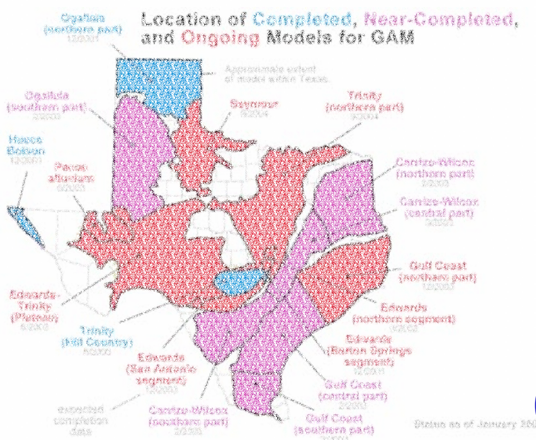
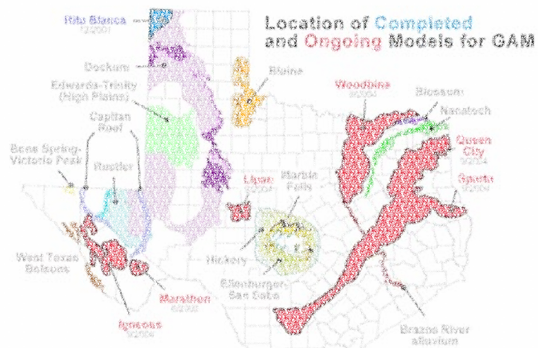
GAM

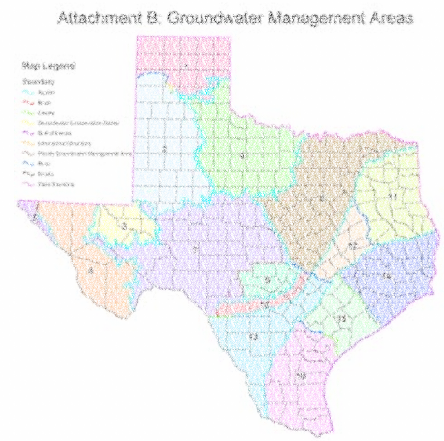
Groundwater Availability Modeling

texas water development board

Groundwater Availability Modeling

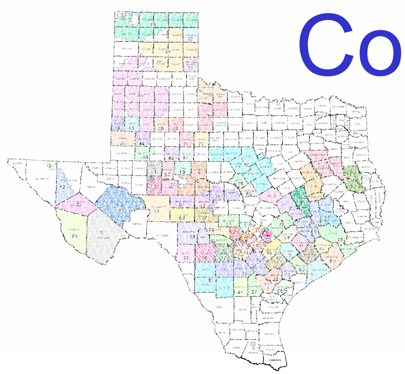


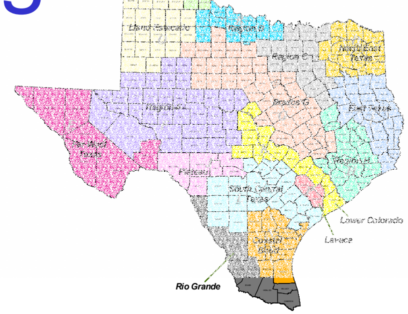




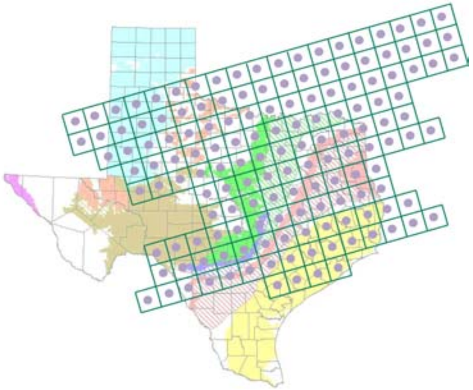
Cindy Ridgeway

Contract & Project Manager



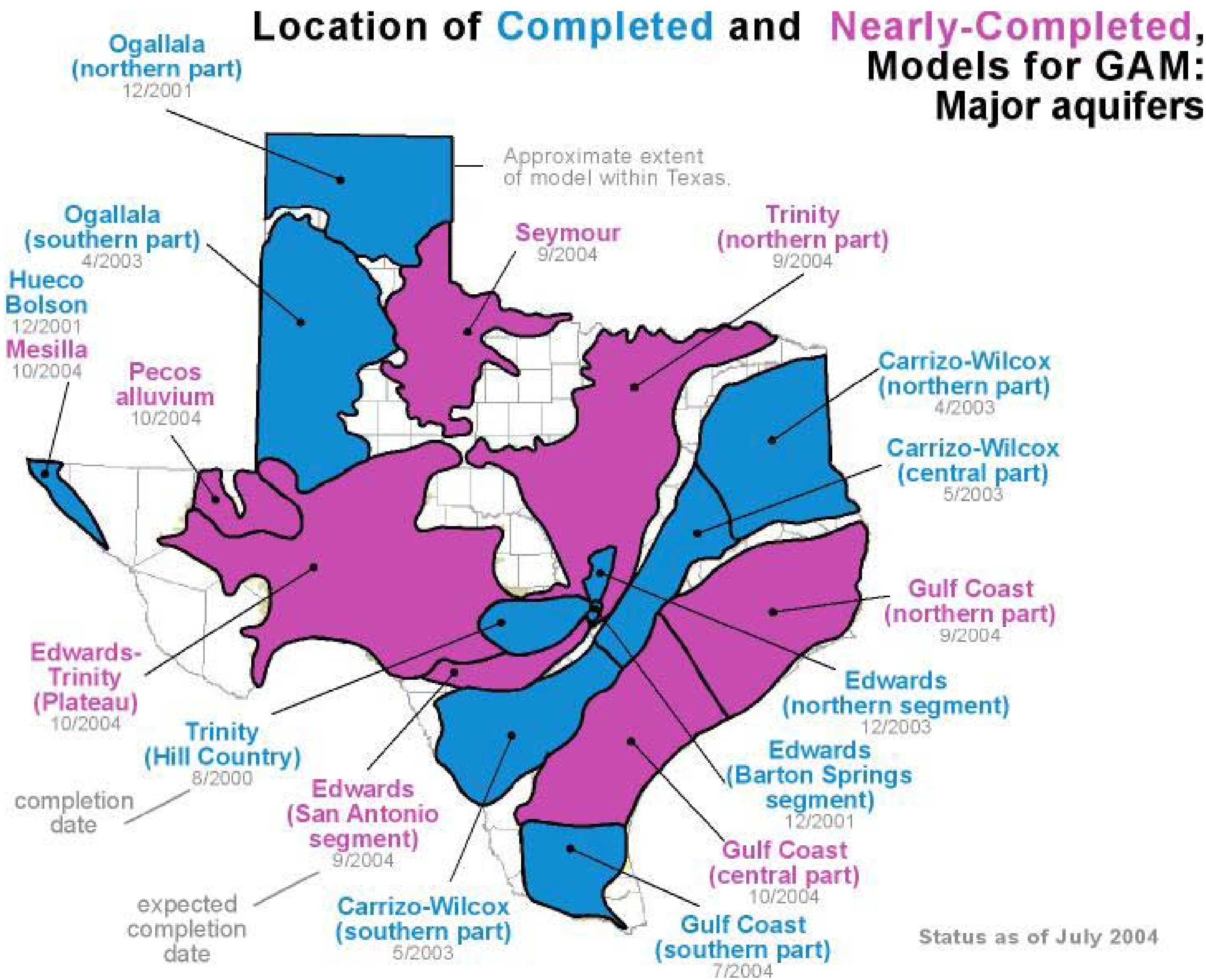


Texas Water Development Board



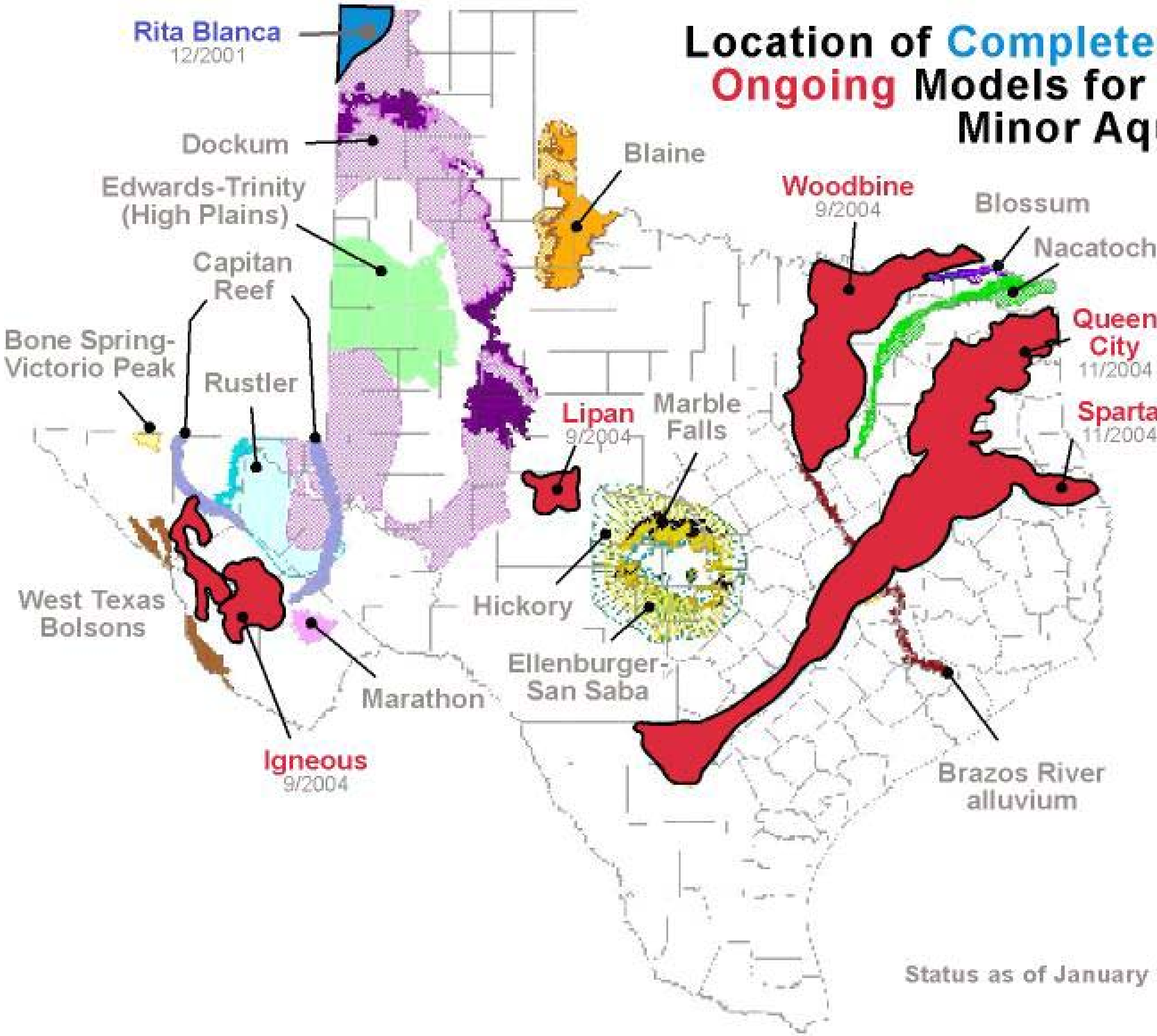
GAM

- Purpose: to develop the best possible groundwater availability model with the available time and money.
- Public process: you get to see how the model is put together.
- Freely available: standardized, thoroughly documented, and available over the internet.
- Living tools: periodically updated.

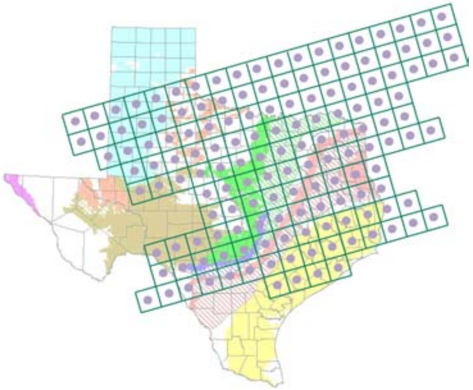


Location of Completed and Nearly-Completed, Models for GAM: Major aquifers
Ogallala (northern part) 12/2001
Approximate extent of model within Texas.
Ogallala (southern part) 4/2003
Hueco Bolson 12/2001
Mesilla 10/2004
Pecos alluvium 10/2004
Seymour 9/2004
Trinity (northern part) 9/2004
Carrizo-Wilcox (northern part) 4/2003
Carrizo-Wilcox (central part) 5/2003
Gulf Coast (northern part) 9/2004
Edwards (northern segment) 12/2003
Edwards (Barton Springs segment) 12/2001
Gulf Coast (central part) 10/2004
Gulf Coast (southern part) 7/2004
Carrizo-Wilcox (southern part) 5/2003
Edwards (San Antonio segment) 9/2004
Trinity (Hill Country) 8/2000
Edwards-Trinity (Plateau) 10/2004
completion date
expected completion date
Status as of July 2004

Location of Completed and Ongoing Models for GAM: Minor Aquifers

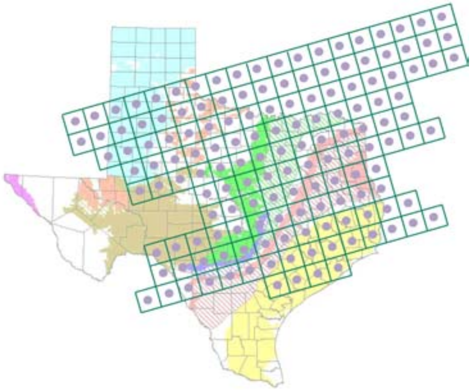


Status as of January 2004



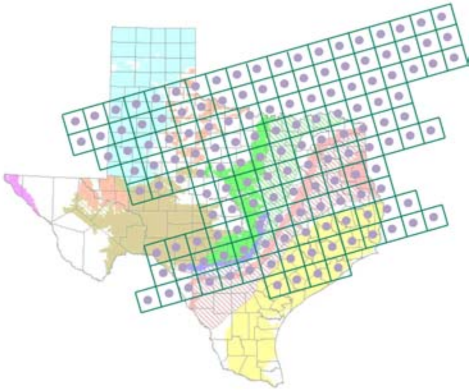
What is groundwater availability?

- …the amount of groundwater available for use.
- The State does not decide how much groundwater is available for use: GCDs and RWPGs decide.
- A GAM is a tool that can be used to assess groundwater availability once GCDs and RWPGs decide how to define groundwater availability.



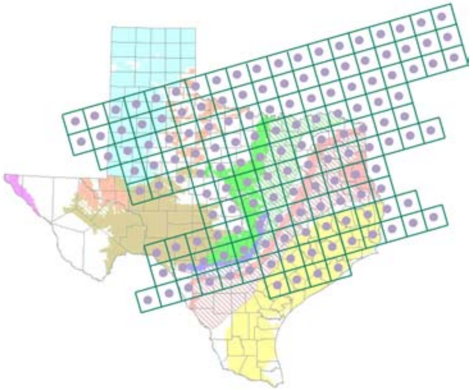
How do we use GAM?

- The model
  - predict water-level trends and regional flow in response to pumping and drought
  - effects of major producing well fields
- Data in the model
  - water in storage
  - recharge estimates
  - hydraulic properties
- GCDs and RWPGs can request runs



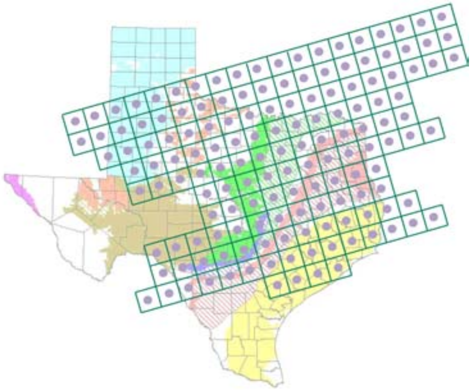
Do we have to use GAM?

- Water Code & TWDB rules require that GCDs use GAM information. Other information can be used in conjunction with GAM information.
- TWDB rules require that RWPGs use GAM information unless there is better site specific information available



Living tools

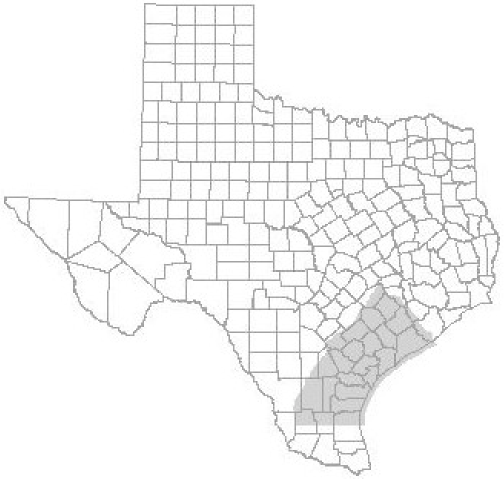
- GCDs, RWPGs, TWDB, and others collect new information on aquifer.
- This information can enhance the current GAMs.
- TWDB plans to update GAMs every five years with new information.
- Please share information and ideas with TWDB on aquifers and GAMs.



Participating in the GAM process

- SAF meetings
  - hear about progress on the model
  - comment on model assumptions
- Report review
  - Summary Report coming soon to the TWDB GAM website.
  - http://www.twdb.state.tx.us/GAM/glfc_c/glfc_c.htm
- Contact TWDB
  - Cindy Ridgeway (512) 936-2386 or Robert Mace (512) 936-0861

Contract & Project Manager
cindy.ridgeway@twdb.state.tx.us
(512)936-2386
www.twdb.state.tx.us/gam



Recalibration of the Central Gulf Coast Groundwater Availability Model (GAM)

Ali Chowdhury, Ph.D., P.G.
Hydrogeologist
Groundwater Resources Division

Acknowledgements

Dr.Shirley Wade, Ms. Cindy Ridgeway, Dr. Scott Hamlin
for reviewing, processing and assigning pumpage information
&
Dr. Robert Mace for supervision and overall guidance

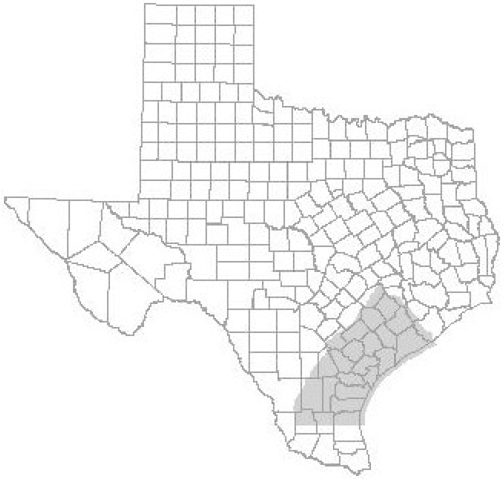
Outline

- Conceptual Model

- Model Recalibration
  - → Steady-State (1900-1940)
  - → Transient (1980-1999)
  - → Prediction (2000-2050)

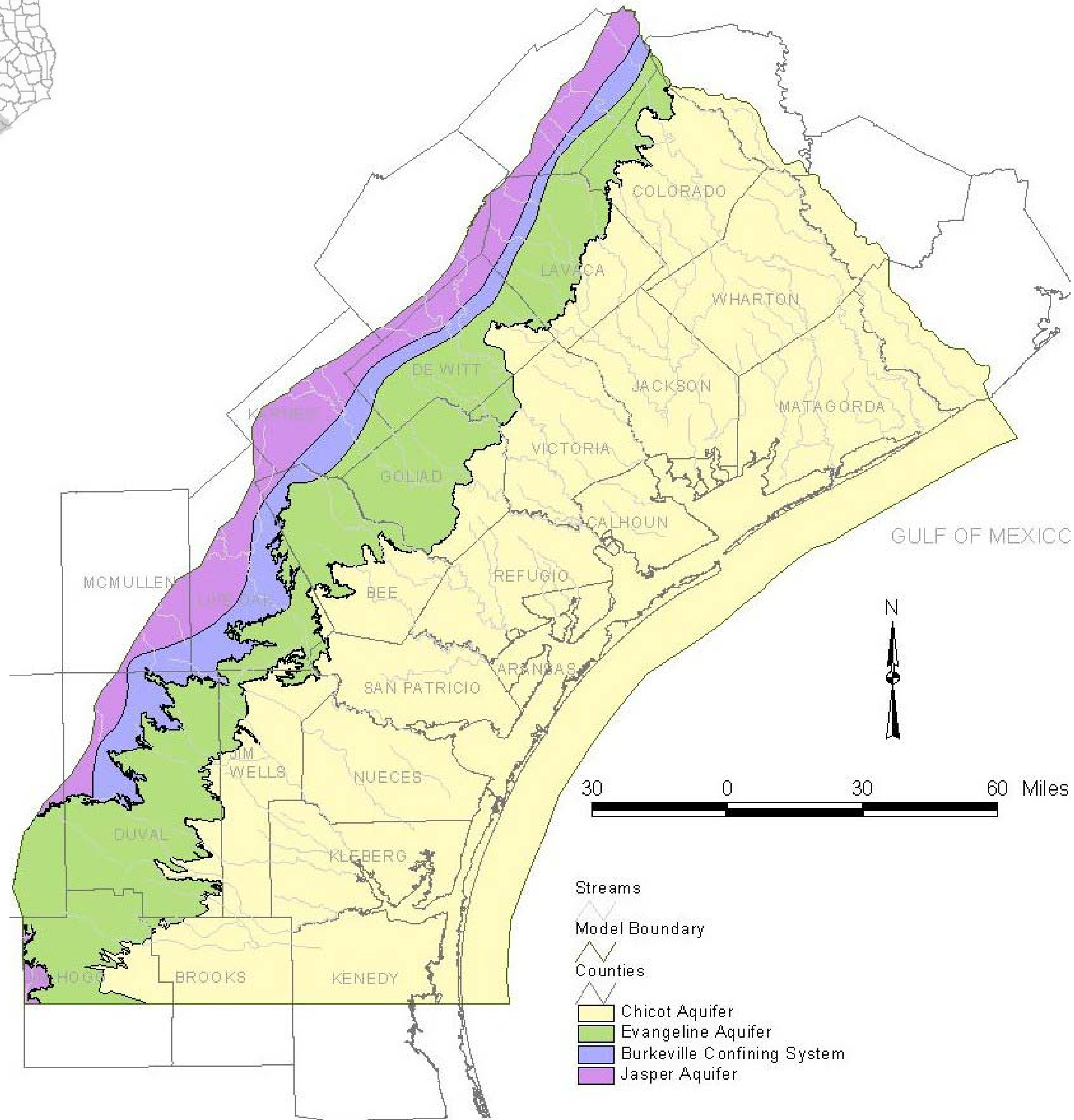
- Model Results
  - → Drawdown Cones developed in Wharton, Victoria and Kleberg counties
  - → Used County-Basin Pumpage

