Groundwater Availability Modeling (GAM) for the Dockum Aquifer

Stakeholder Advisory Forum No. 2
June 7, 2007

John Pickens
Toya Jones

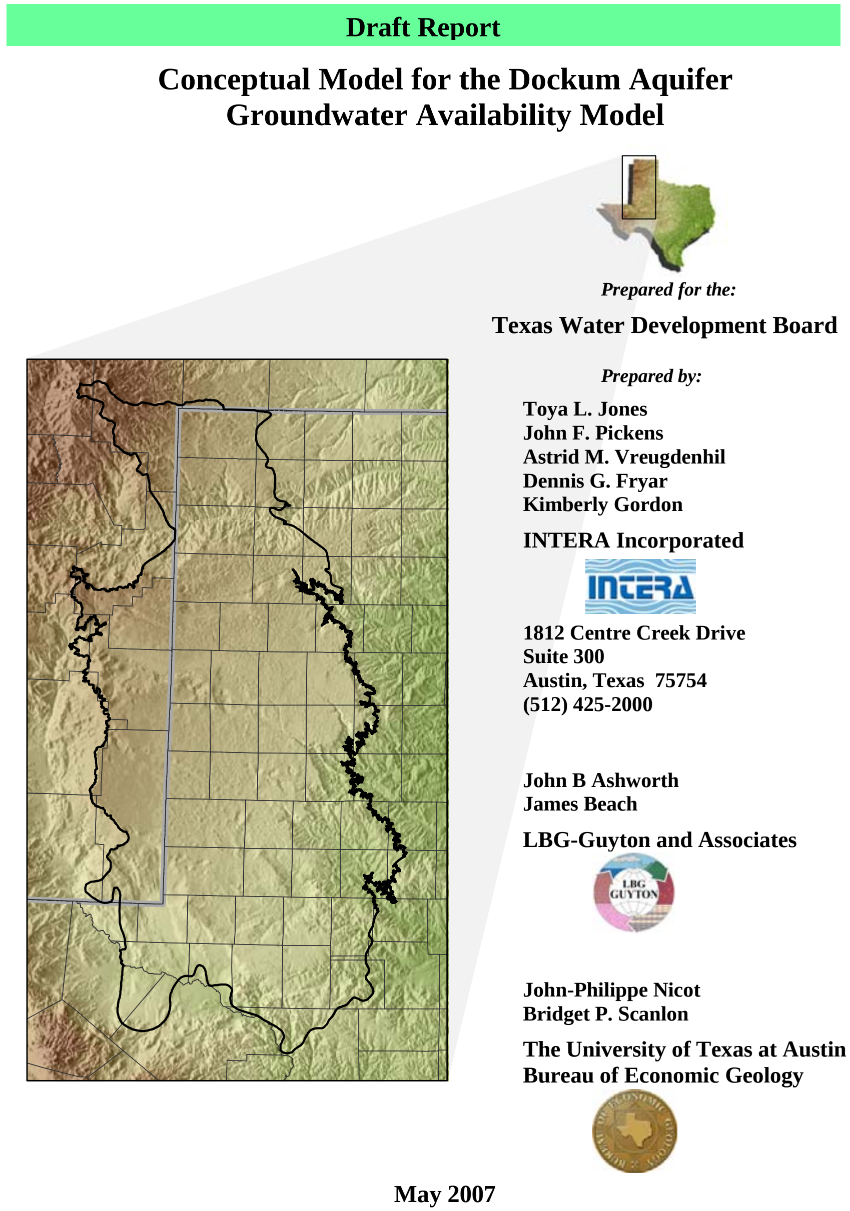
Outline of Presentation

- Draft Conceptual Model Report – Status and Overview
- Definitions
- Key Data Sources
- Aquifer Setting
- Model Descriptions
- Conceptual Model
- Conceptualization of Groundwater Flow
- Future Work and Schedule

Draft Conceptual Model Report Status and Overview

Report Status

- Delivered to TWDB on May 16, 2007
- In public review period until June 8, 2007
- Submit comments in writing to Ian Jones at the TWDB
  - ian.jones@twdb.state.tx.us
  - Ian Jones
    Texas Water Development Board
    1700 North Congress Ave.
    P.O. Box 13231
    Austin, Texas 78711-3231
- Can download report at: http://www.twdb.state.tx.us/gam/dckm/dckm.htm



Draft Report

Conceptual Model for the Dockum Aquifer Groundwater Availability Model

Prepared for the:

Texas Water Development Board

Prepared by:

Toya L. Jones
John F. Pickens
Astrid M. Vreugdenhil
Dennis G. Fryar
Kimberly Gordon

INTERA Incorporated

1812 Centre Creek Drive
Suite 300
Austin, Texas 75754
(512) 425-2000

John B Ashworth
James Beach

LBG-Guyton and Associates

John-Philippe Nicot
Bridget P. Scanlon

The University of Texas at Austin
Bureau of Economic Geology

May 2007

Report Overview

- Section 1 – Introduction
- Section 2 – Study Area
  - Physiography and Climate
  - Geology
- Section 3 – Previous Investigations
- Section 4 – Hydrogeologic Setting
  - Hydrostratigraphy
  - Structure
  - Water Level and Regional Groundwater Flow
  - Recharge
  - Rivers, Streams, Springs, and Lakes
- Section 4 (cont)
  - Hydraulic Properties
  - Aquifer Discharge
  - Water Quality
- Section 5 – Conceptual Model of Groundwater Flow for the Dockum GAM
- Section 6 - References

Definitions

Groundwater Flow - Definitions

- **Aquifer – Water saturated permeable geologic unit that can transmit significant quantities of water (e.g., sands & gravels)**
  - **Unconfined – water table forms the upper boundary**
  - **Confined – has overlying/underlying lower permeabilty layers**
- **Water table – The top of the saturated zone**
- **Hydraulic head – The water level in a well expressed as an elevation**

Groundwater Flow – Definitions

- **Hydraulic conductivity – A physical property of the geologic media representing its ability to transmit water**
- **Specific yield – The volume of water that an unconfined aquifer releases from storage per unit surface area of aquifer per unit decline in water table elevation**
- **Storativity – The volume of water that a confined aquifer releases from storage per unit surface area of aquifer per unit decline in head**

Groundwater Flow – Definitions

- **Recharge – The entry of water to the saturated zone at the water table:**

  Recharge = (precipitation + stream loss) minus (runoff + evapotranspiration).

- **Cross-formational flow – Groundwater flow between separate geologic formations**
- **Stream losses or gains – The water that is either lost or gained through the base of the stream or river**

Key Data Sources

Key Data Sources

- County reports by TWDB & predecessors
- USGS reports
- UT Bureau of Economic Geology reports
- New Mexico State Bureau of Mines and Mineral Resources reports
- TCEQ records
- Brune (2002) and Heitmuller and Reece (2003) – spring locations and flows
- Slade et al. (2002) – stream gain/loss studies
- Data from GCDs

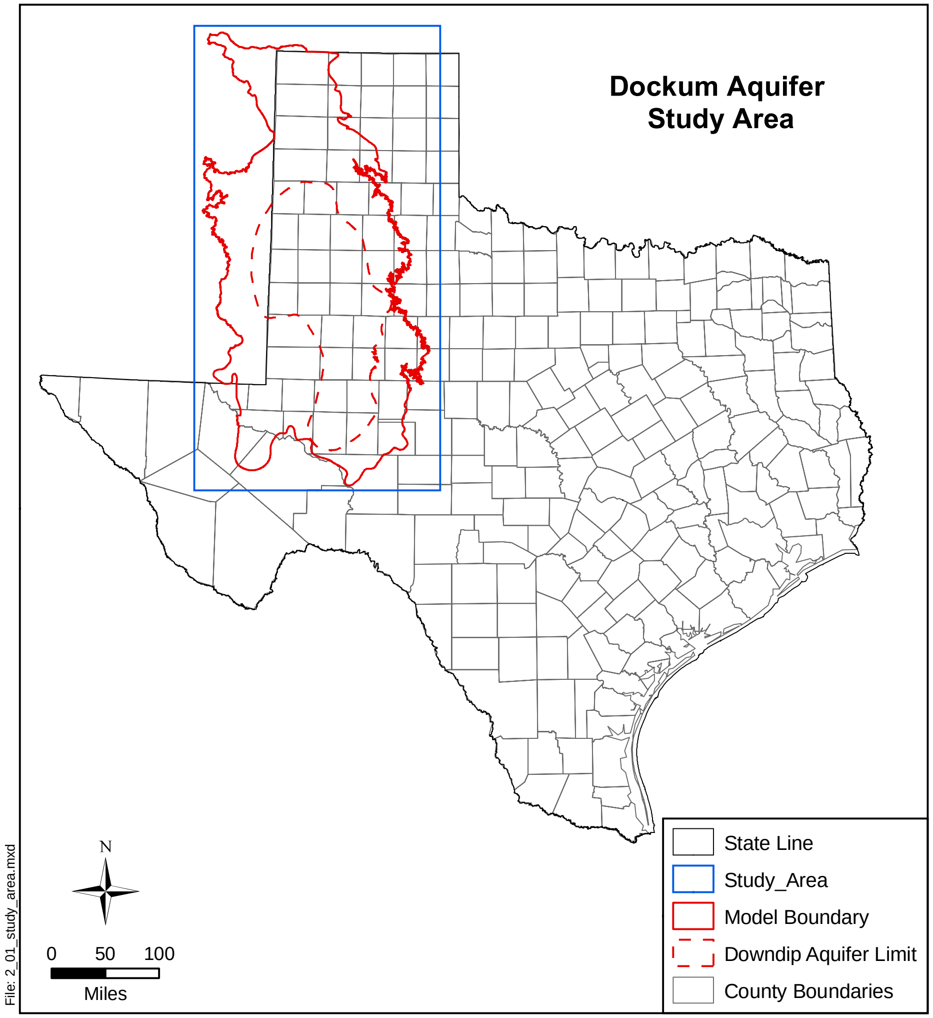
Key Data Sources - Websites

- TWDB
  - Dockum and Dockum with overlying or underlying aquifer (over 2,000 wells)
- U.S. Geological Survey
  - topography
  - surface geology
  - stream flows
  - groundwater data
  - stream gain/loss studies
- U.S. EPA
  - stream characteristics
  - soil type
- Oregon State University & National Climatic Data Center
  - precipitation

