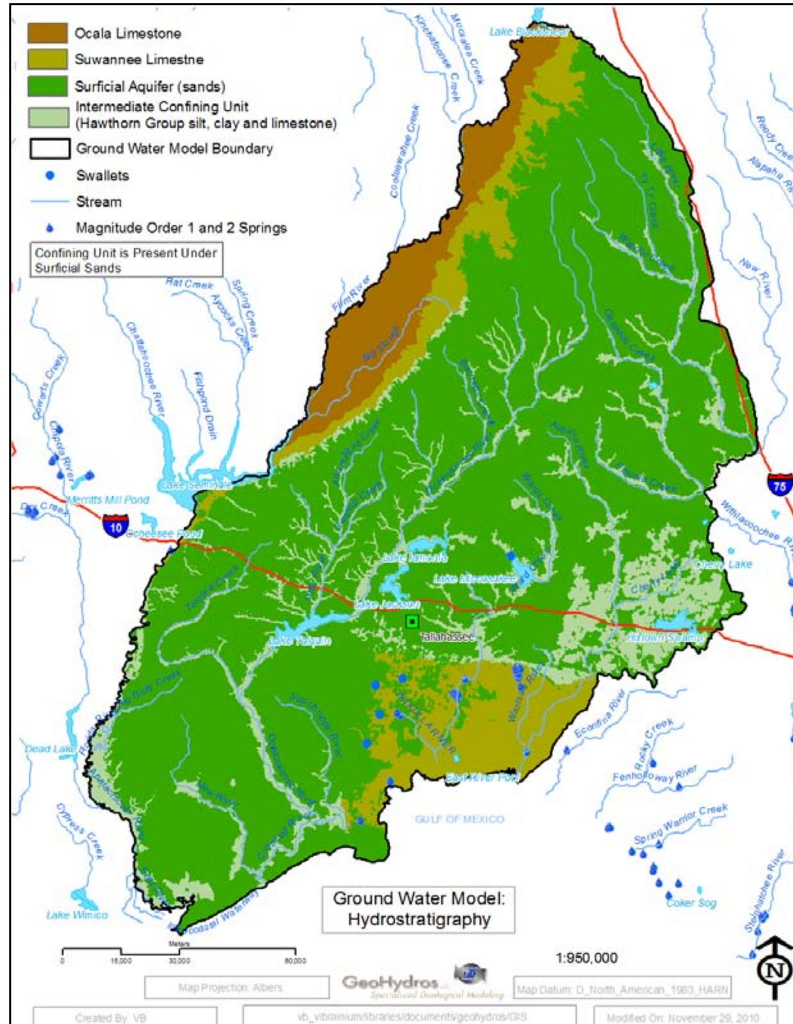
2010 Model Framework

- ~900 wells and boreholes





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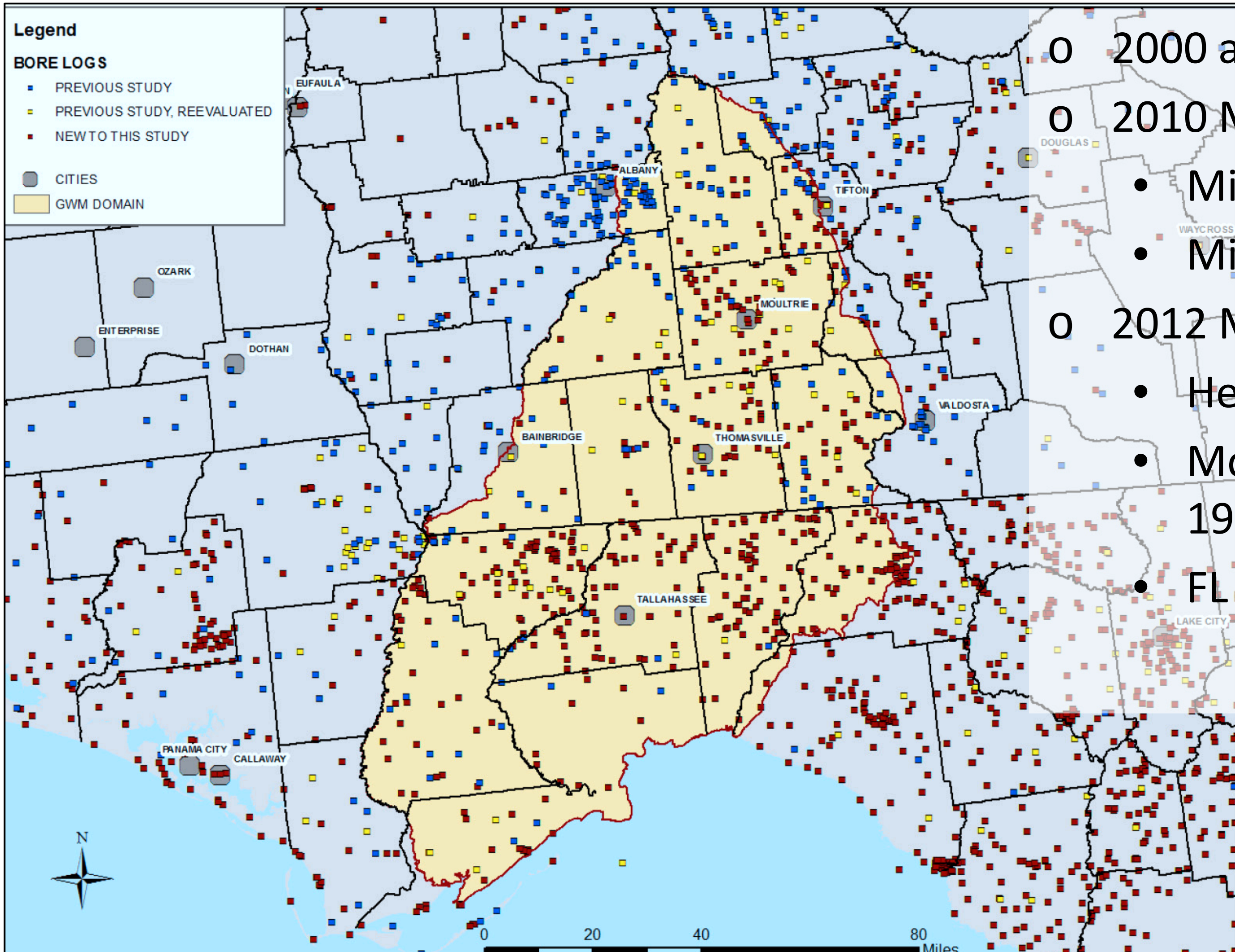
Revised Geology



