Refined Groundwater Availability Model for the Seymour Aquifer in Haskell, Knox and Baylor Counties

Stakeholder Advisory Forum #3

Development of the Numerical Flow Model

Presented by

Groundwater Availability Modeling

Texas Water Development Board

January 29, 2014

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The statements contained in this presentation are my current views and opinions and are not intended to reflect the positions of, or information from, the Texas Water Development Board, nor is it an indication of any official policy position of the Board.

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Outline of Presentation

- Groundwater Availability Modeling (GAM) Program
- Conceptual Groundwater Flow Model
- Development of Numerical Groundwater Flow Model

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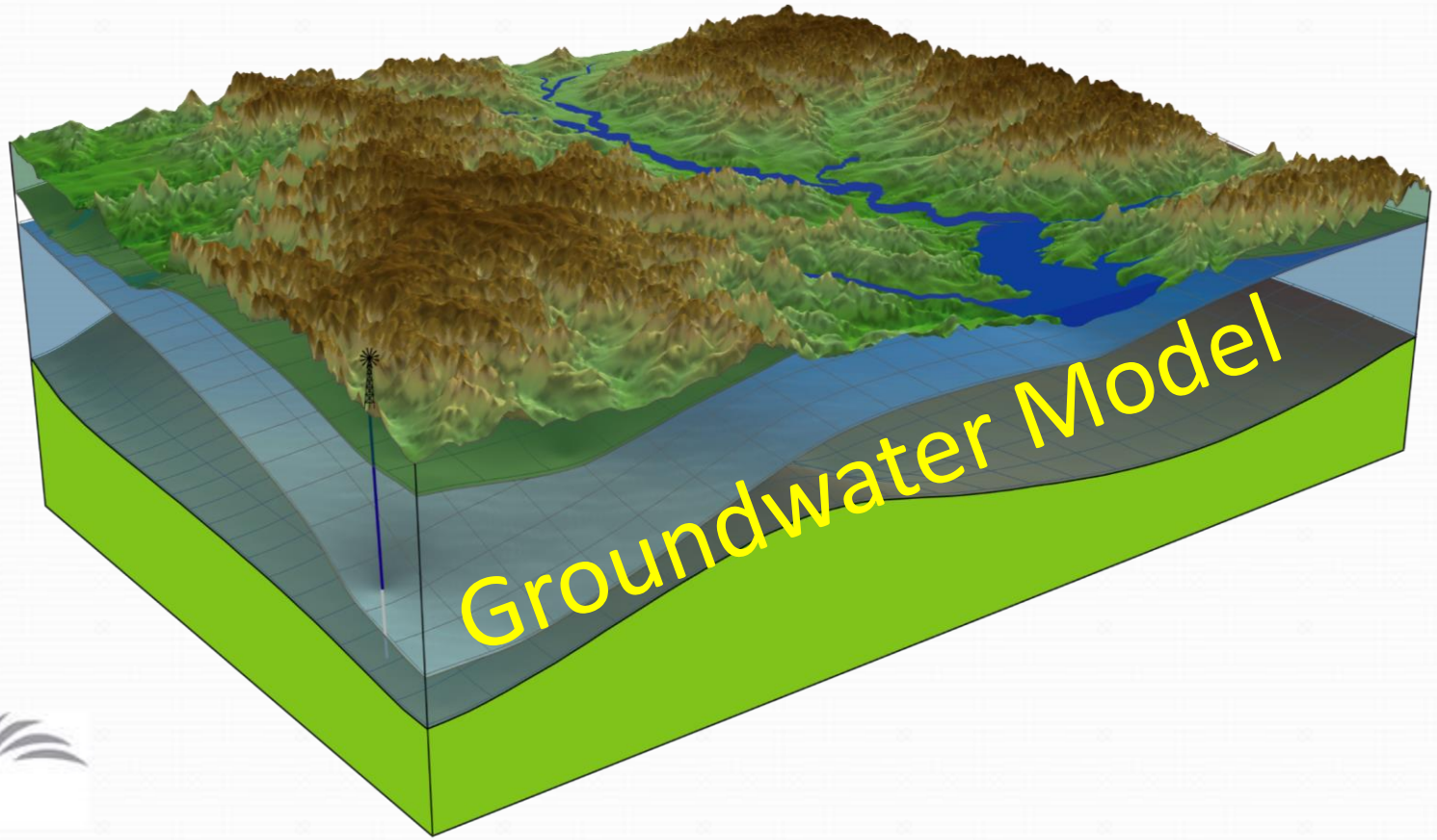
Review of GAM Program

Shirley Wade, Ph.D., P.G.
Groundwater Availability Modeling
Texas Water Development Board



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GAM Program

- **Purpose: to develop tools that can be used to help Groundwater Conservation Districts, Regional Water Planning Groups, and others understand and manage their groundwater resources.**
- **Public process: you get to see how the model is put together.**
- **Freely available: models are standardized, thoroughly documented. Reports available over the internet.**
- **Living tools: periodically updated.**

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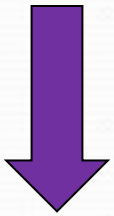
What is Groundwater Availability?

Policy + **Science** = **Groundwater Availability**





Desired Future Conditions + **GAM or other tools** = **Modeled Available Groundwater**

Goal: informed decision-making

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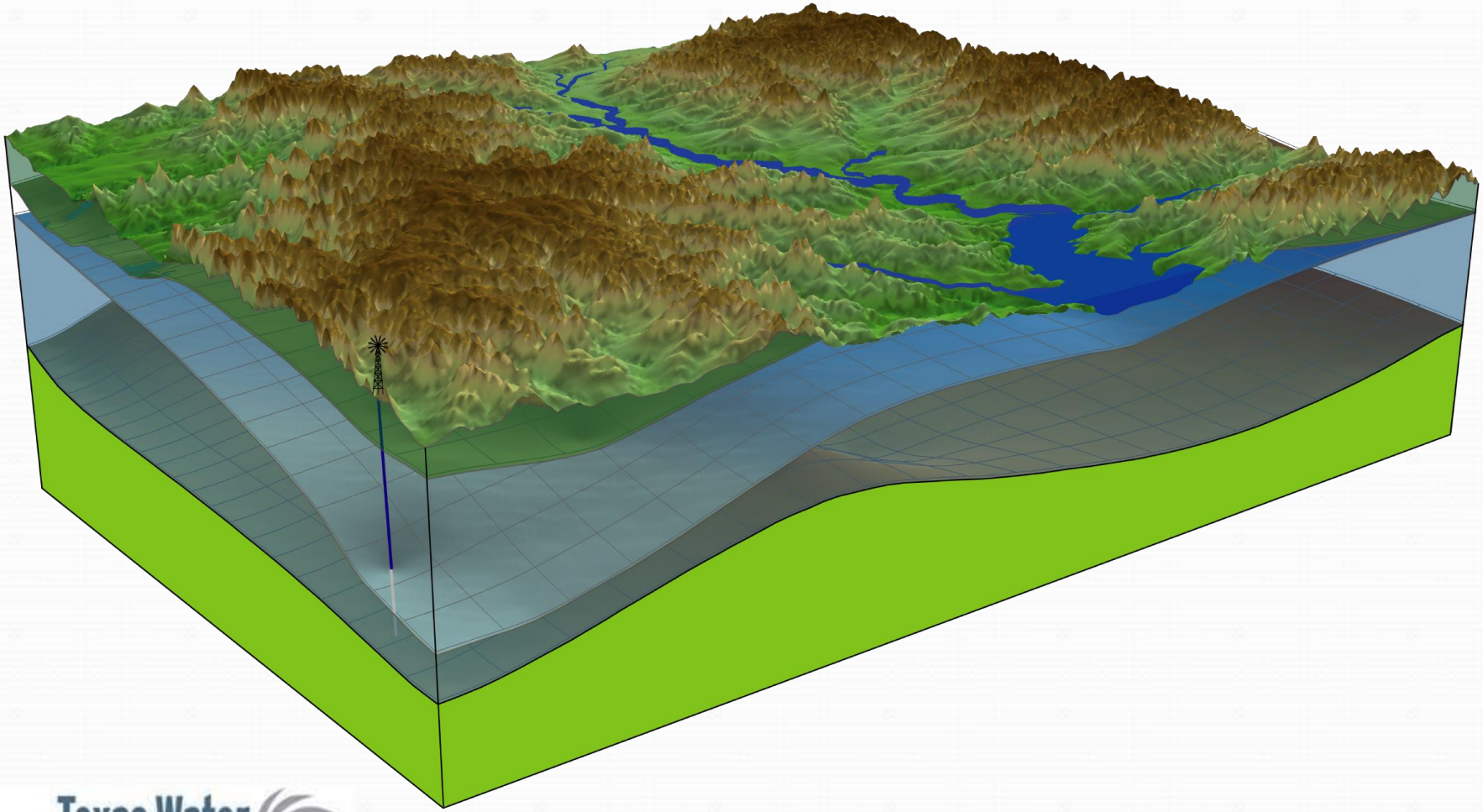
Groundwater Model



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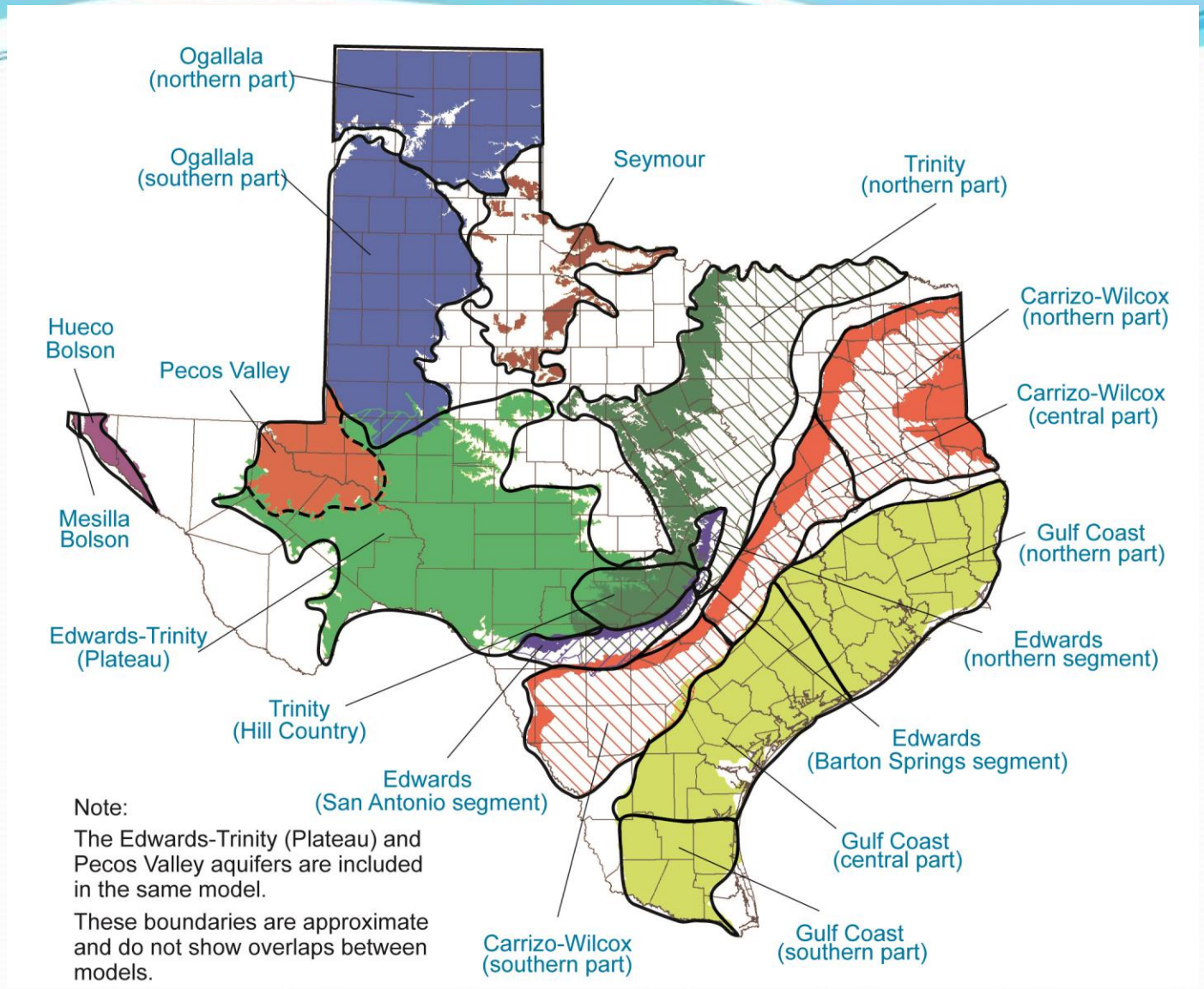