Aquifer Setting

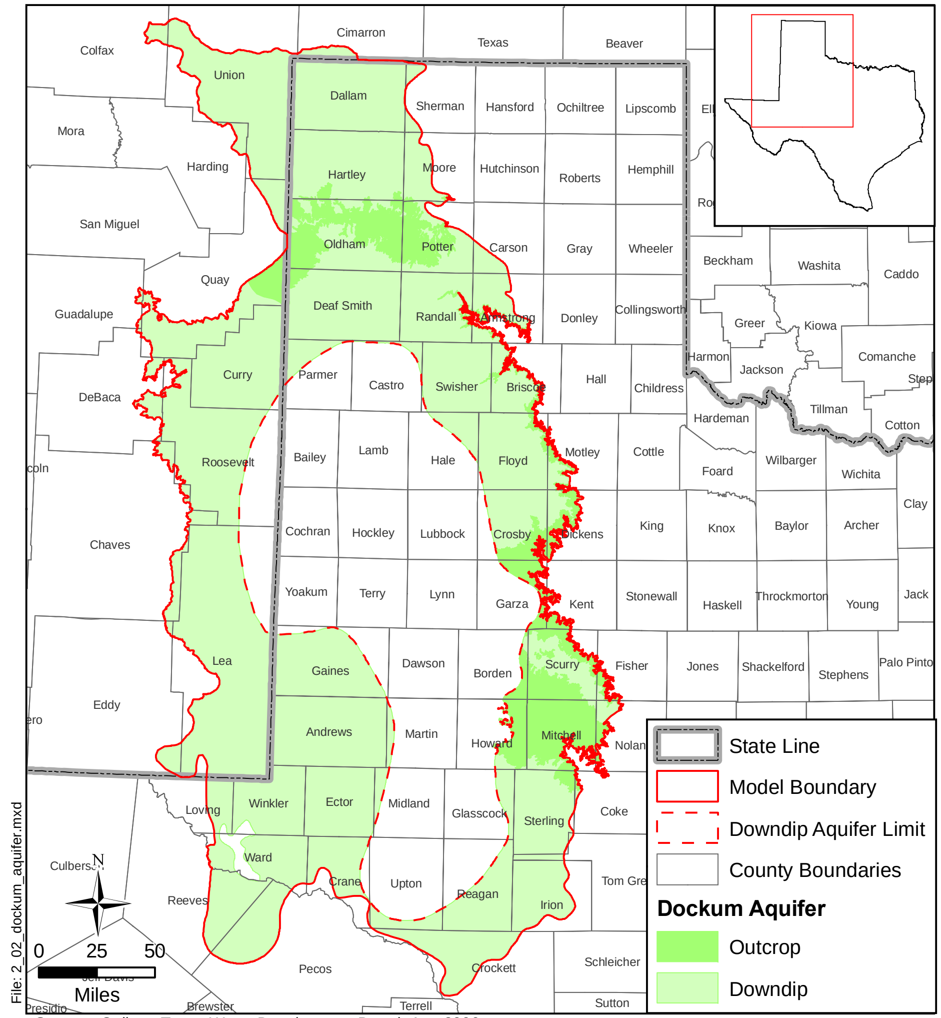
Aquifer Location

Study Area



Source: N/A

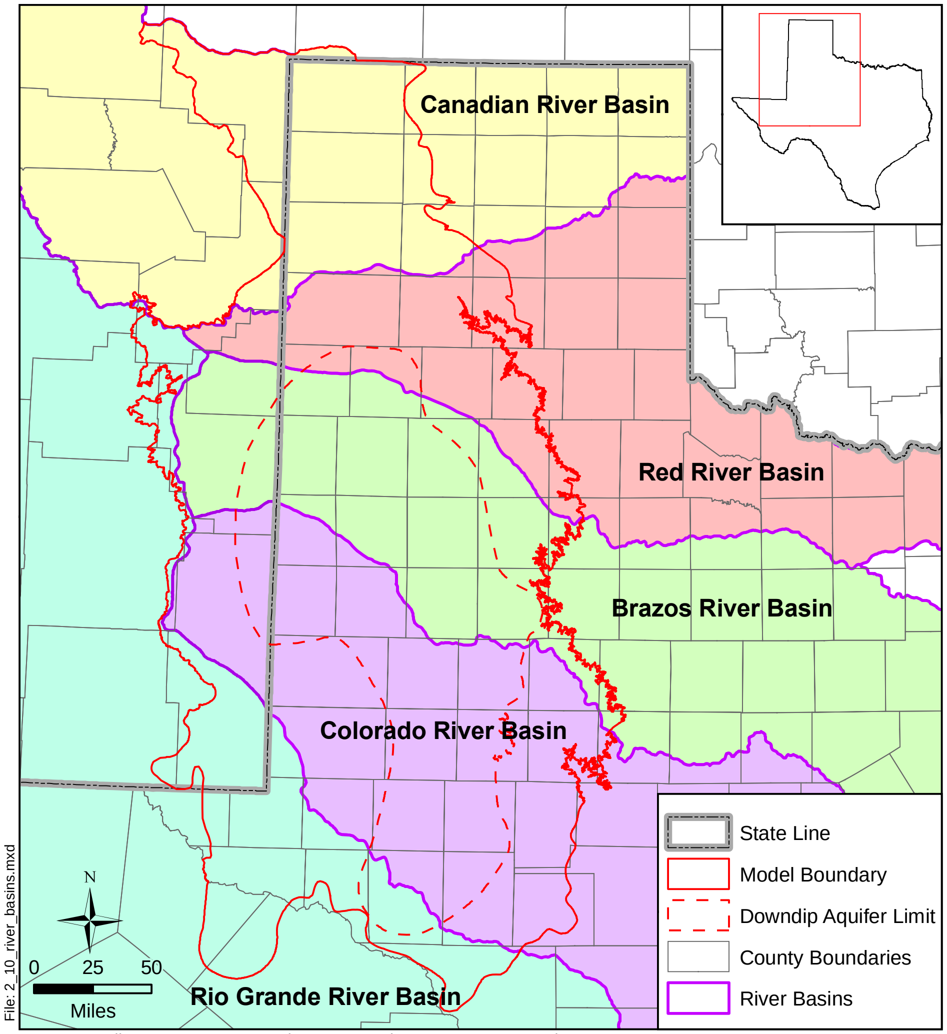
Model Domain



Source: Online: Texas Water Development Board, Aug 2006

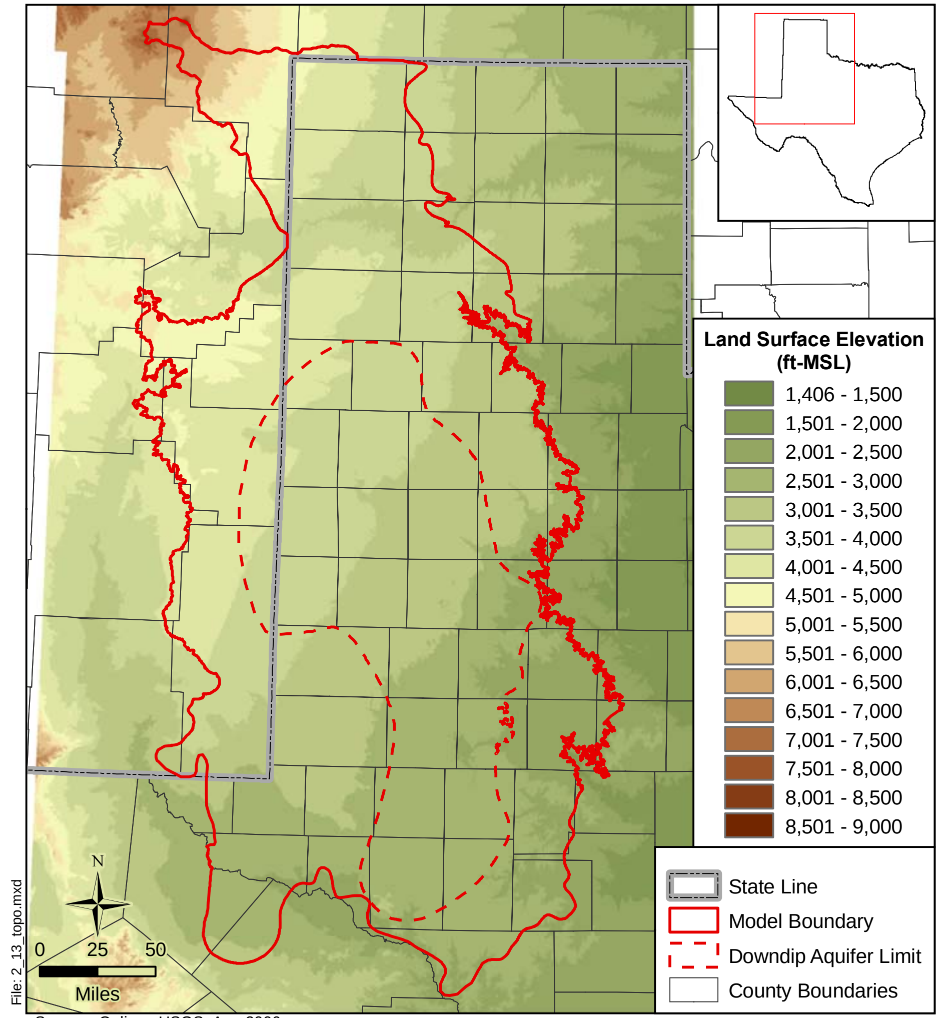
River Basins and Topography

Major River Basins



Source: Online: Texas Water Development Board, June 2006; New Mexico Resource GIS Program, June 2006

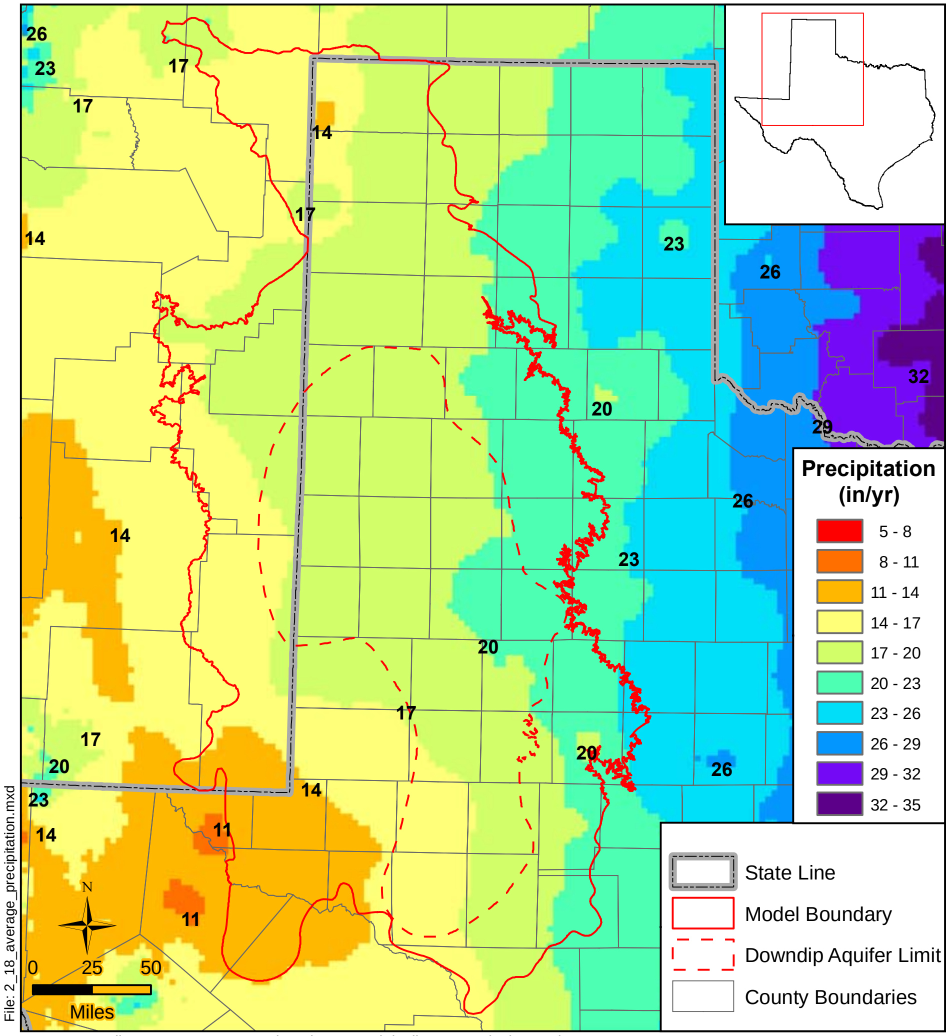
Topography



Source: Online: USGS, Aug 2006

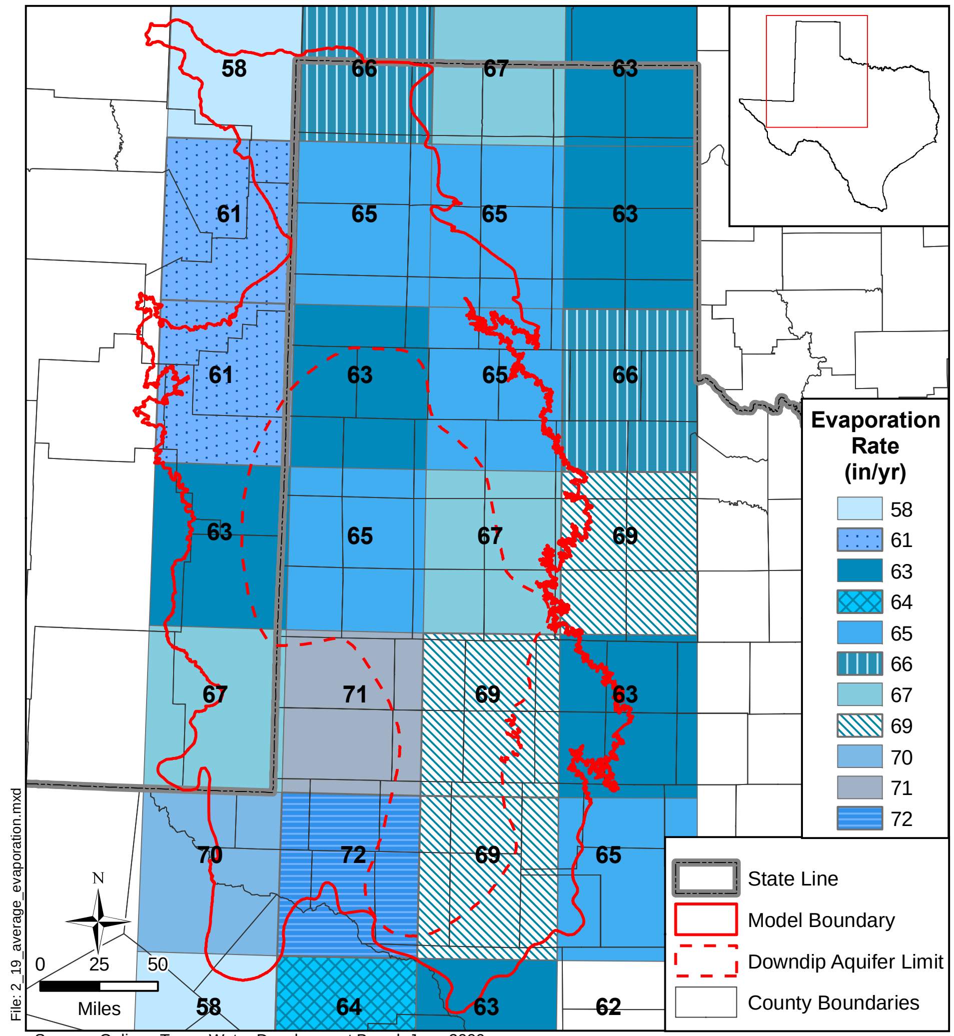
Precipitation and Pan Evaporation

Average Annual Precipitation



Source: Online: Oregon State University's Spacial Climate Analysis Service

Average Annual Pan Evaporation



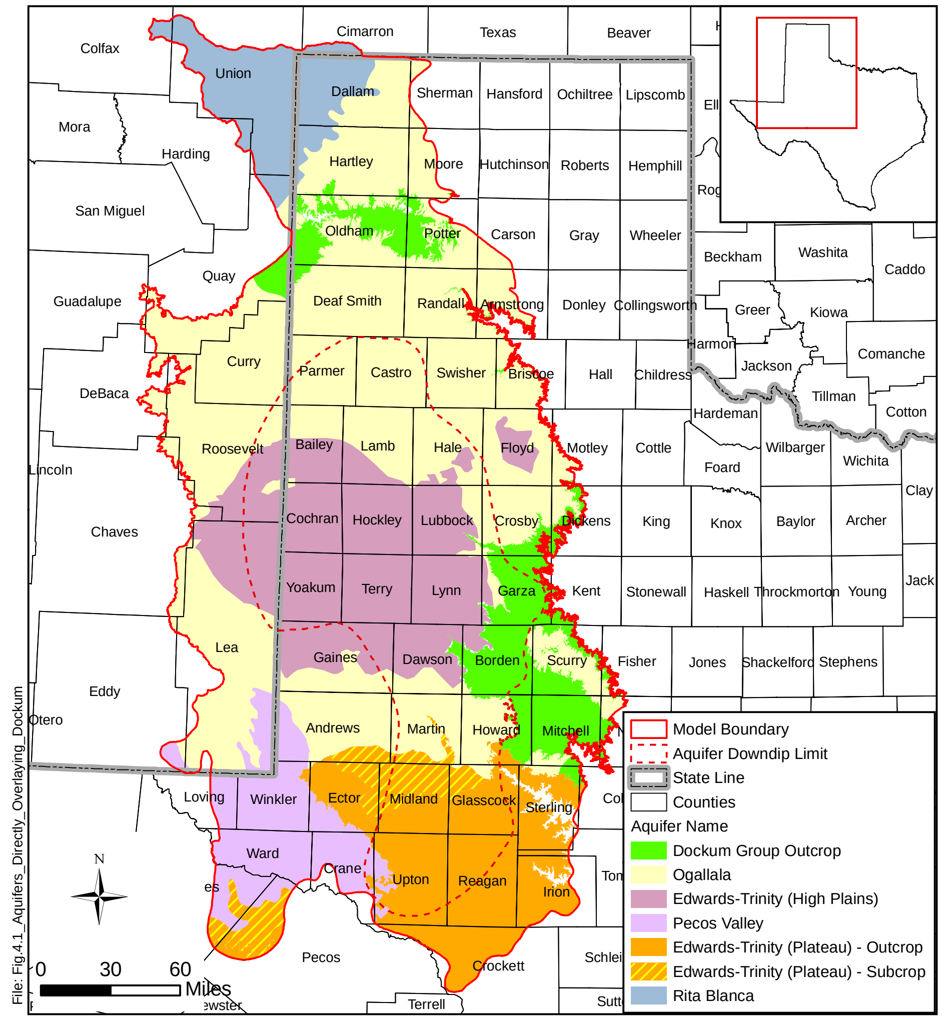
Source: Online: Texas Water Development Board, June 2006

Geology

Stratigraphic Units

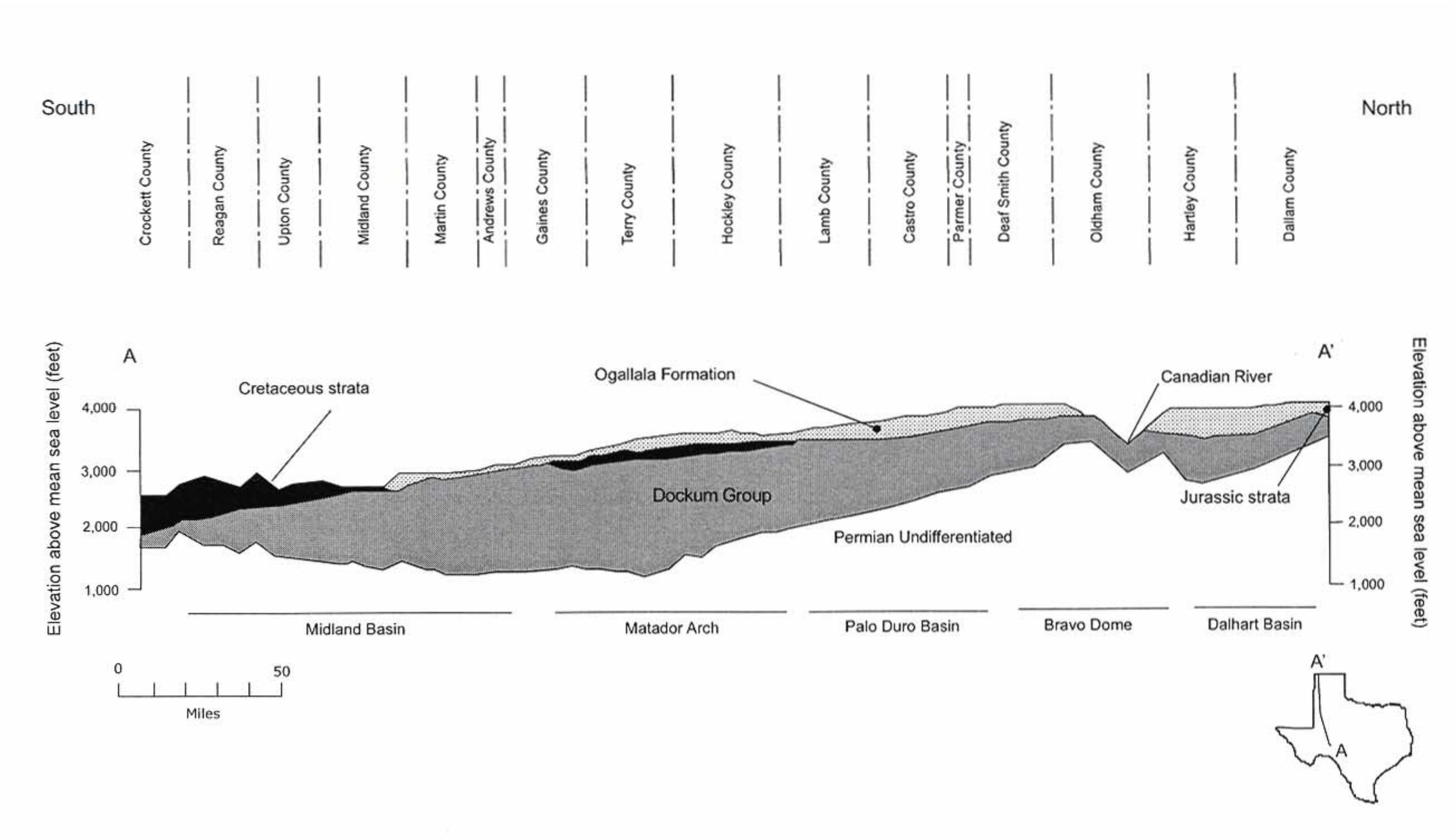
Ogallala/Alluvium	
Cretaceous-age Sediments (not continuous)	
Upper Dockum	Cooper Canyon Formation
	Trujillo Sandstone
Lower Dockum	Tecovas Formation
	Santa Rosa Sandstone
Permian-age Sediments	

Overlying Aquifers



Source: Adapted from Texas Water Development Board, Dec 2006

Geologic Cross-Section



Dockum Aquifer Description

- Dockum Group is composed of mudstone, sandstone, and conglomerate
- Depositional environment yielded large heterogeneity in the hydraulic properties both laterally and vertically
- Upper portion of the Dockum contains more mudstone than lower Dockum
- Lower portion of the Dockum generally yields more water than the upper Dockum
- Thickness of the Dockum Group is up to about 2000 ft.