- 2000 additional borelogs
- 2010 Model
  - Miller 1986
  - Miller 1988
- 2012 Model - *added*
  - Herrick 1961
  - McFadden & Others 1986
  - FL LithProg Database

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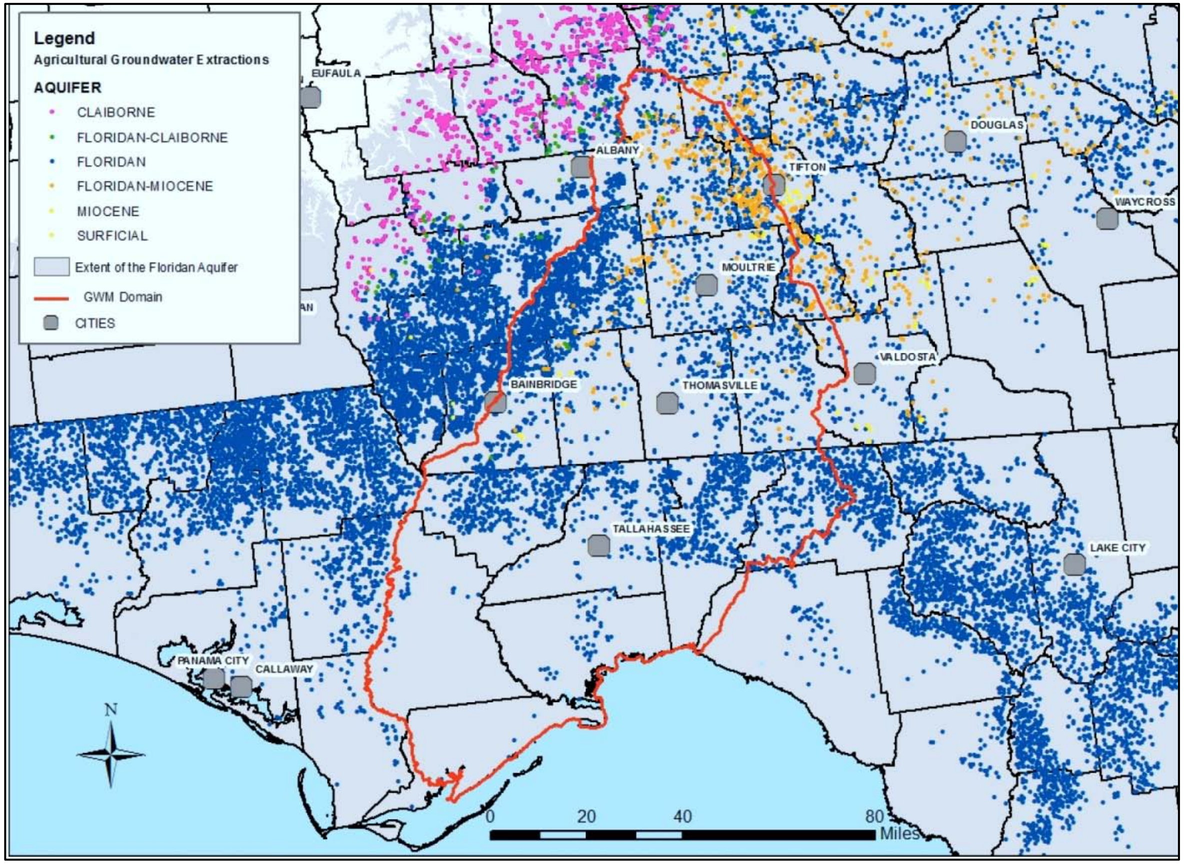
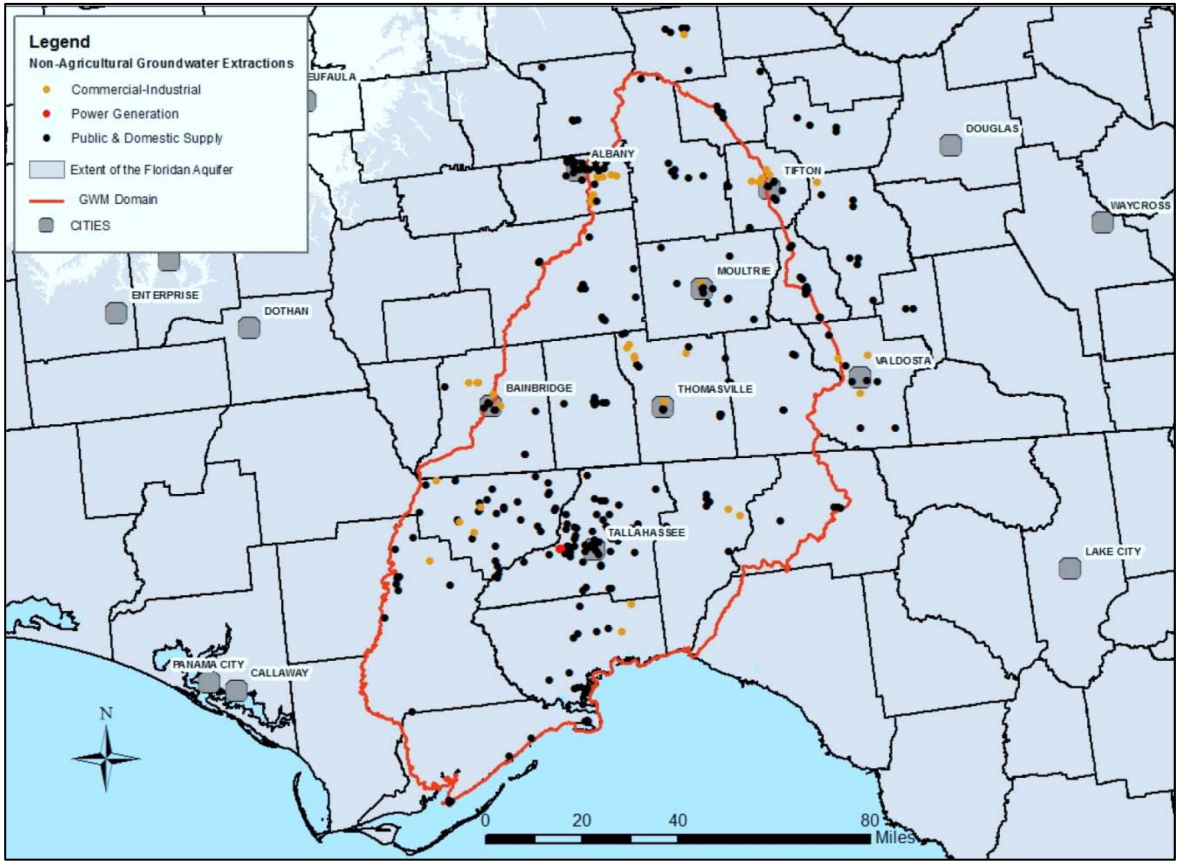
Agricultural Pumping