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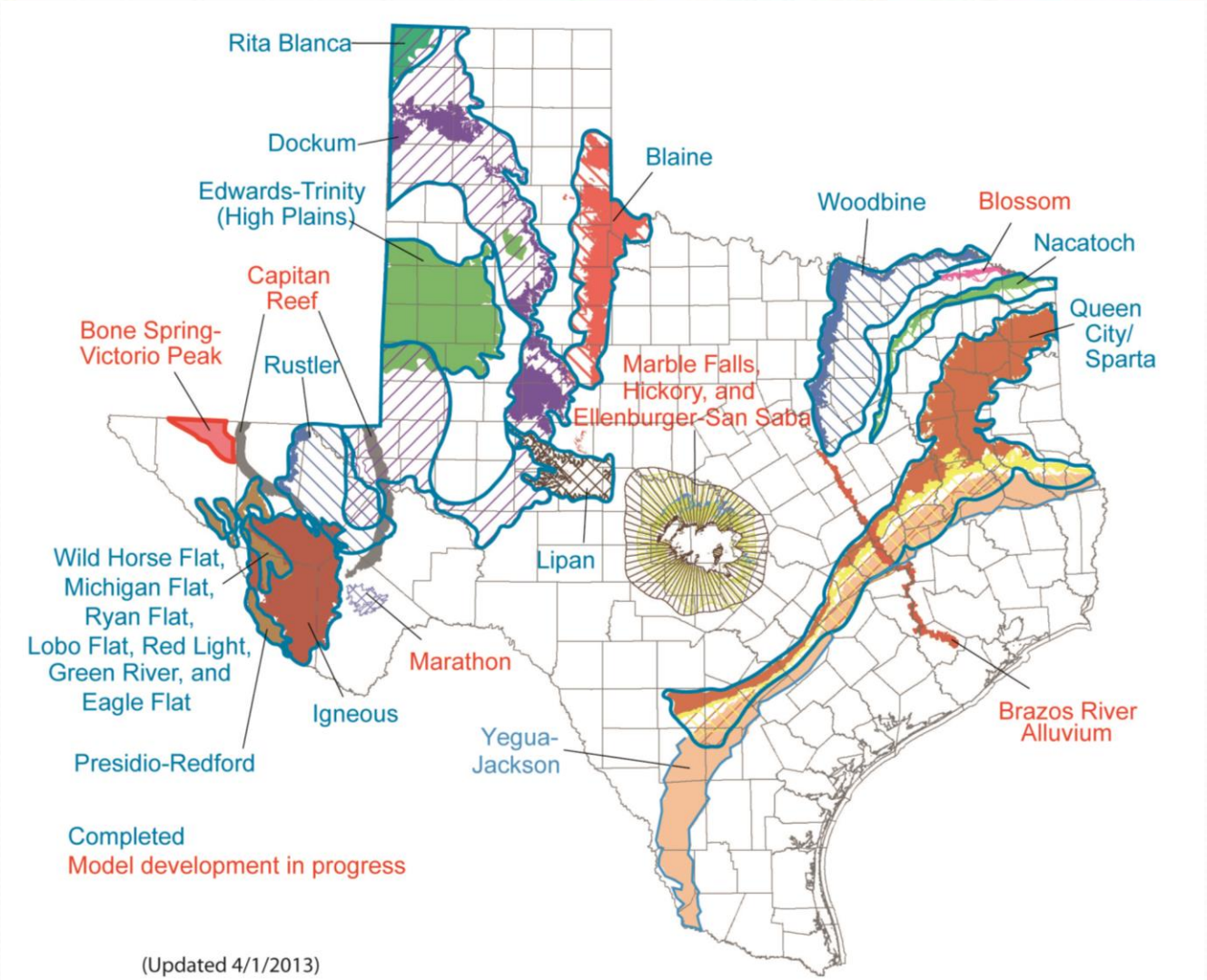
Major Aquifers



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Minor Aquifers

How we use Groundwater Models

- **Texas Water Code, § 36.1071 (h)**

Inform groundwater districts about historical conditions in the aquifer

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Edwards-Trinity (Plateau) Aquifer	140,509
	Pecos Valley Aquifer	14,115
	Dockum Aquifer	0
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Edwards-Trinity (Plateau) Aquifer	31,222
	Pecos Valley Aquifer	9,804
	Dockum Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	32,993
	Pecos Valley Aquifer	3,441
	Dockum Aquifer	554

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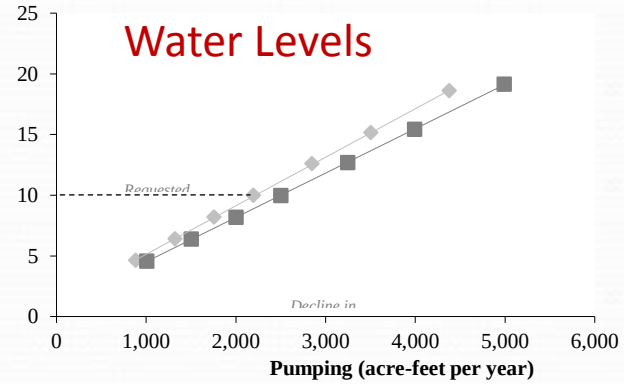
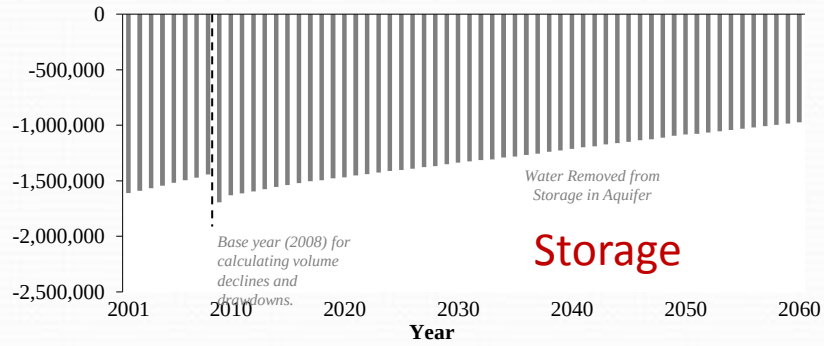
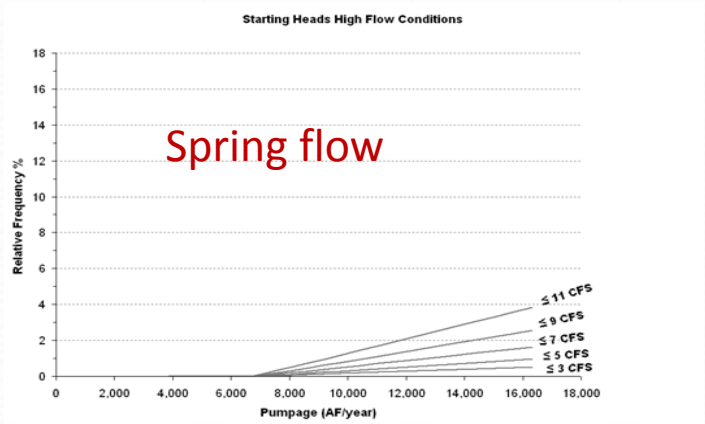
How we use Groundwater Models

- Texas Water Code, § 36.108 (d): the districts shall consider groundwater availability models and other data or information [when developing desired future conditions]







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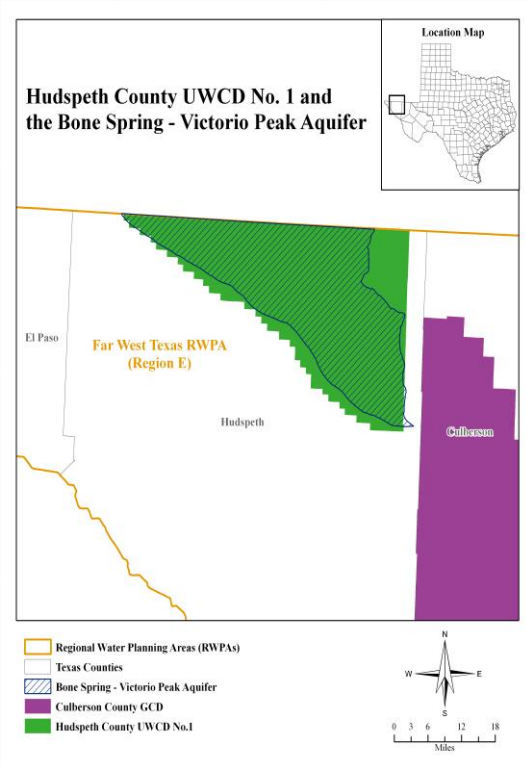
How we use Groundwater Models

- **Texas Water Code, § 36.1084 (b): Develop modeled available groundwater based on desired future conditions**

County	Regional Water Planning Area	Basin	Year					
			2010	2020	2030	2040	2050	2060
Hudspeth	E	Rio Grande	101,429	101,429	101,429	101,429	101,429	101,429

*Modeled available groundwater is in acre-feet per year



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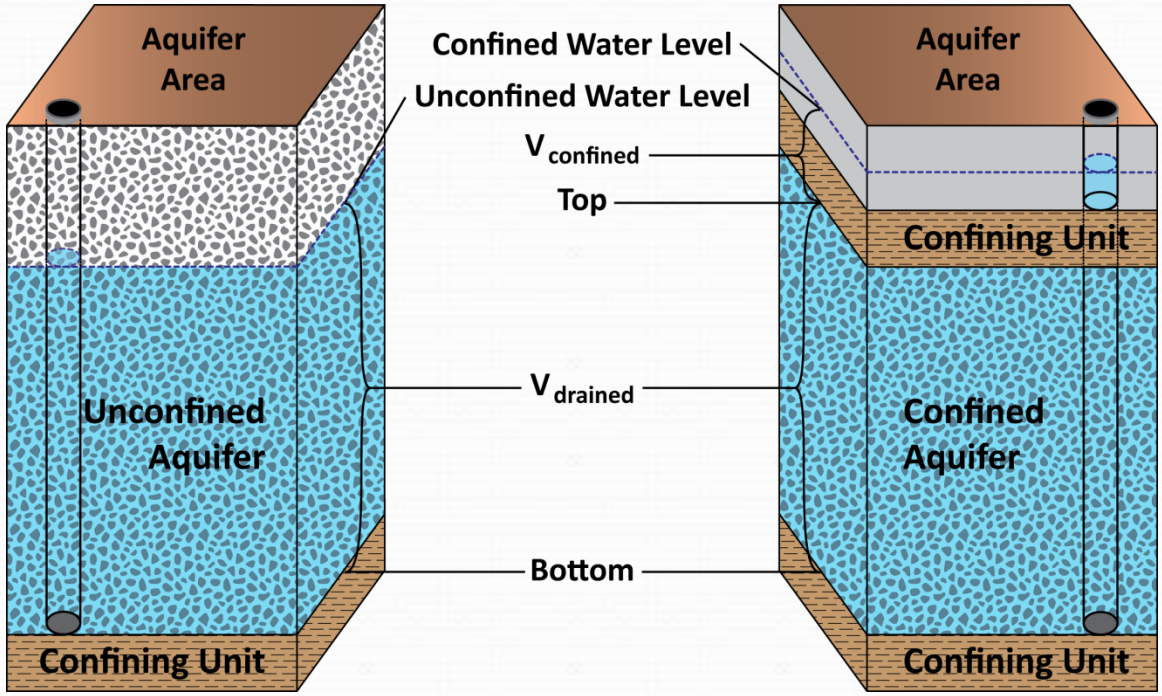
How we use Groundwater Models

- **Texas Water Code, § 36.108 (d) (3)**

Estimating total recoverable storage for explanatory reports



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Stakeholder Advisory Forums

- **Keep updated about progress of the model**
- **Understand how the groundwater model can, should, and should not be used**
- **Provide input and data to assist with model development**

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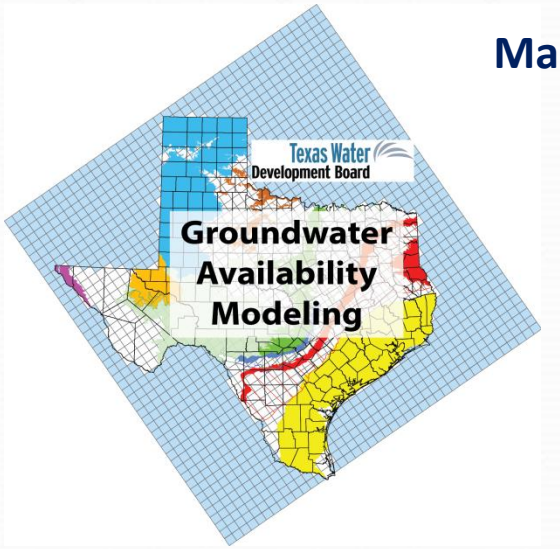
Contact Information



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http://www.twdb.texas.gov/groundwater/index.asp

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Review of Conceptual Groundwater Flow Model

