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

Stakeholder Advisory Forum No. 2

San Antonio River Authority
San Antonio, Texas
June 12, 2003

GAM
Groundwater Availability Modeling
texas water development board

INTERA

RJB

BUREAU OF ECONOMIC GEOLOGY

Outline of Presentation

- GAM Objectives and Expectations
- Hydrogeologic Setting
  - Supporting Database Review
  - Preliminary Conceptual Model
- Preliminary Approach to Model Implementation & Integration with Carrizo-Wilcox GAMs
- Review of Project Milestones & Schedule
- Expectations for the next SAF Meeting

GAM Objectives

- Develop realistic and scientifically accurate GW flow models representing the physical characteristics of the aquifer and incorporating the relevant processes
- GAMs are designed to be tools to help GWCDs, RWPGs, and individuals assess groundwater availability through 2050 based upon current data
- Promote stakeholder participation which is critical to the success of the GAM program

Stakeholder Advisory Forums - SAFs

- Held on 4 month schedule
- First SAF introduced basic information and requested data for the model
- Today's meeting and future meetings will:
  - 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

Why Groundwater Flow Models?

- In contrast to surface water, groundwater flow is difficult to observe
- Aquifers are typically complex in terms of spatial extent and hydrogeological characteristics
- A groundwater model provides the best means for integrating available data for the <u>prediction</u> of groundwater flow at the scale of interest

Definition of a Model

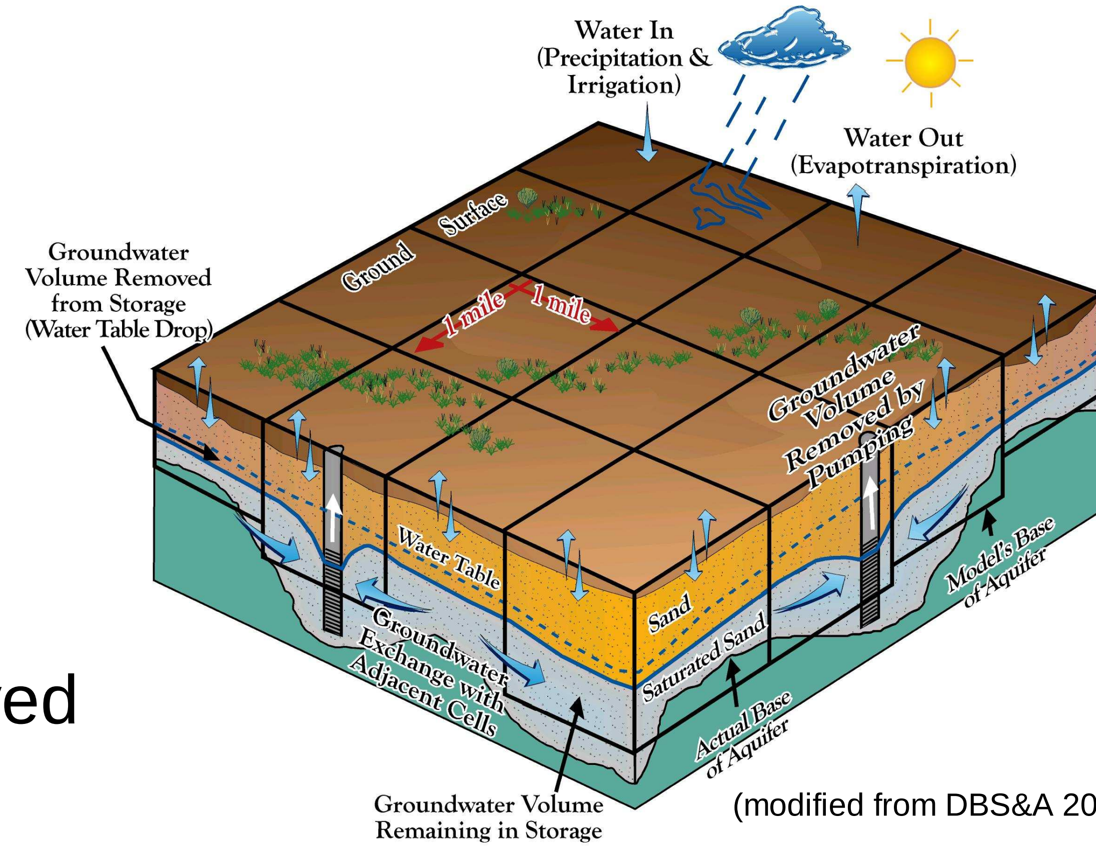
Merriam-Webster Online Dictionary: a description or analogy used to help visualize something (as an atom) that cannot be directly observed

Domenico (1972) defined a model as a representation of reality that attempts to explain the behavior of some aspect of reality and is always less complex than the real system it represents

Wang & Anderson (1982) defined a model as a tool designed to represent a simplified version of reality

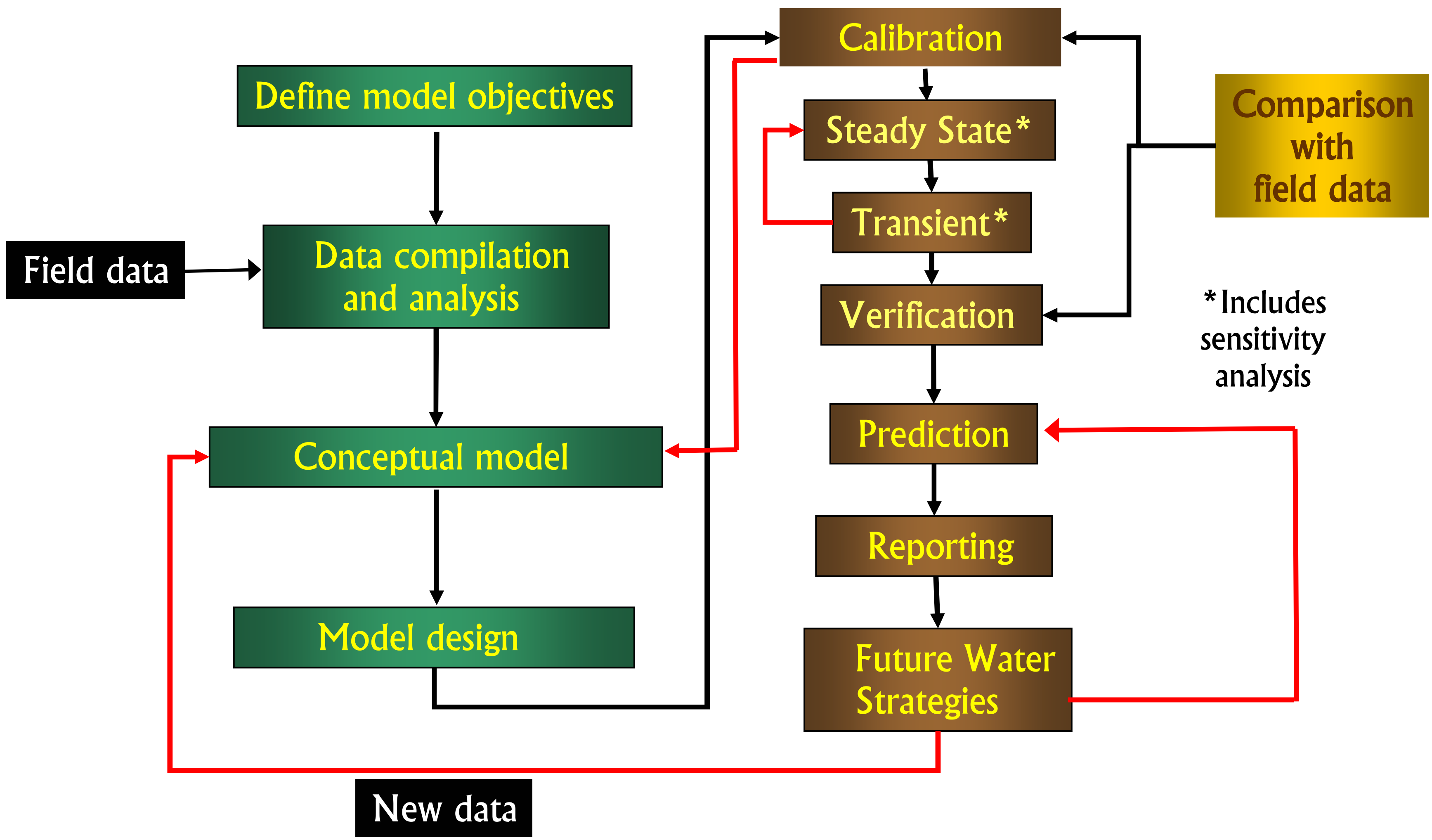
A Model is a Tool

- Model heads are calculated based upon:
  - Recharge
  - Aquifer properties
  - Pumping
  - Natural Discharge
- Model heads are compared to observed water levels
- The tool is used to predict future water levels



(modified from DBS&A 2001)

Modeling Protocol



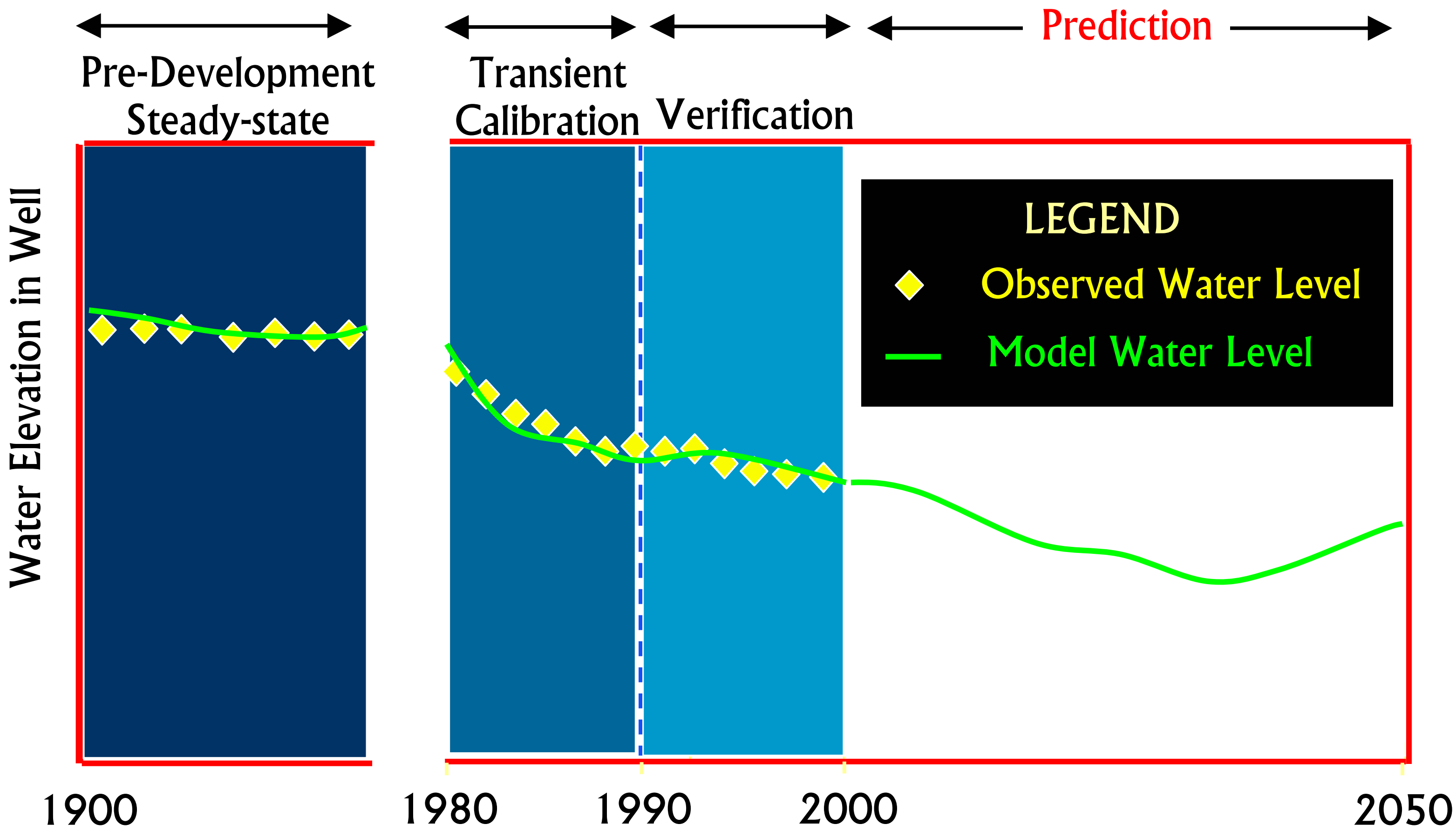
GAM Model Specifications

- Three dimensional (MODFLOW-96)
- Regional scale (1000's of square miles)
- Grid spacing of 1 square mile
- Implement
  - recharge
  - groundwater/surface water interaction
  - pumping
- Calibration to observed water levels

Queen City-Sparta GAM Specifications

- The Queen City and Sparta aquifer GAMs will be incorporated into the current Carrizo-Wilcox GAMs
  – Carrizo-Wilcox GAMs will be modified only as needed to properly add the Queen City and Sparta aquifers and recalibrate the entire model
- The product will be delivered as three models (southern, central, and northern regions)
- One modeling report will be produced

GAM Model Periods

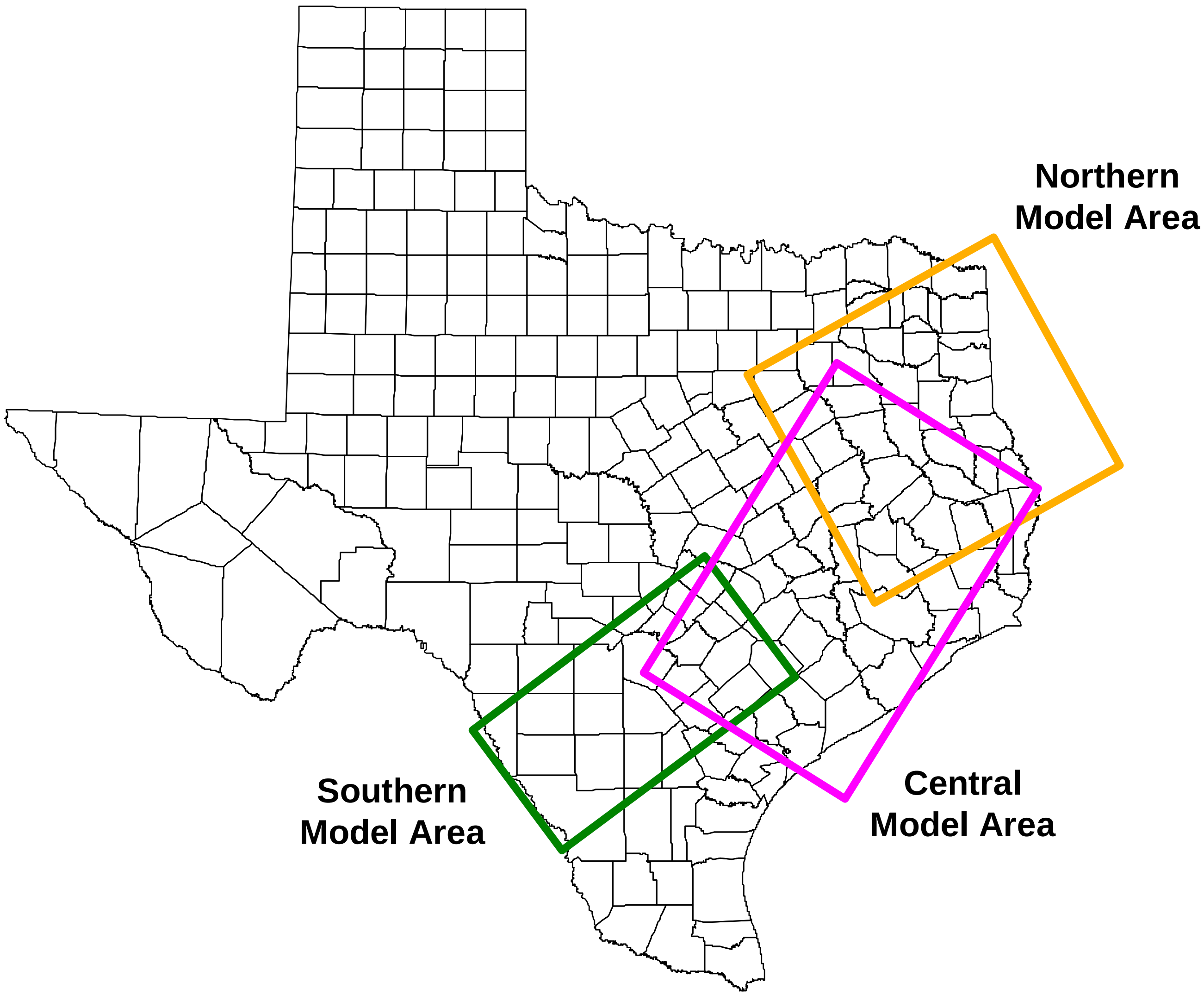


Pre-development and transient calibration periods represent different hydrologic conditions

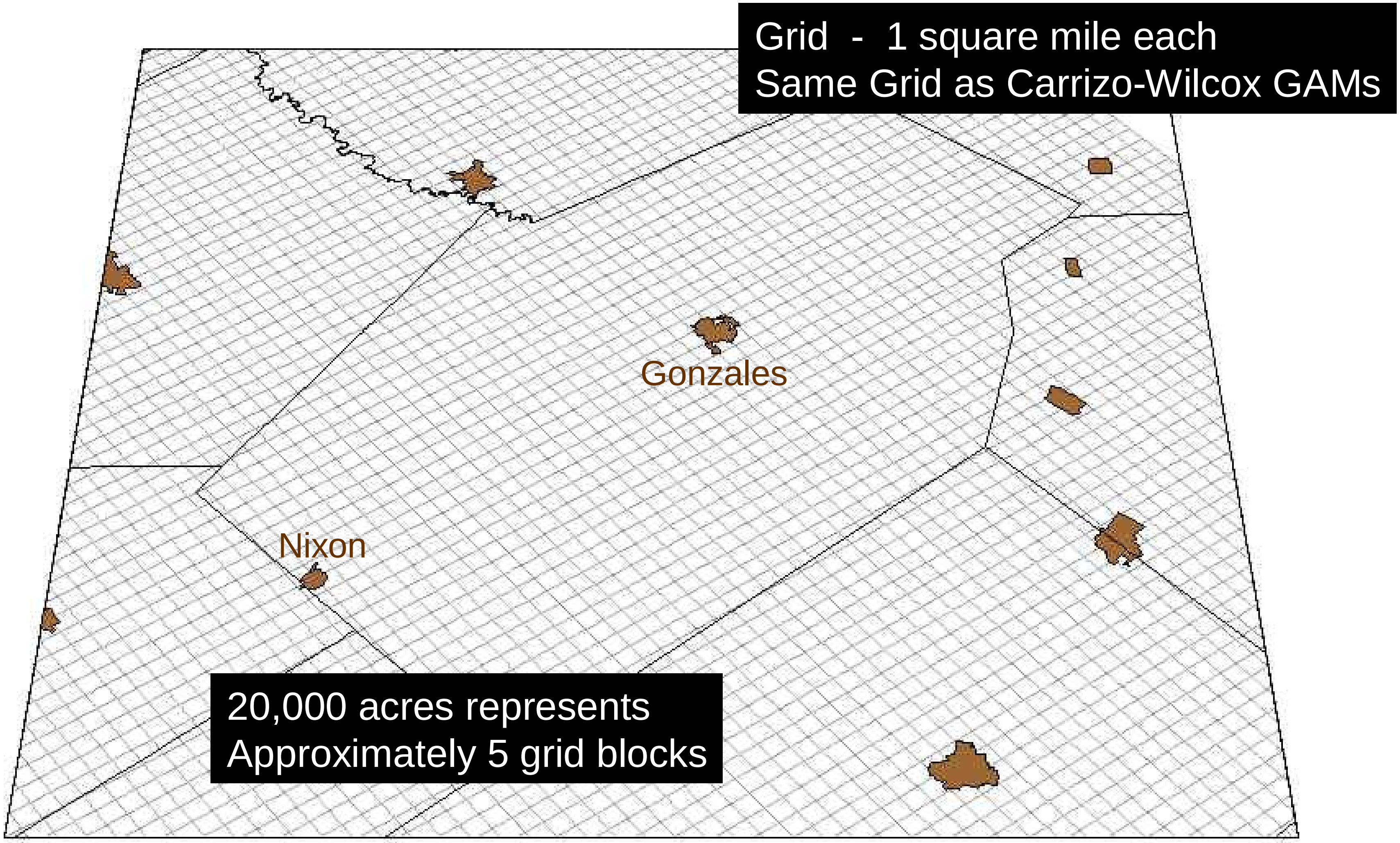
Hydrogeologic Setting

- Study area
- Hydrostratigraphy
- Hydraulic properties
- Regional groundwater flow
- Recharge
- Discharge
  - Pumping
- Streams