- National Environmentally Sound Production Agriculture Laboratory (NESPAL) - University of Georgia's College of Agricultural and Environmental Sciences
- Georgia EPD
- NWFWMD
- SRWMD

GA: 183 MGD – Contributing Counties / 93 MGD Model Domain
FL: 29 MGD – Contributing Counties / 21 MGD Model Domain

Municipal Pumping



- GA: Fanning & Trent 2009
- FL: Maralla 2009
- FL: NWFWMD

GA: 54 MGD – Contributing Counties
FL: 24 MGD – Contributing Counties

Revised Hydrostratigraphic Framework

- Expanded Model to bottom of Oldsmar or equivalent
- 9 model layers (expanded from 5)
- Divisions set to describe lateral and vertical heterogeneity in Floridan aquifer system units

GWM LAYER	AGE	HIGH PERM	LOW PERM	NOTE
1	Post Miocene	Undif. sand & clay		Continuous, vertical K will define where Hawthorn present
	Miocene	Altamaha	Hawthorne	
2	Miocene	Chattahoochee / Tampa / St. Marks		Discontinuous, all Miocene limestones where present
3	Upper Oligocene	Suwannee		Discontinuous, all Suwannee where present
4	Lower Oligocene		Marianna / Undif.	Discontinuous, all Marianna where present
5	Upper Late Eocene	Ocala	Cooper Marl	Discontinuous, all Ocala where present
6	Lower Late Eocene	Wilson	Undif. / Barnwell	Discontinuous, horizontal K will define Wilson / Undifferentiated division
7	Upper Middle Eocene	Avon Park	Lisbon	Continuous, horizontal K will define Avon Park / Lisbon division
8	Lower Middle Eocene	Lake City	Tallahatta	Continuous, horizontal K will define Lake City / Tallahatta division
9	Early Eocene	Oldsmar	HTGB	Continuous, horizontal K will define Oldsmar / HTGB division
-	Paleocene	Cedar Key	Cedar Key	Top of the layer is bottom slice of model