Shirley Wade, Ph.D., P.G.
Groundwater Availability Modeling
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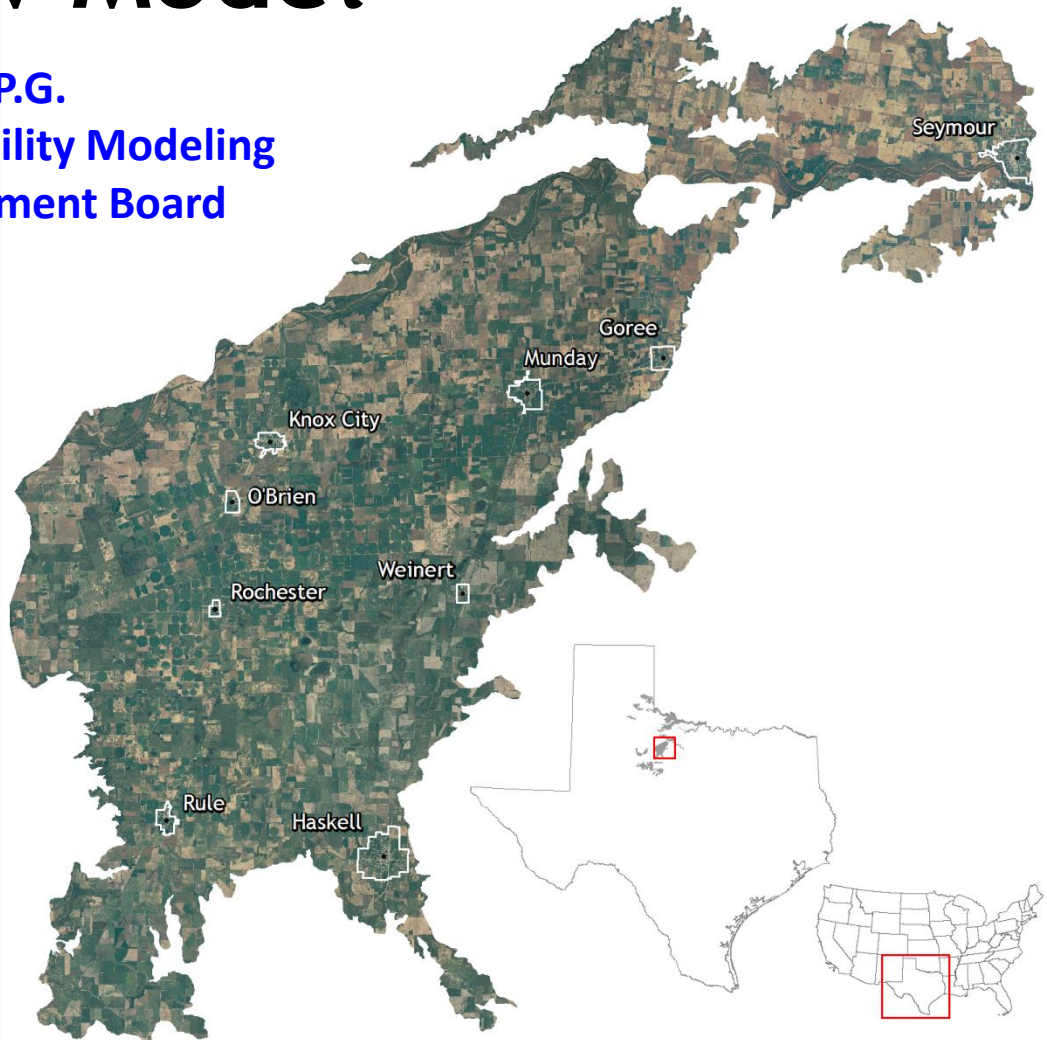

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What is a Conceptual Model?

- The conceptual model is a simplified version of the more complex “real world” that can be handled using a mathematical model.
- Relevant processes and physical elements controlling groundwater flow in the system are identified and quantified (geology, hydraulic properties, water levels, pumping, recharge, etc.)

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Conceptual Flow Model

- The conceptual model for the refined Seymour Aquifer groundwater availability model for Haskell, Knox, and Baylor counties was developed by INTERA Inc. under contract to the TWDB.
- http://www.twdb.texas.gov/groundwater/models/gam/symr_hkb/symr_hkb.asp

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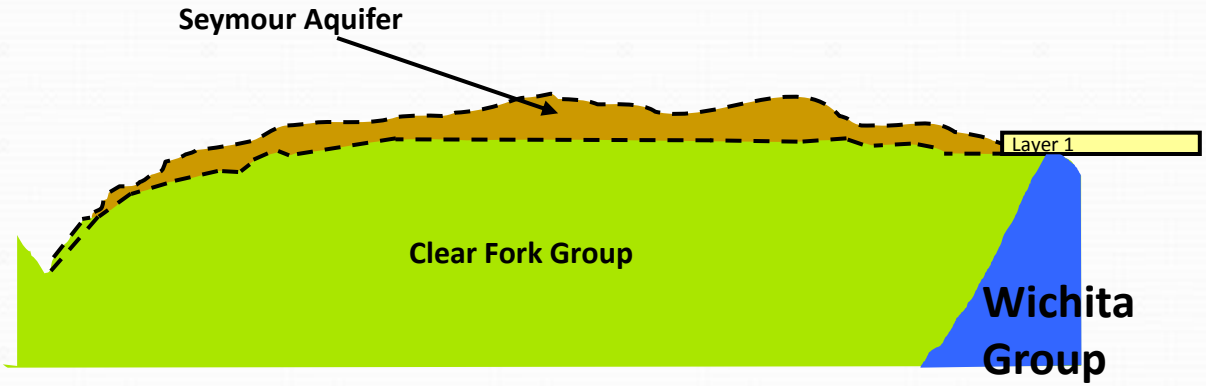
Generalized Geologic Cross-Section



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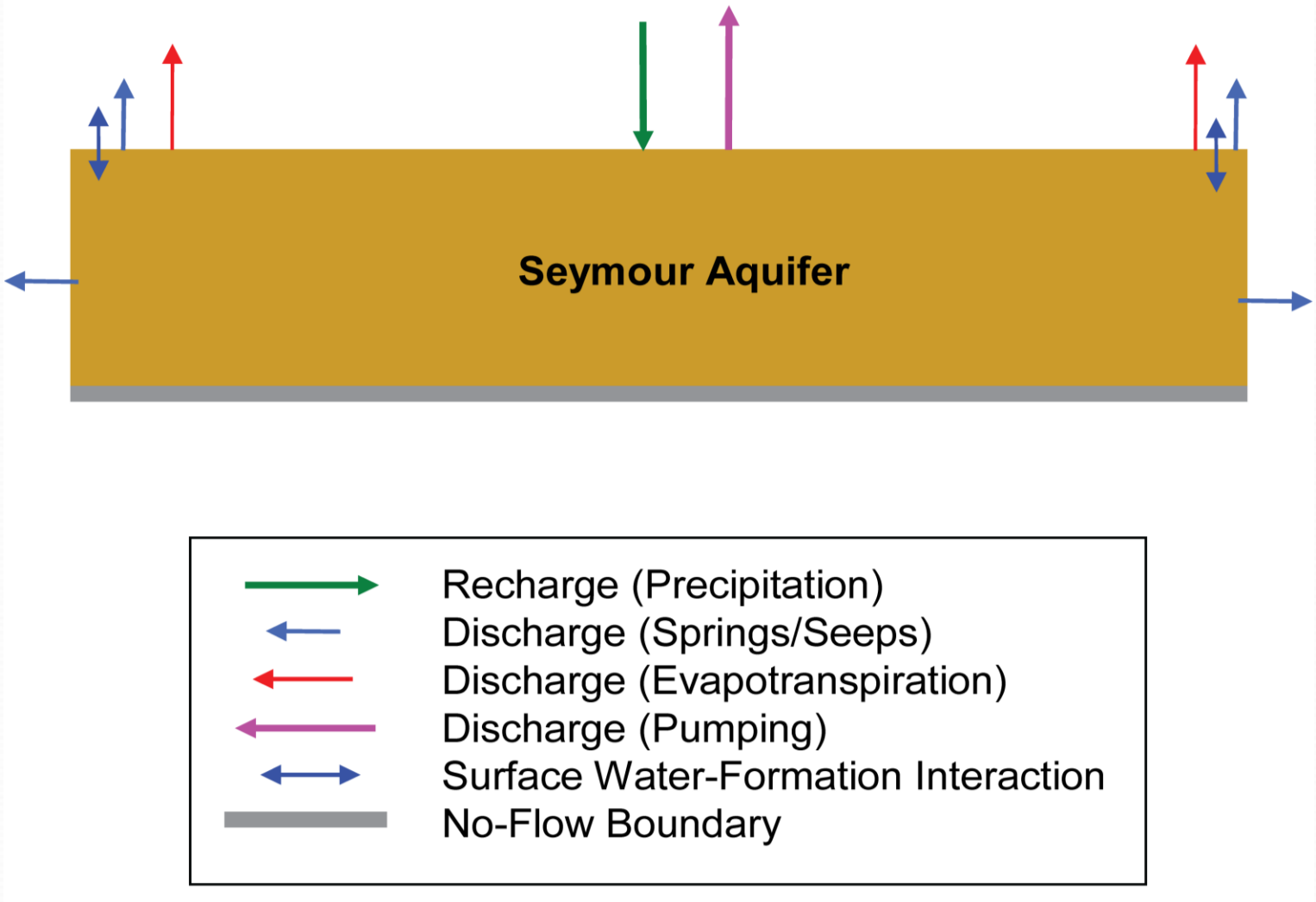
Modified Conceptual Model Diagram



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Modifications to Conceptual Model

- During the development of the refined numerical flow model, some of the model design presented in the conceptual model report (Jones and others, 2012) was revised.
- Direct connection to the Brazos River was excluded from the numerical model on the western border. In the numerical model, water from the Seymour discharges through drains along the western boundary which simulates discharge to the Permian units between the Brazos River and the Seymour Aquifer.
- The only direct connection to the Brazos River is modeled with the river package between the two Seymour islands in Baylor County and a small part of Knox County.

Modifications to Conceptual Model

- Pumping estimates from the conceptual model report were revised during model calibration.
- Recharge zones were revised and an annual dampening factor was applied to reduce the effect of annual variation of precipitation on recharge.
- Irrigation return flow equal to from 5 to 20 percent of irrigation pumping was included in the recharge input file.
- Connection to the underlying Permian Units was deemed to be insignificant and the base of the Seymour is now modeled as a no-flow boundary.

Numerical Groundwater Flow Model

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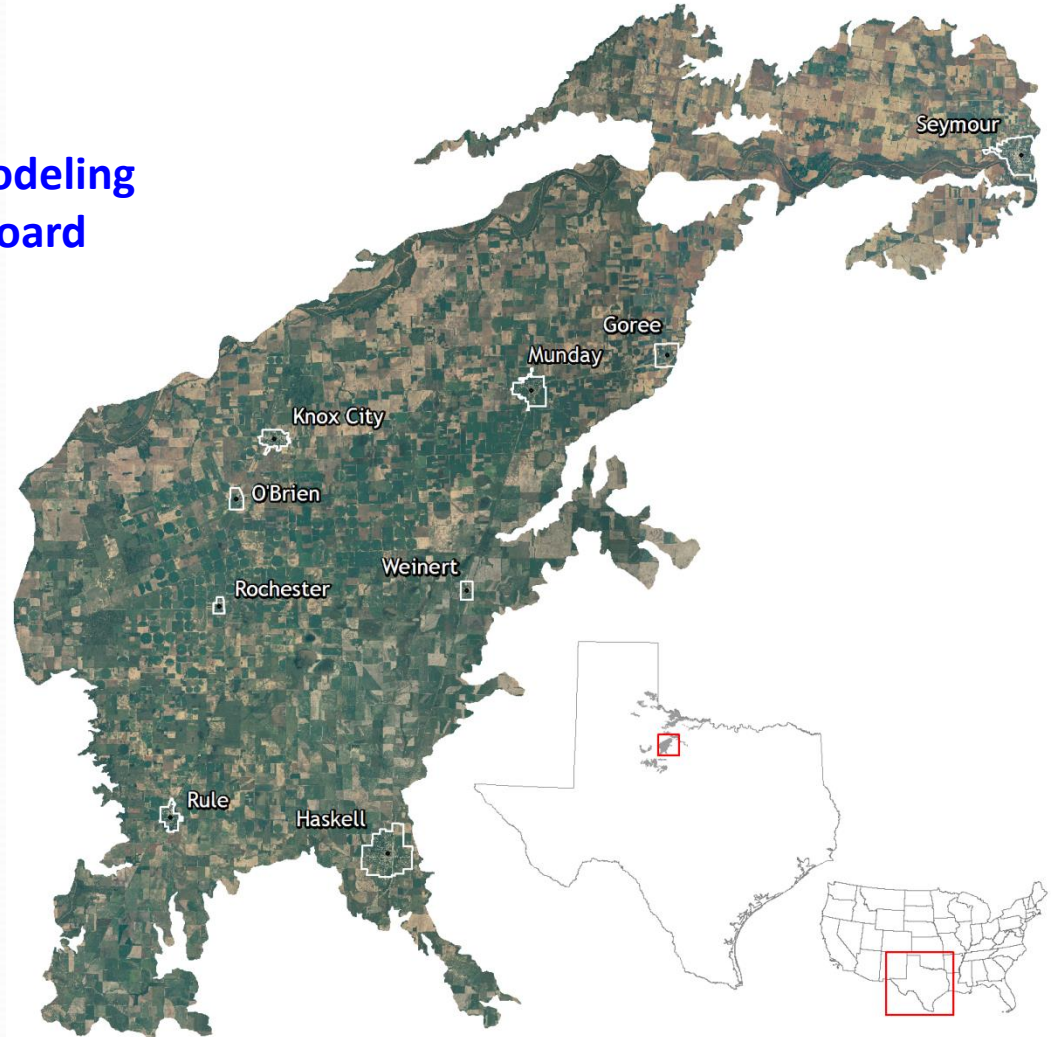

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What is a Numerical Model?