Model Descriptions

Modeling Protocol

- Compile and analyze field and literature data
- Develop a <u>conceptual model</u>
- Design the <u>numerical model</u>
- Calibrate the numerical model (steady state and transient)
- Perform model sensitivity analysis

Conceptual Model

- "A conceptual model is a simplified representation of the site that captures the key site features important to the goals." (EPA, 1979)
- The conceptual model dictates how you have translated the "real world" to a mathematical model.
- Relevant processes and physical elements controlling groundwater flow in the aquifer are identified and quantified (geology, hydraulic properties, water levels, and sources and sinks)
- The data base is developed and documented.

Numerical Model

- A numerical model is a computer software based representation of an aquifer
- Inputs to the model include aquifer geometry, recharge, hydraulic properties, and pumping
  - These are developed from the conceptual model
- Outputs from the model are compared to aquifer data (water levels, spring flow)
  - This is referred to as model calibration

Conceptual Model

Conceptual Model

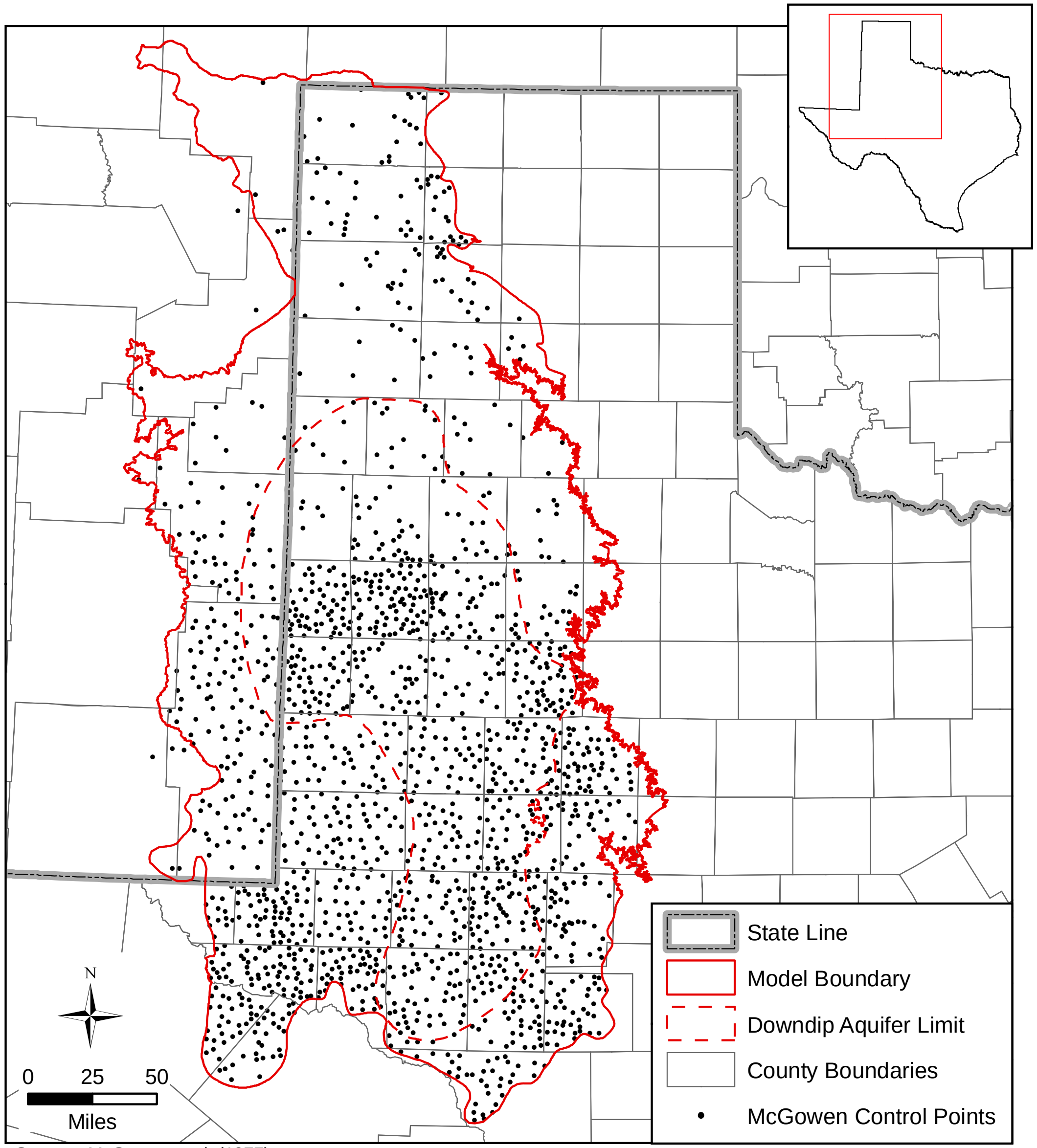
- Structure
- Water Levels
- Hydraulic Properties
- Recharge
- Surface Water
- Pumping
- Groundwater Quality

Structure

Structure – Key Data Sources

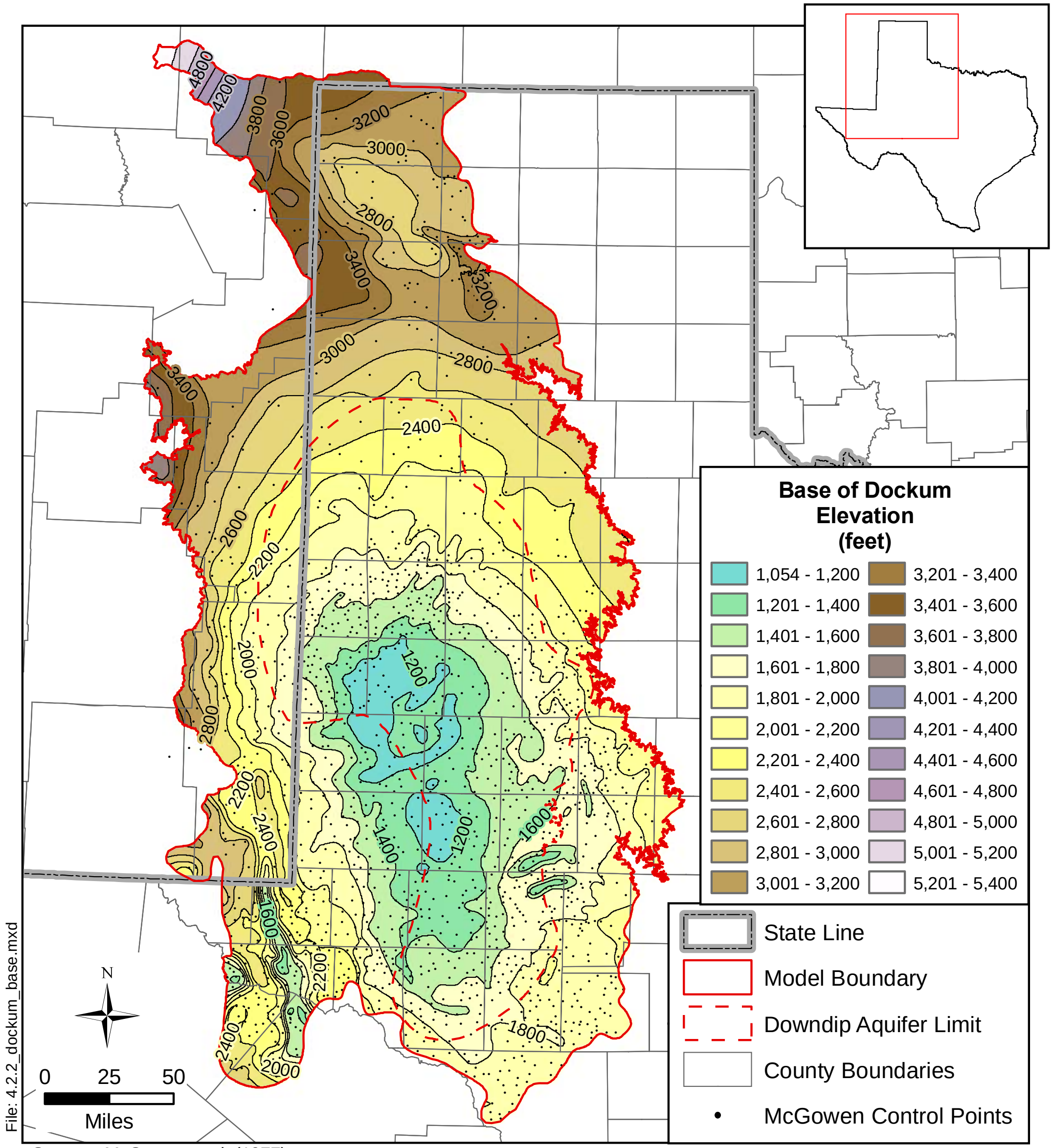
- McGowen et al. (1977) – Depositional Systems, Uranium Occurrence and Postulated Ground-Water History of the Triassic Dockum Group, Texas Panhandle-Eastern New Mexico
- Land surface from 30-meter DEM

McGowen et al. (1977) Control Points



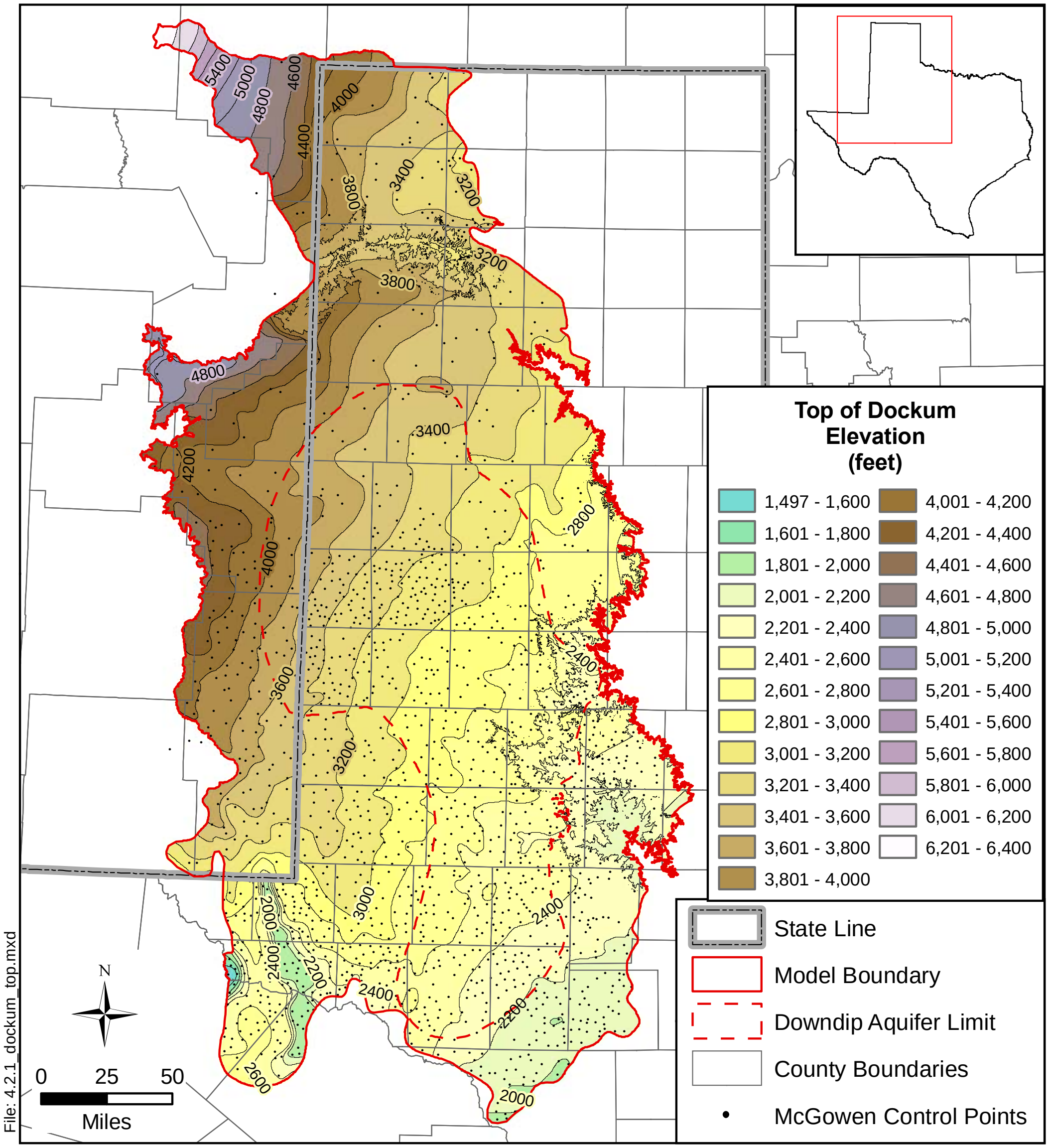
Source: McGowen et al. (1977)