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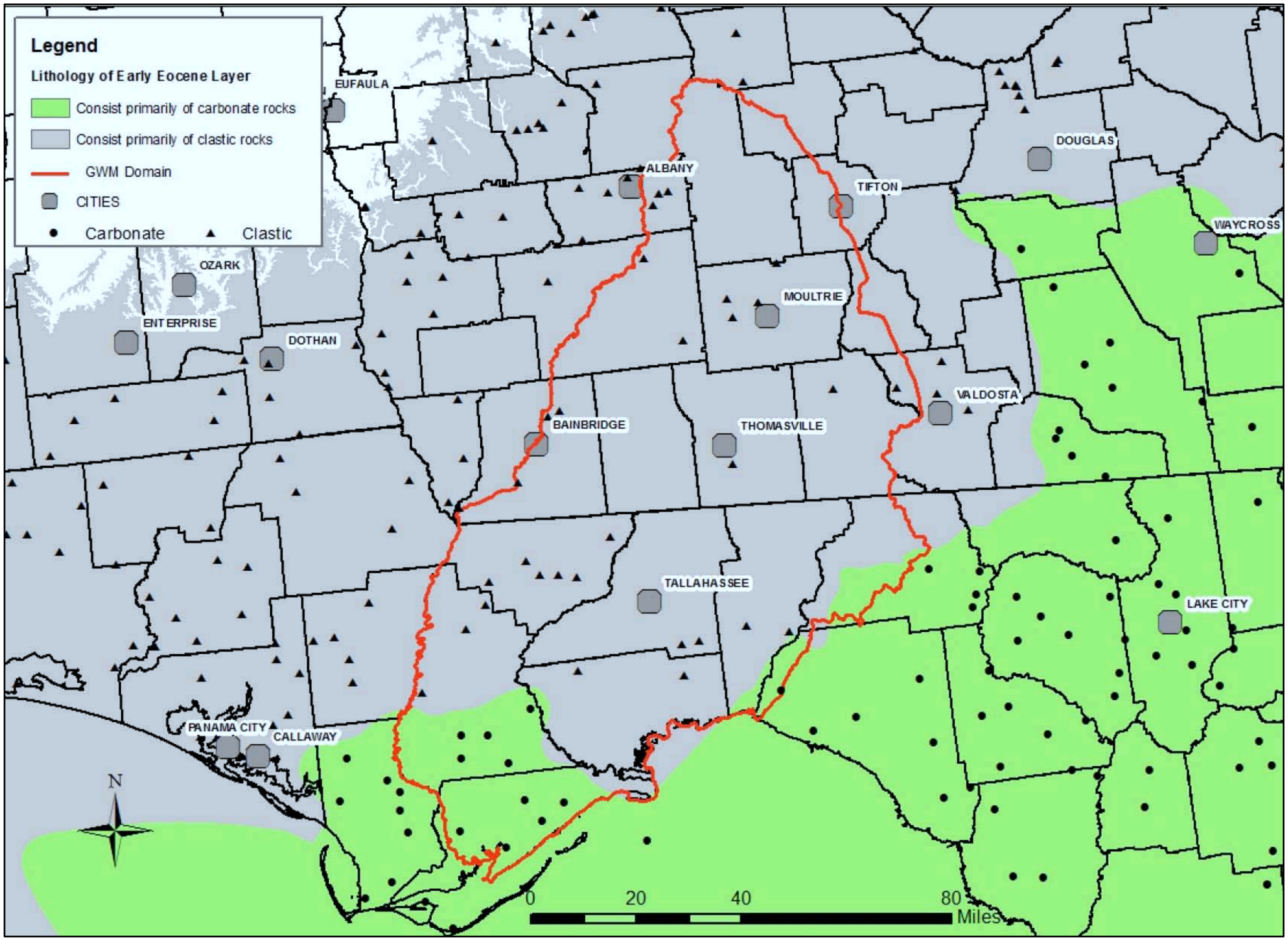
Revised Framework – Early Eocene Layer



