Groundwater Availability Modeling (GAM) for the Queen City and Sparta Aquifers

Stakeholder Advisory Forum No. 5

San Antonio River Authority, Board Room
San Antonio, Texas

July 13, 2004

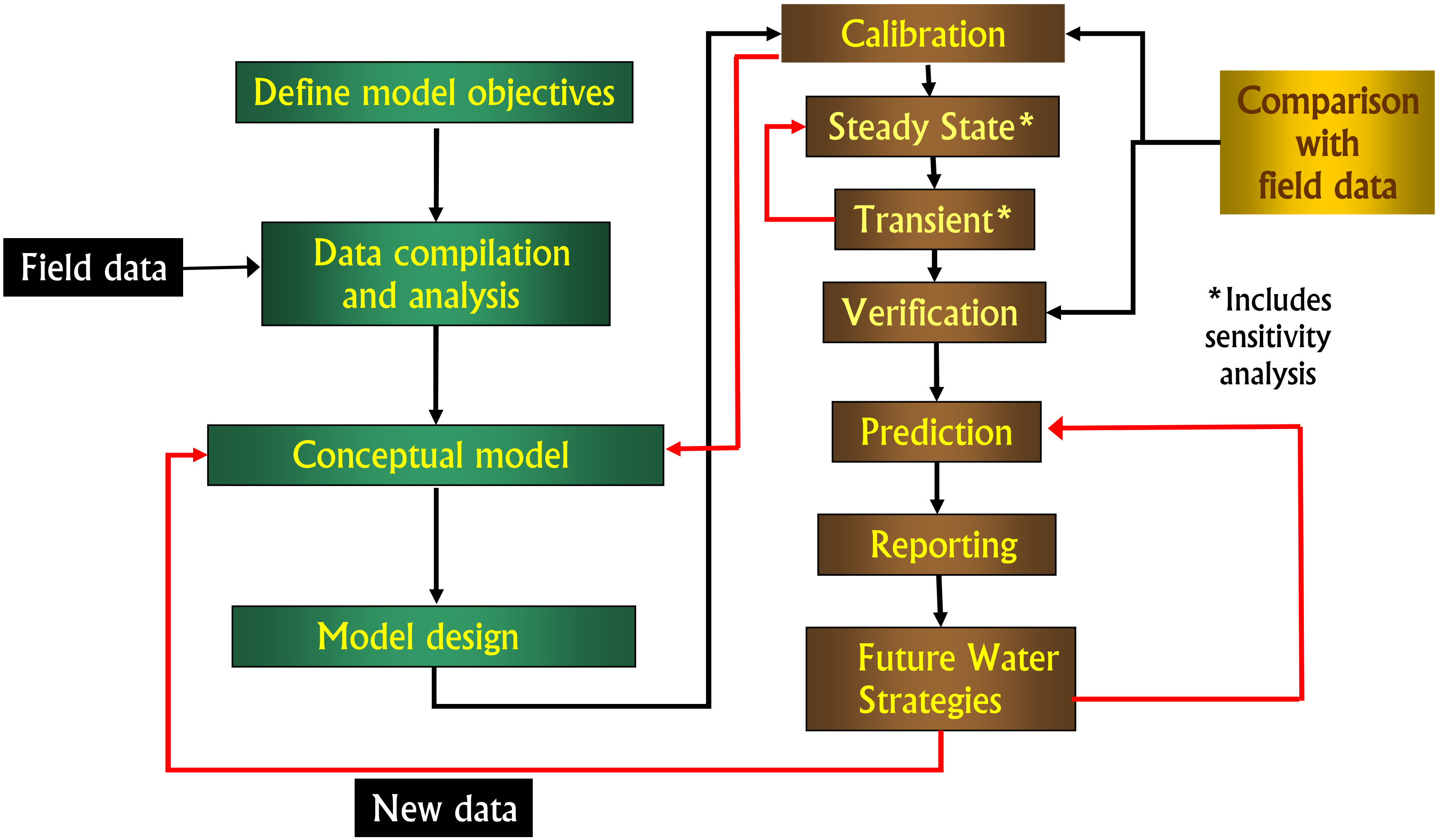
Outline of Presentation

- Introduction
- Model implementation
  - Model parameter overview
- Steady-State Model Overview
- Transient Model Results
- Model Predictions
- Schedule and Milestones
- Expectations for the next SAF

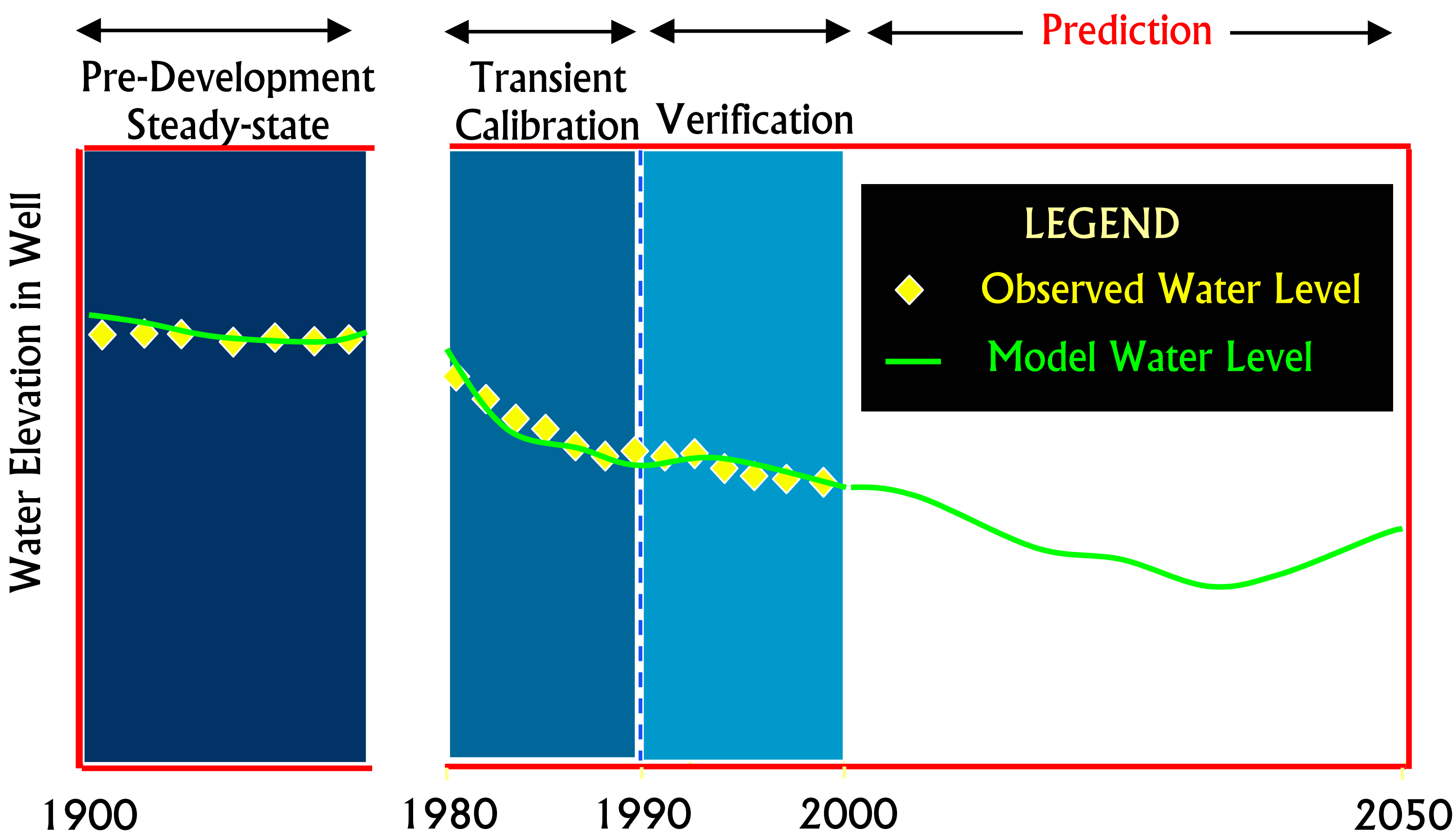
Stakeholder Advisory Forums - SAFs

- Held on 4 month schedule
- Meetings are designed to:
  - provide updates on progress
  - provide an opportunity to offer feedback
- SAF presentations and questions & responses from meetings will be posted at http://www.twdb.state.tx.us/gam/qc_sp/qc_sp.htm
- A model workshop will be held for the last meeting

Modeling Protocol



GAM Model Periods

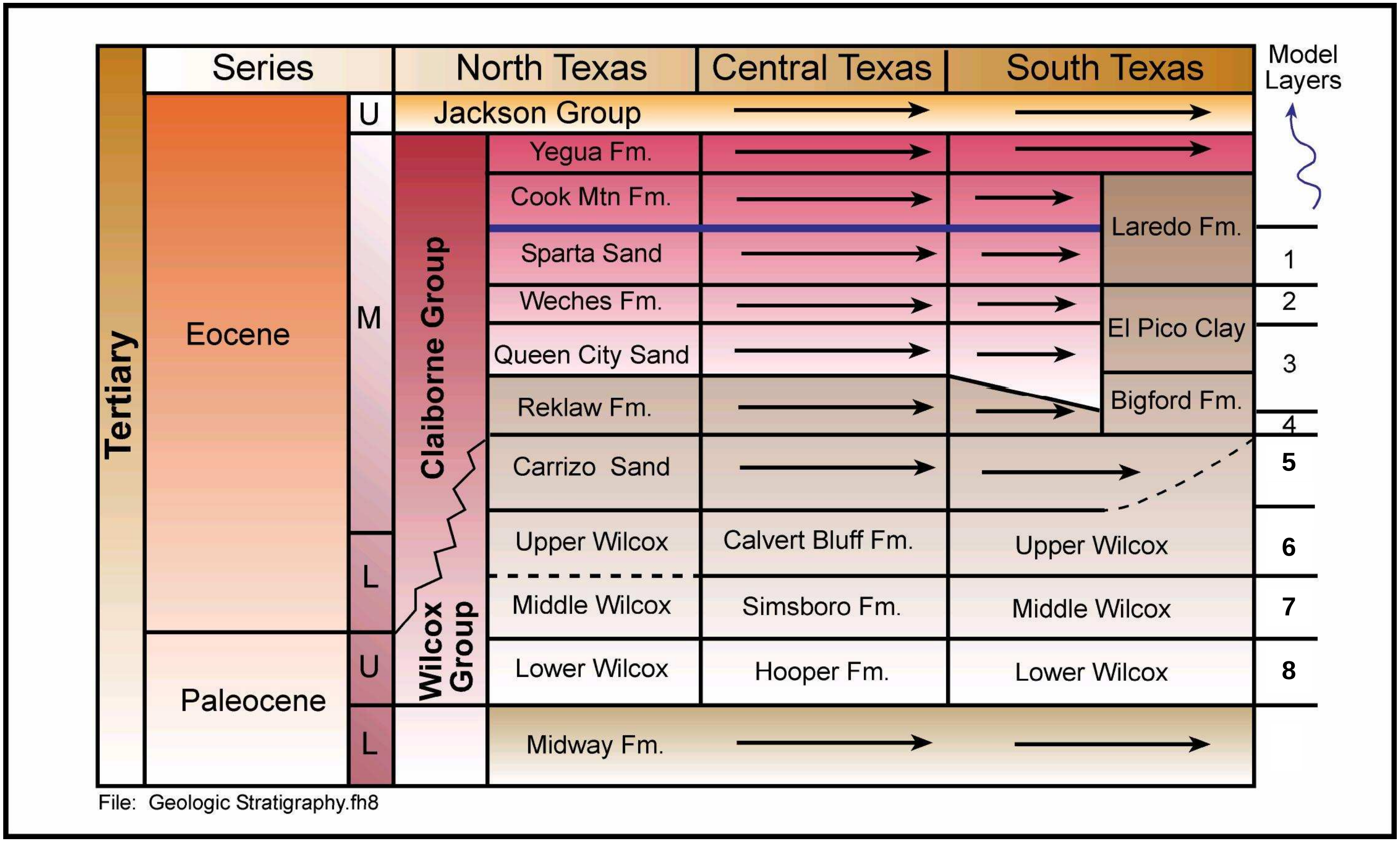


Pre-development and transient calibration periods represent different hydrologic conditions

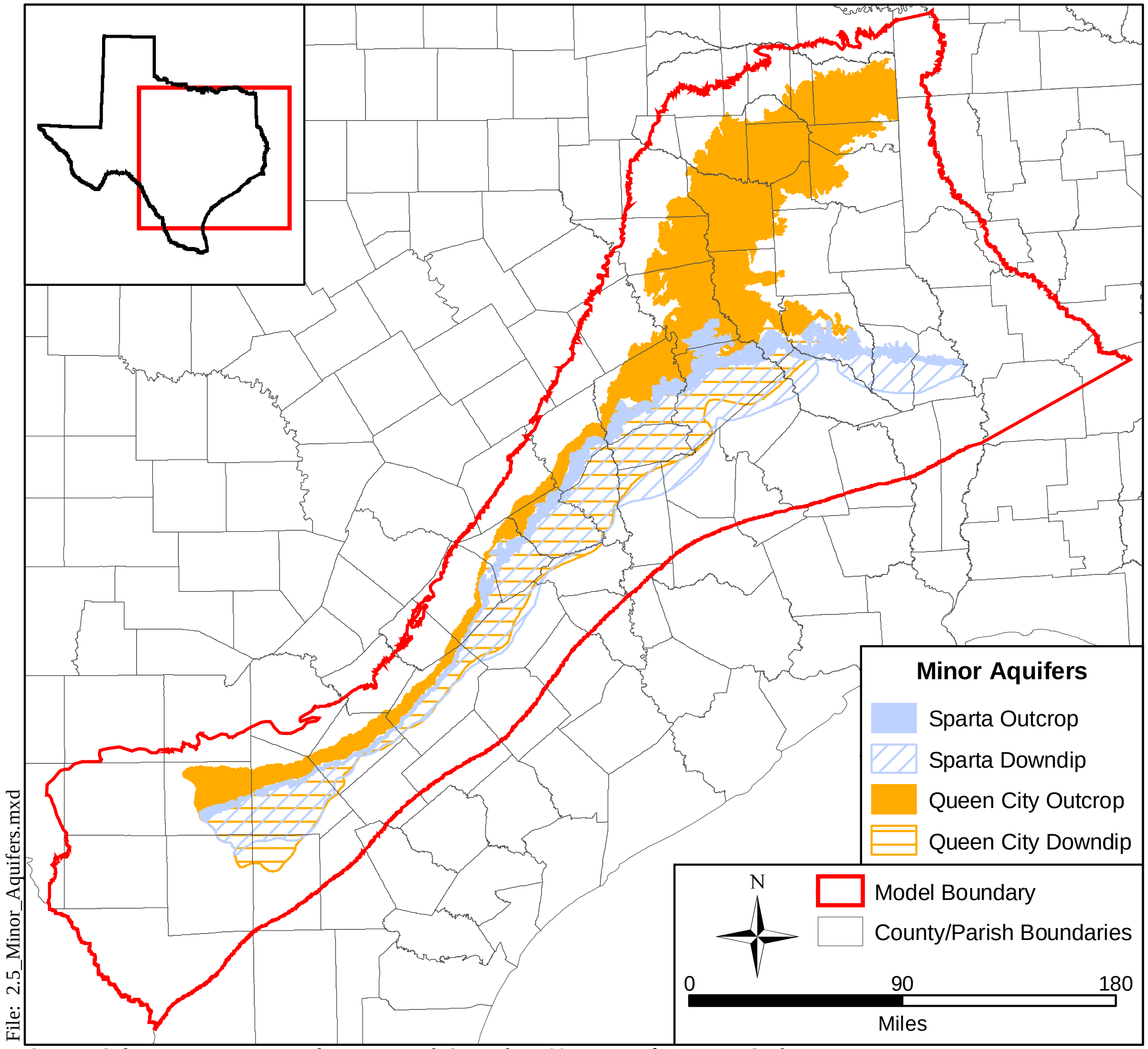
Queen City-Sparta GAM Specifications

- In addition to the generic GAM specifications, the Queen City and Sparta GAMs have additional specifications:
  - The Queen City and Sparta aquifer GAMs will be incorporated into the current Carrizo-Wilcox GAMs
  - The product will be delivered as three models (southern, central, and northern regions)
  - One modeling report will be produced

Model Stratigraphy

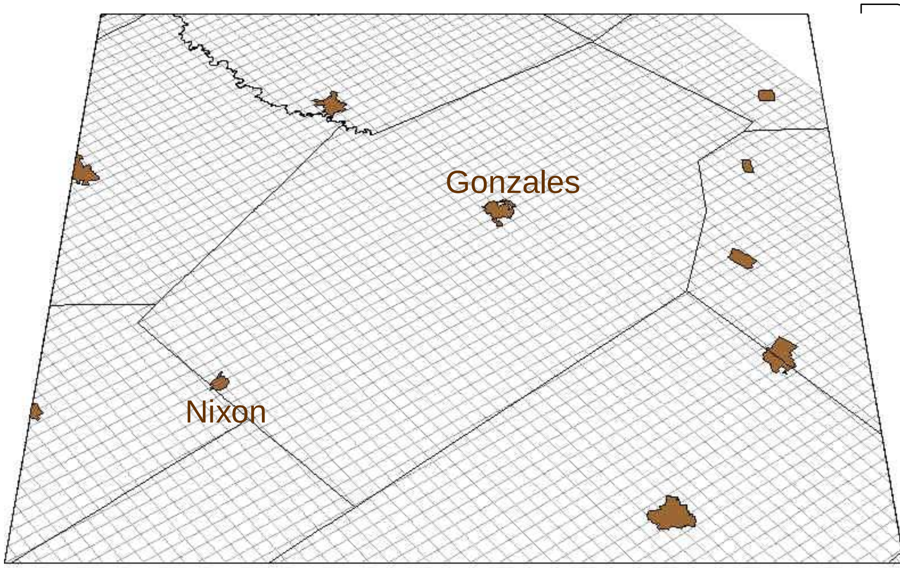


Queen City and Sparta aquifers



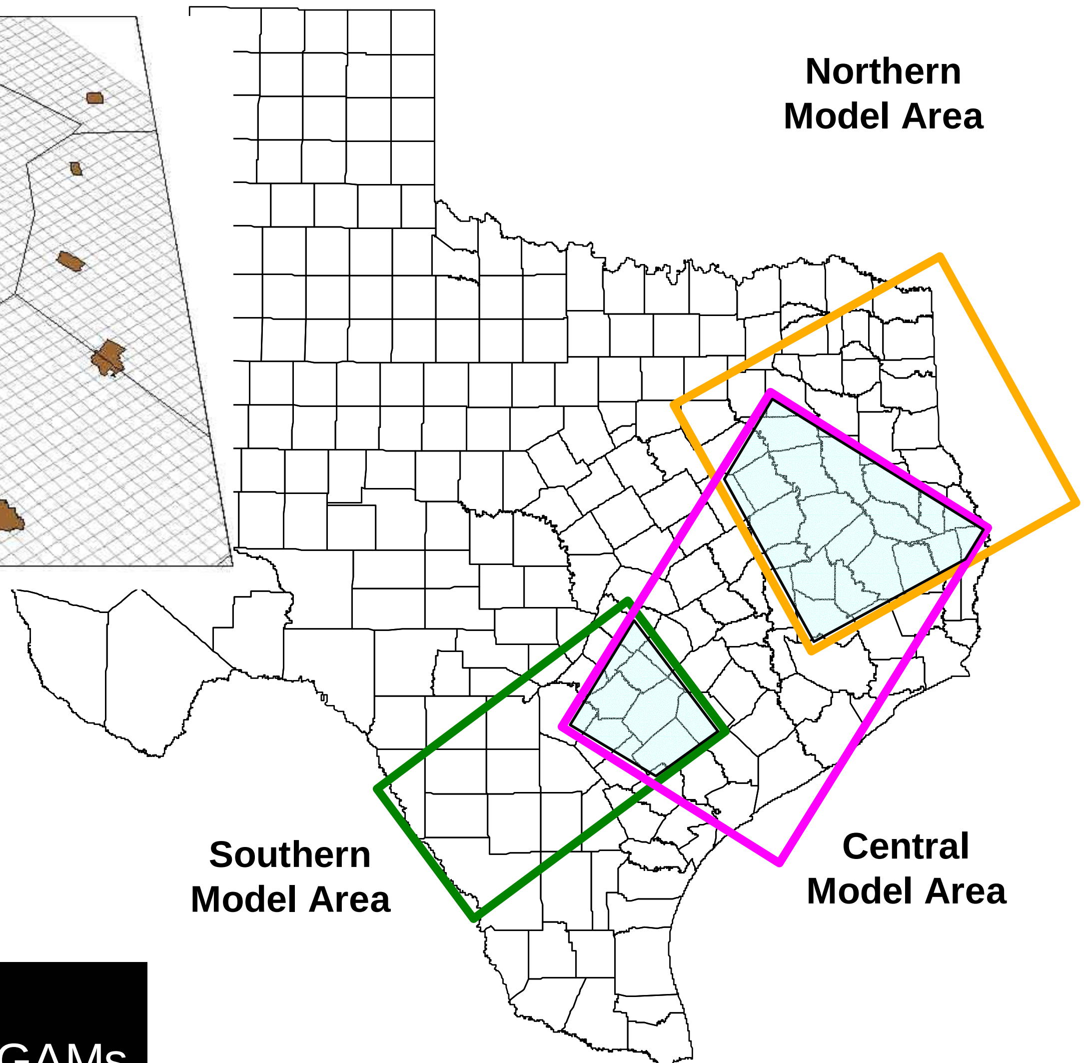
Source: Online: Texas Water Development Board, September 2002, Burea of Economic Geology

Model Domains – Same as C/W GAMs



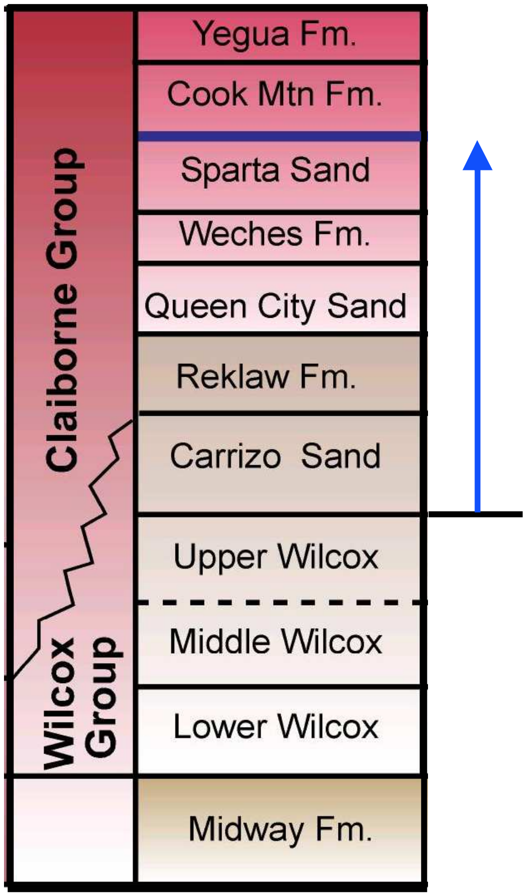
20,000 acres represents
Approximately 5 grid blocks

Grid - 1 square mile each
Same Grid as Carrizo-Wilcox GAMs



Queen City-Sparta GAM Specifications

- Original scope: Carrizo-Wilcox GAMs will be modified only as needed to properly add the Queen City and Sparta aquifers and recalibrate the entire model
- Revised scope: The Carrizo-Wilcox GAMs will be modified to be consistent in the overlap zones from the base of the Carrizo through the Sparta aquifer



Conceptual Model - Predevelopment

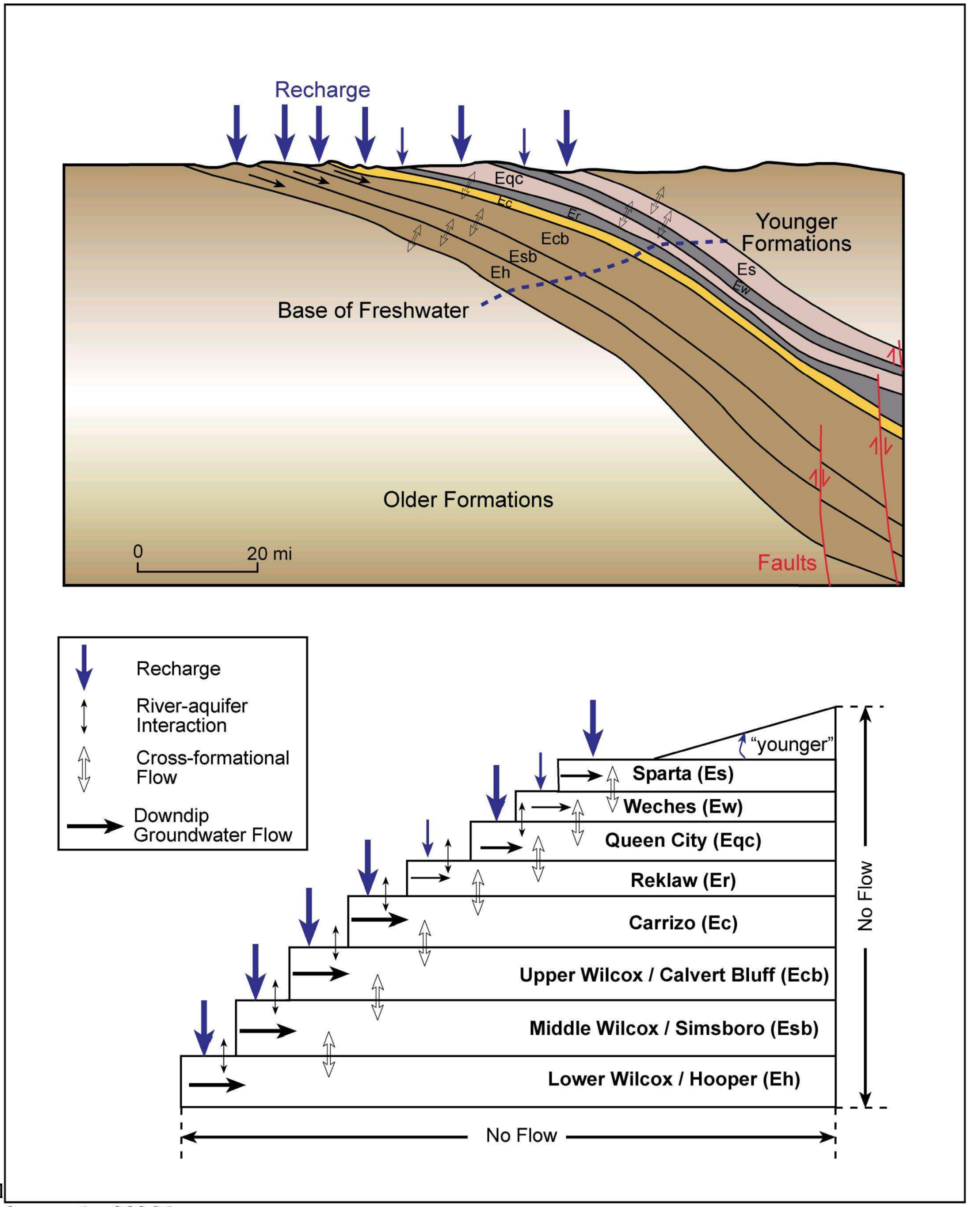
- Steady State Model
- $Q_{in}=Q_{out}$
- Recharge =

  ET groundwater

  spring flow

  stream gains

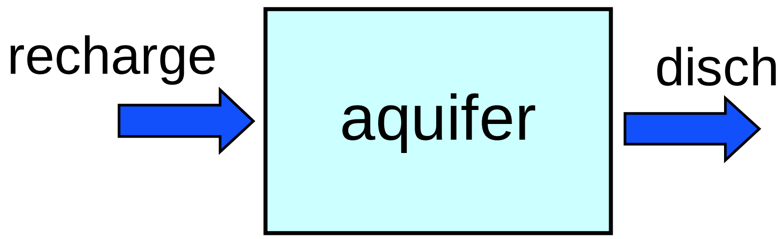
  cross formational flow



Cross-section-QCS.fh8

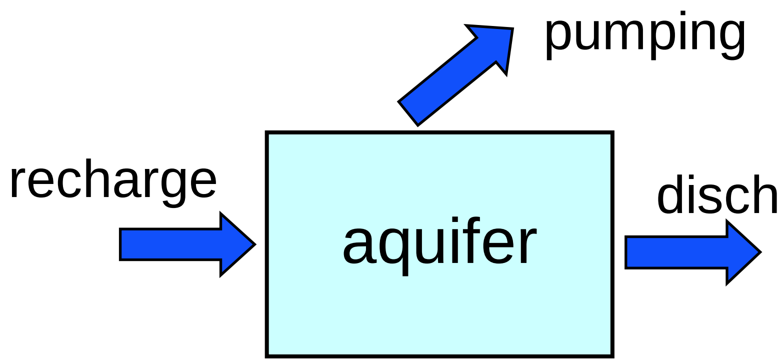
Aquifer Dynamics

Pre-development



Dynamic equilibrium:
Aquifer recharge is balanced by aquifer discharge

Post-development



Dynamic equilibrium:
Pumping is balanced by a Reduction in discharge and in some cases an increase in recharge – sometimes termed "capture"

After Alley et al, (1999) and Bredehoeft (2002)

Aquifer Dynamics – Post-Development

- Development is balanced by:
  - Decrease in storage
  - Reduction in discharge (capture)
    - Stream gains
    - Spring flows
    - Groundwater ET
    - Cross-formational flow
  - Increase in recharge (generally small in comparison to discharge reduction)

Model Implementation

Model Implementation

- Model parameters for the Carrizo through the Sparta were developed state wide to force consistency in the overlap regions
  - Structure
  - Hydraulic Conductivity
  - Hydraulic Heads
  - Recharge
  - Boundaries
  - Storage
  - Pumping
- Parameter changes between models are exchanged during calibration including GHB heads

Geologic Structure Data Sources

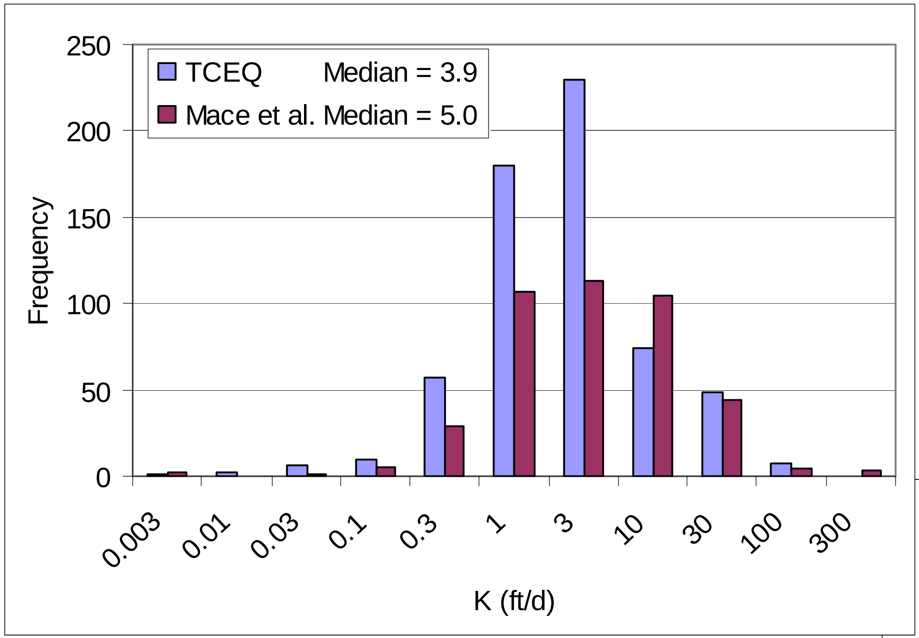
- Structure – Refers to the elevation of the tops of the Queen City, the Weches, and the Sparta formations
- MS Thesis – TCEQ well log database
  - Guevara (1972) & Garcia (1972) – Queen City
  - Ricoy (1976) - Sparta
    - Approximately 250 logs used across the 3 model areas
  - Payne (1968)
  - East Texas Model
- Sand thickness maps:
  - Guevara (1972) & Garcia (1972) – Queen City
  - Ricoy (1976) and Payne (1968) – Sparta
  - GUWCD – Carrizo, Gonzales County

Hydraulic Properties

- **Soft Data:**
  - USGS
    - Payne (1968)
    - McWreath et al (1991)
    - RASA – Prudic (1991)
  - BEG
    - Guevara & Garcia (1972)
    - Ricoy (1977)
  - TWDB
    - Myers (1969)
    - County Reports

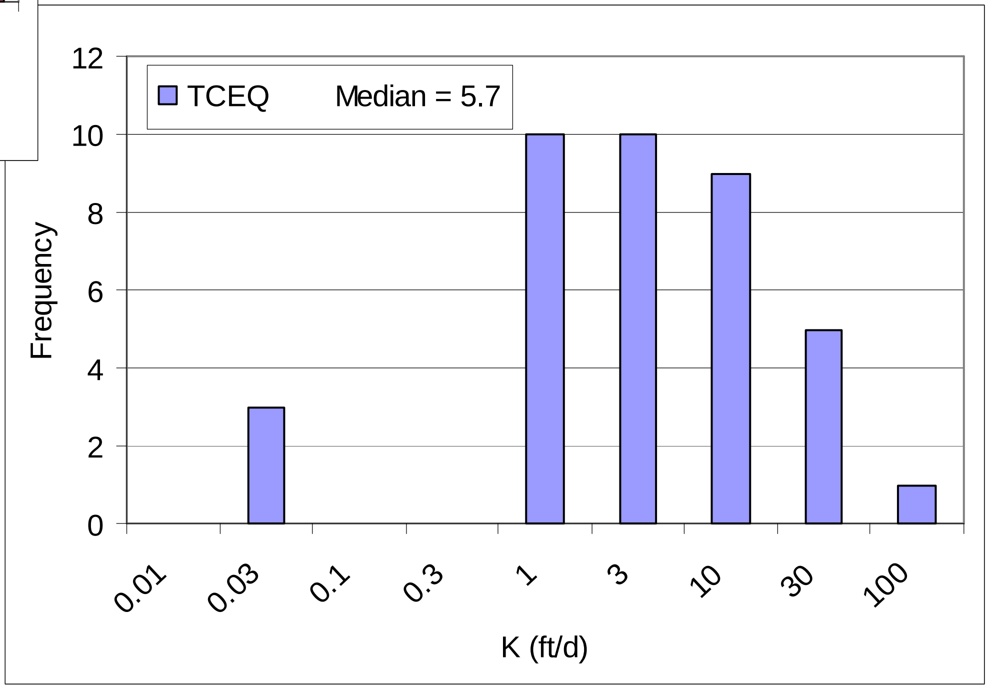
- **Hard Data:**
  - TCEQ file search of the drillers logs
    - Queen City - 444 estimates
    - Sparta - 33 estimates
  - Mace et al. (2000) database