Dockum Base Elevation



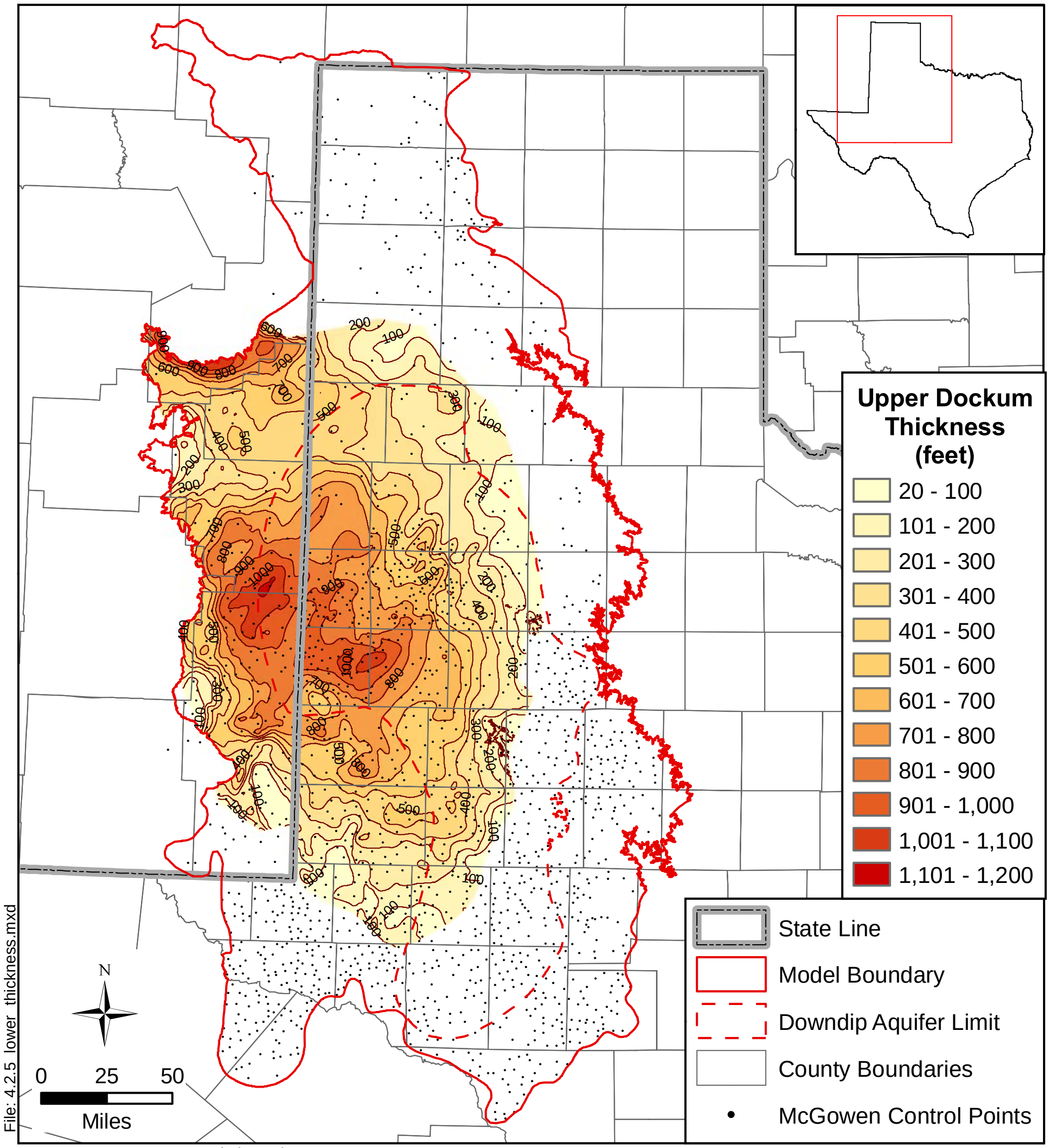
Source: McGowen et al. (1977)

Dockum Top Elevation



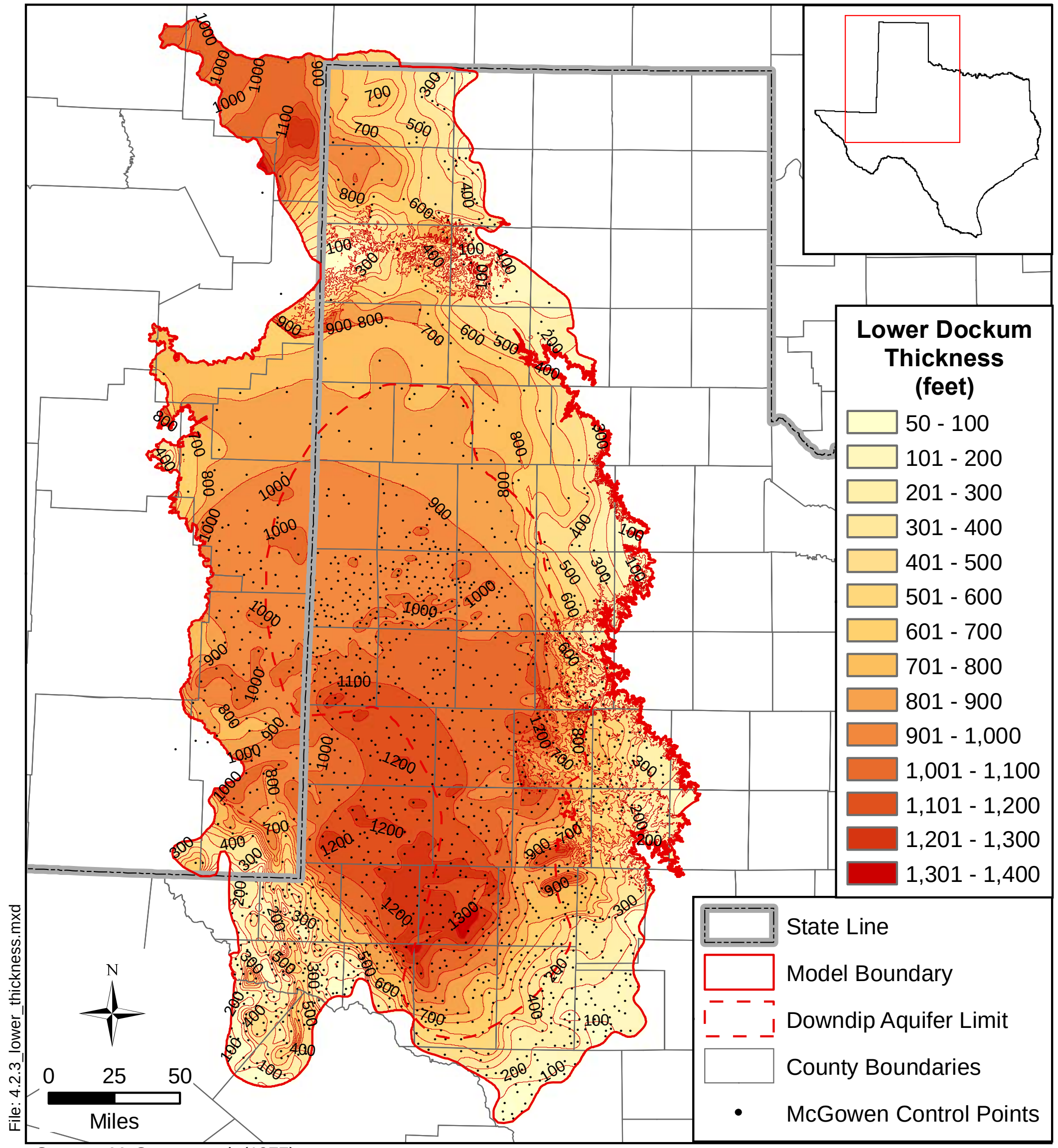
Source: McGowen et al. (1977)

Upper Dockum Thickness



Source: McGowen et al. (1977)

Lower Dockum Thickness



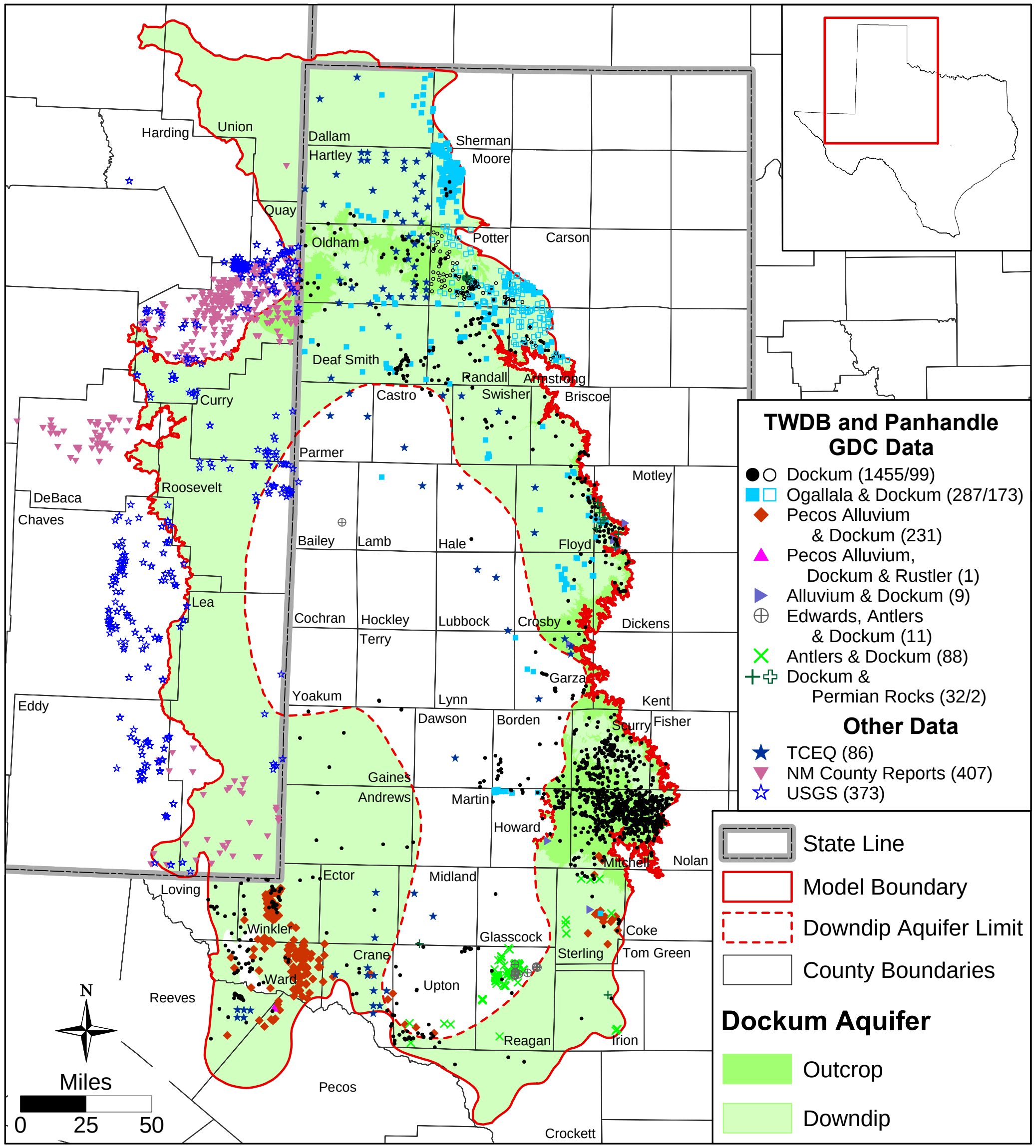
Source: McGowen et al. (1977)

Water Levels

Regional Groundwater Flow

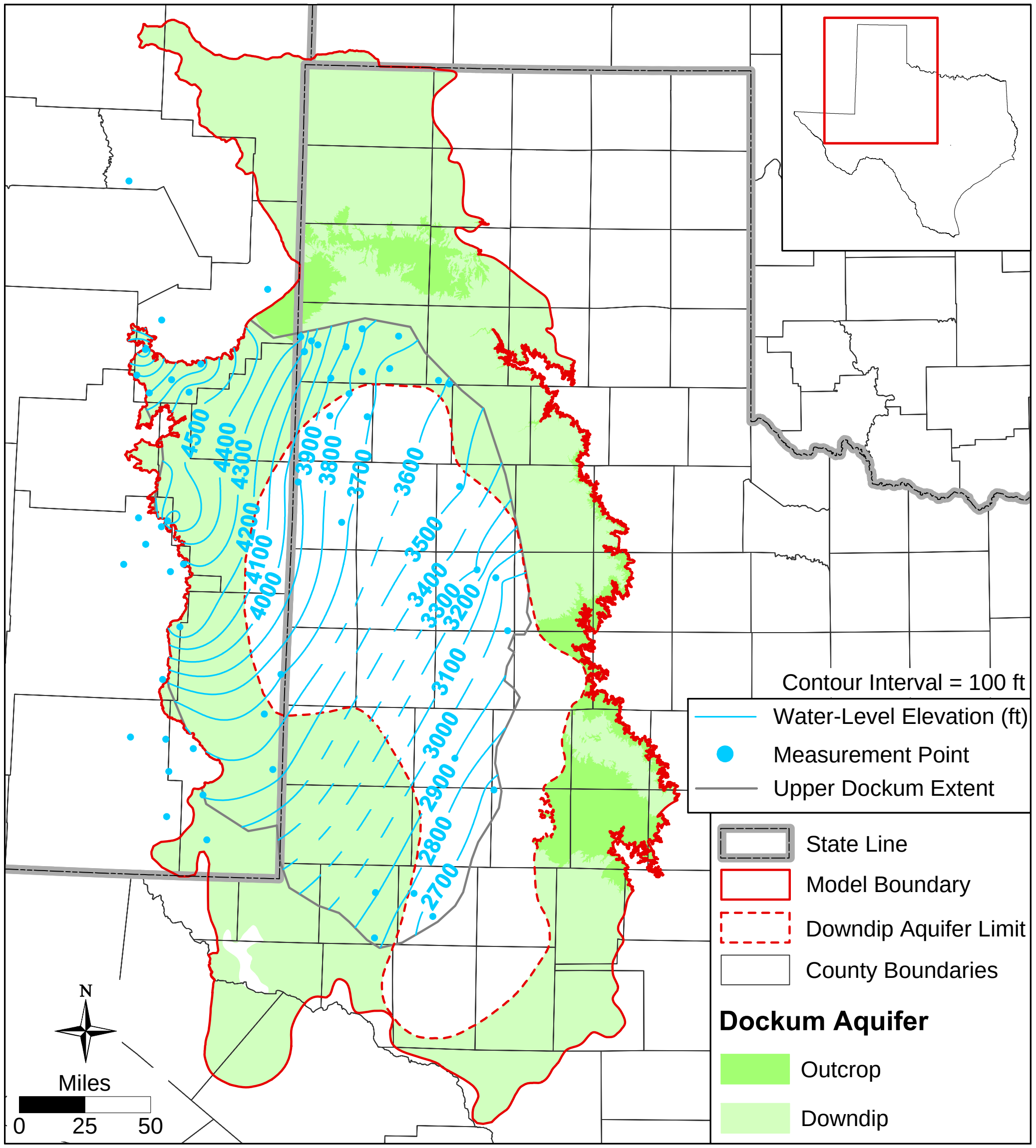
- General flow direction is from the northwest to the southeast
- Very slow flow in the deep, central portion of the depositional basin
- Flow in the northern portion of the model area is toward the Canadian River