- Conclusions

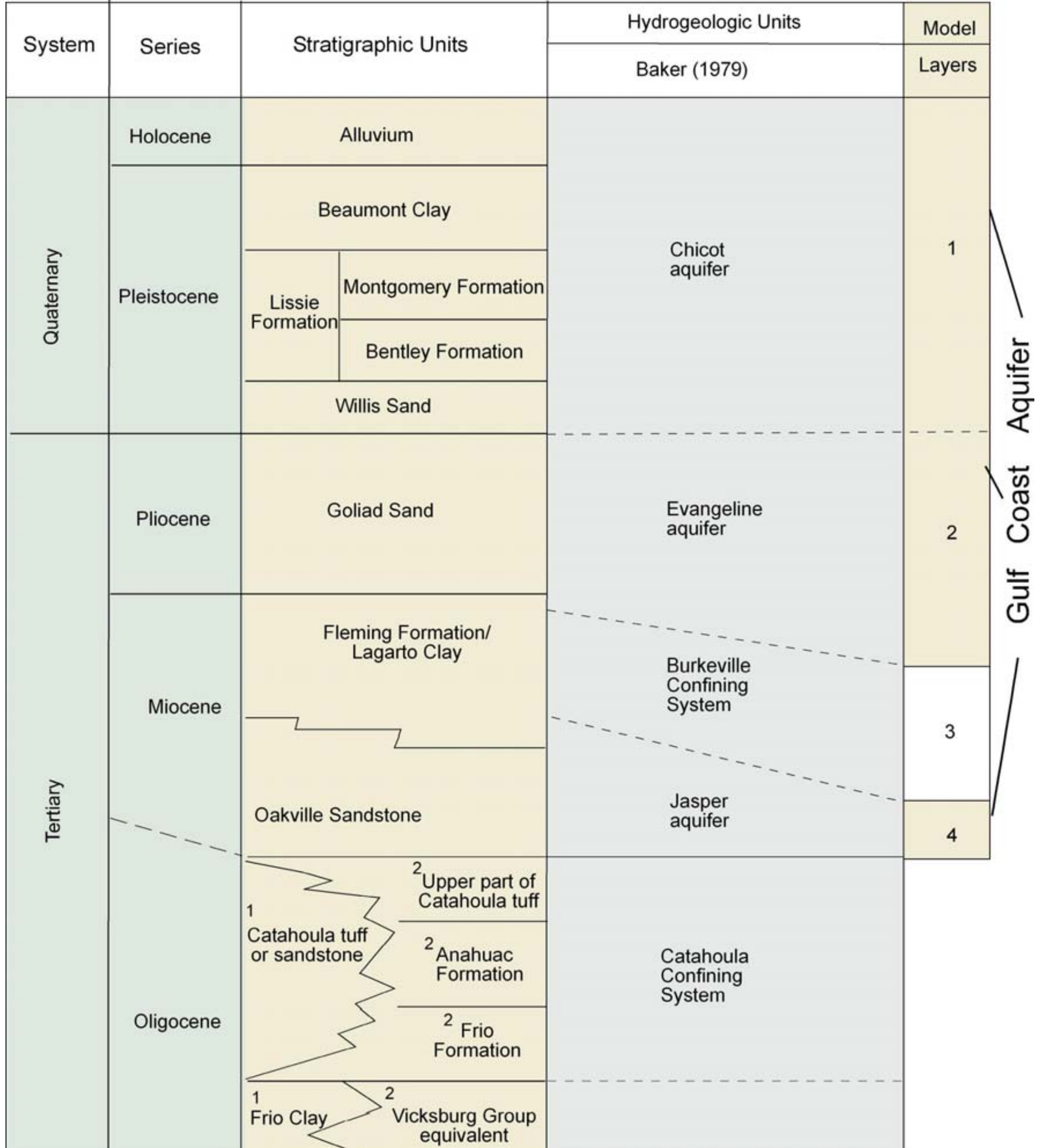


CONCEPTUAL MODEL

Central Gulf Coast GAM Area

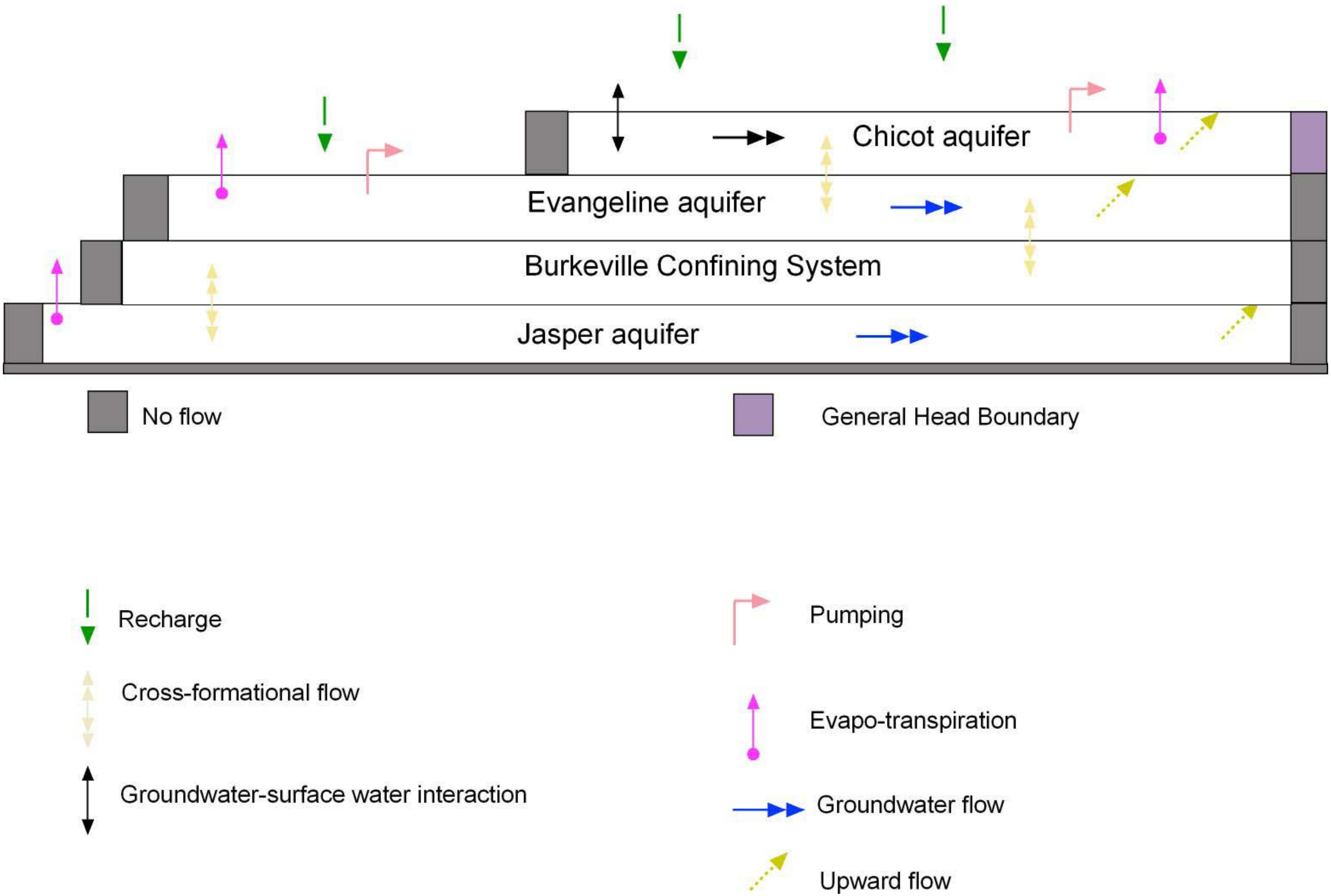


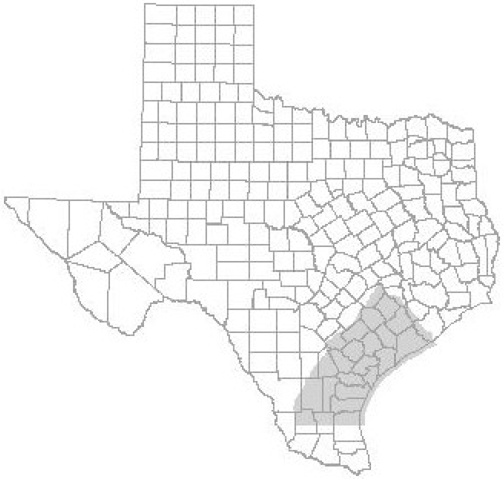
Stratigraphy



1 = outcrop
2 = subsurface
* includes the Lower Rio Grande Groundwater Reservoir

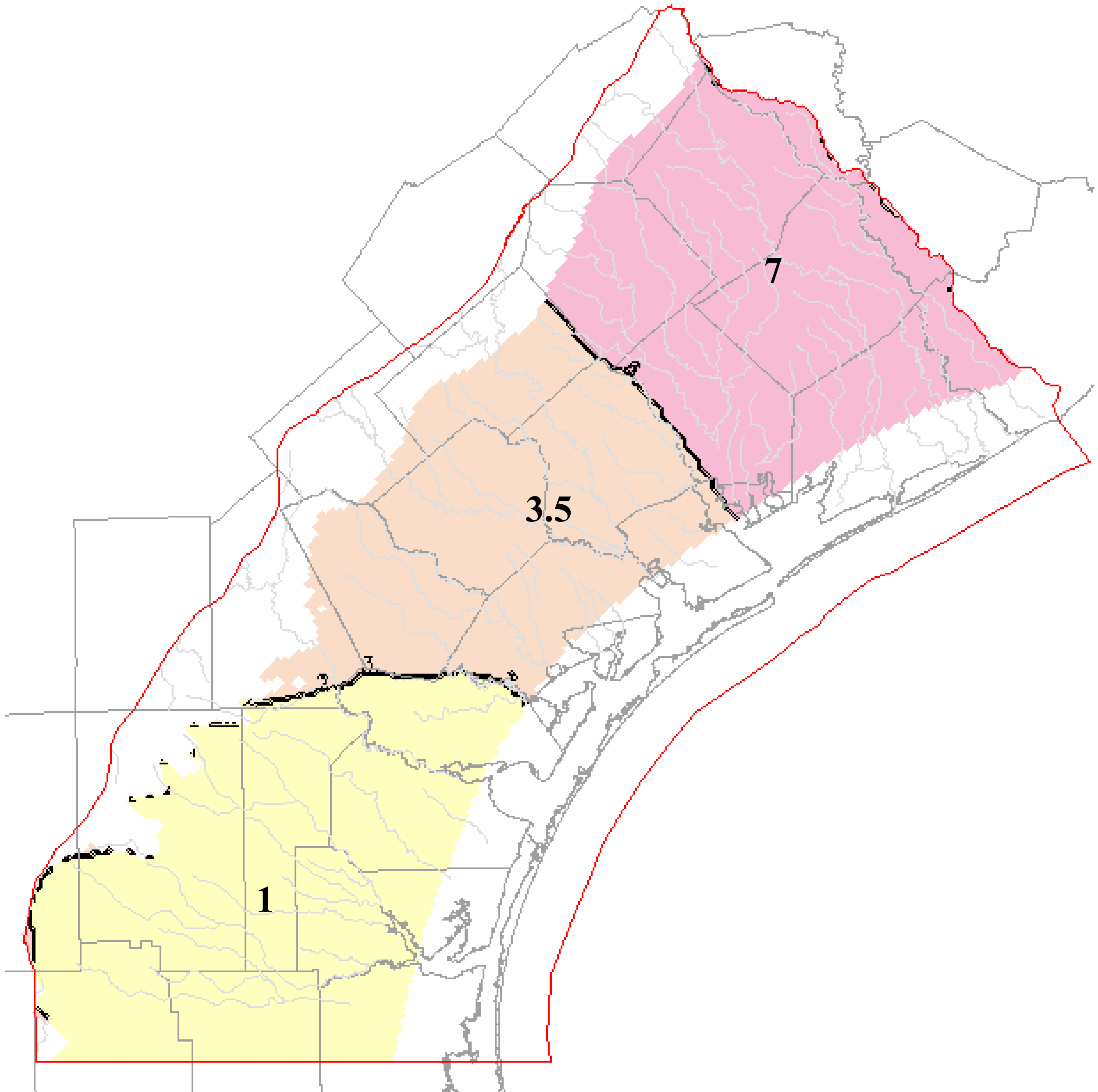
Conceptual Model of the Gulf Coast Aquifer System



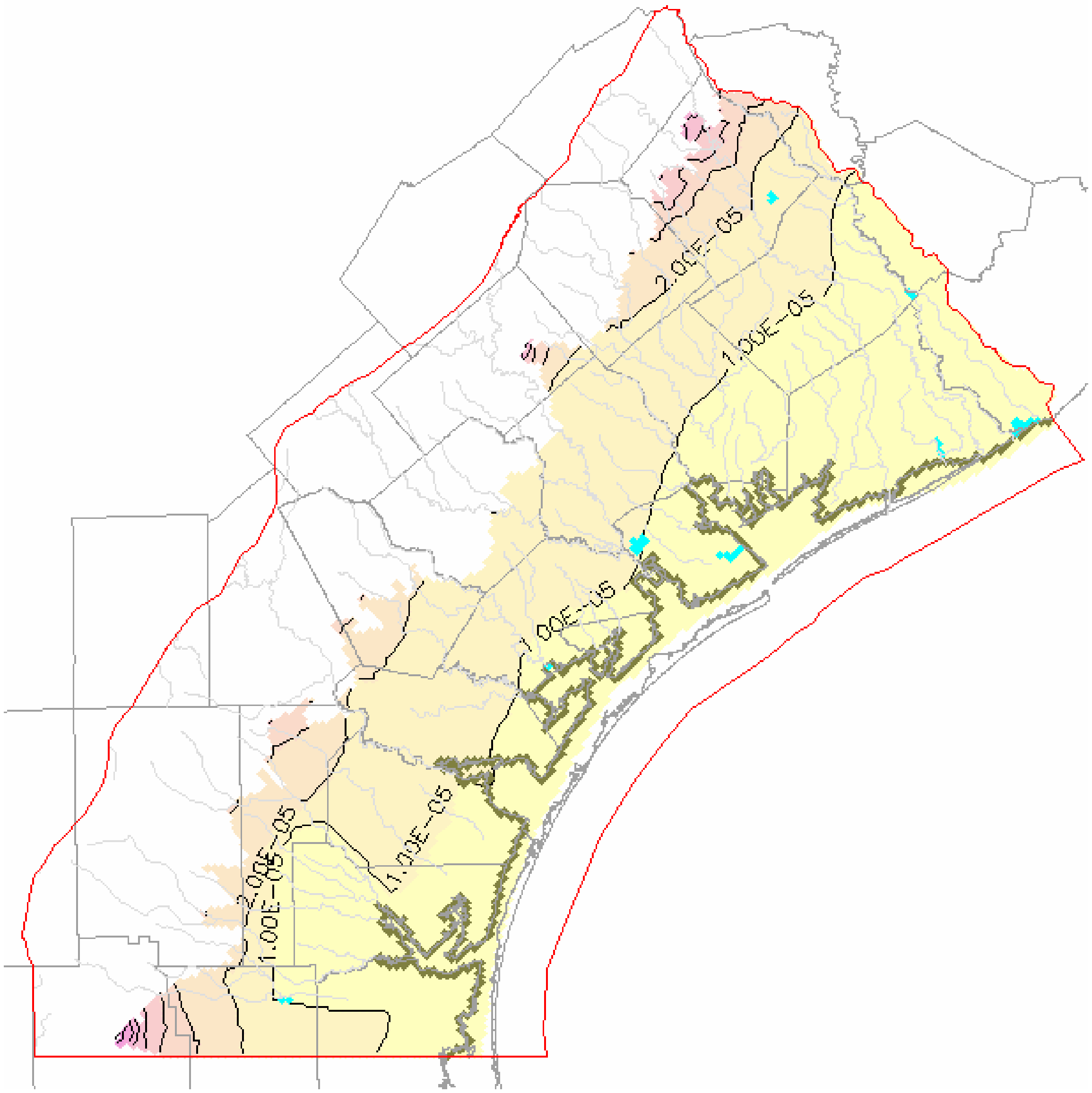


STEADY-STATE MODEL CALIBRATION (1900-1940)

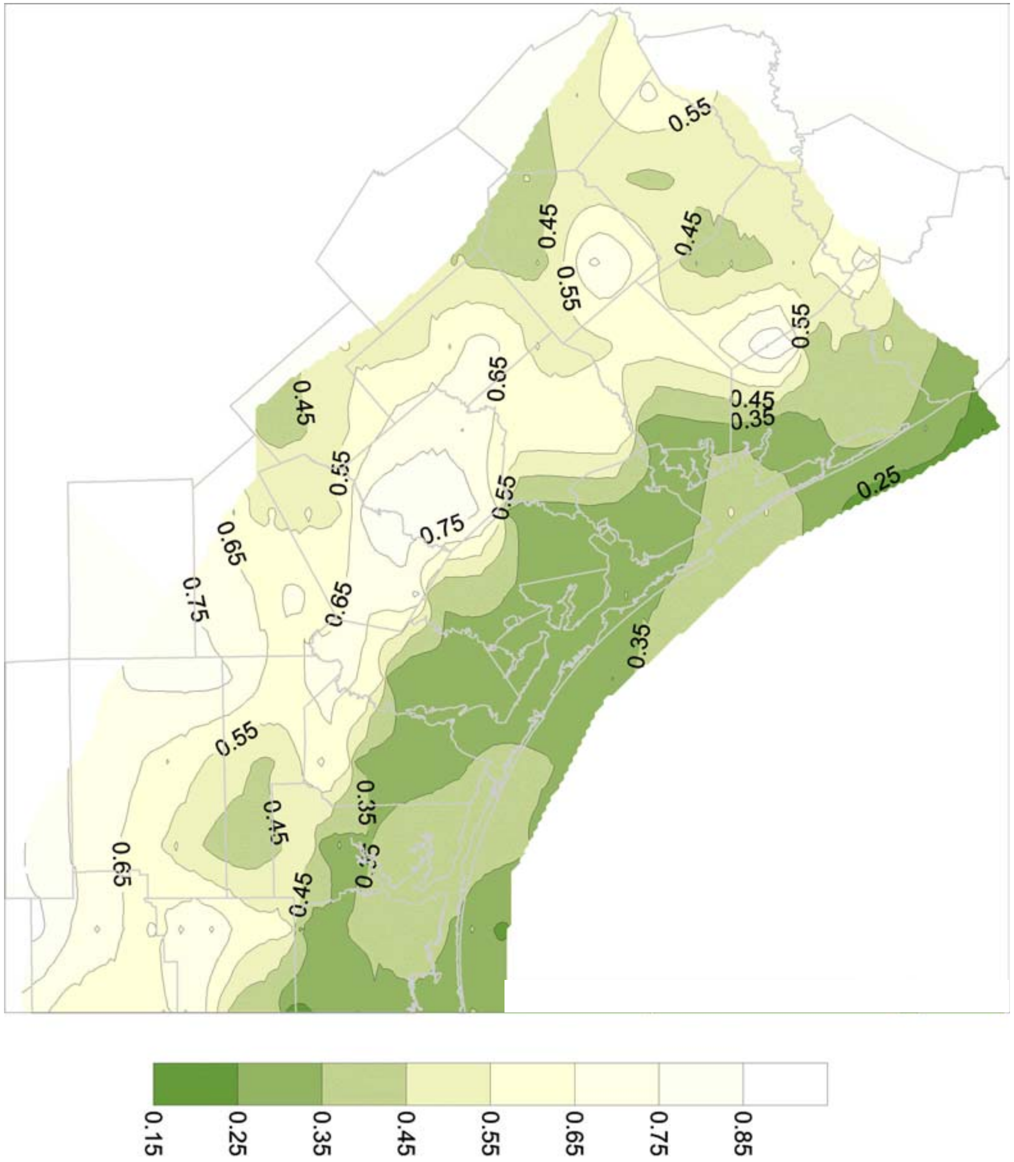
Calibrated Hydraulic Conductivity Zones (ft/d)
Evangeline Aquifer



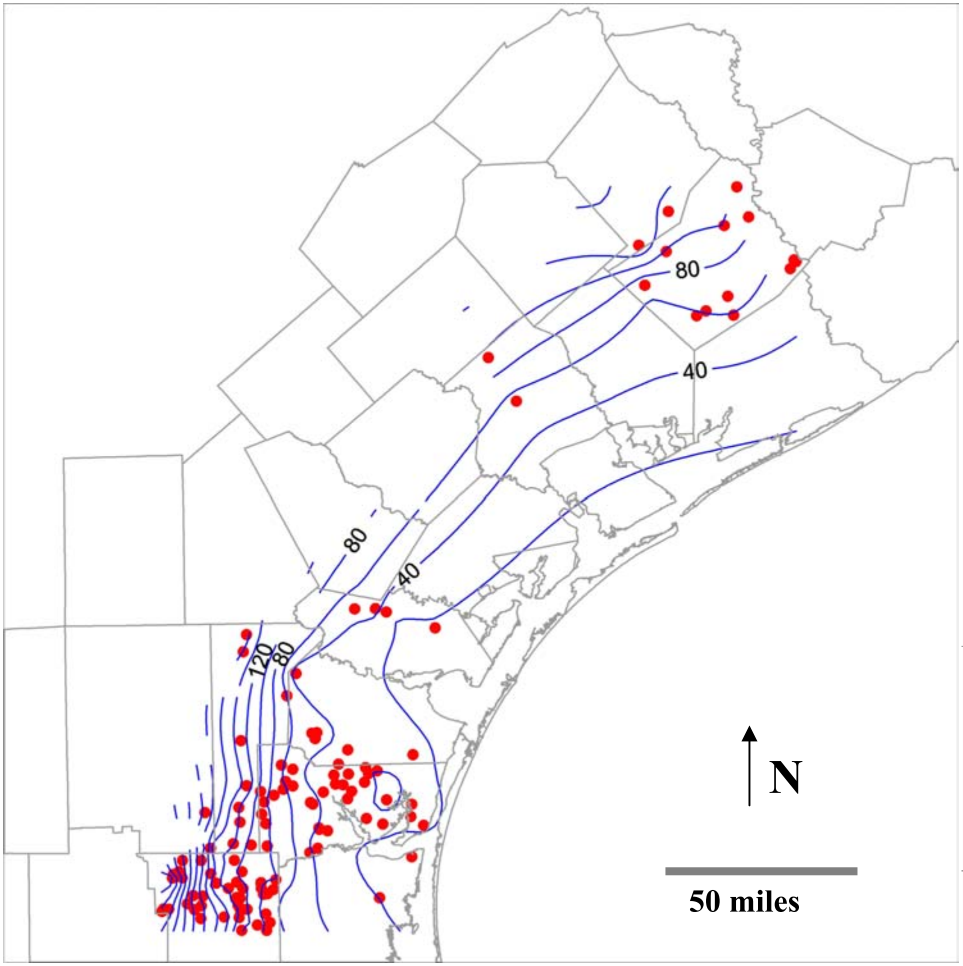
Calibrated Vertical Leakance (ft/d)
Chicot Aquifer



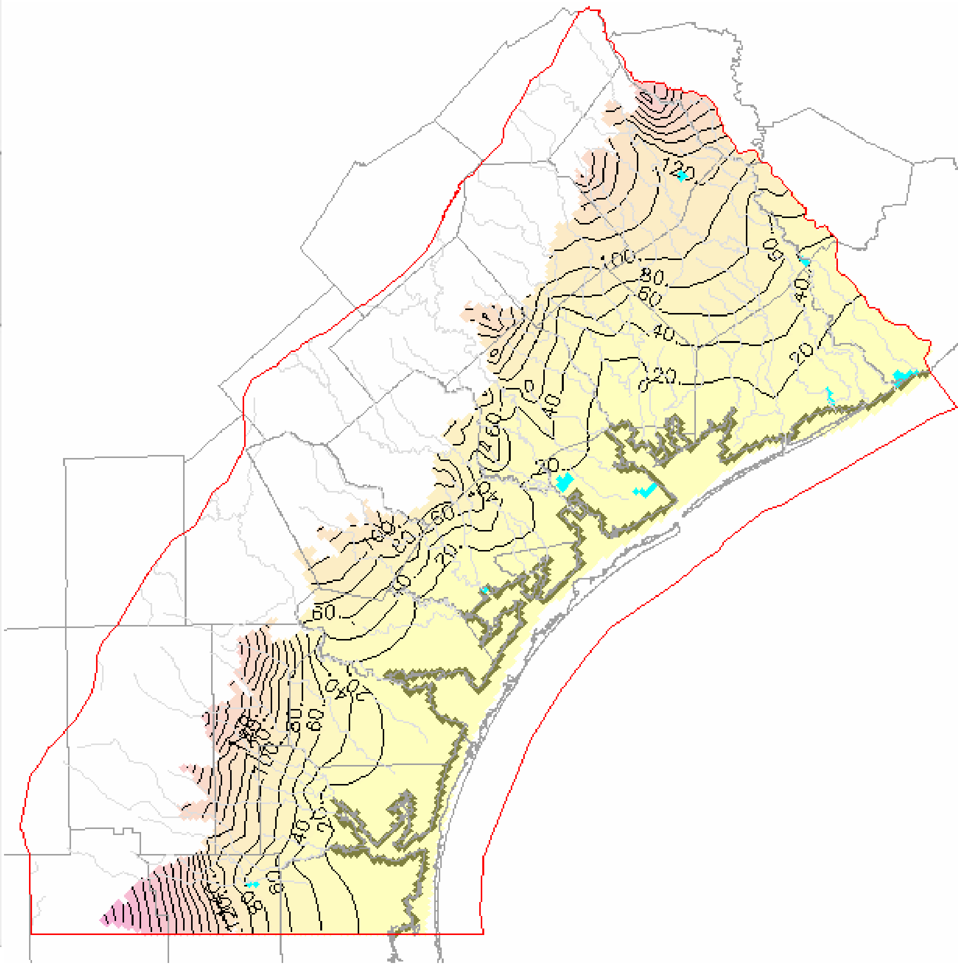
Calibrated Hydraulic Conductivity (ft/d)
Jasper Aquifer



Comparison of Measured and Simulated Water Levels
Steady-State Model, Chicot Aquifer