Hydraulic Conductivity Distributions



Queen City

Sparta



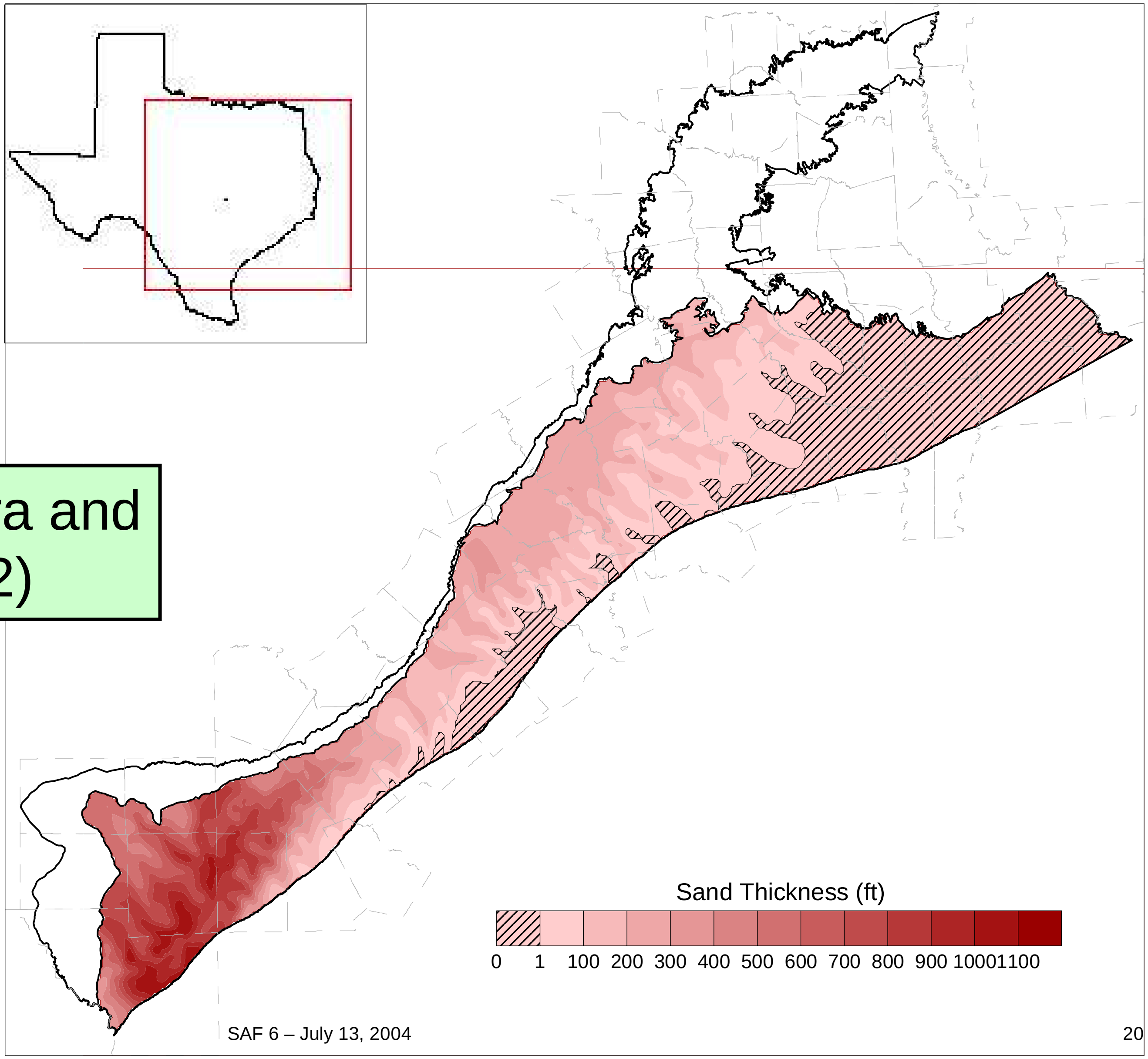
Hydraulic Conductivity Analysis Approach

- Krige available conductivity measurements
- Impose a depth trend based on Prudic (1991)
- Multiply by net sand fraction to convert to effective conductivity for import to MODFLOW

$$K_H = (SF)(K_{sand}) + (1 - SF) \times K_{clay}$$

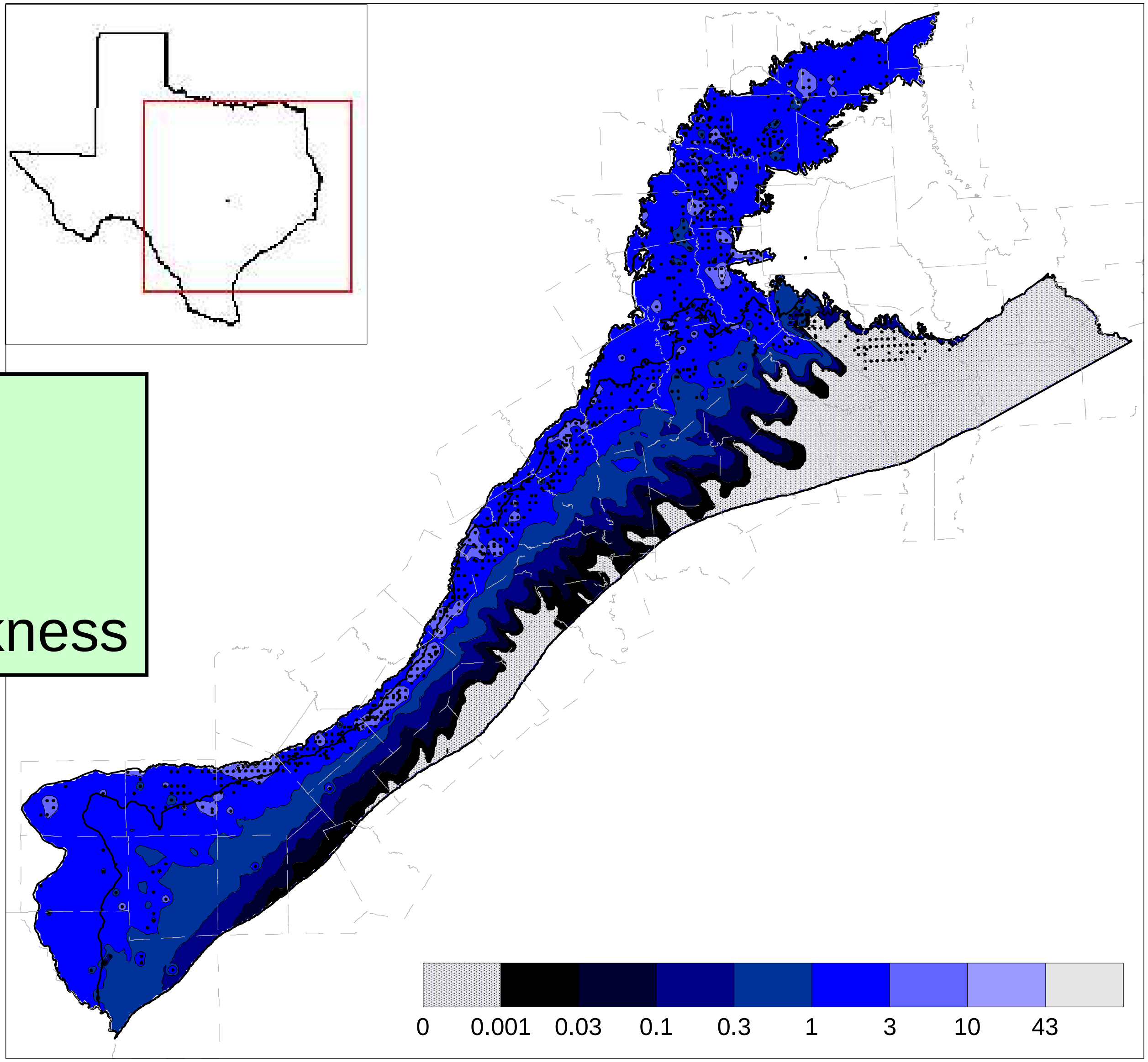
Queen City Net Sand Thickness (ft)

after Guevara and Garcia (1972)



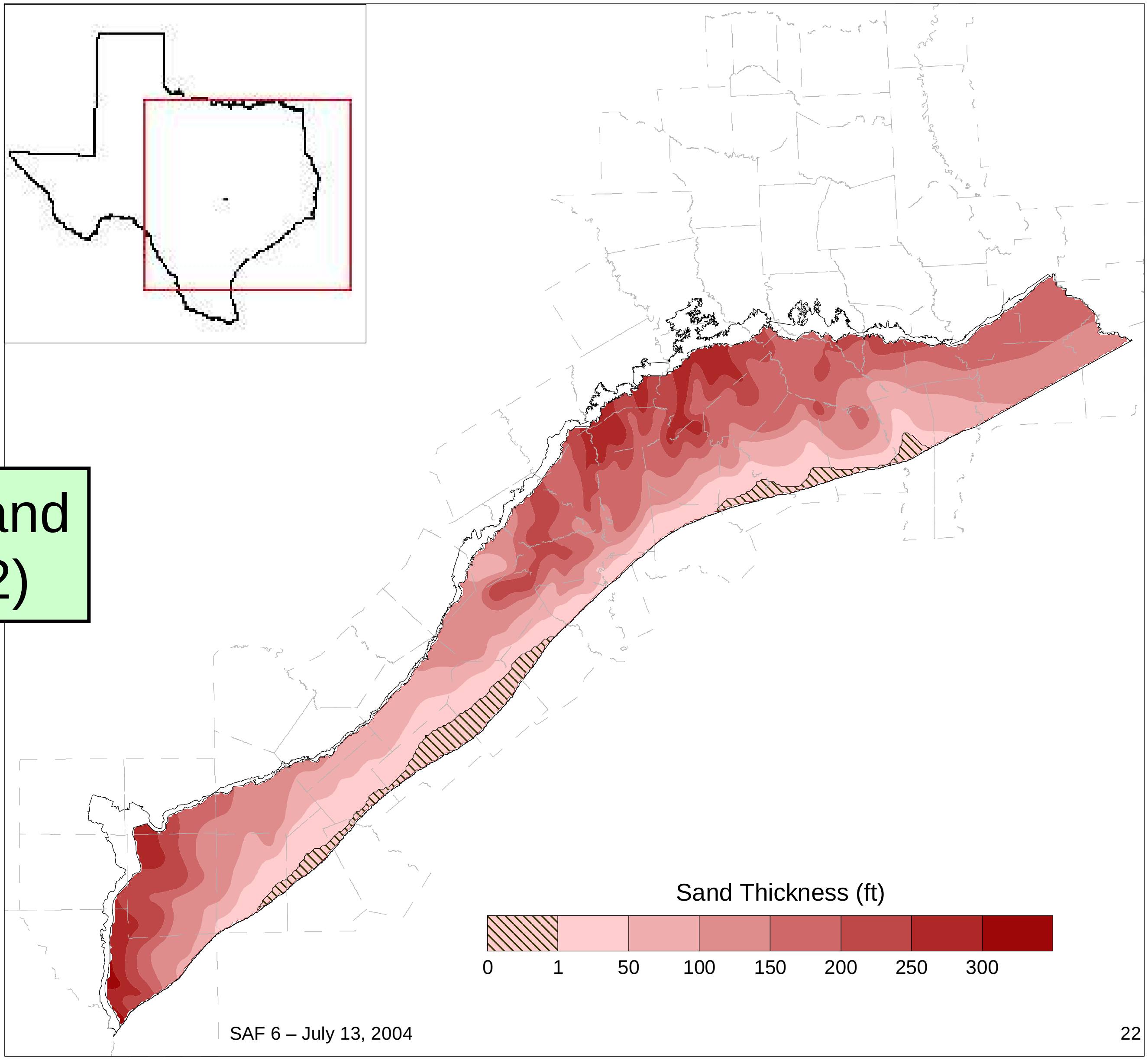
Queen City Effective Hyd. Conductivity

Combines:
* Test data
* Depth trend
* Net sand thickness

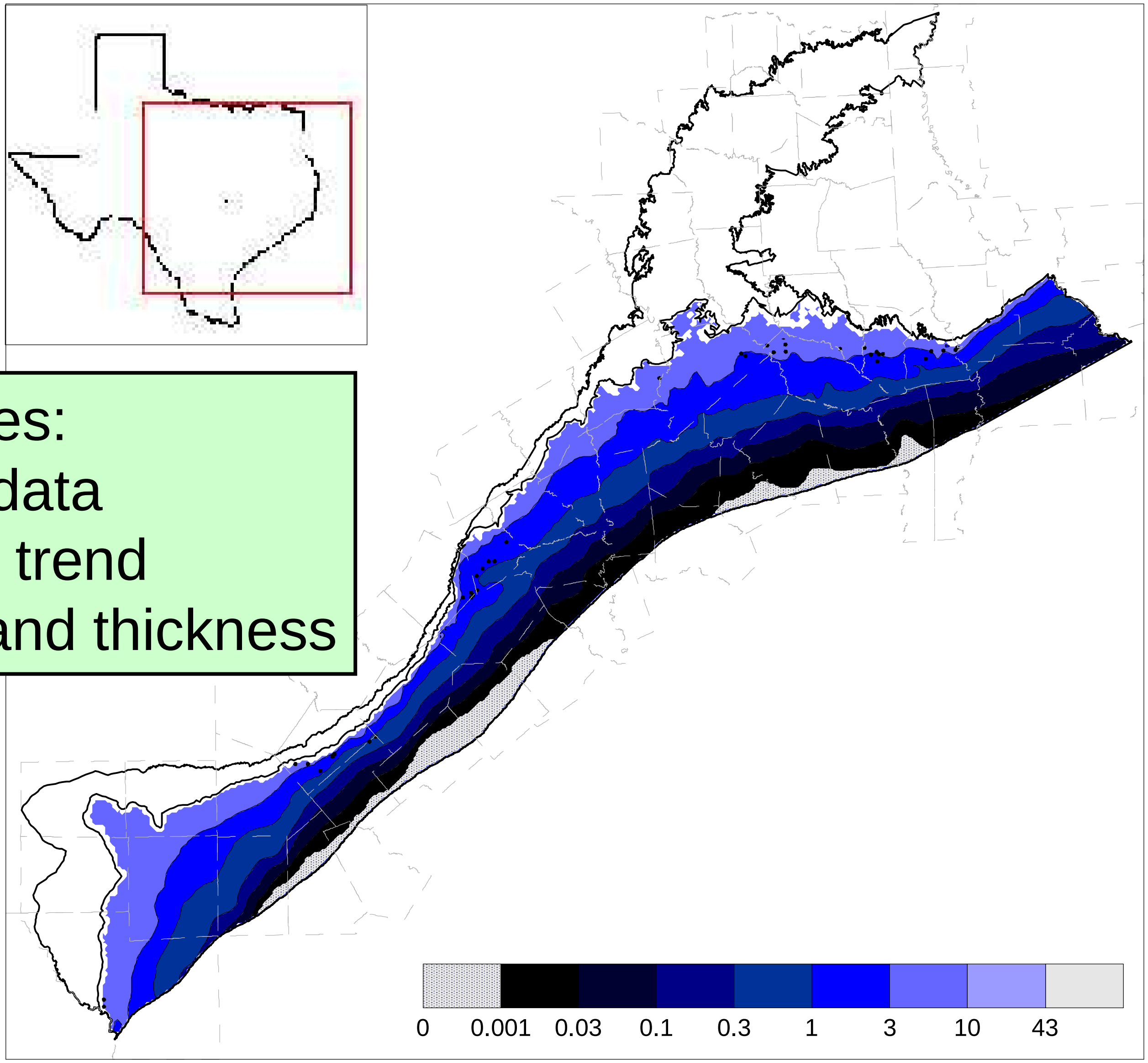


Sparta Net Sand Thickness (ft)

after Ricoy and Brown (1972)



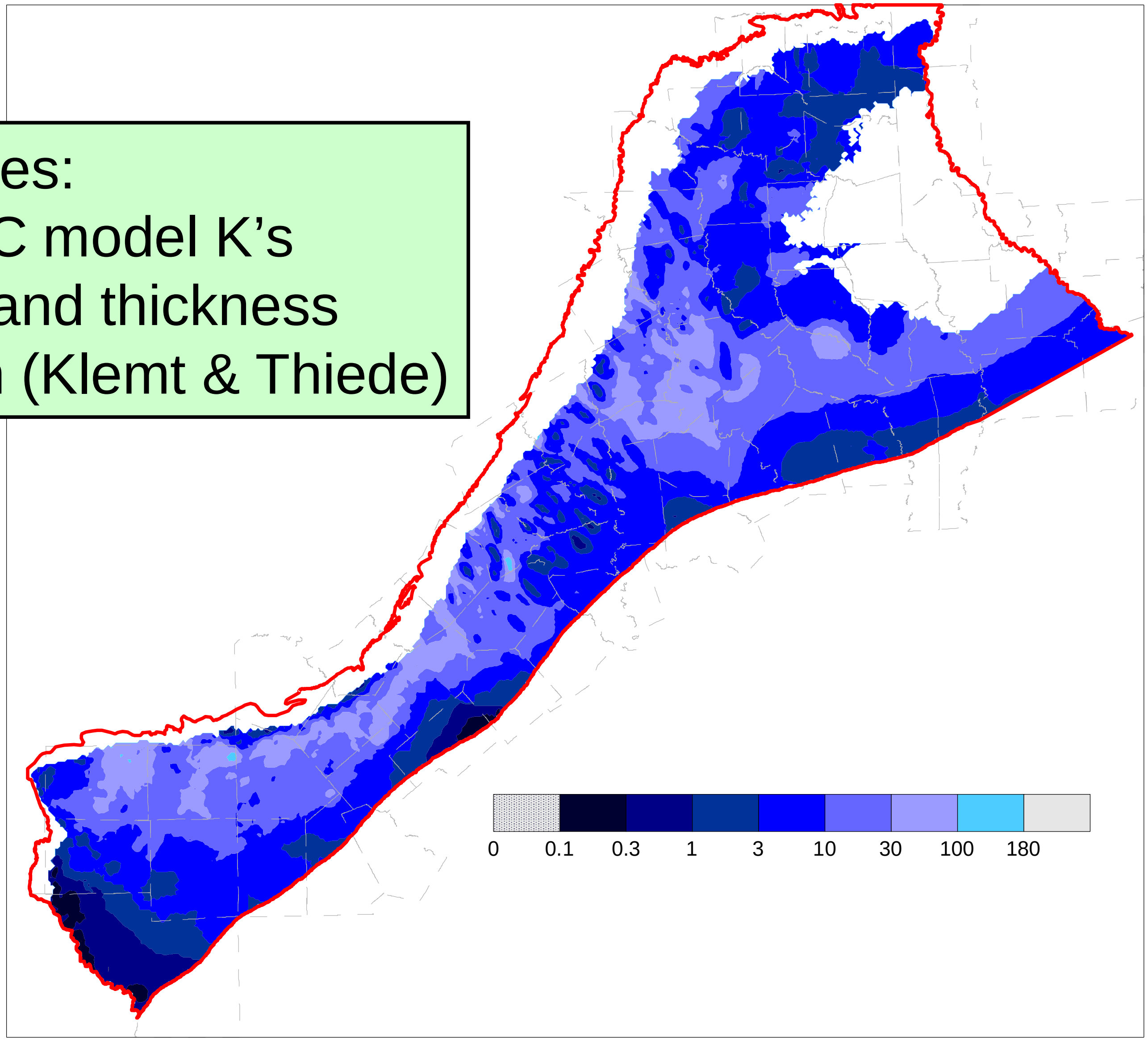
Sparta Effective Hyd. Conductivity



Combines:
* Test data
* Depth trend
* Net sand thickness

Effective K – Carrizo

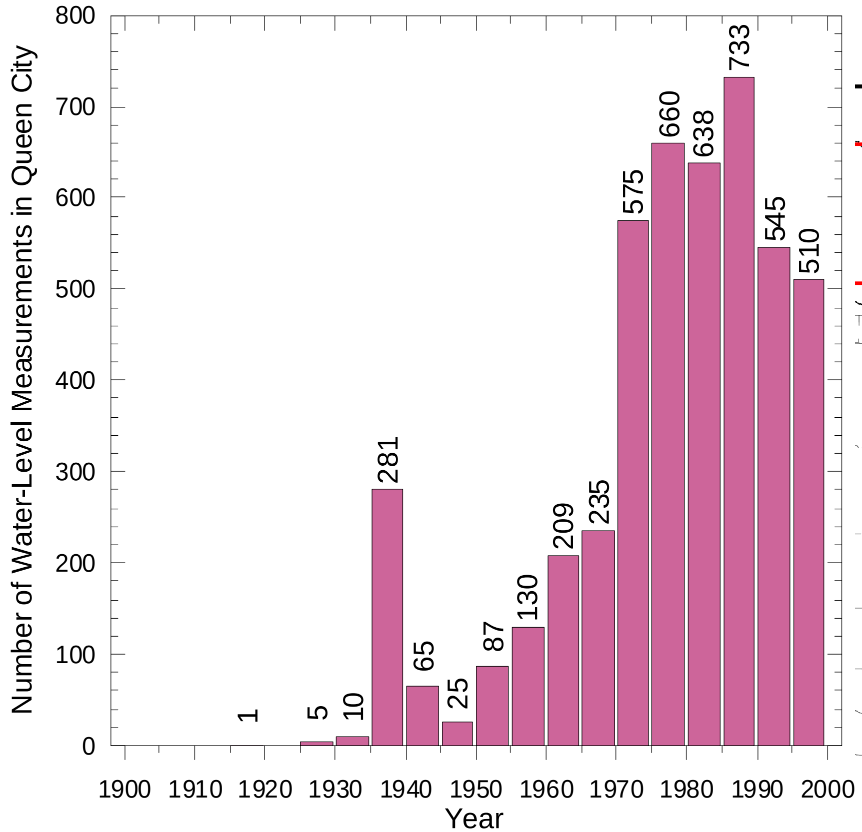
Combines:
* CZWC model K's
* Net sand thickness
* South (Klemt & Thiede)

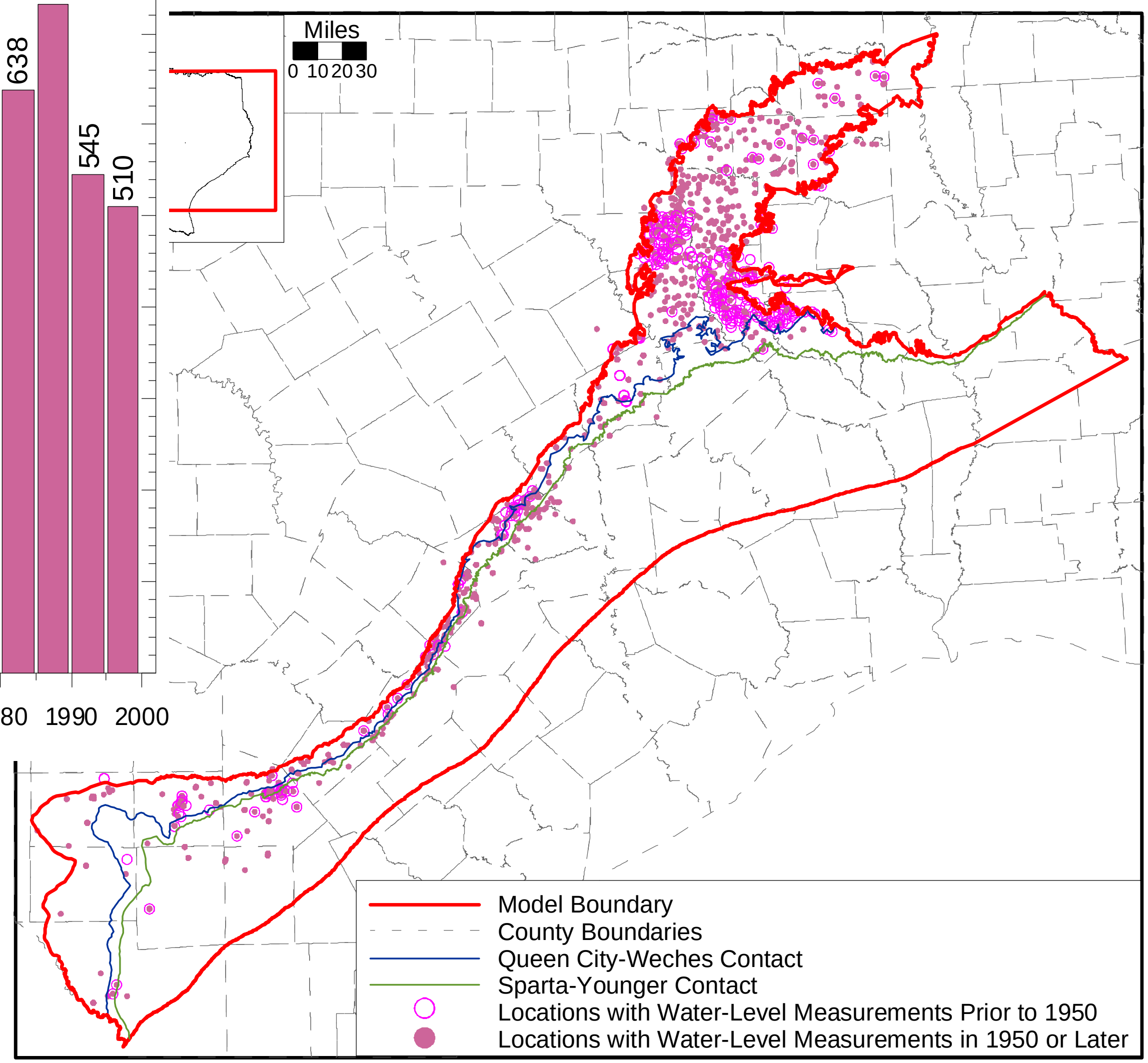


Kv – Implementation

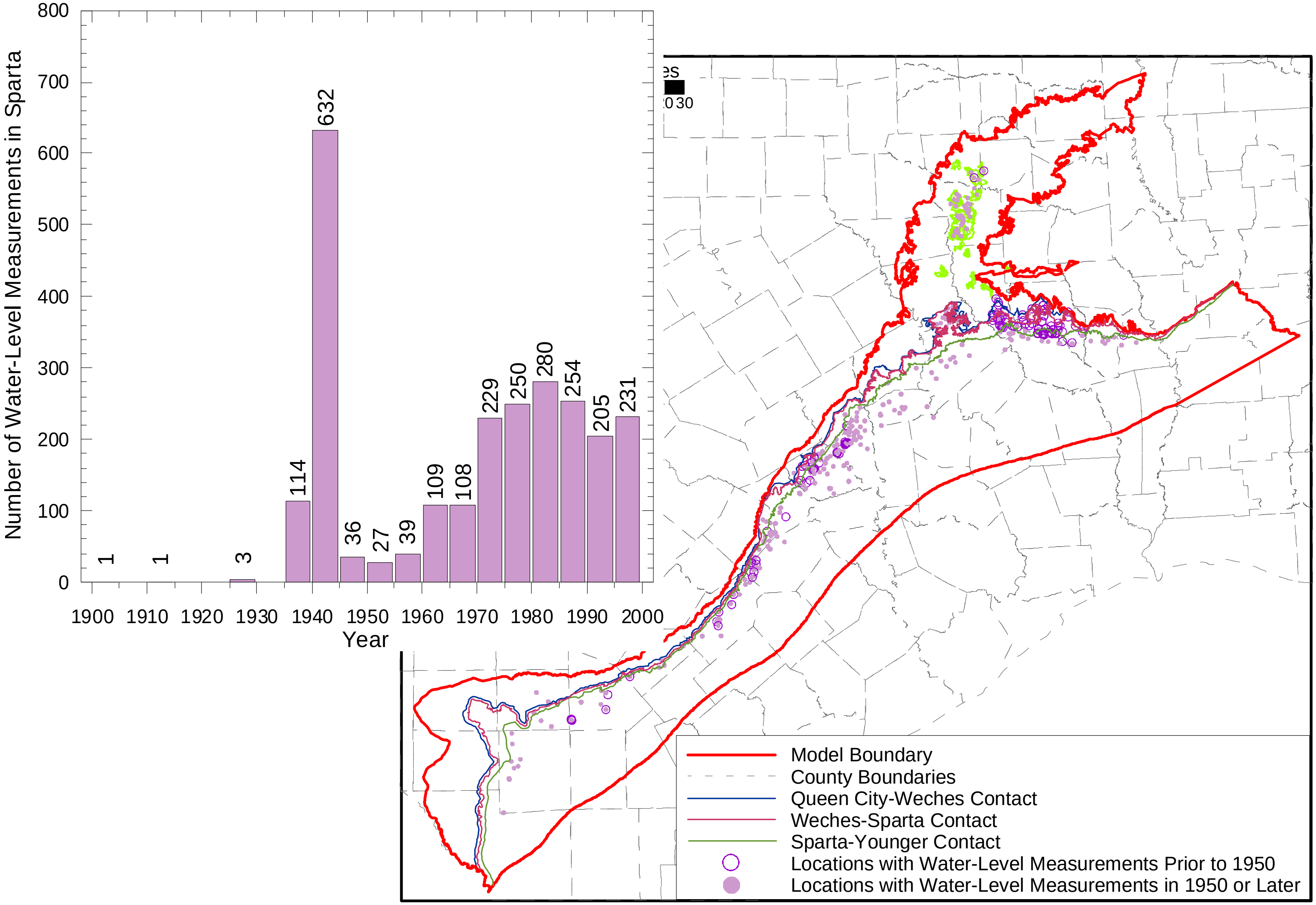
- Aquifers
  - Used clay fraction and an assumed clay conductivity to calculate geometric mean conductivity
- Aquitards
  - Used estimated clay fraction and an assumed clay conductivity to calculate harmonic mean conductivity
- Clay conductivity now set at
  - 1×10^{-4} ft/day, (0.0001)
  - Established as a calibration parameter

Queen City Water Level Control





Water Level Control – Sparta aquifer



Groundwater Flow Conceptual Model

North-Central

- Groundwater flows locally in the Queen City aquifer rather than regionally due to topographic controls (Fogg and Kreitler, 1982)
- Streams are gaining
- Vertical gradients can be controlled by topography (up in river basins and down on topo highs).
- Shallow water table with greater groundwater ET
- Less percentage of recharge to the confined aquifer sections

South-Central

- Groundwater flows regionally in the Queen City and Sparta aquifers from topographic highs in the outcrop areas to topographic lows down dip of the outcrop
- Streams are gaining to losing in west
- Vertical gradients are upward in confined section
- Groundwater ET becomes less in the south
- Greater percentage of recharge to the confined aquifer sections

Recharge Conceptual Model

- Based upon the work of Scanlon (2003), Meyboom (1966) and Toth (1966), we expect recharge to be a function of:
  - Precipitation,
  - Topography, and
  - Underlying geology
- Topographic control:
  - North and Central - Recharge would be enhanced in the higher elevations relative to the low elevations
  - We expect that this trend would be more subdued to reversed in the arid southwest
- In steady-state, recharge is also fixed by the aquifers (also models) ability to discharge

Recharge Implementation

- We developed a method based upon
  - precipitation,
  - topographic relationships, and
  - underlying aquifer properties
- Method is based upon the recently published recharge report by Dr. Scanlon (BEG).
- The recharge estimates are constrained based upon previous estimates
- Consistency in recharge implies some change within the Carrizo-Wilcox models
- Recharge is calibrated in the SS models
- Transient recharge is derived from precipitation variation (SPI)

Precipitation - Simulation Results
(after Scanlon et al., 2003)

Table 11: Simulation results for layered profiles with vegetation. *R/P* represents the ratio of recharge to precipitation expressed as percentage.