Water-Level Locations



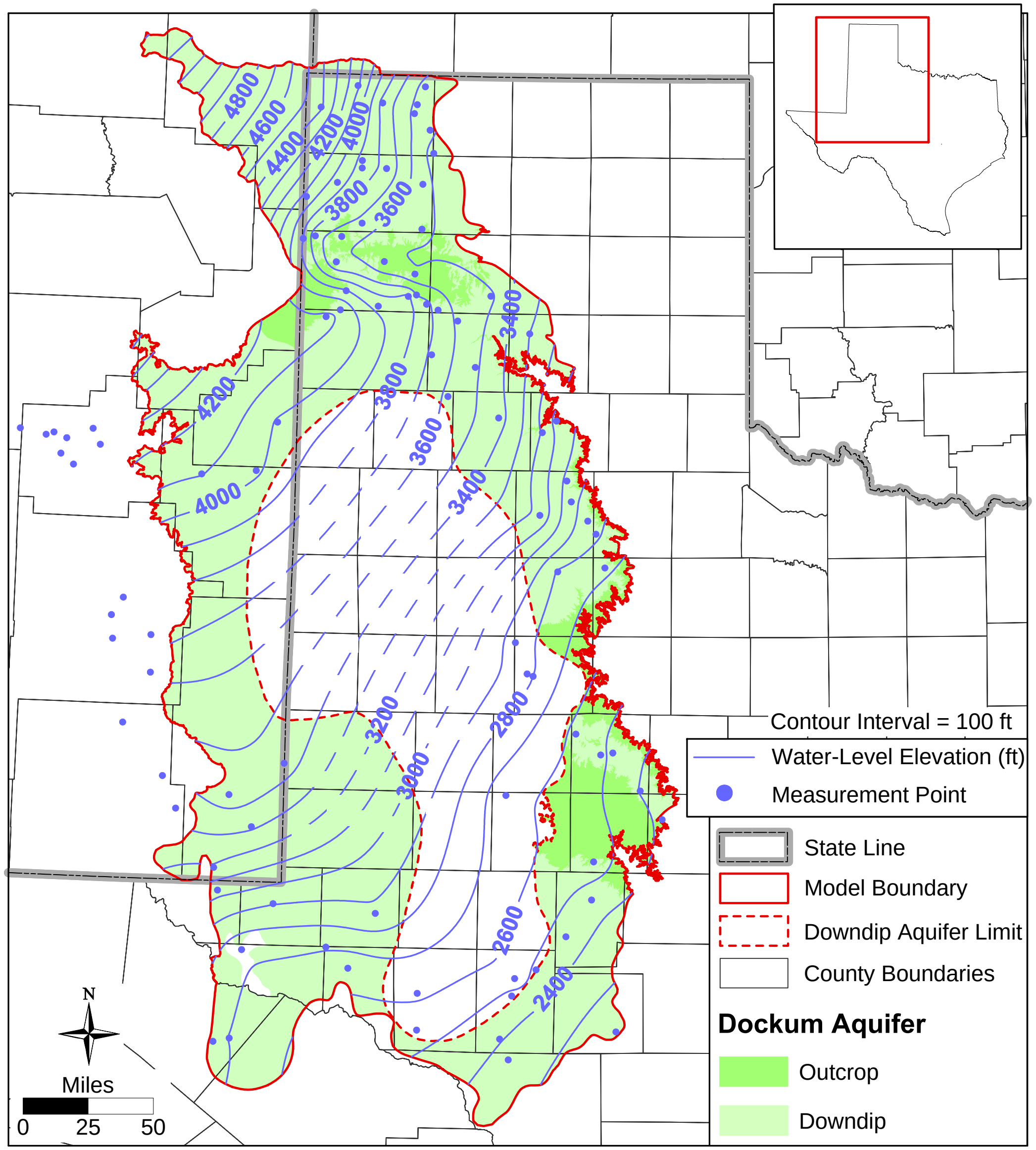
Water-Level Elevations

Upper Dockum Predevelopment



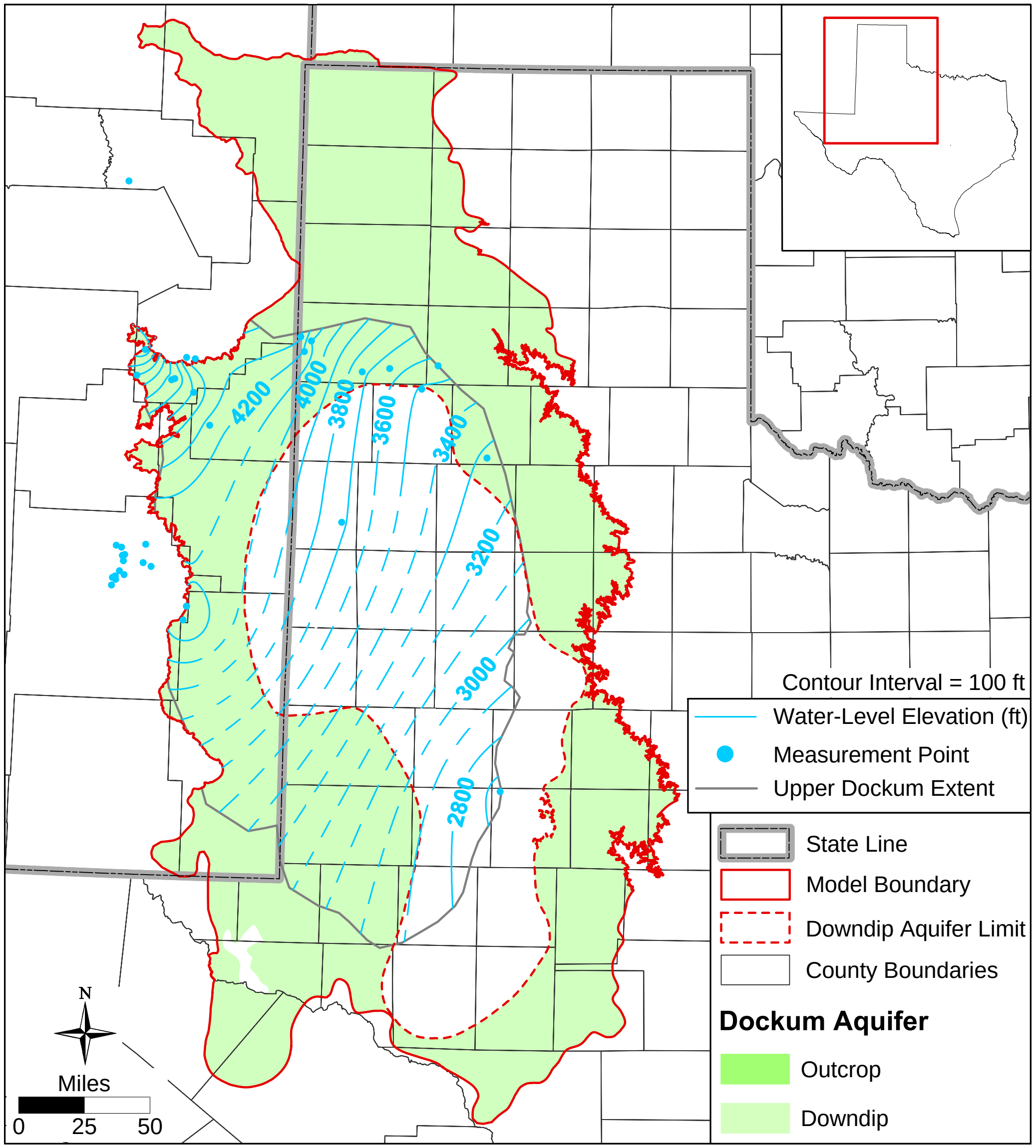
Water-Level Elevations

Lower Dockum Predevelopment



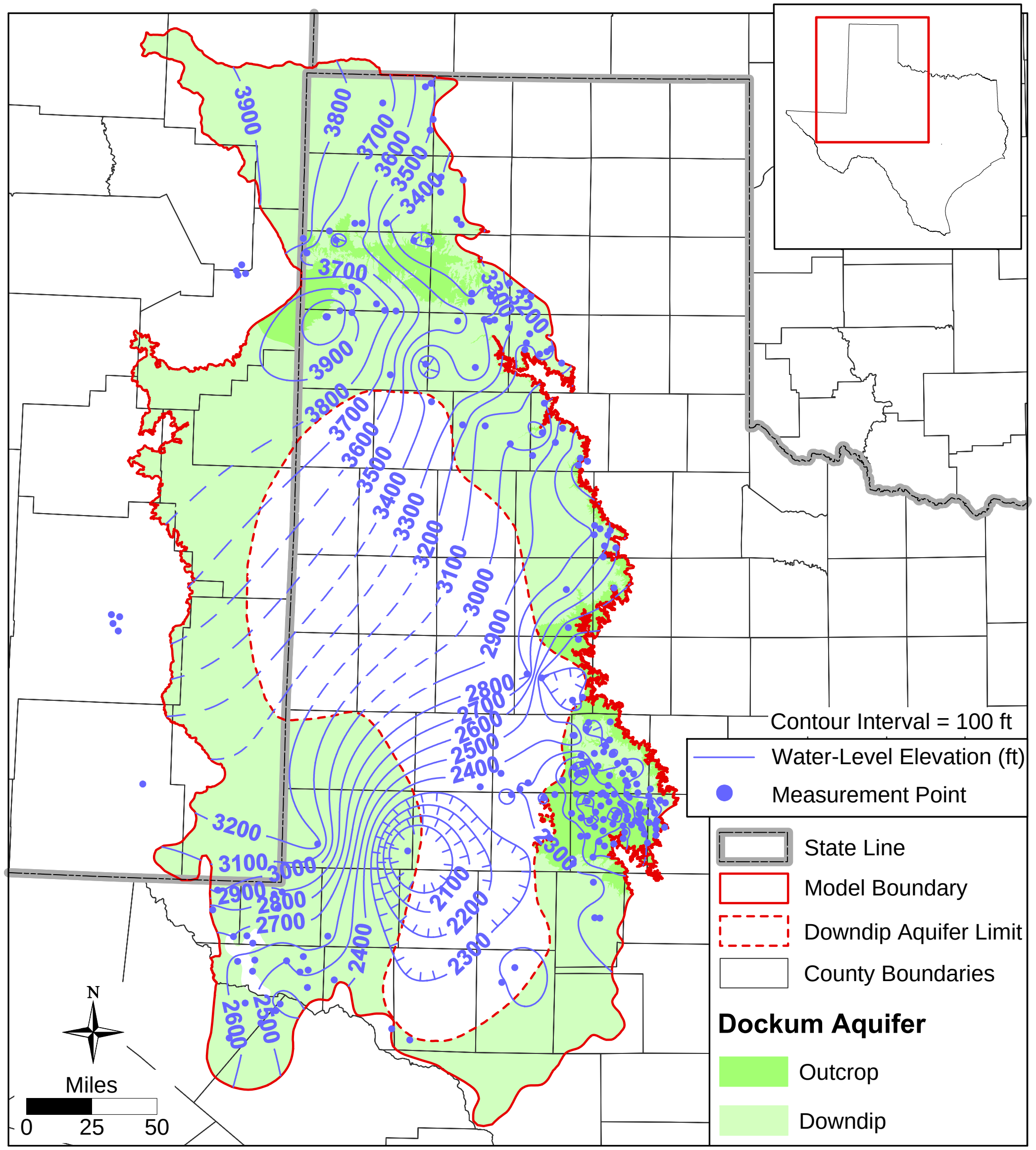
Water-Level Elevations

Upper Dockum 1980

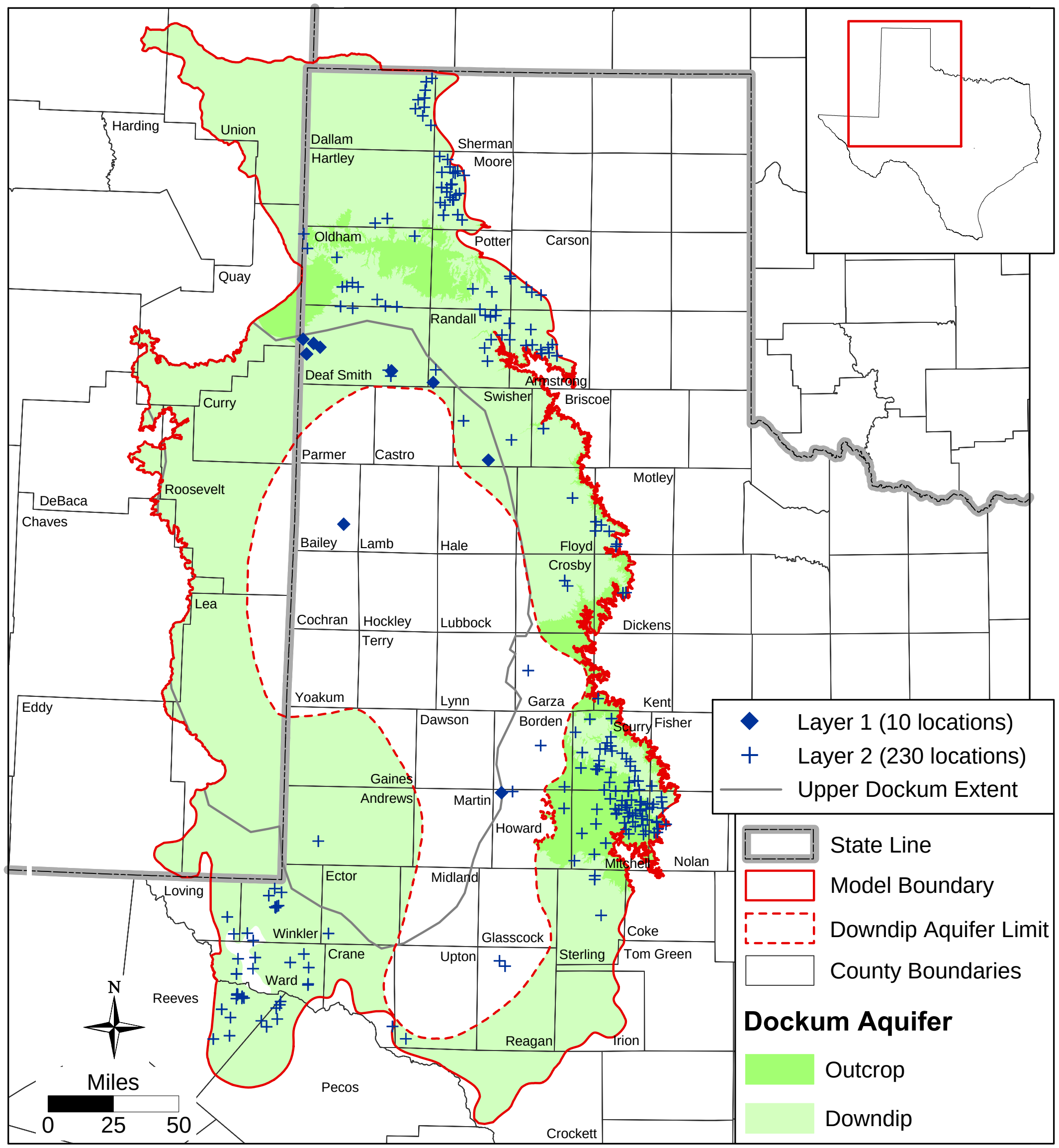


Water-Level Elevations

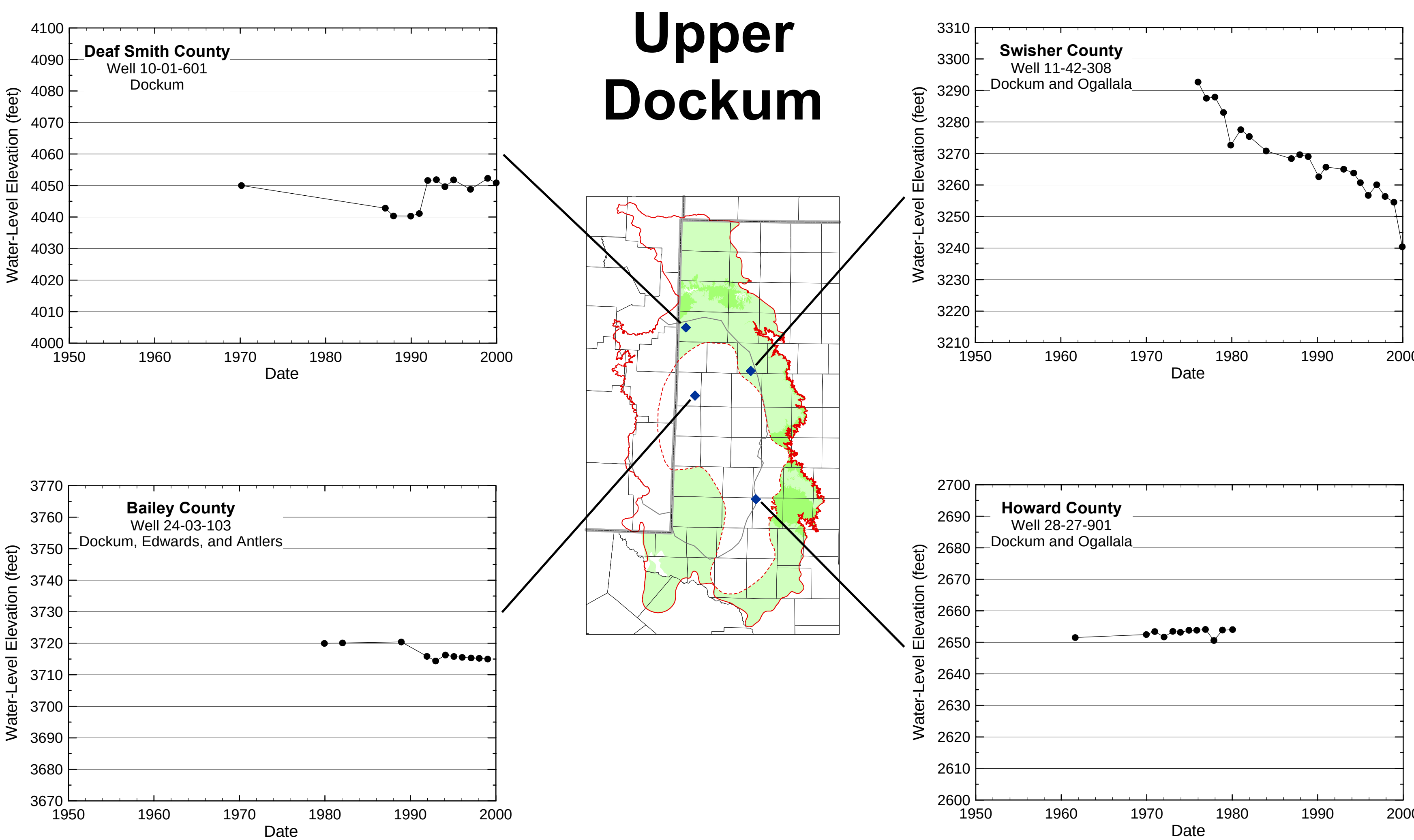
Lower Dockum
1980



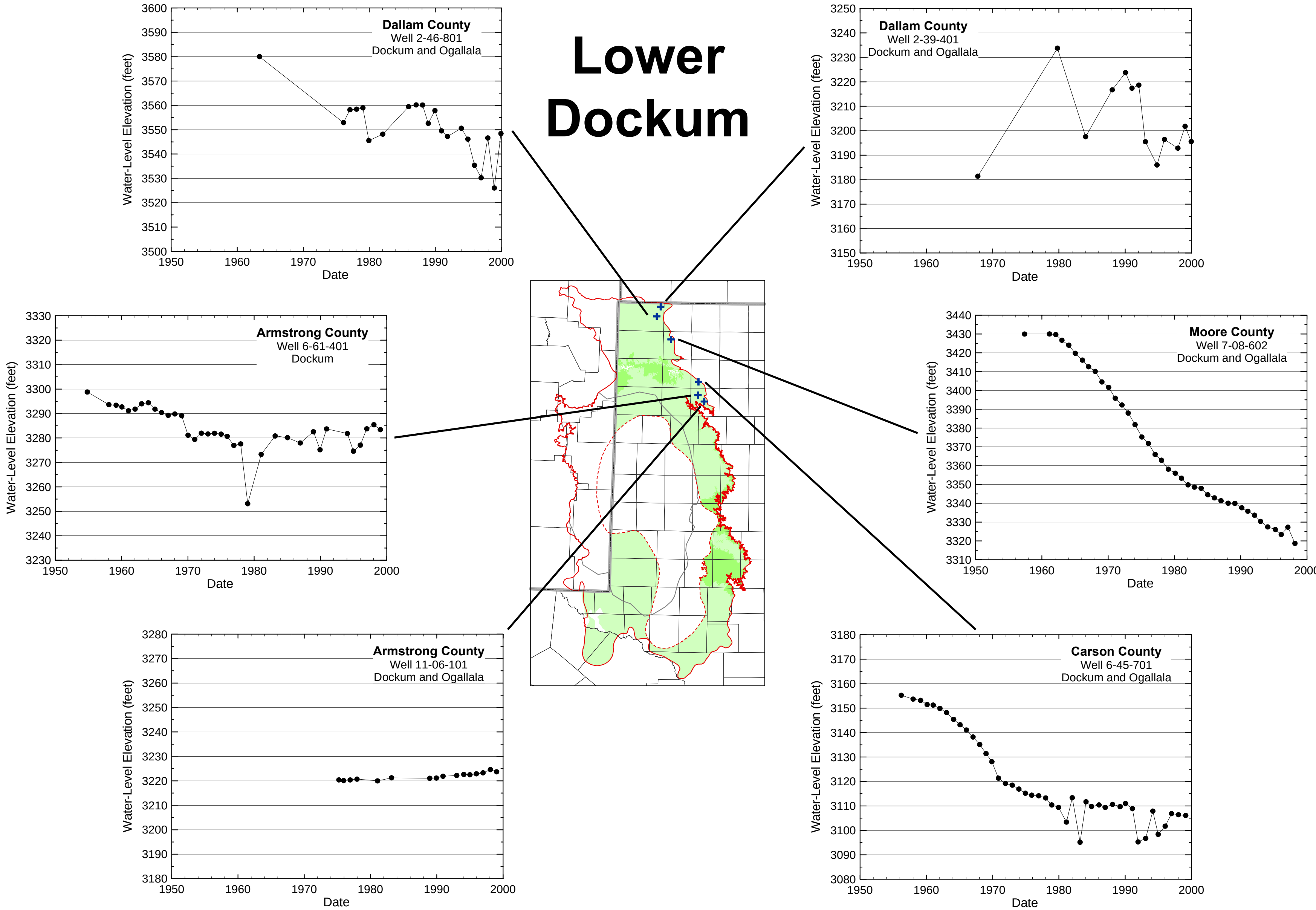
Transient Water Level Locations



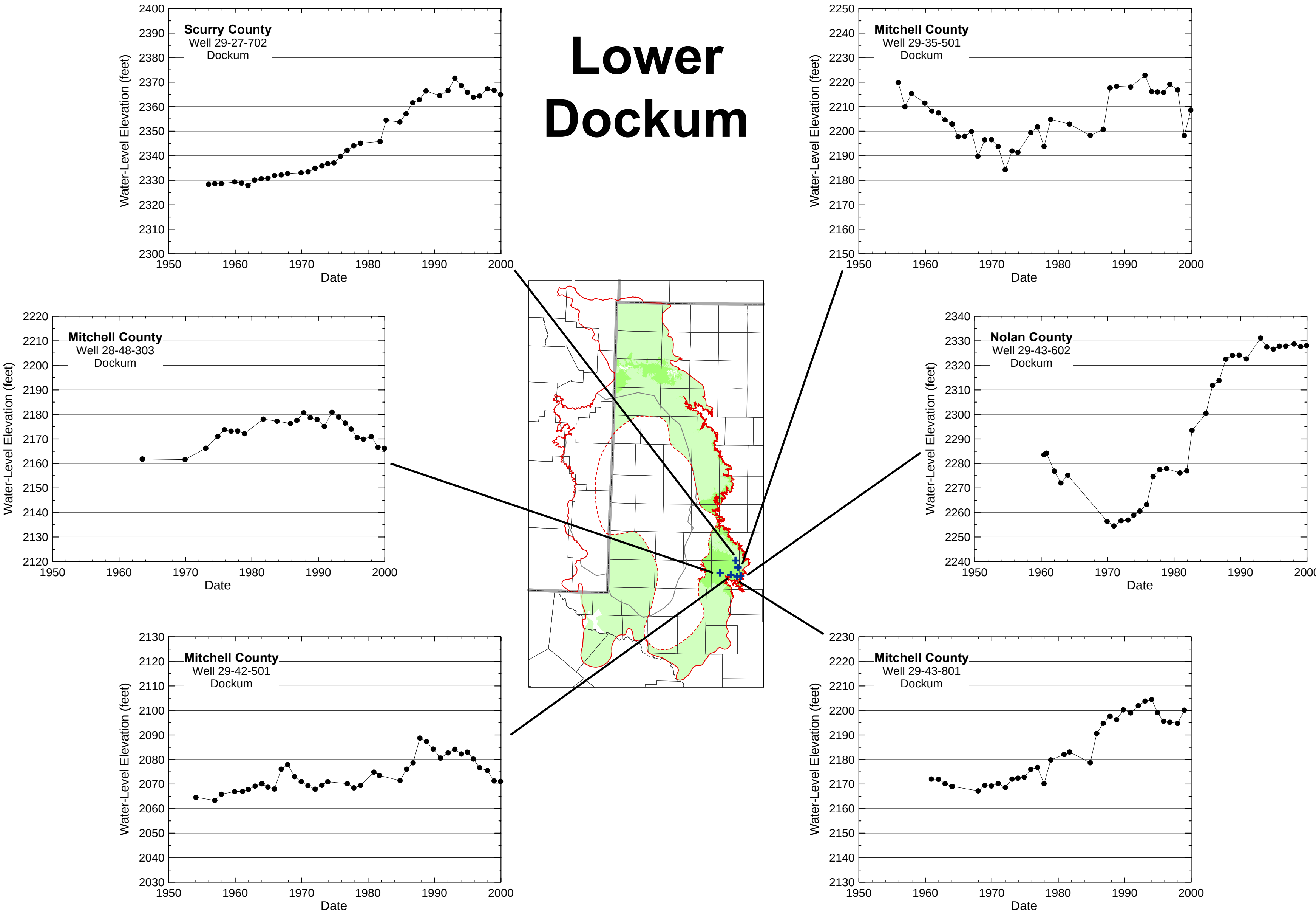
Example Hydrographs



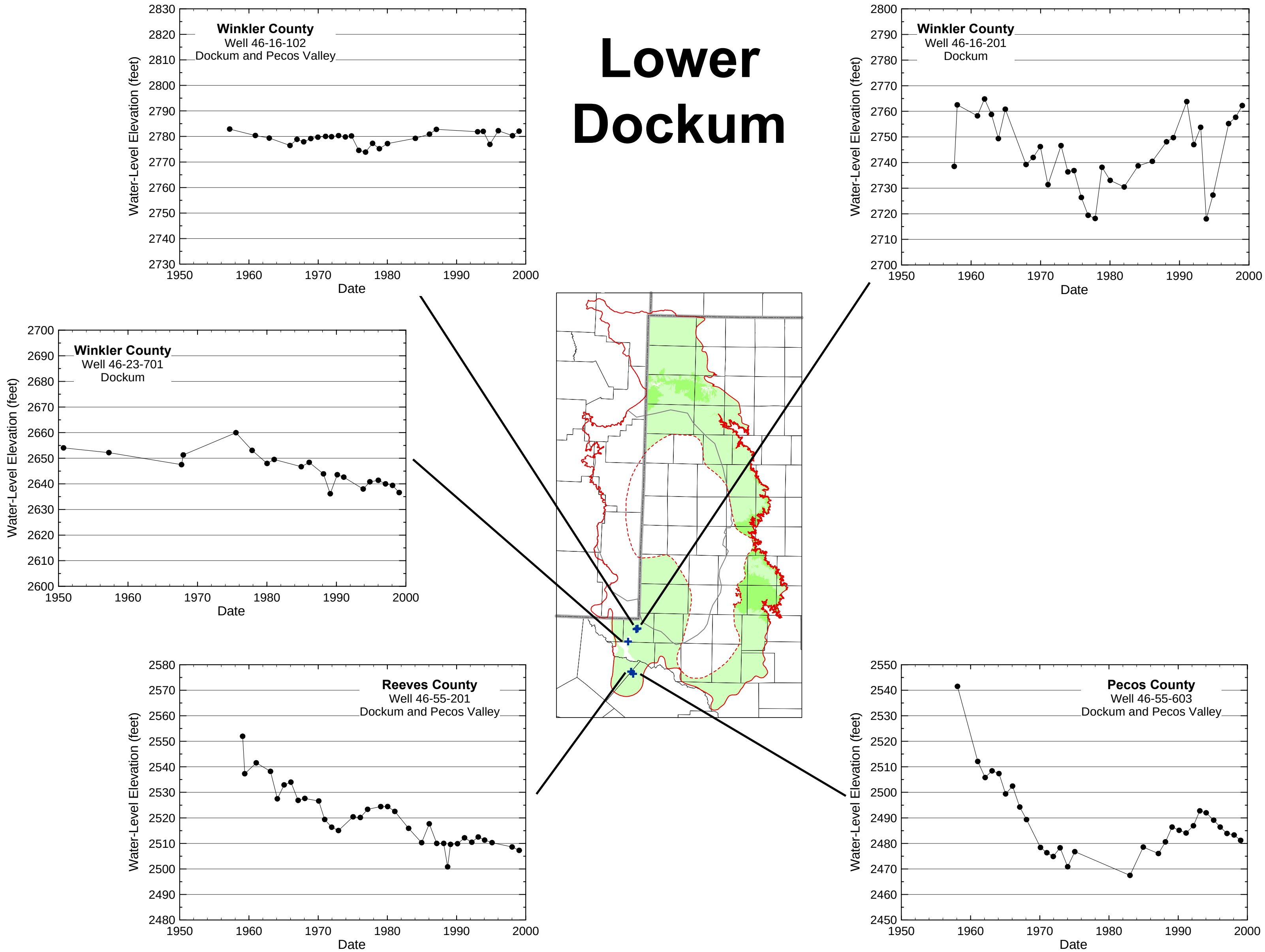