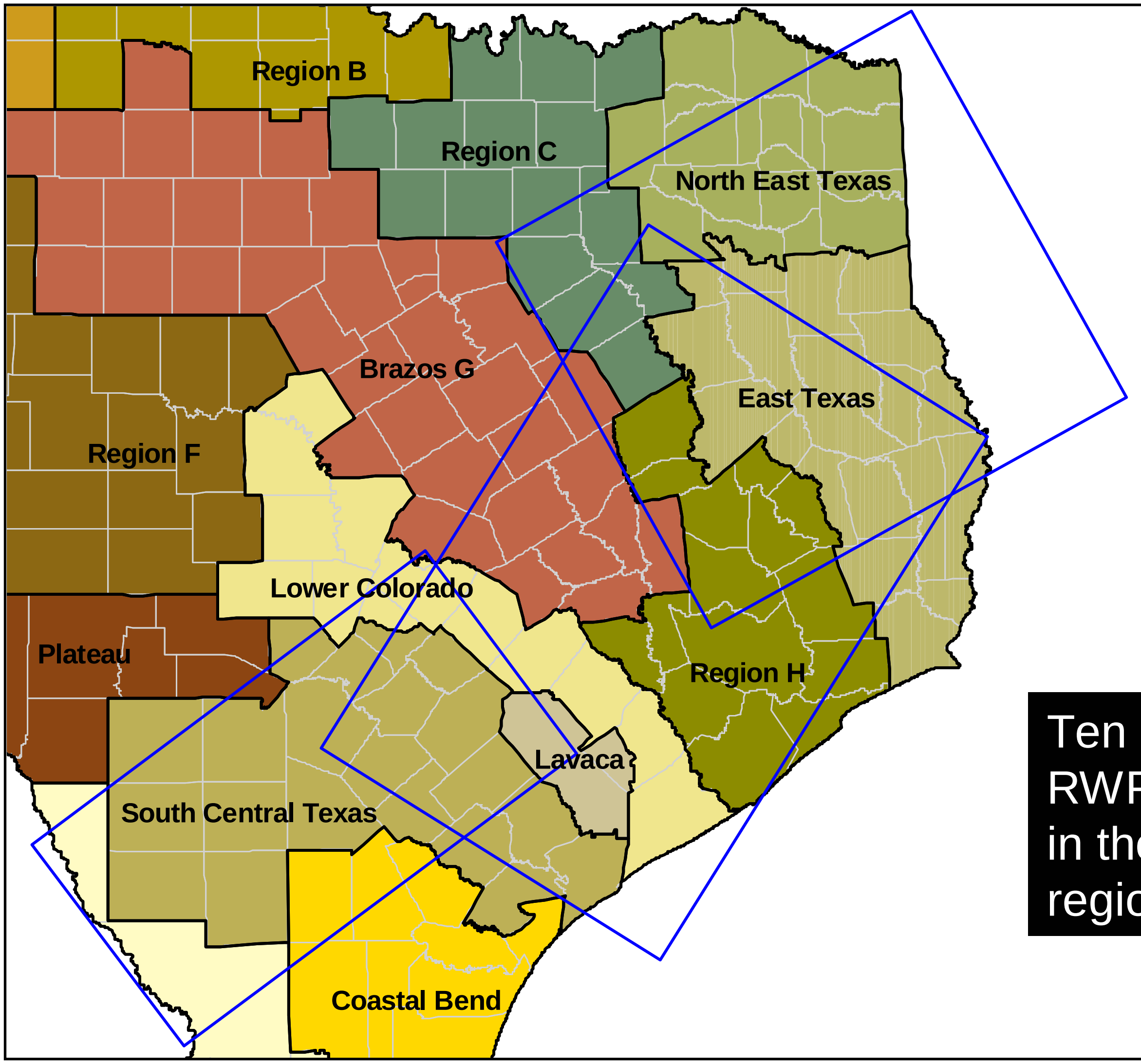
Model Domains



Model Grid Scale – Gonzales Co. Area

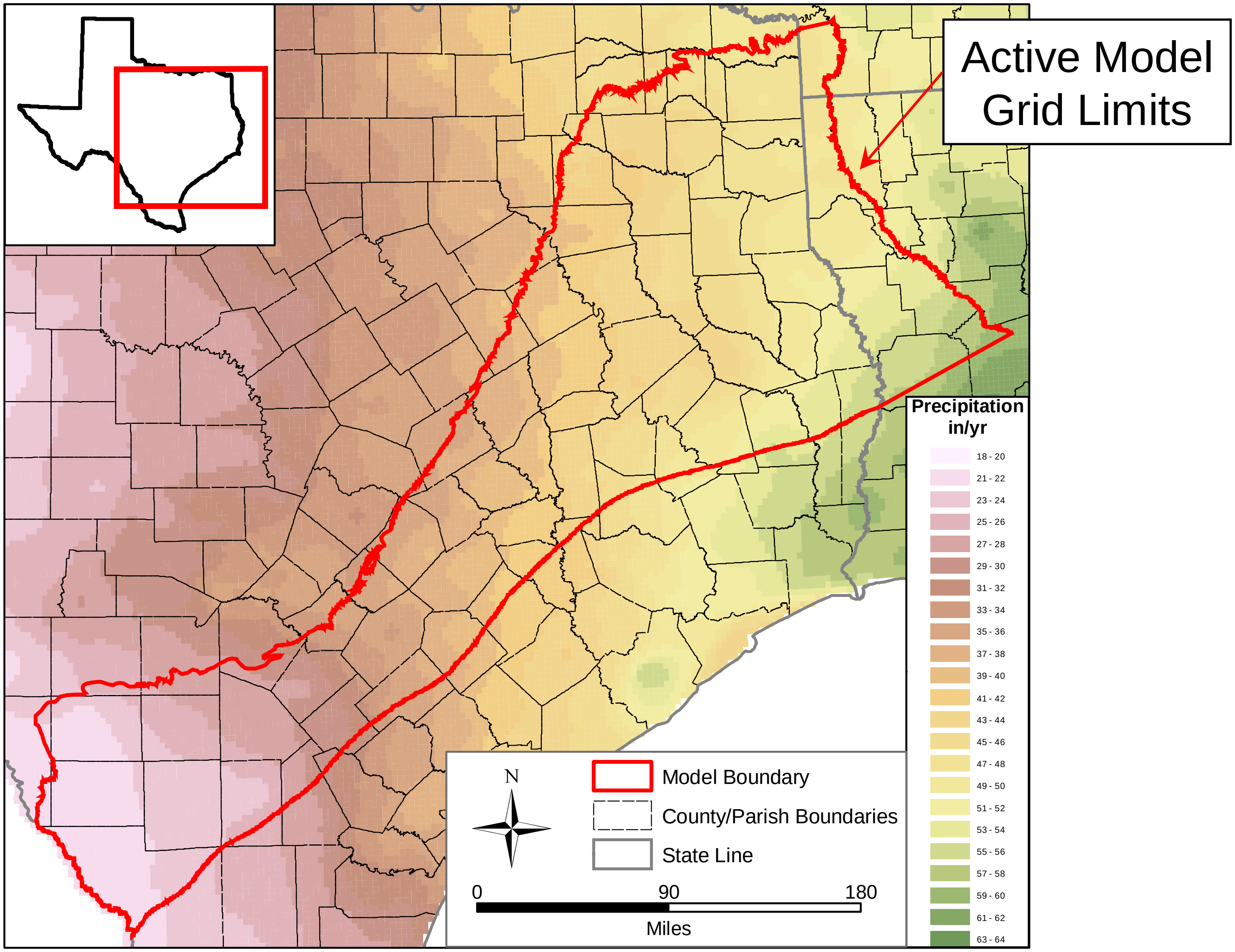


Regional Water Planning Groups

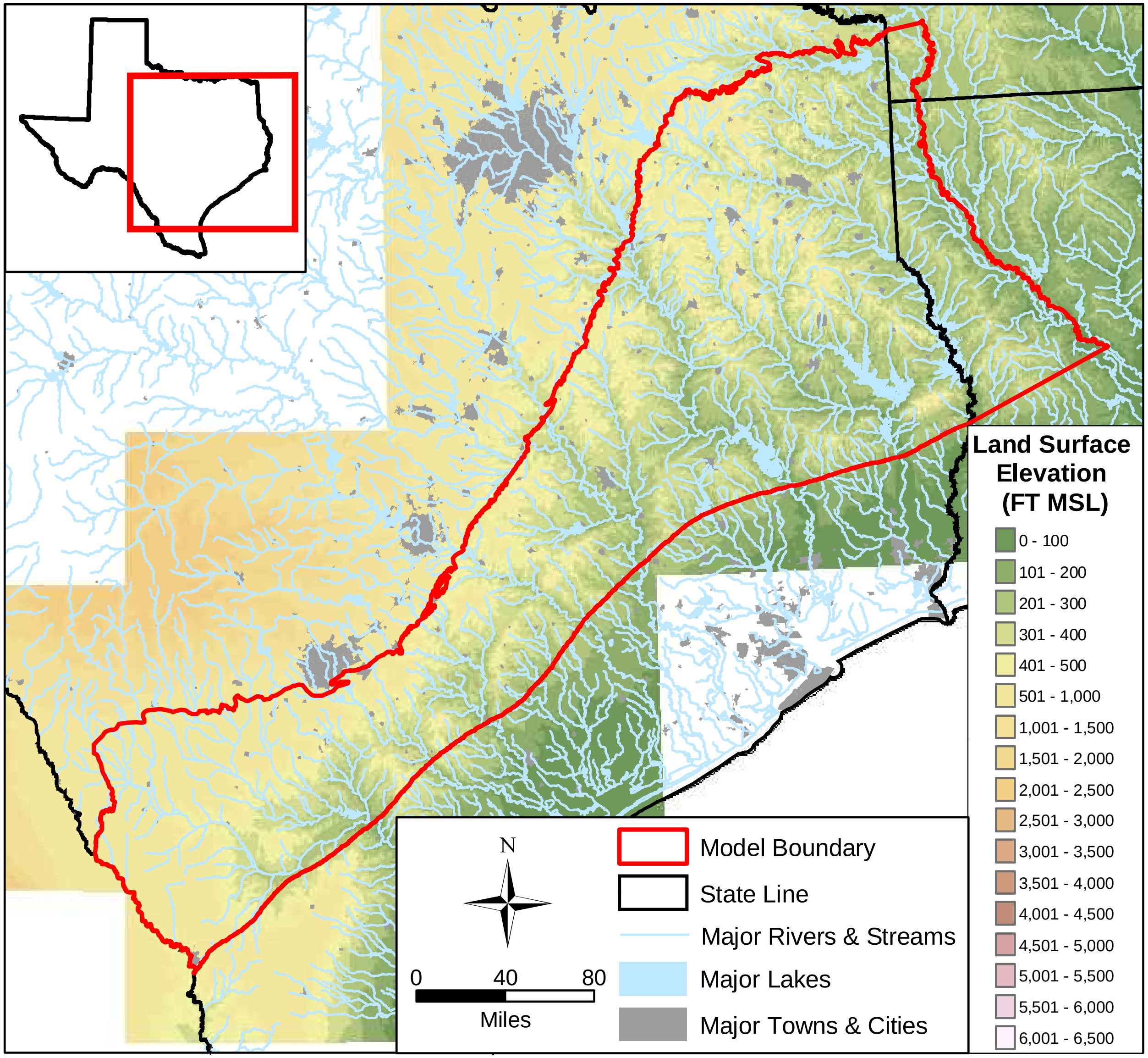


Ten of the Sixteen RWPGs are represented in the three GAM regions

Yearly Average Rainfall

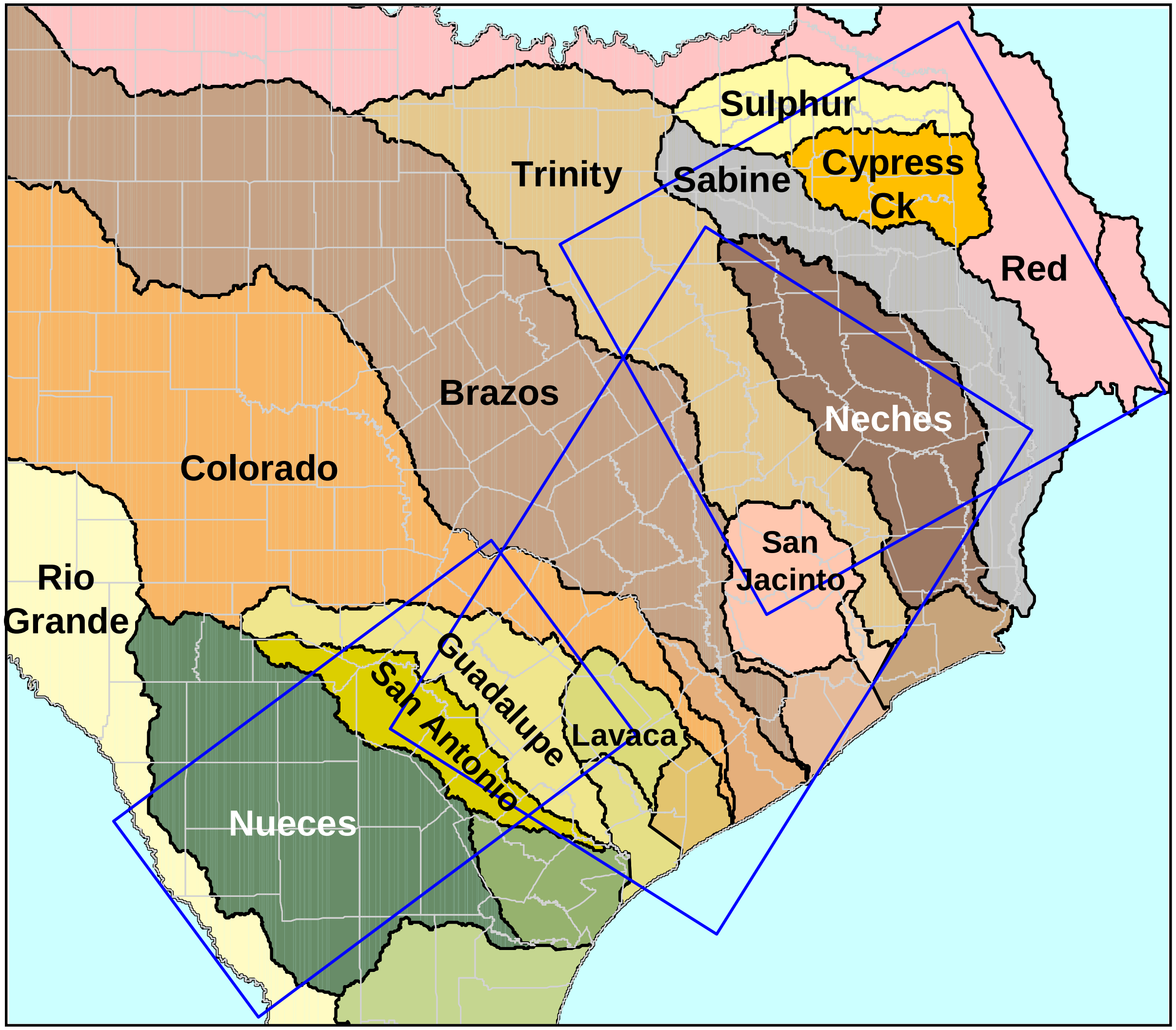


Land Surface Elevation

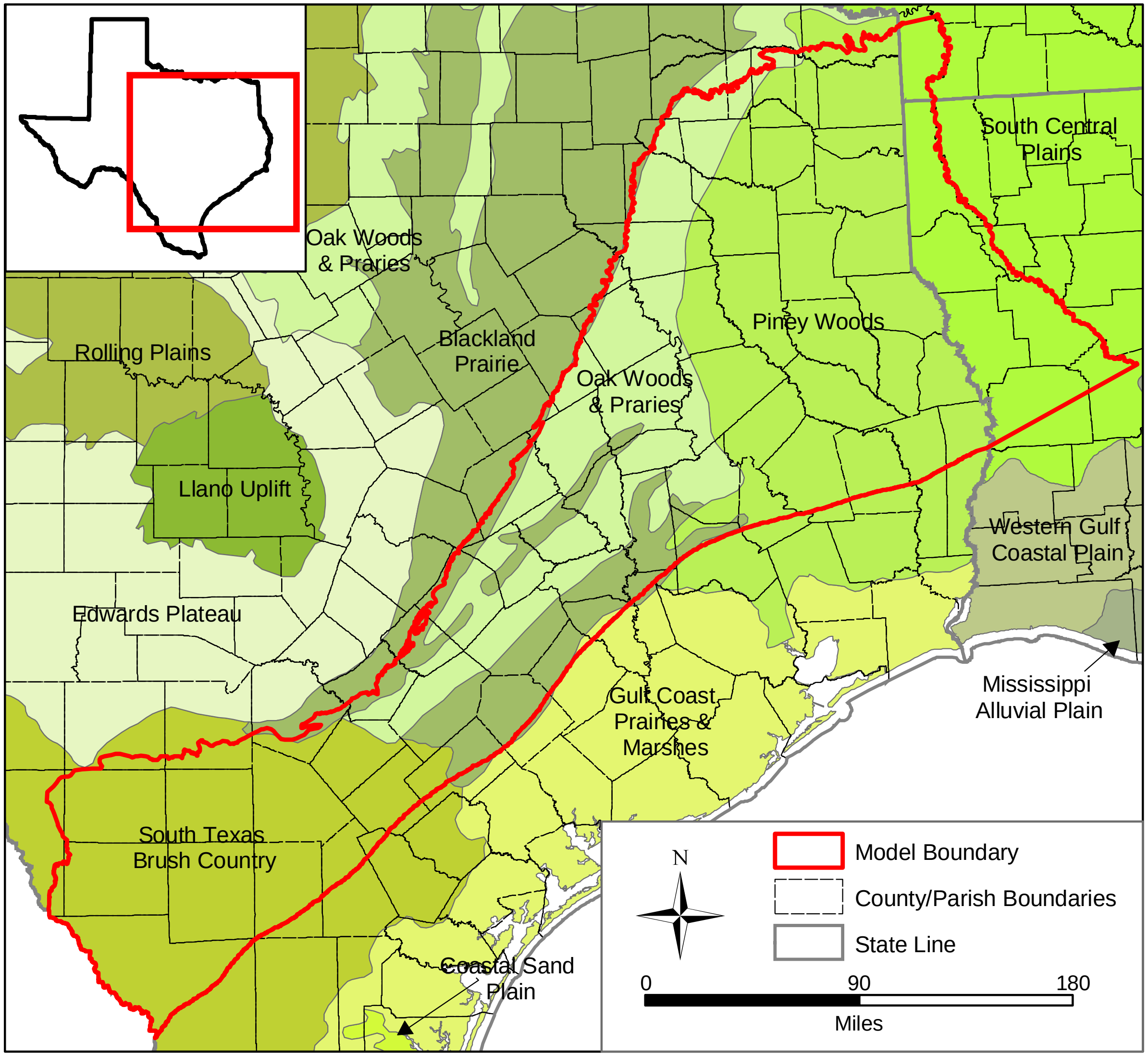


Major River Basins

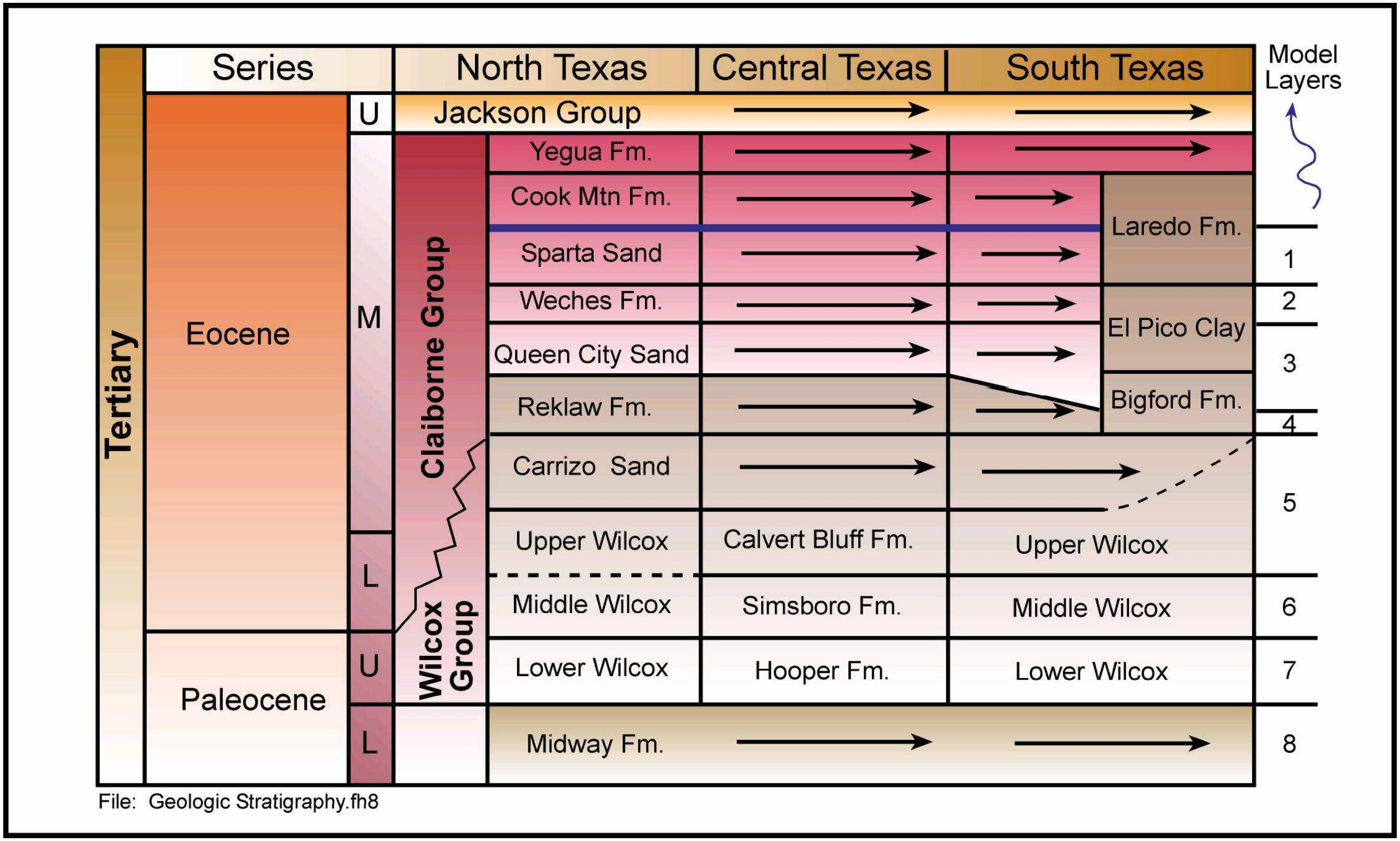
Every major river basin is intersected by at least one of the three model domains



Eco Regions


Oak Woods
& Praries
Rolling Plains
Blackland
Prairie
Oak Woods
& Praries
Piney Woods
South Central
Plains
Llano Uplift
Western Gulf
Coastal Plain
Edwards Plateau
Mississippi
Alluvial Plain
Gulf Coast
Prairies &
Marshes
South Texas
Brush Country
Coastal Sand
Plain
N
Model Boundary
County/Parish Boundaries
State Line
0
90
180
Miles

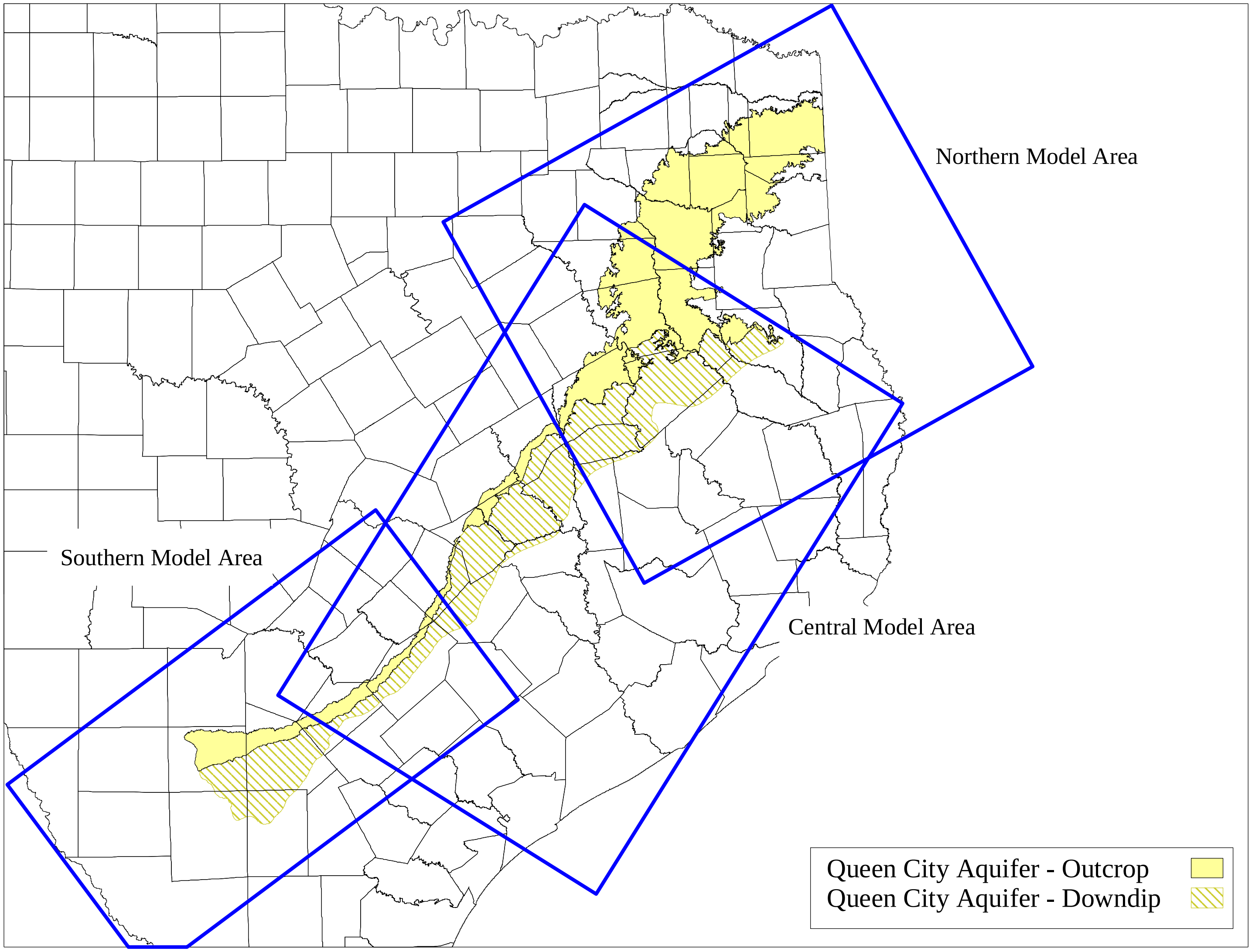