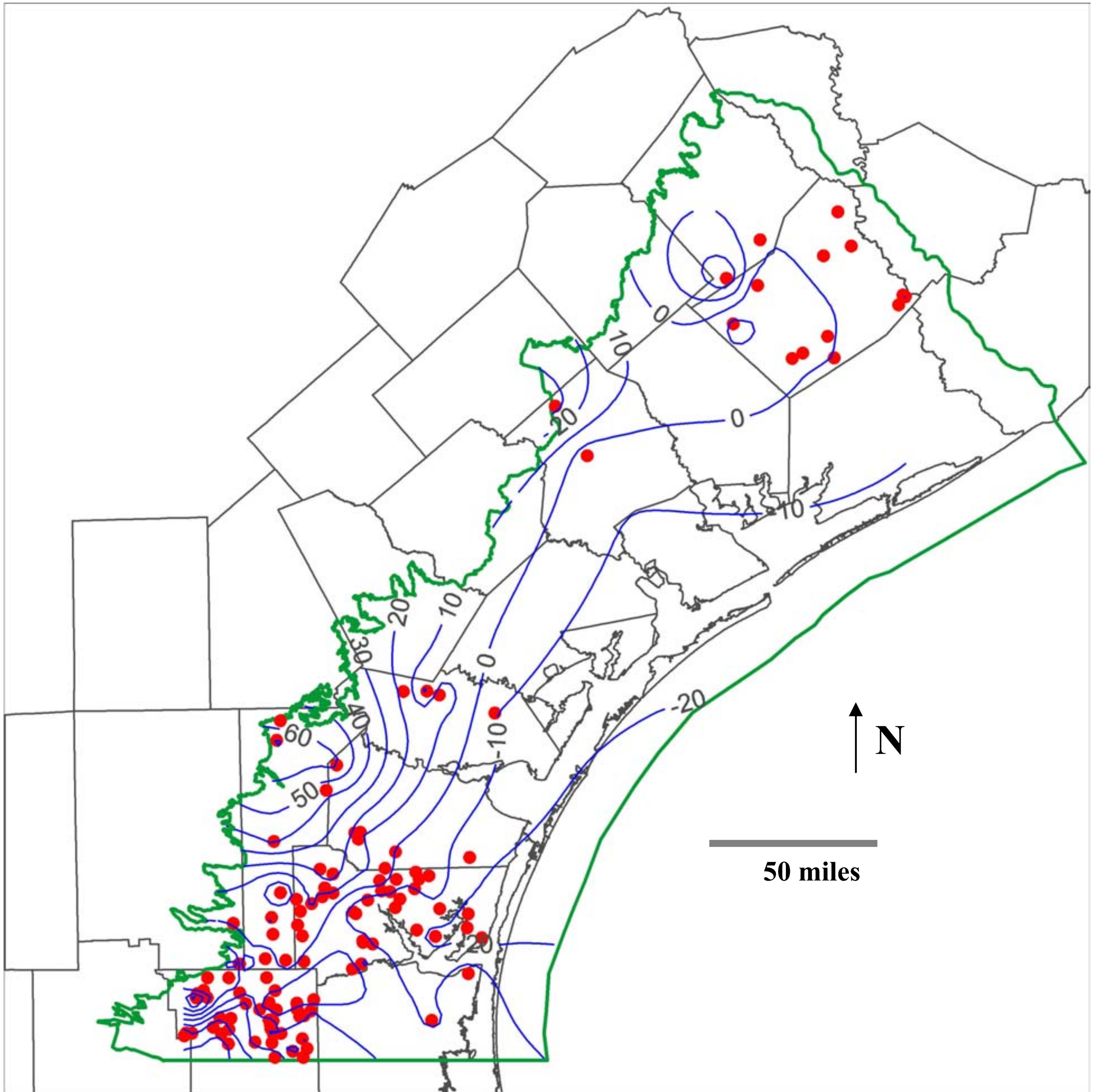


Measured Water Levels

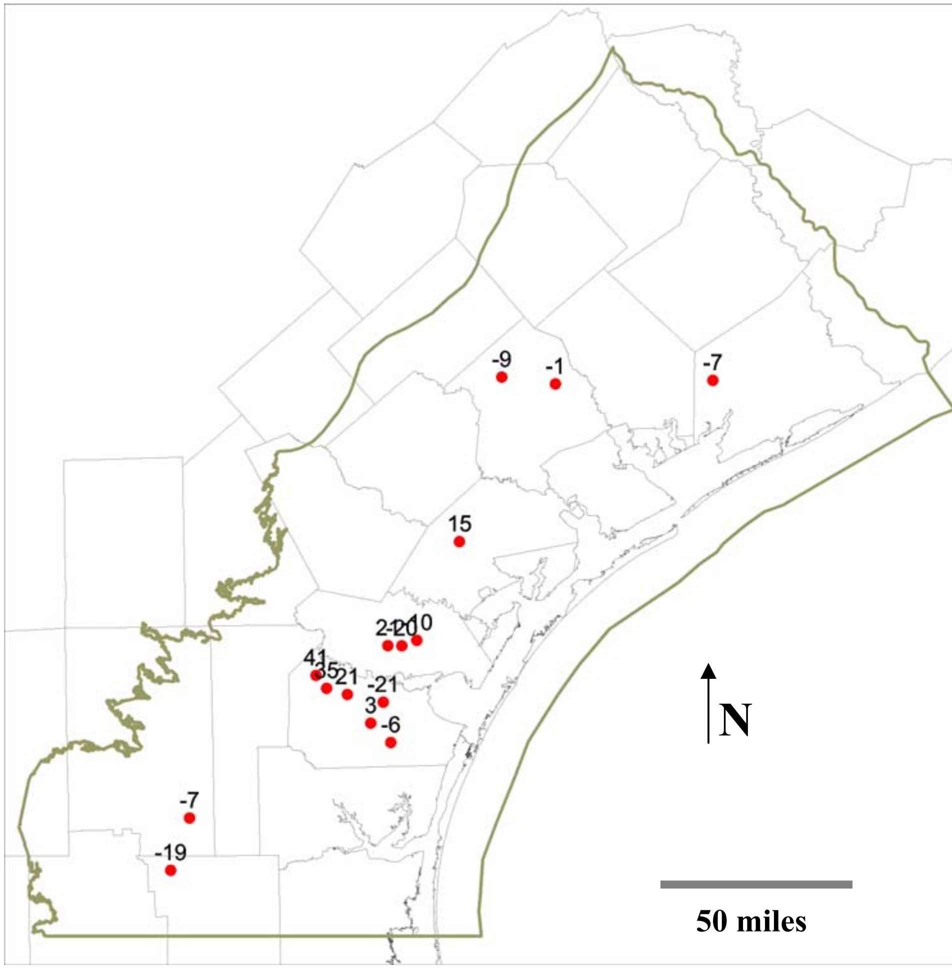


Simulated Water Levels

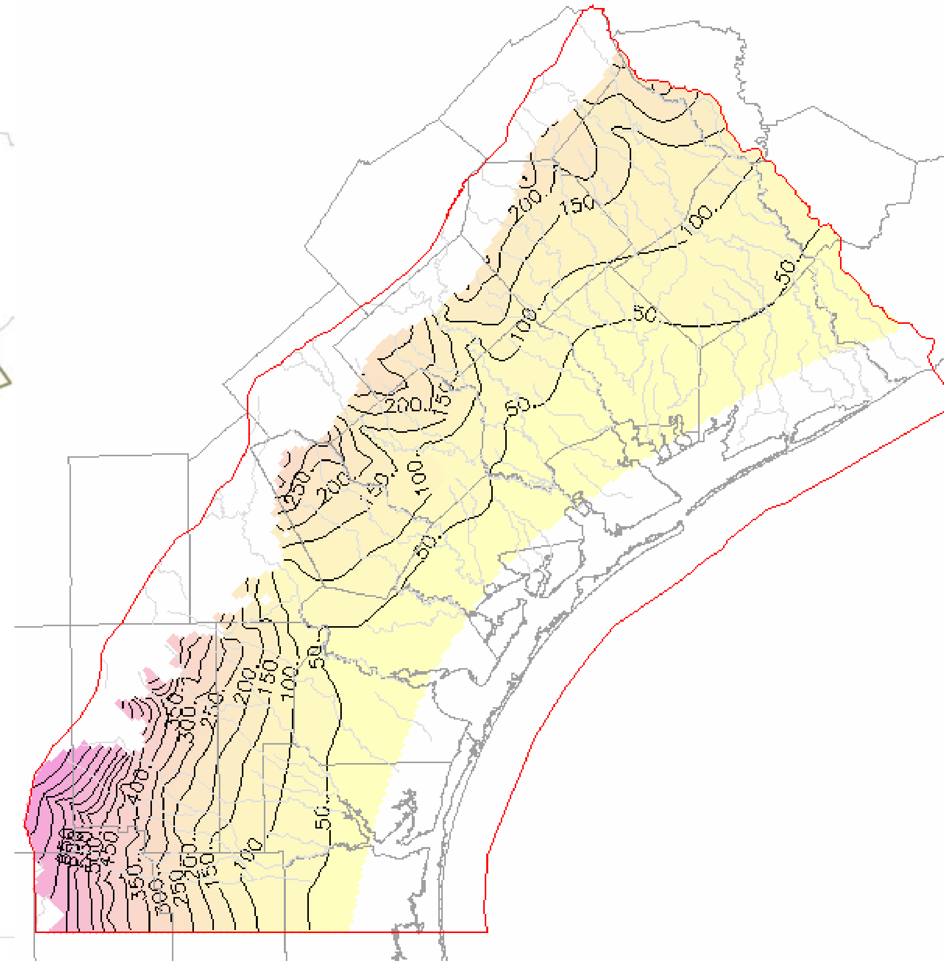
Spatial Distribution of Water-level Residuals (Simulated-Observed) Steady-State Model, Chicot Aquifer



Water Level Residuals and Simulated Water-Level Steady-State Model, Evangeline Aquifer

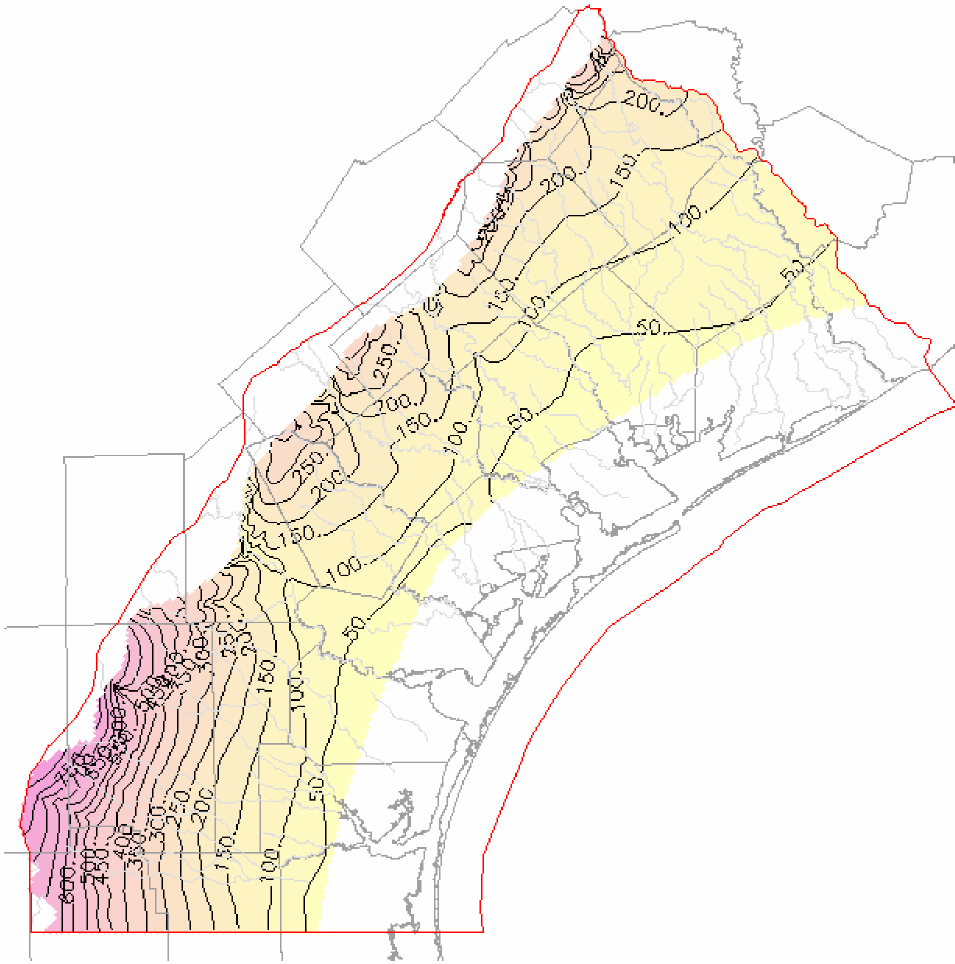


Simulated-Measured Water Levels

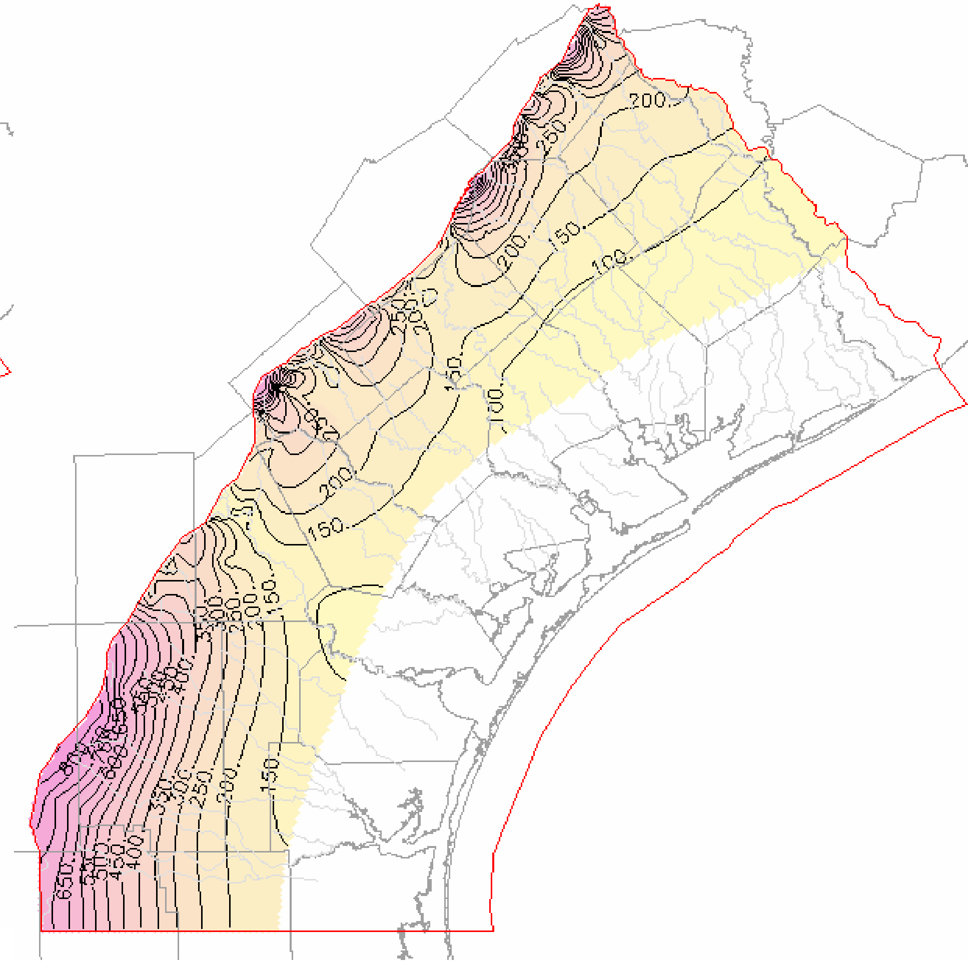


Simulated Water Levels

Simulated Water Levels, Steady-State Model

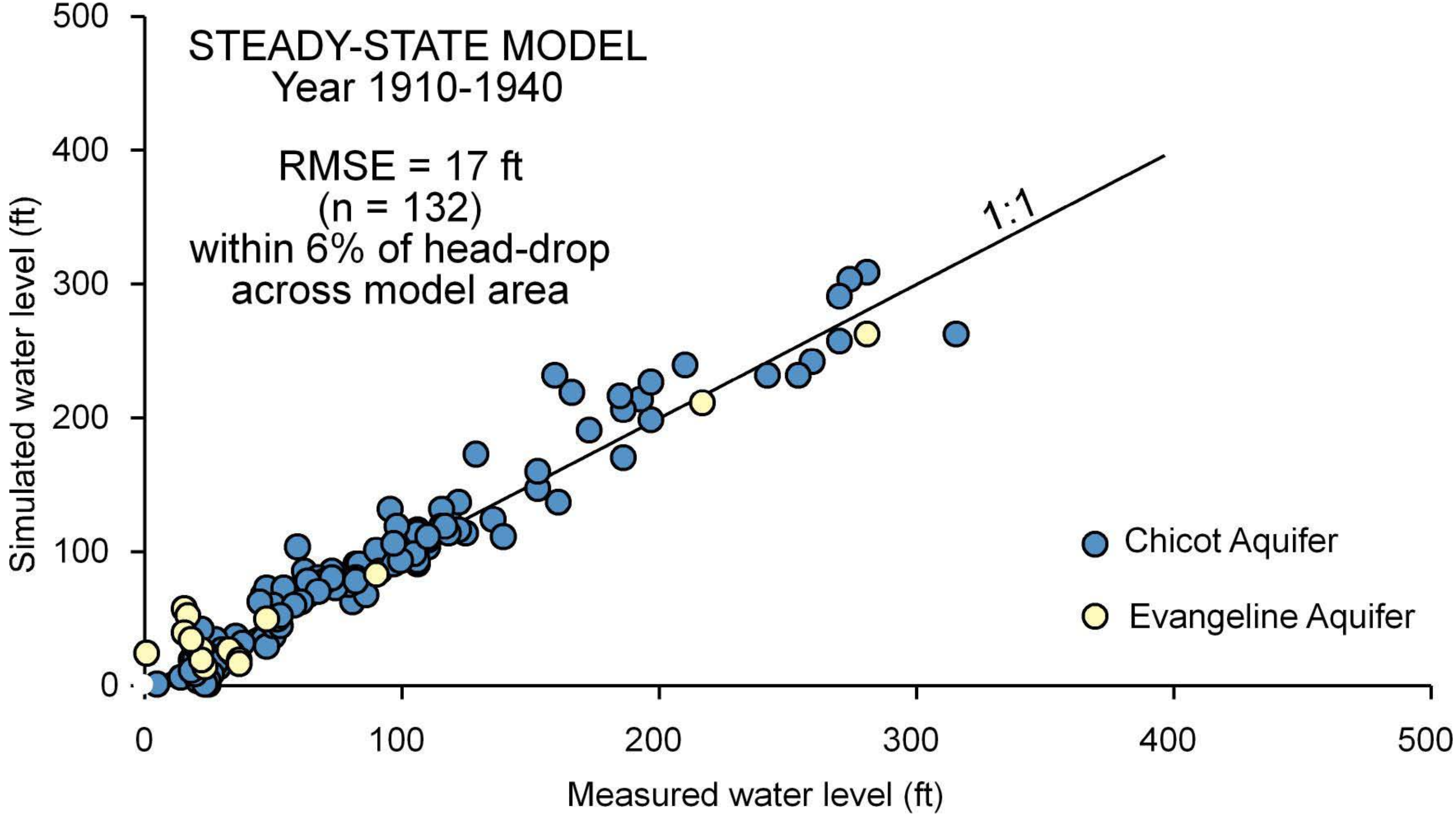


Burkeville Confining System

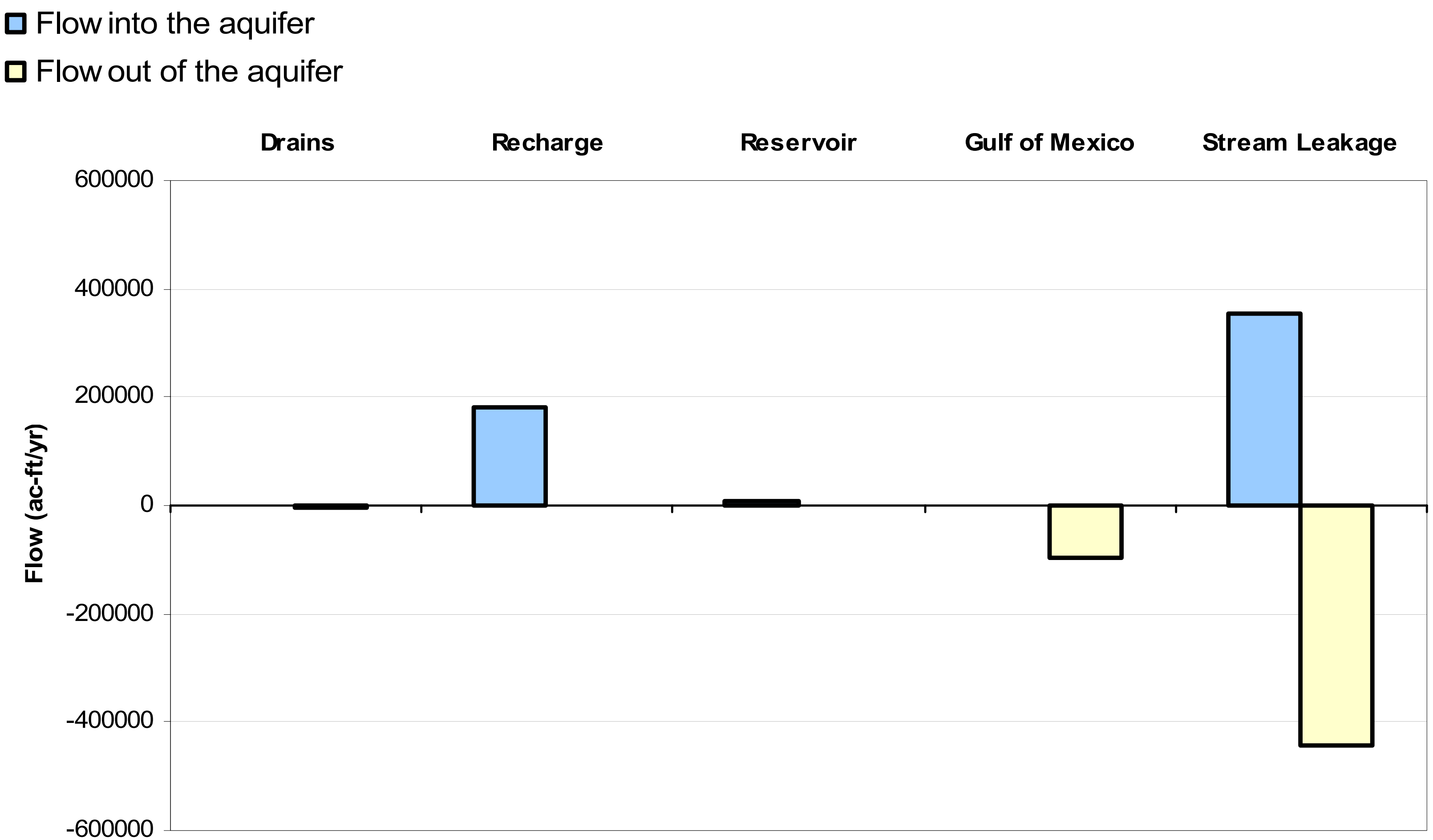


Jasper Aquifer

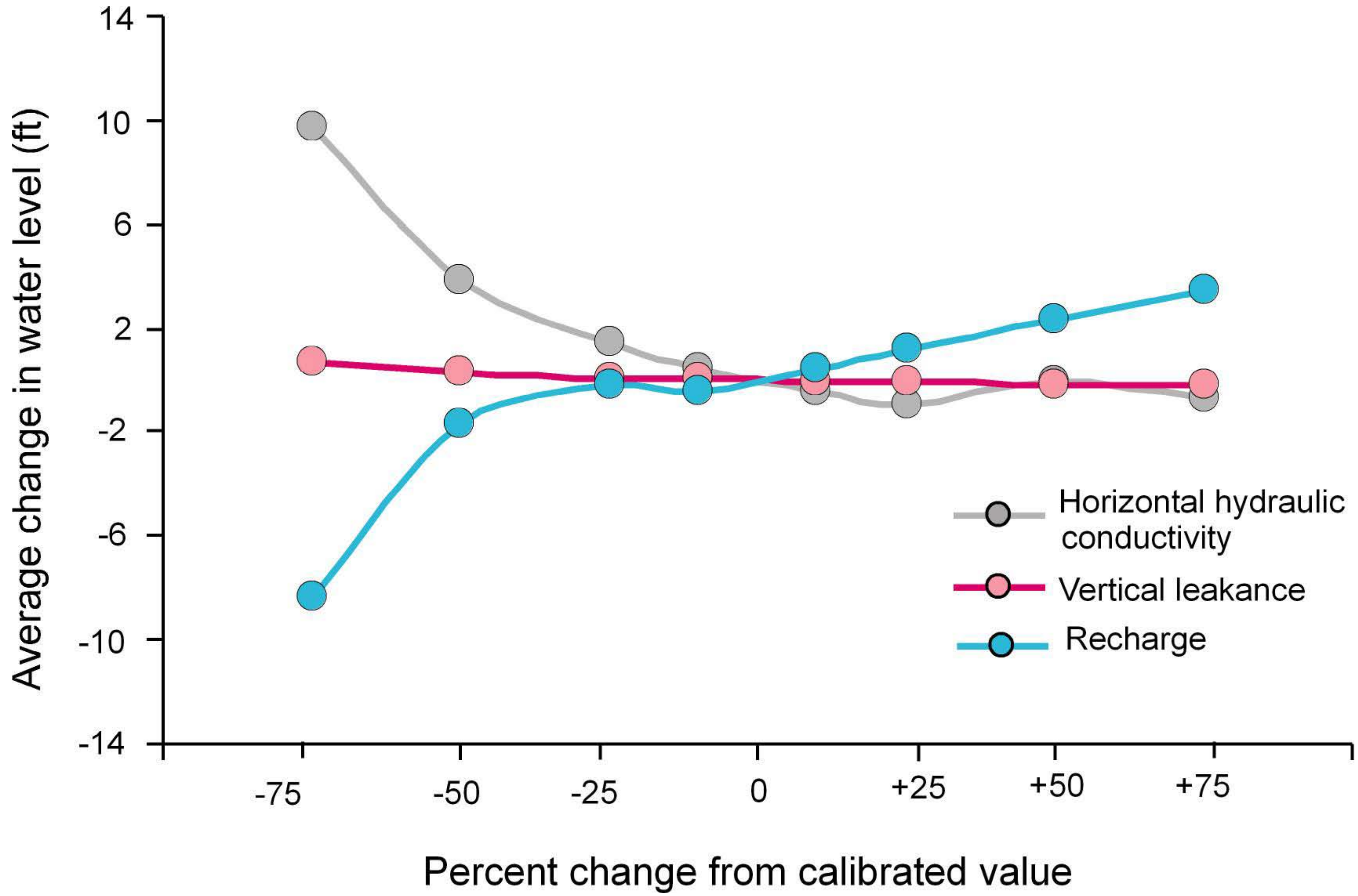
Comparison of Simulated and Measured Water Levels, Steady-State Model