- A computer code used to solve the groundwater flow equations numerically

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Seymour Numerical Model

- MODFLOW-2000 from United States Geological Survey
- One numerical layer representing Seymour Aquifer

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Seymour Numerical Model (cont.)

- The model runs from 1950 to 2005
- Annual stress periods run from 1950 to 1979
- Monthly stress periods run from 1980 to 2005

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Seymour Numerical Model (cont.)

- Grids contains 249 uniform rows and 470 uniform columns, both with an interval of 660 feet
- Grids rotated clockwise for 47 degrees to be consistent with dominant groundwater flow directions

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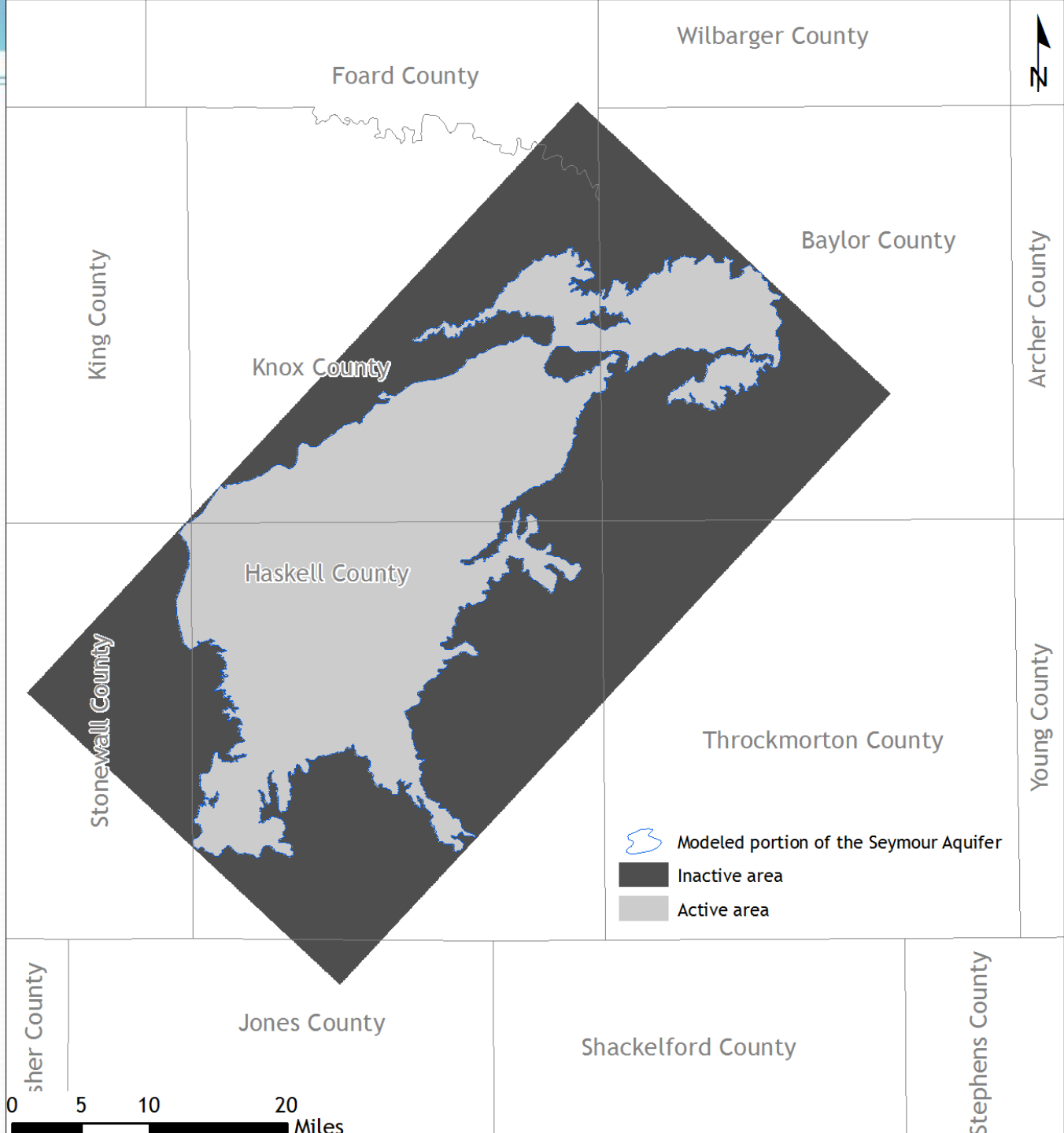
MODFLOW-2000 Packages

Packages	Input Files
Basic (BAS6)	symr_hkb.bas
Discretization (DIS)	symr_hkb.dis
Layer-Property Flow (LPF)	symr_hkb.lpf
Well (WEL)	symr_hkb.wel
Drain (DRN)	symr_hkb.drn
River (RIV)	symr_hkb.riv
Recharge (RCH)	symr_hkb.rch
Output Control (OC)	symr_hkb.oc
Geometric Multigrid Solver (GMG)	symr_hkb.gmg

Modeled Area



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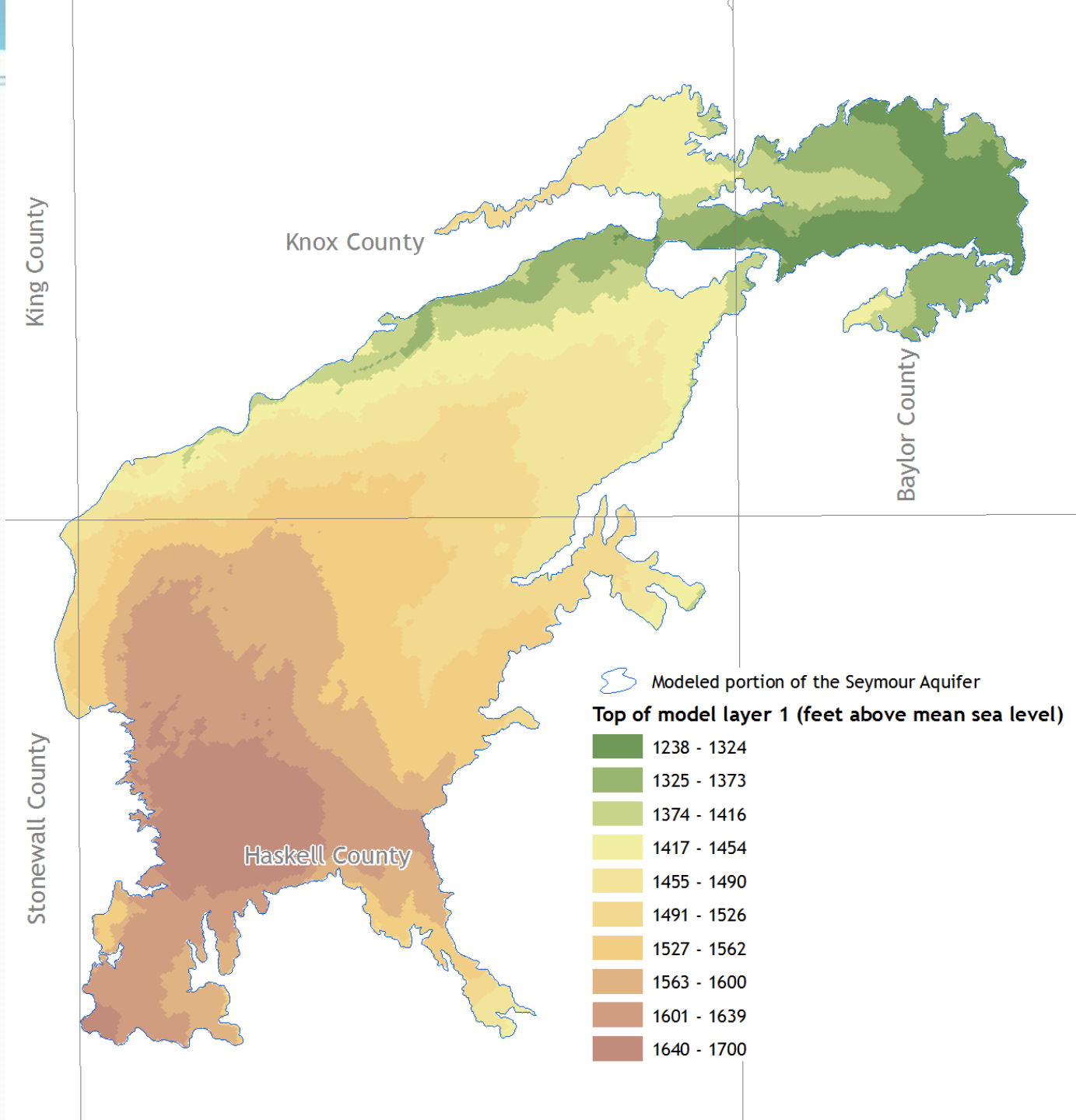
Aquifer top defined by U.S.G.S. digital elevation model (DEM)



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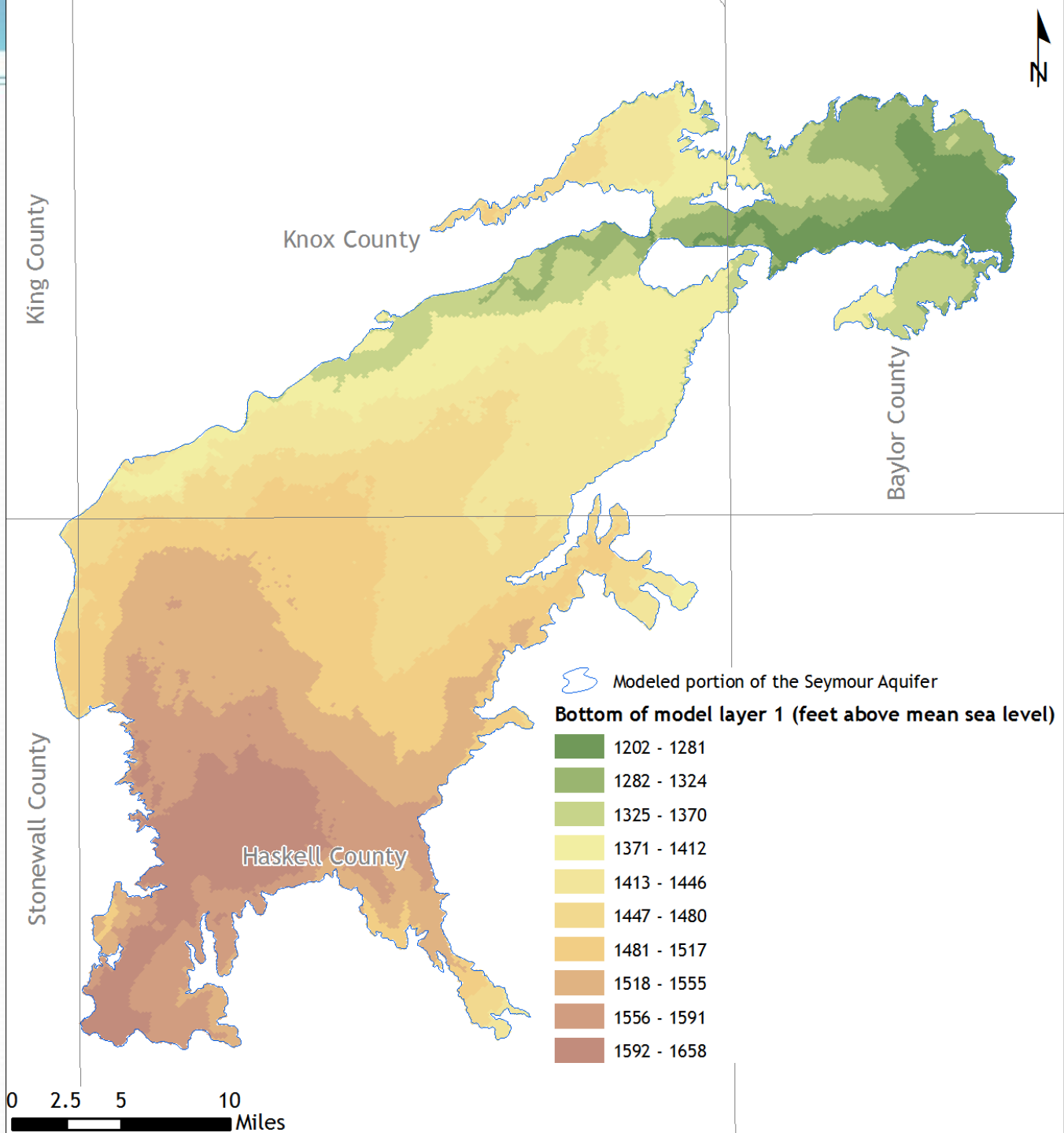
Aquifer bottom defined by well logs