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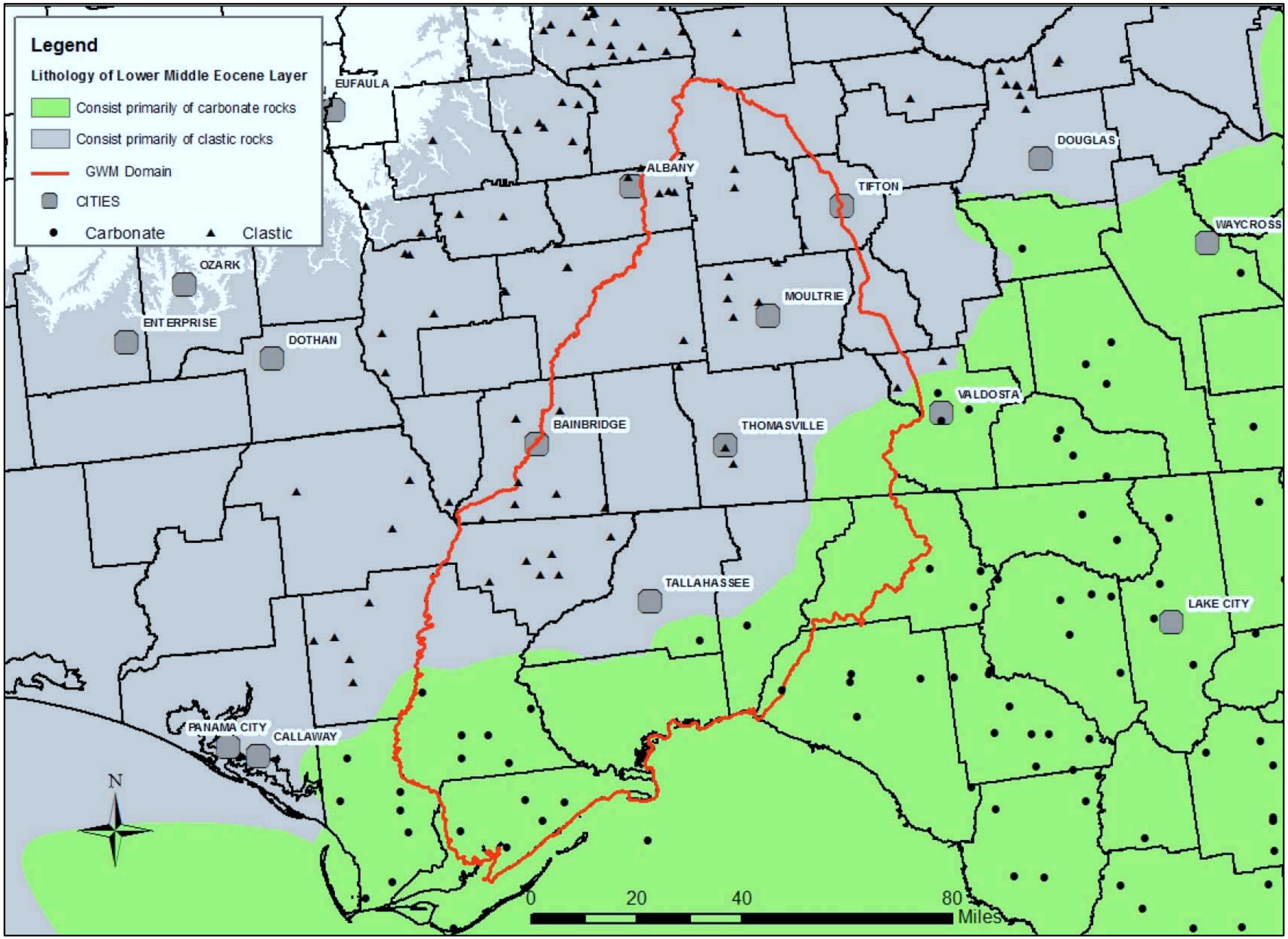
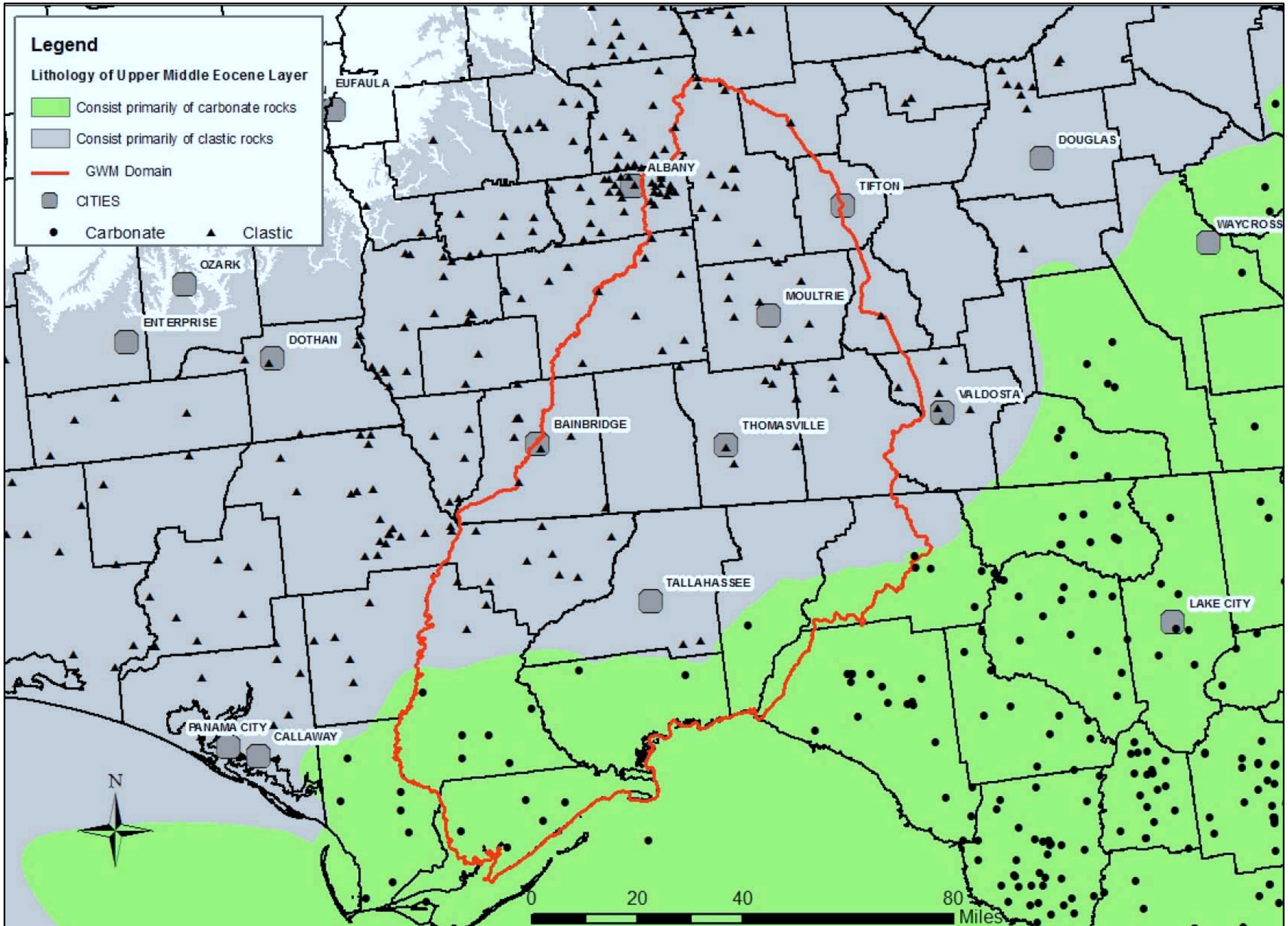
Revised Geology – Lower Middle Eocene Layer