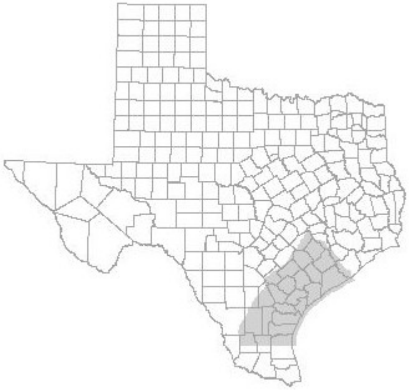


Water Budget
Steady-State Model



Sensitivity of the Calibrated Steady-State Model





TRANSIENT-MODEL CALIBRATION (1981-1999)

Storage Parameters

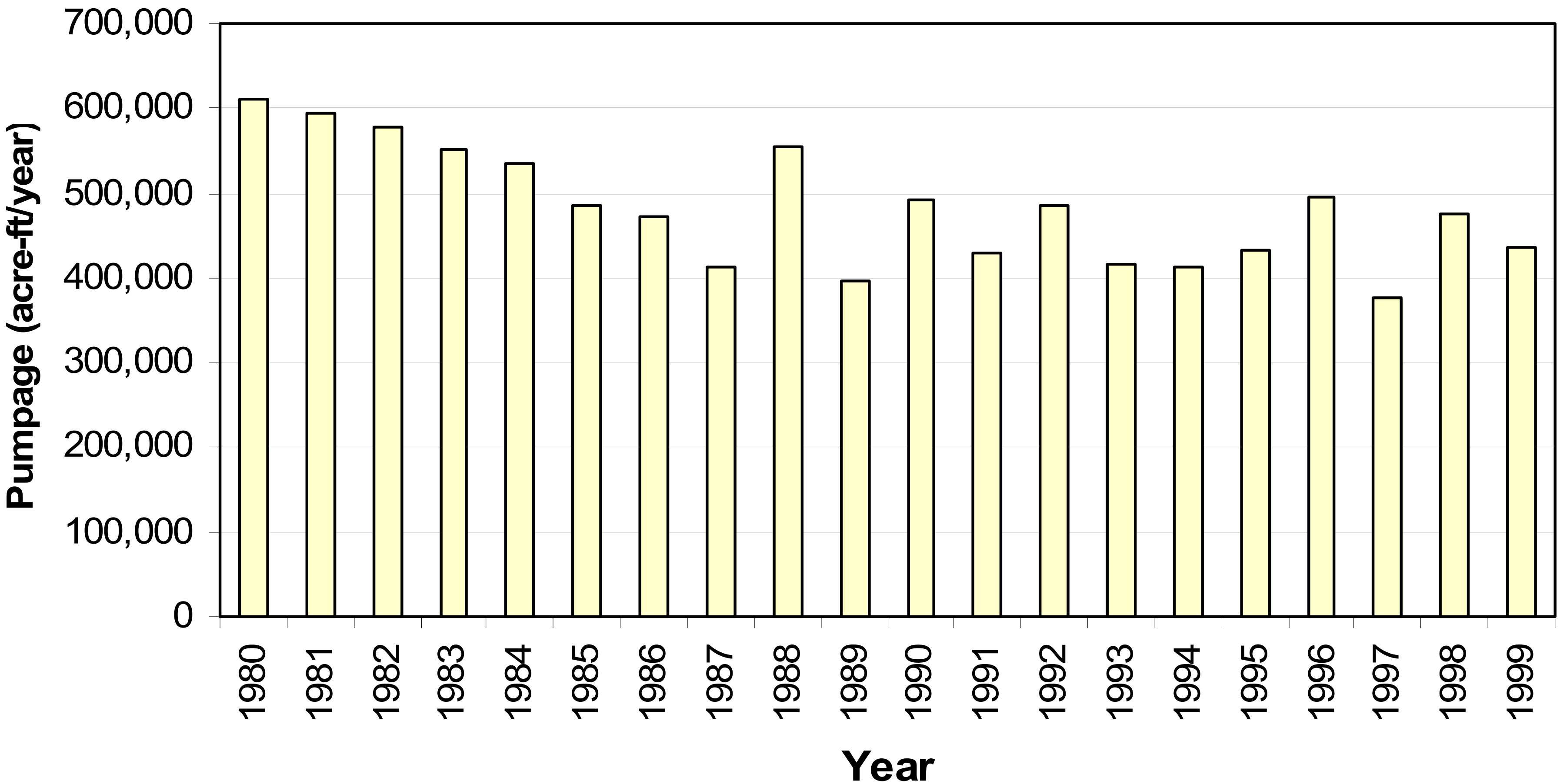
A. Specific Yield

Chicot Aquifer – 0.05
Evangeline Aquifer – 0.01
Burkeville Confining System – 0.001
Jasper Aquifer- 0.05

B. Specific Storage

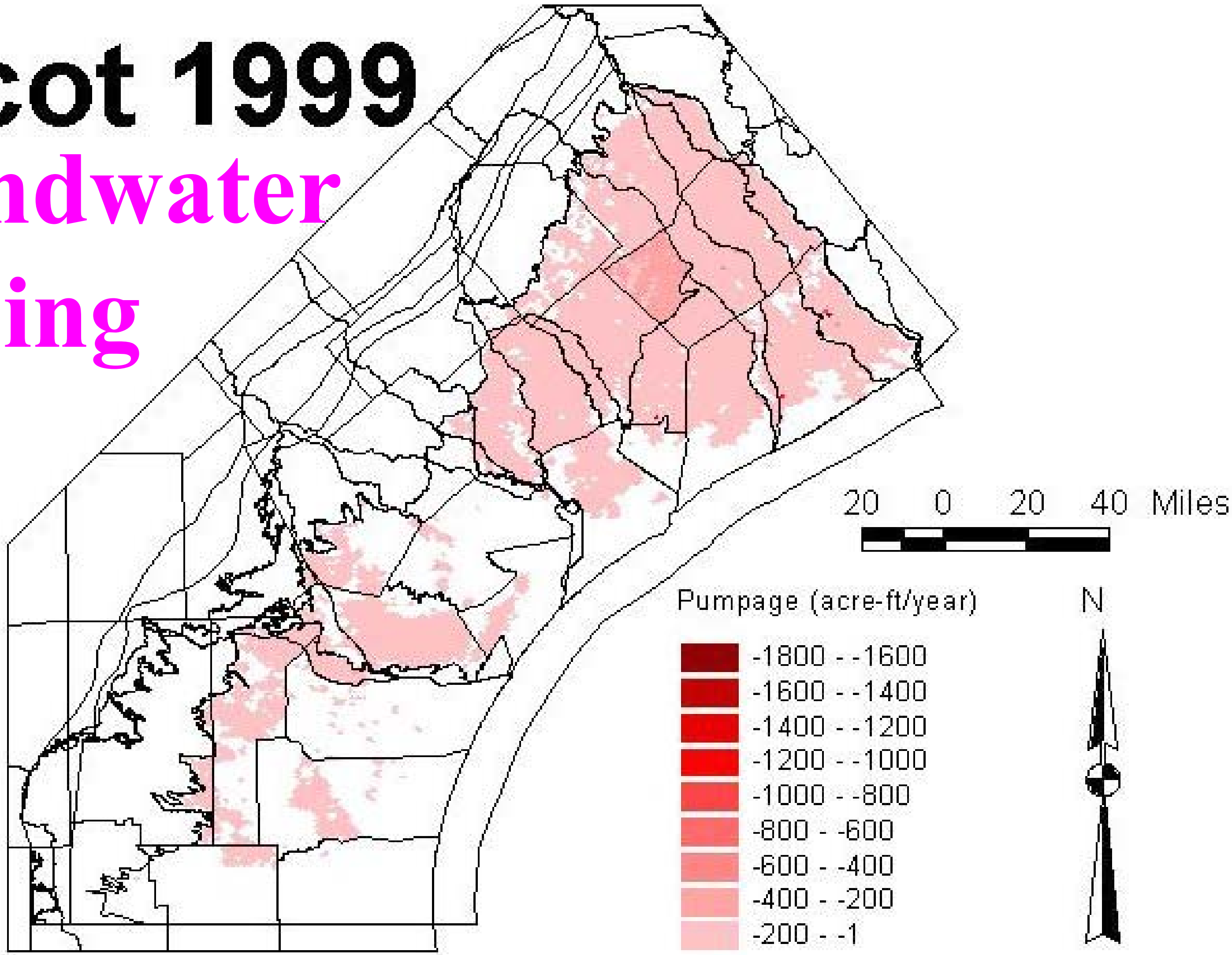
Chicot Aquifer – 0.00008
Evangeline Aquifer – 0.000001
Burkeville Confining System – 0.00001
Jasper Aquifer- 0.00008