Units: mm/yr	P	Dryland					Irrigated			
Study Area		*R*	*R/P*	*RO*	*E*	*T*	*R*	*RO*	*E*	*T*
El Paso County	224	0.2	0.1	0	119	89				
Midland County	380	2	0.5	5	192	201	4	5	199	216
Cenozoic Pecos Alluvium	380	7	1.8	13	179	186				
Lubbock County	474	1	0.2	55	164	148	6	116	208	235
Carson County	497	0.5	0.0	244	148	125	0.5	367	158	148
Fisher/Jones Counties	619	7	1.1	179	262	197	7	180	262	199
Starr County	676	31	4.6	31	303	221				
Bastrop County	809	16	2.0	192	307	327				
Parker County	855	27	3.2	162	352	361				
Hopkins/Rains Counties	855	24	2.8	59	403	386				
Upshur/Gregg Counties	855	38	4.4	27	325	491				
Victoria County	932	21	2.3	401	310	227				
Liberty County	1184	114	9.6	325	318	432				

P: precipitation, *R*: recharge, *RO*: runoff, *E*: evaporation, *T*: transpiration

Precipitation - Simulation Results
(after Scanlon et al., 2003)

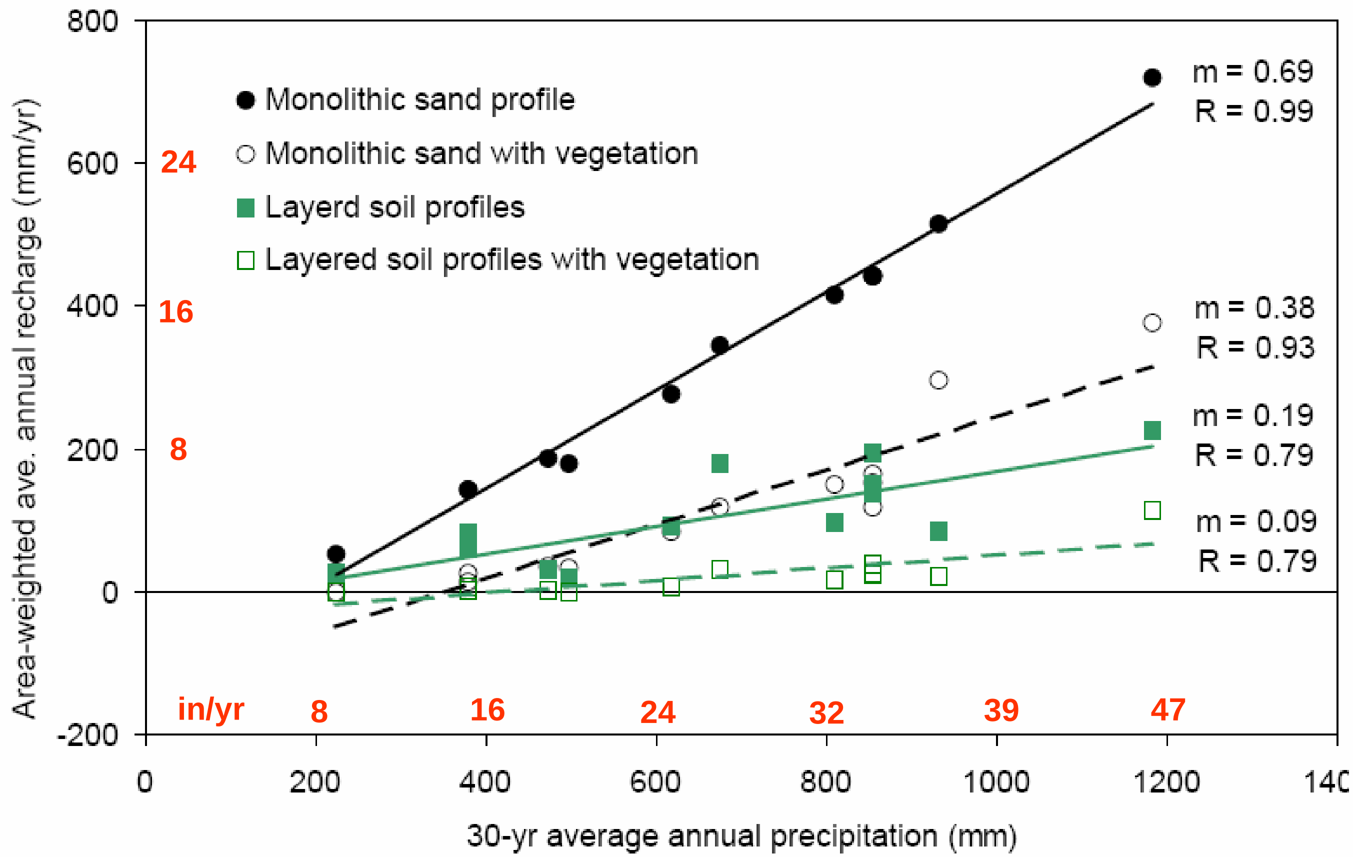
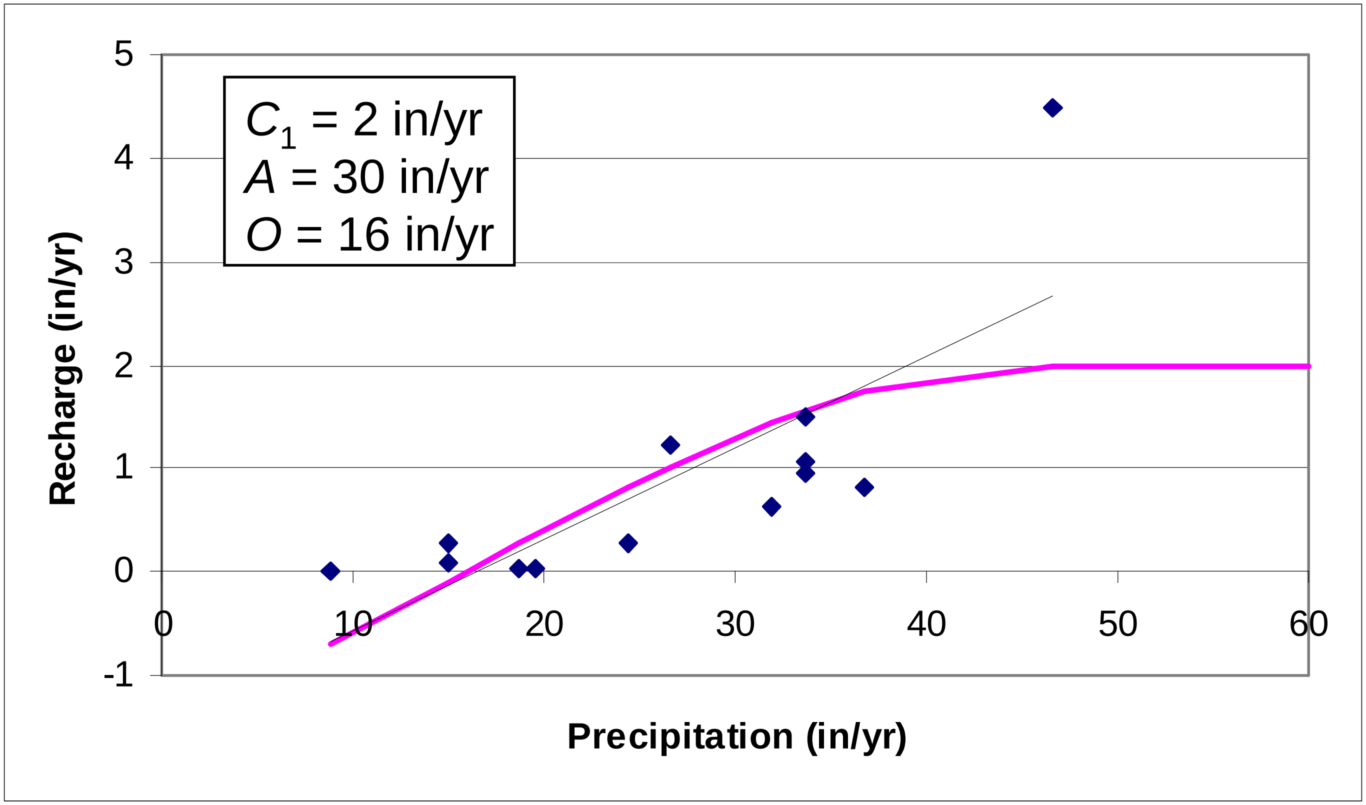


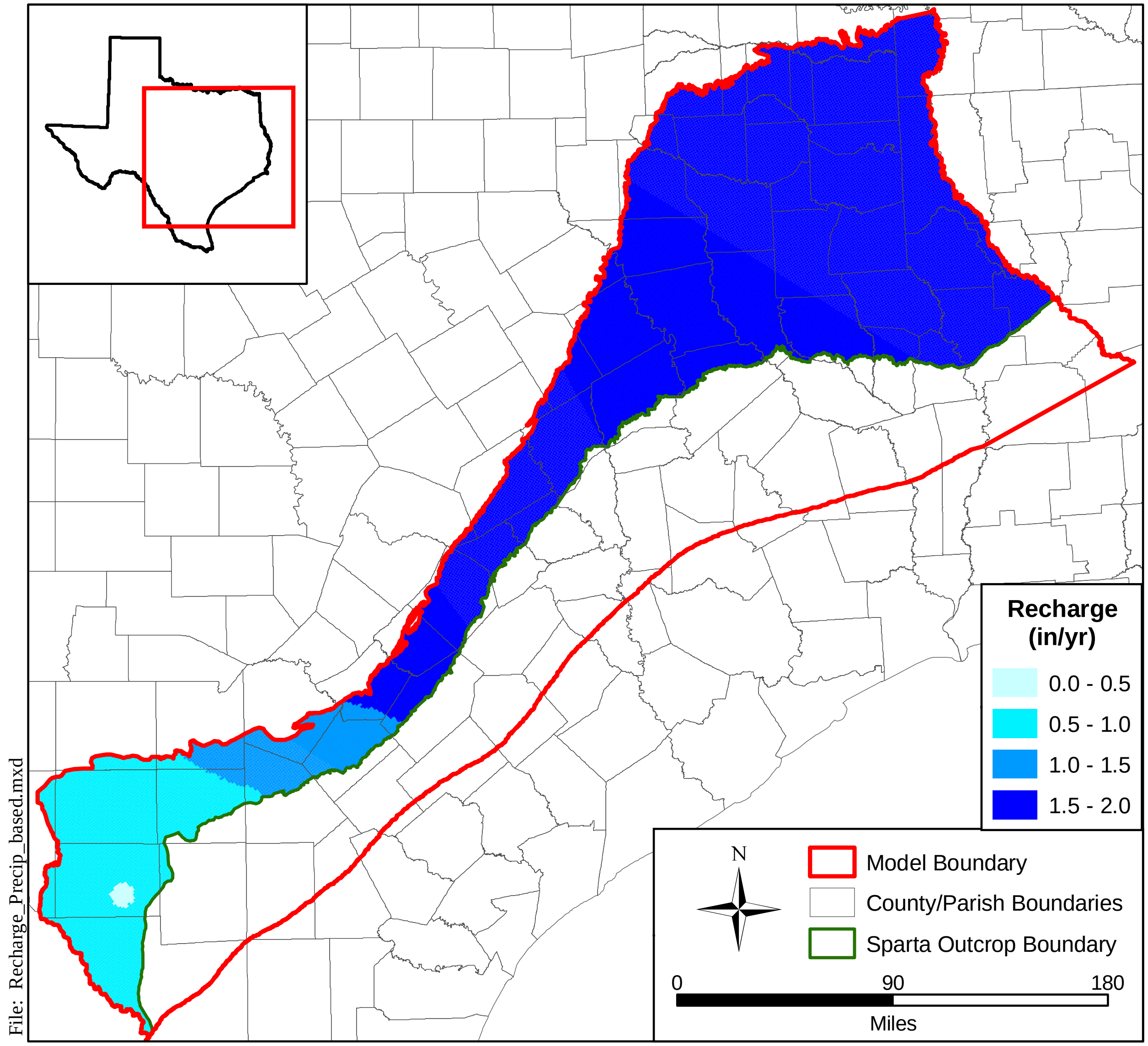
Figure 10: Relationships between precipitation and simulated area-weighted average annual recharge. (R = correlation coefficient, m = slope of regression line.)

Fit to Scanlon et al. 2003 simulations

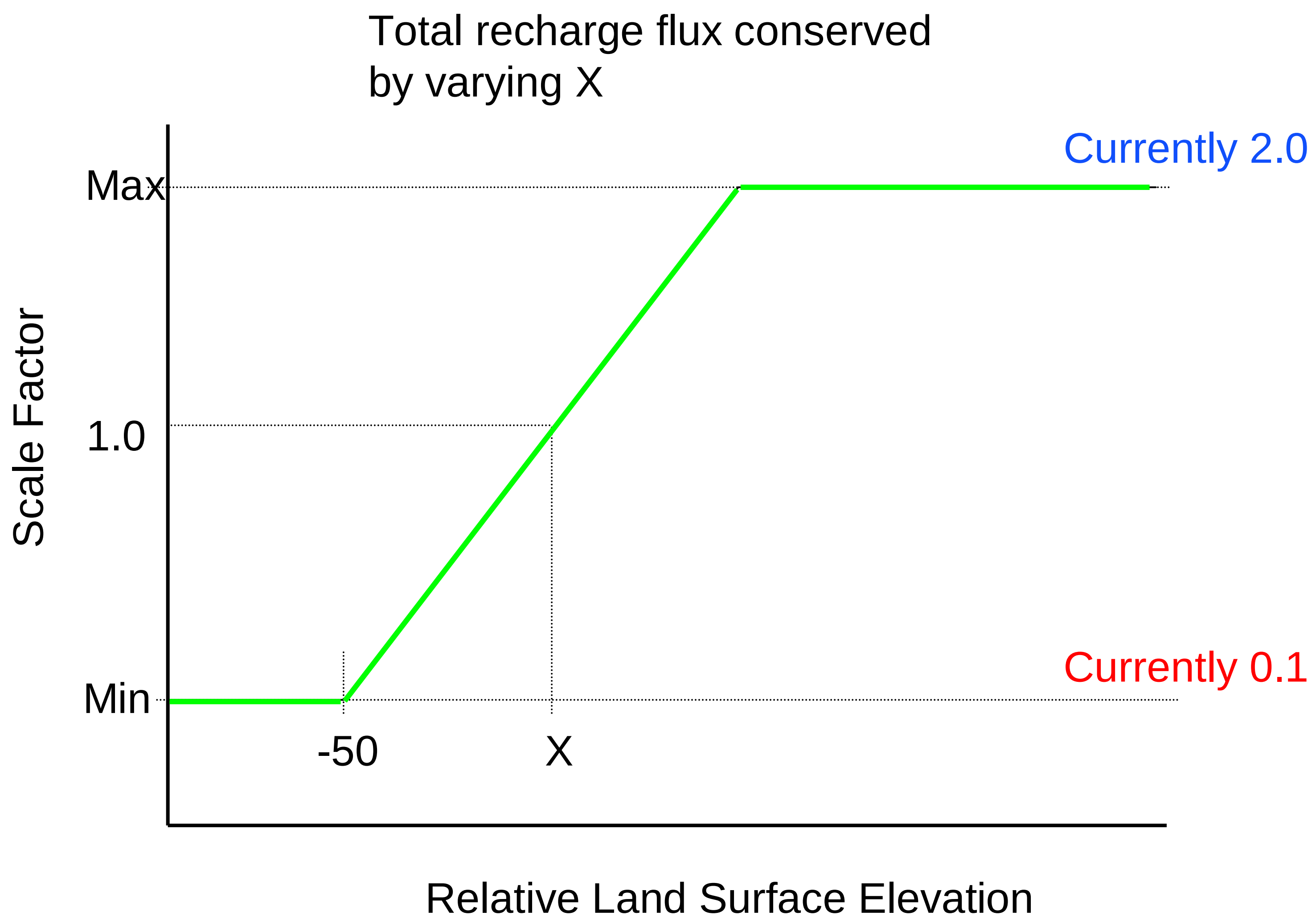
$$R(P) = \begin{cases} C_1\left(1.5\dfrac{P-O}{A} - 0.5\left(\dfrac{P-O}{A}\right)^3\right) & (P-O) < A \\ C_1 & (P-O) \geq A \end{cases}$$



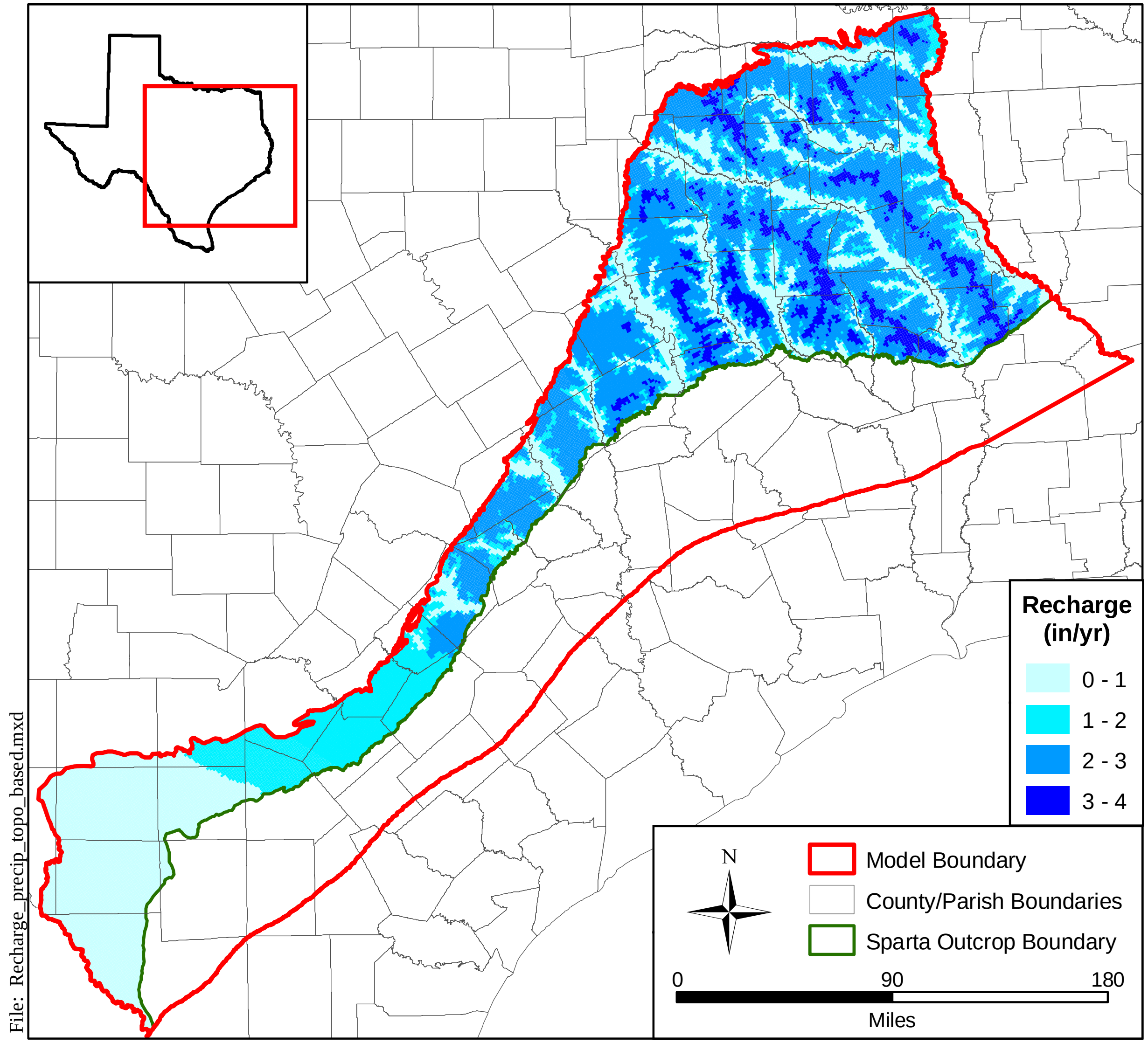
Base Recharge



Topographic Scale Factor



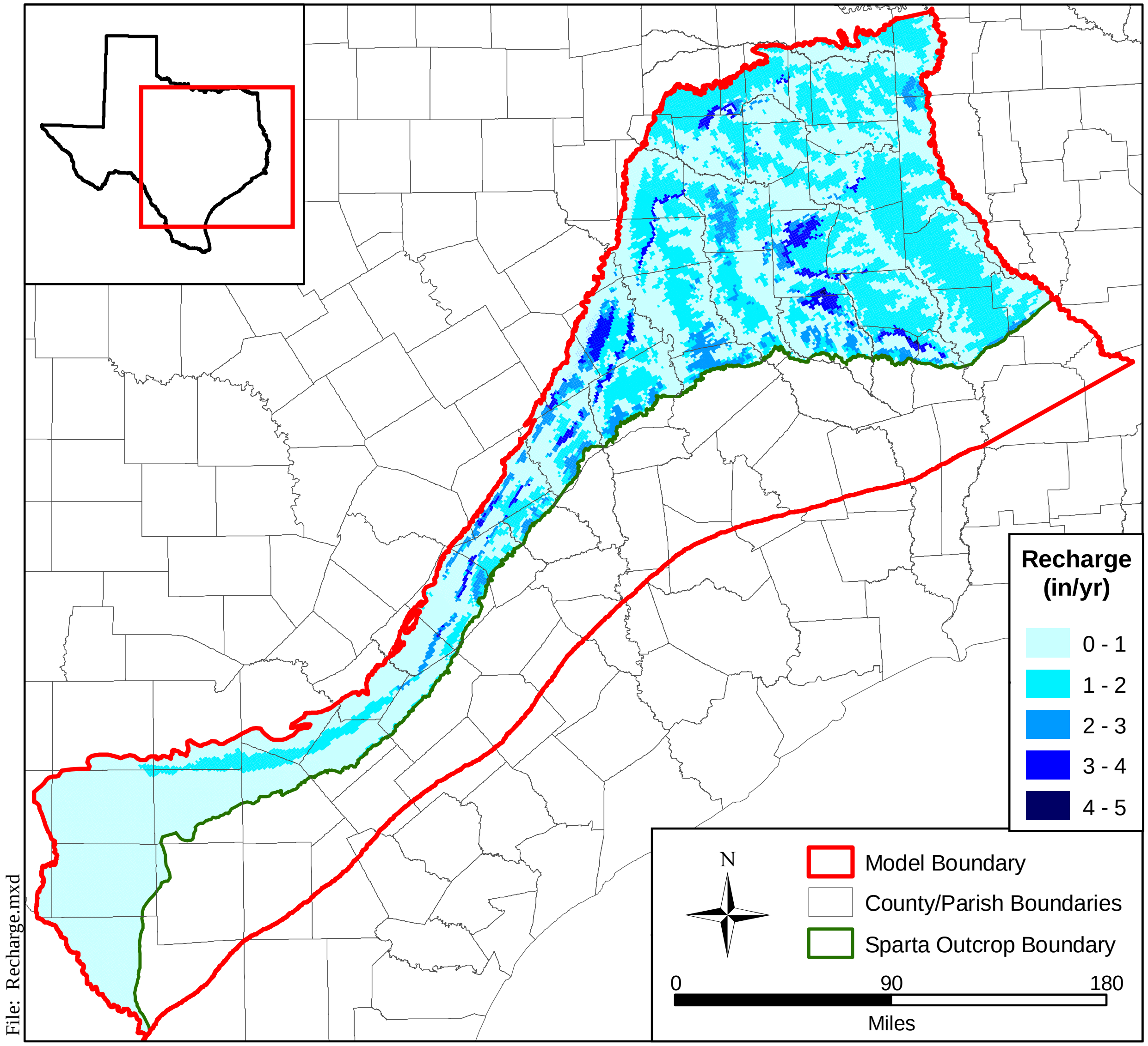
Topographic Scaled Recharge



Formation Scale Factor

Formation	Layer	All	S	C	N
			Model Region		
Sparta	1	0.8			
Weches	2	0.2			
Queen City	3	0.5	0.5	0.5	0.4
Reklaw	4	0.2			
Carrizo	5	1.2			
Upper Wilcox/Calvert Bluff/Upper Wilcox	6		0.4	0.4	0.5
Upper Wilcox/Simsboro/Upper Wilcox	7		0.4	1.2	0.5
Upper Wilcox/Hooper/Upper Wilcox	8		0.5	0.3	0.3

Recharge Distribution



Calibrated SS Recharge

Recharge (AFY) (Minus the Reklaw and Weches)

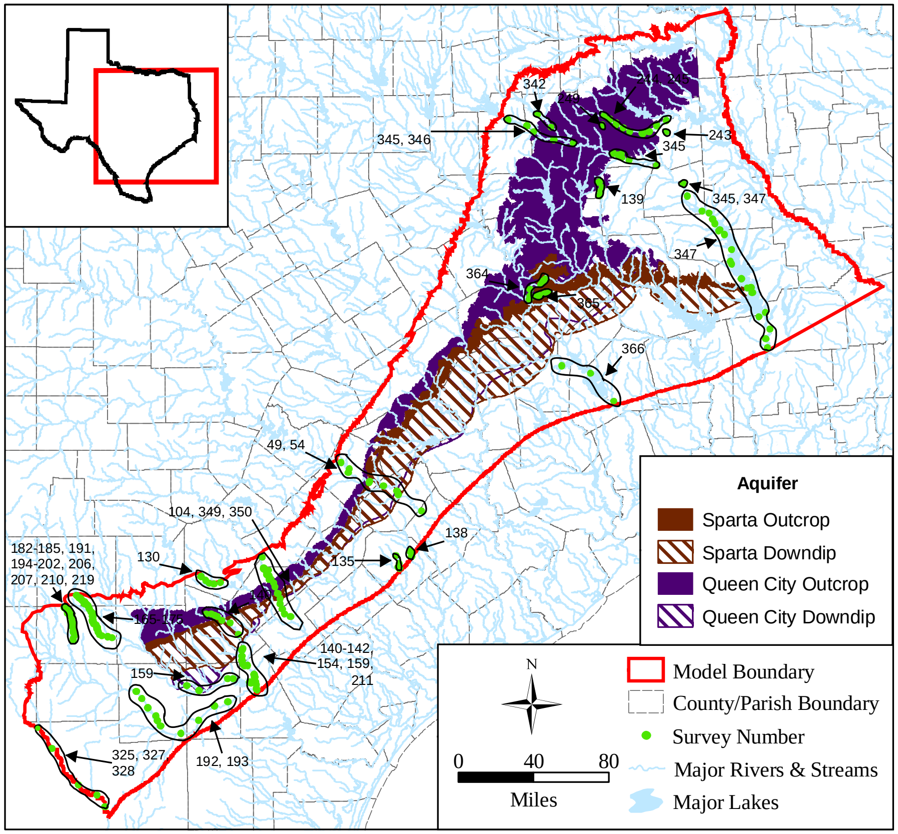
Aquifer	South GAM	M&P 1979	Central GAM	M&P 1979	North GAM	M&P 1979
Sparta	24,486	60,000	126,400	136,400	140,025	96,800
Queen City	69,019	23,800	154,300	294,300	275,580	655,600
Carrizo/W	113,602	186,340	220,300	479,700	728,106	327,460
Total	207,107	270,140	501,000	910,400	1,143,711	1,079,860

Recharge (in/year)

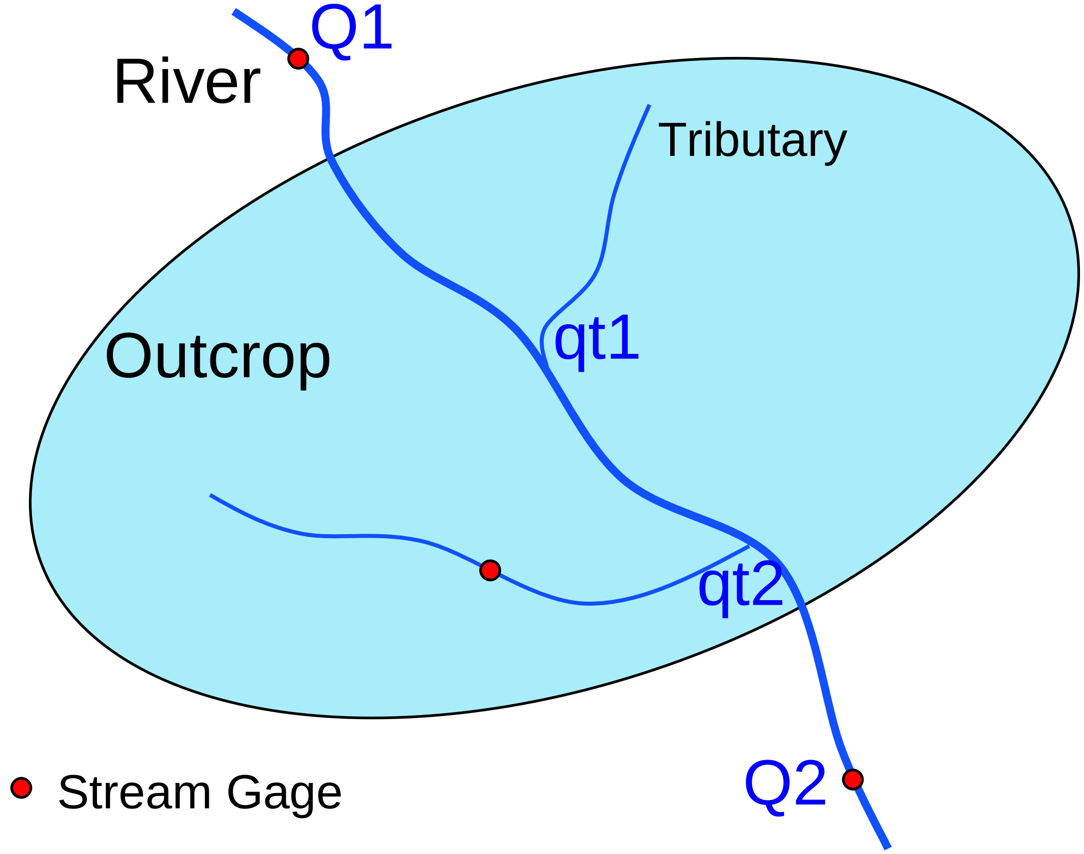
Formation	South GAM	Central GAM	North GAM
Sparta	0.6	1.6	1.7
Weches	0.2	0.4	0.5
Queen City	0.4	0.8	0.8
Reklaw	0.2	0.3	0.4
Carrizo	1.2	2.2	2.6
U. Wilcox	0.5	0.7	1.2
M. Wilcox	0.4	1.8	1.3
L. Wilcox	0.6	0.6	0.5

Stream Gain/Loss Calibration Targets

- LBG-HDR (1998)
- Slade et al., (2002)
- HDR Central GAM (Dutton et al., 2003)
- This Study
  - R.J. Brandes WAM Study



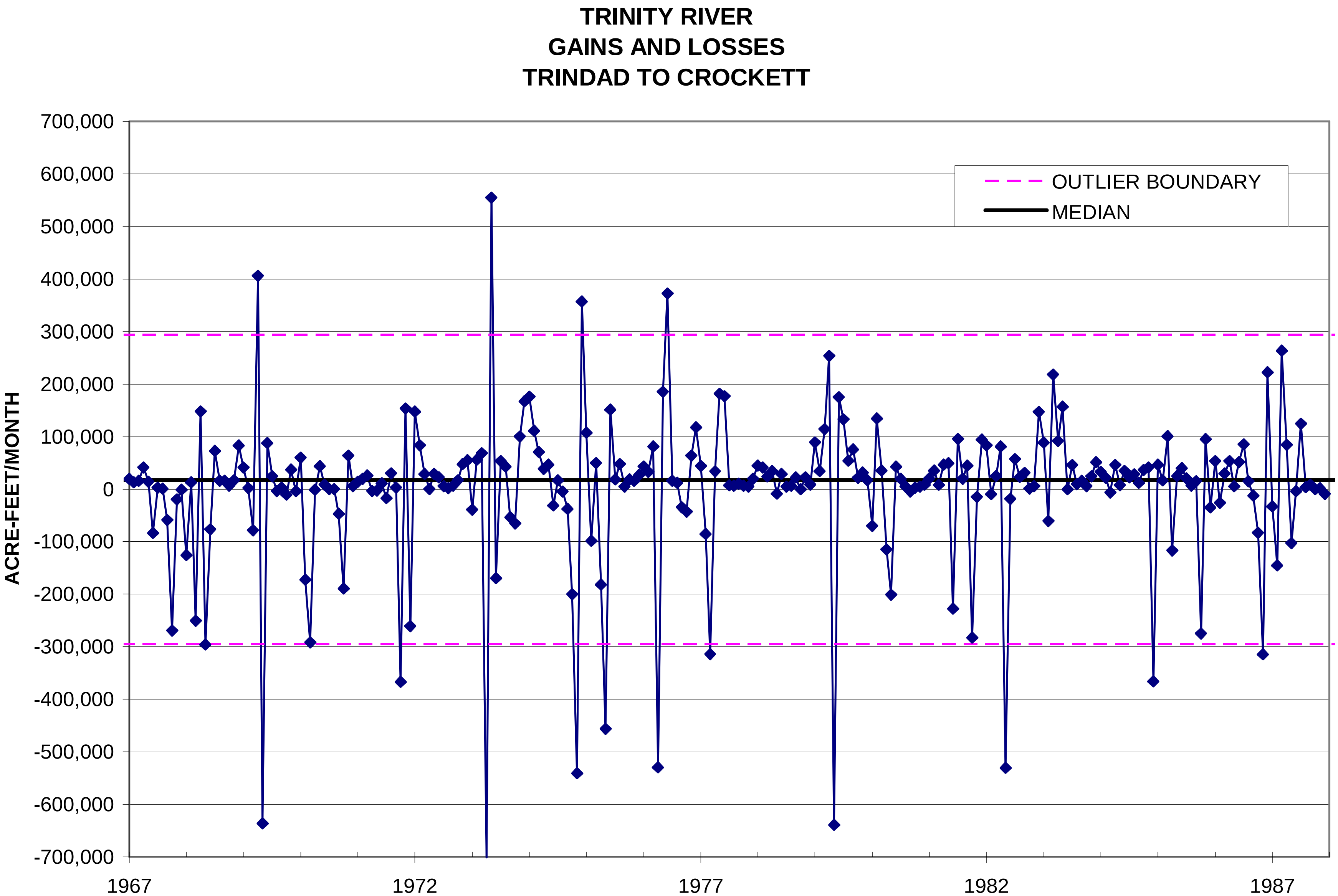
WAM Gain/Loss Method



- WAM Naturalized stream flows
- Removes anthropological effects
  - diversions,
  - return flow,
  - dams and impoundments

Gain/loss = Q1 – Sum qt – Q2

Trinity Gain/Loss (AF/month)



WAM Gain/Loss Results

River	Incremental Distance (miles)	Mainstem Incremental Drainage Area (square miles)	# of Tributary Gages	Tributary Drainage Area (square miles)	Tributary DA/ Mainstem DA (%)	Gain/Loss (ft^3/day/mile)	Gain/Loss (AF/day/mile)
ANGELINA R	43	1,278	2	534	41.80%	-32,639	-0.7
ATASCOSA R	65.8	1,171	1	783	66.90%	18,064	0.4
BIG CYPRESS CREEK	-----	-----	-----	-----	-----	-----	-----
BLACK CYPRESS BAYOU	48.5	365	1	383	104.90%	64,198	1.5
BRAZOS R	152.8	13,444	4	9,723	72.30%	159,763	3.7
CIBOLO CR	69.2	553	1	549	99.30%	4,895	0.1
COLORADO R	68.5	363	NA	NA	NA	4,846	0.1
FRIO R	79.4	2,798	4	1,341	47.90%	12,926	0.3
GUADALUPE R	180.5	2,874	3	1,435	49.90%	28,038	0.6
LEONA R	-----	-----	-----	-----	-----	-----	-----
NAVASOTA R	93	1,214	1	97	8.00%	5,223	0.1
NECHES R	249	7,342	2	268	3.70%	153,851	3.5
NUECES R	263.4	13,566	3	5,383	39.70%	-18,924	-0.4
RIO GRANDE	139.3	5,266	NA	NA	NA	-8,344	-0.2
SABINE R	134.1	2,232	4	964	43.20%	41,845	1.0
SAN ANTONIO R	57.5	370	1	827	223.50%	25,690	0.6
SAN MARCOS R	37.9	426	1	309	72.50%	-33,111	-0.8
SULPHUR R	114.7	2,916	2	770	26.40%	-557	0.0
TRINITY R	125.8	5,373	5	2,261	42.10%	202,366	4.6

Steady-State Model Review

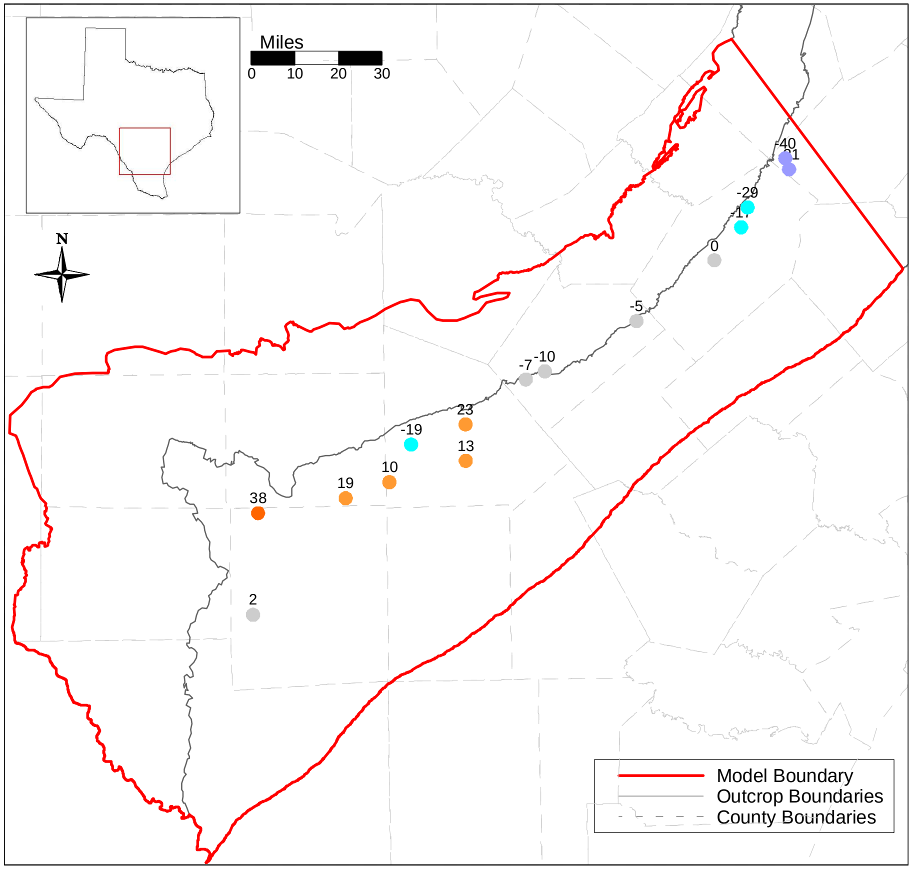
Steady-State Calibration Approach

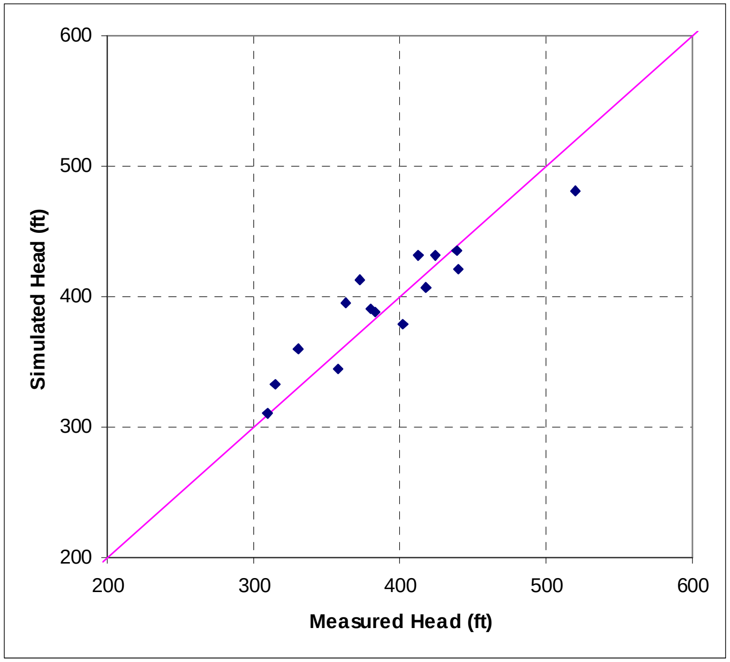
- Approach to Calibration
  - Use multiple performance measures
    - Statistics
    - Head surfaces
    - Stream Gain and Loss
  - Use regularization (interpolation functions) to estimate parameters trying to limit the degree of unknowns
    - Kh depth trend
    - Recharge factors and topographic scalar
  - Parameters poorly known were preferentially altered if they were important (the model responded to them)