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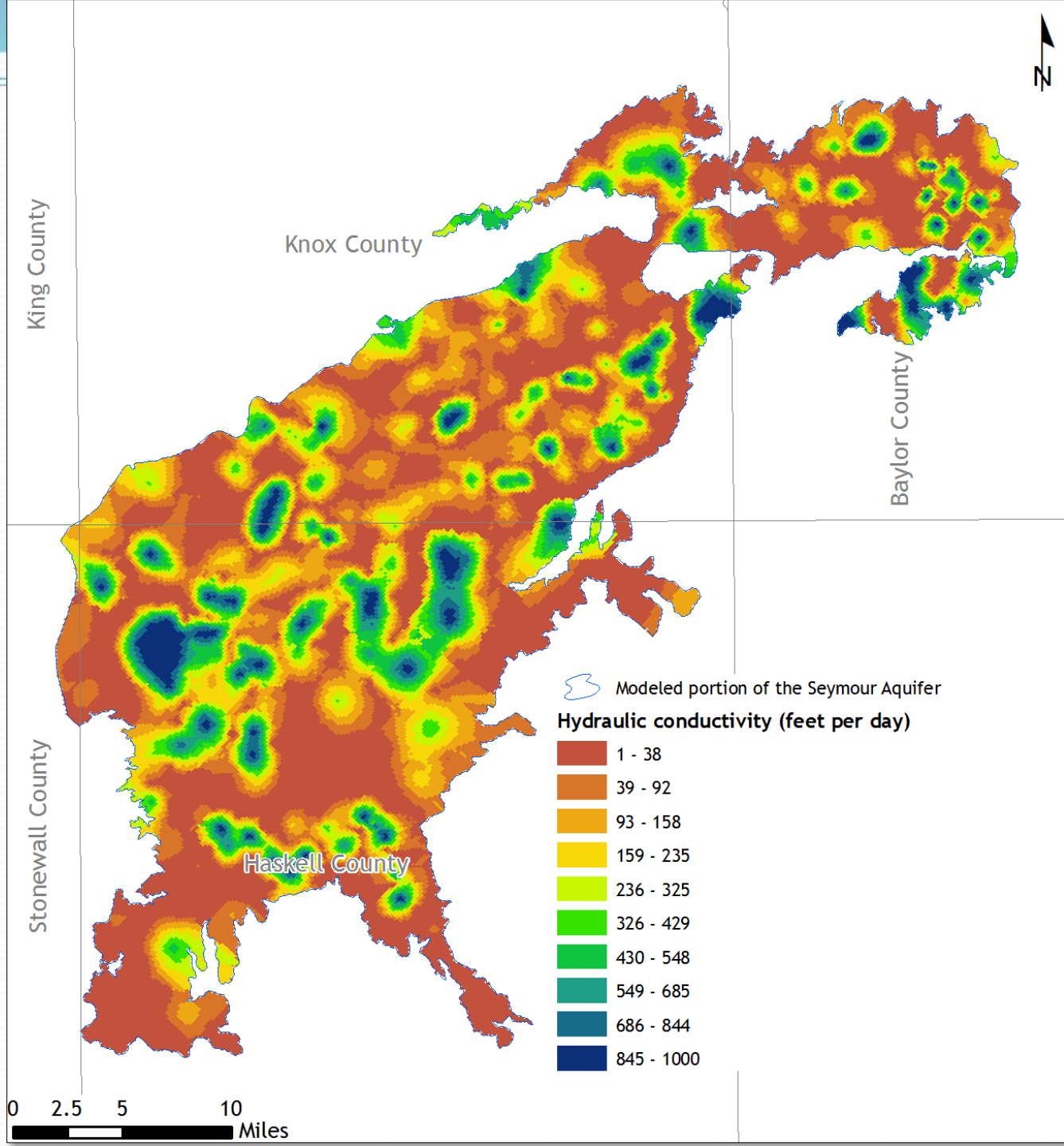
Aquifer horizontal hydraulic conductivity along southwest-northeast direction



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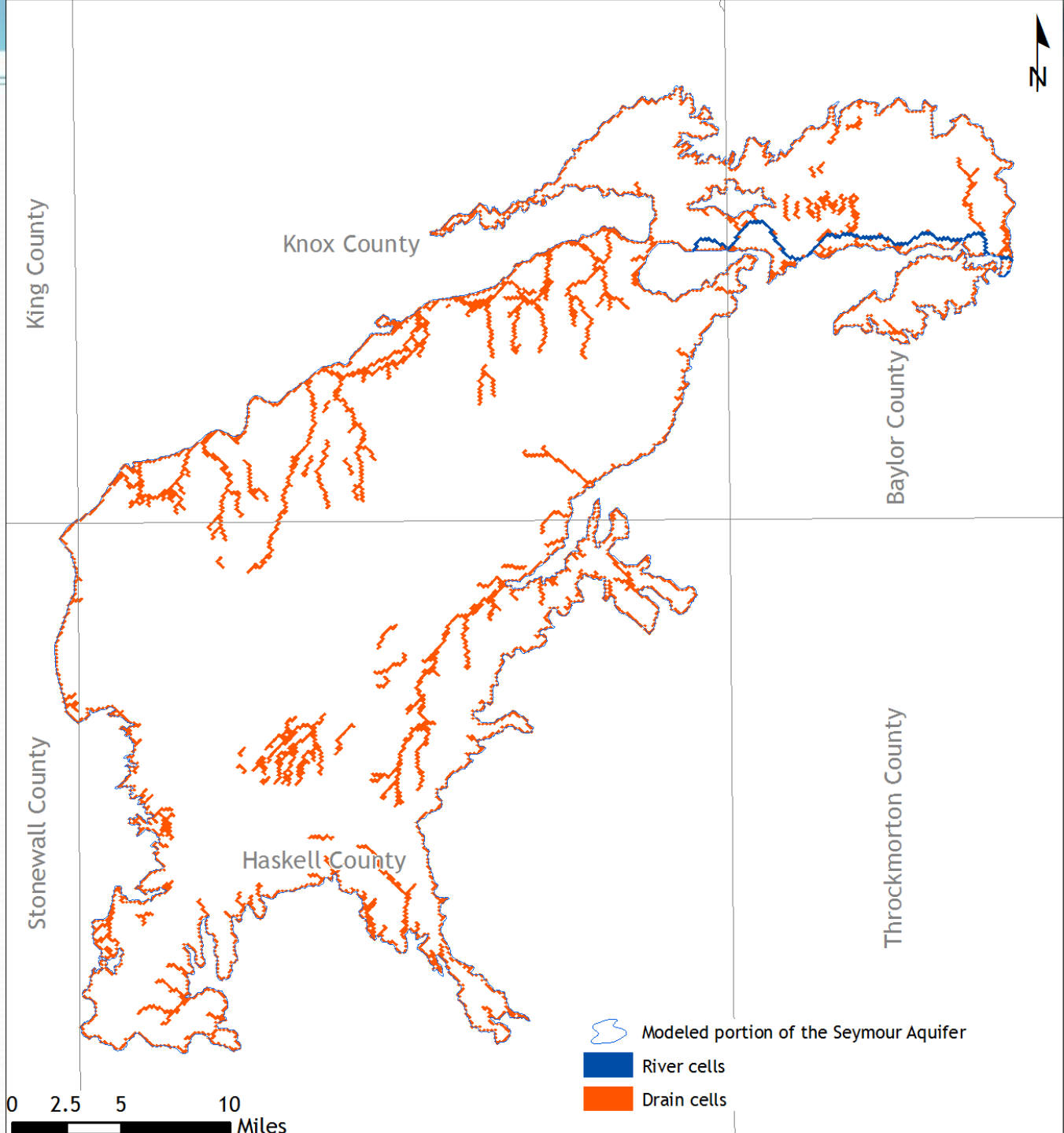
Surface water bodies



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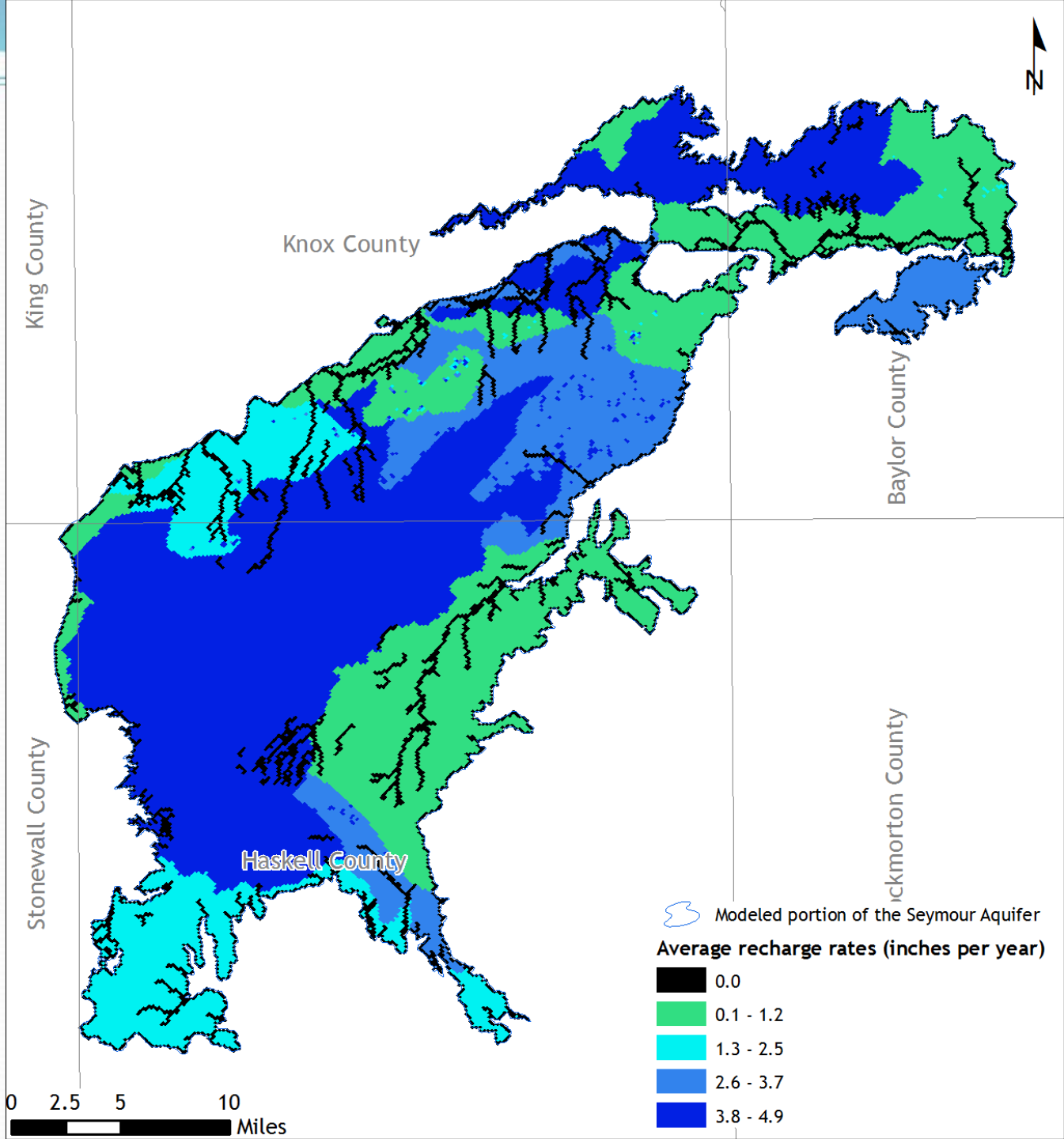
Average total recharge