Historical Groundwater Pumpage



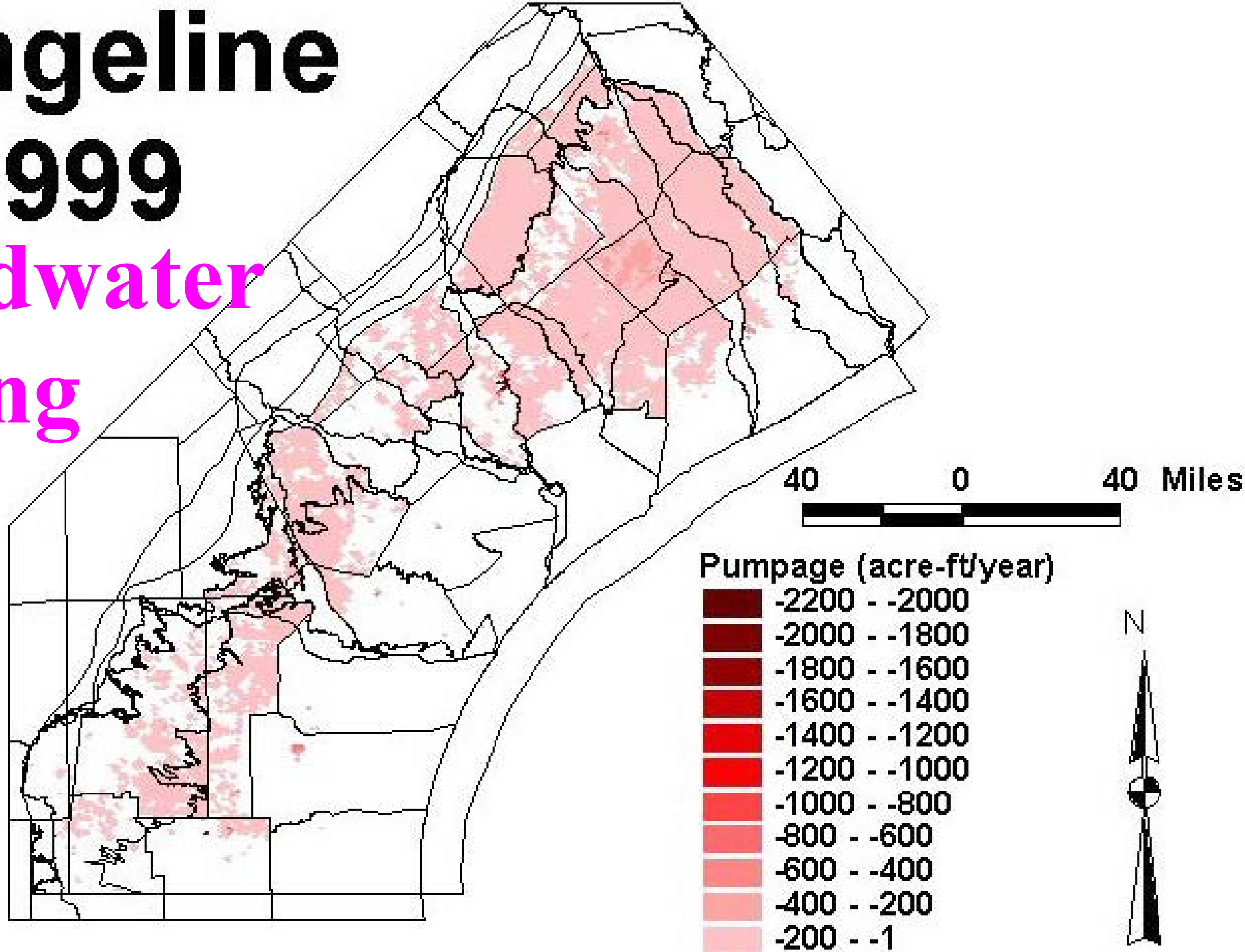
Chicot 1999

Groundwater Pumping



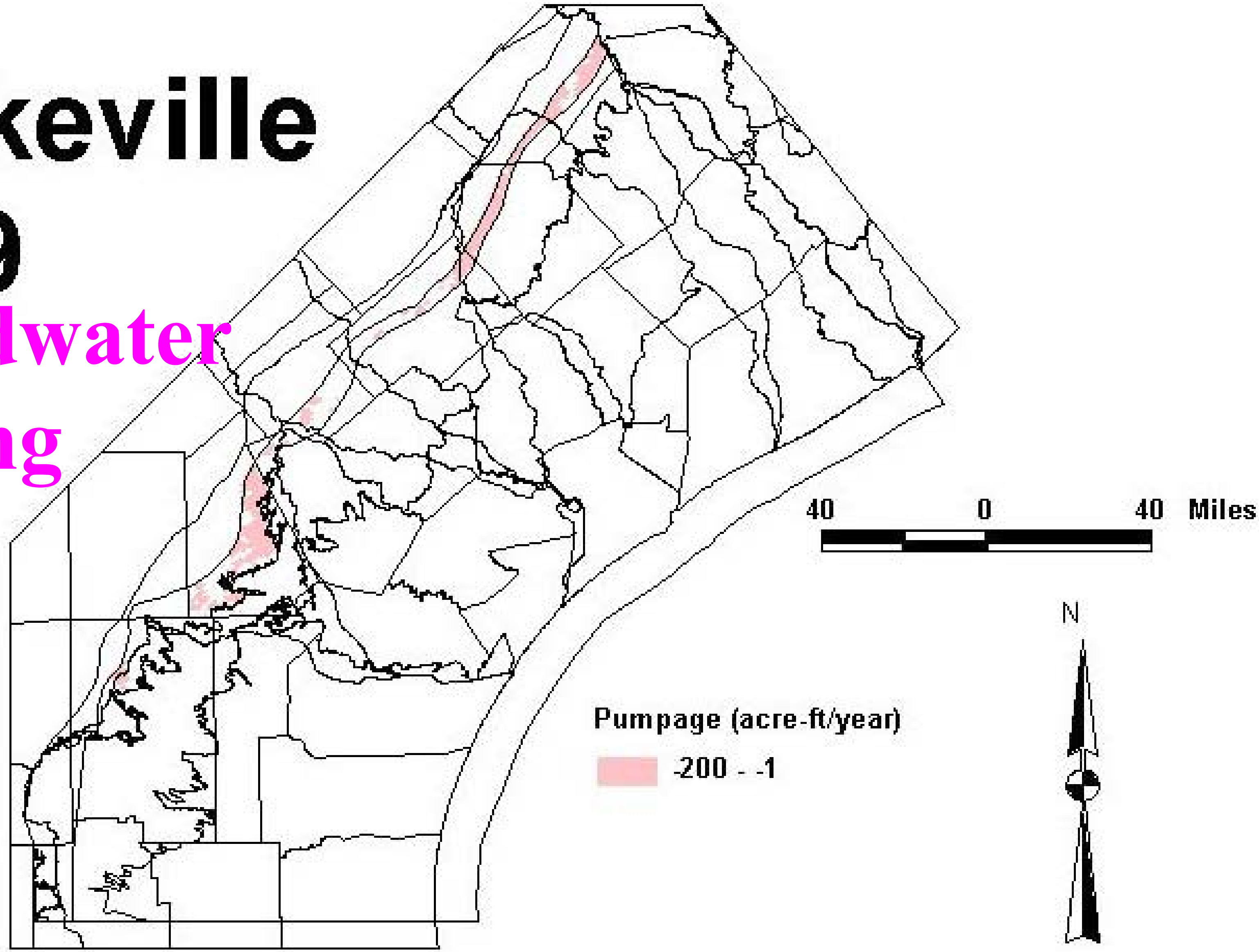
Evangeline 1999

Groundwater Pumping

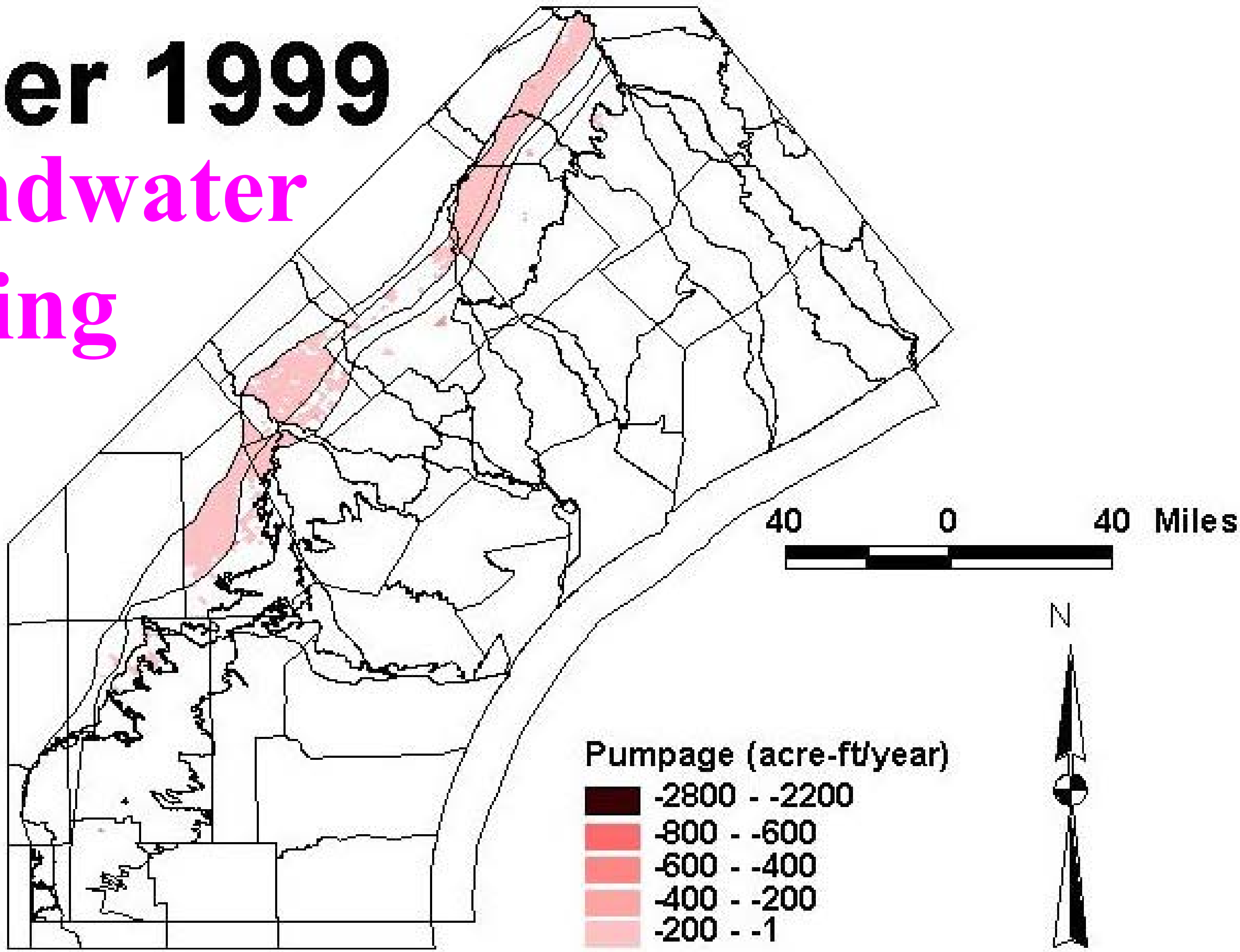


Burkeville 1999

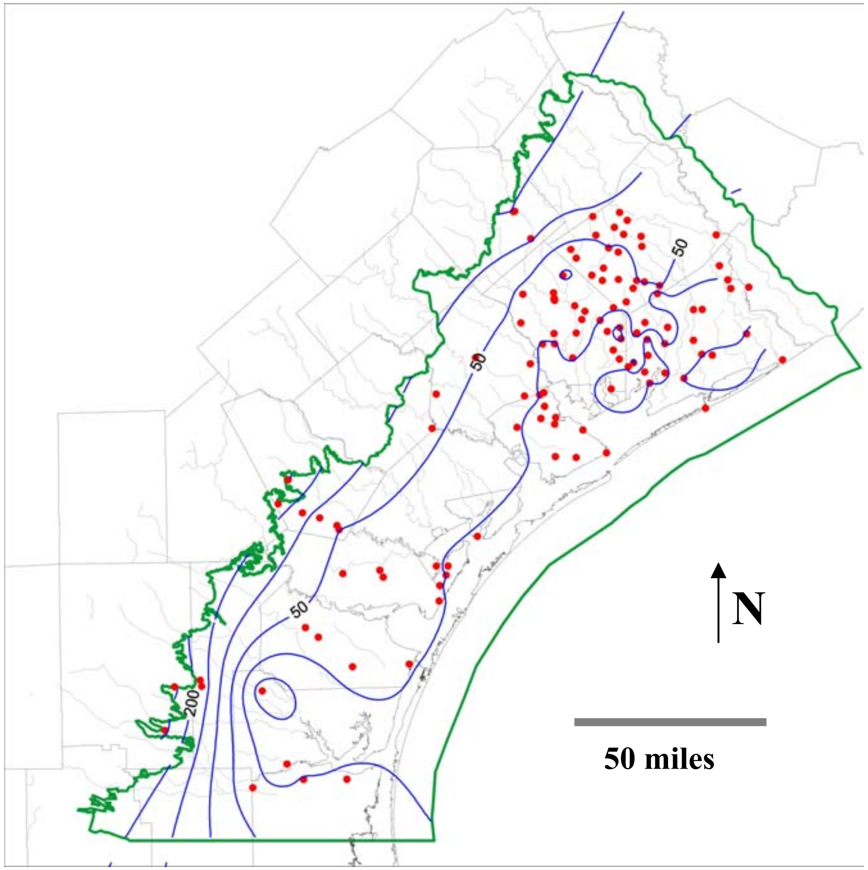
Groundwater Pumping

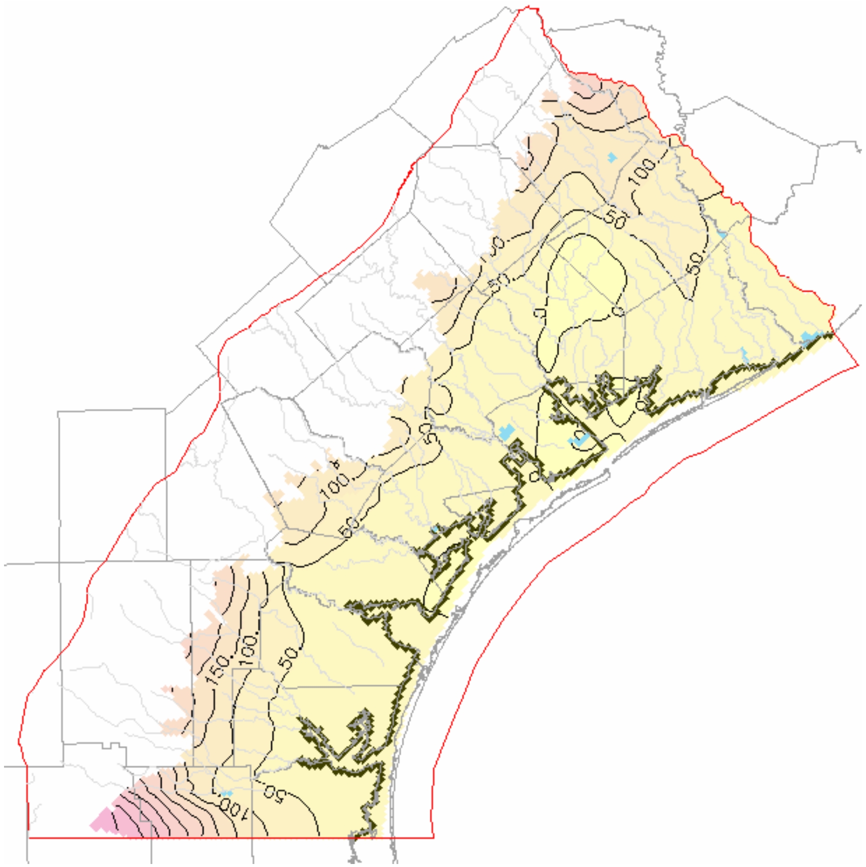


Jasper 1999
Groundwater Pumping



Comparison of Measured and Simulated Water Levels
Chicot Aquifer, 1989

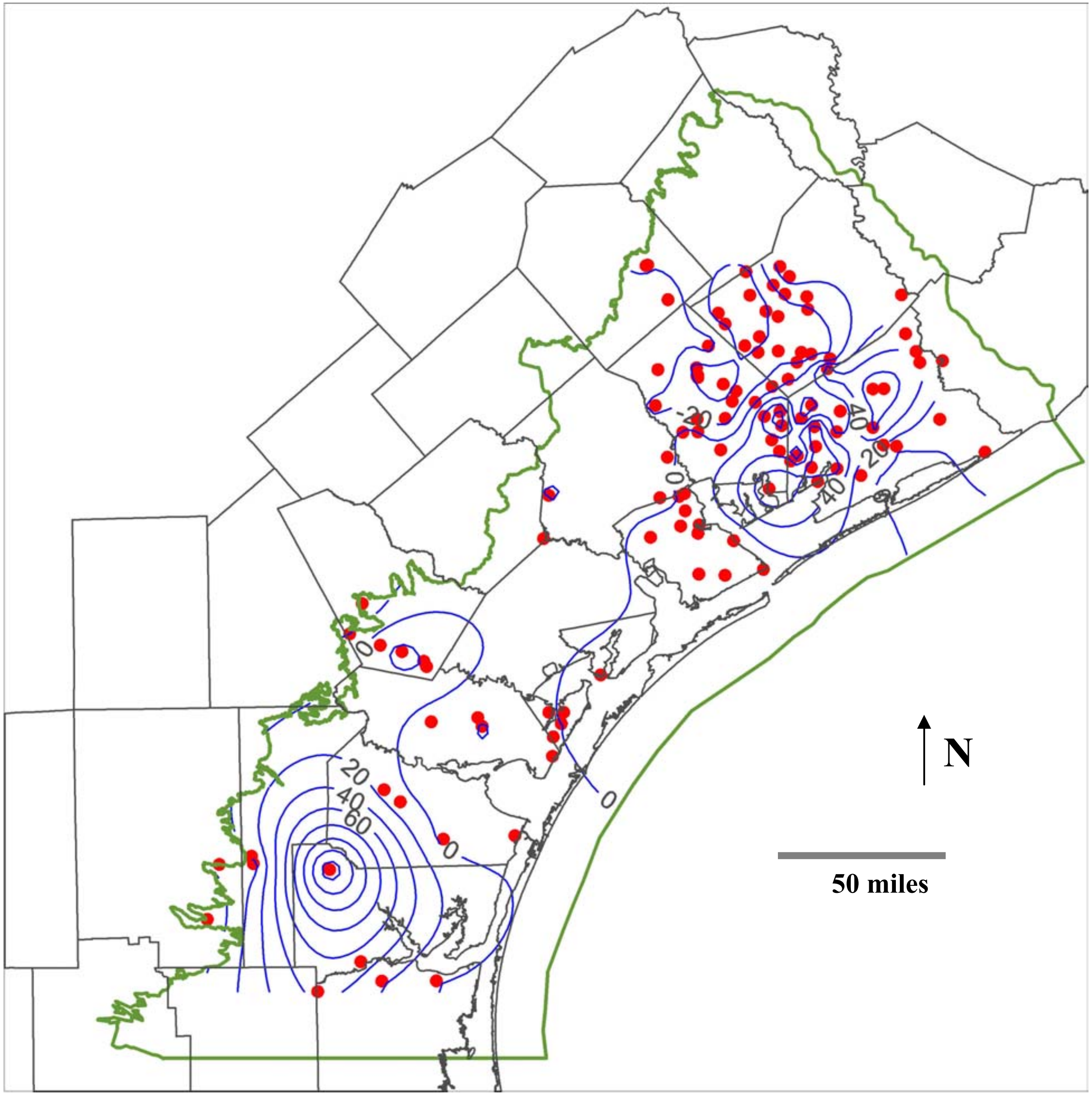




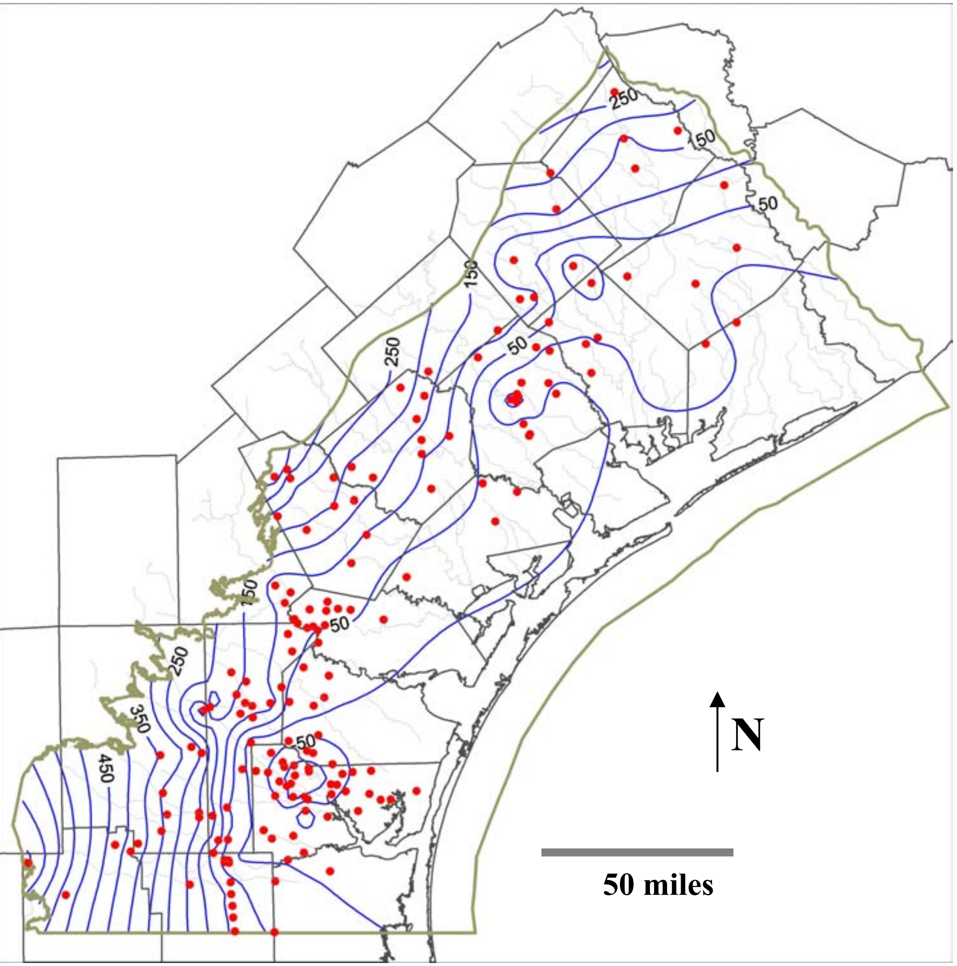
Measured Water Levels

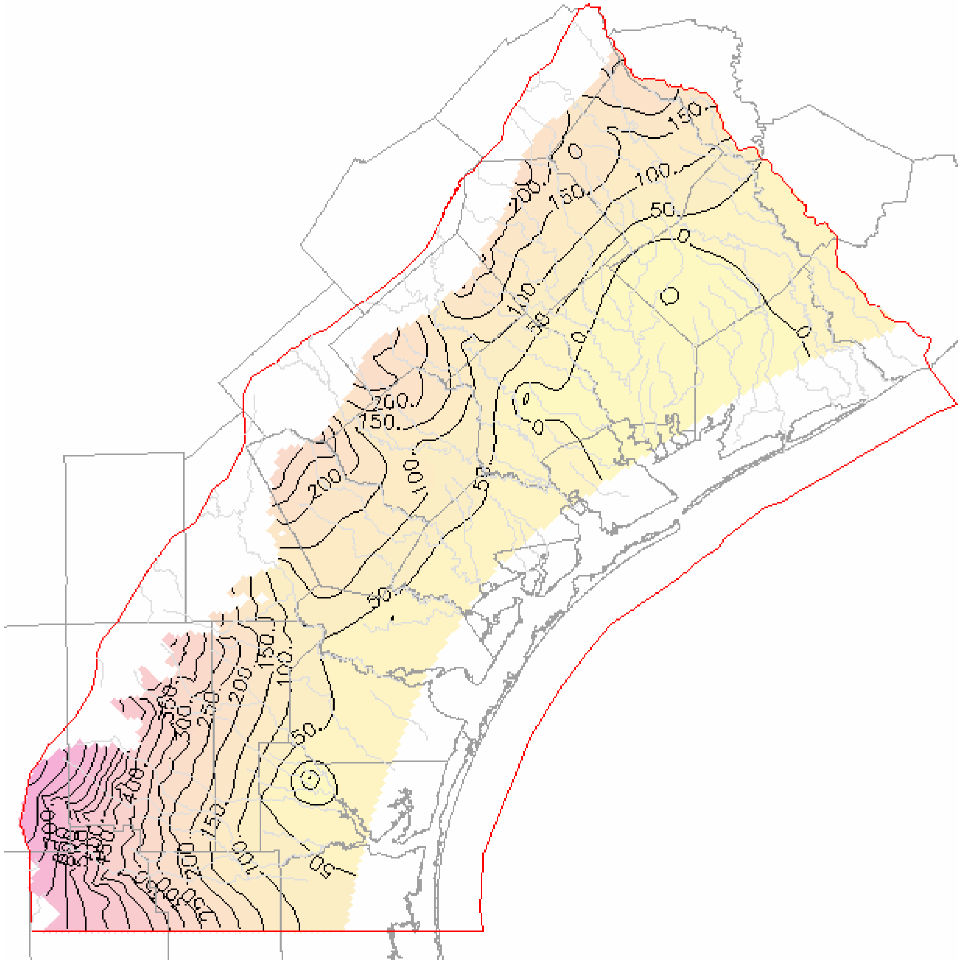
Simulated Water Levels

Spatial Distribution of Water-Level Residuals (Simulated-Observed) Chicot Aquifer, 1989



Comparison of Measured and Simulated Water levels Evangeline Aquifer, 1989

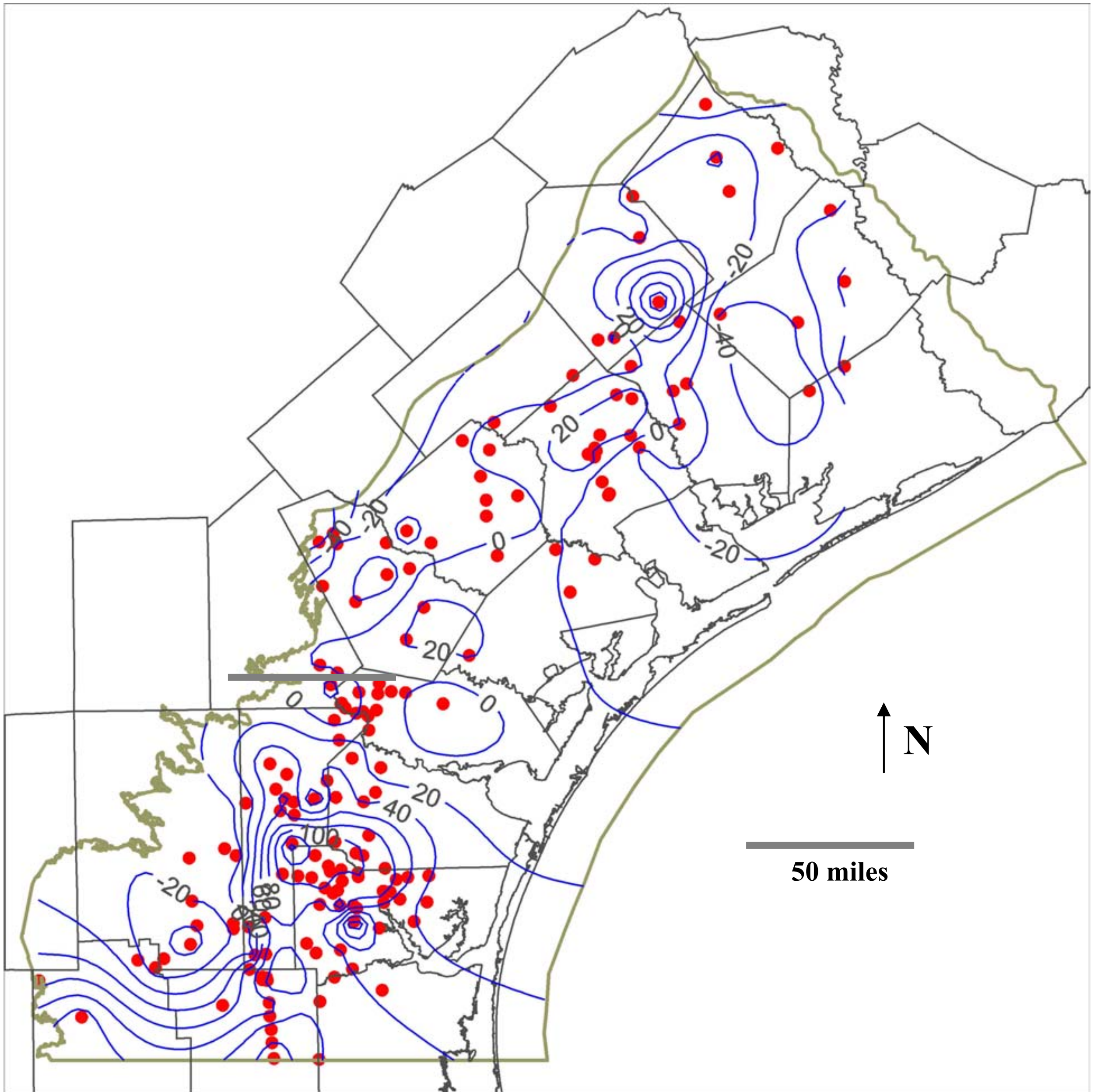




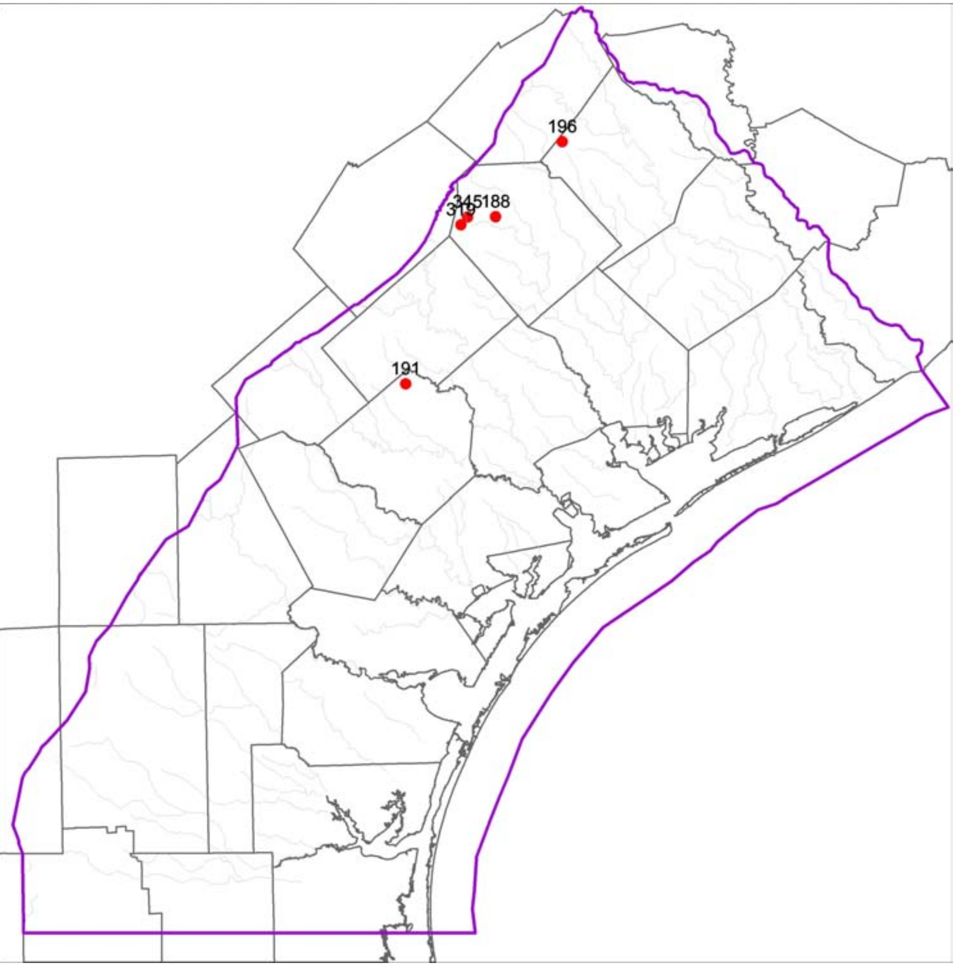
Measured Water Levels

Simulated Water Levels

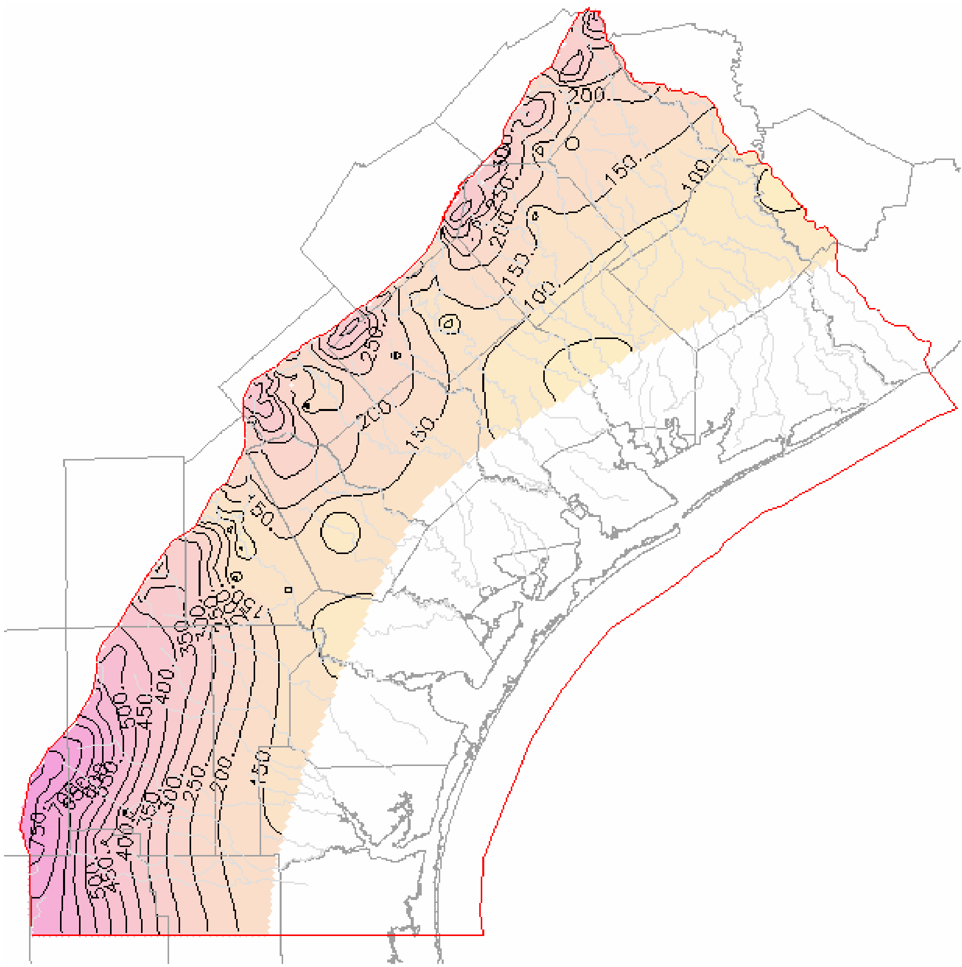
Spatial Distribution of Water-Level Residuals (Simulated-Observed) Evangeline Aquifer, 1989