Significant Initial Parameter Changes

- Storativity was calculated by a different method in North and South GAMs for Carrizo through Sparta (method will be described later)
- Confining unit clay conductivity was initialized at 1×10^{-4} ft/day
- All faults are modeled with hydraulic barrier package, but only those with evidence are activated (lower conductance)
- Carrizo horizontal conductivity fields merged
- Recharge

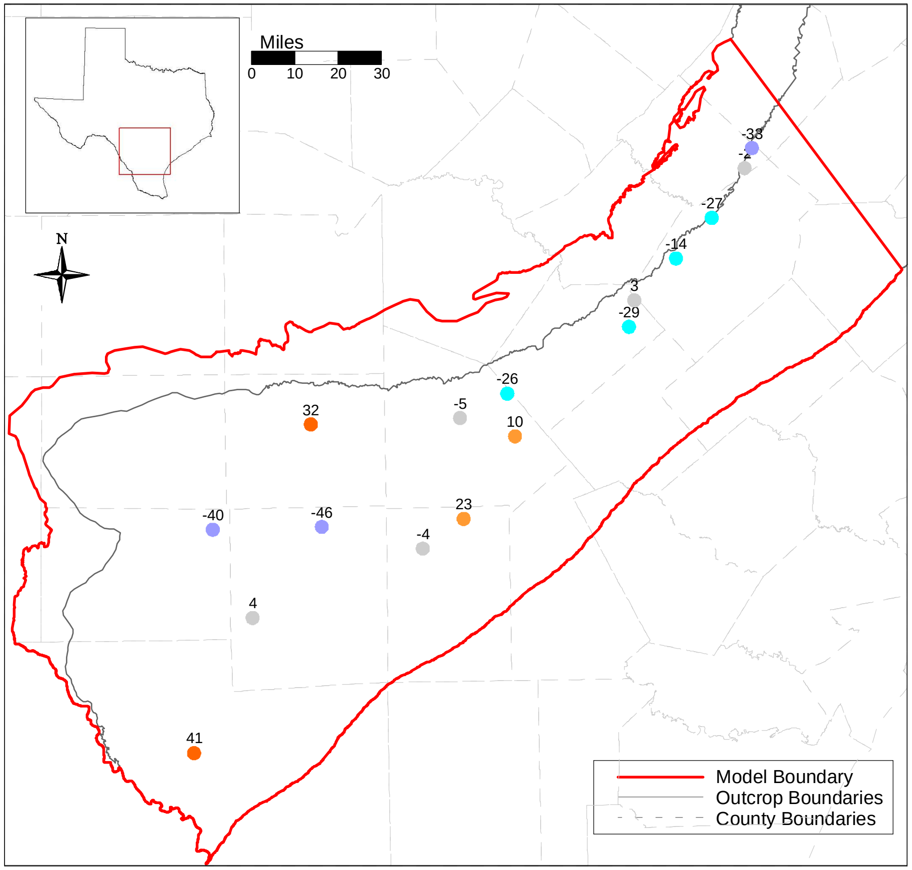
South GAM Sparta

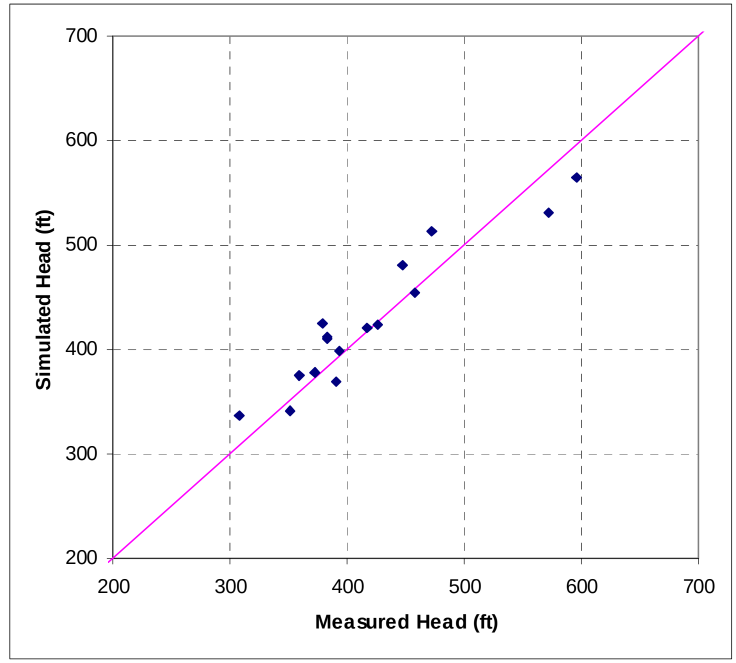




Layer	Count	ME (ft)	MAE (ft)	RMSE (ft)	Range (ft)	RMSE/ Range
1	15	-3.8	18	22	210	0.10
3	16	-7.4	22	26	288	0.091
5	31	-3.7	16	22	308	0.071

South Queen City





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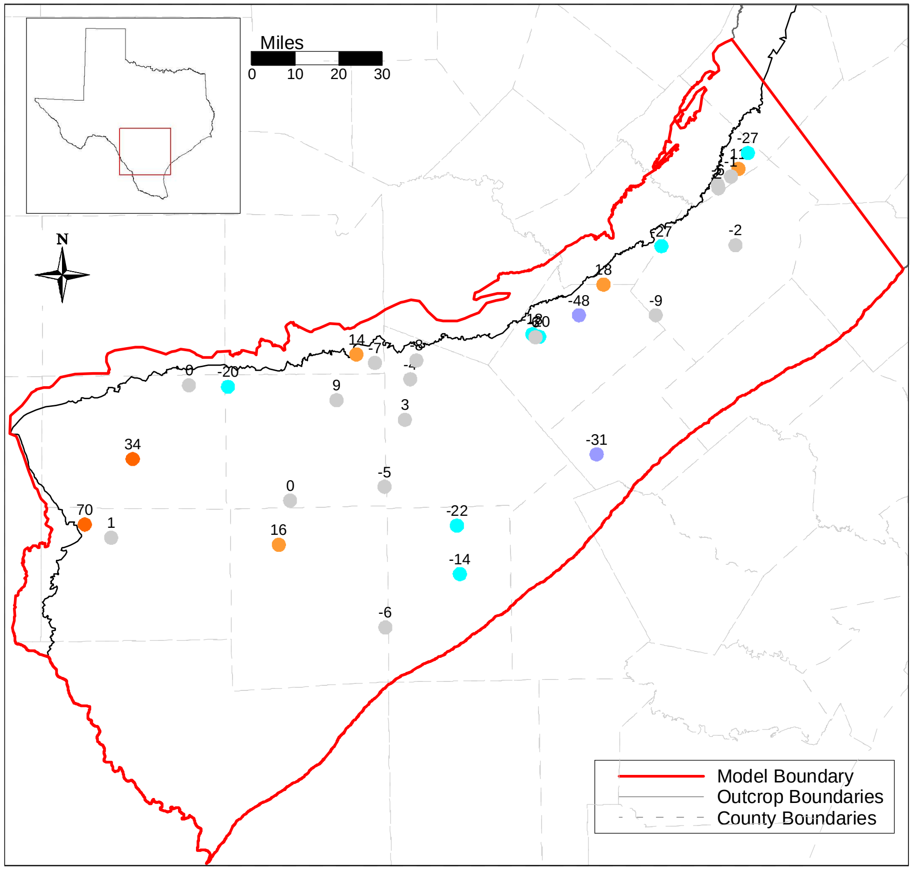
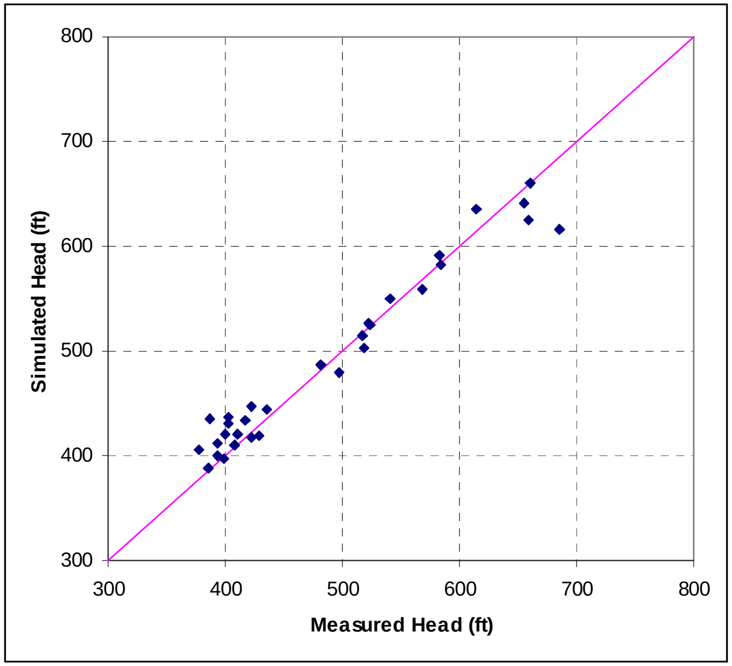
Carrizo – Southern GAM





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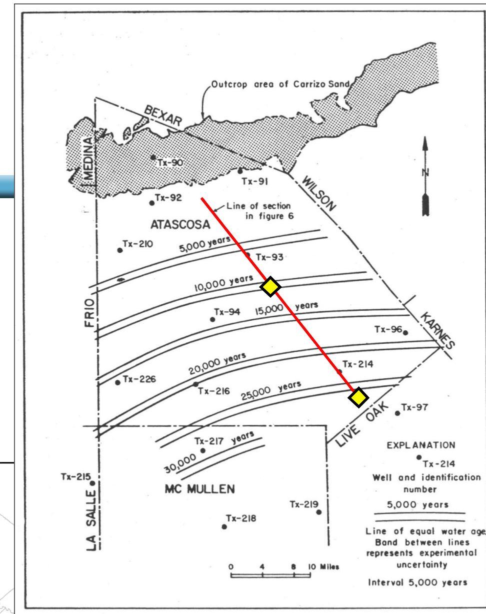
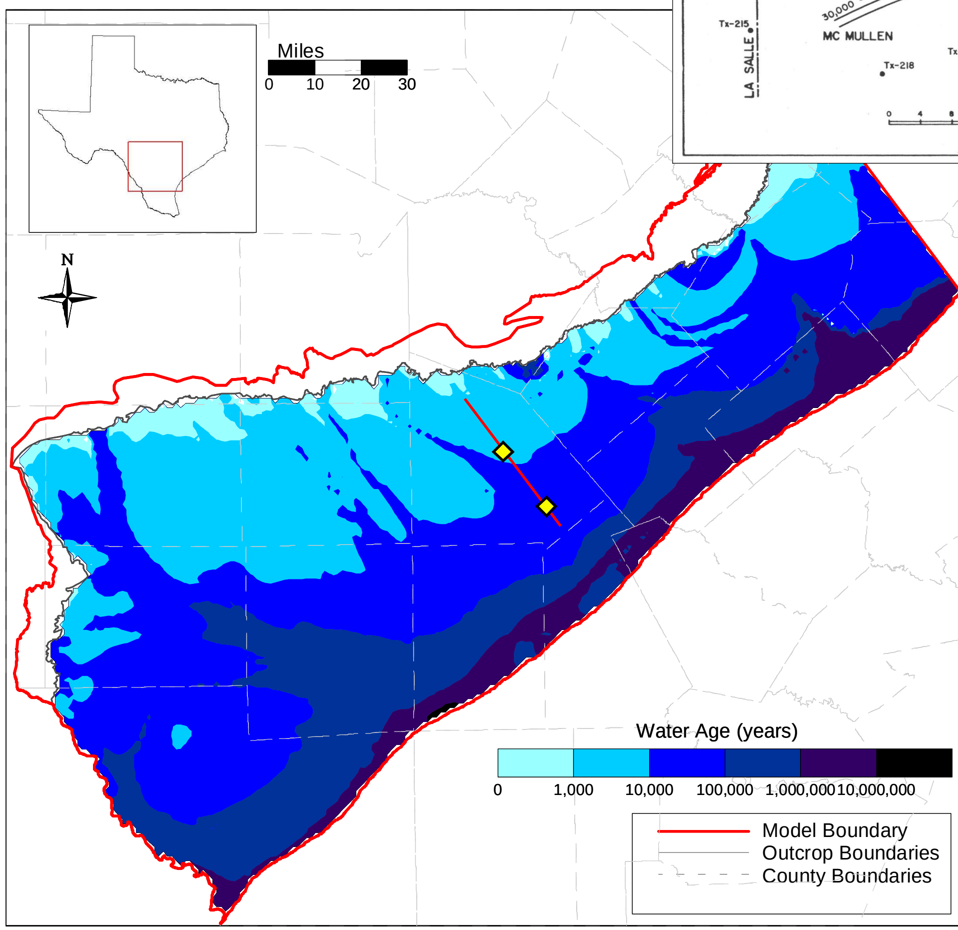
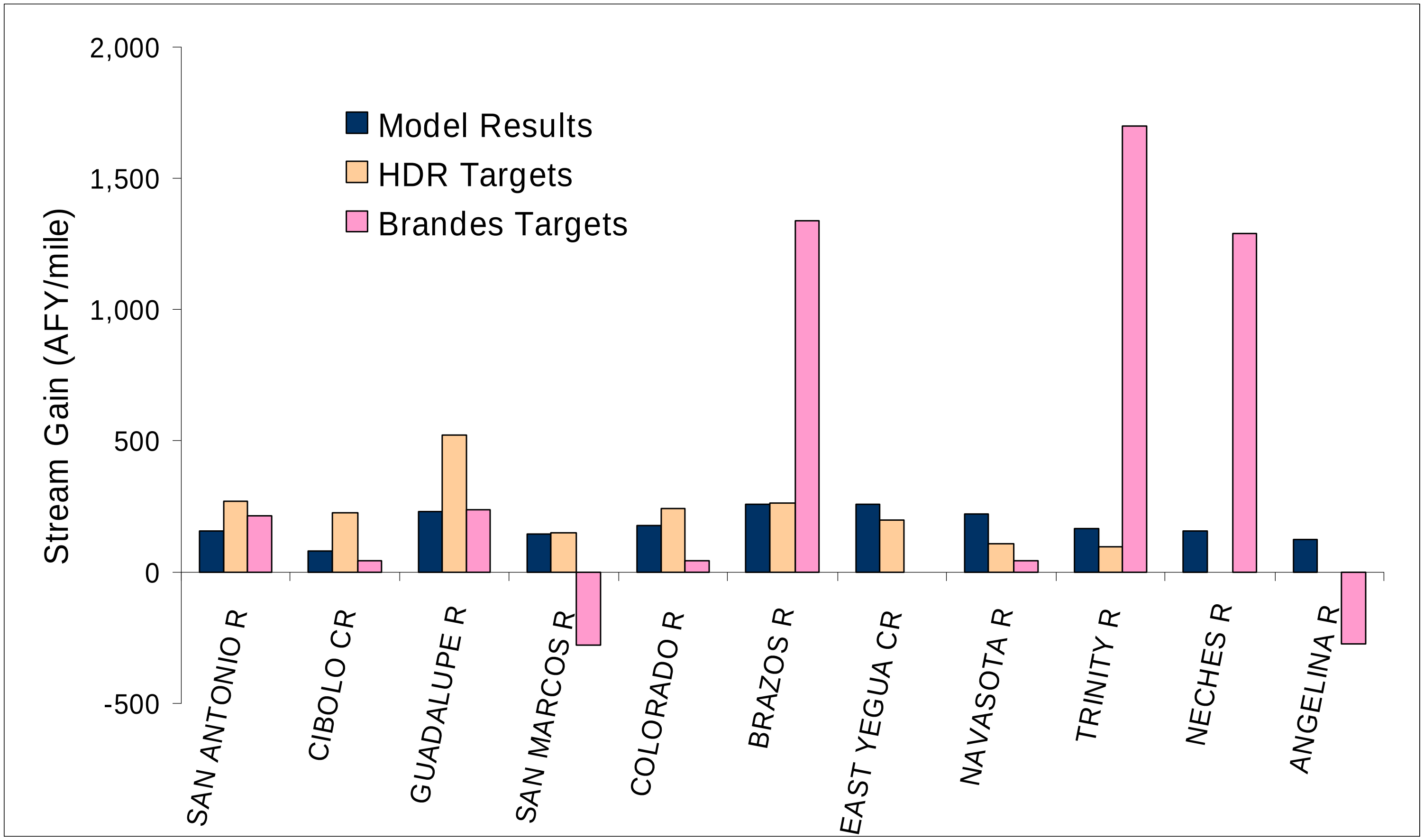
Travel Time (years)





Central GAM Stream Targets



Steady-State Calibration Statistics

Central GAM

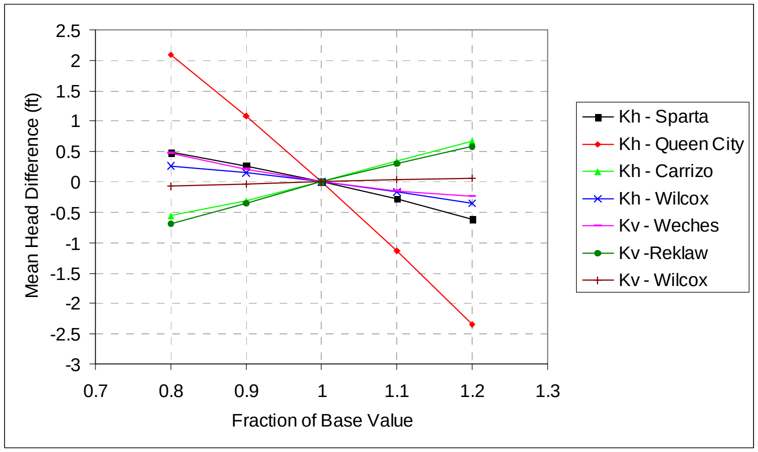
	RMSE (ft)	Range (ft)	%	ME (ft)	MAE (ft)	#Points
Layer 1 (Sparta)	29.9	378.6	7.9%	-4.3	25.4	43
Layer 3 (Queen City) All	37.7	429.0	8.8%	2.6	27.0	201
Cluster	37.7			1.6	26.9	178
Remainder	37.7			10.0	28.1	23
Layer 5 (Carrizo)	25.7	230.1	11.2%	6.2	21.0	42
Layer 7 (Simsboro)	32.4	270.0	12.0%	19.3	30.1	14

Northern GAM

Layer	ME (ft)	MAE (ft)	RMSE (ft)	Range (ft)	RMSE/Range
Layer 1 (Sparta)	-5.28	22.27	27.74	394	0.070
Layer 3 (Queen City)	-12.82	20.03	25.54	395	0.065
Layer 5 (Carrizo)	-8.25	25.96	29.72	340	0.088
Layer 6 (upper Wilcox)	7.85	29.36	33.43	264	0.126
Layer 7 (middle Wilcox)	9.39	24.44	32.48	444	0.073

Sensitivity

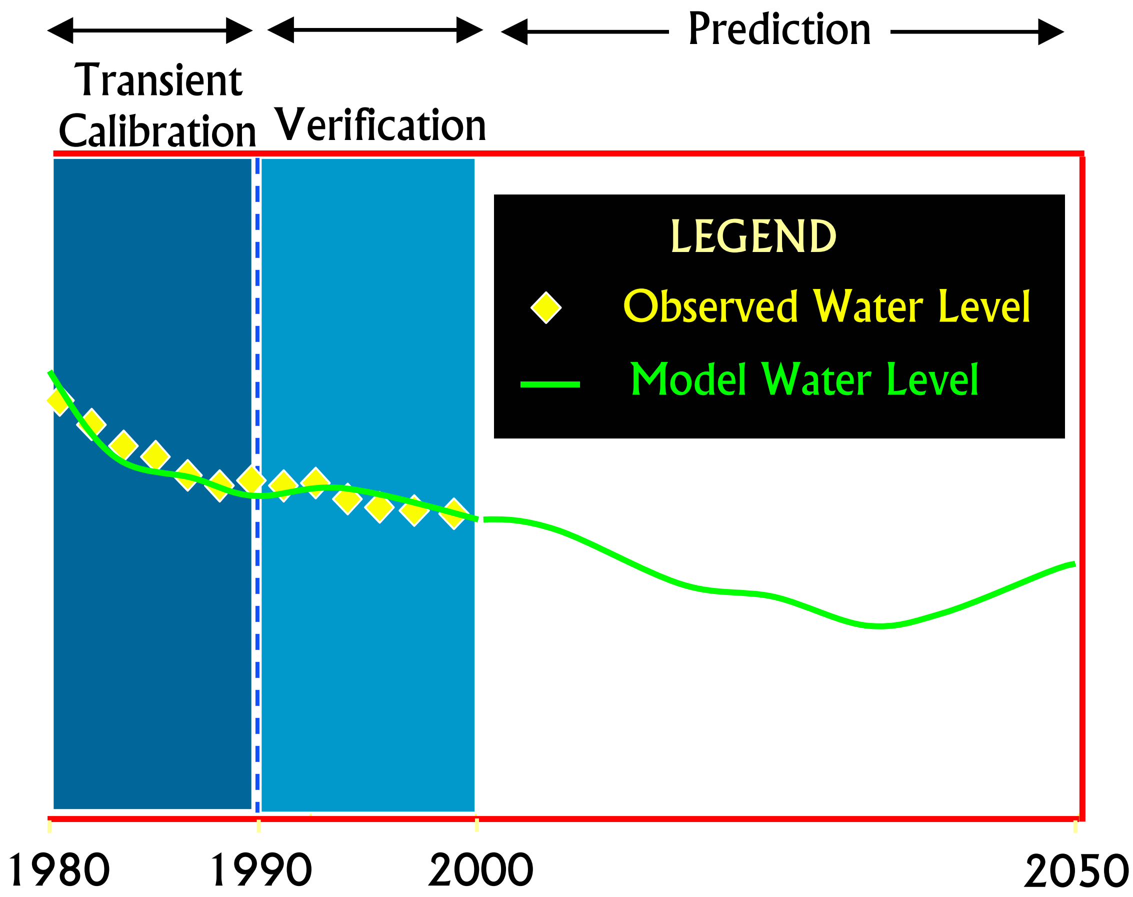
- Sparta
  - Dominated by GHB head and K
  - In North, recharge (+), sparta Kh (-)
- Queen City
  - Still impacted by GHB head and K
  - S & Central – Kv Reklaw (+), Kv Weches (-)
  - North – Recharge (+), Queen City Kh (-)
- Carrizo
  - Removed from dominance of GHBs
  - Recharge (+), Reklaw Kv (-)



Steady-State Flow Balance Summary

GAM	Recharge (AFY)	GWET (%)	Streams/drains (%)	Confined flow (%)
South	218510	8%	69%	23%
Central	561600	34%	64%	8%
North	1187821	50%	48%	2%
	Recharge (AFY)	GWET (AFY)	Streams/drains (AFY)	Confined flow (AFY)
South	218510	16607	151209	50913
Central	561600	191400	357500	43900
North	1187821	593910	570154	23756

Transient Model



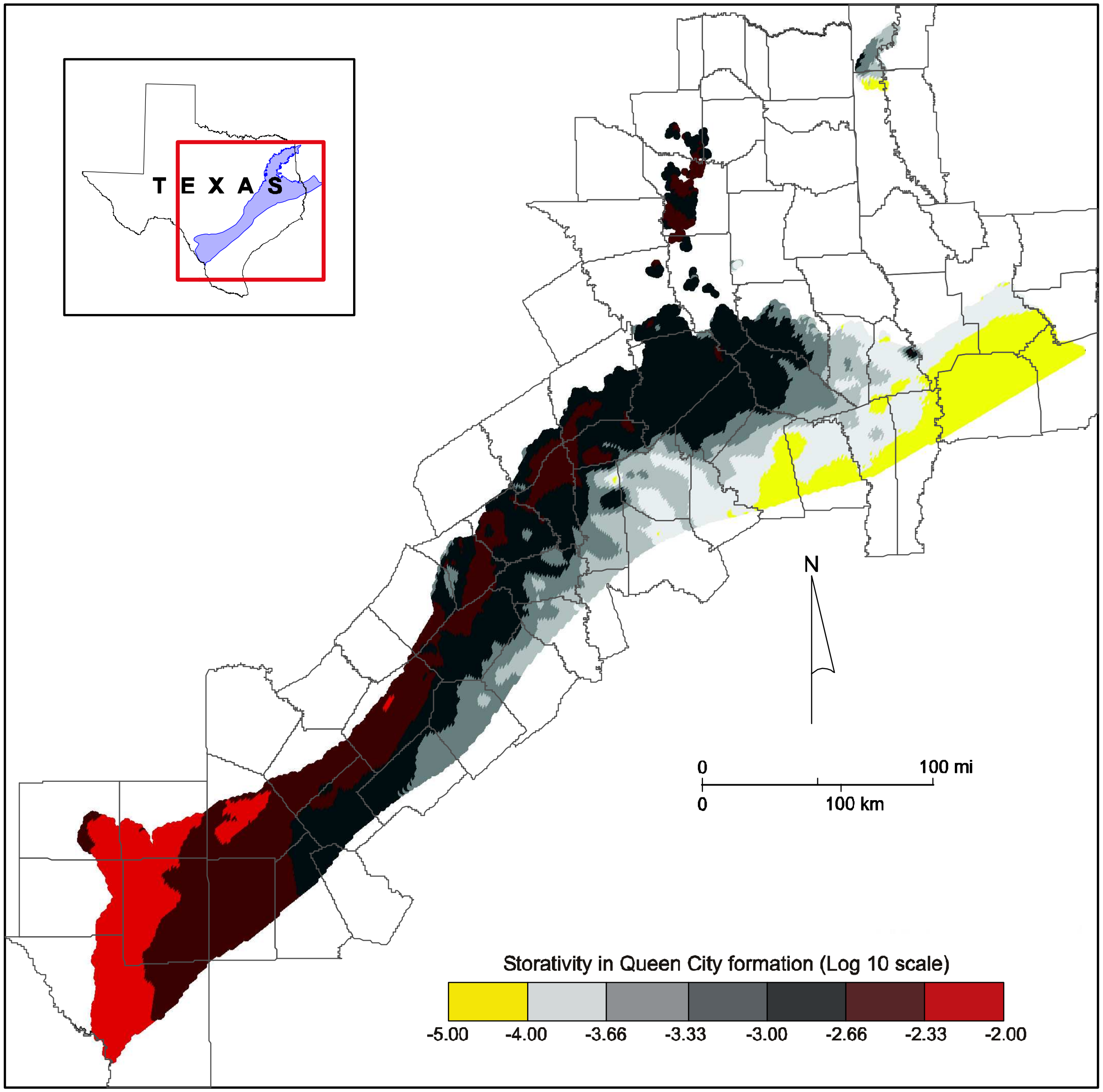
Storativity

- Storativity = Ss * b
- Specific Storage is f (depth, lithology)

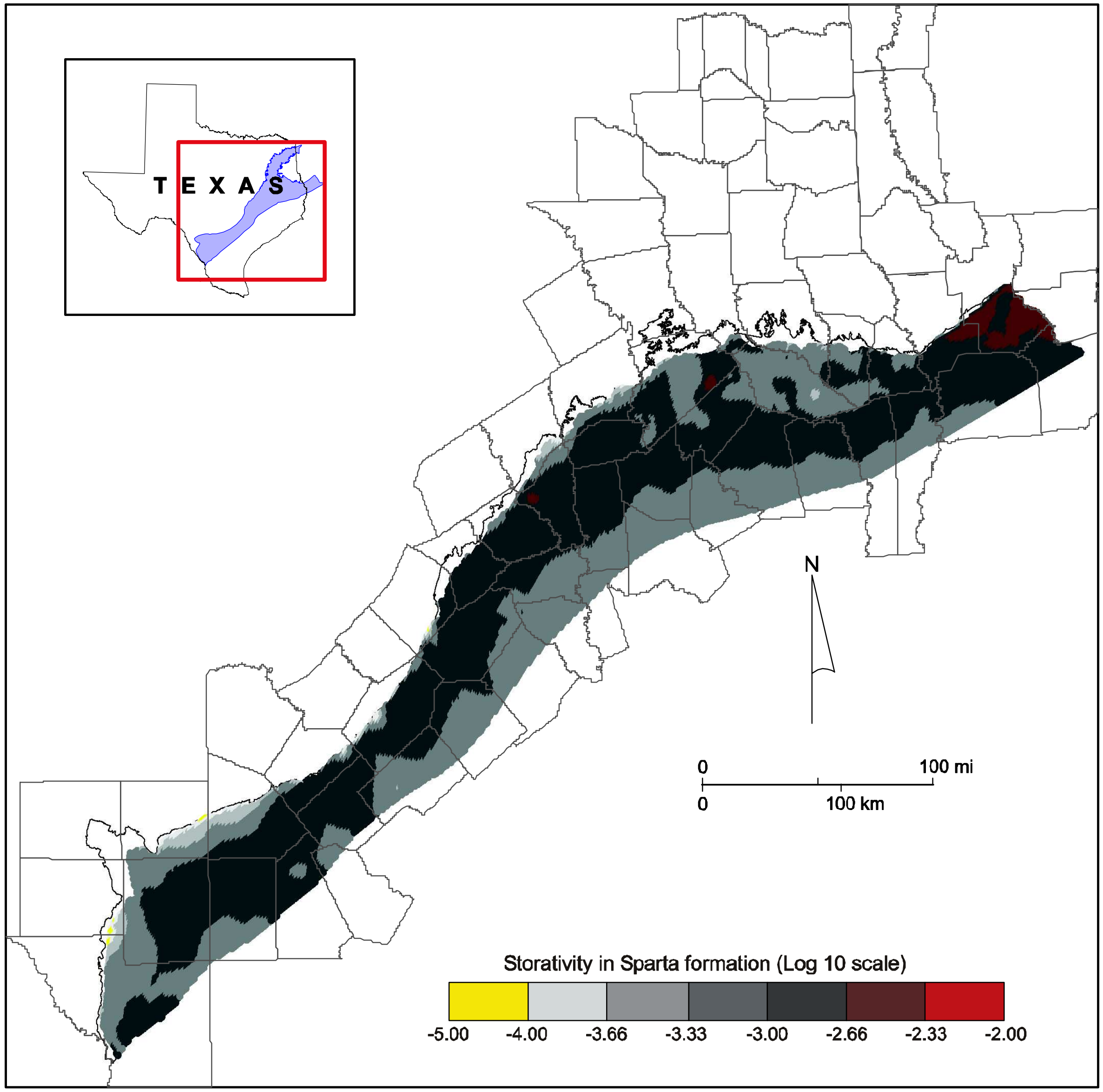
$$Ss = max\left[10^{-\frac{D_{up}-D}{D_{down}}}\left(SF \times Ss_{sand} + (1 - SF)Ss_{clay}\right), Ss_{min}\right]$$

Queen City Storativity

- Method accounts for lithology and depth
- Prevents non-physical matrix compressibility



Sparta Storativity



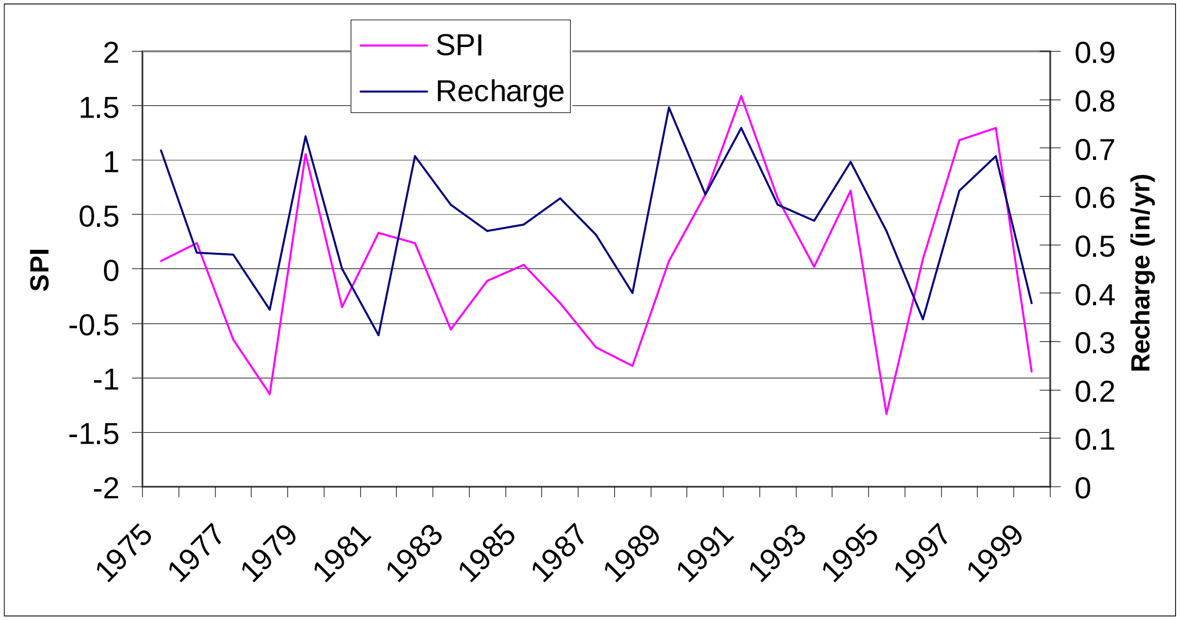
Transient Recharge Implementation

- Based upon an annual SPI
- R(t) = ((SPI(t) * 1/3) + 1) * Rss
- The limits are constrained by Scanlon (2003)
- The method reverts to the mean

Validation in Gonzales Co.