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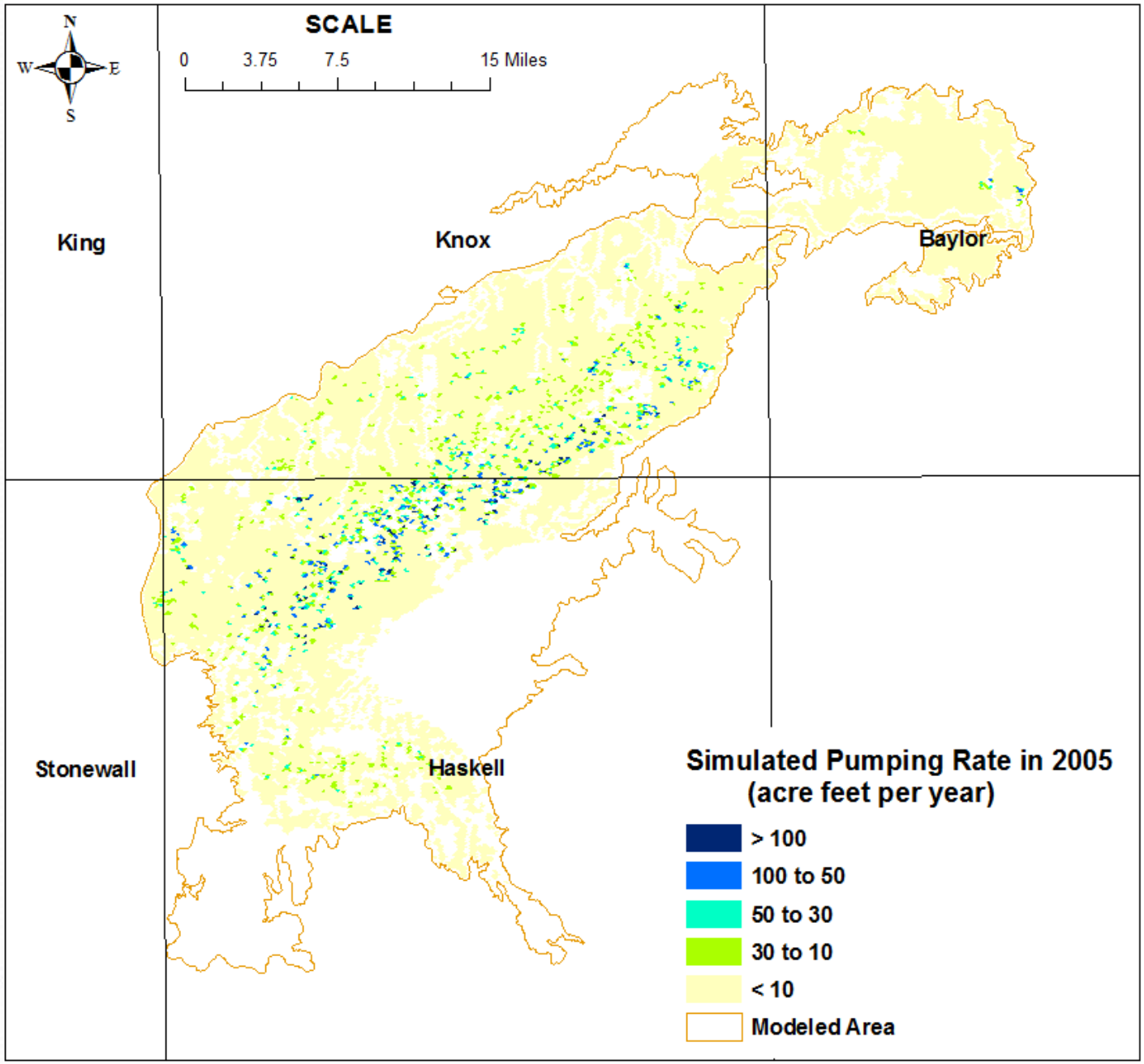
Pumping Rate in 2005



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Model Calibration

- 2,949 measured water levels
- Observed groundwater flow patterns
- One measured river flow (Preston, 1978)
- Calibration aided by parameter estimate program: PEST/BeoPEST (Schreuder, 2009)

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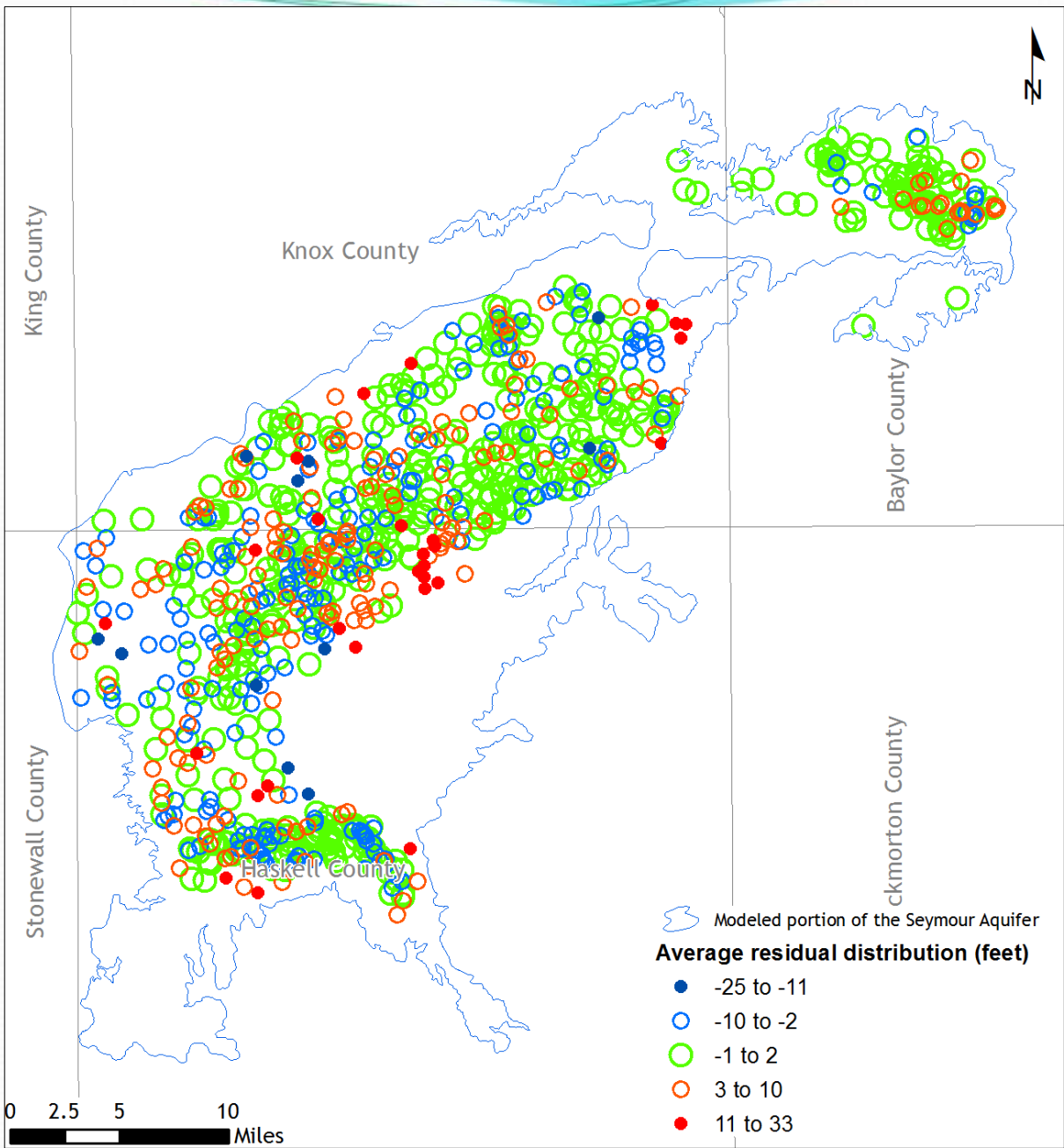
Model Calibration Result: Water Level

Spatial distribution of average water-level residuals (i.e. observed – simulated)



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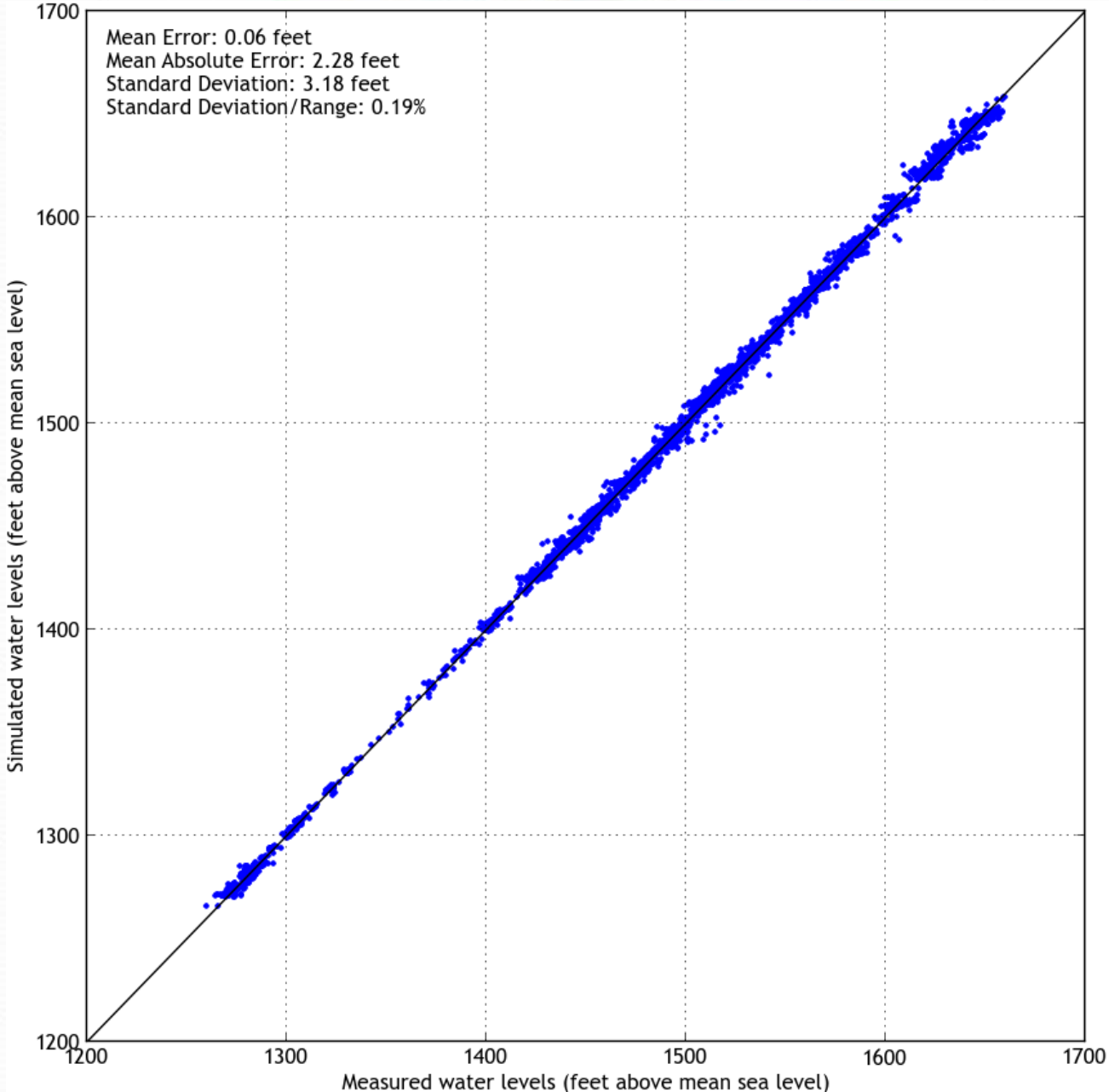
Model Calibration Result: Water Level

Simulated versus observed water levels (solid line represents perfect match)