Model Stratigraphy



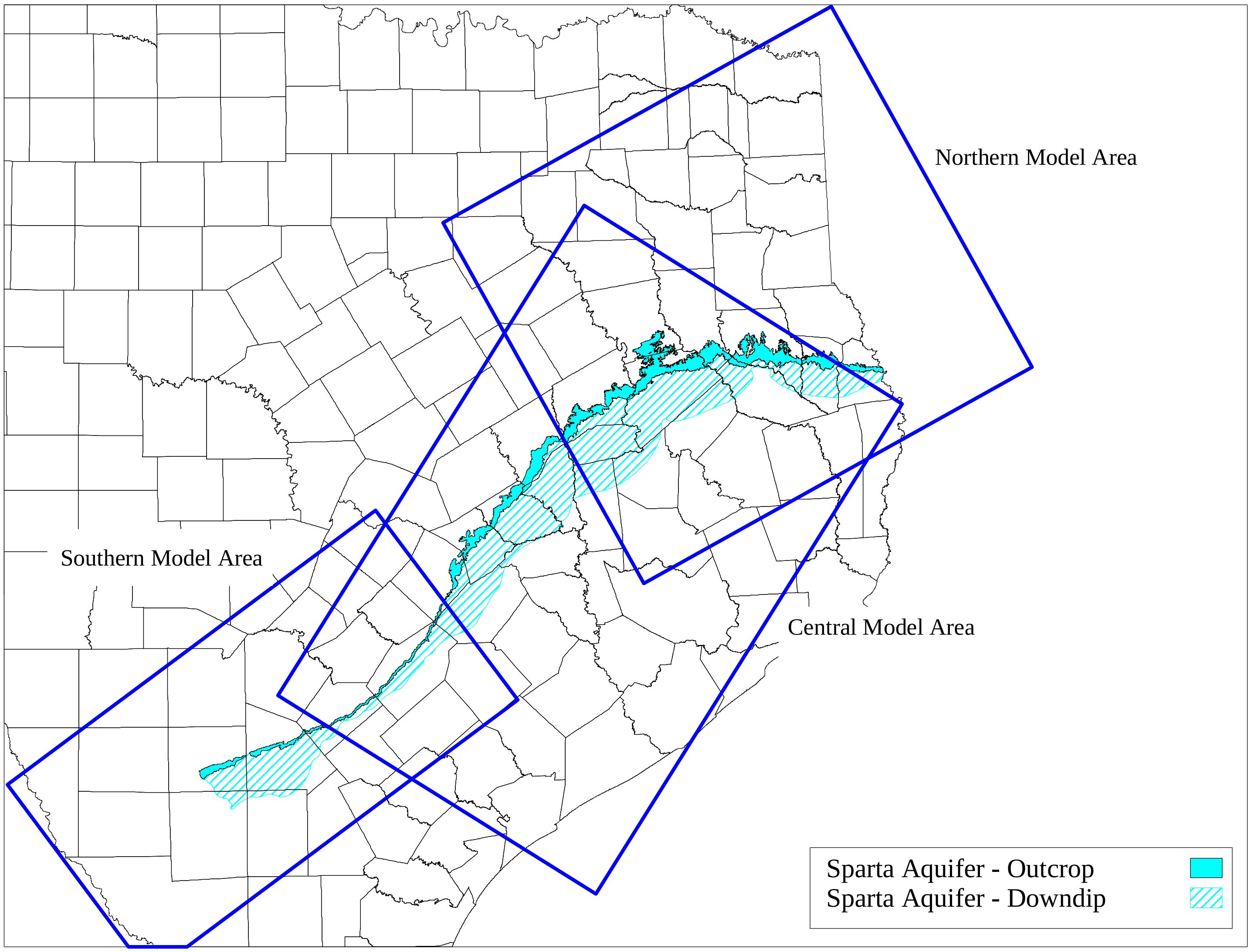
Queen City & Sparta Aquifers

- The Queen City and Sparta Aquifers extend from South Texas northeastward through East Texas into Ark. & La.
  - Sediments of the Tertiary Claiborne Group
  - Queen City aquifer consists of sand, loosely-cemented sands, and interbedded clays
  - Sparta Aquifer consists of sand and interbedded clays with massive basal sands which gently dip toward the Gulf Coast (average thickness of 400 ft.)
  - Aquifers are separated by the Weches Formation which is a marine confining unit

Queen City Aquifer



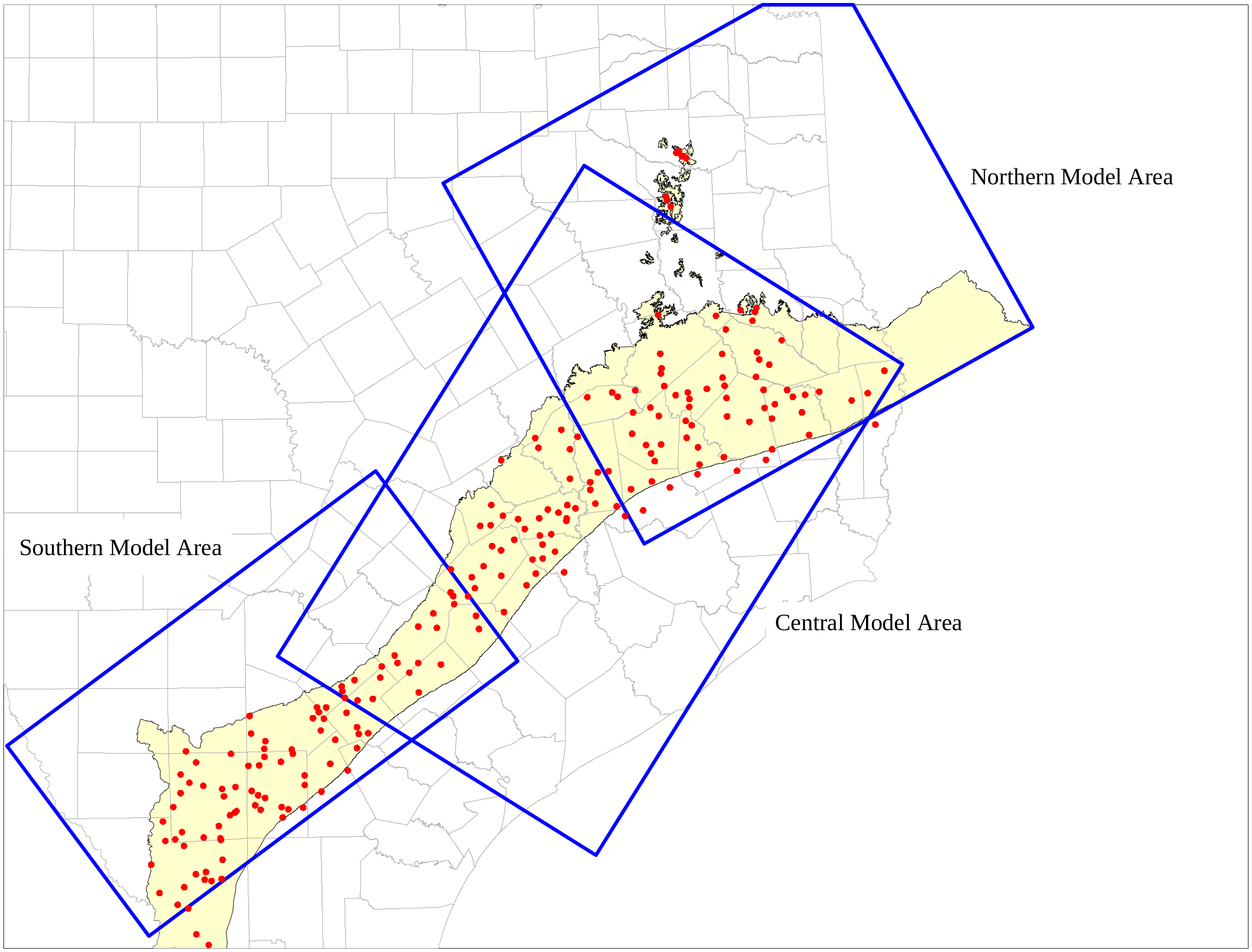
Sparta Aquifer



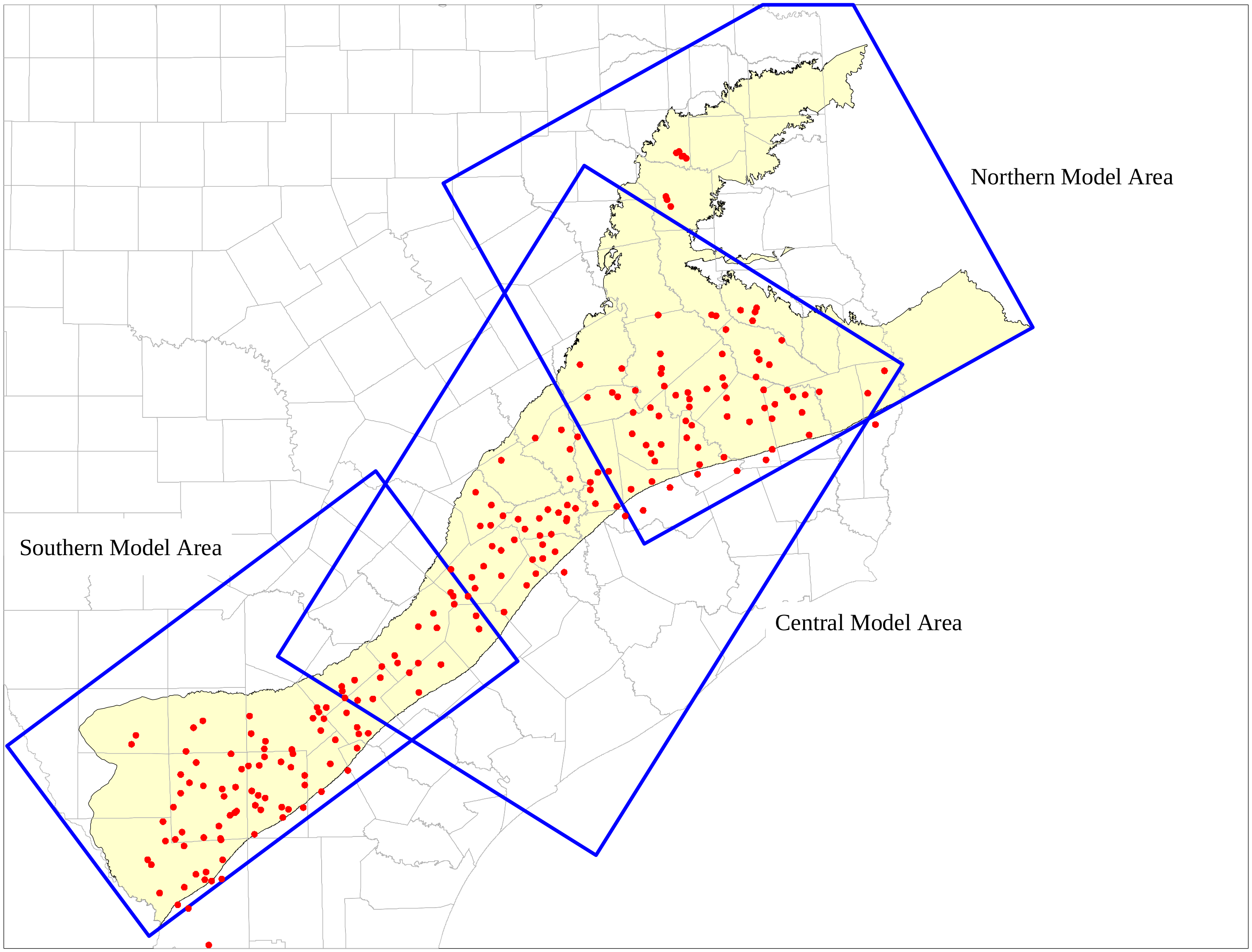
Geologic Structure Data Sources

- 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
    - 700 Logs available across the 3 model areas
- Sand thickness maps:
  - Guevara (1972) & Garcia (1972) – Queen City
  - Ricoy (1976) and Payne (1968) - Sparta