SPI from nearby gage, not used
To generate transient recharge.

Method shows good regional trends
and reverts to the SS recharge at
SPI = 0.

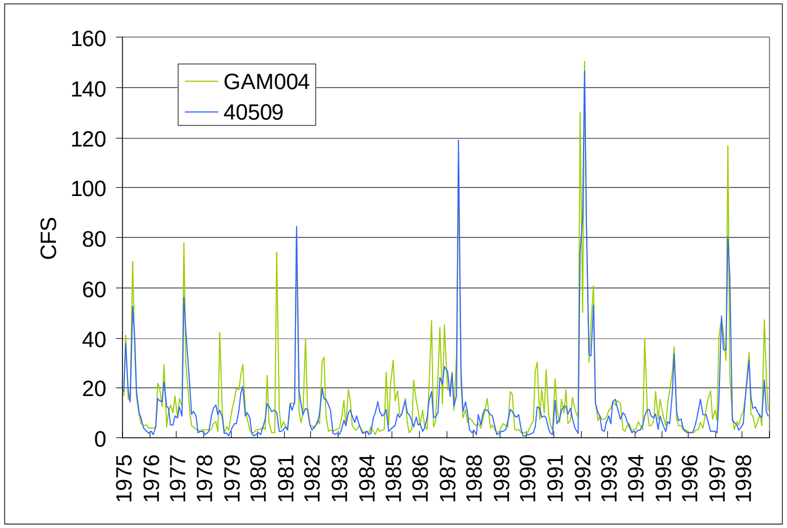


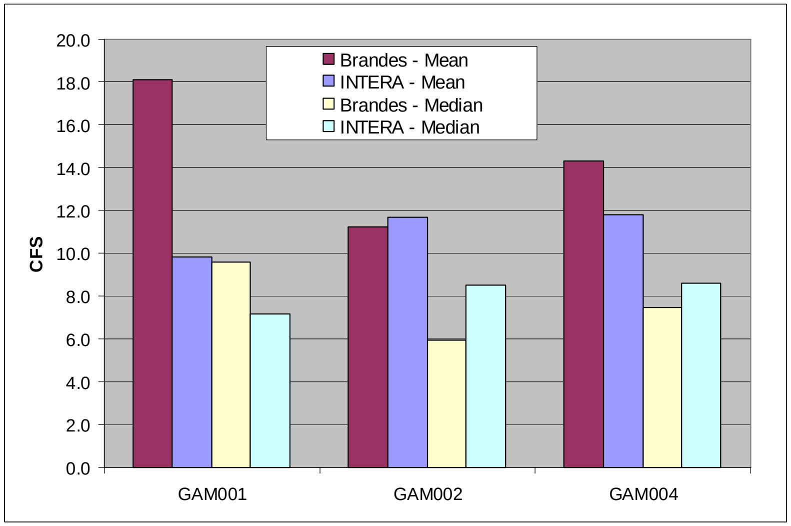
Transient Model Boundaries

- Stream Headwaters
- Lateral Boundaries
- Younger sediment GHBs

Stream Headwaters - Approach

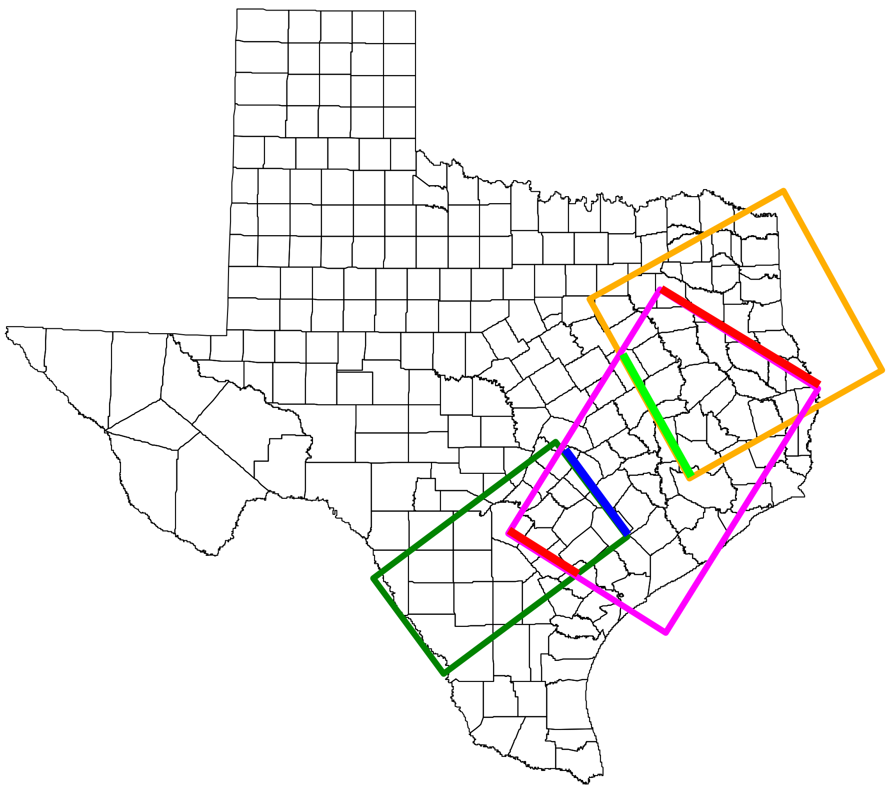
- Monthly stream flows are logarithmically distributed
- Average stream flows from RF1 dataset are accurate
- Proximal streams react similarly. Stream 2 reacts similarly to Stream 1
- $Stdev(Log(Q_2)) = Stdev(Log(Q_1))$





Lateral Boundaries

- Lateral Boundaries are treated as General Head Boundaries
- We exchanged lateral heads between models



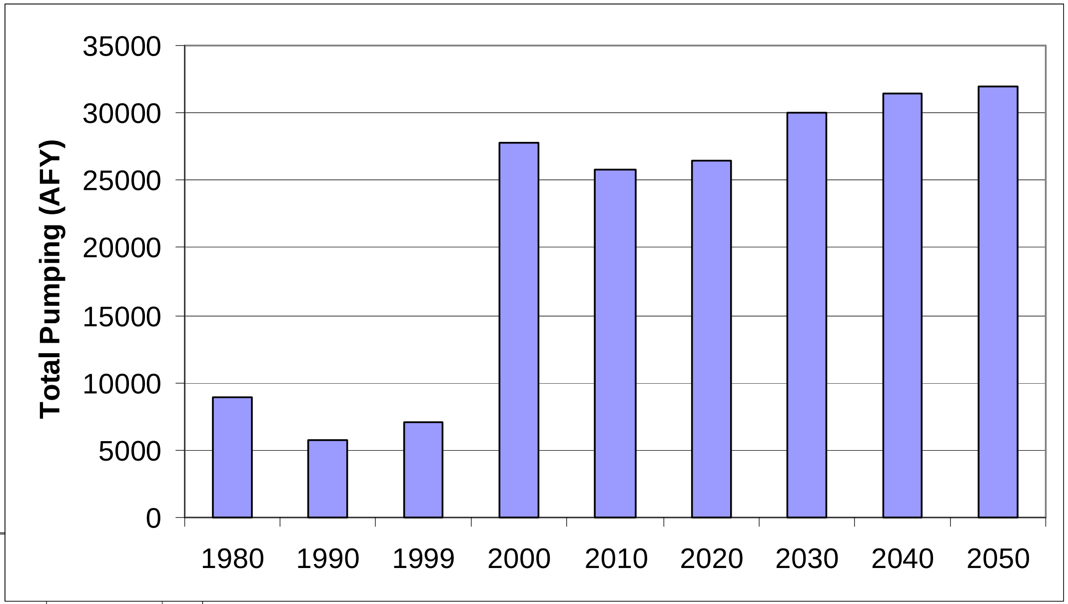
Younger Wedge - GHB

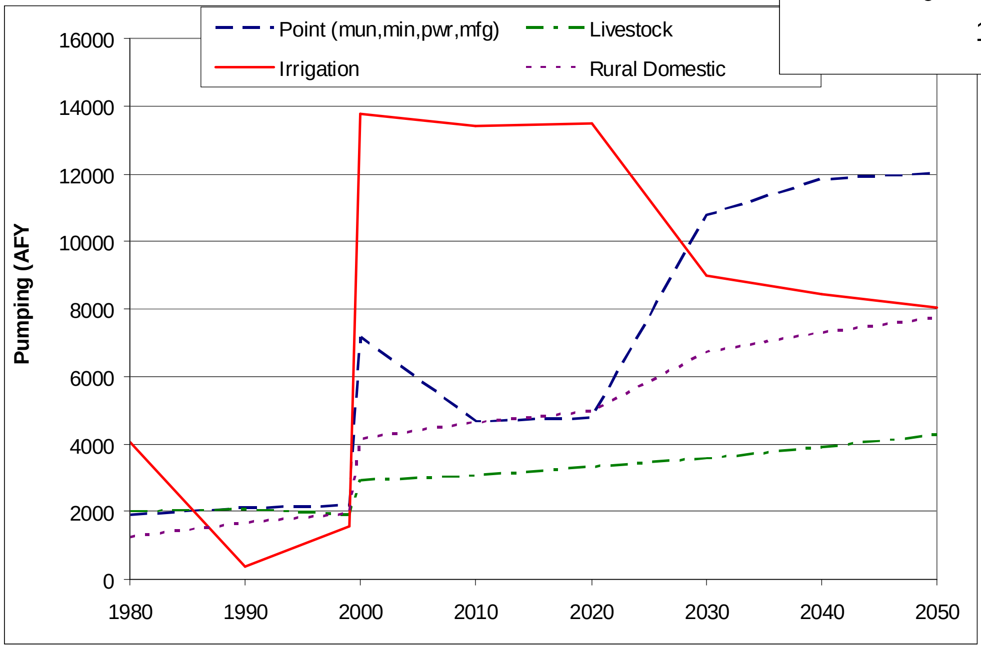
- Steady-state heads were estimated based upon the RASA water table regression.
- Conductances are based upon harmonic mean of overlying lithologies
- Transient heads adjusted down approximately 20 – 35 feet from SS
  - Conductance same as steady-state model

Pumping

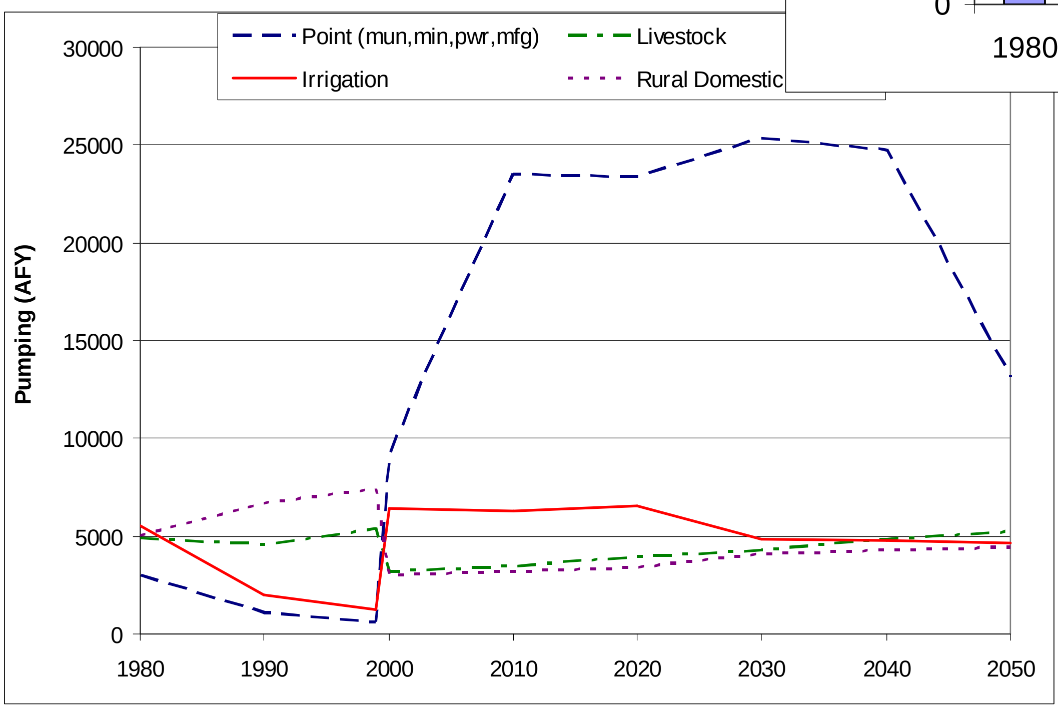
- Used SOP originally developed by Parsons based upon TWDB guidance
- Pumping in the non-overlap regions in the Carrizo-Wilcox was largely unaffected with the exception of County-Other
- With the addition of Queen City and Sparta aquifers, County-Other was re-allocated to account for modeling of additional aquifers
- Pumping distributions in overlap zones were made consistent based upon fidelity to TWDB database

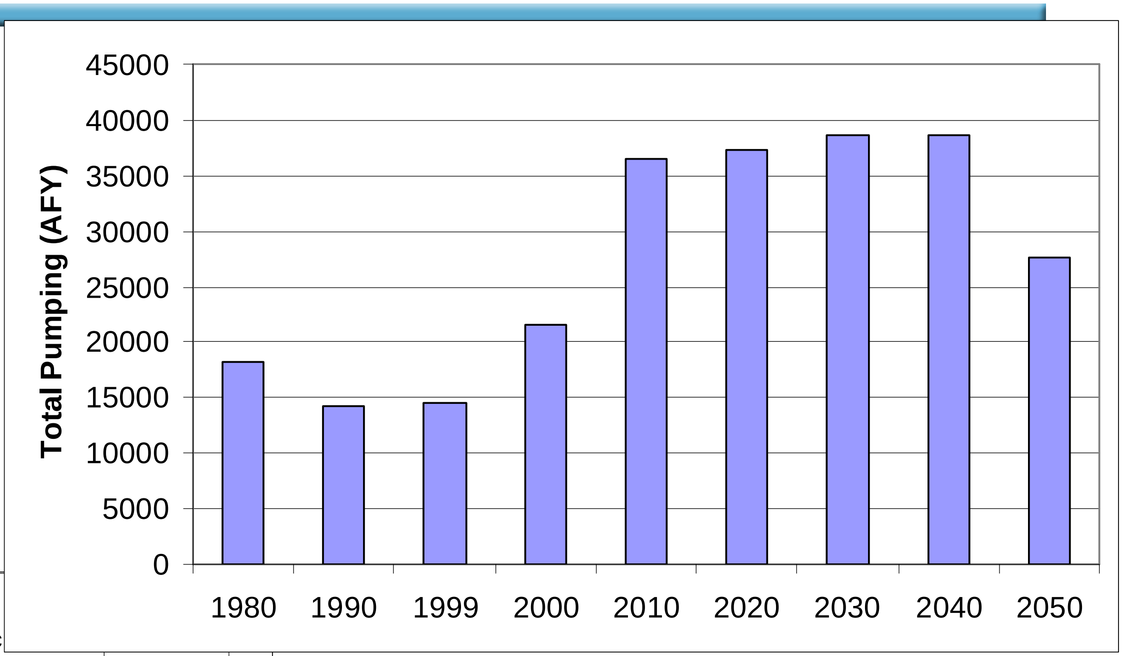
Sparta Pumping



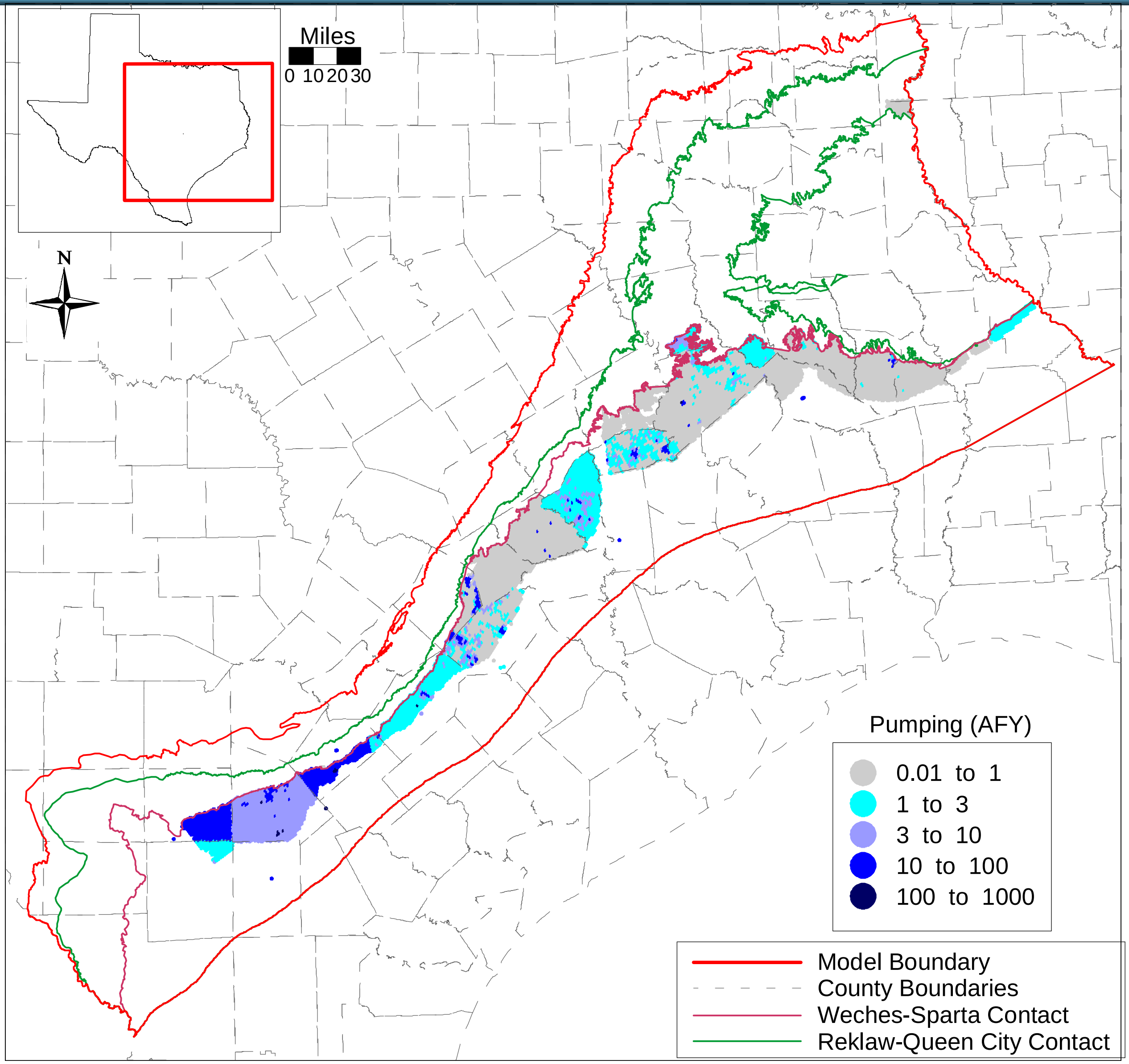


Queen City Pumping

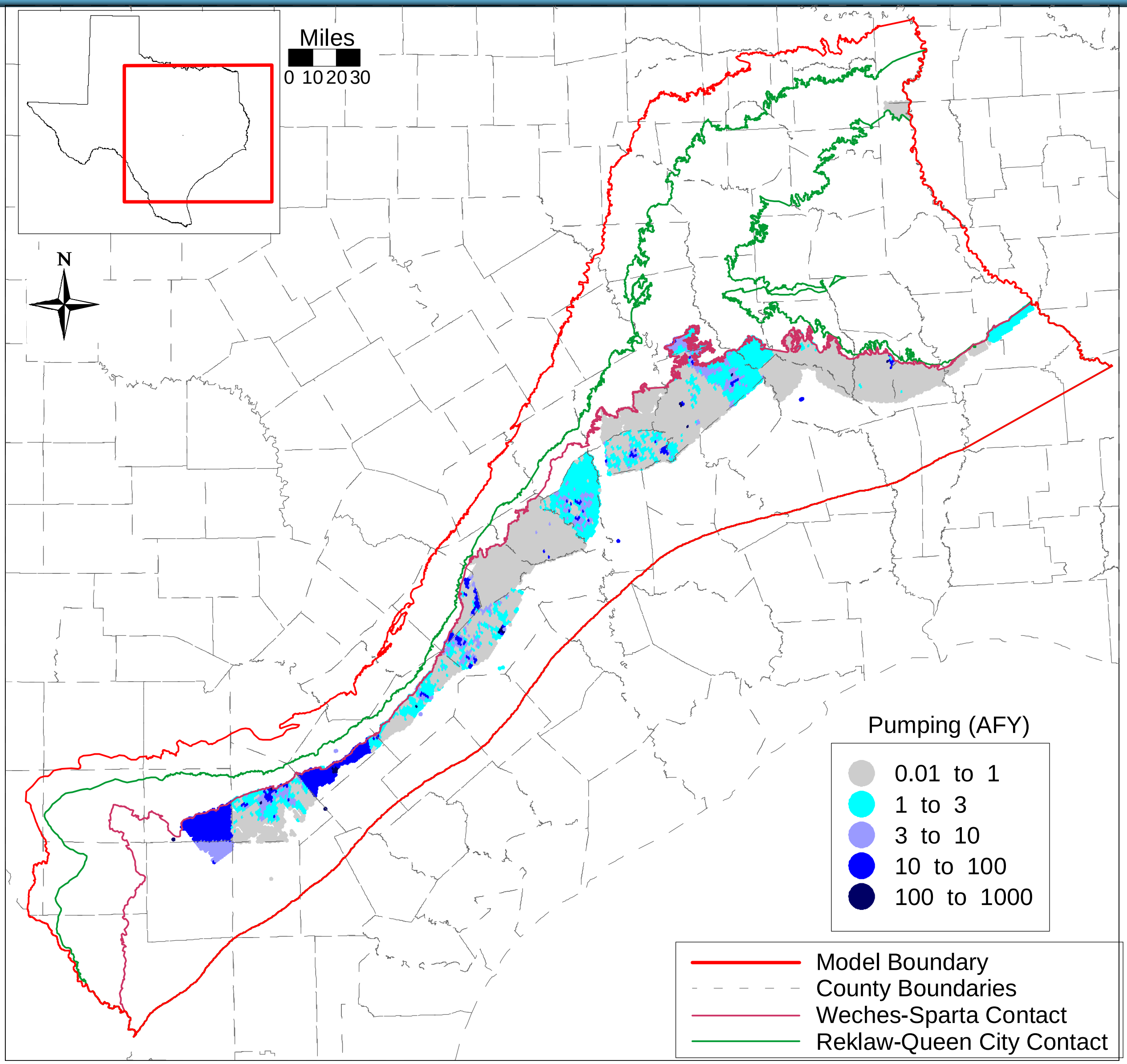




Sparta 2000

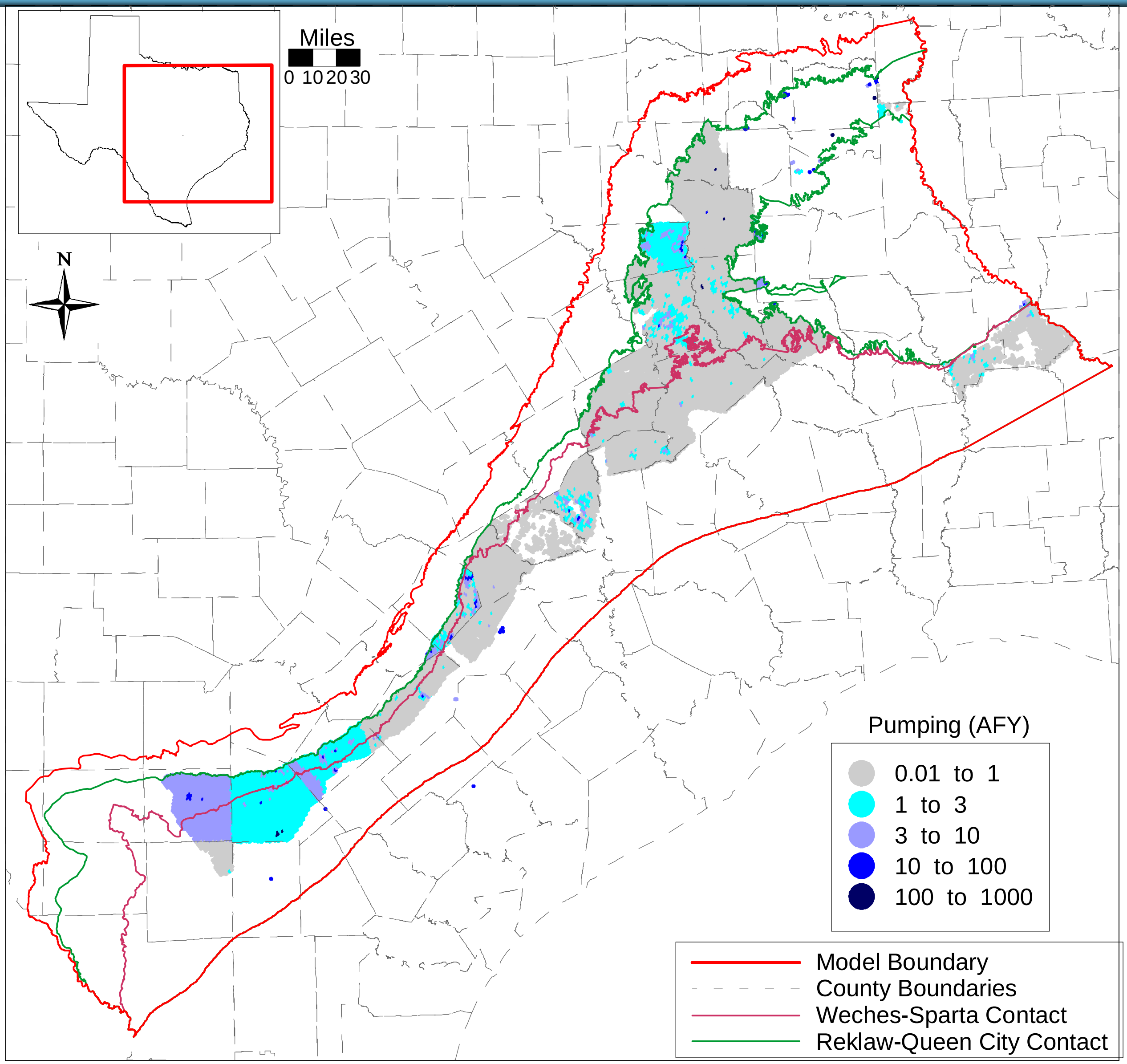

Miles
0 10 20 30
N
Pumping (AFY)
0.01 to 1
1 to 3
3 to 10
10 to 100
100 to 1000
Model Boundary
County Boundaries
Weches-Sparta Contact
Reklaw-Queen City Contact

Sparta 2050

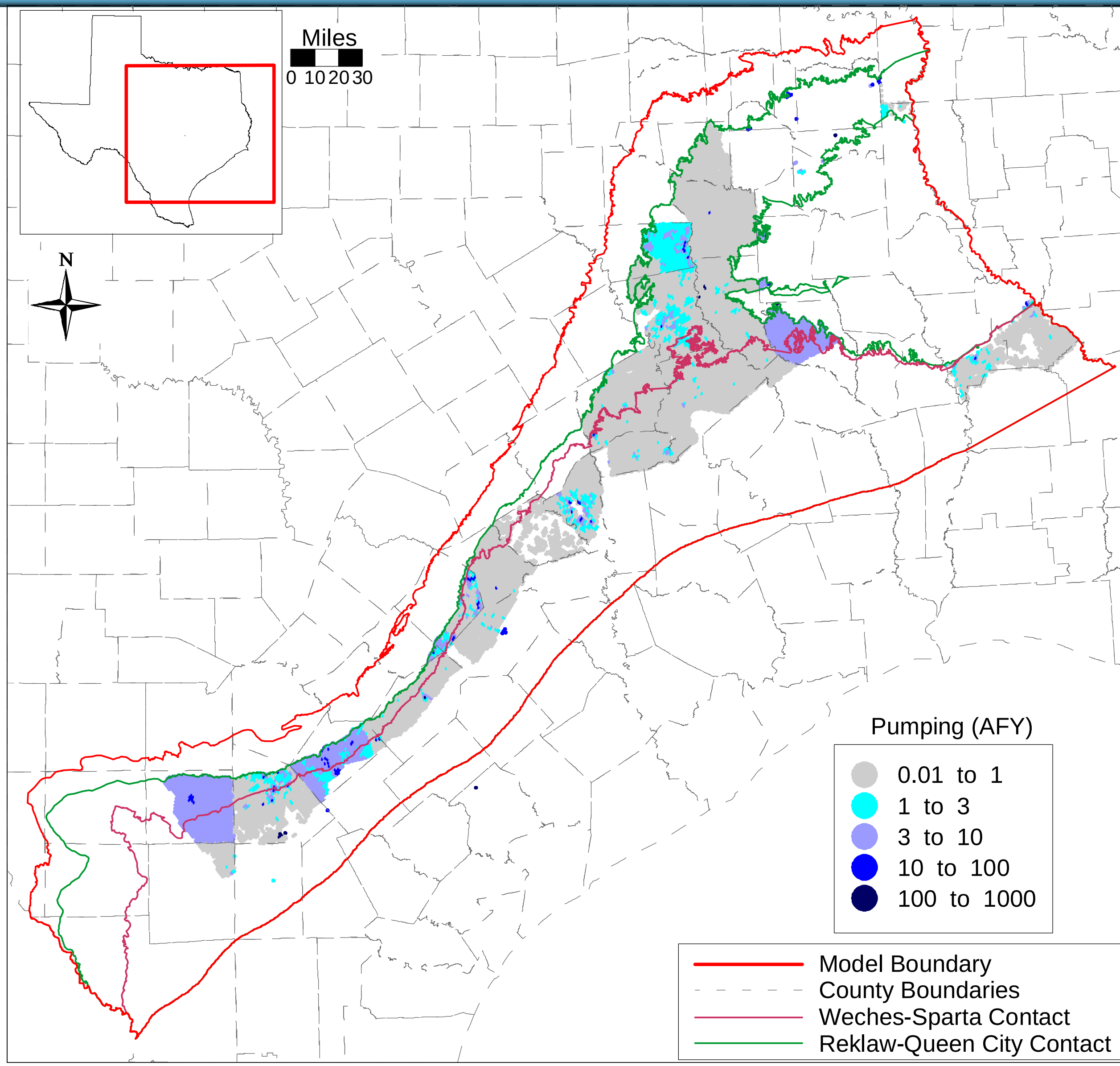


Miles
0 10 20 30
N
Pumping (AFY)
0.01 to 1
1 to 3
3 to 10
10 to 100
100 to 1000
Model Boundary
County Boundaries
Weches-Sparta Contact
Reklaw-Queen City Contact

Queen City 2000



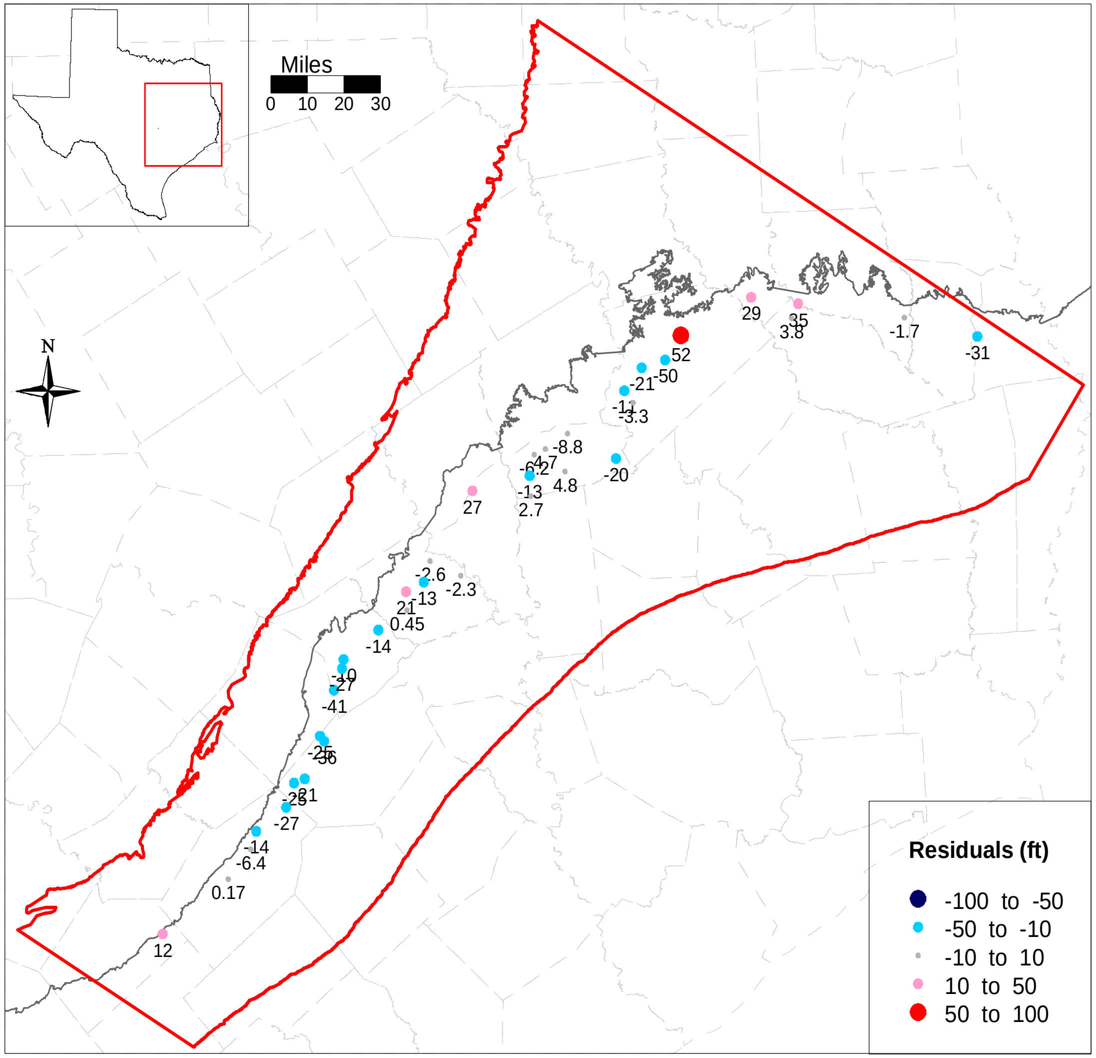
Queen City 2050

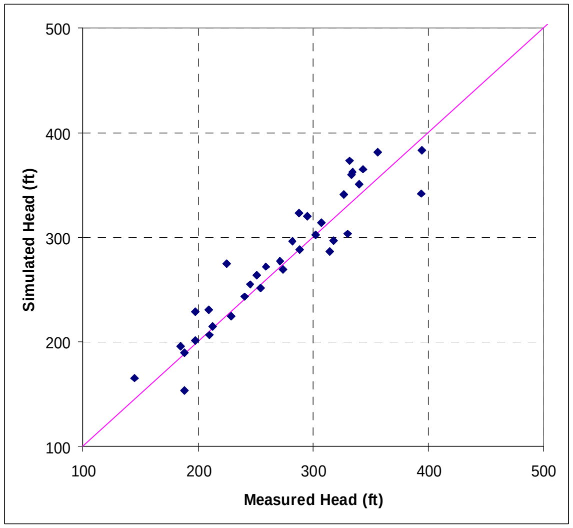


Transient Model

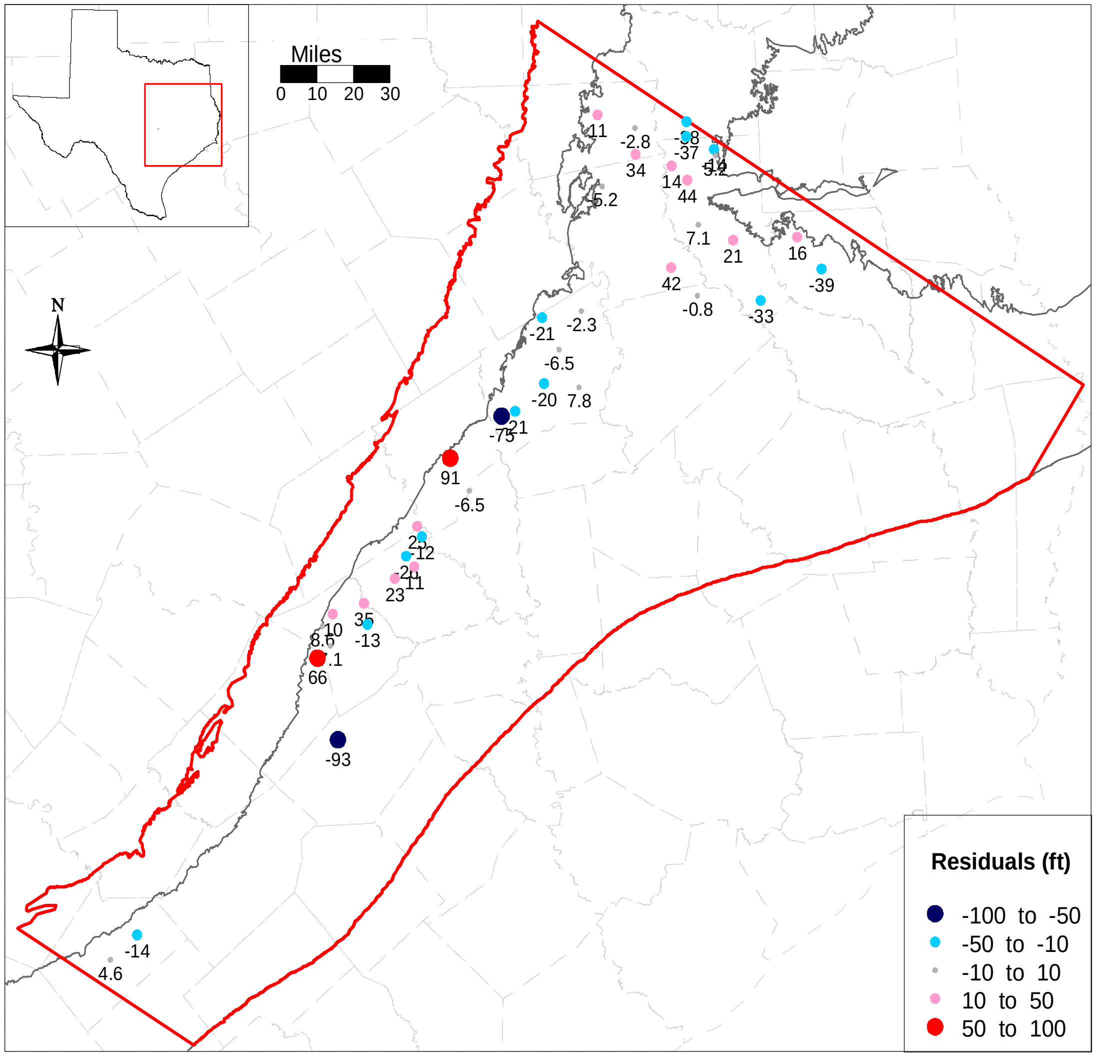
- Calibration Period – 1980 through 1989
- Verification Period - 1990 through 1999
- Approach to Calibration
  - Use multiple performance measures
    - Statistics
    - Head surfaces
    - Stream Gain and Loss
  - We use regularization (interpolation functions) to estimate parameters trying to limit the degree of unknowns
    - Kh depth trend
    - Storage depth trend and endpoints
    - Recharge factors and topographic scalar
  - Parameters poorly known were preferentially altered if they were important (the model responded to them)