Comparison of Measured and Simulated Water levels (1989)
Jasper Aquifer

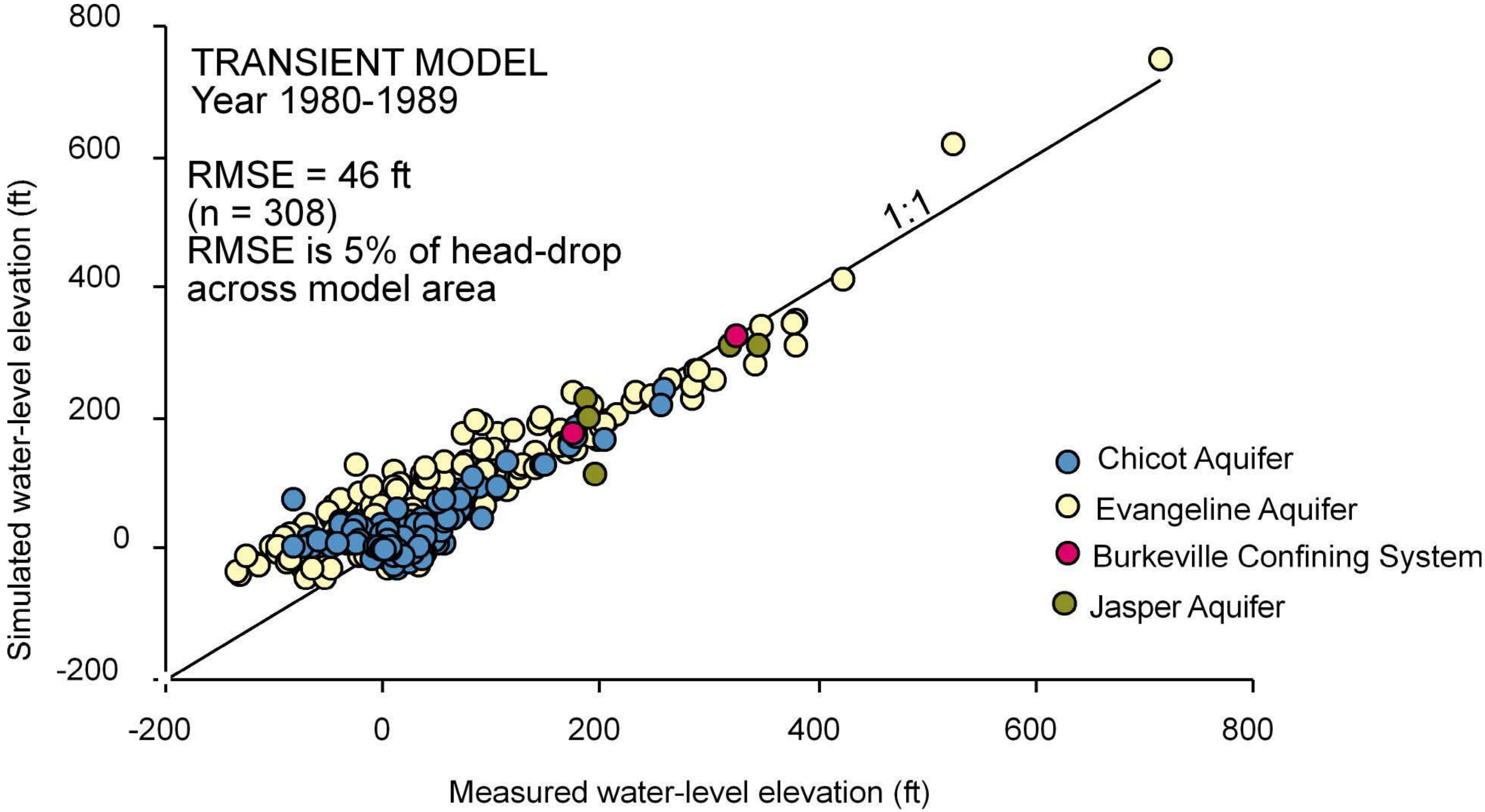


Measured Water Levels

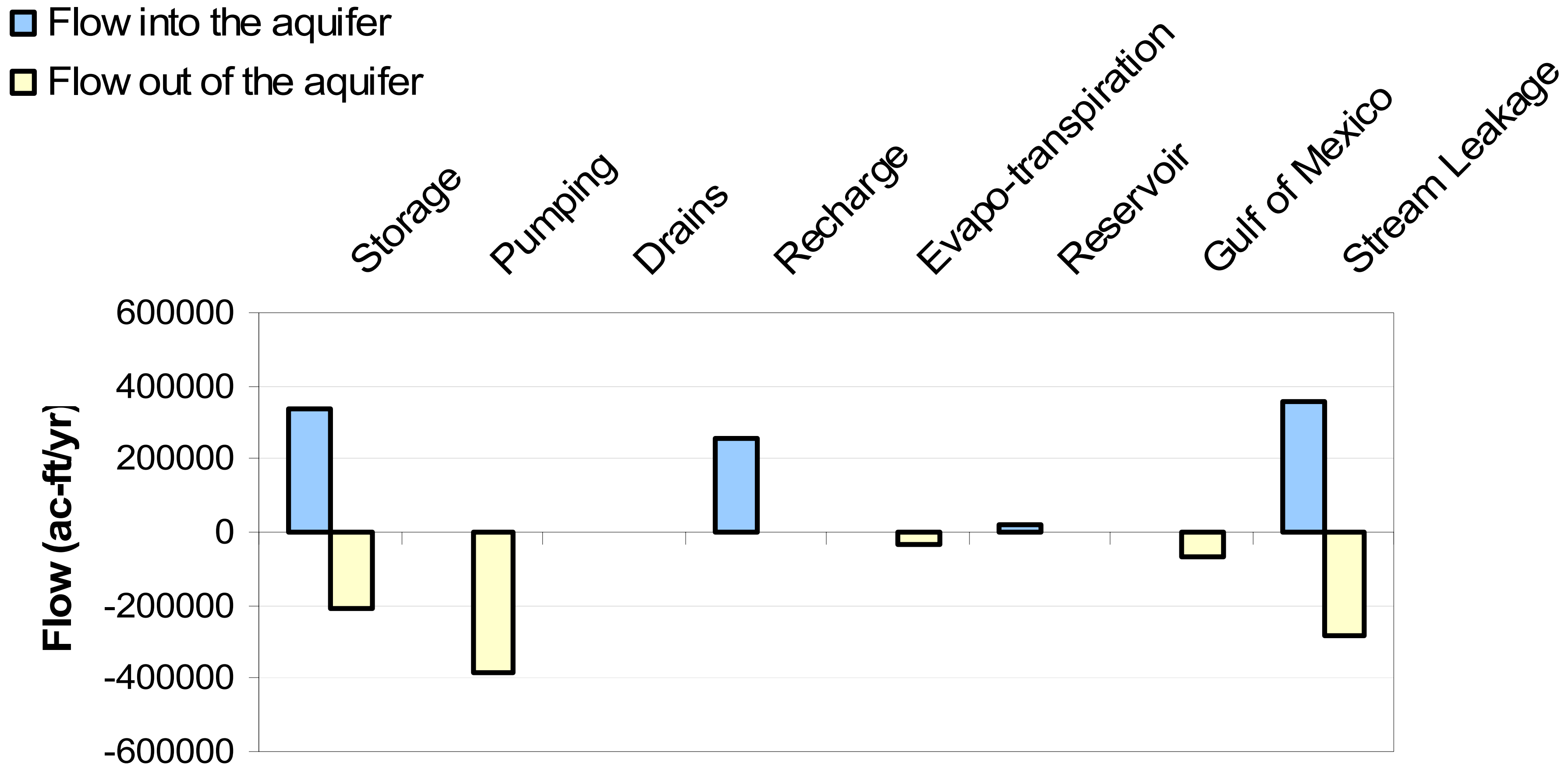


Simulated Water Levels

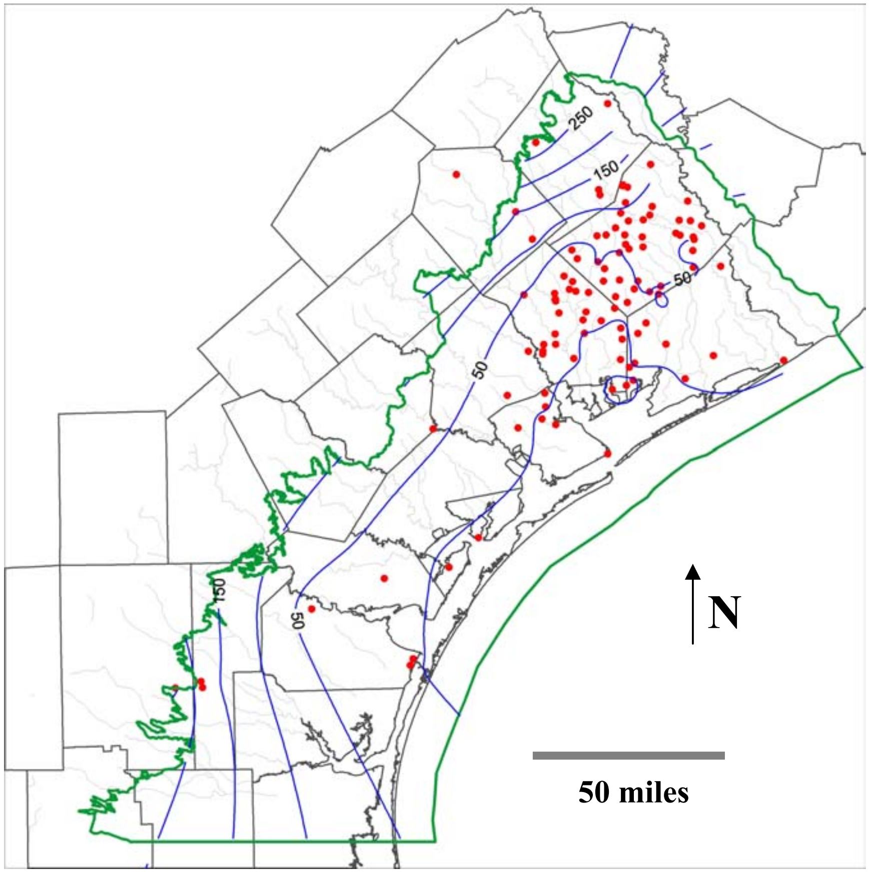
Comparison of Simulated and Measured Water Levels, 1989



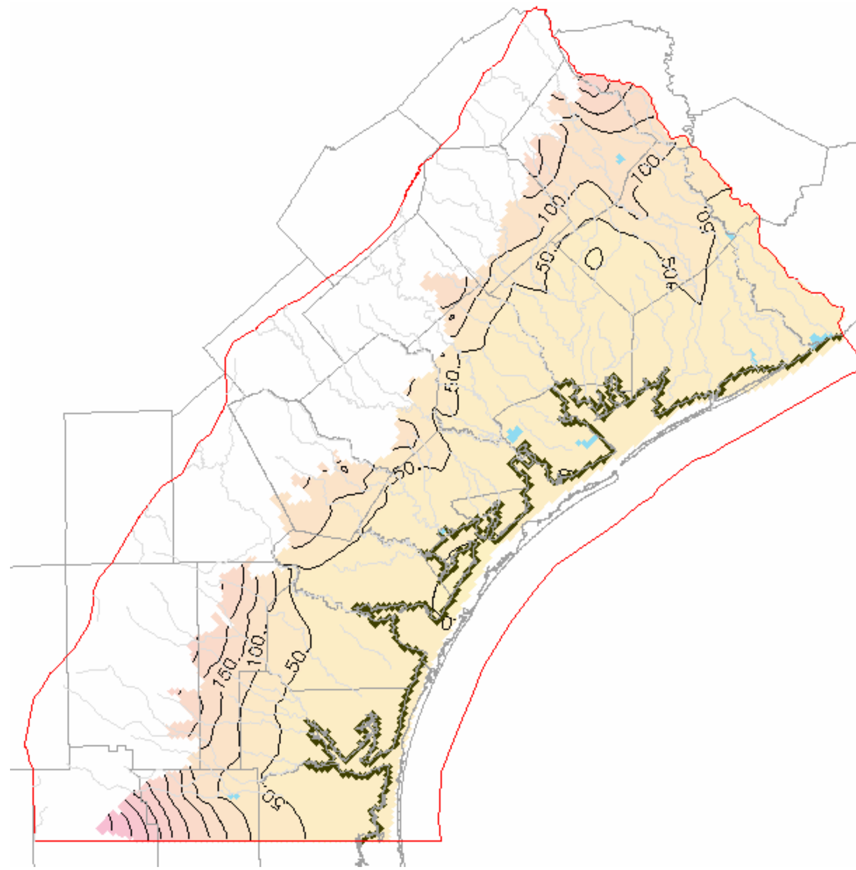
Water Budget
Transient-Model (1989)



Comparison Between Measured and Simulated Water Levels, Chicot Aquifer, 1999

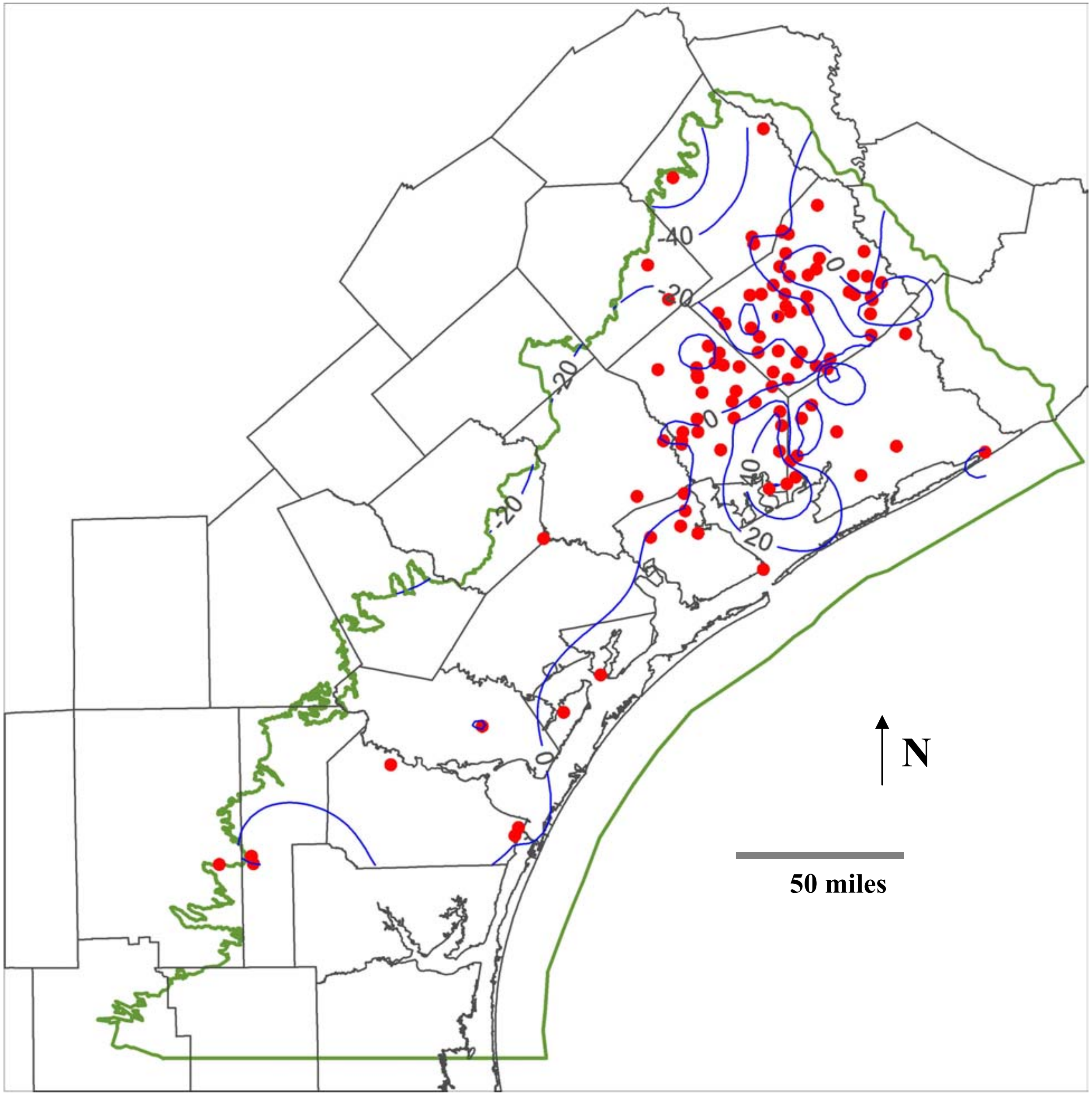


Measured Water Levels

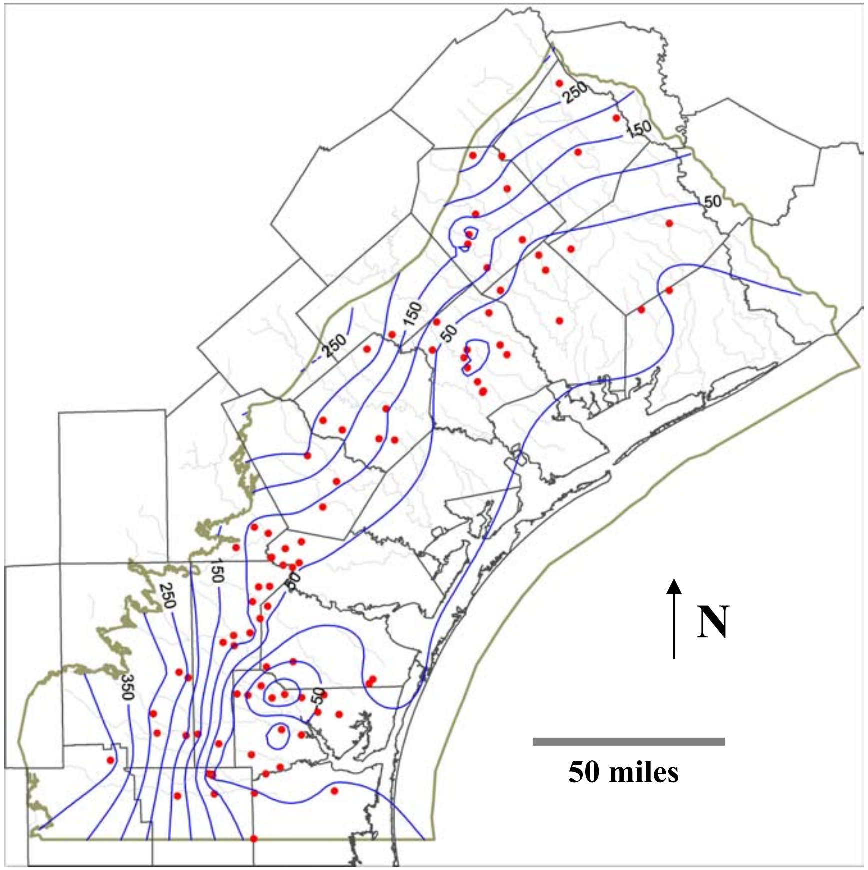


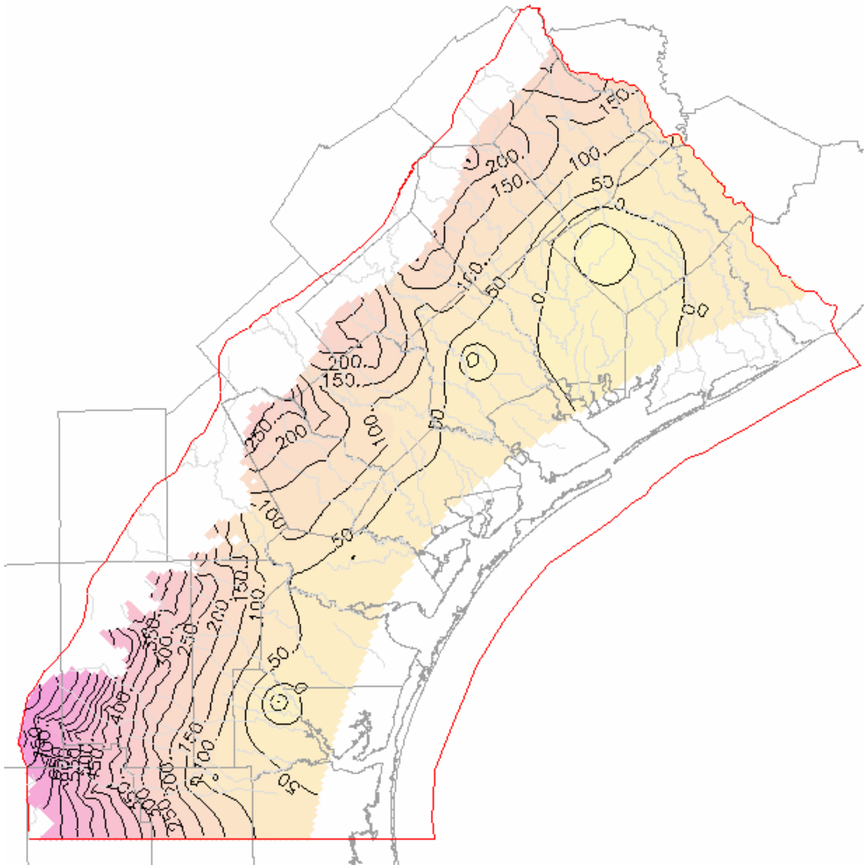
Simulated Water Levels

Spatial Distribution of Water-Level Residuals (Simulated-Observed) Chicot Aquifer, 1999



Comparison of Measured and Simulated Water levels Evangeline Aquifer, 1999

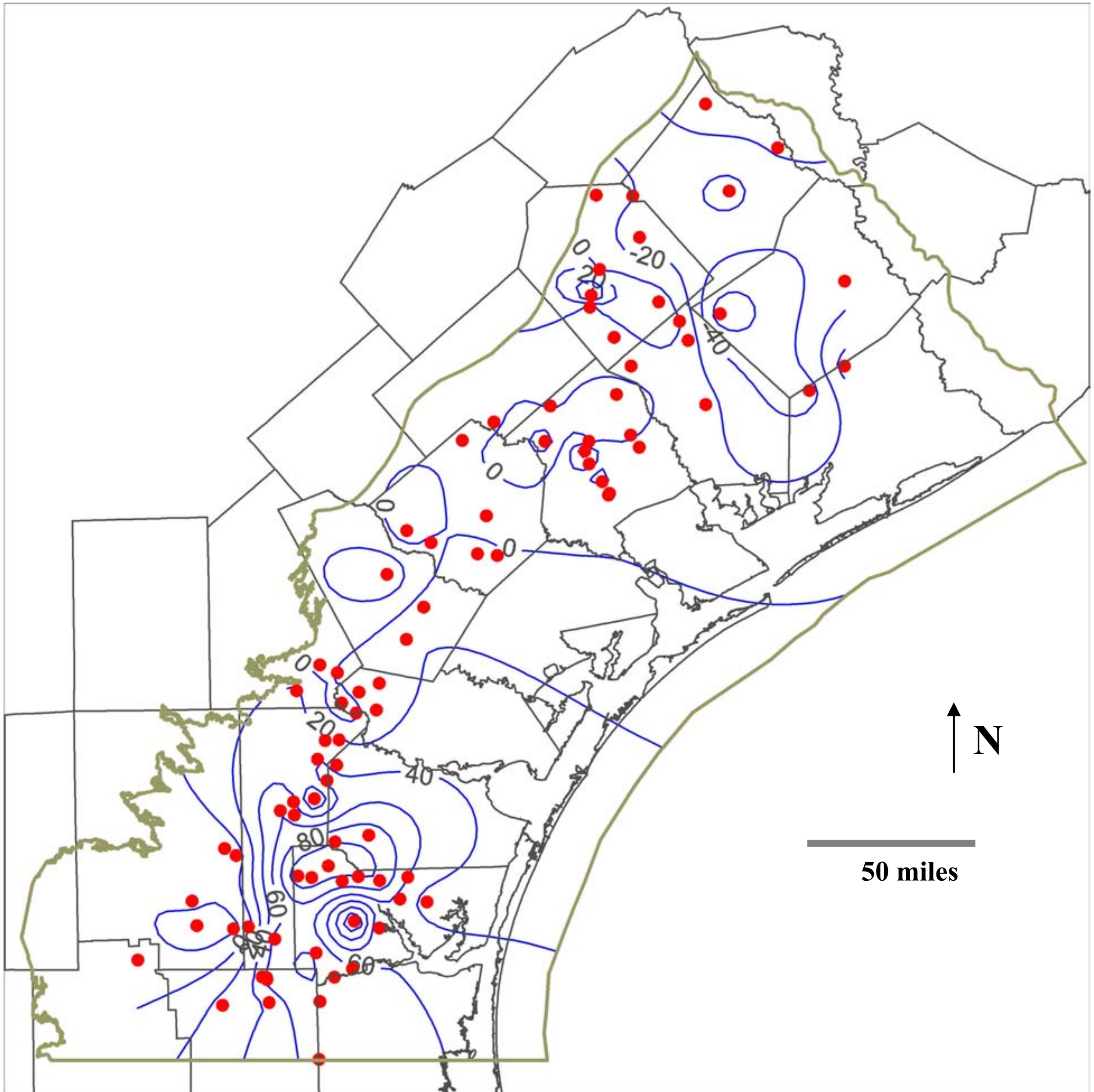




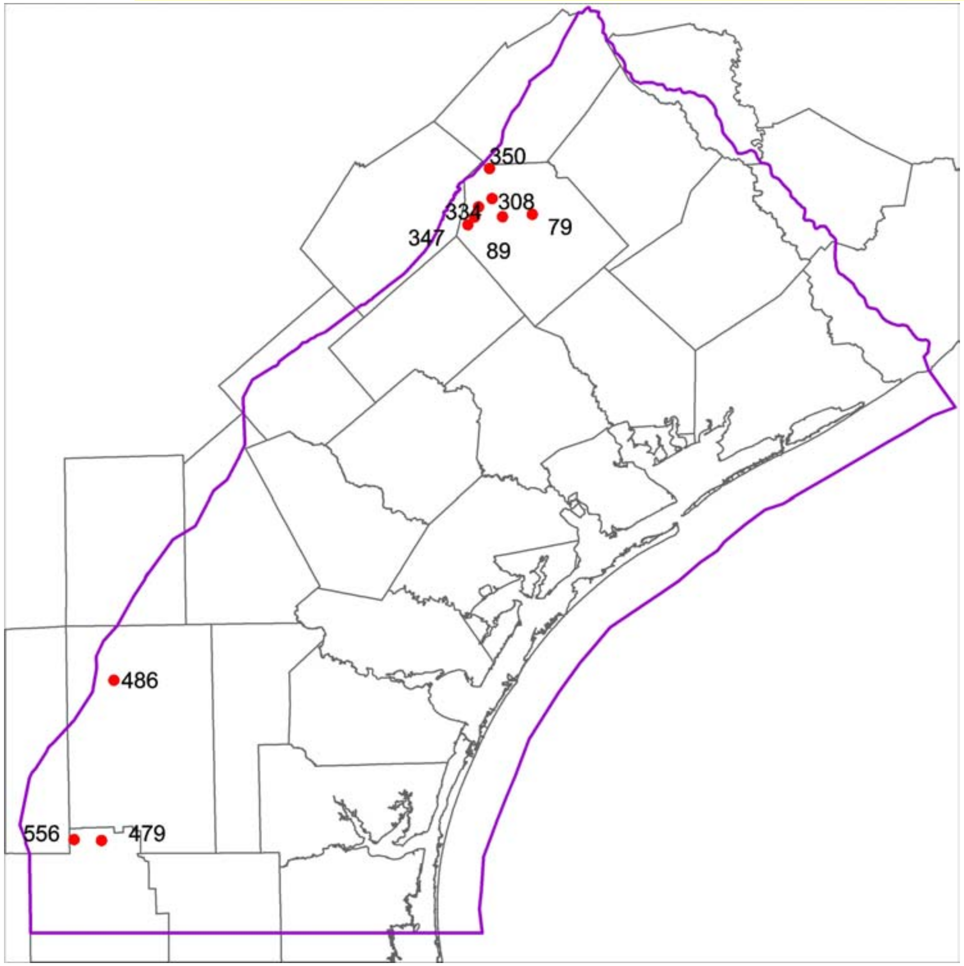
Measured Water Levels

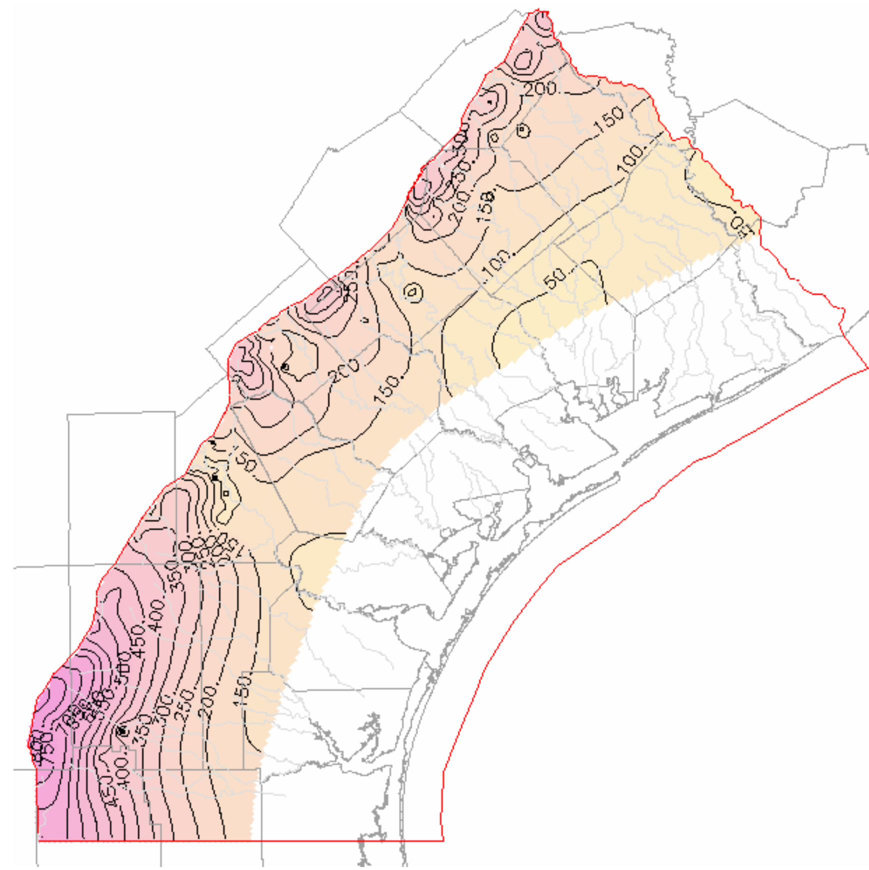
Simulated Water Levels

Spatial Distribution of Water-Level Residuals (Simulated-Observed)
Evangeline Aquifer, 1999