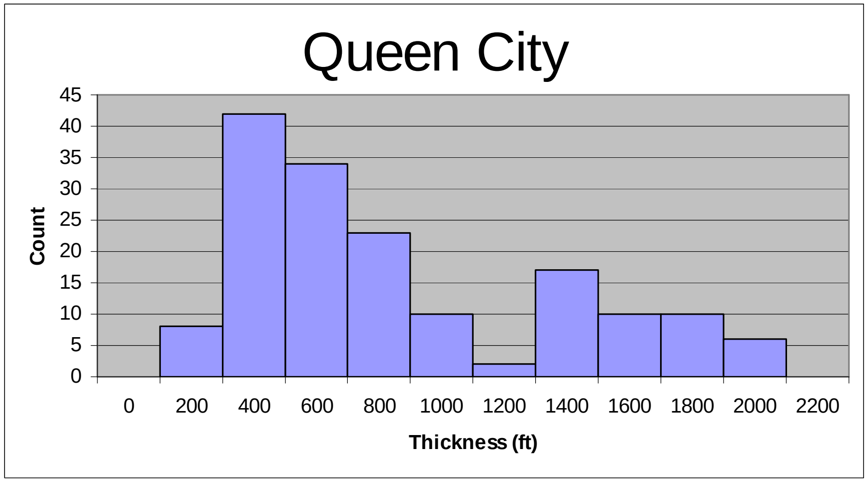
Sparta Aquifer – Structure Control

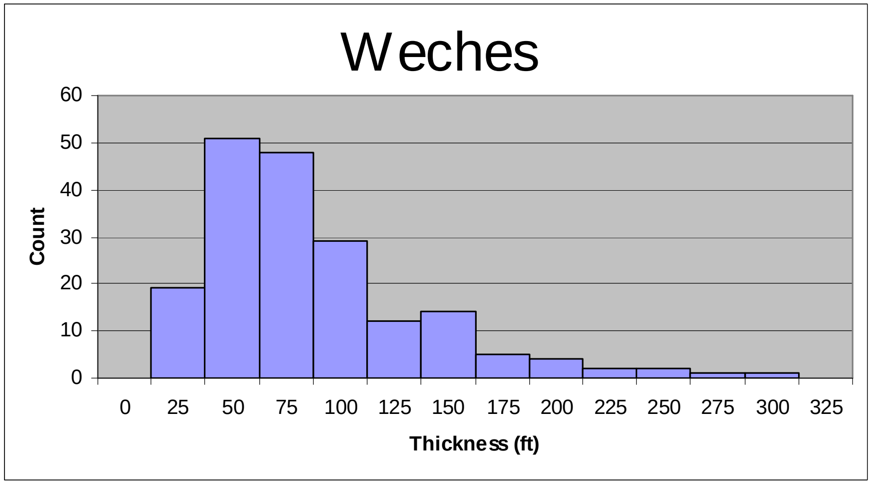


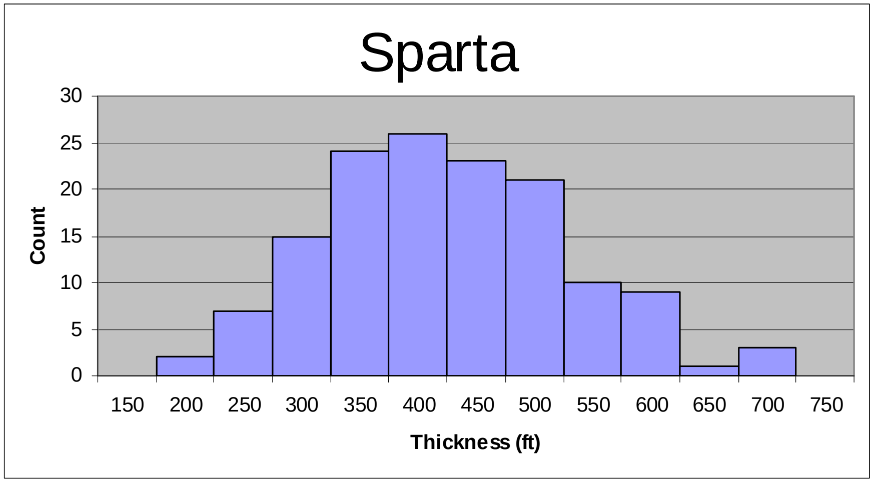
Queen City Aquifer – Structure Control



Aquifer Thickness - Draft

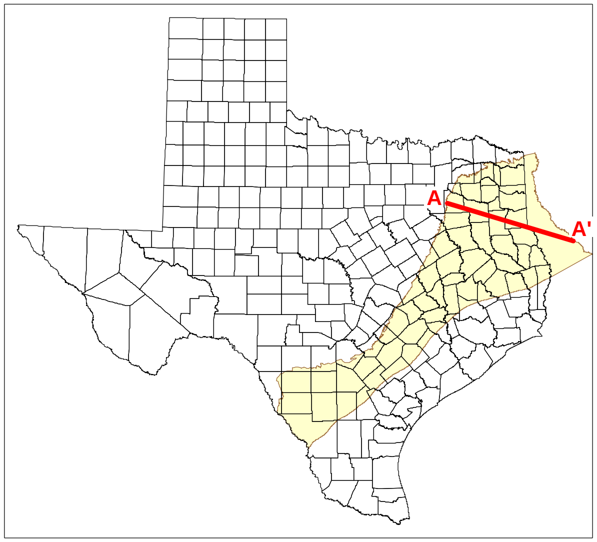


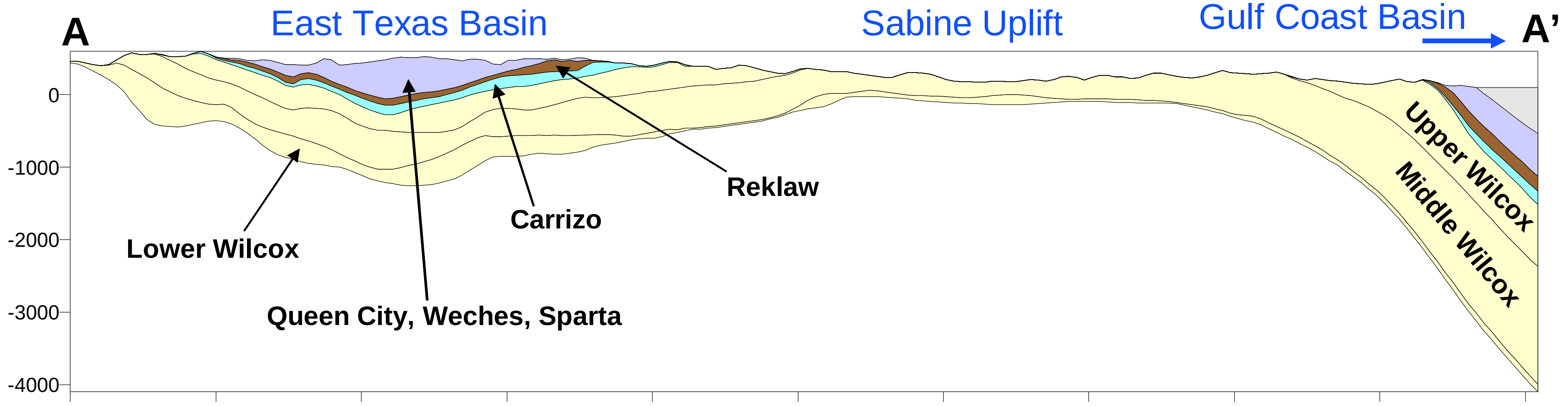




Hydrogeologic Cross Section

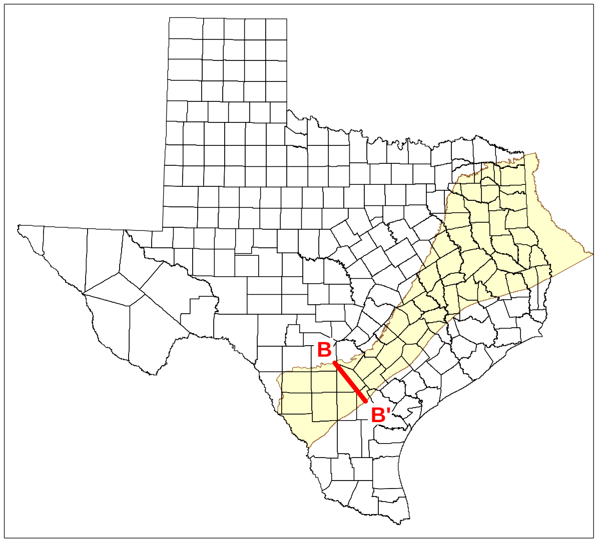
- **Northern Model Region**
  - Queen City outcrops over the majority of the East Texas Basin
  - Queen City and Sparta eroded across the Sabine Uplift
  - South of Sabine Uplift aquifers dip into the Gulf Coast Basin

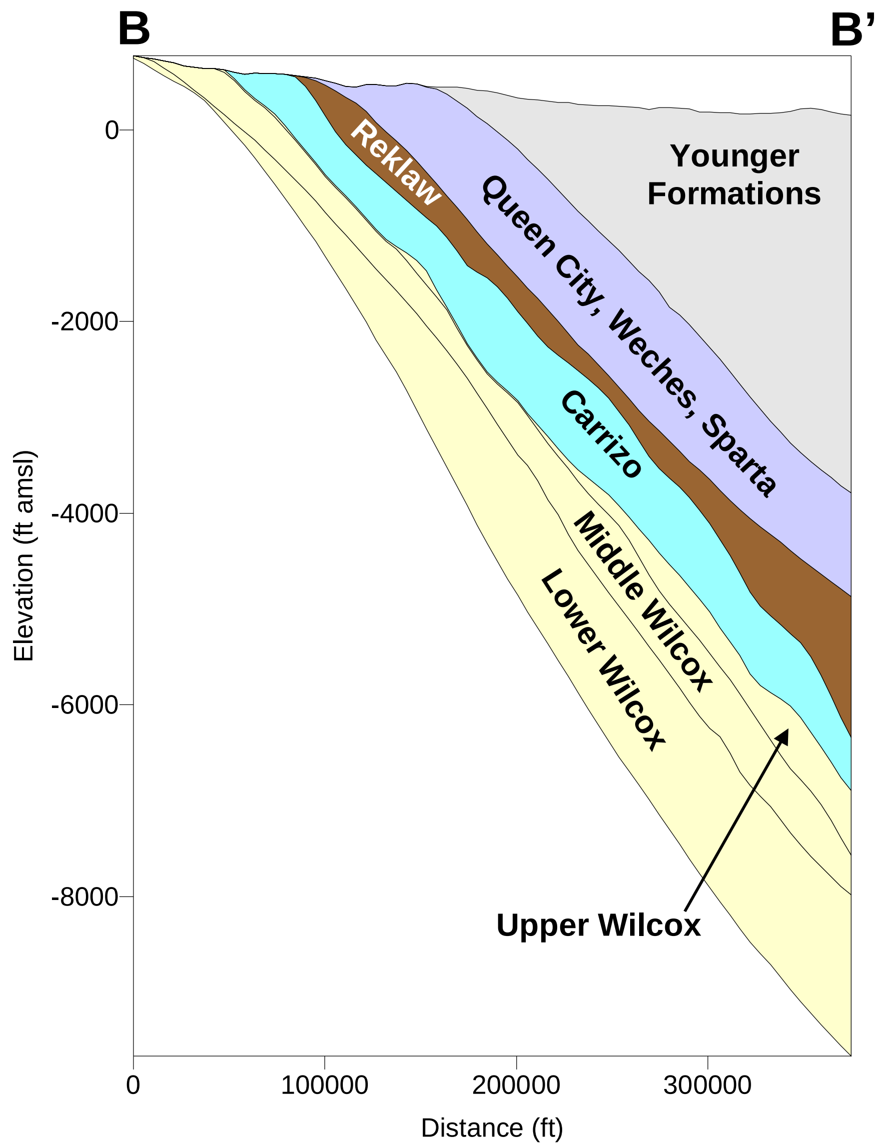




Hydrogeologic Cross section

- **Central and Southern Models**
  - Outcrops are very narrow
  - Dips are very steep averaging 100 ft/mile or >





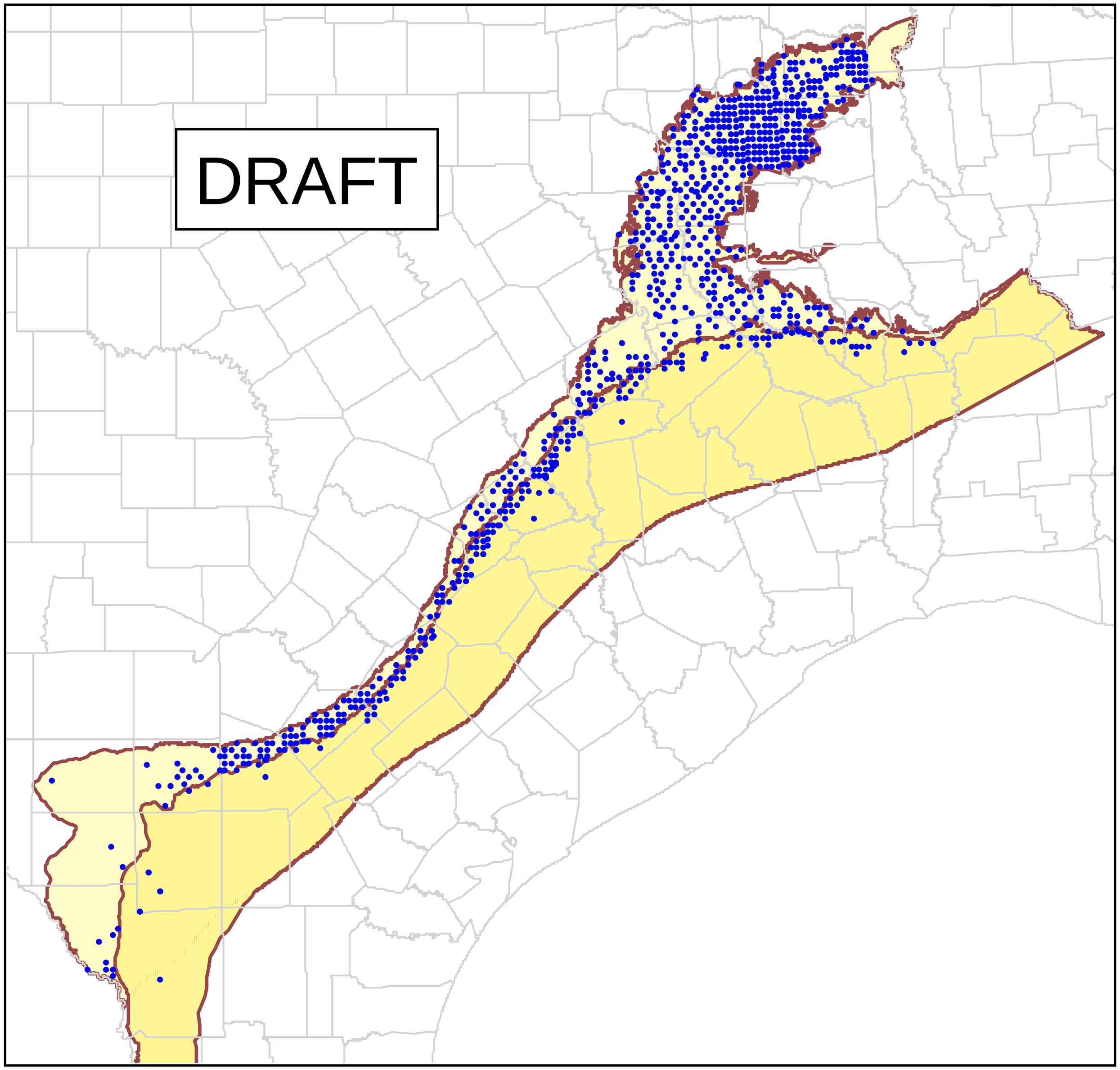
Hydraulic Properties

- Published Reports:
  - USGS
    - Payne (1968)
    - Hays et al (1998)
    - RASA – Prudic (1991)
  - BEG
    - Guevara & Garcia (1972)
    - Ricoy (1977)
  - TWDB
    - Myers (1969)
    - County Reports
- TCEQ file search of the drillers logs
  - Estimates of specific capacity will be used to augment published values
- Stakeholder provided data

Hydraulic Conductivities

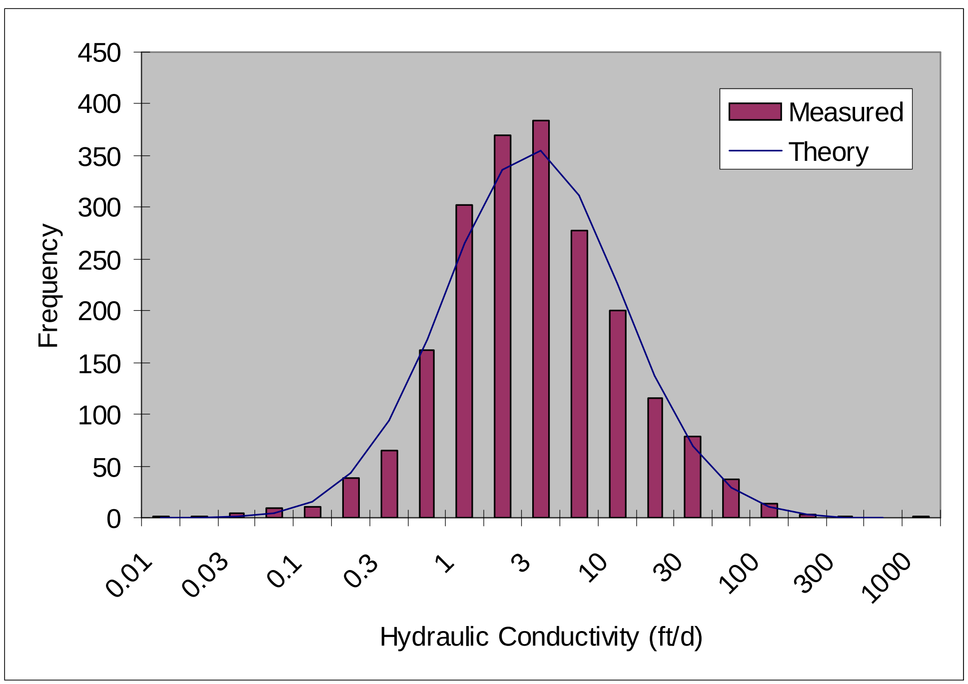
- Completed a literature review for available hydraulic conductivity measurements (TWDB reports, TWDB GWDB, BEG publications.
- BEG has compiled specific capacity data from the TCEQ records (>2000 estimates).
- We will add hydraulic conductivity estimates from Mace et al. (2000) if they vertically fall within the Queen City and are without aquifer code

Hydraulic Conductivity Control



TCEQ Hydraulic Conductivity Data

	WELL GEOMETRY								WELL TEST					
County	Date Drilled	Well Diameter (inch)	Well Depth (ft)	Pump Depth (ft)	Gravel Packed (Y-N)	Tubing1 Diameter (inch)	Screen1 Top (ft)	Screen1 Bottom (ft)	Measu-rement Date	Depth to Water (ft)	Pump rate (gpm)	Drawdown (ft)	Pumping Time (hr)	Test Type1
CASS	08/02/99	6.75	65	56	Y	4	30	57	08/03/99	33	10	40	1	JETTED
CASS	10/23/99	6.75	340	150	Y	4	180	280	10/23/99	47	50	100	1	JETTED
CASS	10/07/83	6.75	360	200	N	2	276	360	10/12/83	80	30	100	0.5	JETTED
CASS	07/02/96	6.75	360	264	Y	2	N/A	N/A	N/A	100	5	165	4	JETTED
CASS	03/15/00	6.75	502	320	Y	4	450	495	03/18/00	187	20	100	1	JETTED
CASS	07/15/97	6.75	575	280	Y	4	531	565	07/15/97	156	25	80	1	N/A
CASS	08/04/87	8.75	98	96	Y	4	78	98	08/06/87	66	5	30	2	N/A
CASS	08/02/87	8.75	98	95	Y	4	78	98	08/02/87	66	7	30	2	ESTIMATED
CASS	05/04/87	6.75	242	160	Y	2	218	238	05/04/87	86	10	40	1	N/A
CASS	09/15/87	N/A	605	300	Y	2	580	605	09/20/87	180	12	27	6	PUMP



- Draft analysis
- Average is 3.6 ft/day
- Awaiting final structure for discrimination between aquifers and confined/unconfined

Vertical Hydraulic Conductivity (Kv)

- Kv values for the Northern and Southern Carrizo-Wilcox models were set using constant Kh/Kv ratios over large zones.
- Kv values for the Central Carrizo-Wilcox model were calculated as the harmonic mean assuming and calibrating a clay conductivity.
- We propose to use clay fraction and an assumed clay conductivity to define Kv zones which would then be varied within limits during calibration.