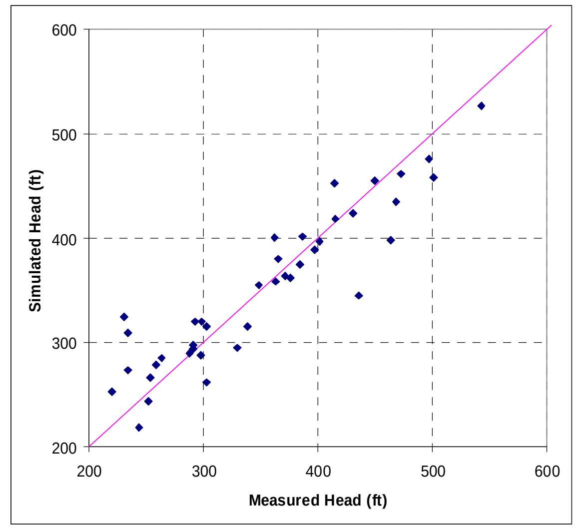
Sparta End of Calibration 1989- Central





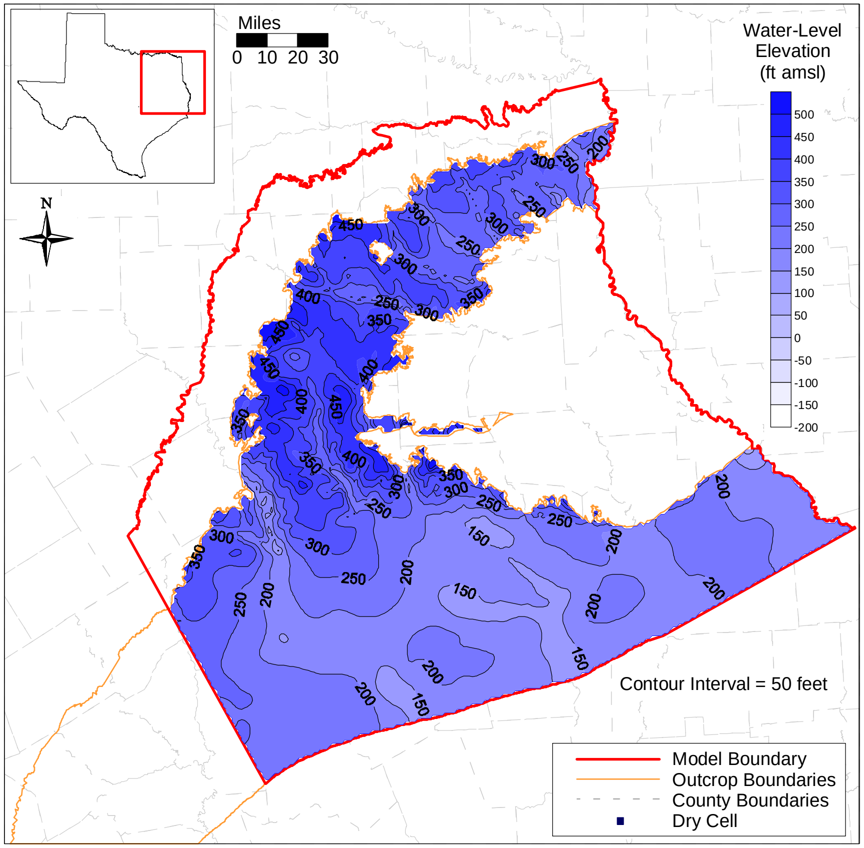
Queen City End of Verification 1999-Central



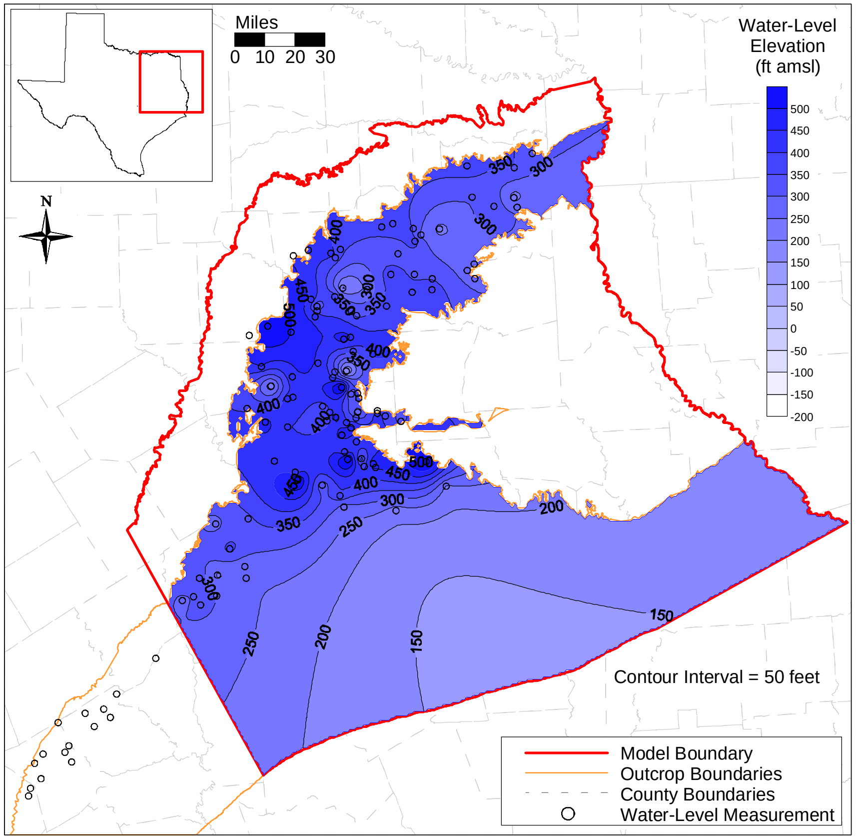


Queen City End of Calibration 1989- North

Simulated

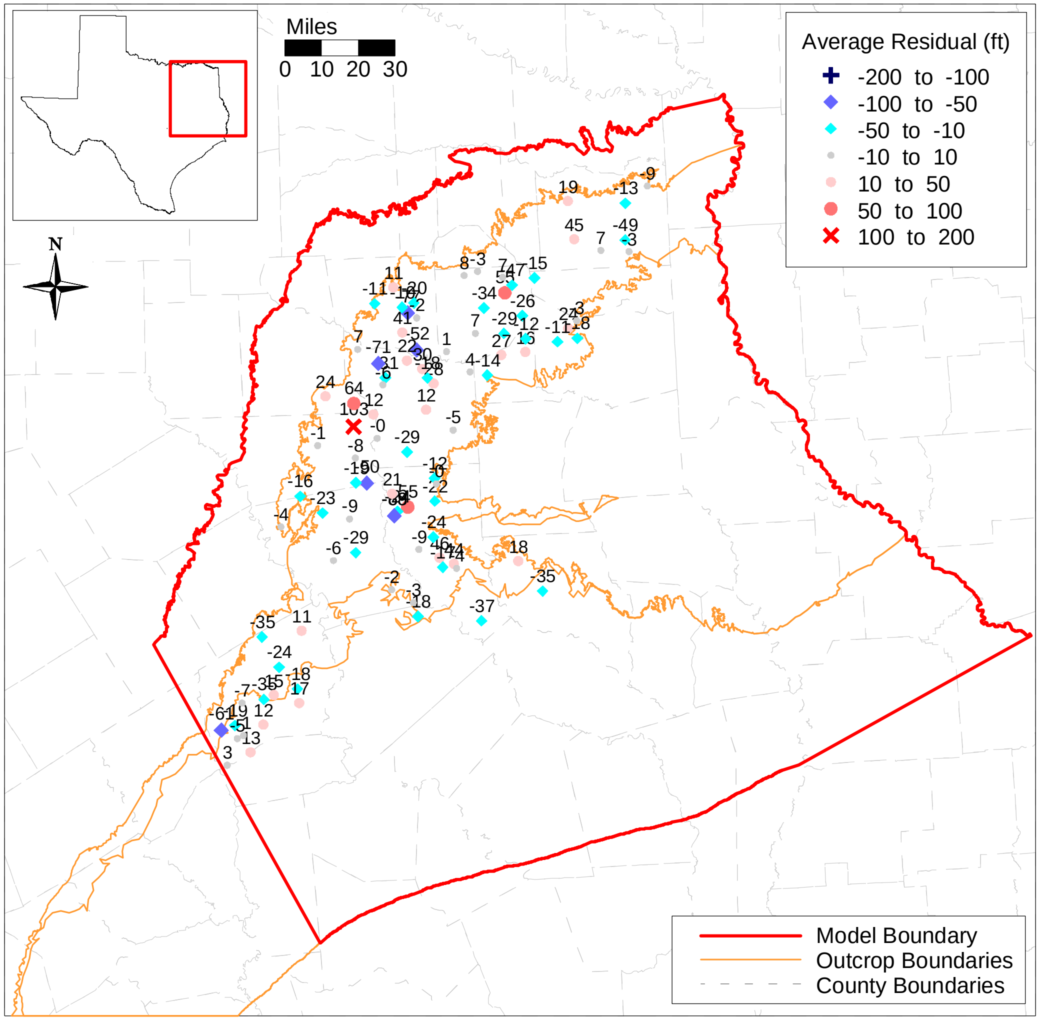


Observed

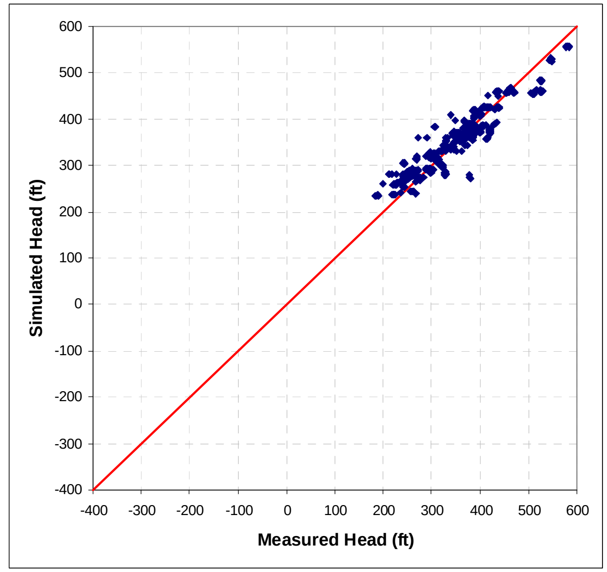


Queen City End of Calibration 1989- North

Residuals



Crossplot



Transient Calibration Statistics - North

Calibration period (1980-1989)						
	Layer 1	**Layer 3**	**Layer 5**	**Layer 6**	**Layer 7**	**Layer 8**
ME	-0.31	-3.56	3.42	-0.29	4.24	-10.06
MAE	15.56	21.48	24.77	20.90	26.24	20.03
RMSE	20.66	28.19	34.24	27.58	33.54	24.18
Range	352	401	742	470	516	298
RMSE/Range	0.059	0.070	0.046	0.059	0.065	0.081

Verification period (1990-1999)						
	Layer 1	**Layer 3**	**Layer 5**	**Layer 6**	**Layer 7**	**Layer 8**
ME	1.31	-4.78	-2.28	-7.05	0.19	-18.59
MAE	15.09	23.62	28.18	24.42	28.59	25.27
RMSE	21.15	30.76	41.21	34.24	36.64	30.59
Range	374	412	820	643	515	289
RMSE/Range	0.057	0.075	0.050	0.053	0.071	0.106

Transient Calibration Statistics – Central

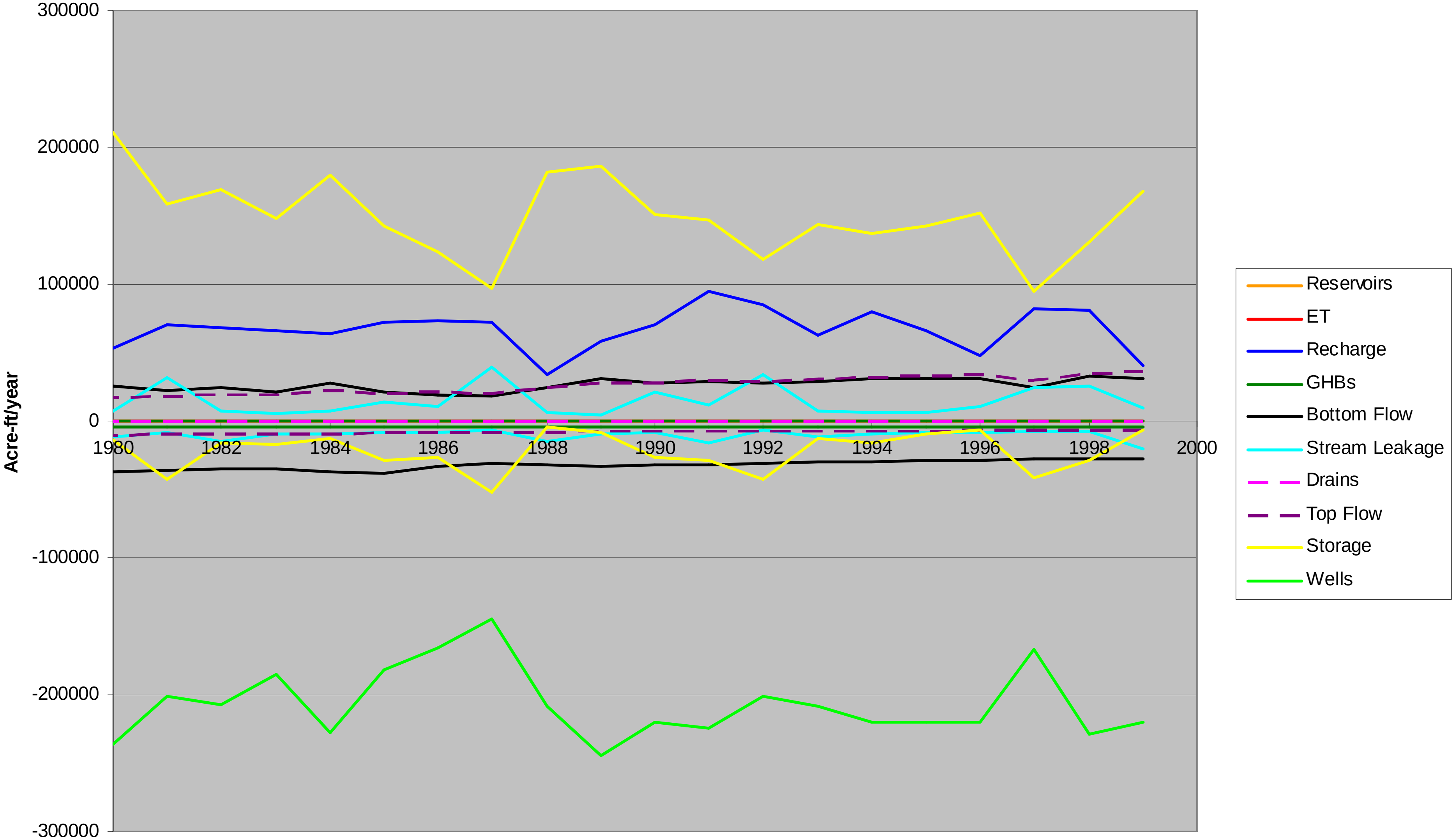
	RMSE (ft)	Range (ft)	%	ME (ft)	MAE (ft)	#points
Calibration Period						
Layer 1 (Sparta)	22.1	249.9	8.86%	6.6	17.3	36
Layer 3 (Queen City)	26.5	328.3	8.06%	3.4	20.8	62
Layer 5 (Carrizo)	36.3	730.1	4.97%	6.8	23.0	115
Layer 7 (Simsboro)	30.8	362.7	8.48%	11.9	22.3	42
Verification Period						
Layer 1 (Sparta)	23.8	236.7	10.1%	3.8	18.2	30
Layer 3 (Queen City)	33.1	322.4	10.3%	-0.1	24.1	40
Layer 5 (Carrizo)	31.8	747.2	4.3%	14.7	23.6	80
Layer 7 (Simsboro)	43.2	498.0	8.7%	17.3	31.3	32

Transient Calibration Statistics - South

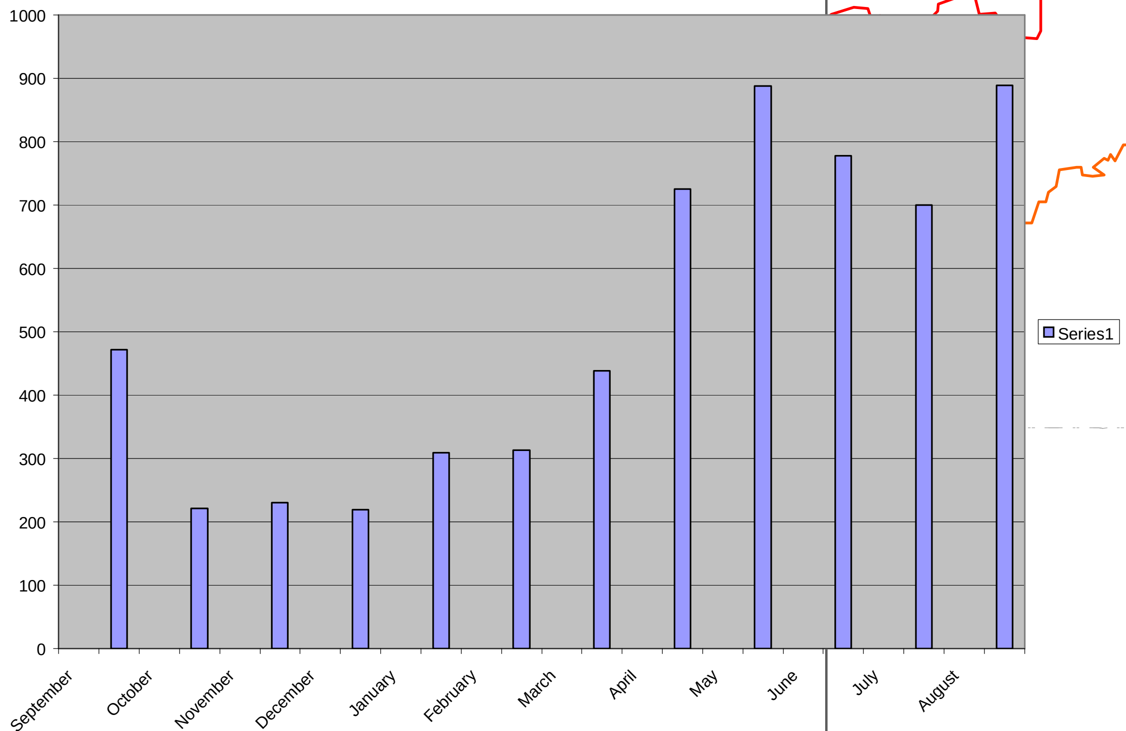
Calibration period (1980-1989)						
Layer	**Count**	**ME (ft)**	**MAE (ft)**	**RMSE (ft)**	**Range (ft)**	**RMSE/ Range**
1	204	-3.2	18.2	22.9	285.6	0.080
3	189	-0.7	15.5	18.1	228.9	0.079
5	1325	0.7	24.6	33.1	509.5	0.065

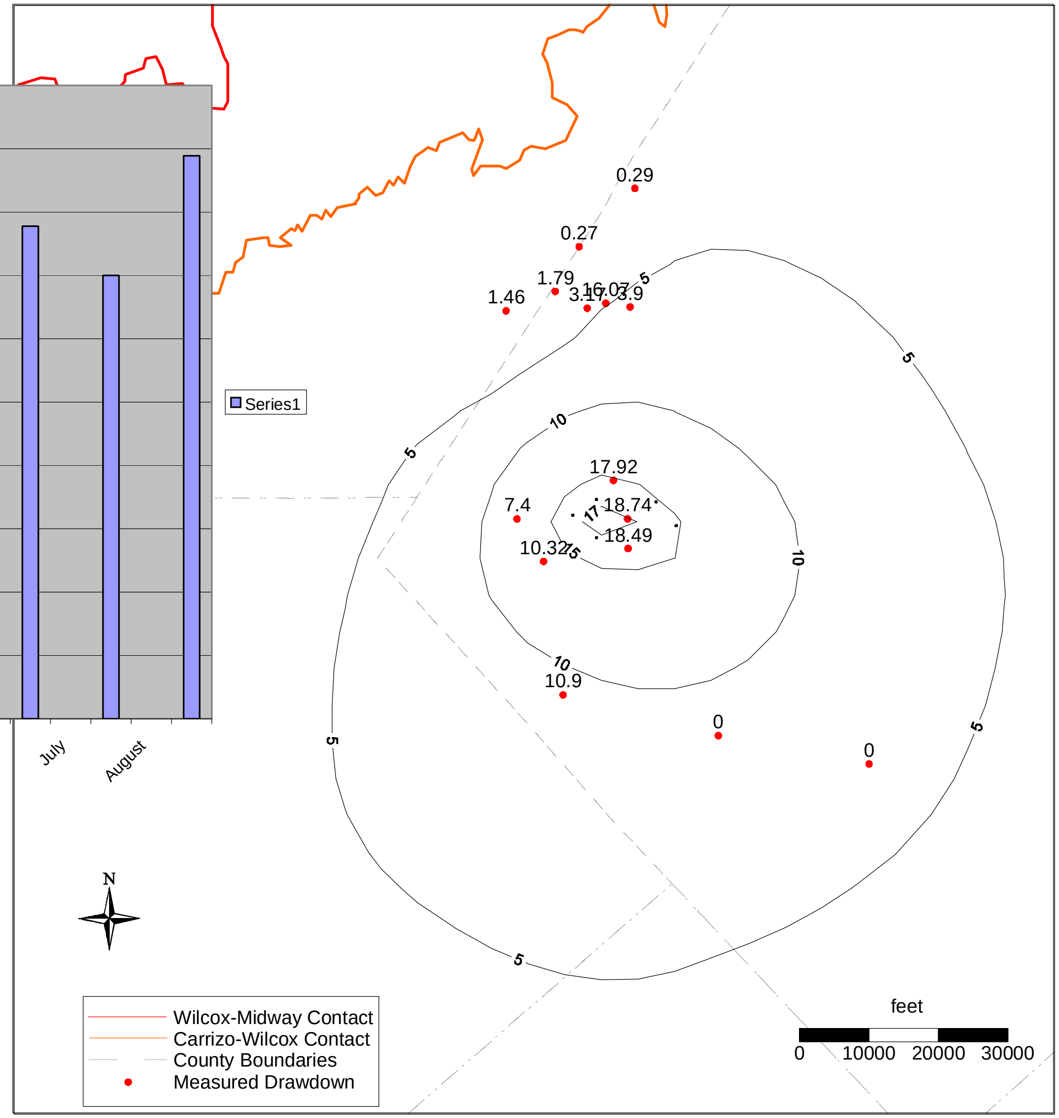
Verification period (1990-1999)						
Layer	**Count**	**ME (ft)**	**MAE (ft)**	**RMSE (ft)**	**Range (ft)**	**RMSE/ Range**
1	133	-2.4	14.9	19.1	207.4	0.092
3	111	-5.7	18.3	21.6	221.5	0.097
5	883	4.3	35.1	47.6	564.8	0.084

Carrizo Flow Balance



Schertz-Seguin (September 2002-2003)

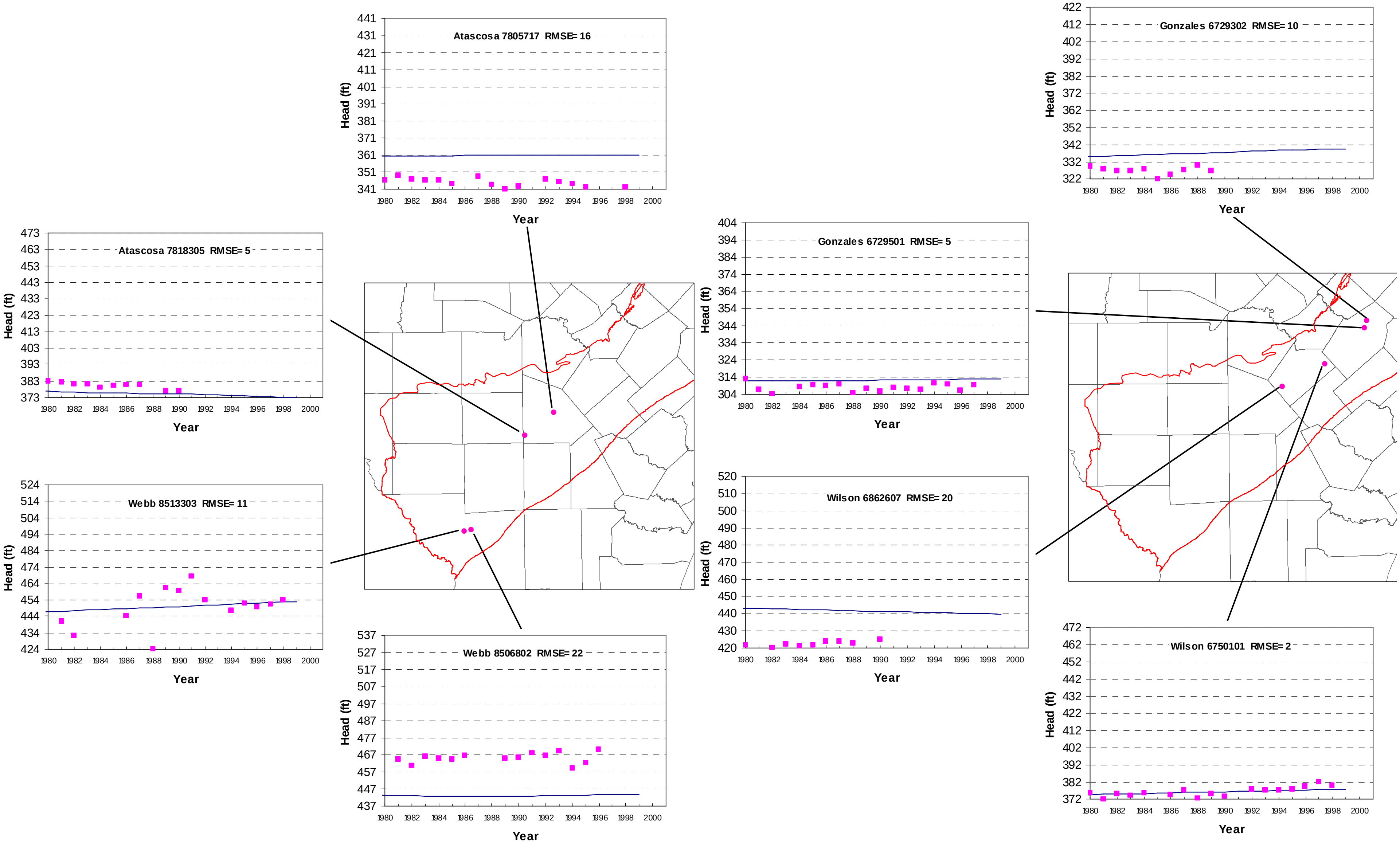




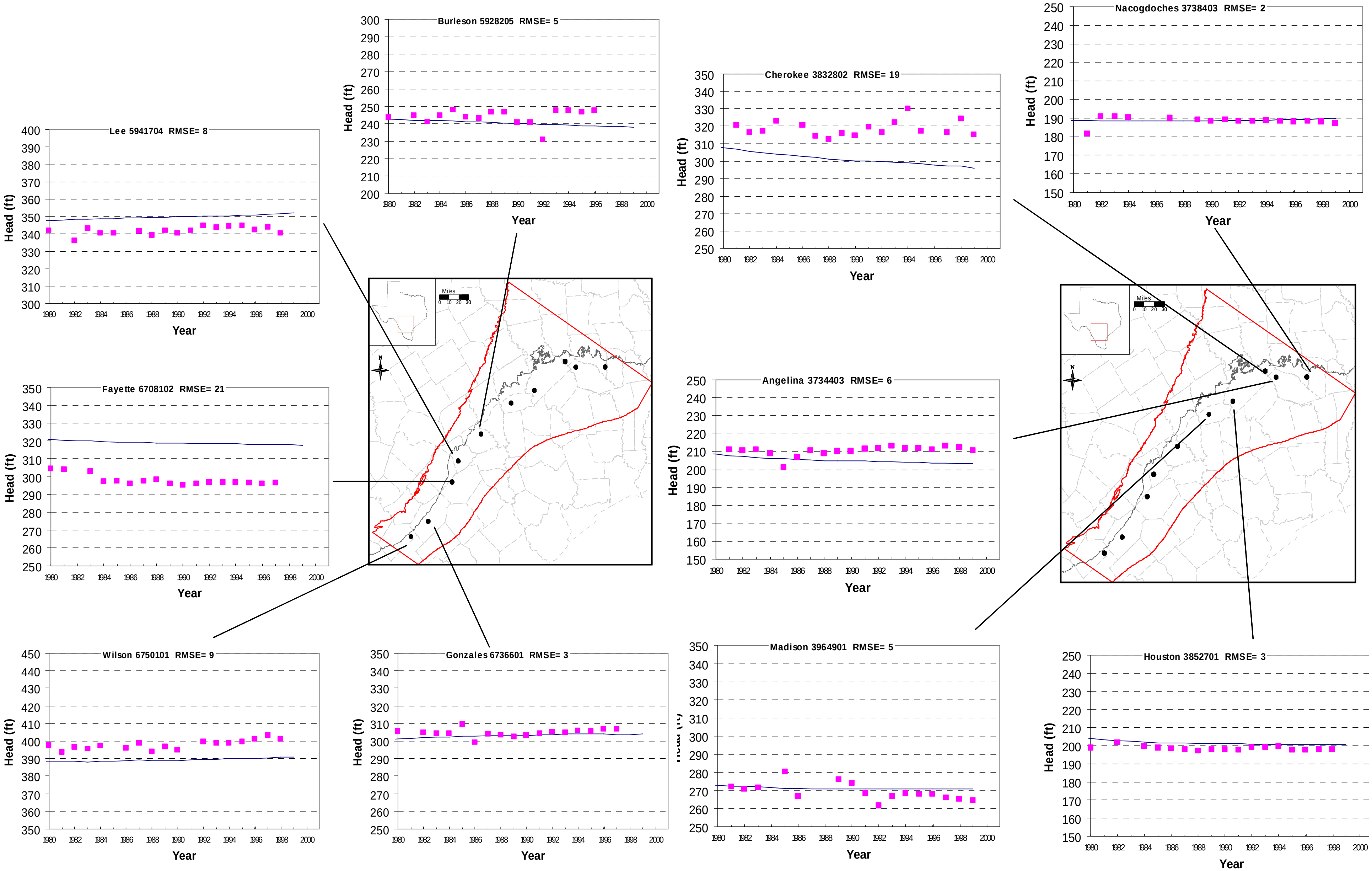
Hydrographs

- Combined error in absolute head values is on the order of 30 to 50 feet:
  - Grid elevation errors
  - LSD errors
  - Scale errors
    - effective wellbore radius,
    - vertical gradients
- Both trend and magnitude should be considered
- Offsets in magnitude of 30 feet are within the error defined above