Comparison of Measured and Simulated Water levels Jasper Aquifer, 1999

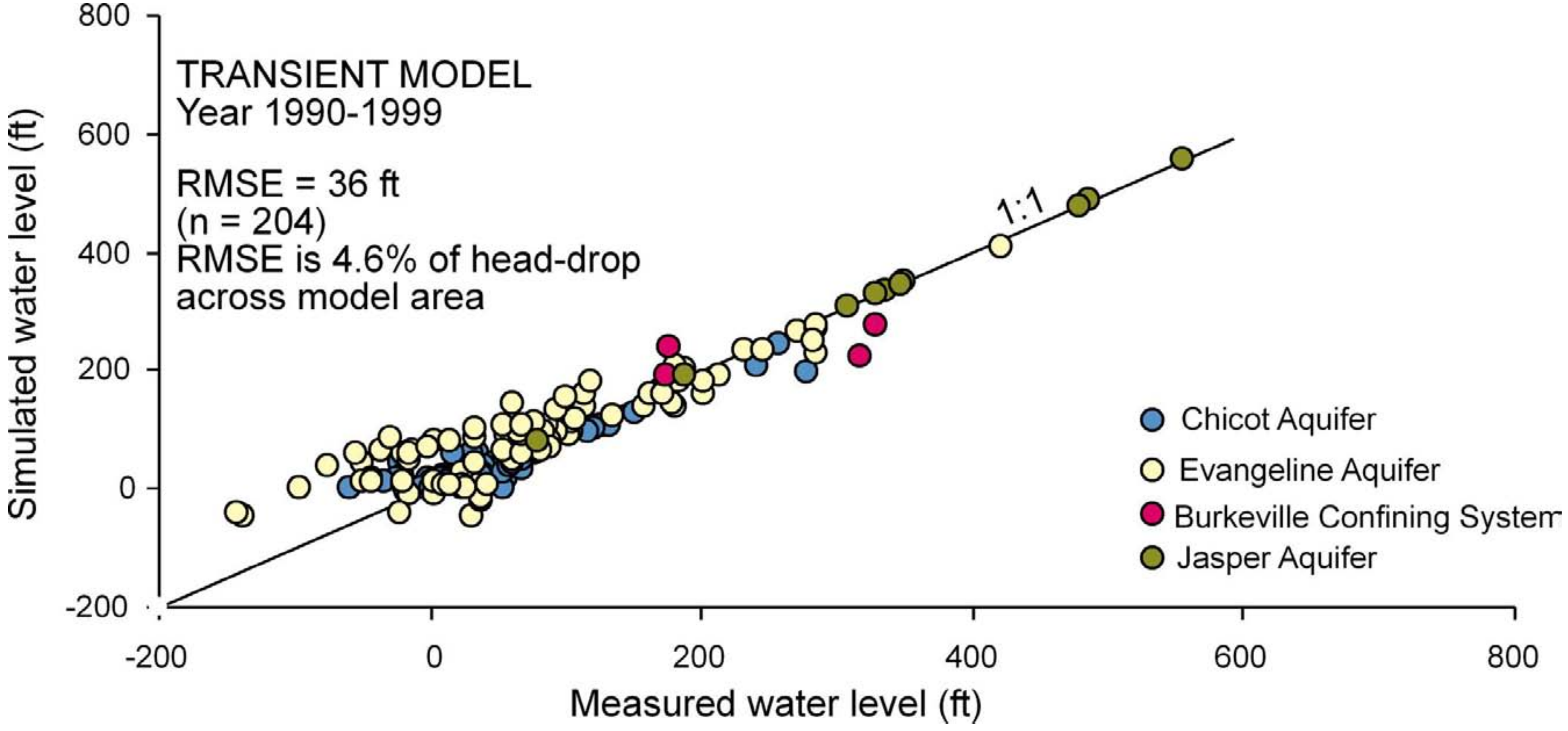




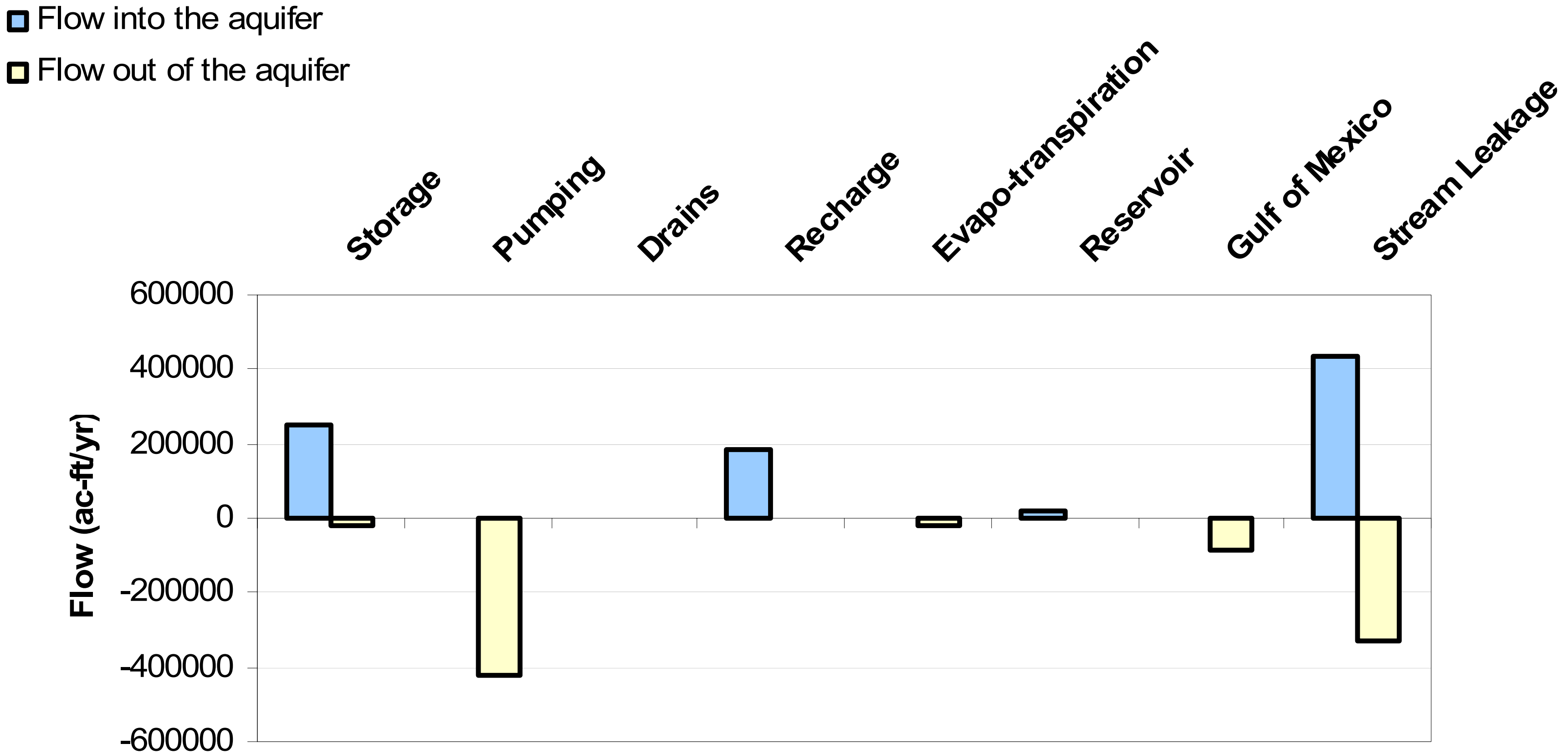
Measured Water Levels

Simulated Water Levels

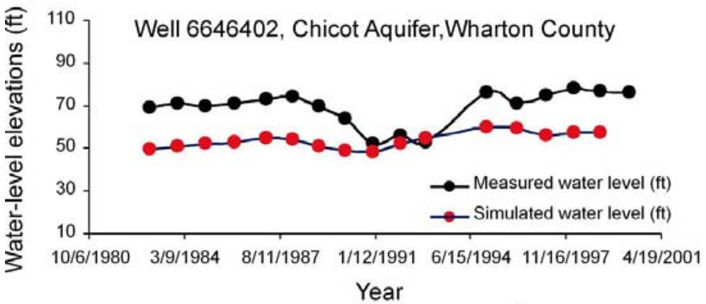
Comparison of Simulated and Measured Water Levels, 1999

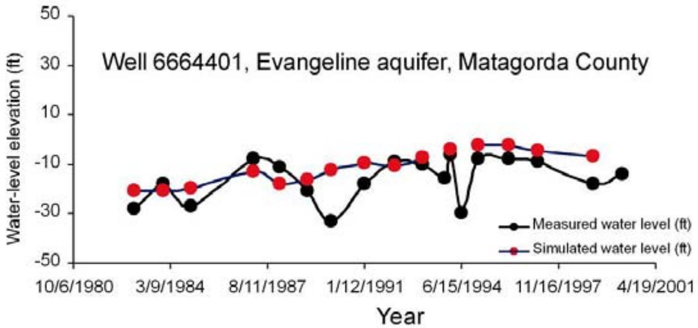


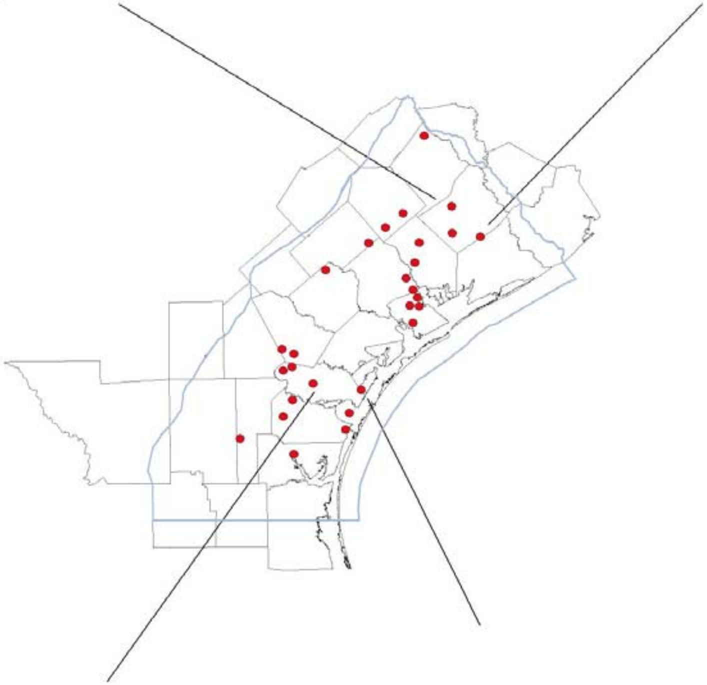
Water Budget
Transient-Model (1999)

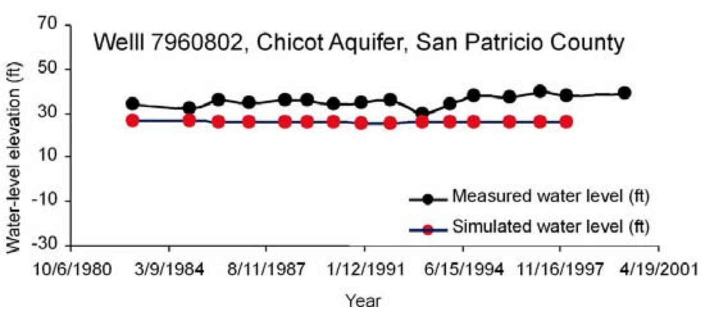


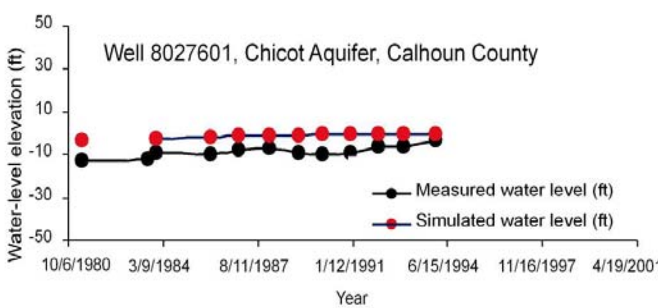
Transient Hydrographs



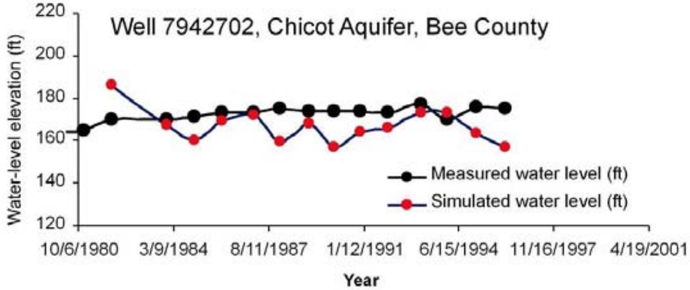


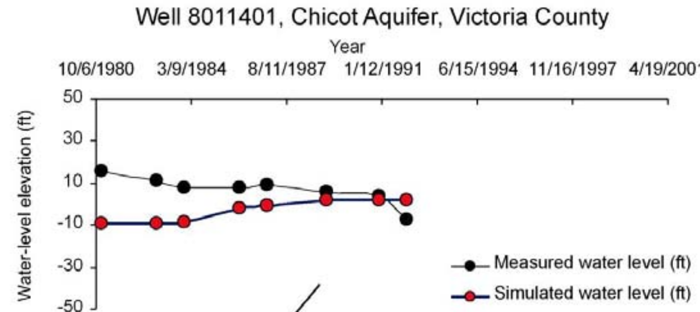


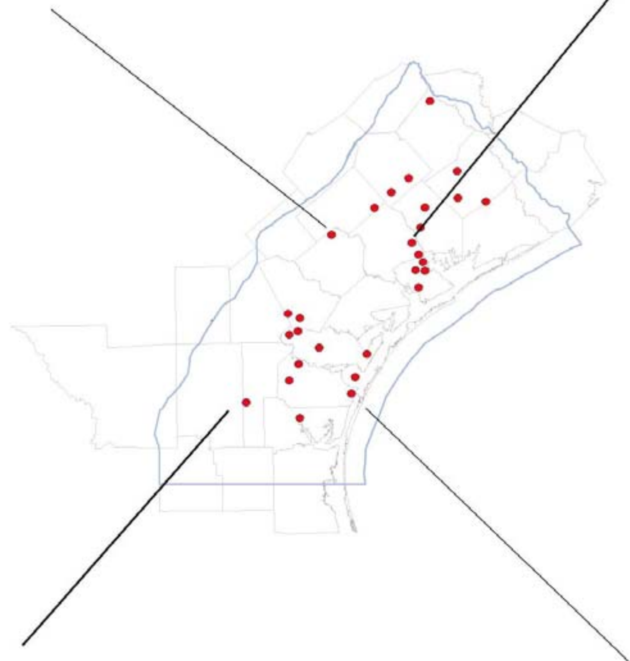


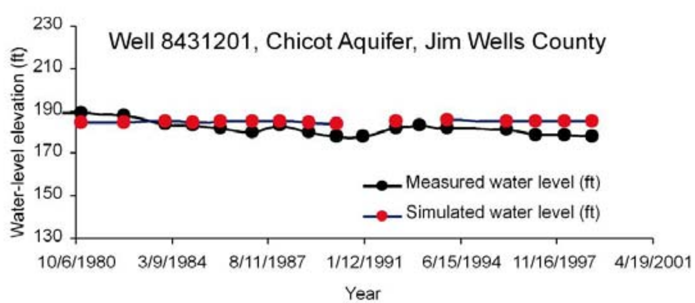


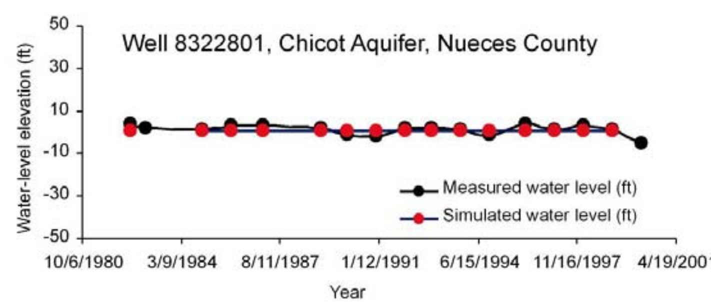
Transient Hydrographs











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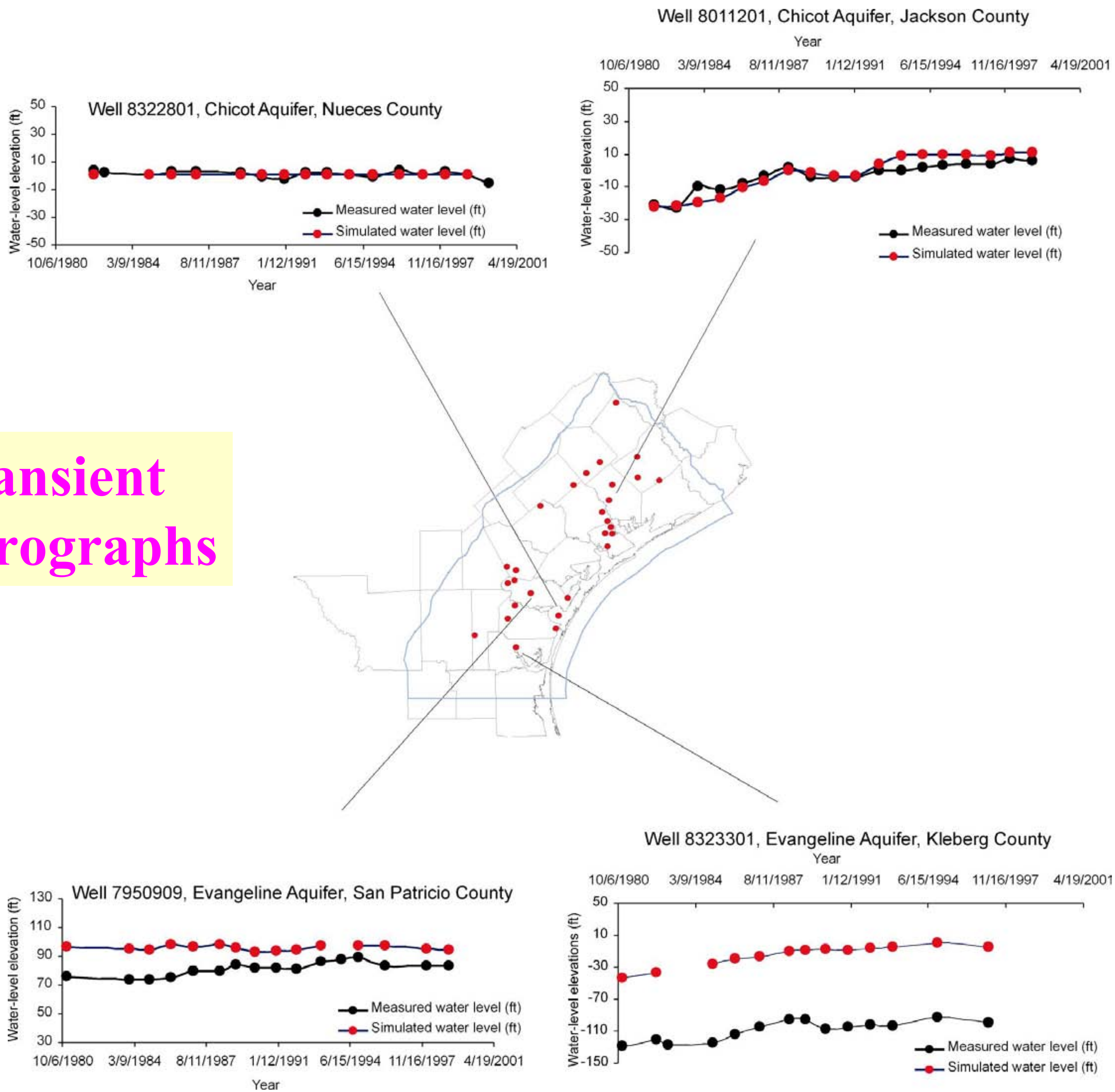

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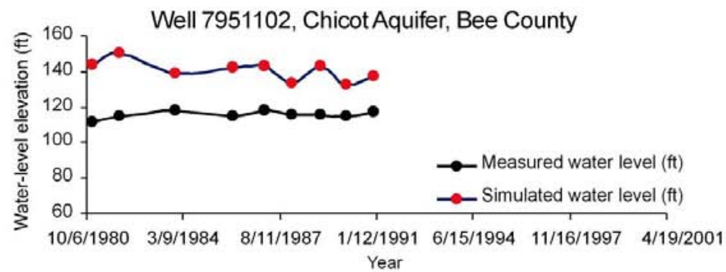
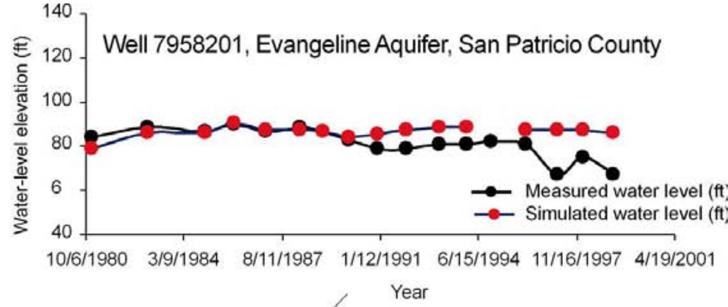
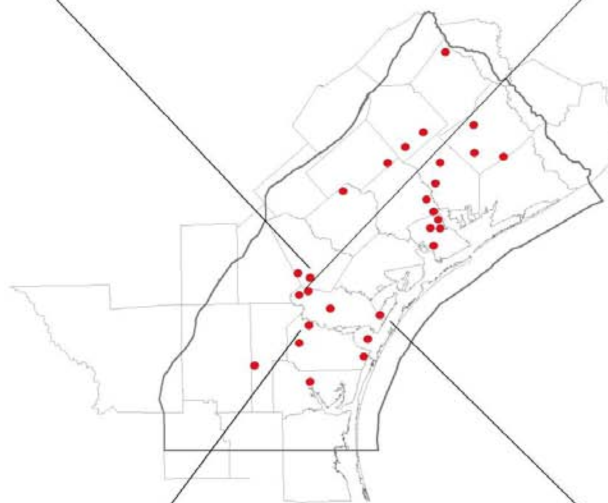
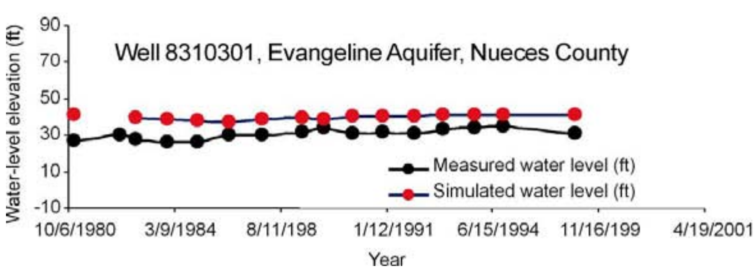
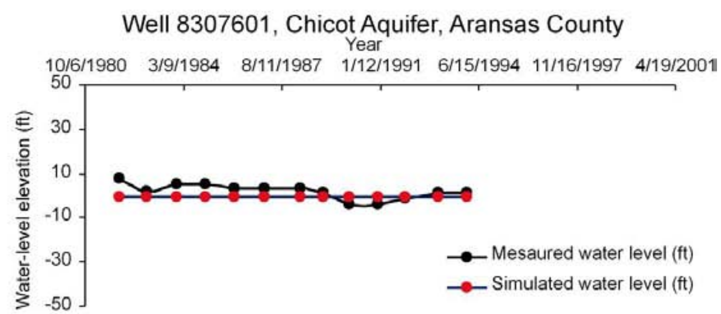