Regional Groundwater Flow

- In the northern portion of the study area, groundwater flows locally in the Queen City aquifer rather than regionally due to topographic controls (Fogg and Kreitler, 1982)
- In the central and southern portions of the study area, 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

Water Levels

- Objectives
  - Develop water-level elevation contours of predevelopment conditions
  - Develop water-level elevation contours for
    - The start of model calibration (1980)
    - The end of model calibration (1990)
    - The end of model verification (1999)
  - Evaluate transient water-level conditions and select hydrographs for use as calibration targets
  - Evaluate cross-formational flow

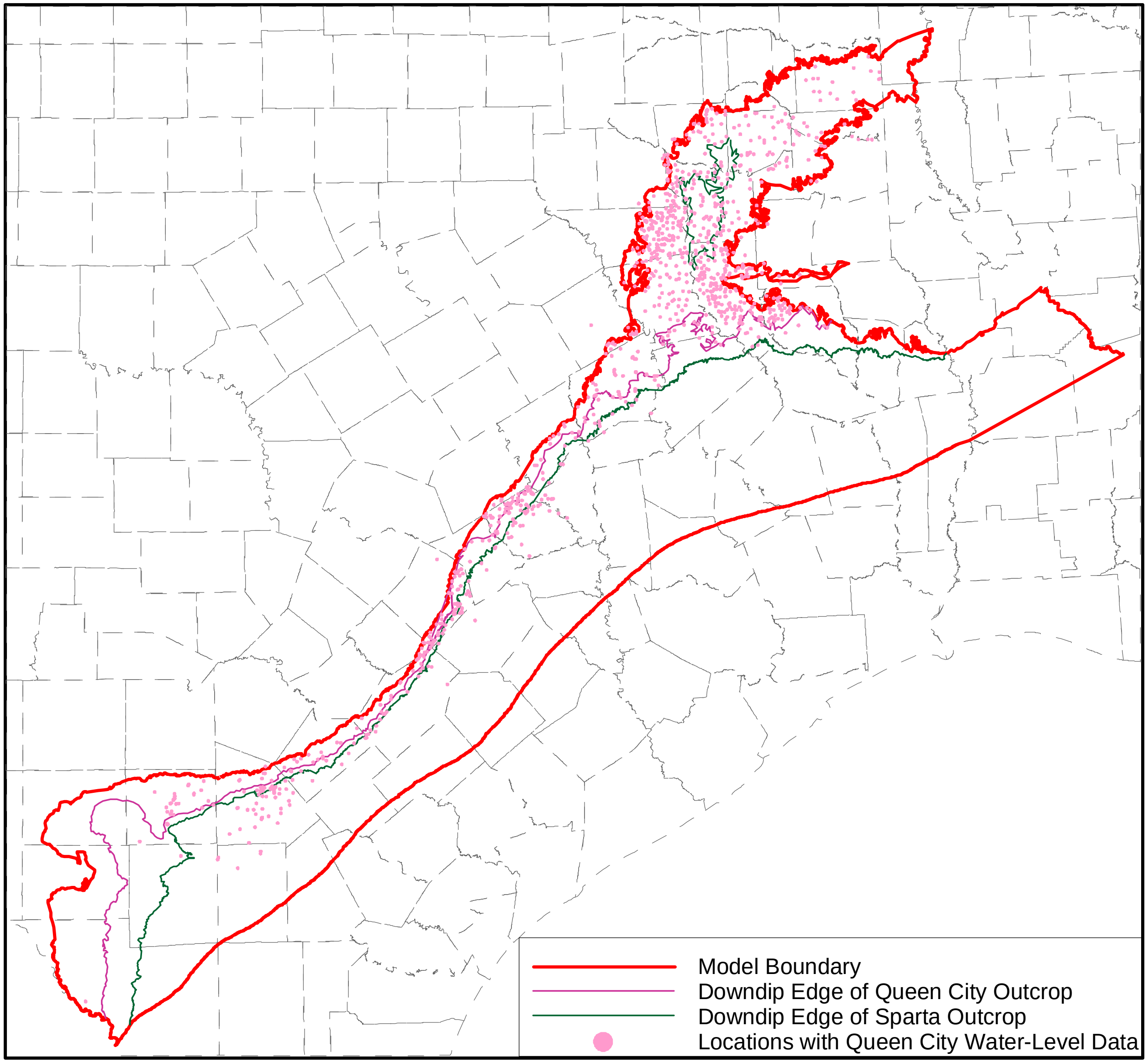
Water-Level Data

- Development of Water-Level Elevation Contours
  - Used data from the TWDB website
  - Averaged data from two years before and two years after the year of interest
  - Created contours for the Queen City and Sparta aquifers separately

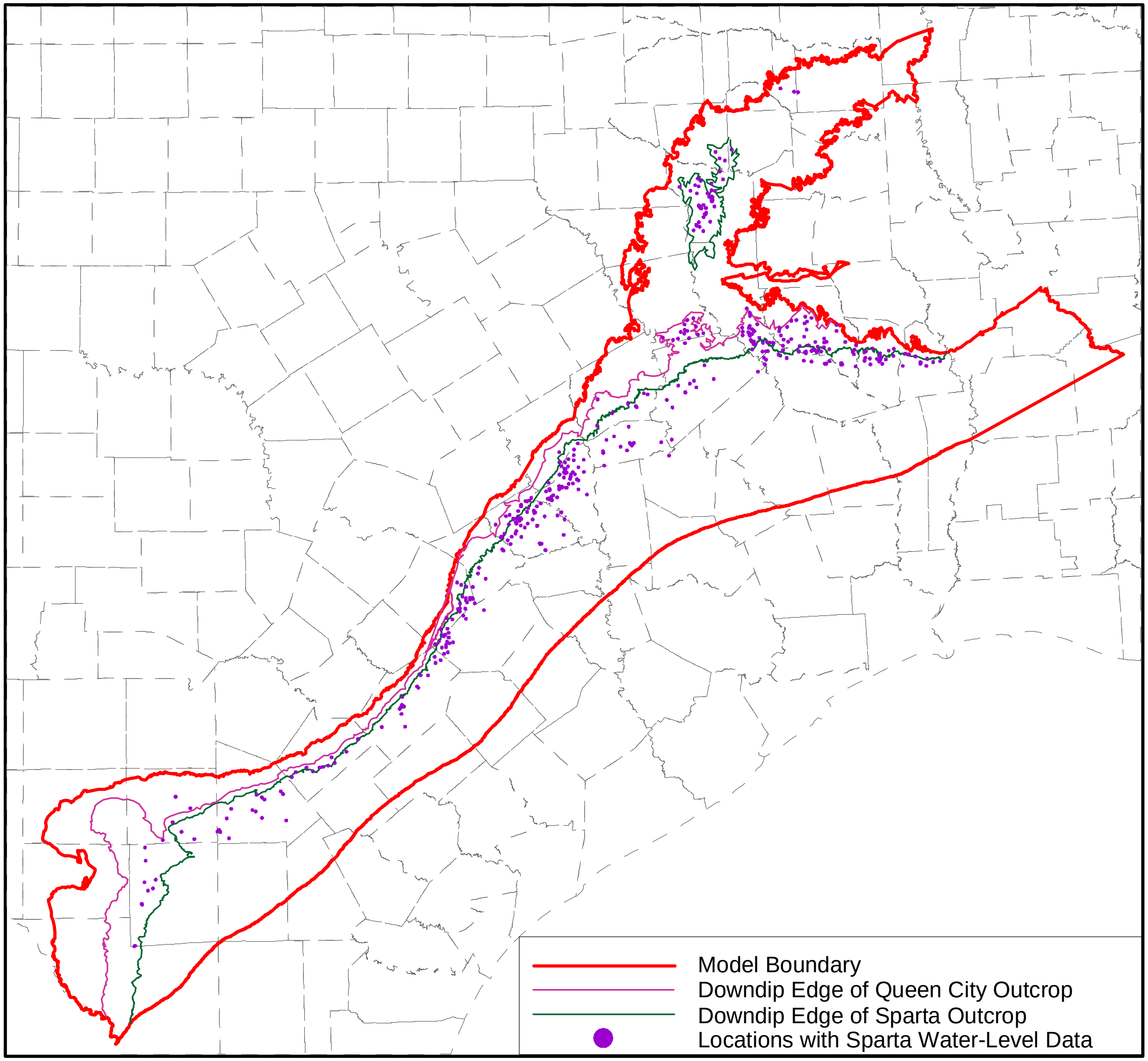
Water-Levels

- Challenges
  - Identification of predevelopment conditions
  - Inconsistent data coverage from year to year and county to county
  - Little well control down dip of the outcrop
  - Irregular topography in northern portion of the study area resulting in complex water-table surfaces for the Queen City and Sparta aquifers