Example Hydrographs



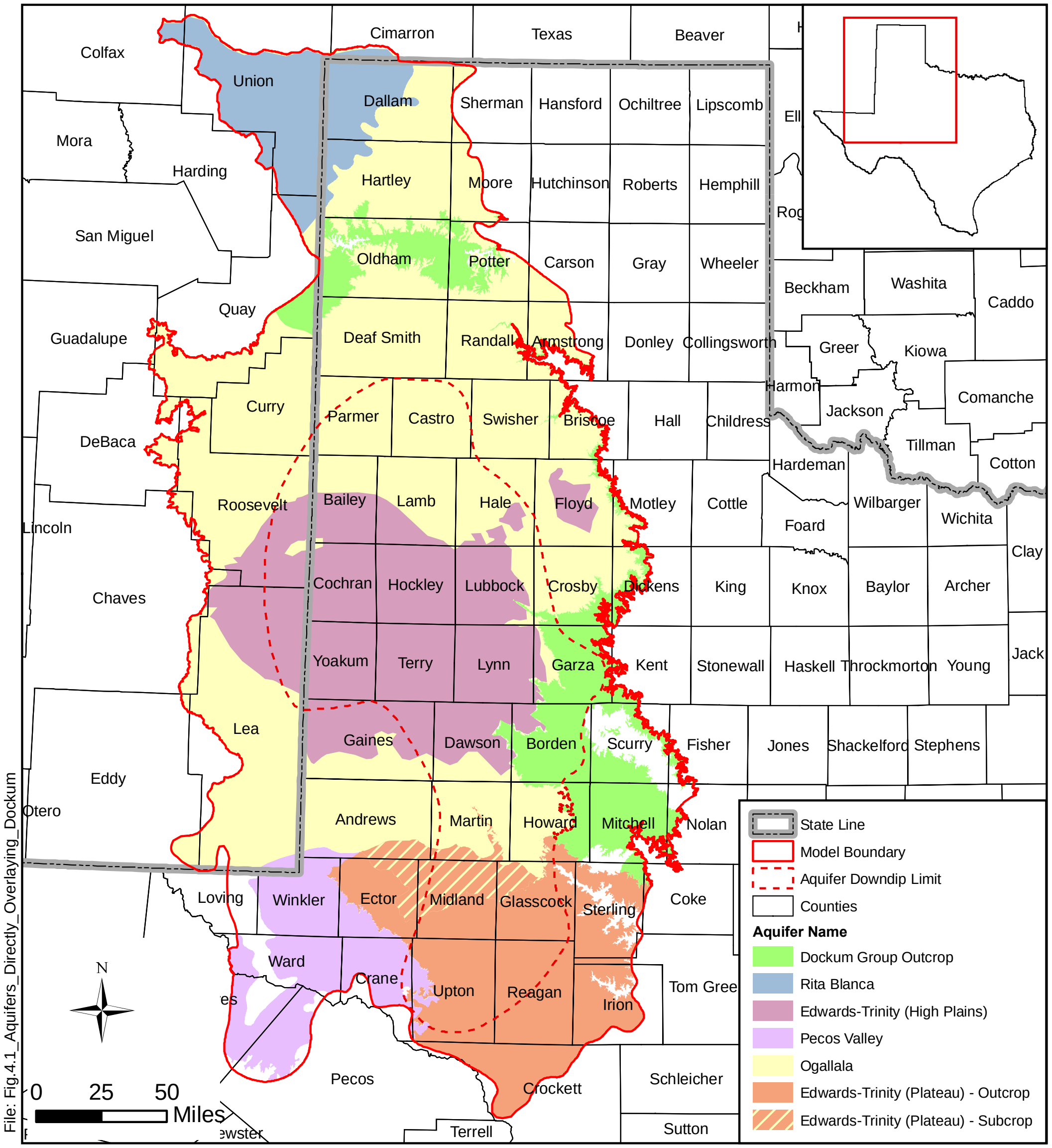
Example Hydrographs



Example Hydrographs

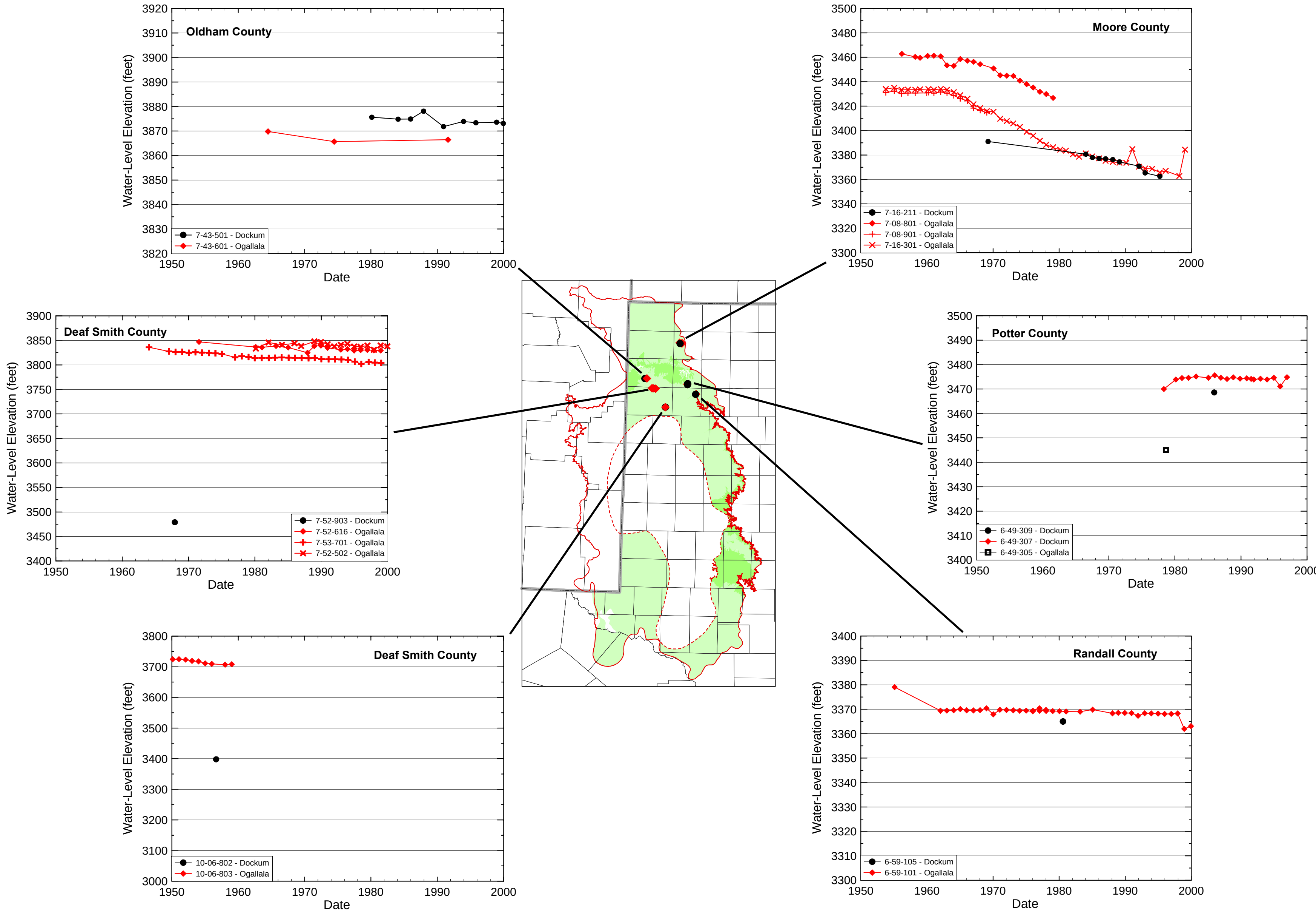


Aquifers Directly Overlying Dockum

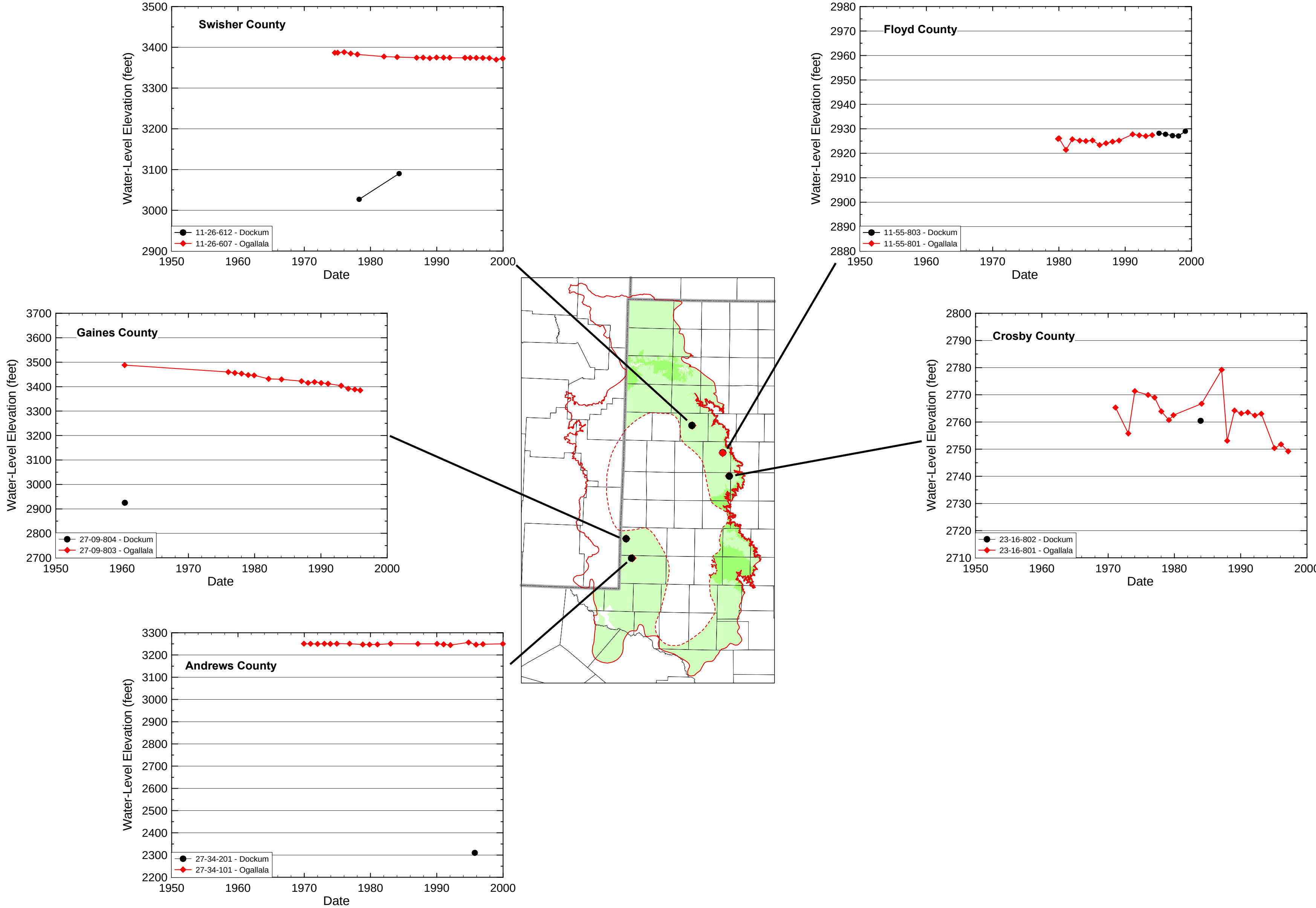


Source: Adapted from Texas Water Development Board, Dec 2006

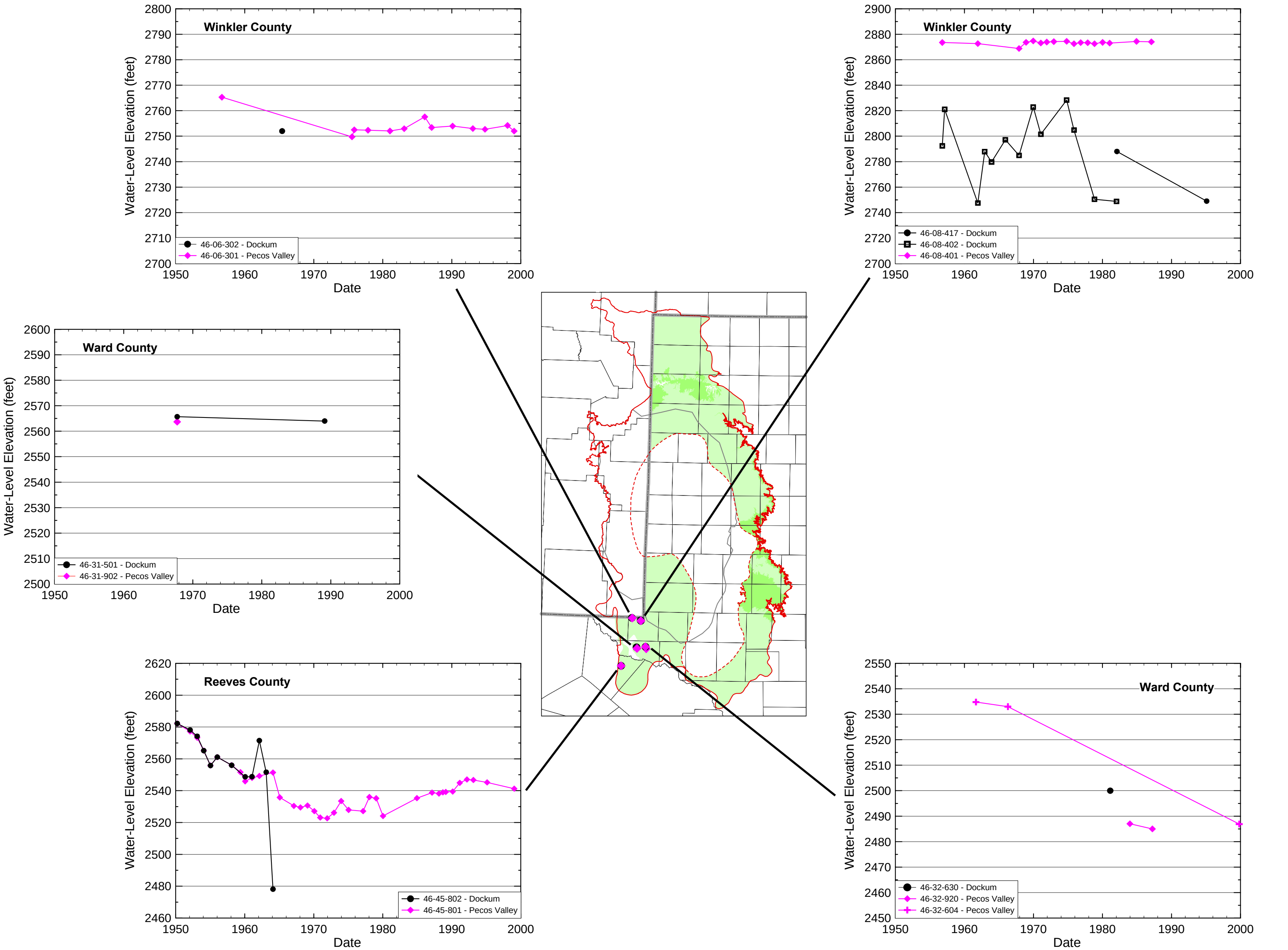
Vertical Differences in Water-Level Elevations – Northern Model Area



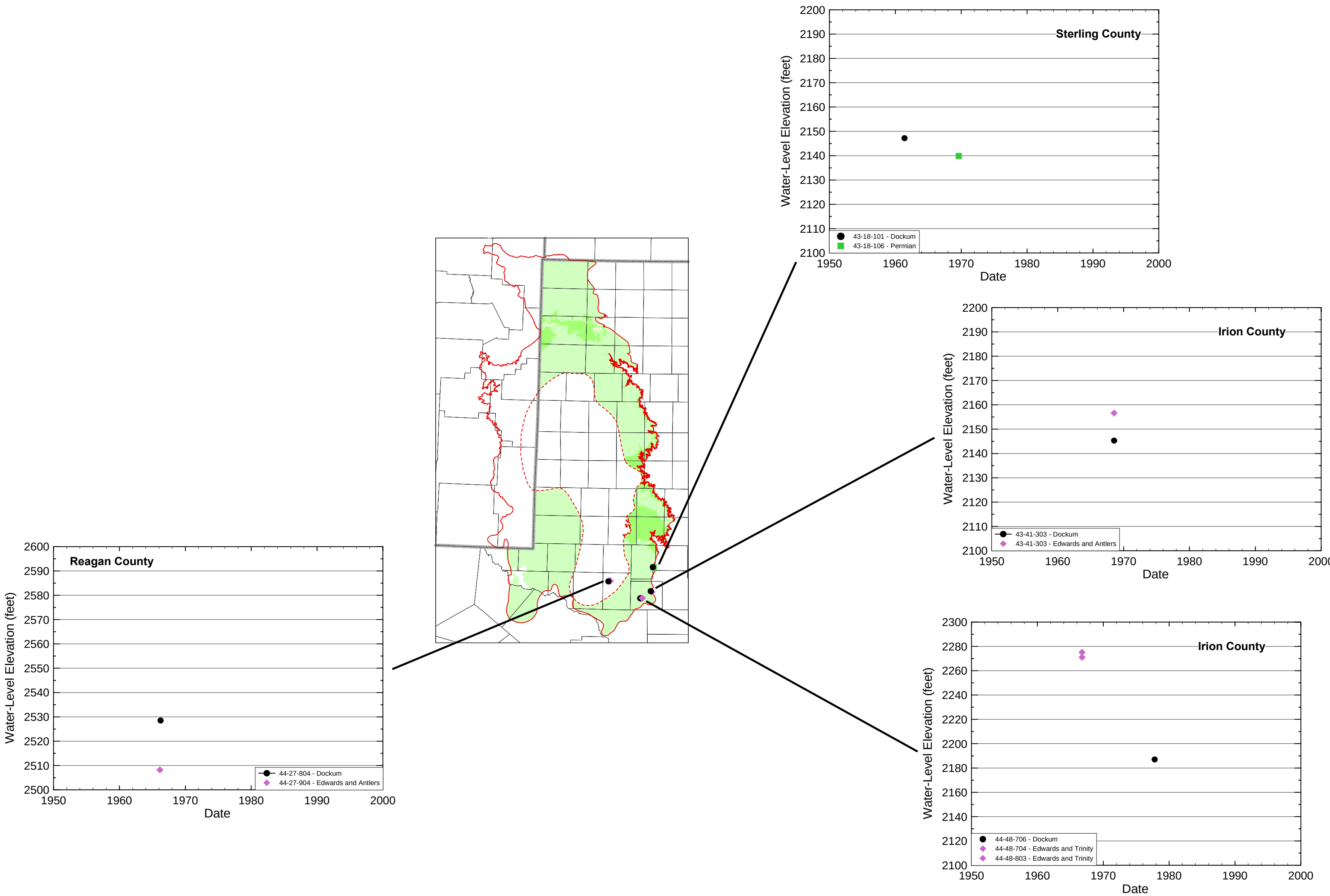
Vertical Differences in Water-Level Elevations – Central Model Area



Vertical Differences in Water-Level Elevations – Southwestern Model Area



Vertical Differences in Water-Level Elevations – Southeastern Model Area



Cross-Formational Flow

- Evaluation and literature review
  - Generally, there is greater communication between the Ogallala and Dockum in areas where the upper Dockum is not present
  - Communication between the Ogallala and Dockum is limited where the upper Dockum is present
    - Groundwater chemistry indicates distinct difference between Ogallala and Dockum waters
    - Time period for flow is very long
  - Potential for flow from the Dockum to the Ogallala in some discharge areas along the eastern escarpment