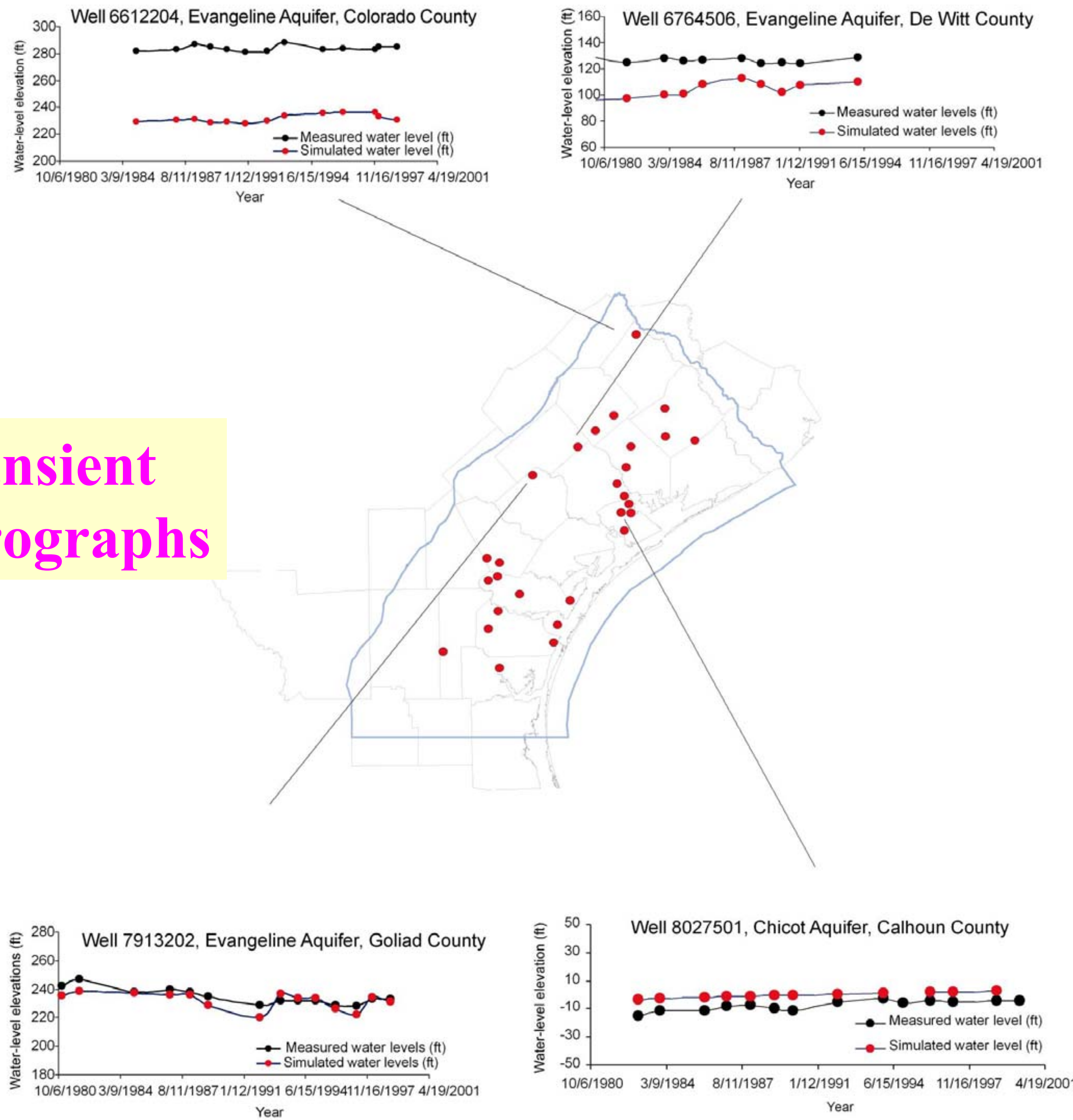








Transient Hydrographs



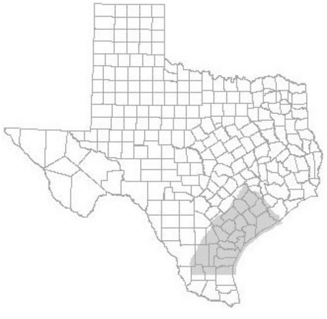
Conclusions

- Recalibrated the model honoring pumpage values

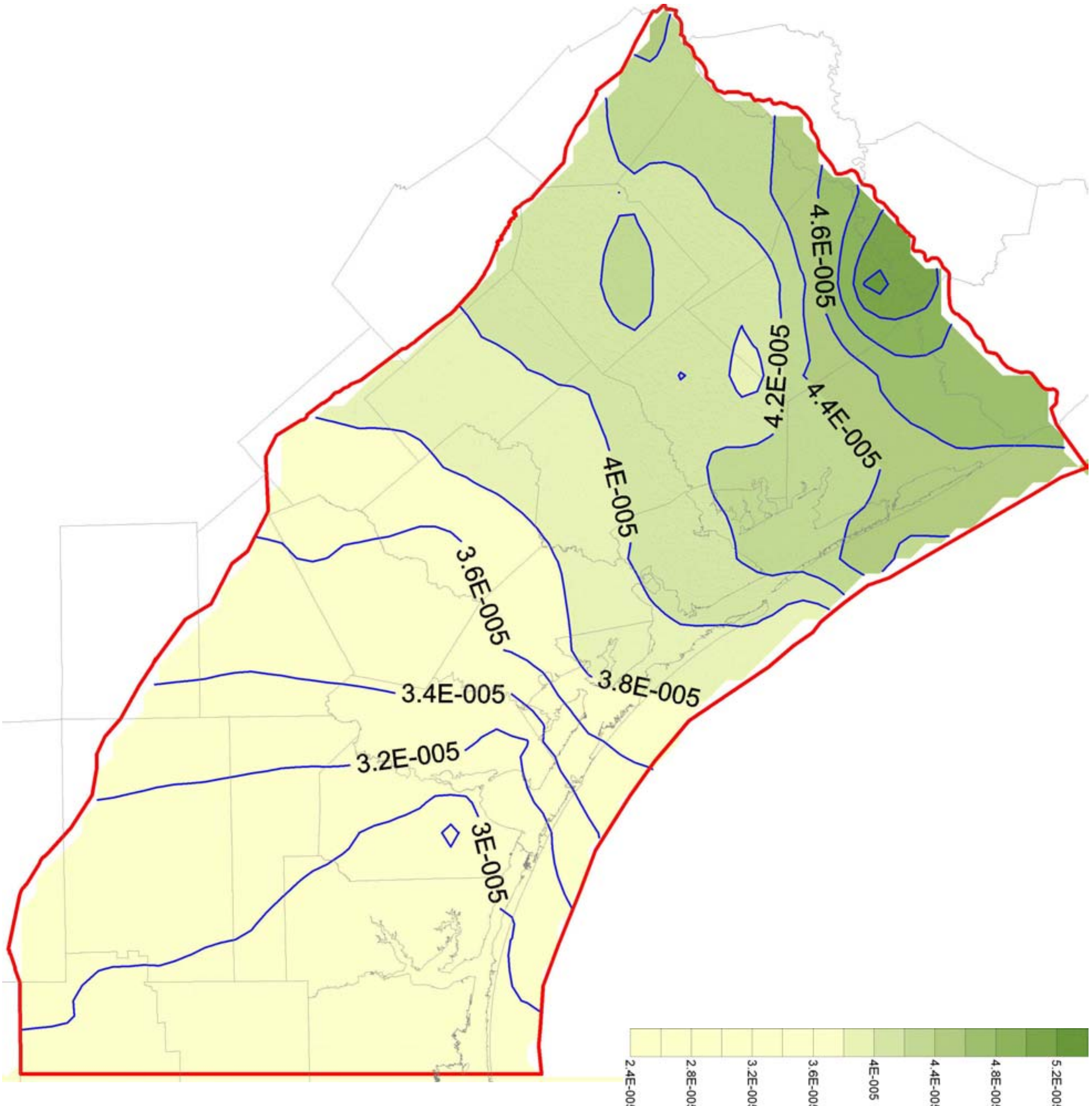
- Reproduced the drawdown cones in Wharton, Victoria and Kleberg counties

- Recalibrated the model by changing horizontal hydraulic Conductivity of the Evangeline and the Jasper aquifers, vertical leakance of the Chicot aquifer and storage parameters

- Predictive runs with RWPG pumpage data are being completed and results will be included in the report

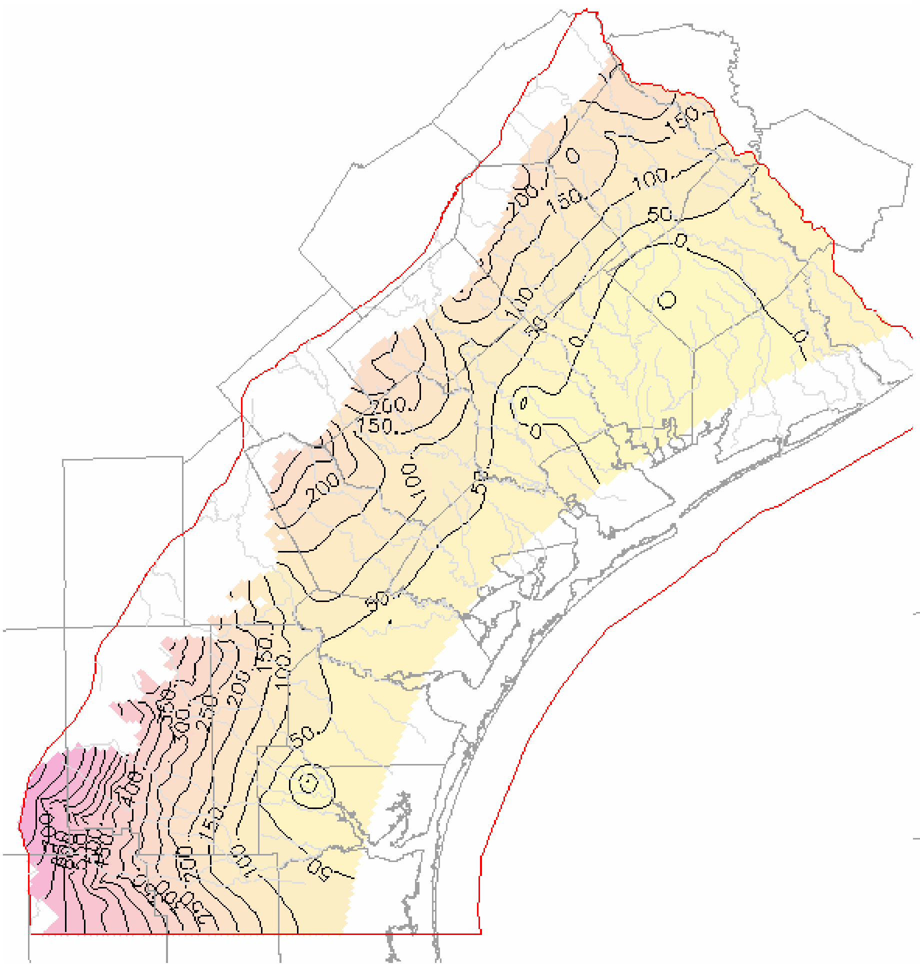


Calibrated Recharge (ft/d), Steady-State Model

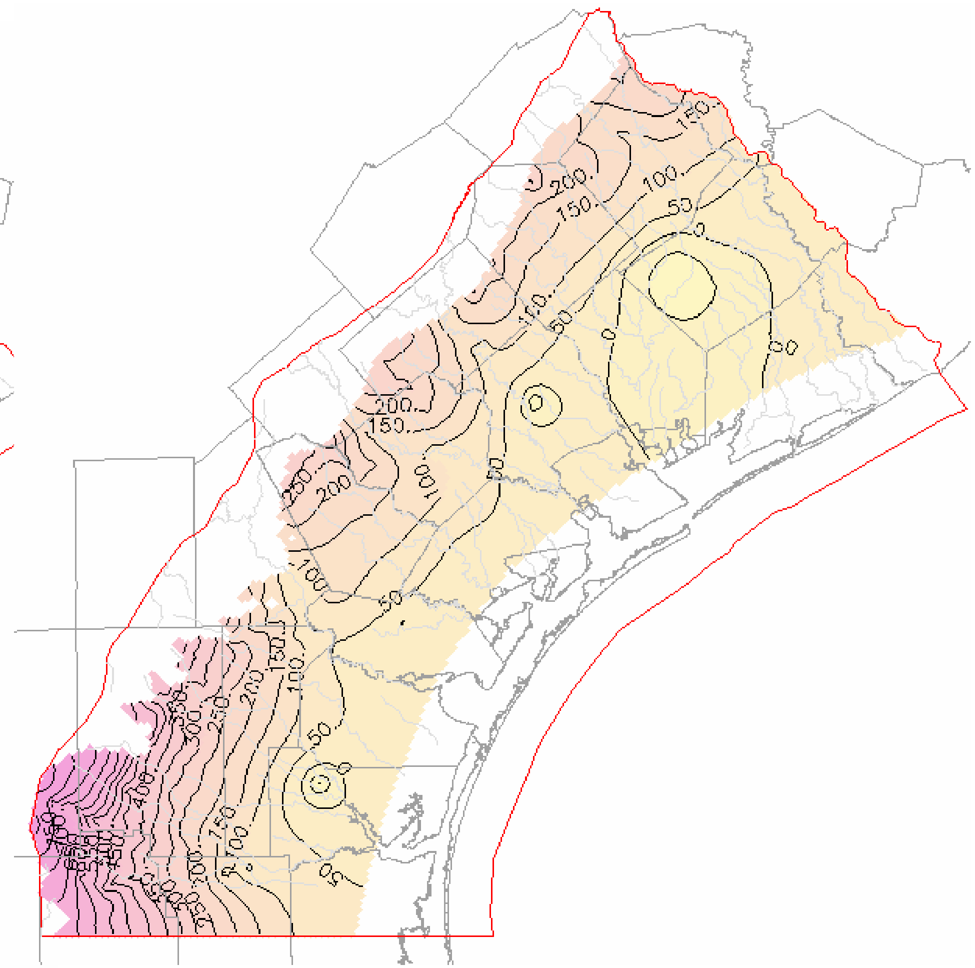


COMPARISON OF RECHARGE RATES IN THE GULF COAST AQUIFER SYSTEM

Source	Recharge Rate (in/yr)	Study Area	Recharge Method
Groschen (1985)	0.06	San Patricio to Jim Hogg counties	Constant head
Ryder (1988)	0 to 6	Texas Gulf Coast	Specified head, top layer of the model
Dutton and Richter (1990)	0.1 to 0.4	Matagorda and Wharton counties	Head-dependent flux boundary, top layer of the model
Noble and others (1996)	6	Harris, Montgomery and Walker counties	Isotopes
Hay (1999)	0.078	Navidad River to Willacy County	Constant head
Harden and Associates (2001)	0.1 to 0.2	Brownsville and vicinity	Used maximum potential recharge (3 inches) and MODFLOW's River Package
Ryder and Ardis (2002)	0.12[1]-0.25[2]	Texas Gulf Coast	Specified head, top layer of the model
Kasmarek and Strom (2004)	0.32[3]-0.43[4]	Northern Gulf Coast GAM	Specified head, top layer of the model
Chowdhury and Mace (2004)	0.09 to 0.15	Southern Gulf Coast GAM	Calibrated recharge as a percent of distributed rainfall
This Study (Pre-development)	0.15	Central Gulf Coast GAM	Calibrated recharge as a percent of distributed rainfall and soil properties
1 = average recharge for the predevelopment model, 2 = average recharge for 1982	3 = average recharge for 1977, 4 = average recharge for 2000		



Simulated Water-levels, 1989, Evangeline Aquifer



Simulated Water-levels, 1999, Evangeline Aquifer

Central Gulf Coast GAM Stakeholder Meeting
JULY 22, 2004

Natural Resources Center
Texas A&M University
6300 Ocean Drive, Room 1003
Corpus Christi, Texas

#	NAME	AFFILIATION
1	Larry Akers	EUWCD
2	Leslie Dodson	City of Texas City
3	Larry Land	HDR Engineering
4	James Beach	LBG-Guyton
5	Neil Hudgins	Coastal Bend GCD
6	Wayne Tschirhart	GBRA
7	Rick Hay	CWSS TAMU-CC
8	Alan Berkebile	CWSS TAMU-CC
9	Venki Uddameri	TAMU-Kingsville
10	Garrett Engelking	Refugio GCD
11	Muthu Kuchanur	TAMU-Kingsville
12	Bob Pickens	Region K/Colorado County
13	Haskell Simon	Region K/Matagorda County
14	Melissa Bryant	SARA
15	Phil Weynand	San Antonio River Authority
16	Steve Raabe	San Antonio River Authority
17	Richard Bowers	Groundwater Services, Inc.
18	Robert Mace	TWDB
19	Ali Chowdhury	TWDB
20	Cindy Ridgeway	TWDB

Central Gulf Coast Stakeholder Meeting
July 22, 2004
Questions and Responses:

Q: Please clarify if pumpage was adjusted [volumetrically at the county/basin level] to calibrate the final model or just in the draft model version.
A: The pumpage used in the final model honored historical estimates at the county/basin level.

Q: Is an overlap study scheduled between the Northern Gulf Coast (NGC) GAM and the Central Gulf Coast (CGC)?
A: TWDB will discuss the differences in the overlap area in the [final] report [Note: the summary report may not discuss this in as much detail as the final report].

Q: If TWDB approved the parameters in both [NGC and CGC GAMs] models and they do not match, which do we use?
A: It depends on your question. Different approaches and assumptions were used to address slightly different goals. The models have different transmissitivity and recharge values and different boundary conditions.

Q: Is the structure the same in the [NGC and CGC] models?
A: Structure for both of the models was derived from the SWAP (Source Water Assessment Program –TCEQ) data. Slight differences may occur may occur downdip of the 3,000 ppm water quality line; however, both models based extending the structure using much of the same data, cross-sections, from Ryder and Baker.

Q: Subsidence: doesn't dewatering occur early in the process from clay versus sand in volumetrics?
A: Yes, the USGS believes that about 30 percent of the water budget is derived from subsidence. CGC will show greater declines [since it didn't use the subsidence package].
Q: Could [adjusting] storativity compensate for this [during calibration]?
A: Yes

Q: Will you be releasing the logs [used to develop the structure]?
A: No, the structure was based on SWAP.
Q: [Will you be releasing] other data?
A: Source data used will be available upon request [A slight charge for processing may be charged per CD of data].
Q: How did you develop the storativity if you didn't use log data?
A: It was a model calibrated parameter that was cross-checked against referenced material.
Q: How about sand thickness maps?
A: Will be included in the source data files or cited references provided.

Q: Define SWAP.
A:SWAP is the Source Water Assessment Program at TCEQ.

Q: Hydraulic properties were held constant at the boundaries?
A: Hydraulic properties varied along the boundaries.

Q: [Block Diagram Slide] For discharge out of the aquifer, are you also getting surface water/groundwater interaction?
A: Yes.
Q: OK, how much is leaving the through bay interaction?
A: Water flows up-gradient near the Gulf, at least in predevelopment times. No studies on seepage were done. Water enters the system as recharge and flows downdip. We know it doesn't continue this trend forever and the water must go somewhere. With much effort the water is forced to flow up-dip near the coast.

Q: Why are the parameters not the same if water is pumped from the top [of the Evangeline aquifer unit] as from the bottom [of the Evangeline aquifer unit]?
A: Although the aquifer is included in the model as a single layer, in reality the aquifer is much more complex with interbedded clays and sands. A well only completed in the top of the aquifer probably does not have an effect on the lower part of the aquifer.
Q: Doesn't vertical leakance help this?
A: No, we're talking about the water being extracted from the top, middle, or bottom of a single model cell not the communication between cells.
Q: So why didn't you use more layers to better match [completion of] wells.
A: Would be a painful process; may add more layers later. This current model may not help in the analysis of future wells that penetrate deeper in the Evangeline.
Q: How would the current model respond if you tried to model a high-producing deep well?
A: It would show greater drawdown than what would occur. Again, the solution would be to add more layers.

Q: Why did you zone hydraulic conductivity in the Evangeline?
A: The observed data appeared clumped. We used the median value of the observed data in each clump [zone].

Q: How much pumpage did you use in the steady-state?
A: None.
Q: You used average water levels between 1900 and 1940 for the steady-state model?
A: Yes.
Q: How many water-levels measurements was this based on?
A: Around 100.

Q: What are the model boundaries?
A: General head along the Coast in the top layer, no-flow along the other sides and layers.
Q: Did you make any changes to the streams or springs from the draft version?
A: No.

Q: Are there any patterns in stream leakage in the model: for example, did you see any trends going north to south or in zones?
A: We will discuss this in the [final] report.

Q: [In the steady-state cross plot figure] Do the dots represent average change in calibration points?
A: Yes
Q: How did you bring water levels from 1940 to 1980 conditions i.e. from the steady-state to the beginning of the transient runs? Did you ramp up?
A: Ran the 1980 pumpage for a long time.
Q: The source of the 1980 pumpage?
A: TWDB estimates.
Q: Wharton County pumped the heaviest in the 1970s, not 1980 [between the steady-state and transient. How is that factored into your approach?]
A: We reviewed hydrographs for plateaus and determined Kingsville, Victoria, and Wharton were evening out in 1980. We needed a steady water level to start the transient.

Q: Was the same recharge used that was in the draft model?
A: Yes. We compared the recharge to the other Gulf Coast GAMs and recharge was within a reasonable range.
Q: Did you use the same drains and stream locations and parameters?
A: Yes, we initially did an audit of the parameters in the draft model before we tried to recalibrate the model.

Q: In the overlap, near the boundaries, are you going to provide a guidance document.
A: No, this will be a case-by-case exercise.

Q: Was the model maybe too large? Should the northern and southern parts of the model be separated?
A: No, not in our opinion.
Q: So is this going to be the final model?
A: Yes, at this time.

Q: Since both the draft model and this model were calibrated using different parameters, doesn't that make the solution non-unique?
A: Yes. We reviewed the raw TWDB pumpage estimates and believed the pumpage estimates appeared reasonable. We decided we should honor historical TWDB pumpage estimates and adjust other parameters to calibrate the model.

Q: Does anything warrant zoning storativity in the Evangeline?
A: There may be a geologic reason for zoning storativity in the Evangeline [such as varying sand percentages. However, the model is not as sensitive to storativity as it is to other parameters].

Q: Did you use automated calibration software or process?
A: No
Q: Did you use MODFLOW-96 or MODFLOW 2000?
A: MODFLOW-96
Q: Which solver did you use?
A: SIP [We answered this incorrectly at the meeting. This should be PCG-2.]

Q: Since you compromised on the storativity value used between estimates in the northern portion and the southern portion of the model area is the model better in a certain area?
A: We minimized errors in both areas. However, there is a set of values that work better in the northern and a set that works better in the southern. This will be discussed in the [final] report.

Q: Any suggestions for improvements to the model?
A: More data, possibly more layers.

Q: Back to the earlier question, should you make smaller models from the regional model?
A: No, it is not necessary.
Q: Could varying sand percentages [between the northern and southern portion of the study area] cause some of the calibration issues?
A: Maybe.

Q: Explain storage.
A: Water released from [or taken into] the aquifer for an associated change in water level. Drains in the outcrop area. More of an elastic release in the confined portions.

Q: Please explain why and what was wrong during the recalibration. Vertical properties or horizontal hydraulic properties?
A: Our approach was to start simple and get more complex when needed. The breakthrough for us was when we tried to get the model to reflect the partial penetration of wells in Evangeline.
Q: When and why did you stop calibration? What was the basis for stopping?
A: We continually visually compared the simulations results to the calibration targets. Our GAM standard is within 10 percent of Root Mean Squared (RMS) of head differences. The recalibrated model is below the 10 percent RMS.

Q: What are the practical uses for the model?
A: The model does not exactly reflect water levels for the Kingsville and Wharton areas. However, the model does well showing trends and rebounds. It is better for analyzing changes in water levels not absolute water levels. It is not good for studying impacts of wells fully penetrating to the base of the Evangeline; however, it would be a good first step analysis before doing a smaller scale site study.
Q: How should a GCD use the model?
A: We do not want to dictate to GCDs. The statute states they shall use GAM unless better data is available. They can use different parts or parameters from the model. They can do model runs. They can use data from the source files.
Q: How definitive are GAM runs? Do they show impacts on 1-mile, 2-mile, 5-mile radius.
A: Depends on the production. More site specific data may be needed. Possibly use an analytical model.
Q: So is refining a GAM considered "using GAM"?
A: Depends on how the GAM is refined.
Q: Is there a precedence [procedure or protocol] for refining a regional GAM?
A: Yes and no. The Barton Springs district is an example of changing a GAM, although in this case the aquifer is small and fully contained within the district. Stakeholder and TWDB

involvement is important. [Region A has been making changes to the northern Ogallala GAM and has been working closely with TWDB staff during the process].

Q: Can the model be used to determine sustainability?
A: If you believe in the model [assumptions and approach]. It also depends on how you define sustainability. We have learned during the GAM program that large volumes of recharge can be offset or balanced with ET (Evapotranspiration). Recharge can be non-unique. Many people misinterpret that recharge is equal to sustainability. TWDB is continually seeking to do things better. TWDB Board has approved a study of ET to help us with model imputs and model recharge. We will be having a TAG meeting later this year to discuss ways to improve the GAMs.

Q: So if you don't think you will be using a GAM, for example using a smaller model with different refinements, is there any precedence?
A: Suggest getting involved with TWDB staff early in the process since our EA will ask for our opinion. We'd be looking at this on a technical level. For example, Barton Springs got many people involved when they refined the Edwards Barton Springs GAM.

Q: Back to the ET project you mentioned. Does it include rejected recharge?
A: Kind of. The whole ET process is a kind of mechanism for rejected recharge.