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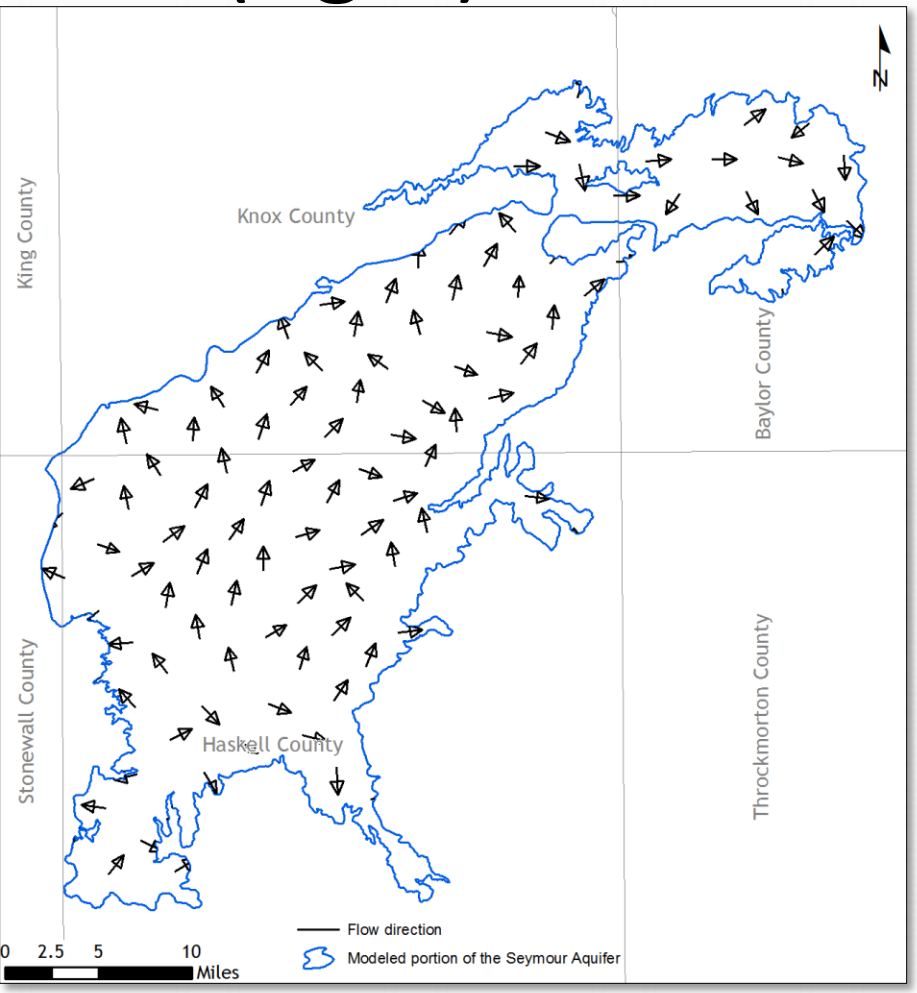
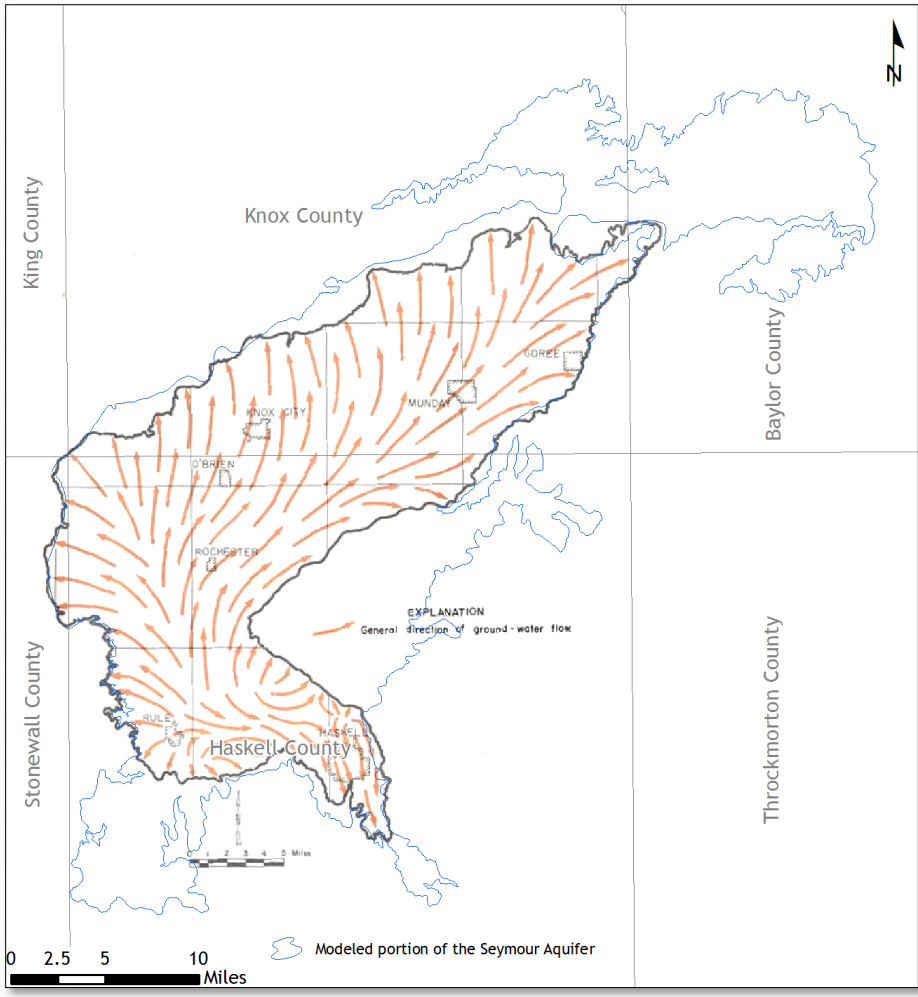
Simulated (left) versus Observed (right) Groundwater Flow Patterns





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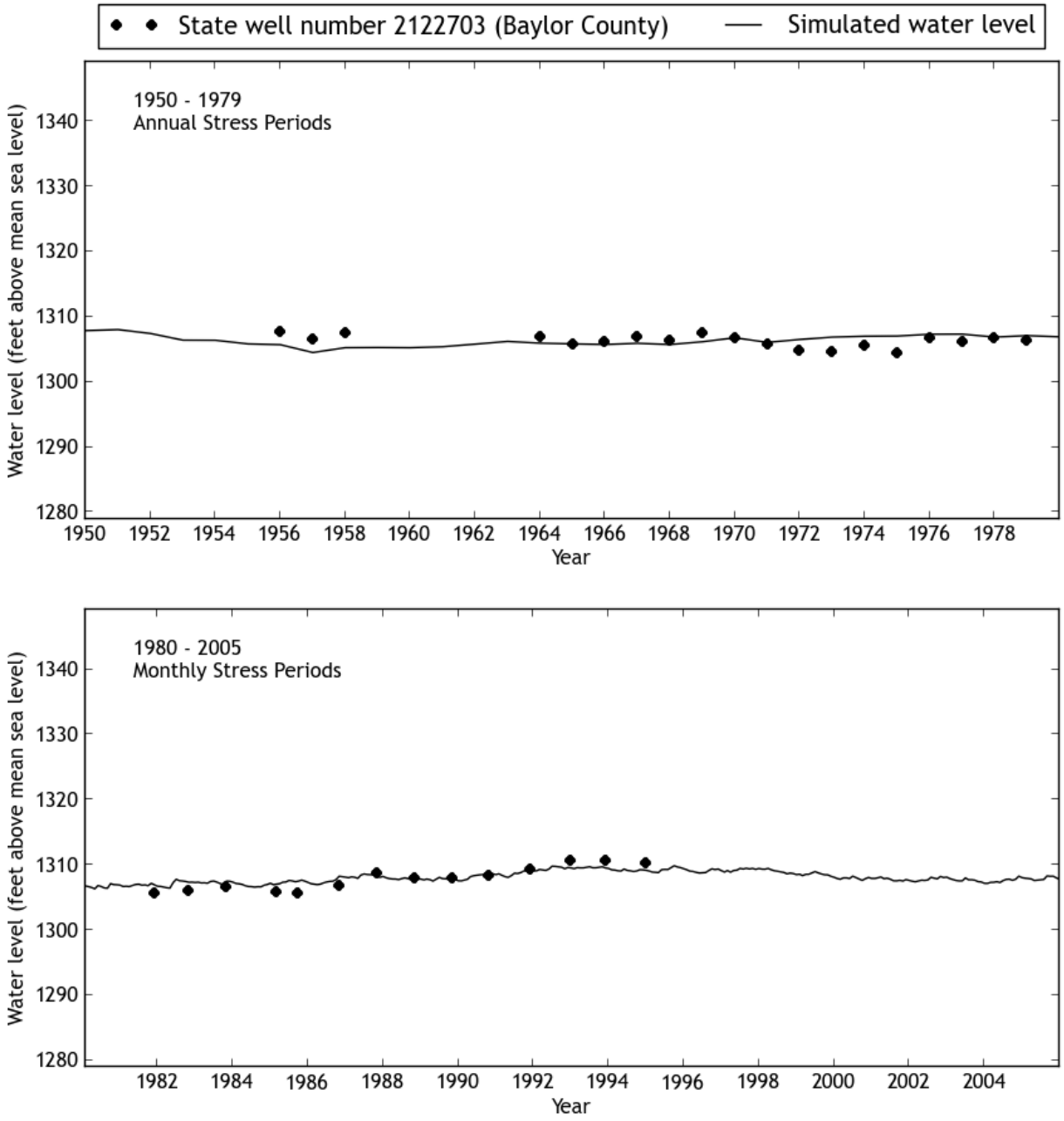
Example Simulated versus Observed Hydrograph (Baylor County)



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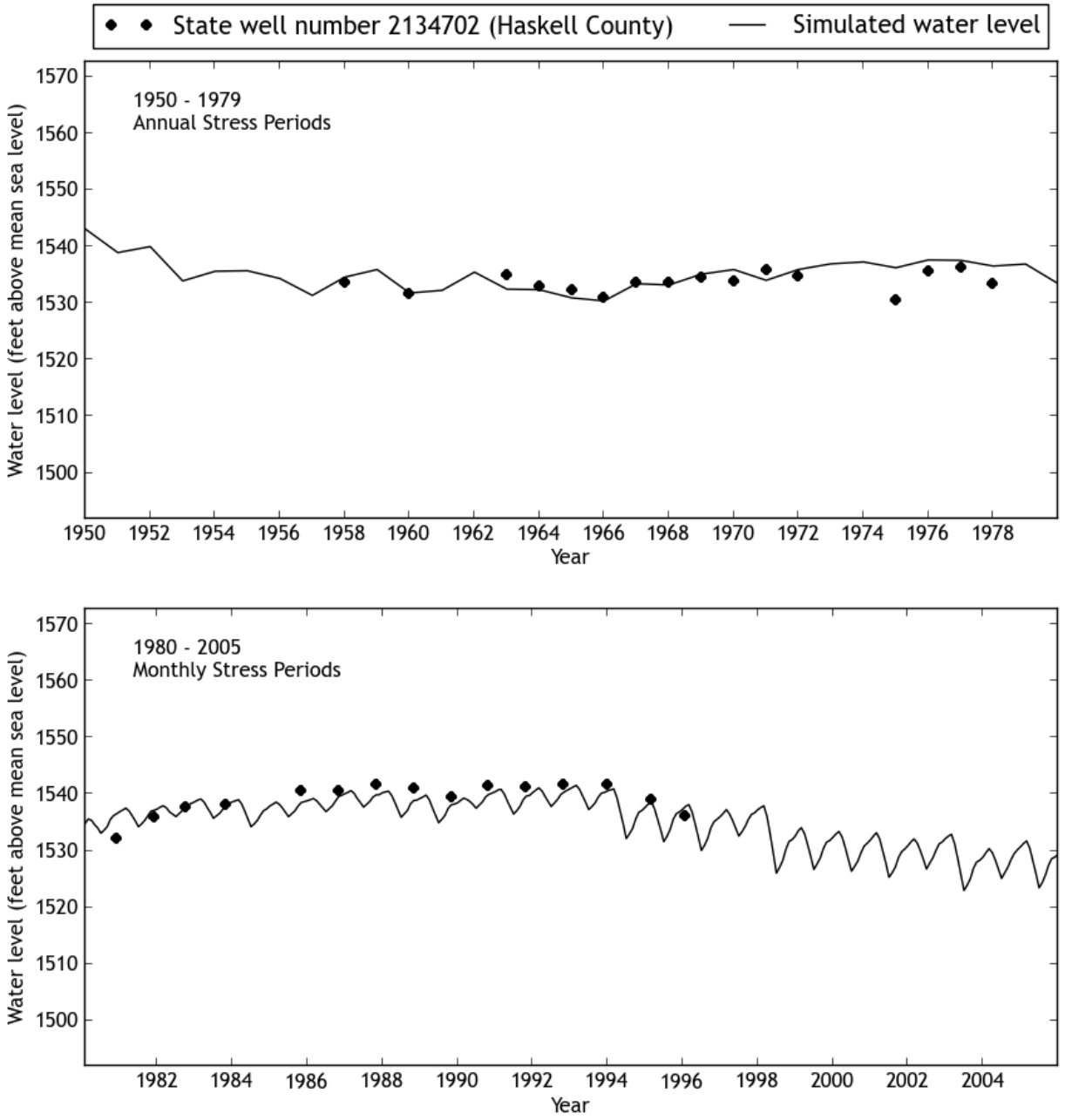
Example Simulated versus Observed Hydrograph (Haskell County)