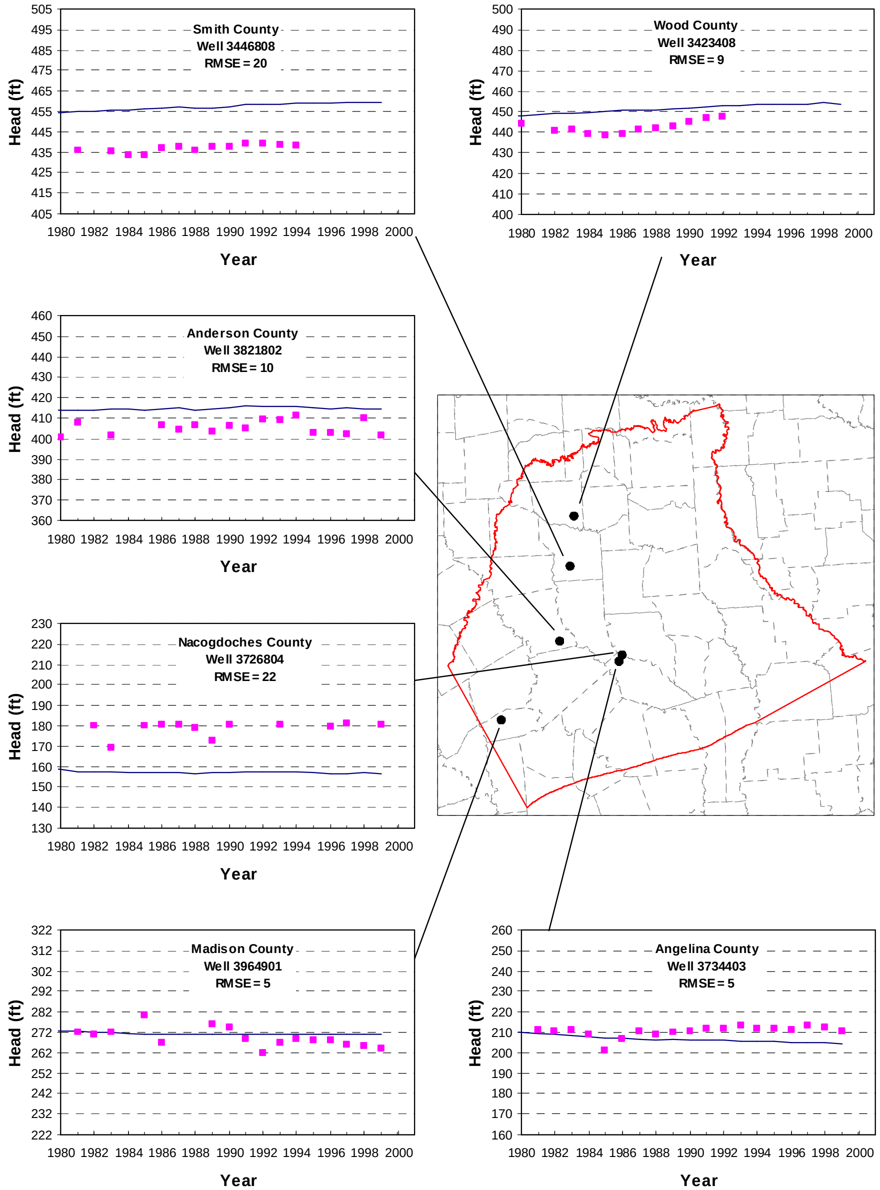
Sparta Aquifer – Southern Region



Sparta Aquifer – Central Region

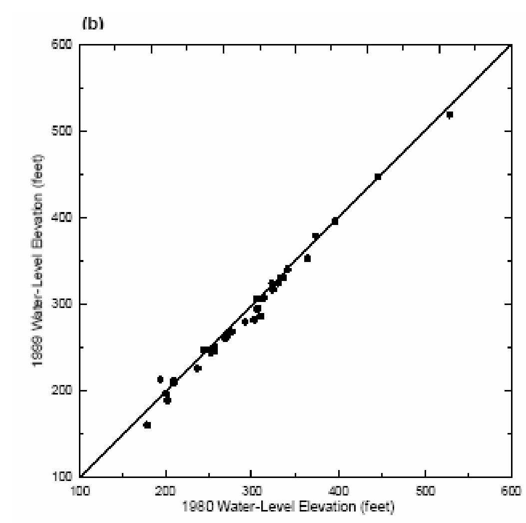


Sparta Aquifer – Northern Region

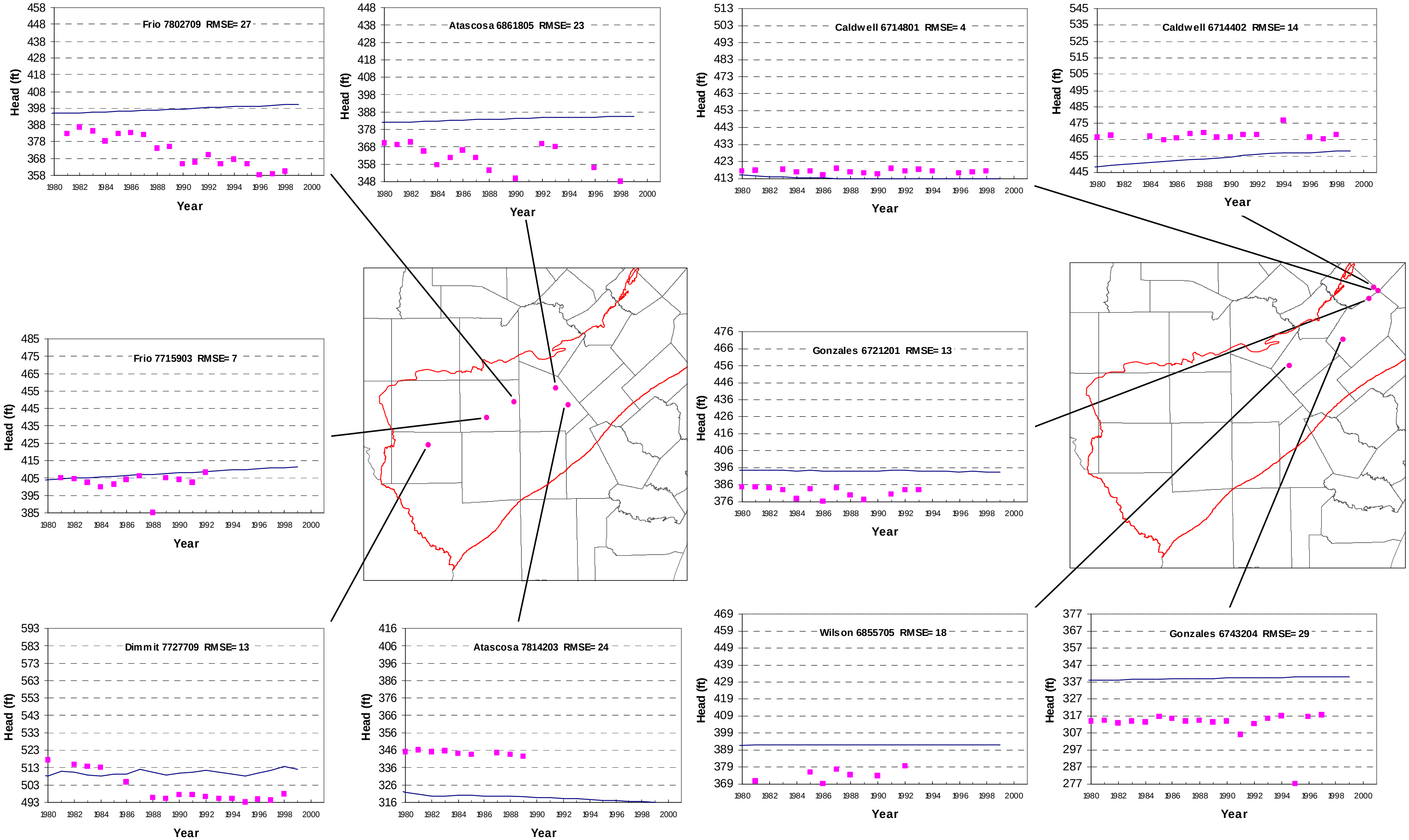


Sparta Summary

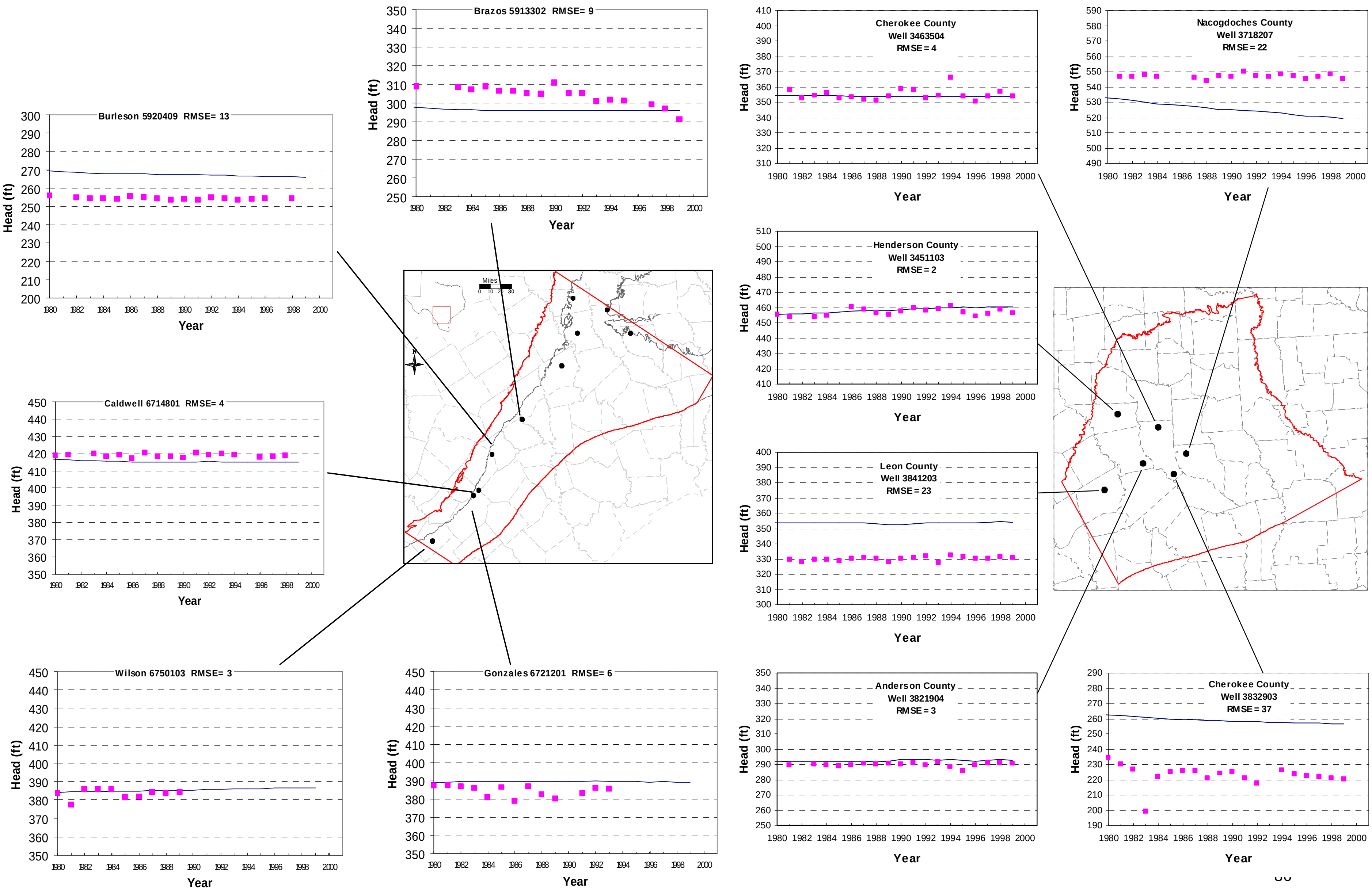
- Not a significant amount of regional scale drawdown in calibration period.
- Drawdown tends to be local when they occur.



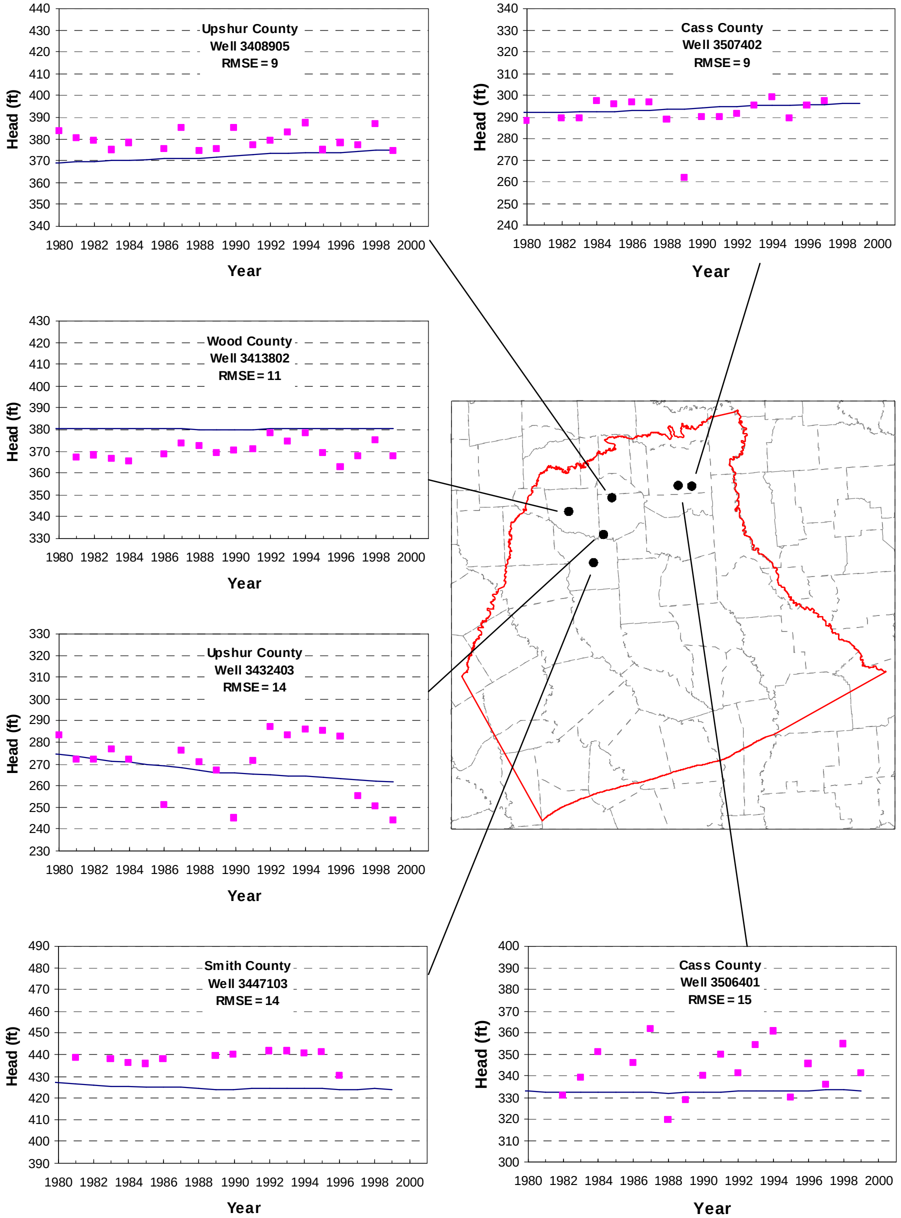
Queen City Aquifer - South



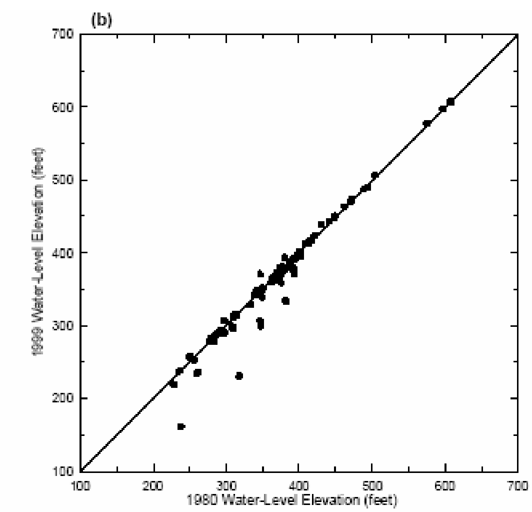
Queen City Aquifer – Central to North



Queen City Aquifer - North



- Queen City Summary
  - Greater regional scale drawdown in calibration period.
  - Again drawdown tends to be local except in select counties

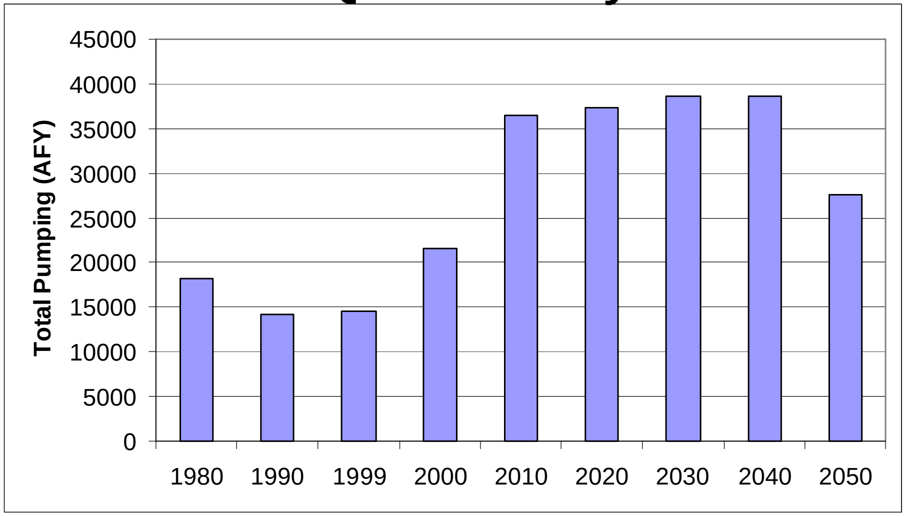


Significant calibration parameter changes

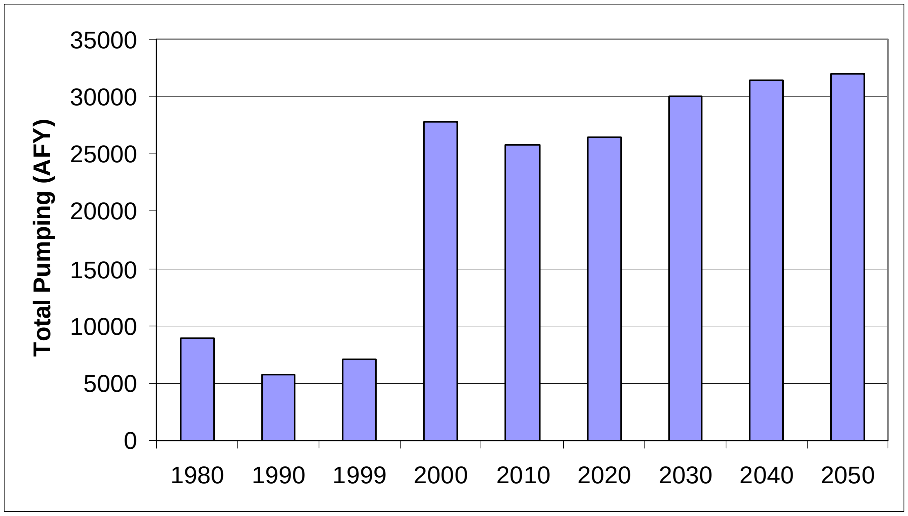
- Recharge varied significantly but our initial estimates were found to be best for the three models (compromise in overlap zones)
- Recharge in Sabine Uplift for L. and M. Wilcox slightly increased
- Reklaw Kv lowered in North GAM to $1x10^{-5}$ ft/day
- Reklaw Kv held at $1x10^{-4}$ ft/day in Nacagdoches, S. Rusk and E. Cherokee counties
- Kh lowered in Carrizo in Upshur and Smith counties and in Angelina county (Lufkin)
- Streams conductances were locally adjusted when gain/loss estimates were grossly in error

Predictive Models

Queen City



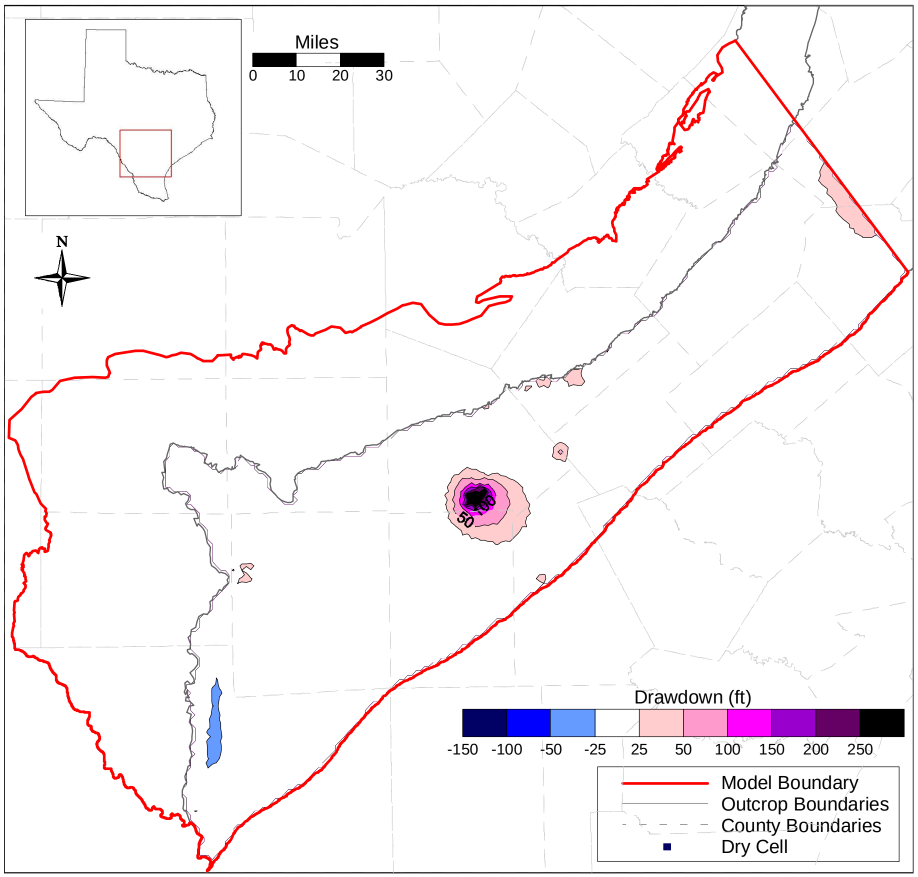
Sparta

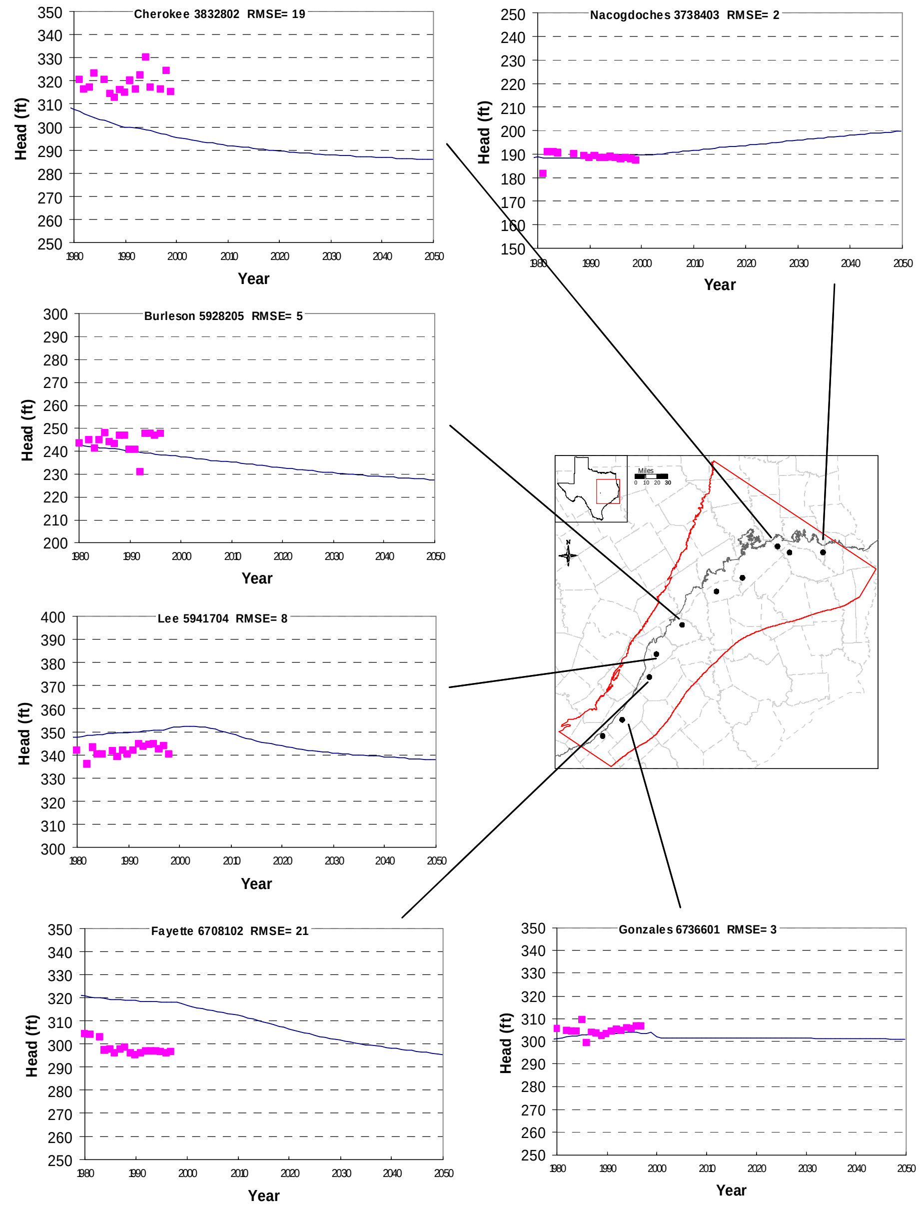


Predictive Simulations

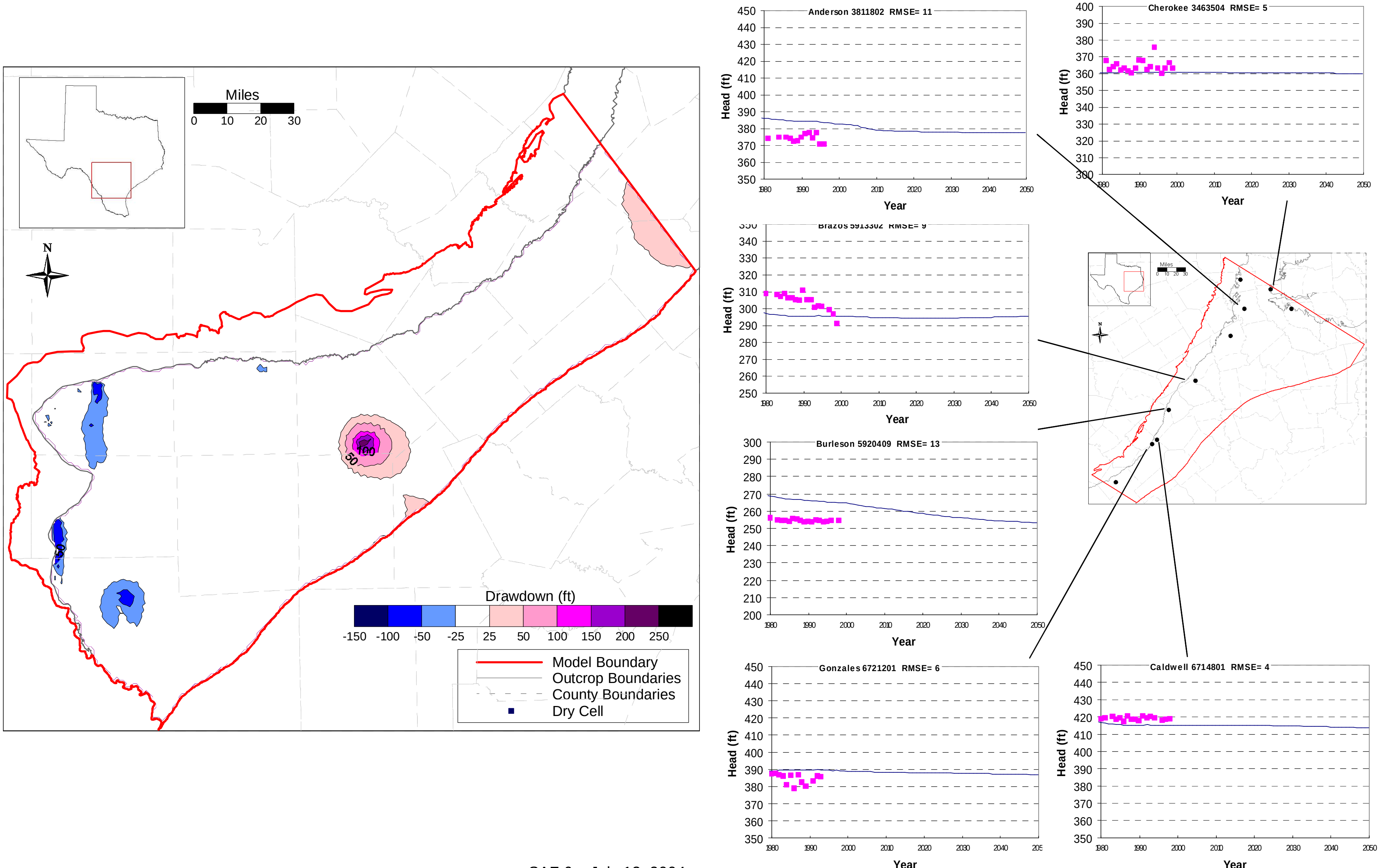
- Six Model Scenarios:
  - Average Recharge Conditions through 2050
  - Average Recharge Conditions ending with the drought of record (DOR) in 2010
  - Average Recharge Conditions ending with the drought of record (DOR) in 2020.
  - Average Recharge Conditions ending with the drought of record (DOR) in 2030.
  - Average Recharge Conditions ending with the drought of record (DOR) in 2040.
  - Average Recharge Conditions ending with the drought of record (DOR) in 2050.
- DOR is 1954 through 1956