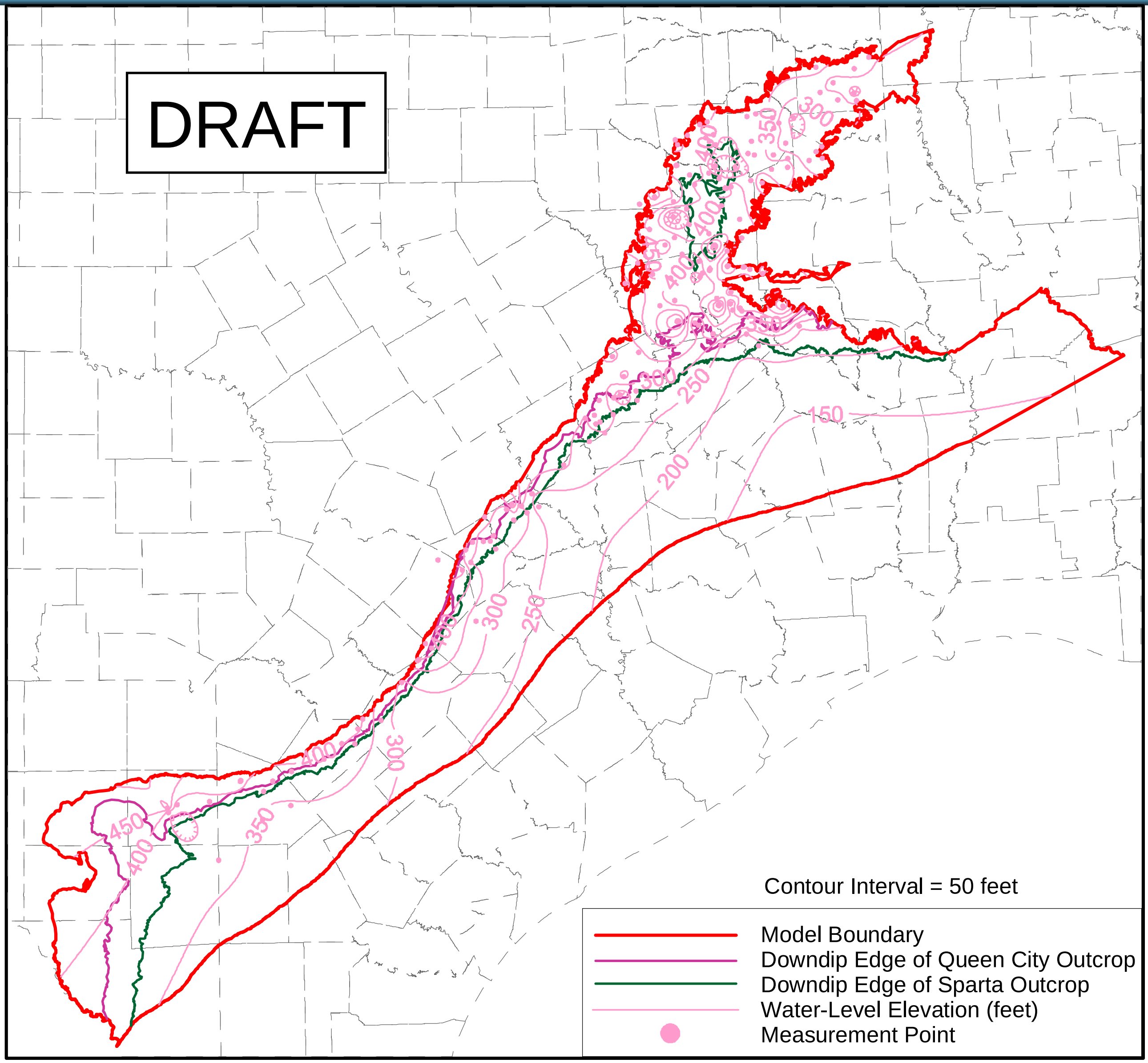
Queen City Water Level Control



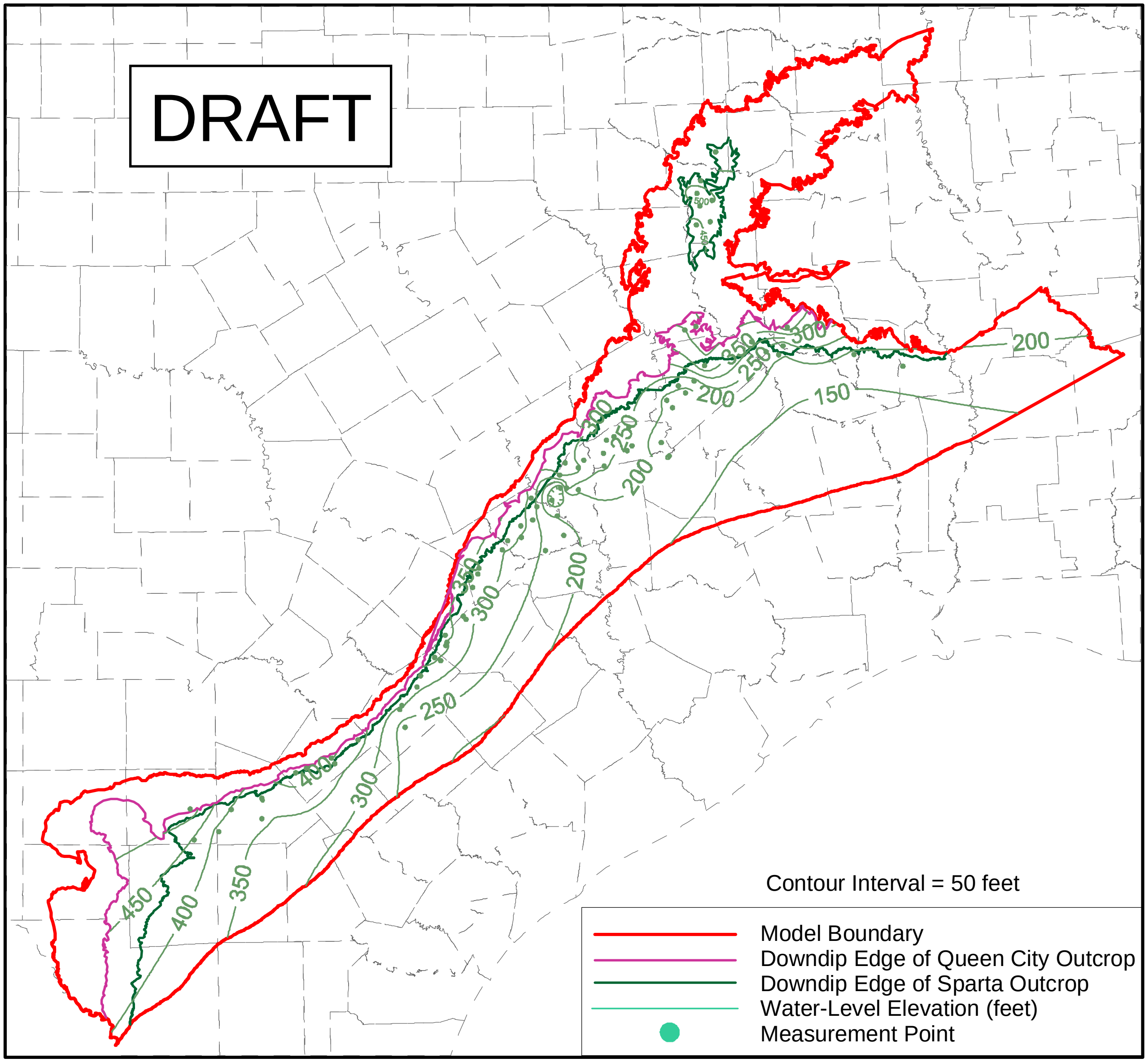
Sparta Aquifer Water Level Control



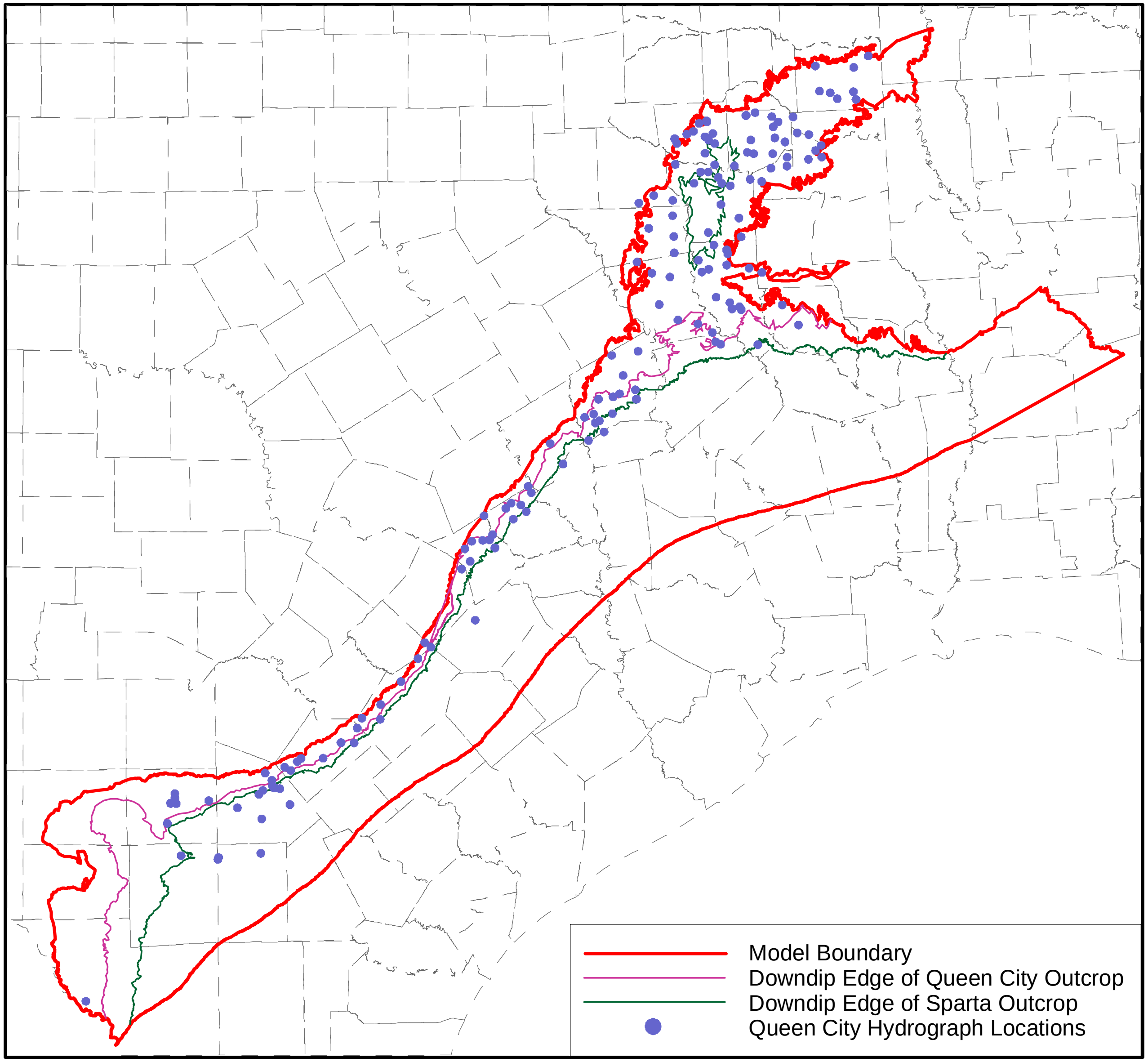
Queen City 1980 Water Level Elevation

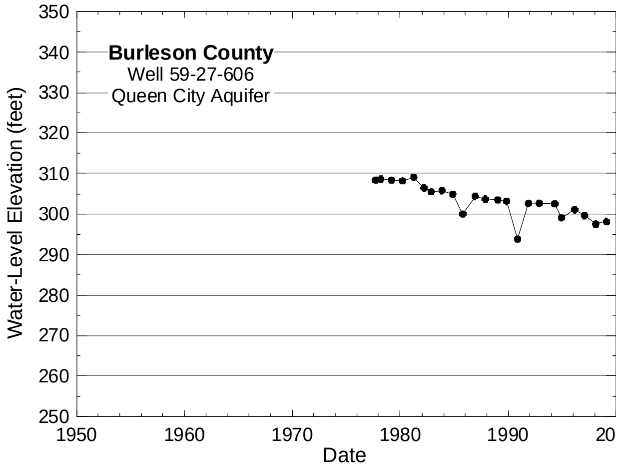


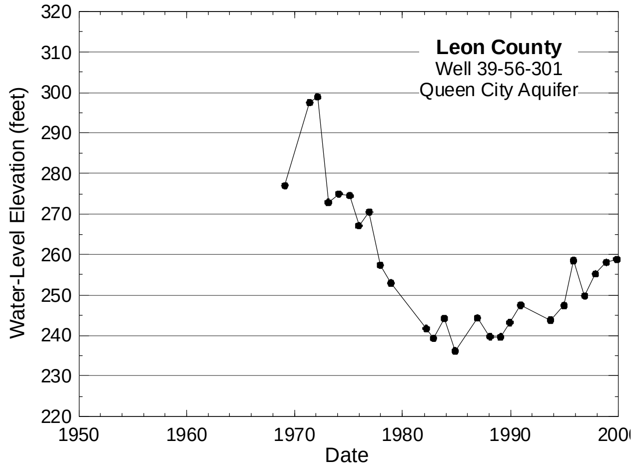
Sparta 1980 Water Level Elevation

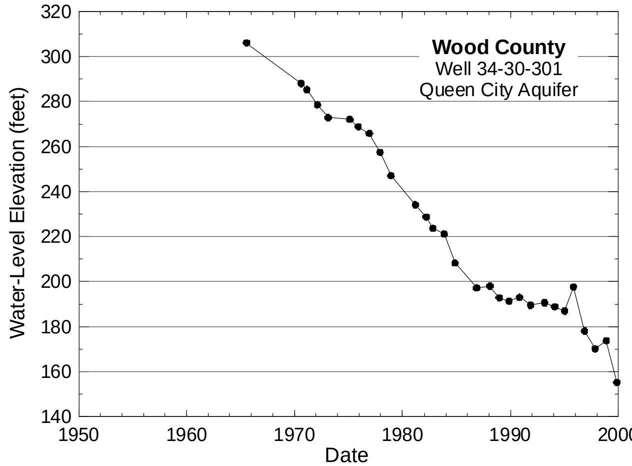


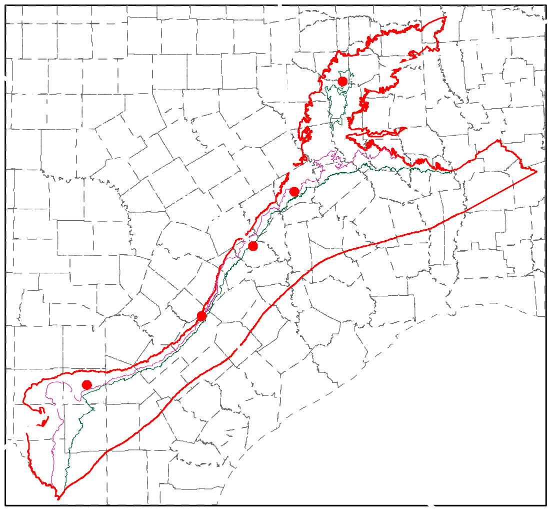
Queen City Hydrograph Locations

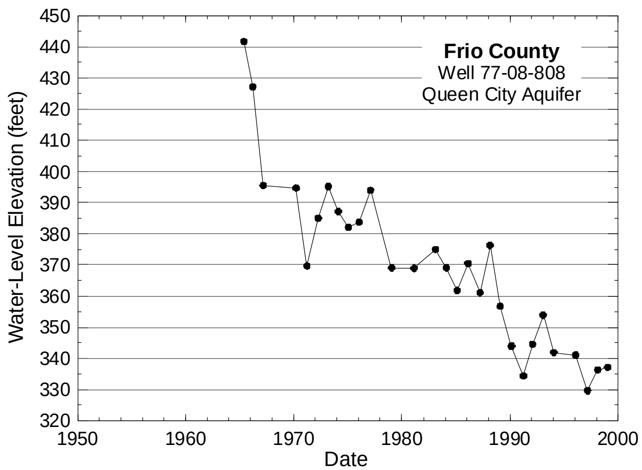


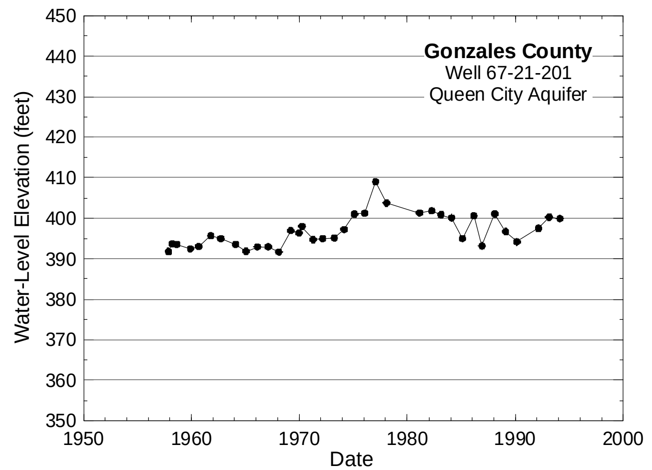






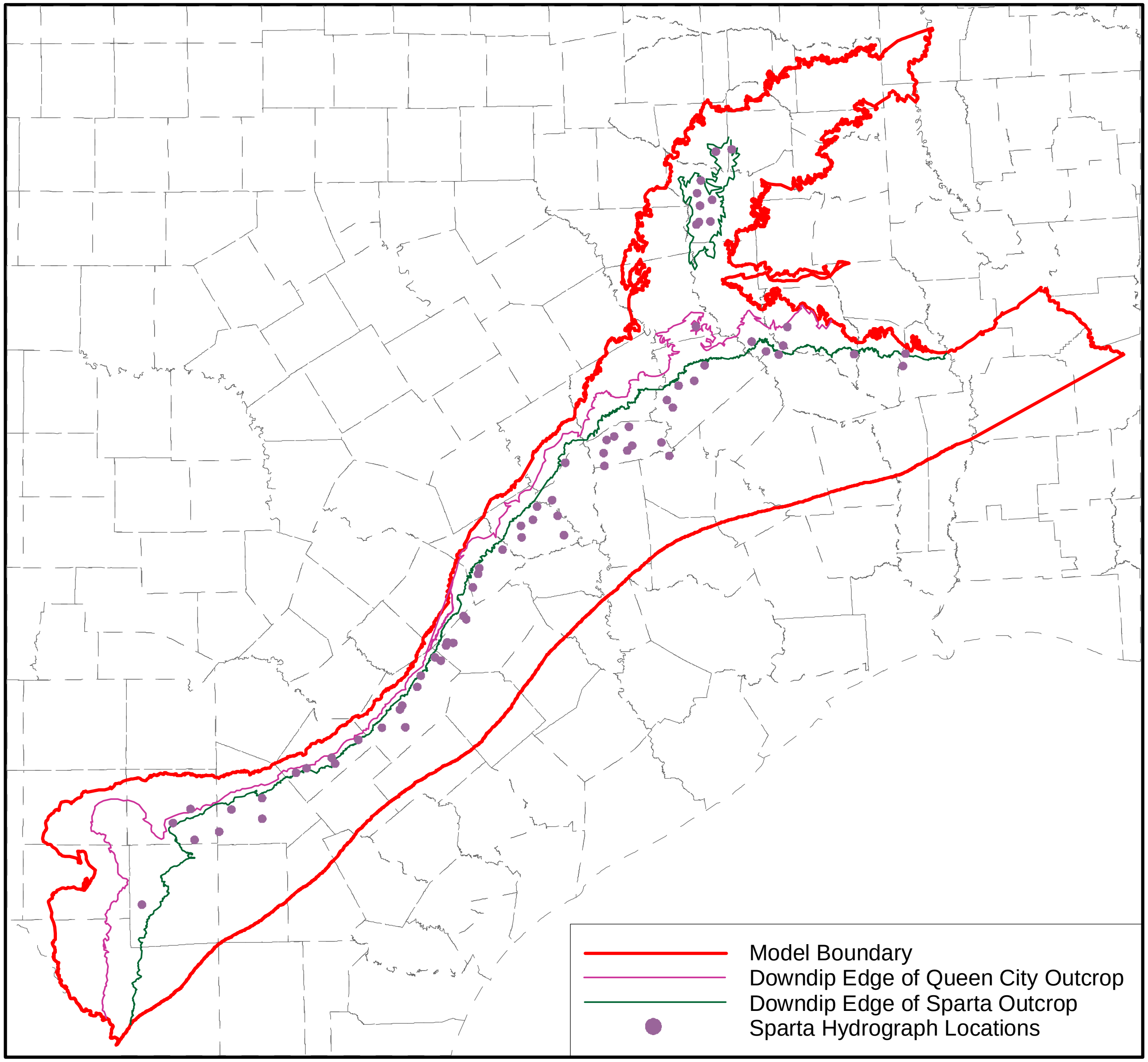


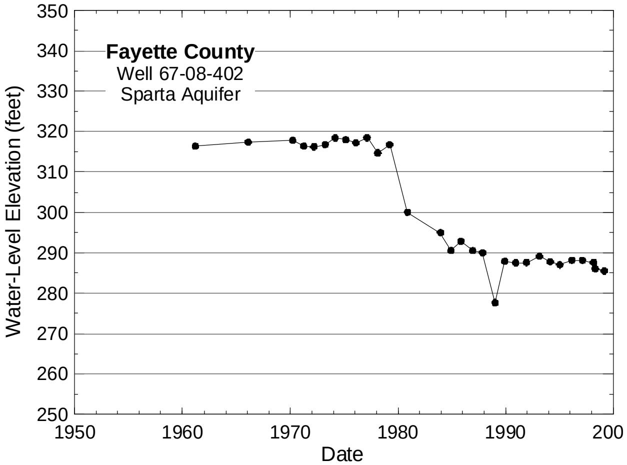


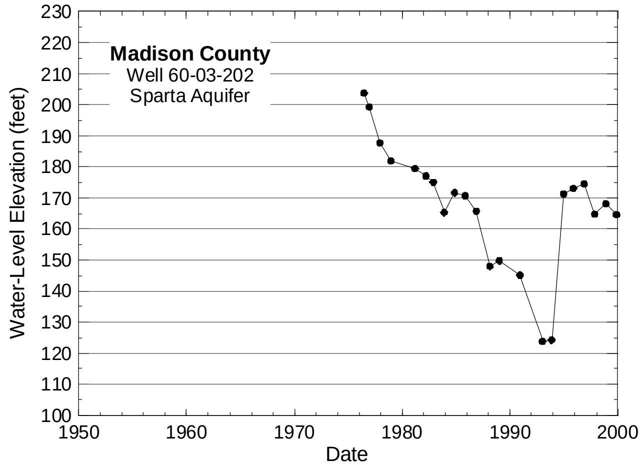


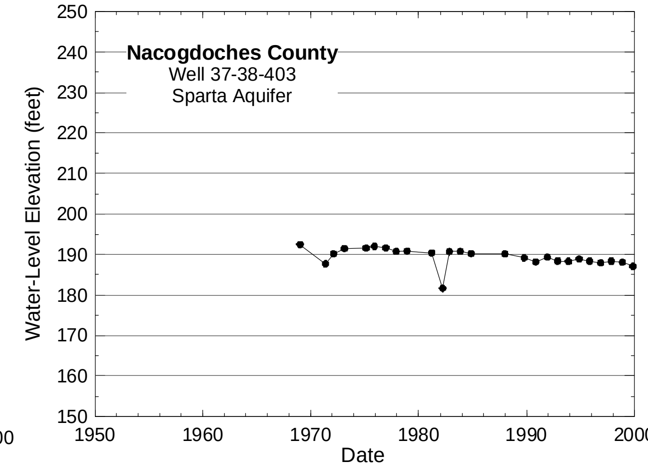
SAF 2 - June 12, 2003

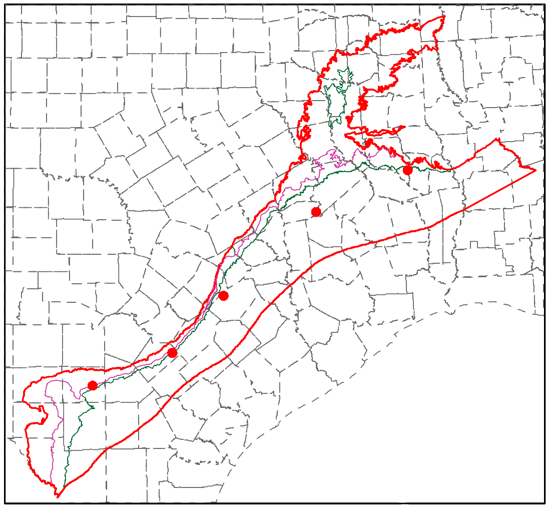
Sparta Hydrograph Locations

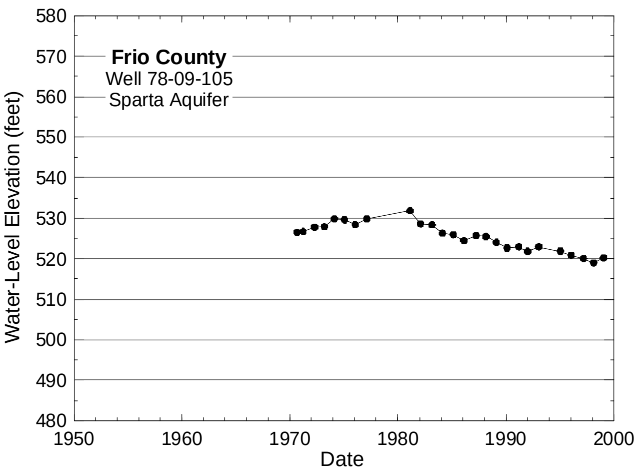


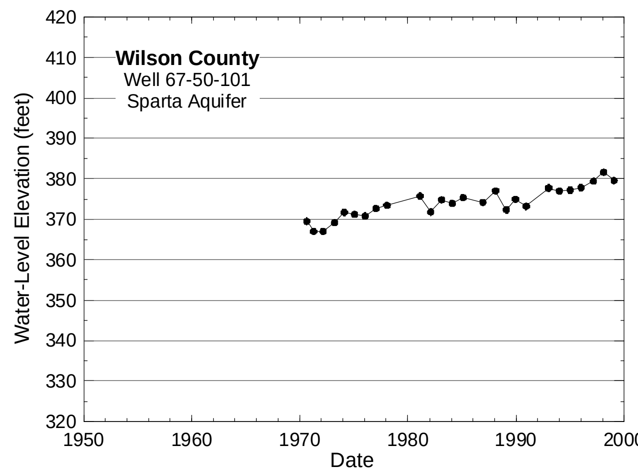

Fayette County
Well 67-08-402
Sparta Aquifer
Water-Level Elevation (feet)
Date
350
340
330
320
310
300
290
280
270
260
250
1950
1960
1970
1980
1990
200


Madison County
Well 60-03-202
Sparta Aquifer
Water-Level Elevation (feet)
Date
230
220
210
200
190
180
170
160
150
140
130
120
110
100
1950
1960
1970
1980
1990
2000


Nacogdoches County
Well 37-38-403
Sparta Aquifer
Water-Level Elevation (feet)
Date
250
240
230
220
210
200
190
180
170
160
150
1950
1960
1970
1980
1990
2000




Frio County
Well 78-09-105
Sparta Aquifer
Water-Level Elevation (feet)
Date
580
570
560
550
540
530
520
510
500
490
480
1950
1960
1970
1980
1990
2000


Wilson County
Well 67-50-101
Sparta Aquifer
Water-Level Elevation (feet)
Date
420
410
400
390
380
370
360
350
340
330
320
1950
1960
1970
1980
1990
2000

Recharge

- Recharge – The addition of water to the water table. Recharge equals water inputs at ground surface (precipitation + irrigation + stream loss) minus water losses (runoff + evapotranspiration)
- Recharge is a complex function of
  - Precipitation (rate, volume, distribution),
  - Evapotranspiration (ET)
  - Runoff
  - Soil moisture, soil type
  - Runoff
  - Depth to water
- Recharge is not directly measurable on a model scale
- Recharge varies as a function of time and space

Recharge

- Northern and Southern Carrizo-Wilcox GAMs
  - SWAT models used to predict recharge variation both temporally and spatially
  - Recharge based primarily on daily precipitation data, MRLC land use data, and STATSGO soil parameters.
  - SWAT recharge results in the Northern Carrizo-Wilcox model & northern part of the Southern model were decreased during calibration.
- Limitations to Method as applied
  - Rates too high in high precipitation regions
  - Method is decoupled from underlying aquifer properties

Recharge

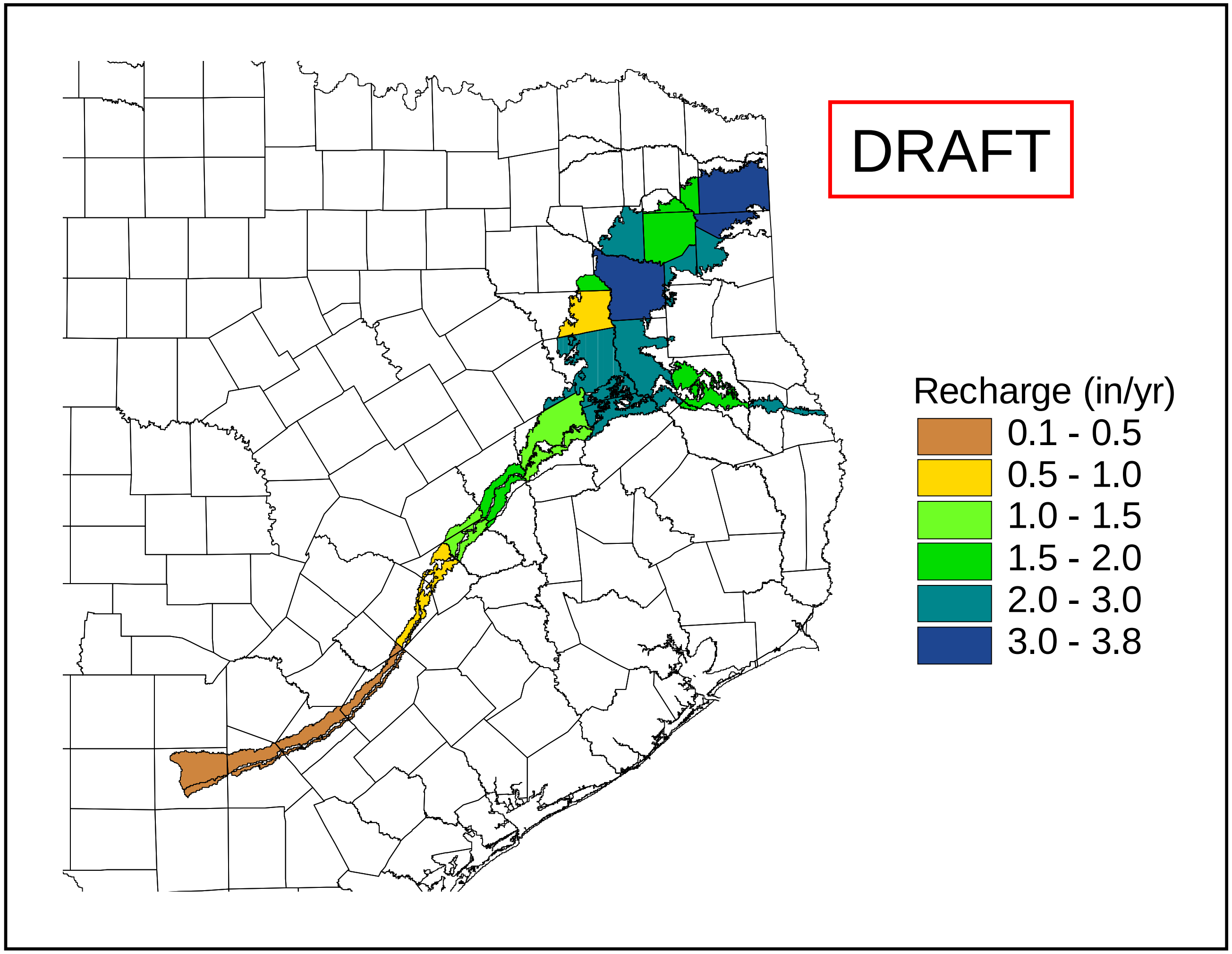
- Central Carrizo Wilcox Model
  - *Estimated* minimum and maximum temporal recharge rates (corresponding to minimum and maximum precipitation) for each formation.
  - Scaled the recharge spatially based on soil hydraulic conductivity, with maximum recharge occurring for a soil column vertical hydraulic conductivity greater than or equal to 1.75 ft/day.
- Limitations to Method as applied
  - Subjective specification of formation minimum and maximums
  - Limits recharge areally which may tend to limit total recharge volumes