Revised Geology – Upper Middle Eocene Layer



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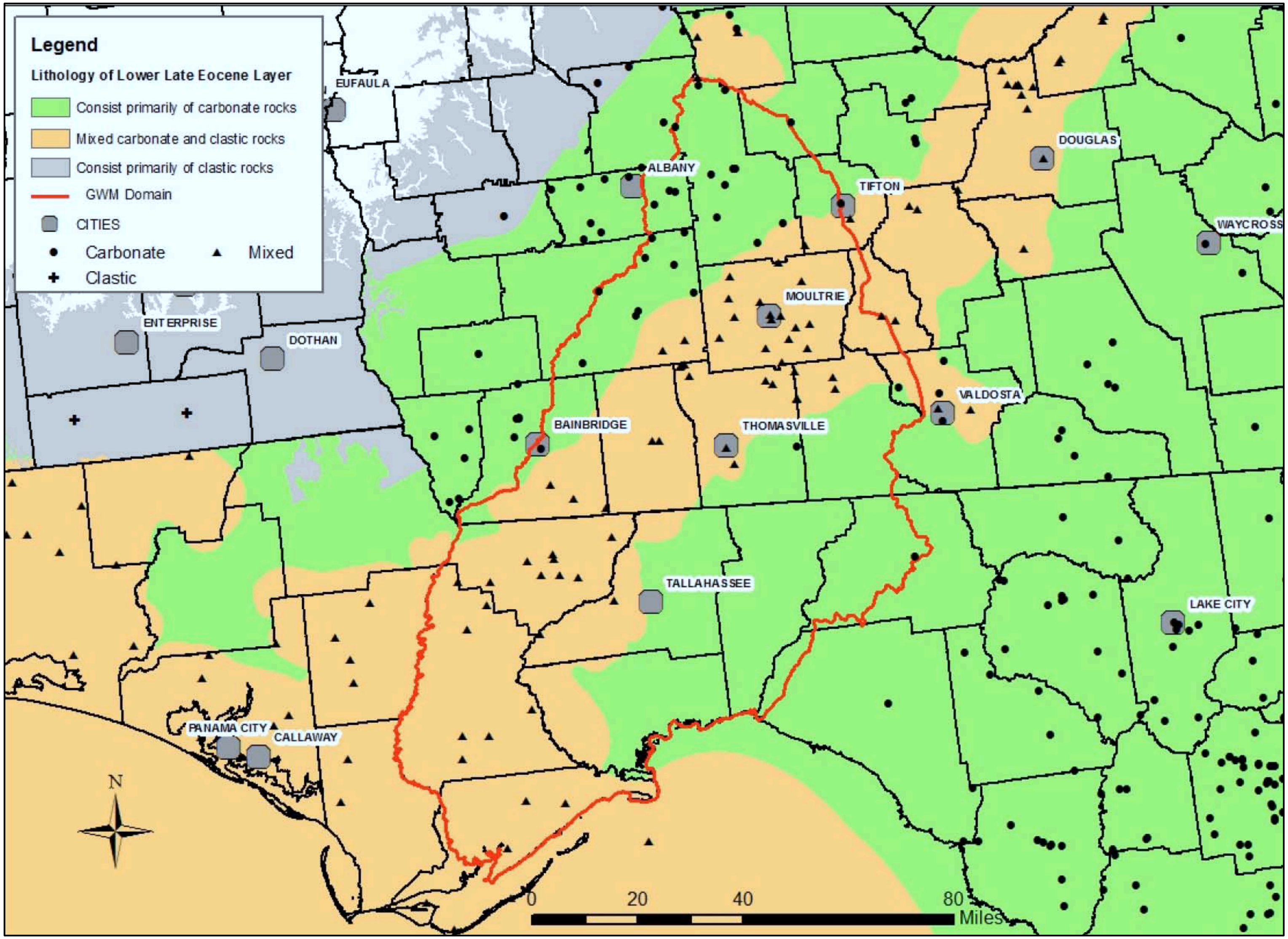
Revised Geology – Lower Late Eocene Layer



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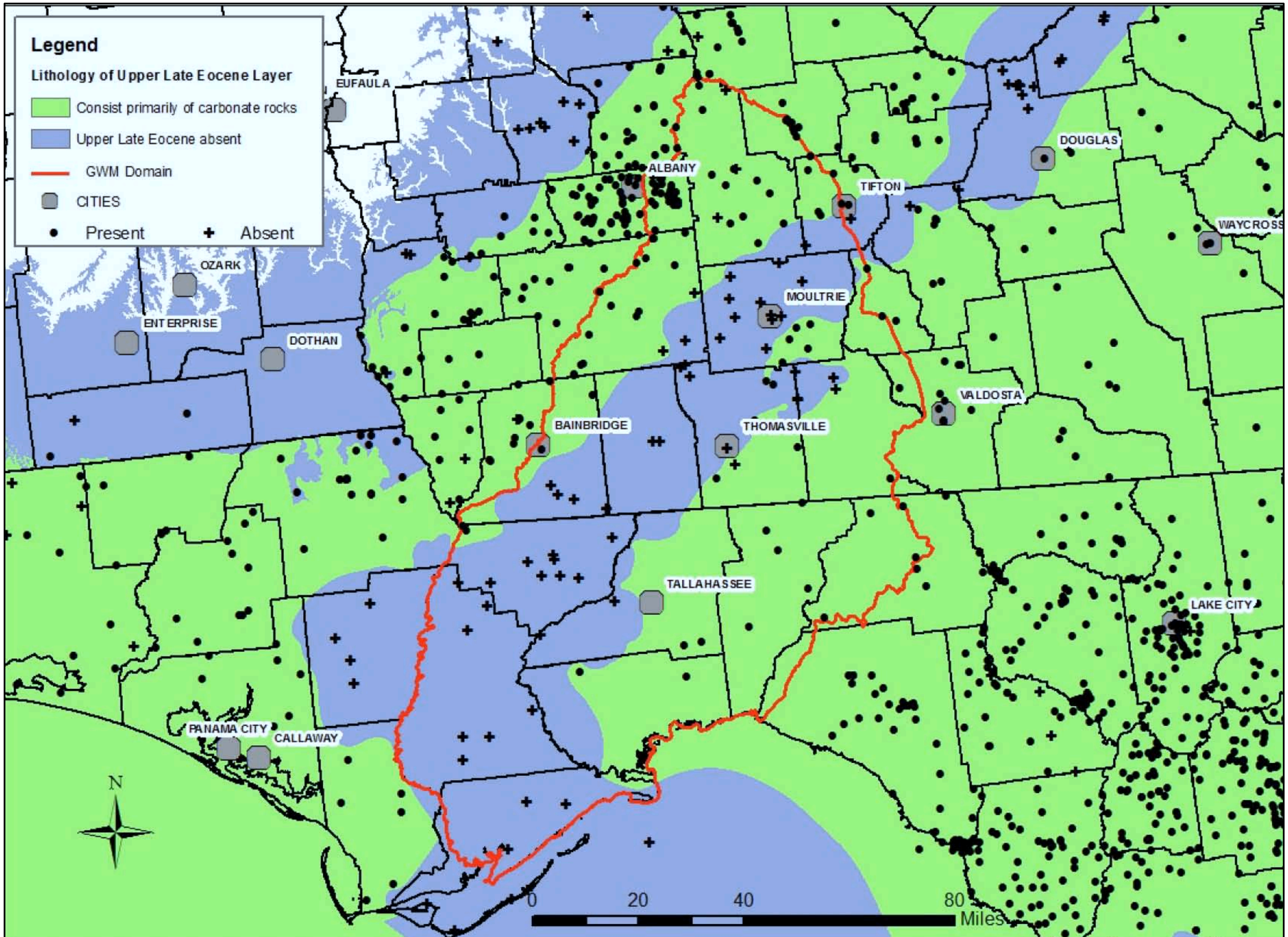
Revised Geology – Upper Late Eocene Layer