Sparta Drawdown at 2050 - South

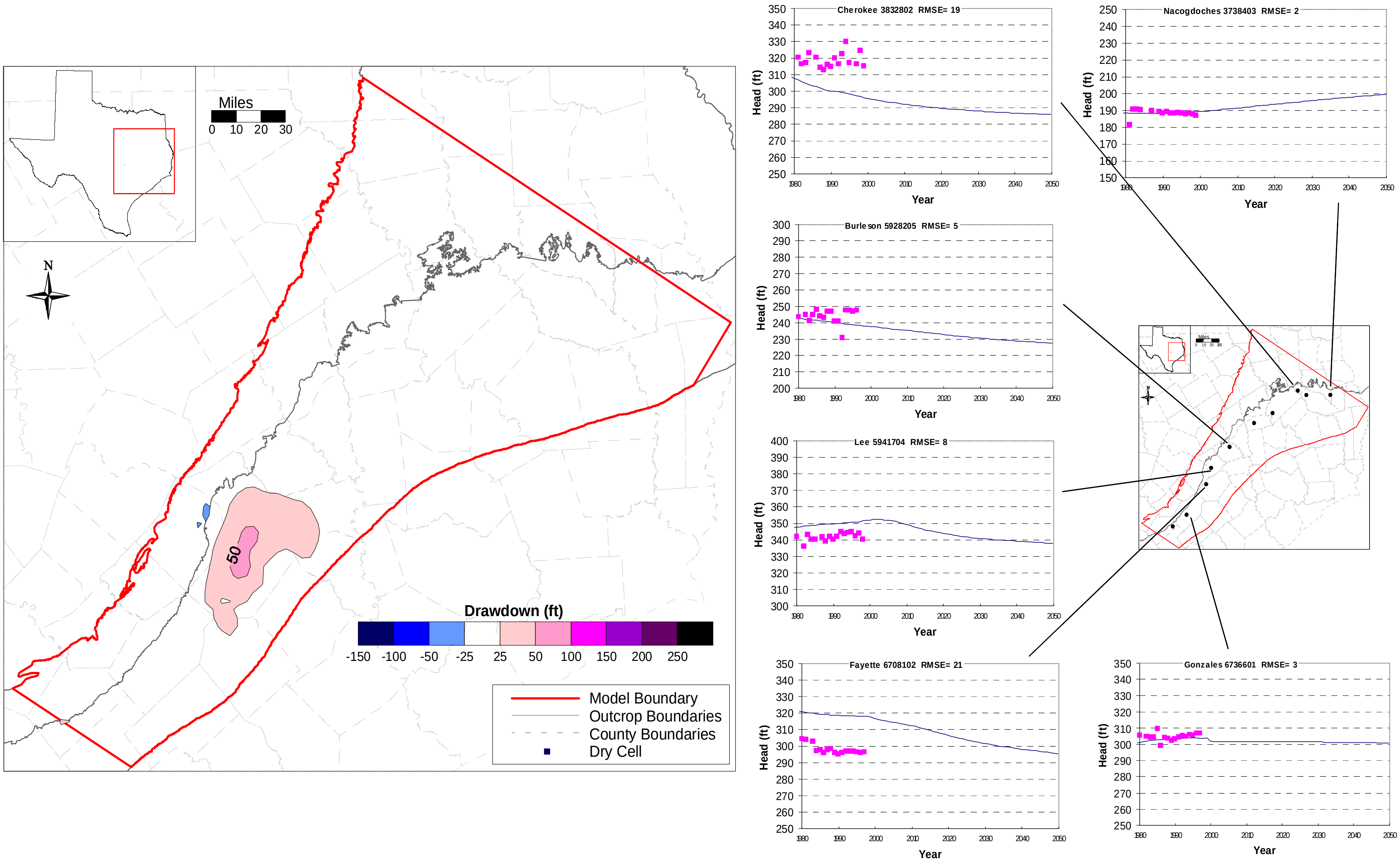




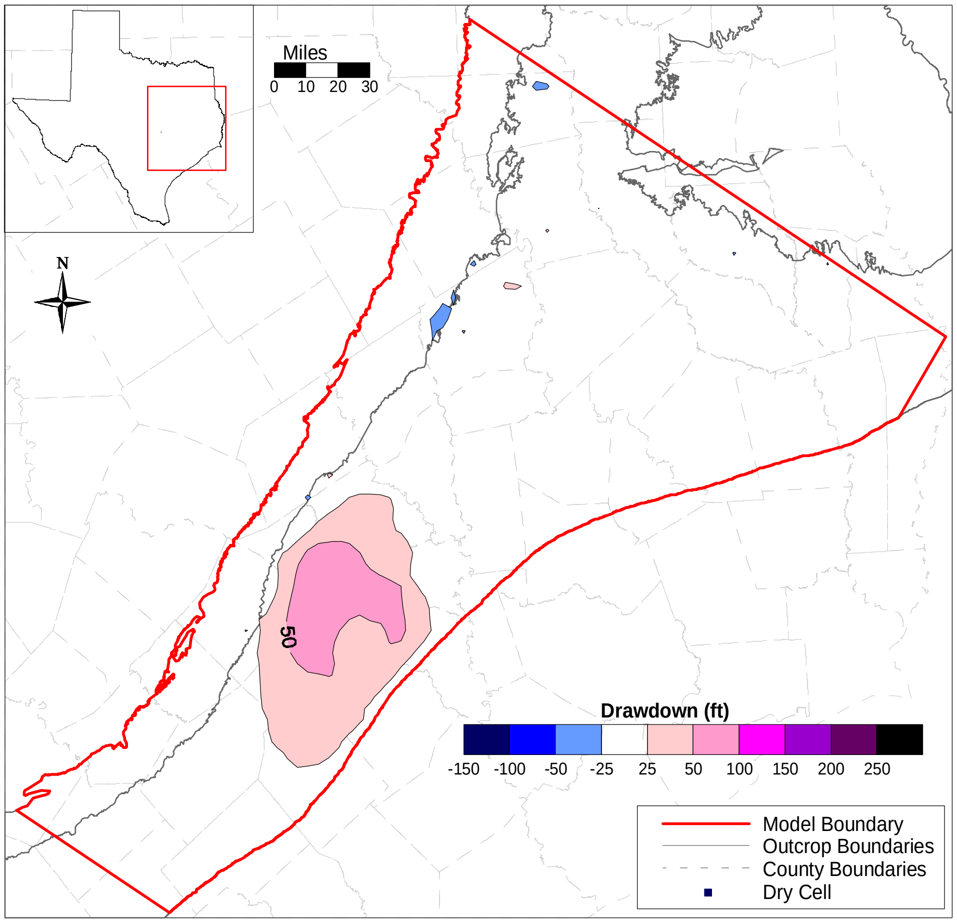
Queen City Drawdown 2050 - South

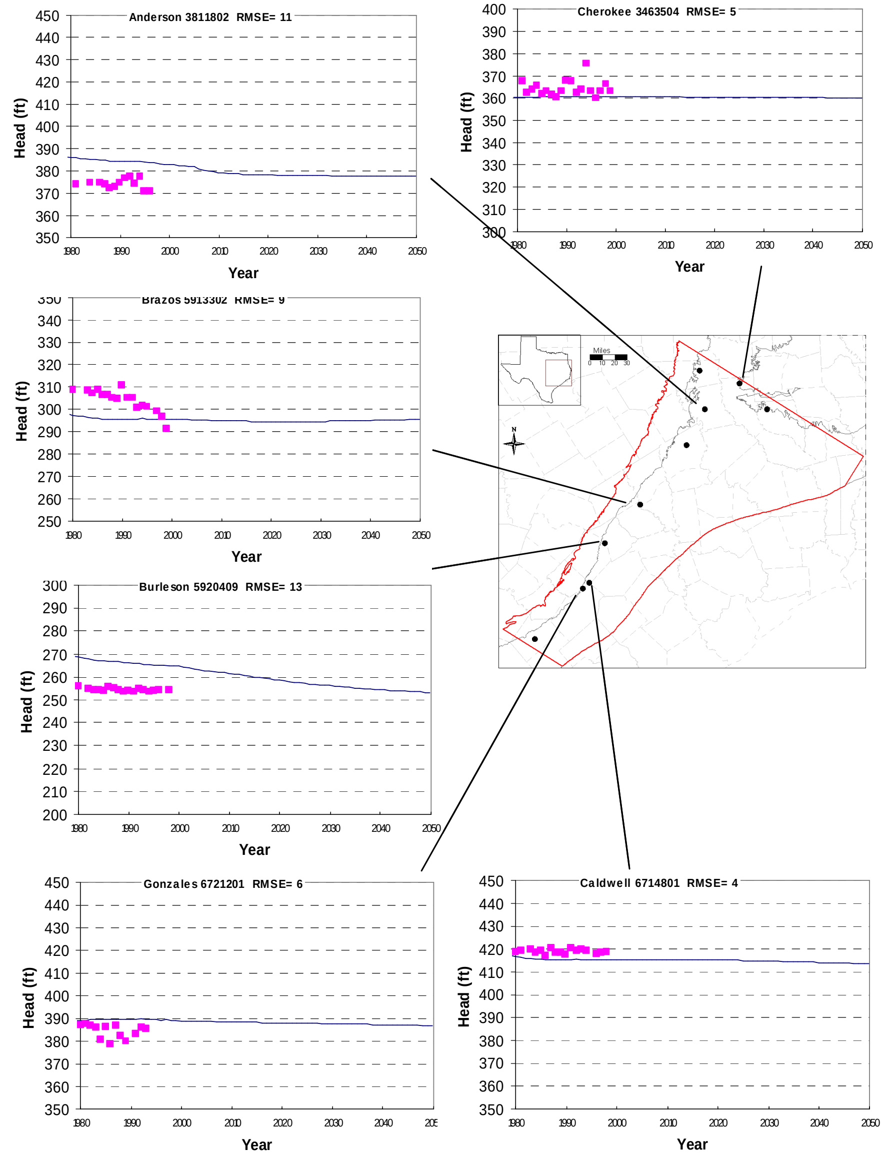


Sparta Drawdown 2050 - Central

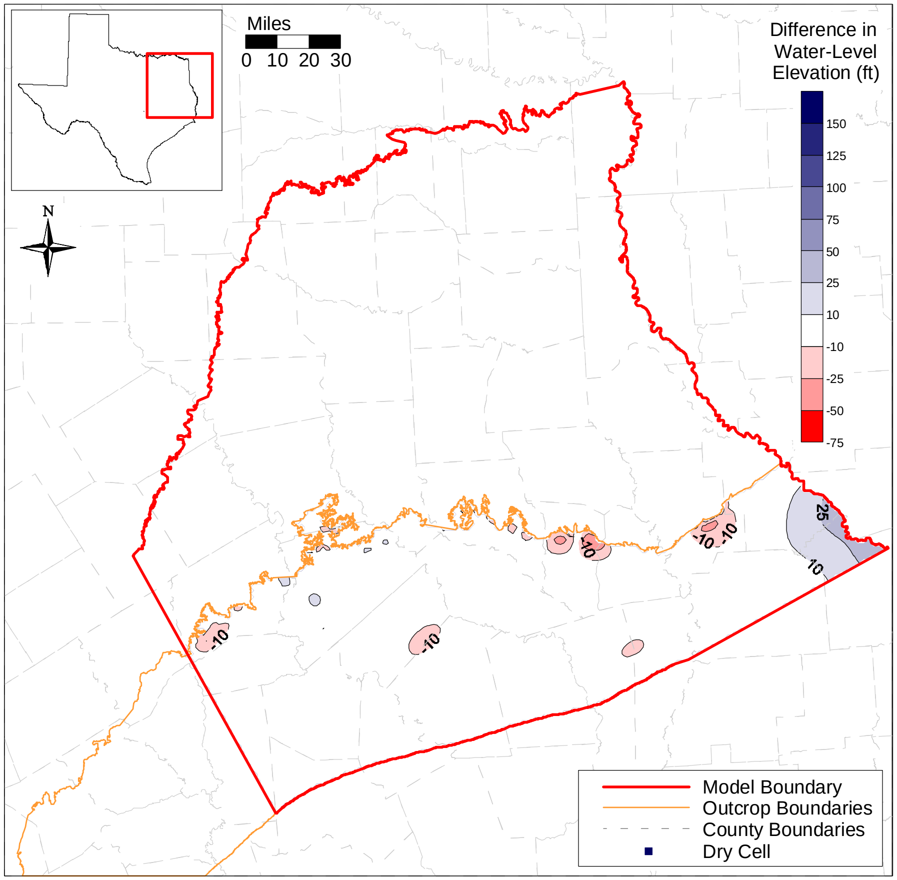


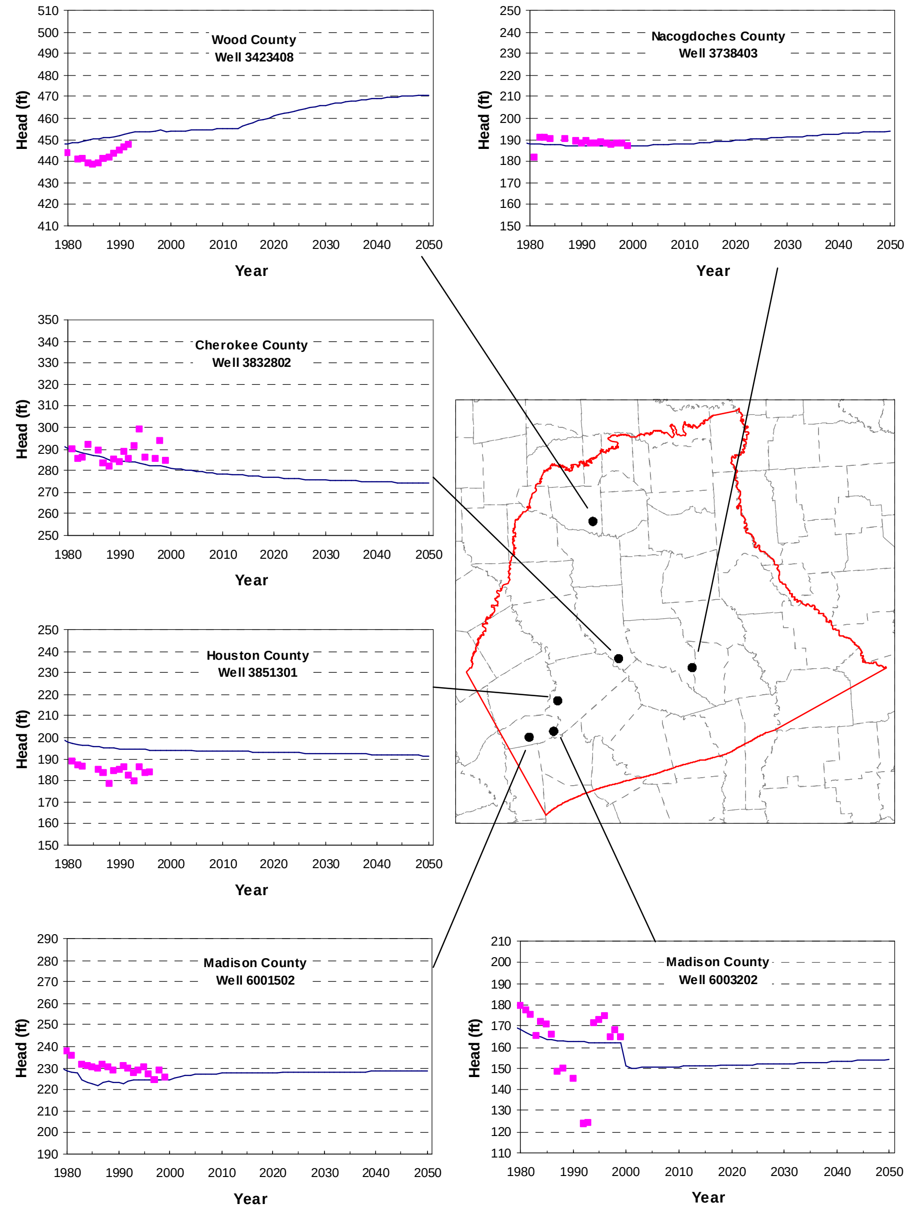
Queen City Drawdown 2050 - Central



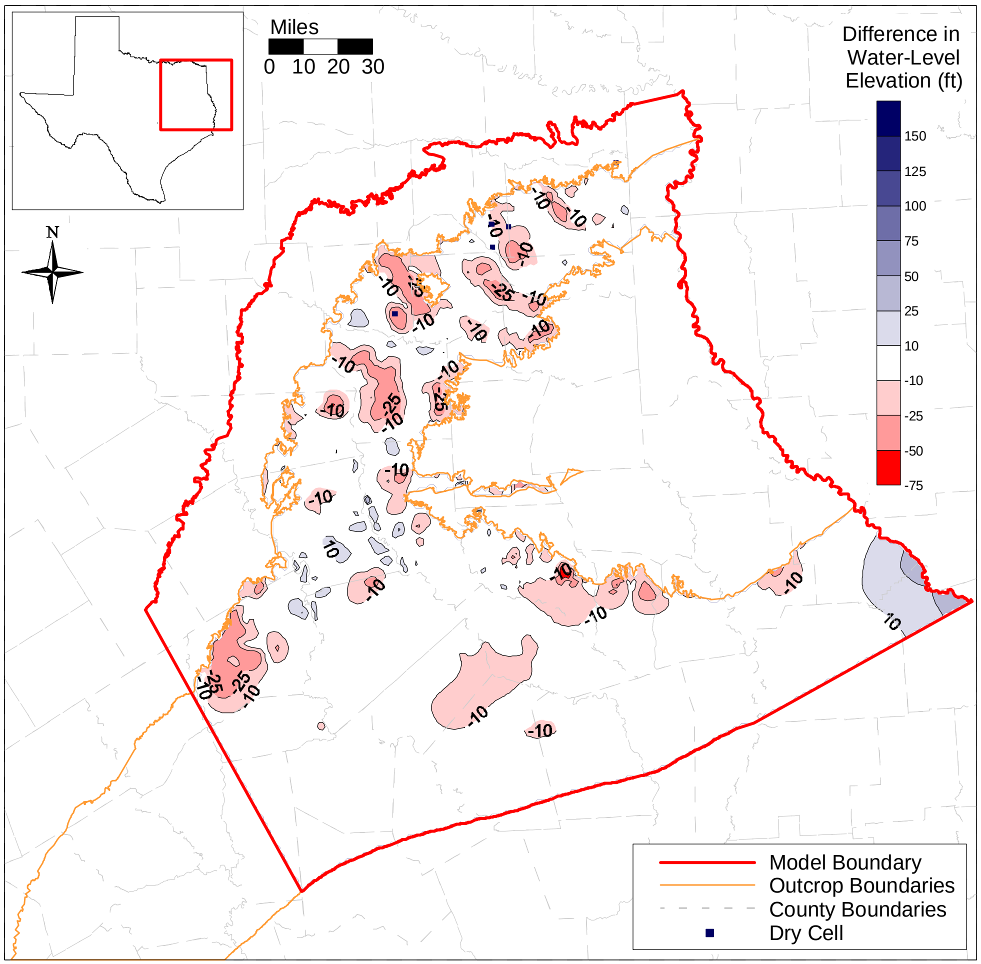


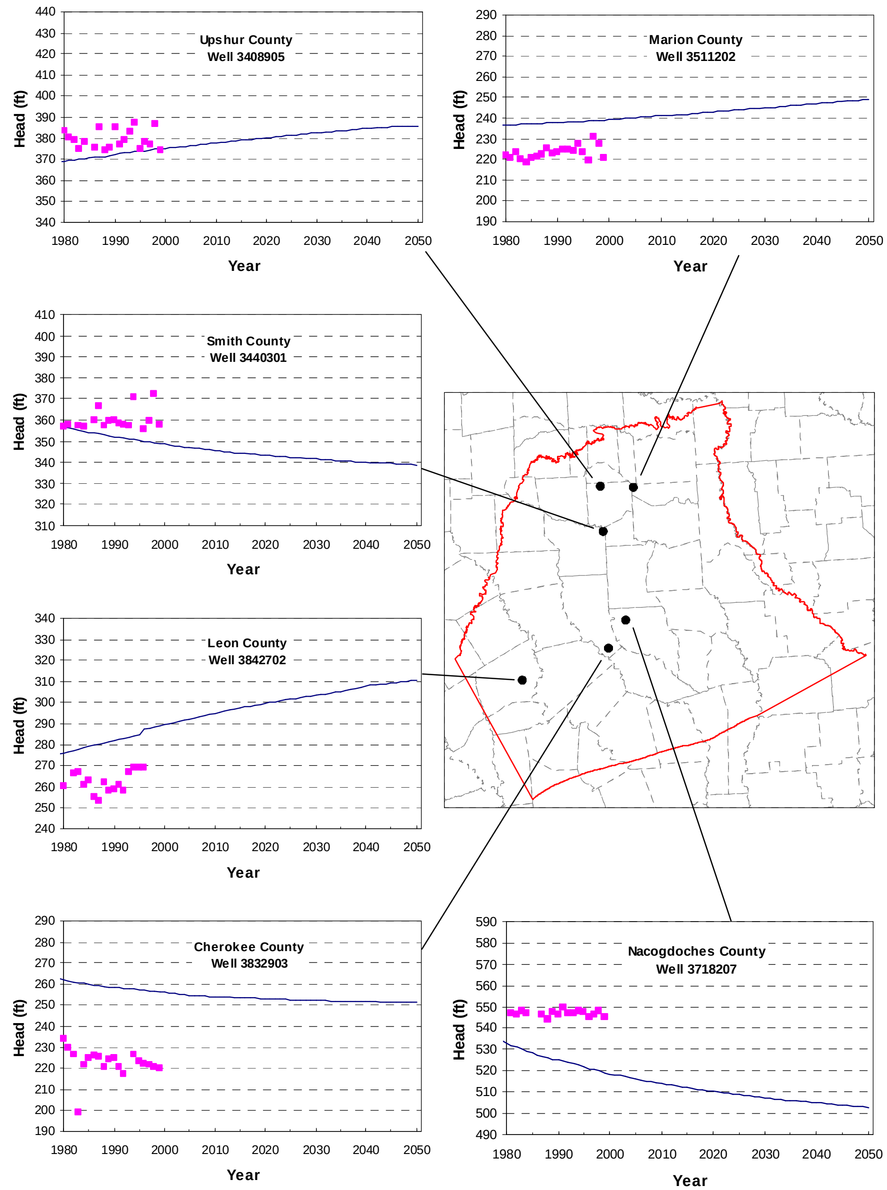
Sparta Drawdown 2050 - North



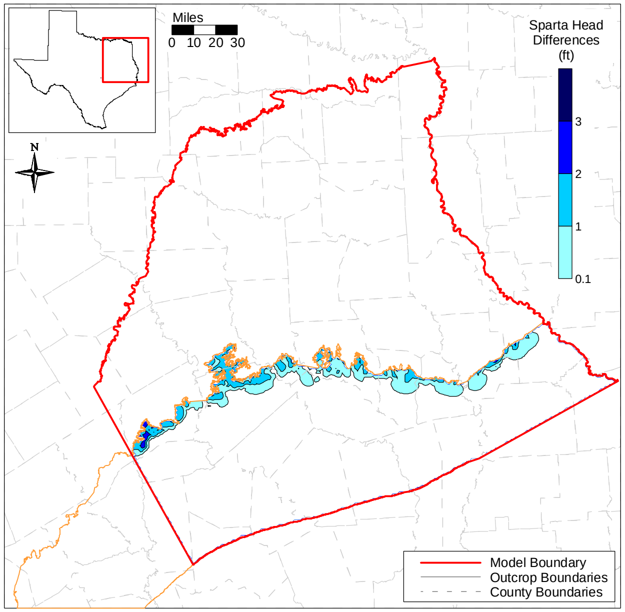


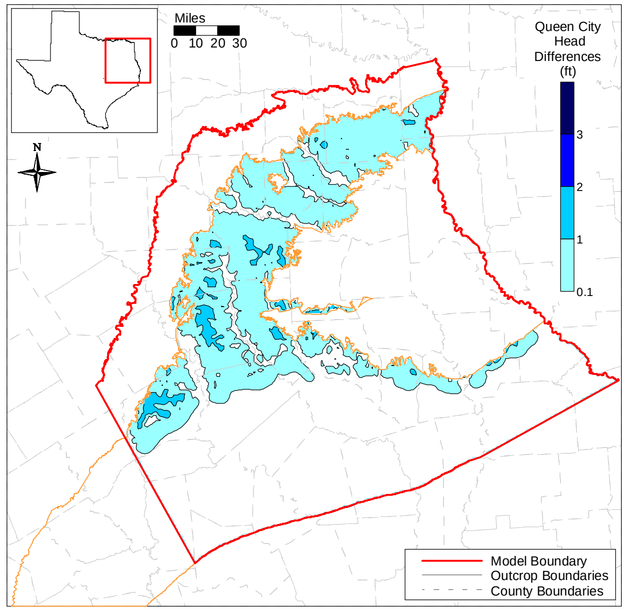
Queen City Drawdown - 2050

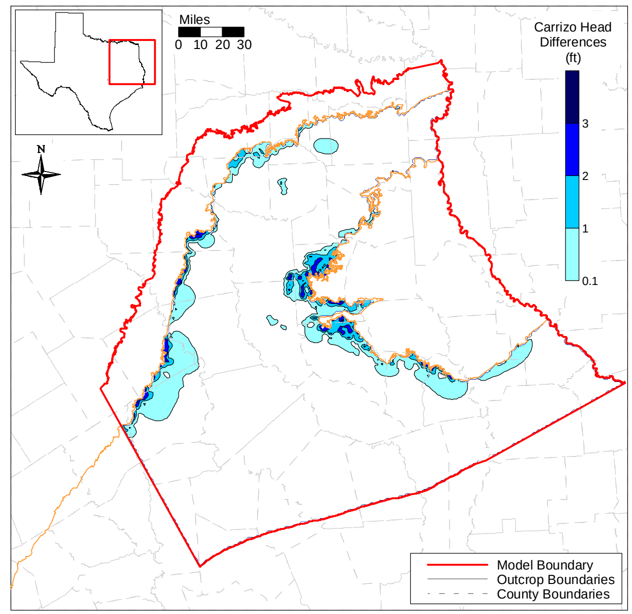




Effect of DOR on Heads - North







Conclusions from Predictive Simulations

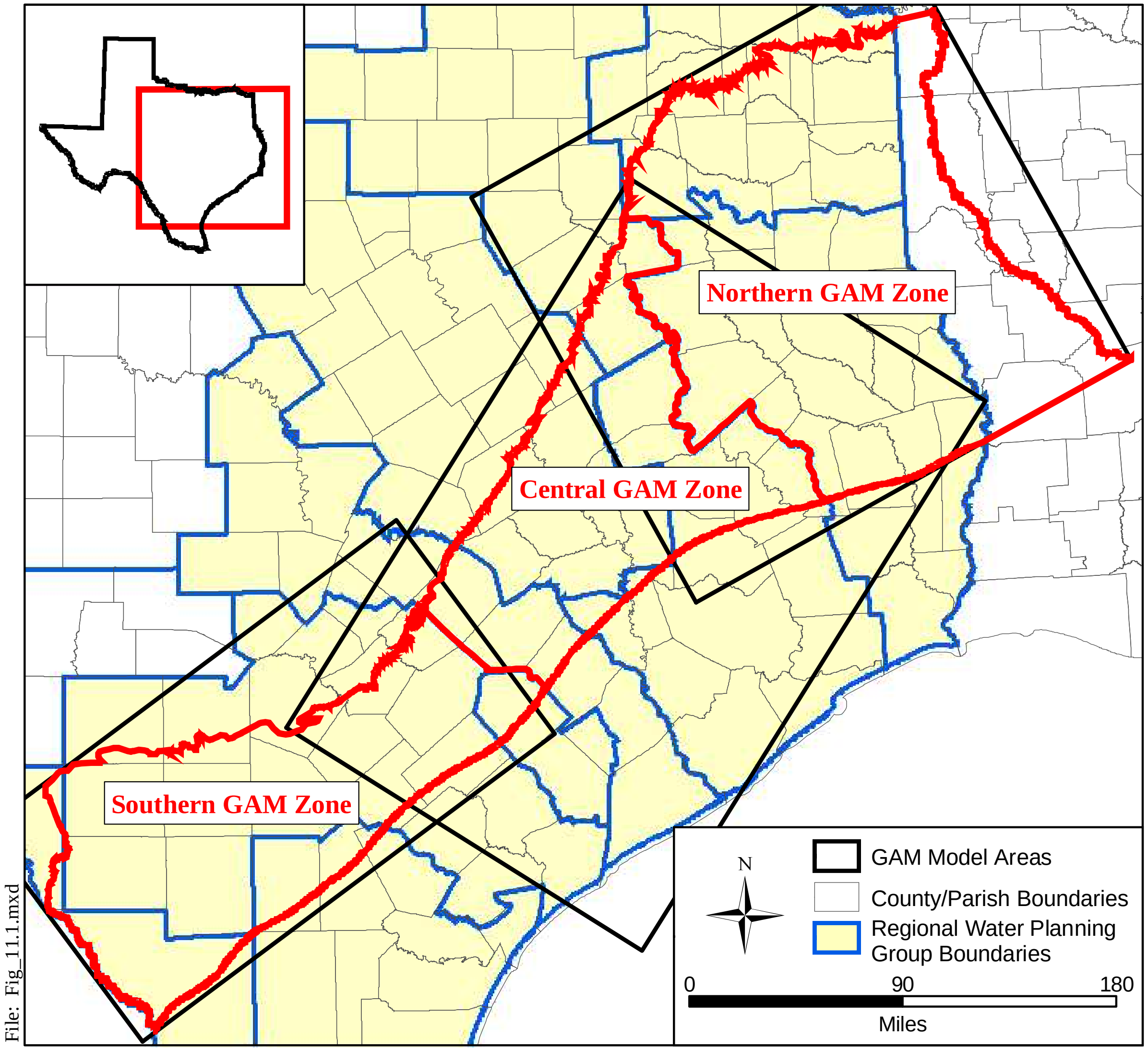
- Significant drawdown is limited:
  - Southern Atascosa County in the Southern GAM
  - Fayette and surrounding counties in the Central GAM

- No significant effect of DOR
  - Pumping estimates do not increase in DOR

Conclusions

- GAMs for the Queen City and Sparta aquifers:
  - Incorporated all relevant features, data on aquifer properties, recharge estimates, and pumpage
  - Calibrated to specifications:
    - pre-development
    - transient conditions (1980-1989)
    - verified from (1990-1999)
  - Required some adjustment of properties during transient calibration (not beyond measured data)
- Developed a consistent recharge distribution across CZWX and QCSP in Texas
- Developed consistent parameterization between GAMs in the overlap

Regions of Applicability - DRAFT



- Caveats
  - This is a recommendation by the model developers and is subject to review by TWDB
  - If modeling the Simsboro, always use the Central GAM

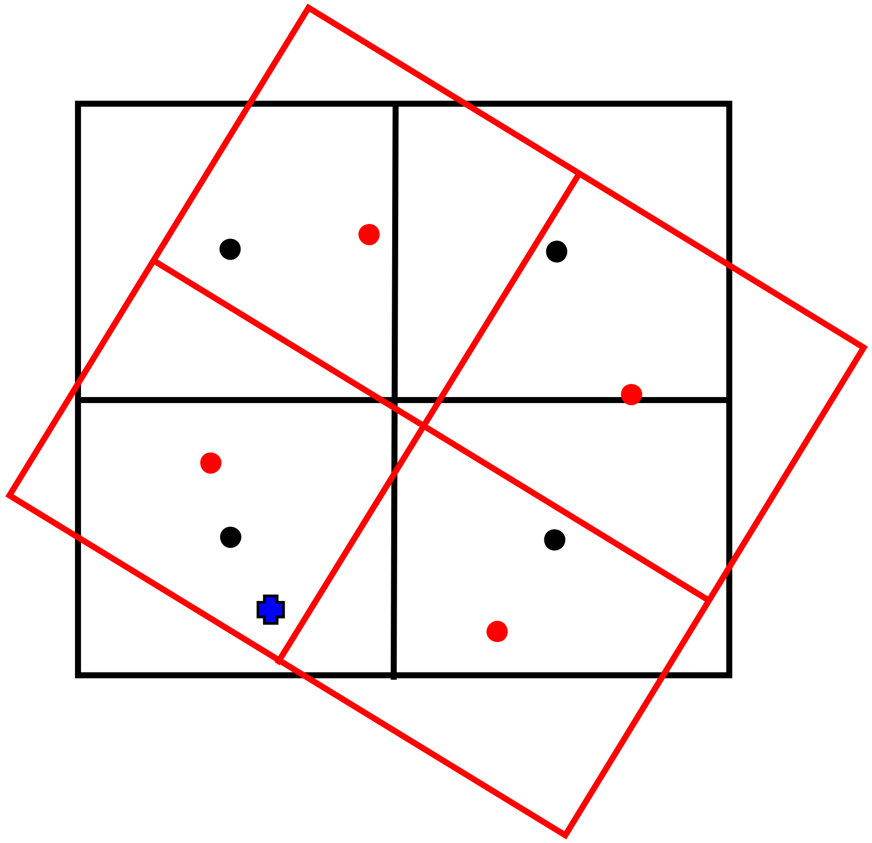
Limited to regional scale assessments

- The GAM is a tool capable of being used to predict aquifer responses to pumping scenarios on a regional scale
  - The model is not capable of being used in it's current state to predict aquifer responses at particular points such as a particular well
- The model is well suited for refinement to address local-scale water resource questions.

$Re = 0.198 \triangle x$

Steady-State Drawdown High-Production Well - 12 inch well		
Effective Radius of Observation	1000 gpm 1.4 MGD	500 gpm 0.7 MGD
well (0.5 ft)	43.9	22.0
gridblock (908 ft)	17.9	9.0

Grid Limitations in overlap



- Models will have slightly different parameters and predicted heads as a result of the grids not being oriented

Schedule – Milestones

2003

SAF 1 — Feb 28

Stakeholder - Apr 31
Data

SAF 2 — June 12

Jan 23 — Kickoff Meeting

- Complete database
- Evaluate data
- Preliminary model design

July 31 — Draft Conceptual Model Report

2004

SAF 3 — Jan 9

SAF 4 — April

SAF 5 — July

Stakeholder Comments

SAF 6 — Sep

March — Steady-state model review

June — Transient model review

June — Predictive model review

July 1 — Draft report

Oct 30 — Final Report & Model

Who to Contact?

- Van Kelley

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- Dr. Shirley Wade

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Thank You

Name	Affiliation
Bob Kier	Robert S. Kier Consulting
J.P Nicot	Bureau of Economic Geology
Van Kelley	INTERA Inc.
Brian Woods	HydroGeoLogic, Inc.
Bob Perez	San Antonio River Authority
Melissa Bryant	San Antonio River Authority
Ronnie Hernandez	San Antonio River Authority
Steve Raabe	San Antonio River Authority
Randy Williams	Turner, Collie and Braden, Inc
Shirley Wade	TWDB

Meeting Minutes for the

Fifth Queen City/Sparta Groundwater Availability Model (GAM) Stakeholder Advisory Forum (SAF) Meeting

July 13, 2004

San Antonio River Authority Board Room

San Antonio, Texas

The fifth Stakeholder Advisory Forum (SAF) Meeting for the Queen City/Sparta Groundwater Availability Model (GAM) was held on Tuesday, July 13th, 2004 at 1:30 PM in the San Antonio River Authority Board Room located at 100 E Guenther Street in San Antonio, Texas. A list of meeting participants is shown at the end of these meeting notes.

The purpose of the fifth SAF meeting was to provide an update on the progress for the Queen City/Sparta Aquifers GAM and provide an opportunity for feedback from stakeholders.

Meeting Introduction: Shirley Wade, TWDB

The meeting was initiated by Shirley Wade of the Texas Water Development Board (TWDB). She gave a brief introduction to the GAMs and discussed the current status of the GAM program. She then discussed groundwater availability and use of the GAMs, followed by a look at the future of the GAMs and opportunities for public involvement in GAM development.

SAF Presentation: Van Kelley, INTERA Inc

Van Kelley (INTERA) and Jean-Philippe Nicot (BEG) presented a prepared presentation discussing updates and calibration status of Queen City/Sparta Groundwater Availability Model (GAM). The presentation was structured according to the following outline:

1. Model Implementation and Parameterization
2. Steady-State Model Overview
3. Transient Model Results
4. Model Prediction Results
5. Schedule and Milestones
6. Expectations for the next SAF Meeting

The presentation is available on the GAM website:

(http://www.twdb.state.tx.us/gam/qc_sp/qc_sp.htm)

Questions and Answers: Open Forum:

Q: In the slide about transient recharge, you use the expression "revert to the mean" meaning that if you sample the expression for long enough and average all the samples, the mean should be the steady-state recharge. What period of record did you use? In San Antonio, the period from 1970 to 2000 has higher rainfall (32" on average) than the previous years.

A: *The available period of record was used for each precipitation gage to develop the SPI's. So, the method would revert to the long-term mean.*

Q: Did you use gage data for ephemeral streams as well as main streams to estimate headwaters? If you only used large stream gages, your method could estimate flow in ephemeral streams when there actually isn't flow.

A: *We used all available stream gages, ephemeral or not. The error being considered could occur but would be rare in the model region and would have no significant impact on the modeled aquifer predictions.*

Q Relative to the Schertz-Seguin well field, how do your results compare to SAWS's simulations?

A: *Based upon a review of HDR's June 1st presentation material our drawdown compares well to their drawdown and the observed drawdown.*

Q: The GAM predicts drawdown on the order of several feet in regions where there is no observable drawdown. Is there faulting in the area that could explain the disparity between the model and the observed drawdown?

A: *Yes, there is faulting south of the Schertz-Sequin well field that may explain this difference. The difference could also be explained by the fact that the particular well with no observable drawdown is screened at a deeper level within the Carrizo which may not be well connected to the well field. All documented regional faults are included in the model, but only those with good evidence for being hydraulic barriers are restricting flow. If other investigators find evidence that the faults in this region are hydraulic barriers, they can easily be converted to sealing faults.*

Q: In the Southern Carrizo-Wilcox GAM model, the Queen City layer had a lot of recharge relative to historical work. Is this still true?

A: *The Queen City aquifer has a significantly greater (by a factor of three) outcrop area that the Carrizo in the Southern GAM. Therefore, it is misleading to talk in recharge volumes. Recharge rates can be compared between aquifers. In the Southern Carrizo-Wilcox GAM the Queen City had an average recharge rate of 0.8 inches per year as compared to the Carrizo with 1.2 inches per year. In the Queen City and Sparta GAM, the average recharge rate of the Queen City was reduced to 0.4 inches per year and the Carrizo average rate remained approximately 1.2 inches per year.*

Q: In the Southern Sparta GAM there is a drawdown cone in the Sparta aquifer in Southern Atascosa County. Is this the result of pumping in Carrizo or is there pumping projected for the Sparta in that area?

A: *There is pumping in the Sparta and Queen City aquifers in this region and this is the major contributor to the observed drawdown in Southern Atascosa County.*

Q: After approval of the model, would we have separate Queen City and Sparta GAMs and Carrizo-Wilcox GAMs or would they be merged into one large model?

A: (Shirley Wade, TWDB). *The models will be available as they stand. The "official" Carrizo-Wilcox GAMs will be the updated GAMs that include the Queen City and Sparta aquifers once these GAMs are released by the TWDB.*

(Van Kelley, INTERA): *The three GAMs could be lumped into 1 single model, but this is not within the current scope of work. INTERA made recommendations to the TWDB in the draft report as to which GAM should be used in each county. These recommendations have not been accepted by the TWDB and are currently under review by them. If they are approved, users would be able to use the most appropriate single model for their area of interest. The GAMs are consistent in parameterization and calibration from the Carrizo through the Sparta. The GAMs are well suited for refinement.*

Queen City Sparta Stakeholder Advisory Forum 5
July 13, 2004

Attendance

Name	Affiliation
C. Brian Woods	HydroGeologic
Bob Perez	SARA
Randy Williams	TC&B
Melissa Bryant	SARA
Ronnie Hernandez	SARA
Bob Kier	RSKC
Steve Raabe	SARA
Van Kelley	INTERA Inc.
Jean-Philippe Nicot	BEG
Shirley Wade	TWDB