Recharge Estimates – Muller and Price (79)

Basin	Zone	Carrizo Wilcox	Queen City	Sparta
Sulphur	1	4000	7000	
Cypress	1	15000	234500	
Sabine	1	40000	137800	
Sabine	2	4000		7400
Neches	1	124600	253200	30700
Neches	2	25400	8100	23700
Trinity	1	13400	500	
Trinity	2	65300	14500	34800
Trinity	3	300		200
Brazos	4	11100		
Brazos	5	118200	2700	7000
Colorado	3	49200	3700	10000
Guadalupe	2	38600	8000	20000
San Antonio	2	33200	3600	10000
Nueces	1	78700	8500	20000
Rio Grande	2	13700		
		634700	682100	163800

Region	M&P 79	Model
South	186,340	190,400
Central	479,700	273,900
North	327,460	310,582

Queen City-Sparta Recharge Estimates



- Chloride mass balance method
- BEG study in progress (Scanlon and Reedy)
- Based upon 1050 Cl measurements in the outcrop of QC/Sparta

Water Quality

- Data on water quality were obtained from TWDB internet files and TCEQ's public water supply section
- Data were requested from groundwater conservation districts
- Water-quality data from TWDB included:
  - 289 wells with information for the Queen City and El Pico Formations
  - 405 wells with data for the Sparta and Laredo Formations
- Where repeated samples were reported, the most recent analysis was used for mapping

Water Quality Results

- Average total dissolved solids (TDS) increases down dip in the aquifers:
  - Statistics confirms that average TDS in the confined aquifer is greater than in the unconfined parts of the Queen City and Sparta aquifers.
- Average TDS is greater south of Lee County than to the north, as previously reported in TWDB Hydrologic Atlases:
  - Statistical tests confirm findings for both the Queen City and Sparta aquifers.
  - Evaluation of the hydrogeologic control(s) of this regional difference is in progress.

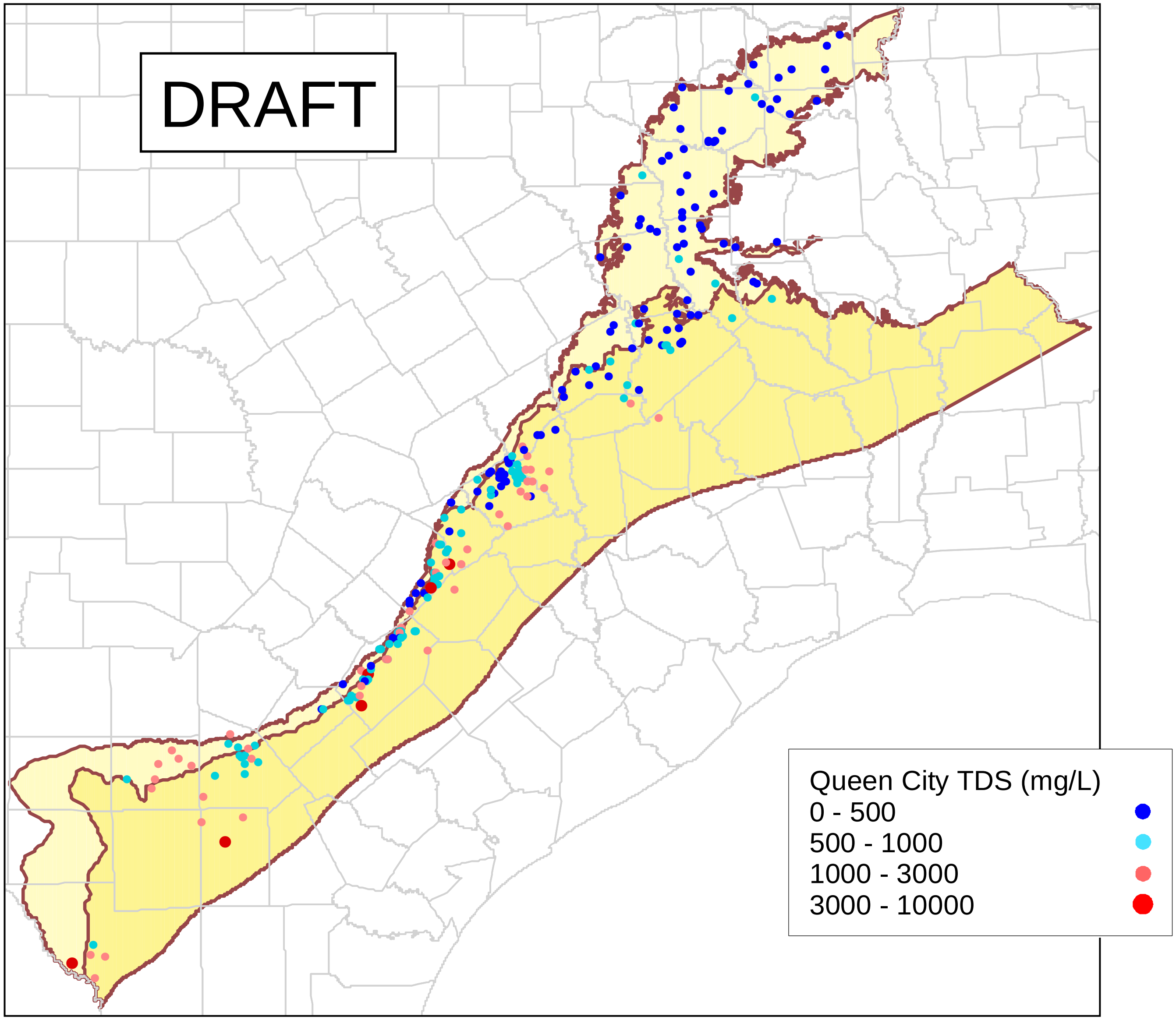
Water Quality Results (cont.)

- Average TDS is greater south of Lee County than to the north, as previously reported in TWDB Hydrologic Atlases:
  - Statistical tests confirm findings for both the Queen City and Sparta aquifers.
  - Evaluation of the hydrogeologic control(s) of this regional difference is in progress.

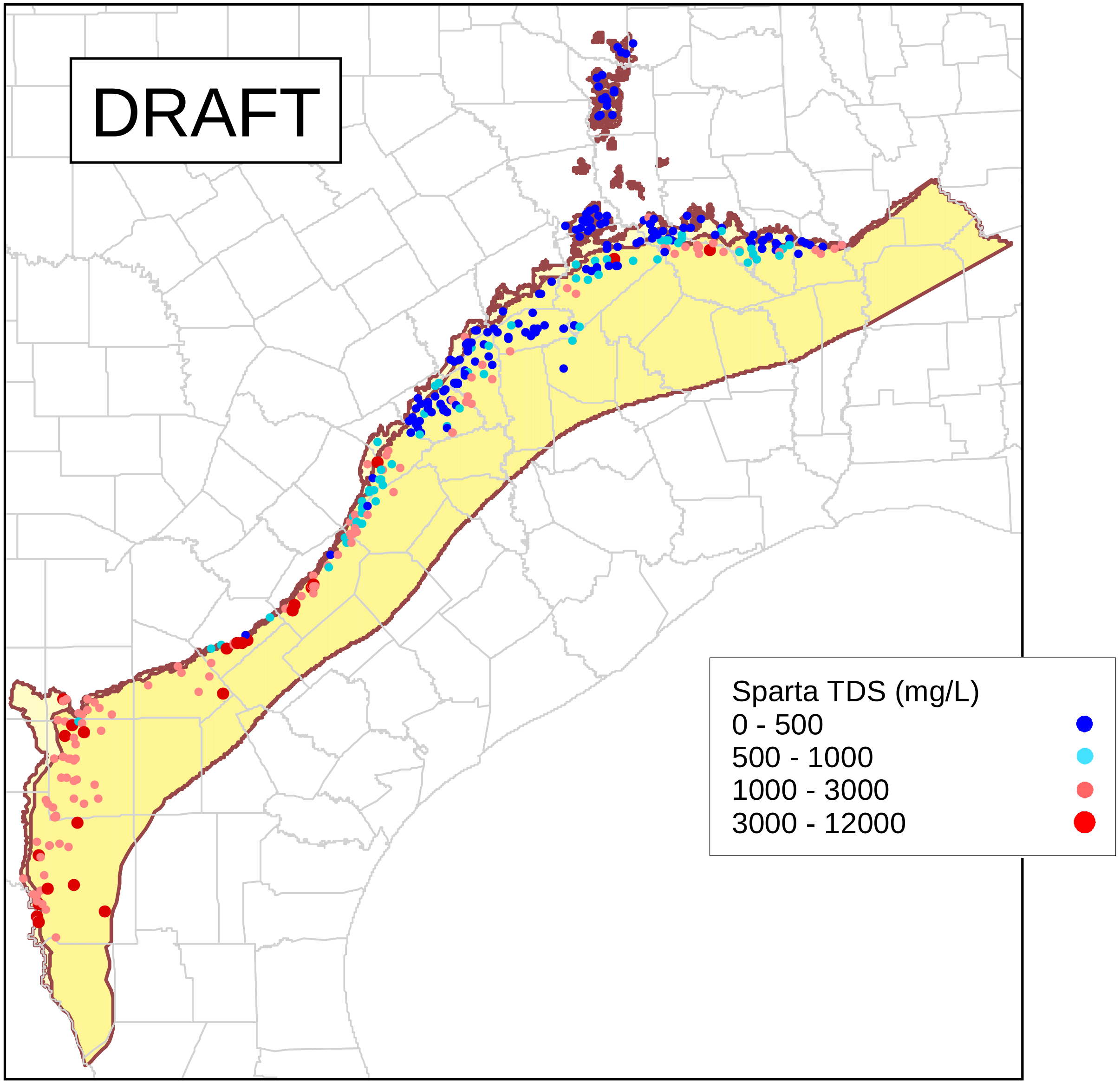
Average Total Dissolved Solids (ppm)

Texas Region	Queen City	Sparta
North	339	319
South	922	1,553

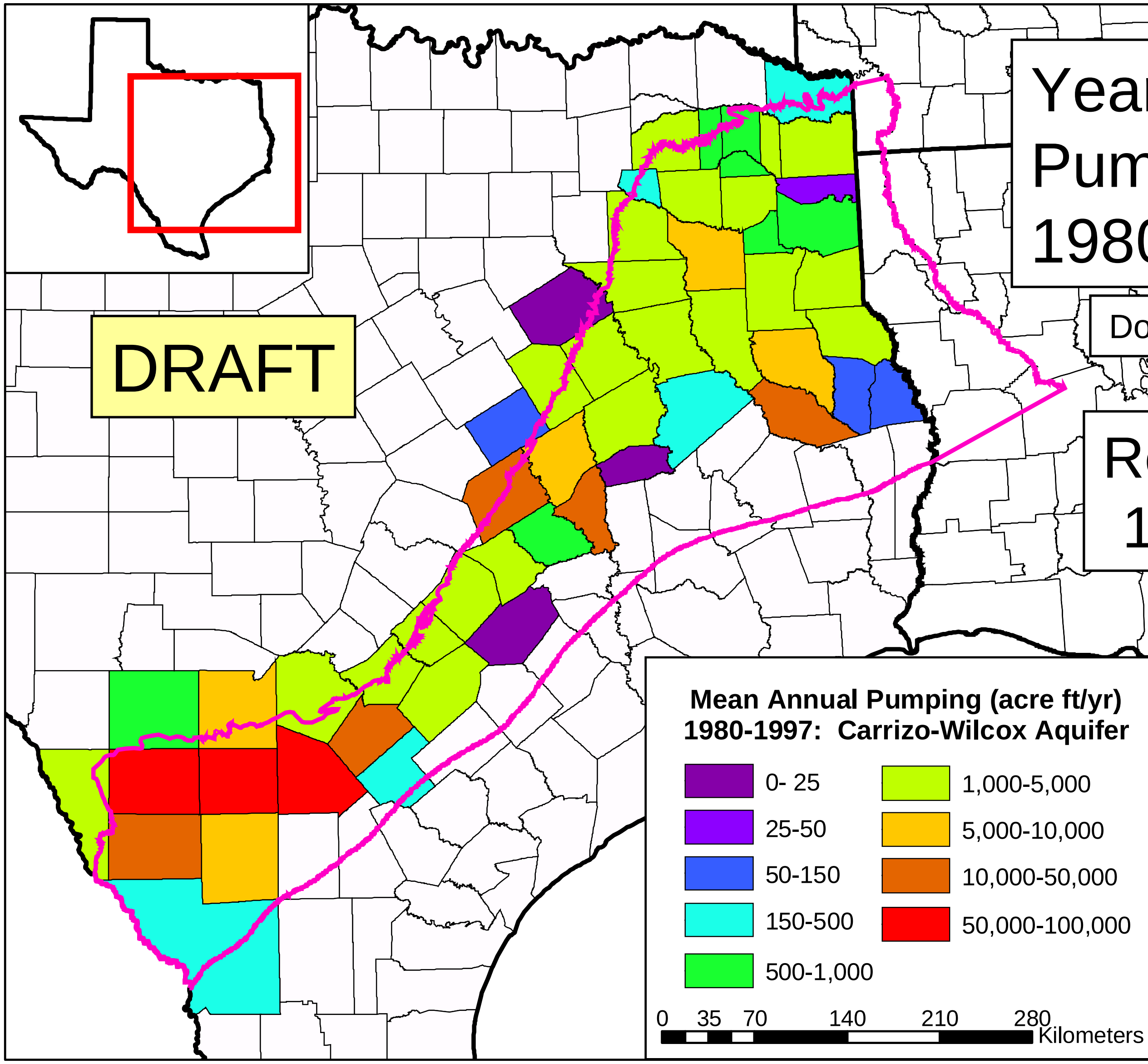
TDS - Queen City Aquifer



TDS - Sparta Aquifer



Carrizo-Wilcox Pumping (AFY)

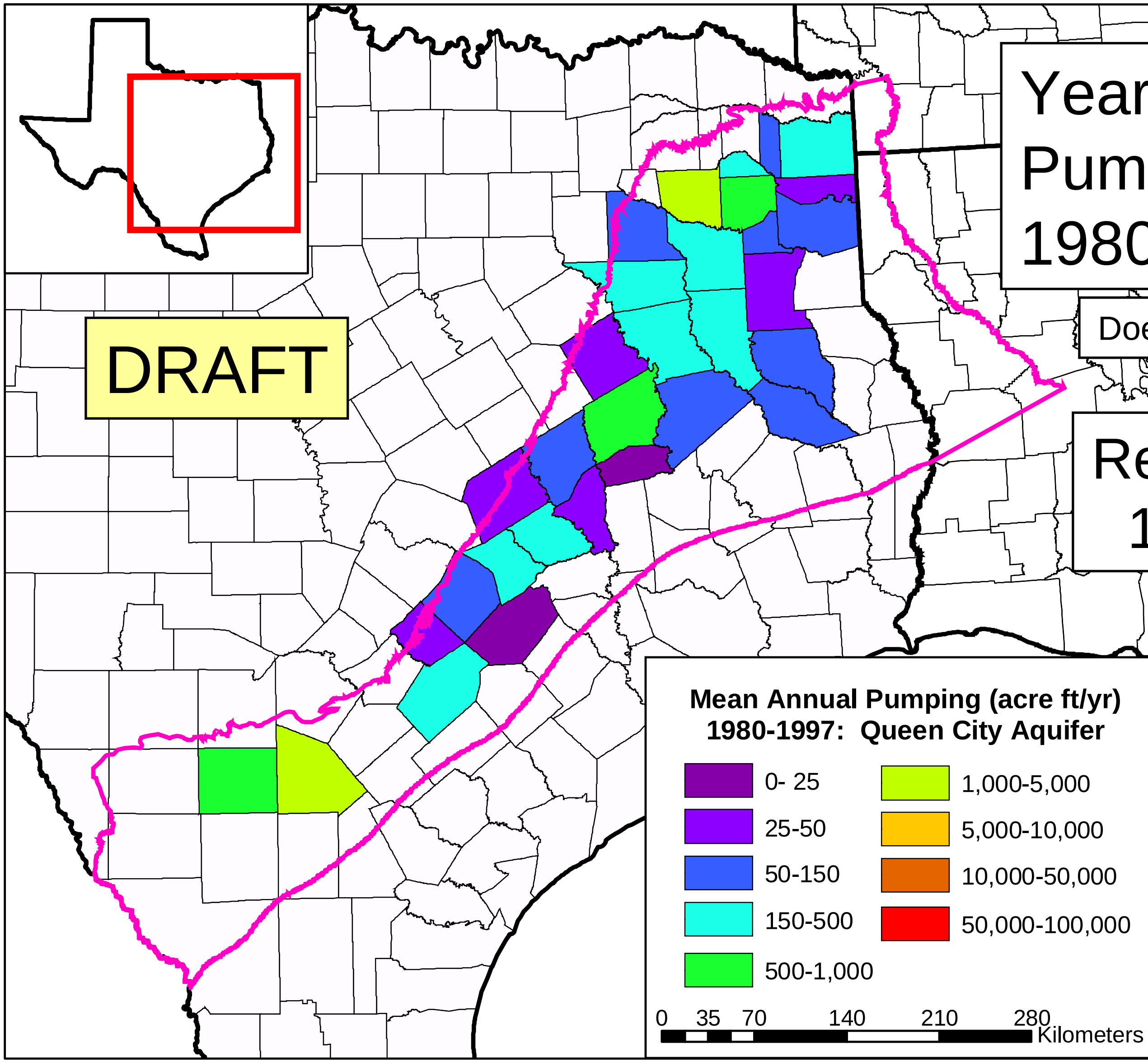


Yearly Average Pumping Rate (AFY) 1980-1997

Does not include rural/domestic

Reported Pumpage 1997 -430,000 AF

Queen City Pumping (AFY)