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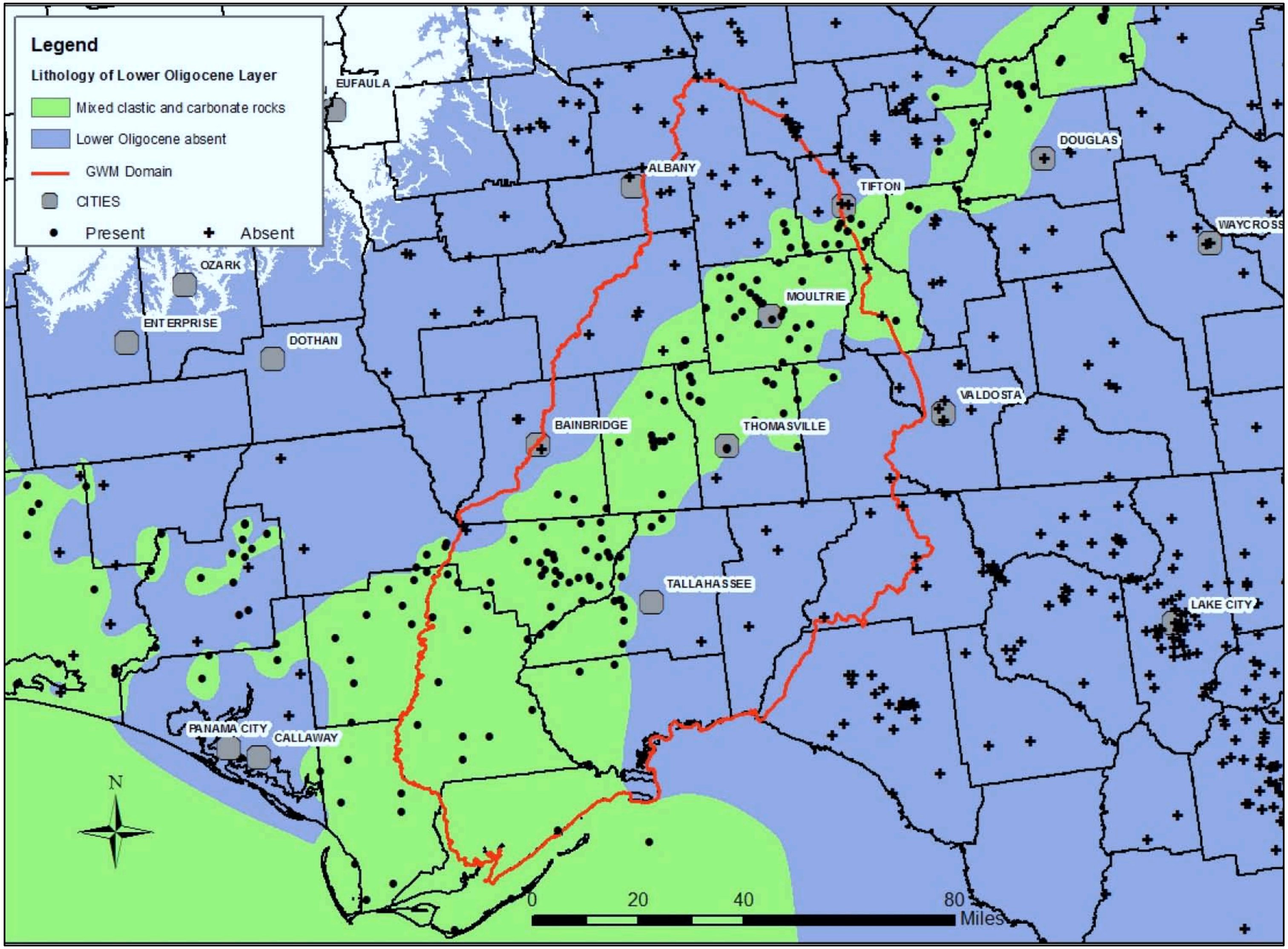
Revised Geology – Lower Oligocene Layer