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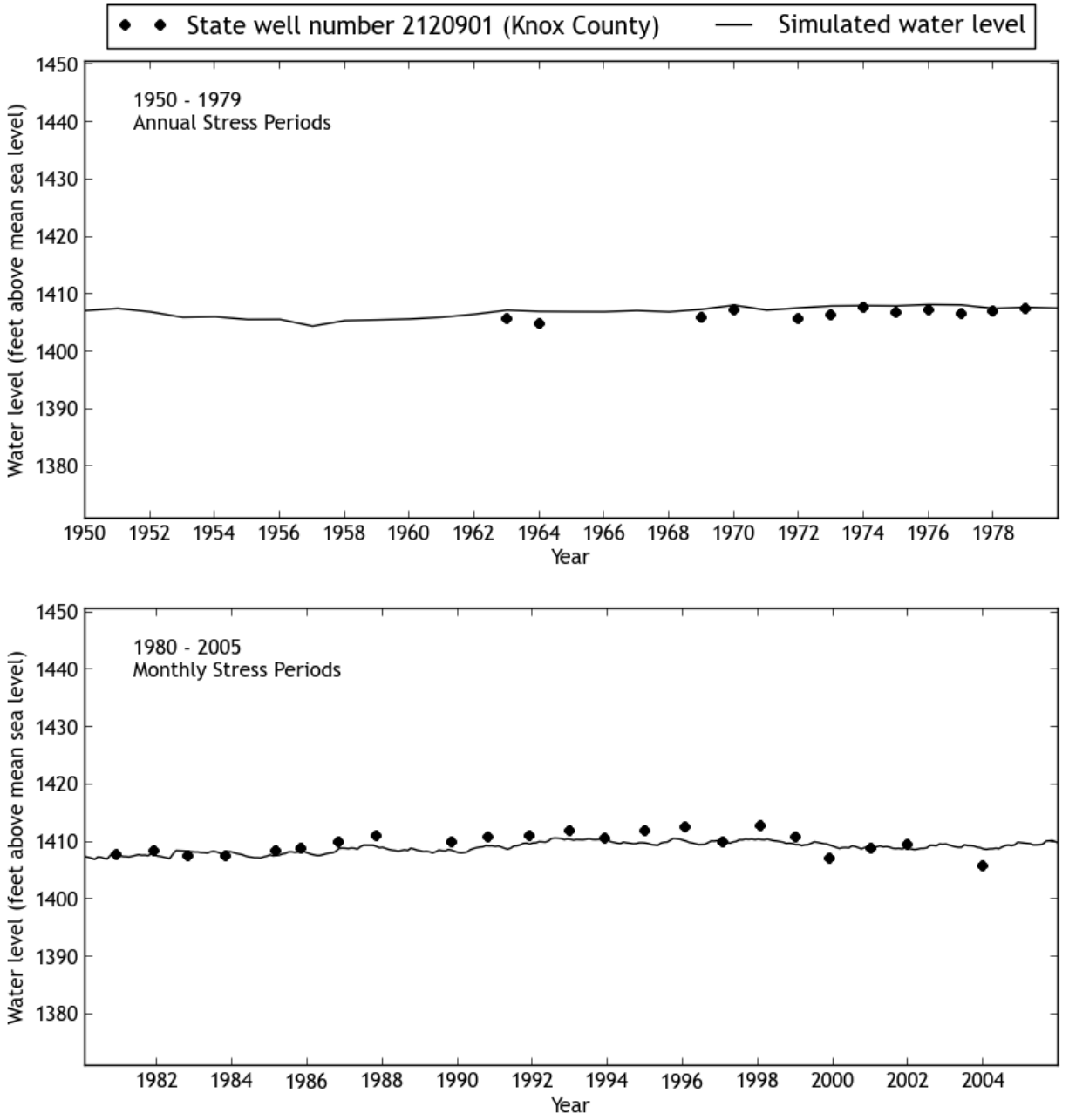
Example Simulated versus Observed Hydrograph (Knox County)



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Simulated versus Measured Base Flow at Brazos River

- One-time measurement collected in February 1970 (Preston, 1978)
- Total base flow was ~ 3,000 acre-feet per year
- Calibrated model produced average base flow ~3,000 acre-feet per year

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Total Average Groundwater Budget (acre-feet per year)

Flow Components		1950 - 1979	1980 - 2005	1950 - 2005
Inflow	Recharge	103,573	106,951	105,141
	Total Inflow	103,573	106,951	105,141
Outflow	Wells	53,805	50,929	52,470
	Drains	57,646	59,195	58,365
	River Leakage	3,169	3,198	3,183
	Total Outflow	114,620	113,322	114,018
Inflow - Outflow		-11,047	-6,371	-8,877
Storage Change		-11,048	-6,369	-8,875
Model Error		1	-2	-2
Model Error (percent)		0.00%	0.00%	0.00%

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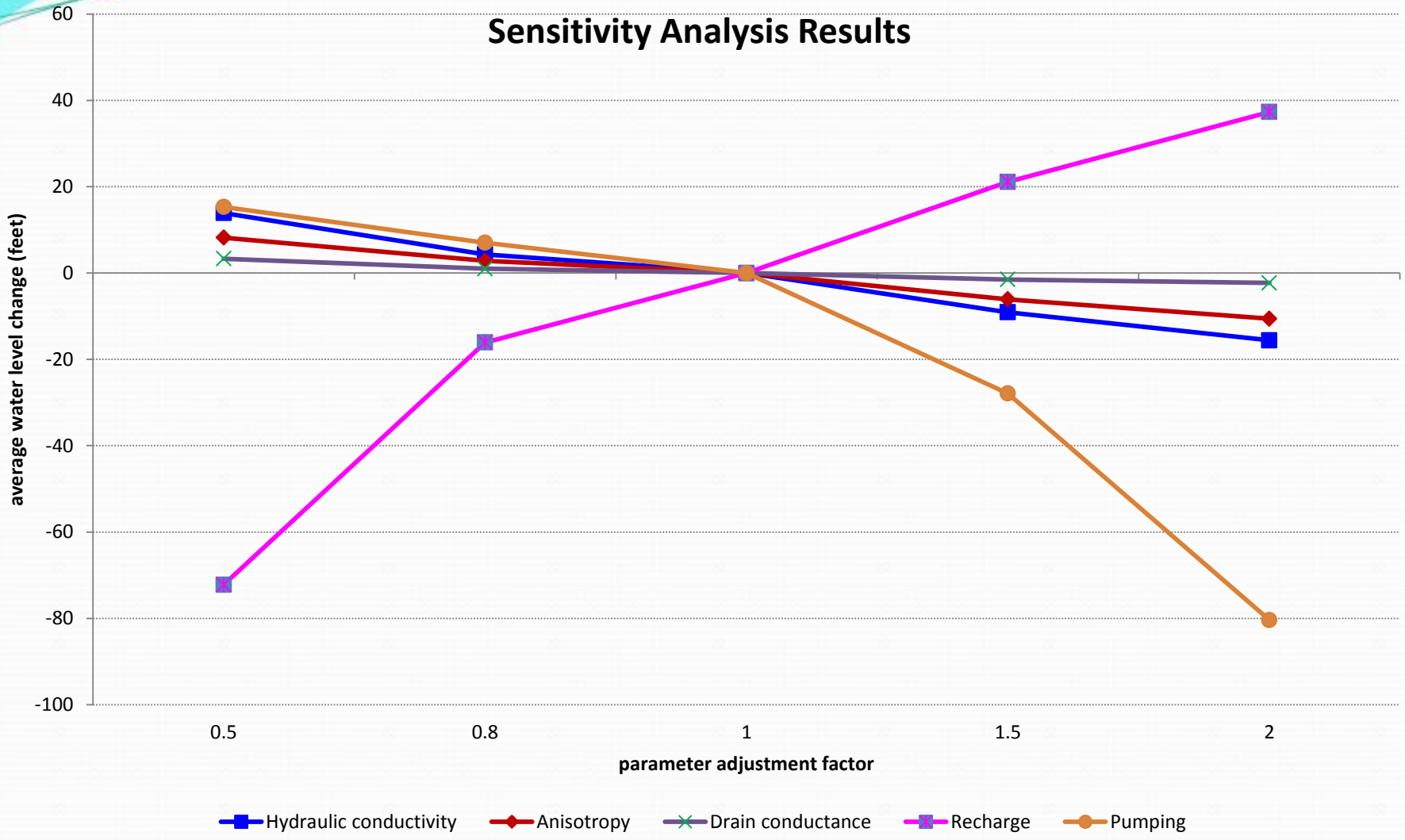
Sensitivity Analysis



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Model Limitations

- Regional model is not intended for local-scale issues such as evaluating well spacing or drawdown at specific wells
- TWDB developed certain preliminary tools that can help on this:

http://www.twdb.texas.gov/groundwater/models/analytical/index.asp

- Limited data and uncertainty such as aquifer properties and seepage/spring flows

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Acknowledgements

- Marius Jigmond led the development of the numerical groundwater flow model
- Bill Hutchison provided supervising role and co-authored the numerical groundwater flow model report
- Mike McGuire/Rolling Plains Groundwater Conservation District for providing data

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Acknowledgements

- Toya Jones, John Ewing, Neil Deeds, Tingting Yan, and John Pickens of INTERA, Bridget Scanlon and Jeff Olyphant of Bureau of Economic Geology of University of Texas, and Andrew Chastain-Howley of Water Prospecting Resource Consultants, for developing the conceptual groundwater flow model and conceptual groundwater flow model report
- John Doherty and W.A. Schreuder for providing parameter estimate programs: PEST and BeoPEST
- Van Kelley and Toya Jones of INTERA for numerical model report review

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Draft Review

- The model and report are available for a 30-day review period until February 10, 2014
- The report can be found here:

http://www.twdb.texas.gov/groundwater/models/gam/symr_hkb/symr_hkb.asp

- Model files are available upon request
- The final model will be distributed after comments are addressed in Spring 2014

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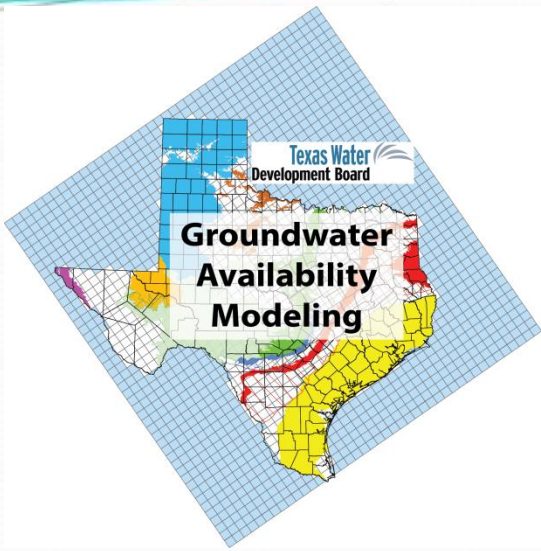
Contact Information



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http://www.twdb.texas.gov/groundwater/models/gam/

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Stakeholder Advisory Forum 3
Refined Seymour Aquifer
Groundwater Availability Model
for Haskell, Knox, and Baylor Counties
January 29, 2014 Attendance

Name	Affiliation
Amy Crowell	Mesquite Groundwater Conservation District
Ray Brady	RMBJ Geo
Jack Campsey	Gateway Groundwater Conservation District
Travis Floyd	Knox County
Wallace Emerson	Haskell County
David Davis	Haskell County
Rima Petrossian	TWDB
Sam Fare	West Central Texas Municipal Water District
Mike McGuire	Rolling Plains Groundwater Conservation District
David Kuehler	North Central Texas Municipal Water Authority
Shirley Wade	TWDB
Jerry Shi	TWDB

Questions and Answers

Q: Does TWDB have a schedule for creating refined models for other Seymour pods?

A: It is not a high priority right now, but we may create other refined models at some point in the future.

Q: What is the resolution of the refined model?

A: Model cells are 660 feet square (1/8 mile) as opposed to 1 mile square for the original groundwater availability model for the Seymour Aquifer.

Q: (Referring to the map of horizontal hydraulic conductivity in the model) for the bulls eye high values of conductivity surrounded by low conductivity areas – where does the water go?

A: Hydraulic conductivity values based on specific capacity tests and driller logs both indicated that the Seymour Aquifer is highly heterogeneous. It is expected more groundwater flows along the high conductivity zone(s). The high conductivity zones at the middle portion of the aquifer had more pumping. Also, Mike McGuire of Rolling Plains GCD noted that the largest area of high conductivity corresponds to recharge zones on the flow map.

Q: What were observed flow patterns based on?

A: Measured water level data.

Q: How many wells were used to calibrate the model?

A: About 3,000 water level observations were used.

Q: What data sources were used for the model?

A: Well logs and water levels from Richard Preston's 1970's study. Water levels starting in the early 1980s were collected by Rolling Plains Groundwater Conservation District.

Q. What was the source of the surface elevation data used in the model. Would it be beneficial to use lidar data to get more accurate ground surface elevations for the wells for future model updates?

A: The U.S. Geological Survey Digital Elevation Model data were used for the land surface. Refining surface elevations for wells would be beneficial in the future especially to areas where the aquifer is thin.