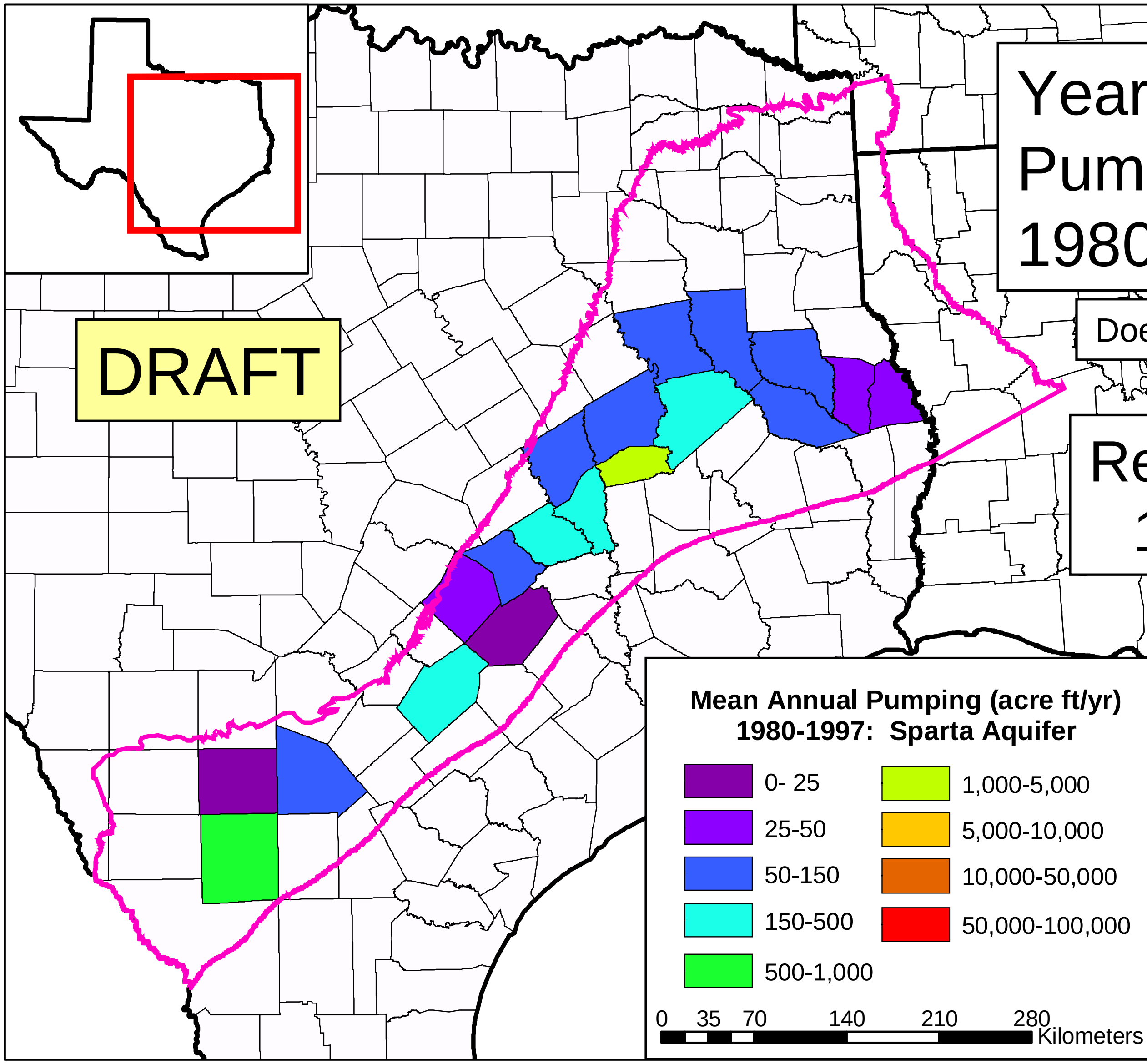


Yearly Average Pumping Rate (AFY) 1980-1997

Does not include rural/domestic

Reported Pumpage 1997 -14,000 AF

Sparta Aquifer Pumping (AFY)

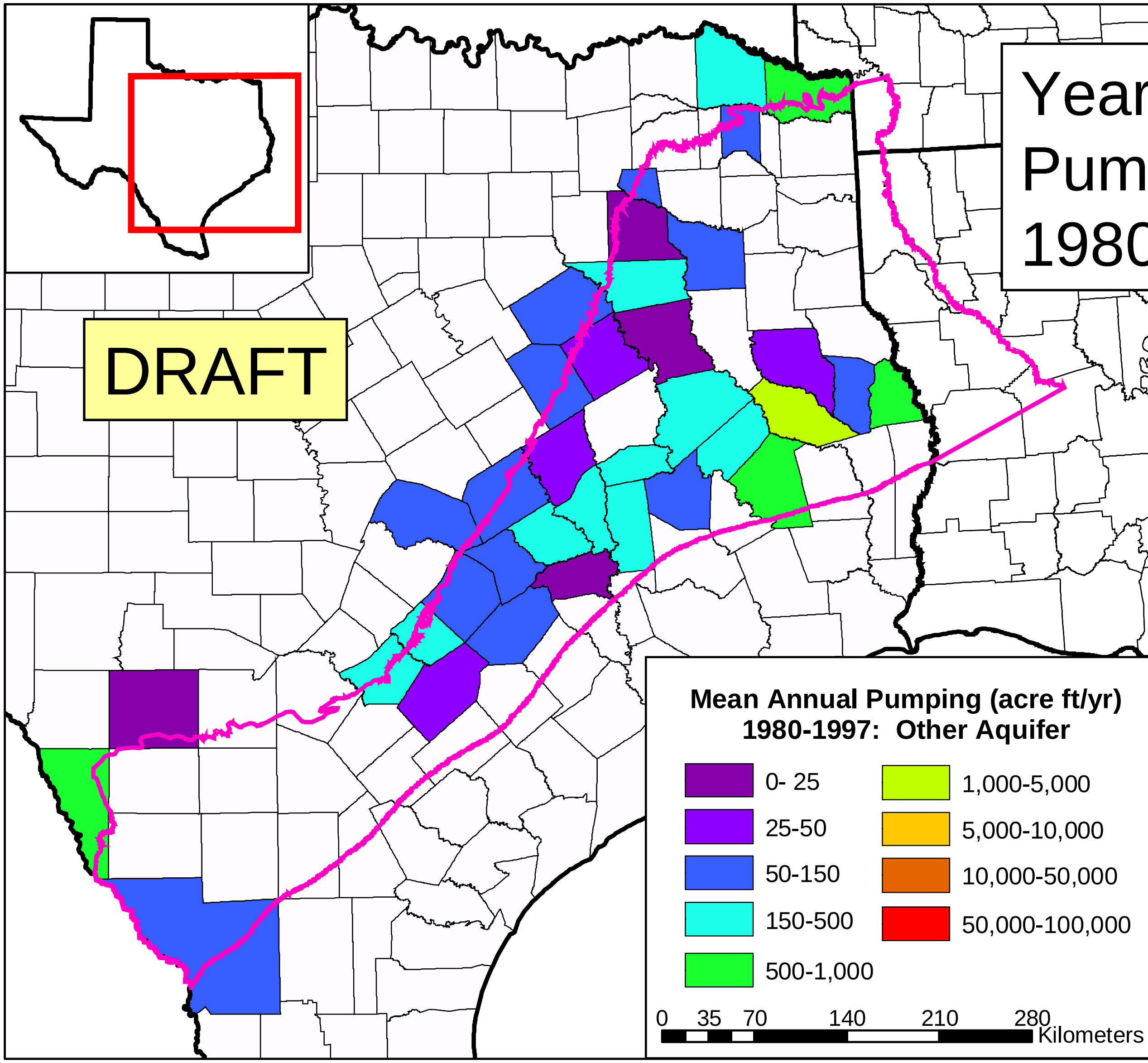


Yearly Average Pumping Rate (AFY) 1980-1997

Does not include rural/domestic

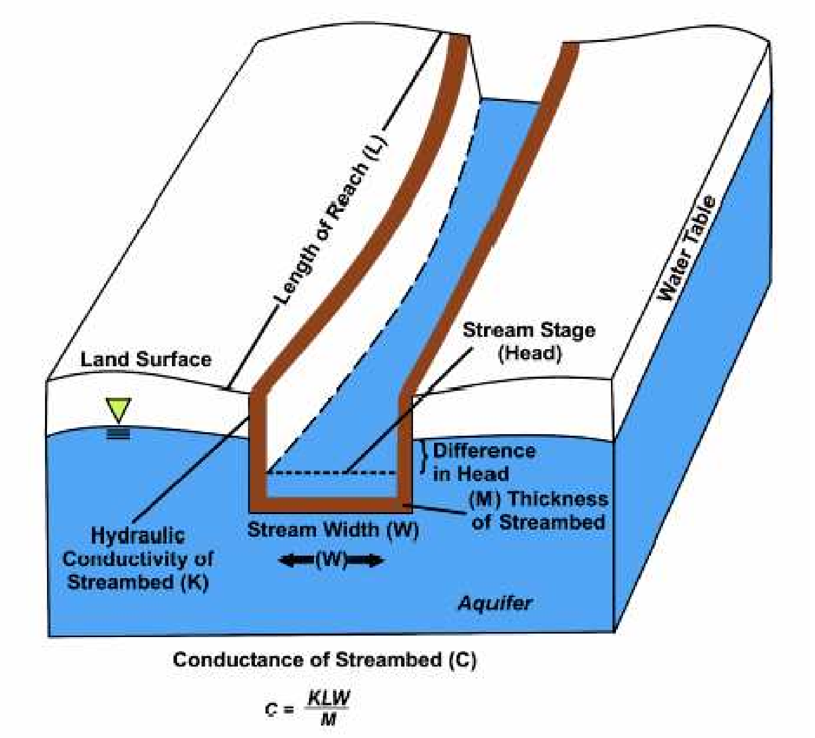
Reported Pumpage 1997 - 6,800 AF

Other Aquifer Pumping (AFY)



Yearly Average Pumping Rate (AFY) 1980-1997

Streams – Prudic (1991)

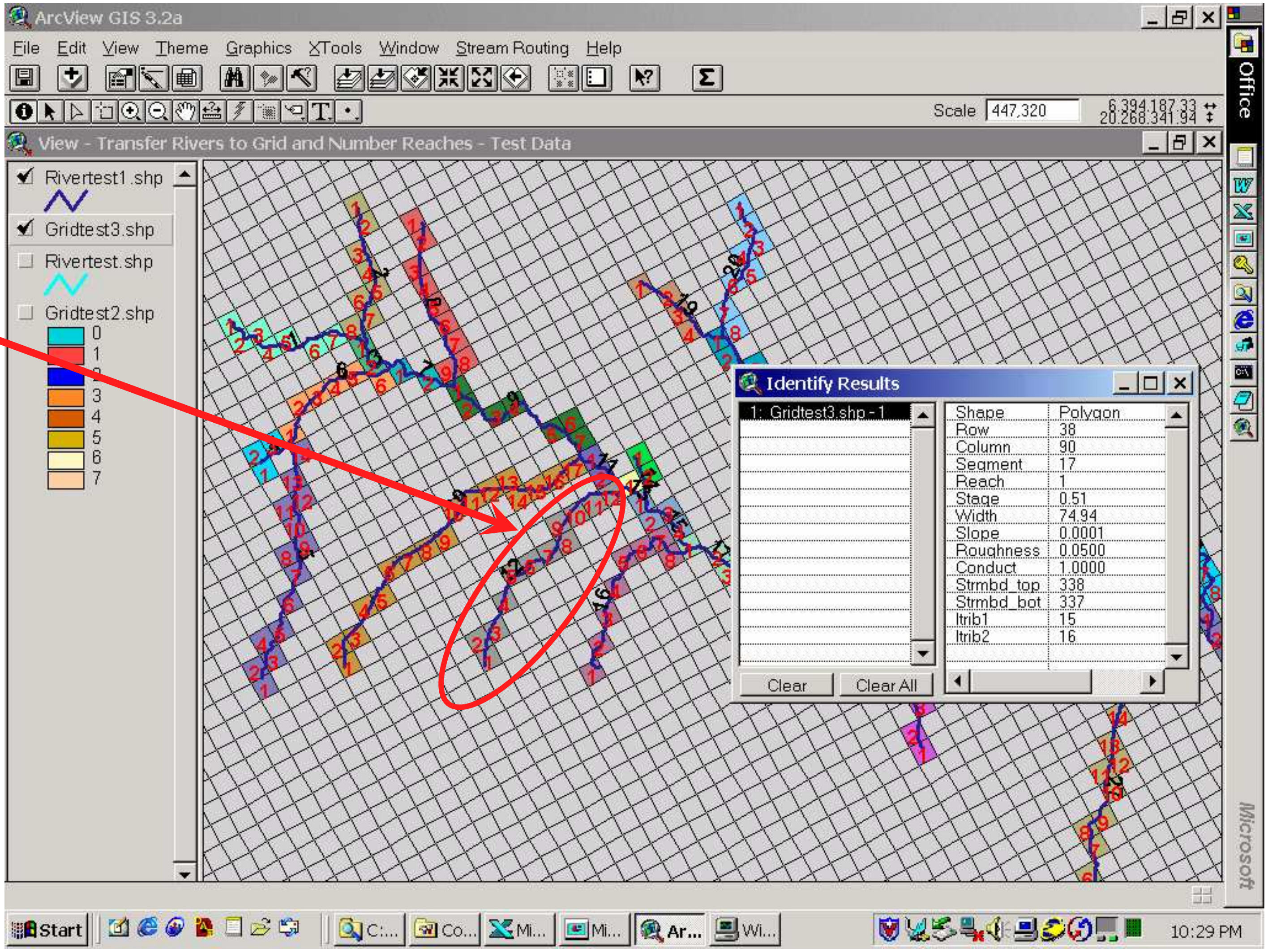


- Stream length (1 mile)
- Stream width
- Streambed thickness
- Streambed hyd. K
- Streambed elevation
- Streambed slope
- Manning's roughness
- Headwater reach Q for every stress period
- Segment connections

Streams

Queen City Sparta GAMs will require the addition of very few new reaches

- **Each cell is a reach**
- **Reaches make up segments**



Streams – Calibration

- Calibrate streambed conductivities to match losses/gains
- Calibration targets:
  - USGS low flow data (Slade et al. 2002) – 366 studies on 249 stream reaches
  - Stream Gage Analysis (base flow)
  - Published estimates from other models (Limited)
  - Stream gage data – upper bound

Ongoing Efforts – Stream Routing

- Review the method(s) used to assign stream flow rates to ungaged headwaters and provide recommendations for improvement.
- Review of the calibration targets used to characterize stream/aquifer interaction.
- Development of additional gain/loss estimates (surface water calibration targets).
- Review and provide recommendations regarding approach for initialization and calibration of stream bed conductance in the completed Carrizo-Wilcox models

Model Implementation

- We will begin with the same values in overlap areas.
  - Structure
  - Hydraulic Conductivity
  - Storage
  - Pumping
  - Recharge
  - Boundaries
- We will monitor parameter changes between models during calibration to insure consistency between models at the end of the day

Recharge - Implementation

- Proposed Approach:
  - We will begin with the same values in overlap areas.
  - We will monitor parameter changes between models during calibration to insure consistency between models.
  - Complete SWAT simulations in remaining Central basins for ET.
  - Further analyze what is driving SWAT results
  - Monitor Dr. Scanlon's research into controls on recharge.
  - Develop calibration methodology based on our analyses and previous estimates.

Boundaries - Implementation

- Top boundary (above Sparta)
  - N & S C/W GAMs used GHBs with a conductance estimated from the Kv of overlying layers and a head estimated from ground surface correlation
  - Central C/W GAM used a constant conductance of 100 ft2/d and heads determined from Queen City water levels.
  - **Proposed:** Use N & S GAM approach
- Northeast and Southwest lateral boundaries
  - N & S C/W GAMs used no flow boundaries
  - Central C/W GAM used GHBs in the confined section.
  - **Proposed:** Boundary condition will be based on observed flow directions in historical period. We will use inter-model iteration for predictive period if drawdowns warrant.

Boundaries - Implementation (cont.)

- Downdip boundary
  - N & S C/W GAMs used a no flow boundary for the downdip boundary
  - Central C/W GAM used a GHB downdip boundary
  - **Proposed:** Use no-flow boundary for the downdip boundary in the Queen City and Sparta. Keep the GHB in the Central C/W model (no effect).

GAM Schedule

2003

SAF 1 — Feb 28

Stakeholder Data - Apr 31

SAF 2 — June 12

SAF 3 — Nov

Jan 23 — Kickoff Meeting

- ☒ Complete database
- ☐ Evaluate data
- ☐ Preliminary model design

July 31 — Draft Conceptual Model Report

Nov — Steady-state model review

2004

SAF 4 — Mar

Stakeholder Comments

SAF 5 — June

Jan — Transient model review

Feb — Predictions review

Mar1 — Draft report review

June — Final Report & Model

Meeting Wrap-Up

- **Next meeting – November**
  - Final conceptual model review
  - Model implementation
  - Draft Steady-state model calibration
  - Pumping Distribution
- **Discussion / comments / questions**

Who to Contact?

- **Van Kelley**

INTERA Inc.
9111A Research Blvd
Austin, TX 78758
(512) 425-2047
vkelley@intera.com

- **Dr. Shirley Wade**

Texas Water Development Board
P.O. Box 13231
Austin, TX 78711
(512) 936-0883
shirley.wade@twdb.state.tx.us

ATTACHMENT A: SIGN-UP SHEET

Name	Affiliation	Contact Information (including email address, if available)
Mike Mahoney	Evergreen UWCD	
Barry Miller	Gonzales UWCD	
Bob Kier	Lost Pines GCD/RSKC	
Melissa Bryant	San Antonio River Authority	
Steve Raabe	San Antonio River Authority	
Ronnie Hernandez	San Antonio River Authority	
Rudy Farias	San Antonio River Authority	

Meeting Minutes for the

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

June 12, 2003

San Antonio River Authority

San Antonio, Texas

The second Stakeholder Advisory Forum (SAF) Meeting for the Queen City/Sparta Groundwater Availability Model (GAM) was held on June 12th from 1:30 until 3:30 PM at the San Antonio River Authority in San Antonio, Texas. Attachment A of these meeting minutes provides a list of all participants who signed up as attending the meeting.

The purpose of the second 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: Dr. Shirley Wade, TWDB

The meeting was initiated by Dr. 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

Van Kelley, Project Manager for the INTERA Queen City/Sparta Team presented a prepared presentation. The presentation was structured according to the following outline:

1. GAM objectives and expectations
2. Hydrogeologic setting
    - Supporting database review
    - Preliminary conceptual model
3. Preliminary Approach to Model Implementation & Integration with Carrizo-Wilcox GAMs
4. Review of Project Milestones & Schedule
5. Expectations for the next SAF Meeting

The presentation is available on the GAM website (*www.twdb.state.tx.us/gam)*.

Questions and Answers: Open Forum:

Q. What number SAF is this?

A: This is the second SAF meeting.

Q: When was the first SAF meeting held?

A: February 28, 2003.

Q: Is INTERA doing all three model sections?

A: The INTERA team is responsible for all three model sections. The Bureau of Economic Geology (BEG) is working with INTERA in model development and will calibrate and run the central section. INTERA will calibrate and run the northern and southern sections.

Q: Is the Queen City aquifer under water table conditions throughout northeast Texas?

A: In the East Texas Basin, the Queen City is under water table conditions throughout, except for those areas that are overlain by isolated islands of Weches and Sparta.

Q: What does the note about rural/domestic on the pumping figures mean?

A: Rural/domestic pumping has not been assigned to individual aquifers at this time. The county volumes shown include only point specific volumes reported to the TWDB. Rural/domestic pumping will be assigned to individual aquifers and included in pumping for model runs.

Q: Will there be only one GAM in each area? Will there be a Carrizo-Wilcox model and a combined Queen City-Sparta and Carrizo-Wilcox model?

A: The Queen City and Sparta aquifers will be added to the existing Carrizo-Wilcox models, modifying the Carrizo-Wilcox data an needed to calibrate the models. Redesigning the Carrizo-Wilcox models was not the intention of this GAM, but some changes will be necessary.

Q: The limitations of the Carrizo-Wilcox models are fairly well documented, but the demand projections are not well documented. How were these developed? The Central model pumping estimates changed between the draft and final reports without an explanation. Procedures for developing pumping should be very well documented.

A: A detailed description of how pumping estimates from the TWDB were distributed is included in the Northern and Southern GAM Reports.

Q: In the Central/Southern model overlap zone, will the water balance change for the Central model or the Southern model when the new models are built?

A: We do not know at this time. This can only be answered after model development and calibration. Vertical hydraulic conductivity may be the most significant factor affecting the transient water balance in the confined section and it may require greater consistency in the overlap area to calibrate the Queen-City-Sparta GAM.