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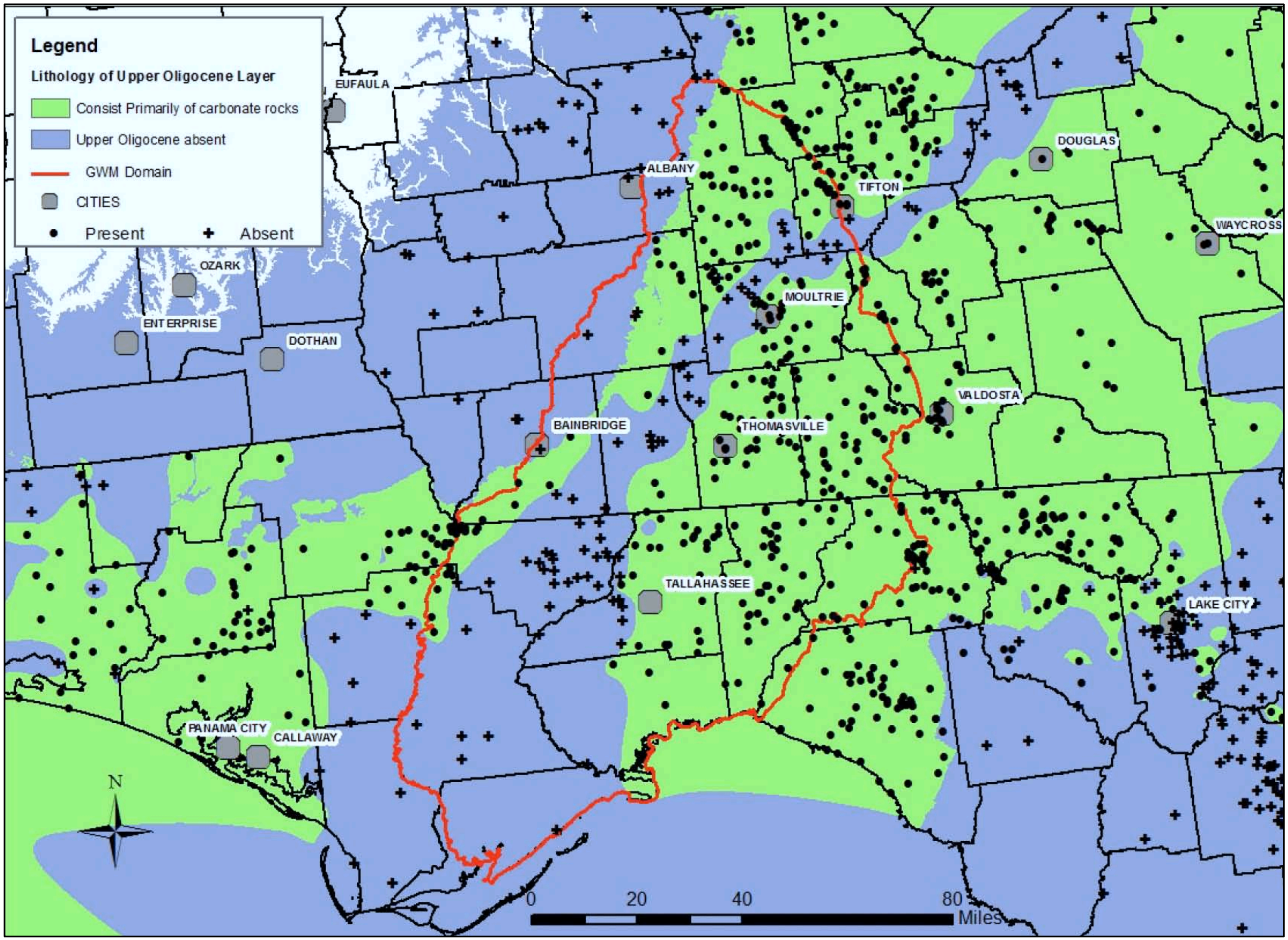
Revised Geology – Upper Oligocene Layer



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Completion Tasks & Objectives

- Revise calibration datasets
  - Typically use one period
  - Would like to use two (high-water & low-water) based on benefits observed in the Santa Fe Model
- Revise model framework with new geologic delineations
- Calibrate Model
  - Simultaneous calibration to two datasets
  - Adapt global parameter estimation (optimization) code to hybrid model
- Develop scenario analyses
  - Impacts of pumping (GA vs FL)
  - Impacts of sea-level rise
- Timeline: 6 months to 1 year – depending on calibration approach

Probable Applications of Completed Model

- Predict impacts of groundwater extraction on spring flows
  - Simulate springshed boundaries and how they interact
  - Simulate specific spring discharges
  - Simulate magnitude and spatial location of pumping
  - Simulate specific groundwater extractions
- Predict impacts of changing recharge conditions on spring flows
  - Simulate land use and land use changes
  - Simulate 3D hydrostratigraphic framework
- Map spring and well vulnerability to contamination
  - Simulate groundwater flow patterns to springs
  - Simulate groundwater velocities
- Identify sources of contamination to springs

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Thanks for Listening

<u>Acknowledgements</u>

- *Florida Geological Survey*
  - Rodney DeHan, Jon Arthur, Scott Dyer, Tom Greenhalgh, Harley Means
  - FGS Staff
  - Applied research to solve problems
  - www.geohydros.com/FGS/

- *The Coca-Cola Company*
  - Vested interest in sustained clean freshwater discharge to the Western Santa Fe River
  - "Diminished water quality & quantity diminishes our business and their brand"
  - *www.geohydros.com/CCNA/*

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