Cross-Formational Flow

- Evaluation and literature review (cont)
  - Generally, groundwater flows from the Pecos Valley aquifer to the Dockum in areas away from the trough and from the Dockum to the Pecos in areas near the trough
  - Based on limited data, potential for groundwater flow is from the Edwards-Trinity (Plateau) to the Dockum and from the Dockum to the Permian in the southeastern region of the model
  - Basically, cross-formational flow occurs between the Dockum and overlying aquifer where the top of the Dockum is sandy

Hydraulic Properties

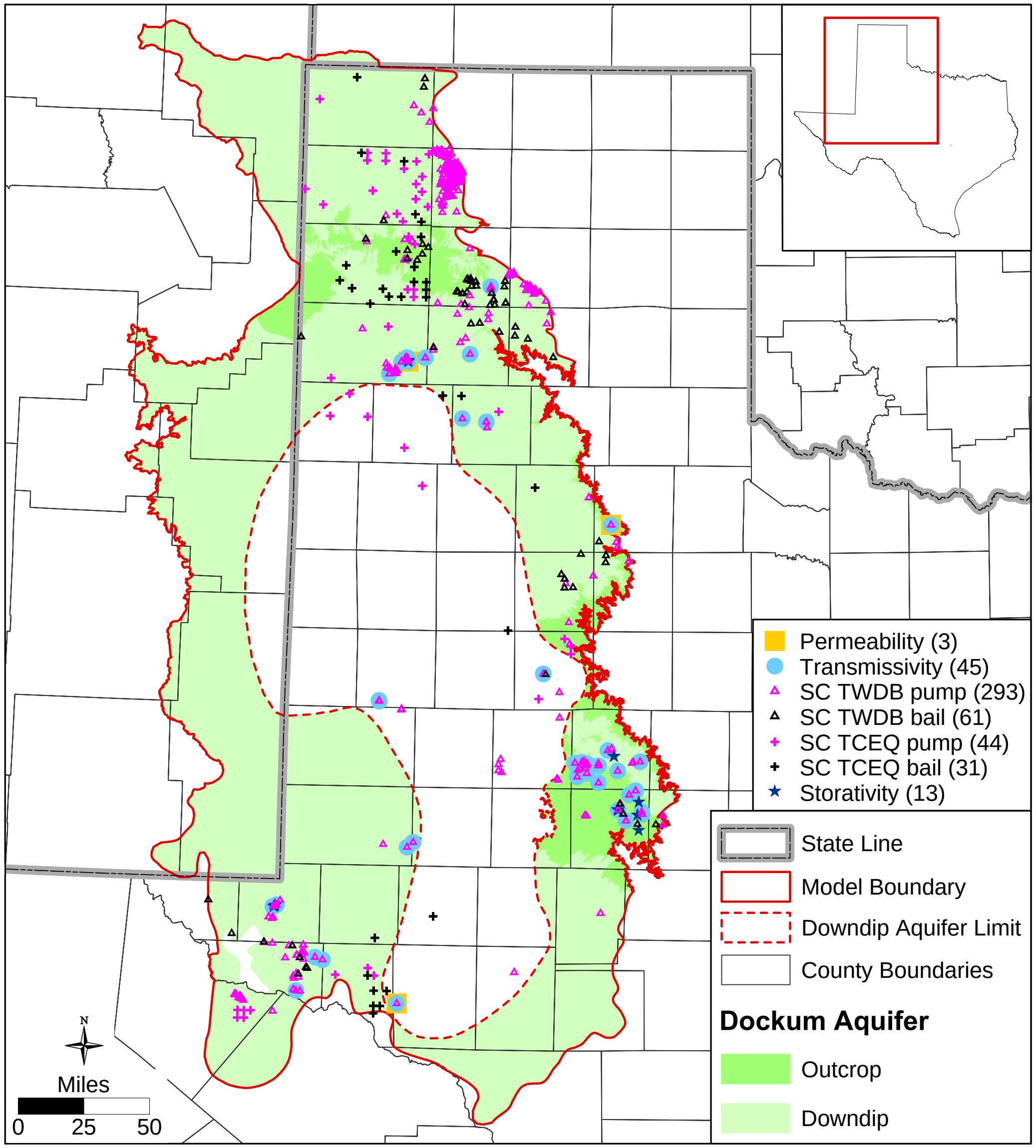
Hydraulic Property Sources

- Bradley and Kalaswad (2003)
  - Transmissivity
  - Specific capacity
  - Storativity
- Dutton and Simpkins (1986)
  - Transmissivity
  - Specific capacity
- Myers (1969)
  - Storativity

Hydraulic Property Sources

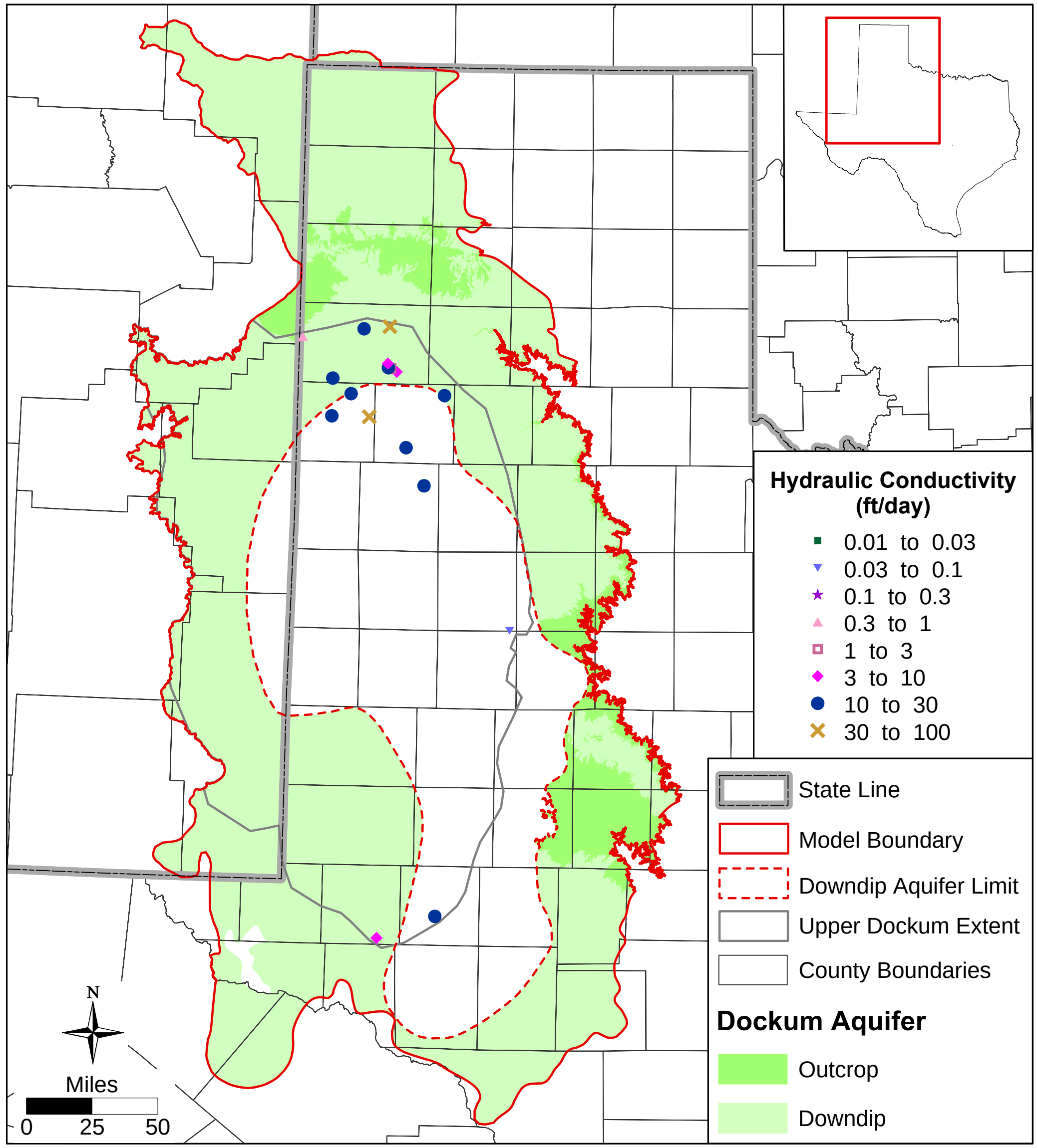
- County Reports
  - Transmissivity
  - Storativity
- TWDB Website
  - Transmissivity
  - Specific capacity
  - Storativity
- TCEQ Well Logs
  - Specific Capacity

Locations and Types



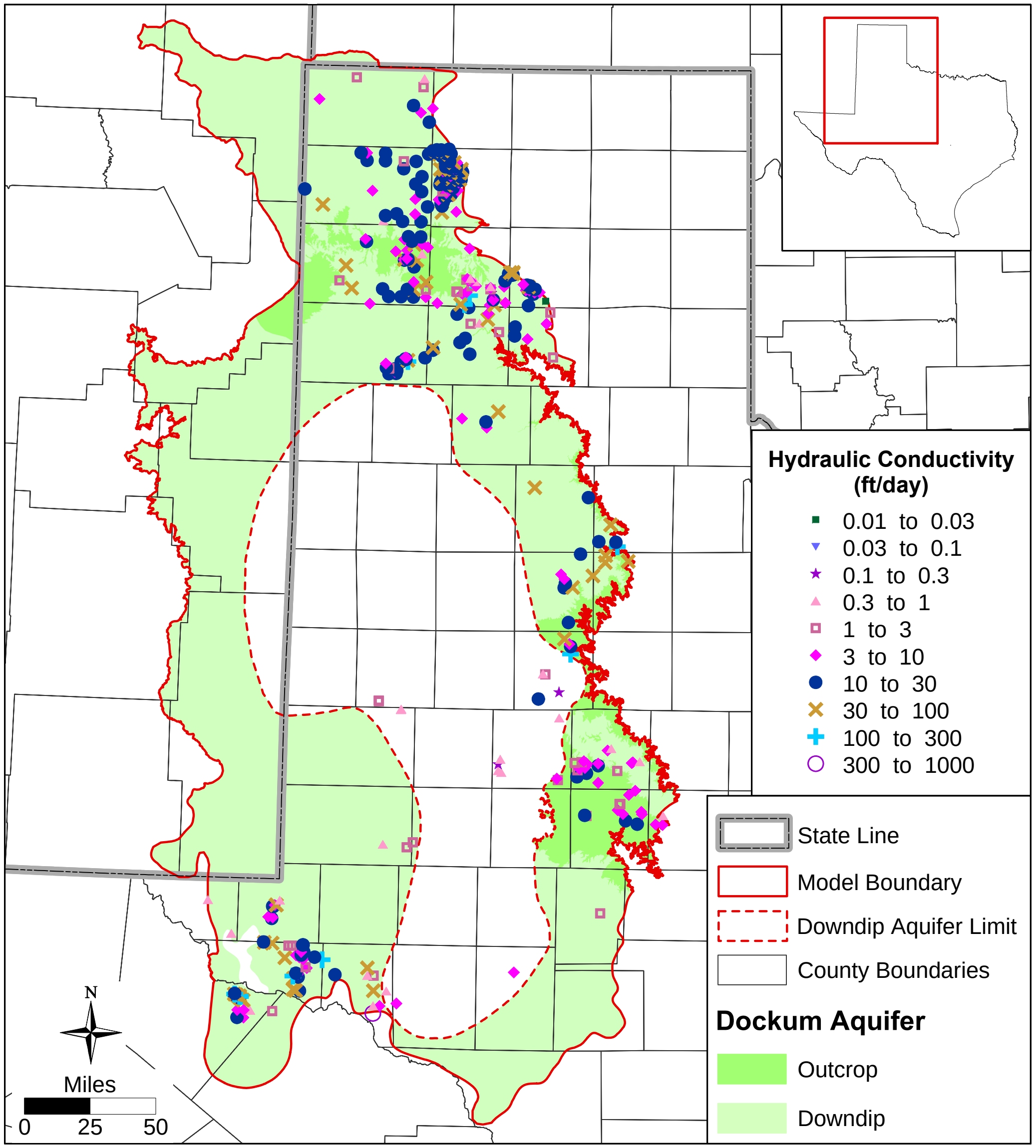
Hydraulic Conductivities

Upper Dockum



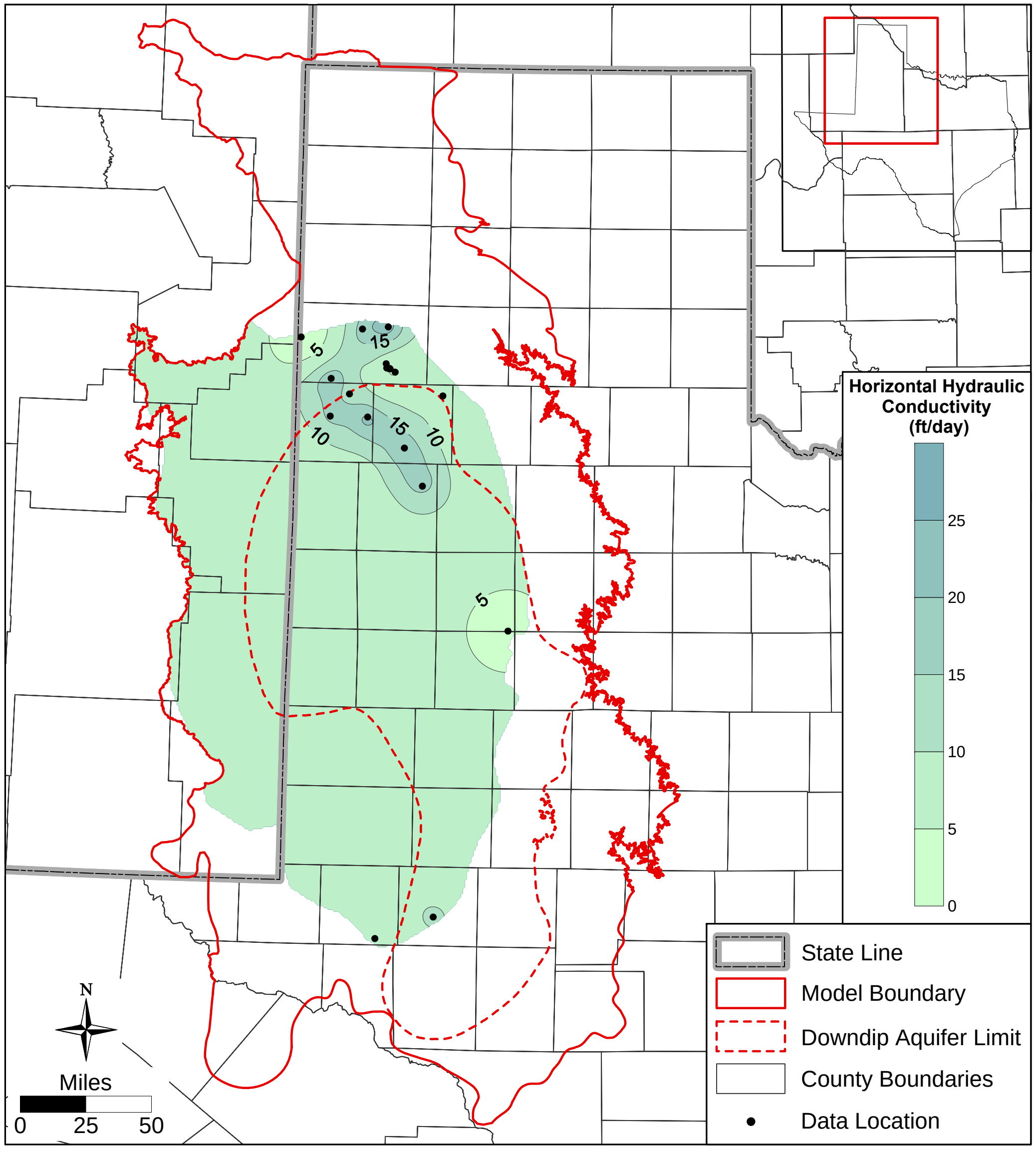
Hydraulic Conductivities

Lower Dockum



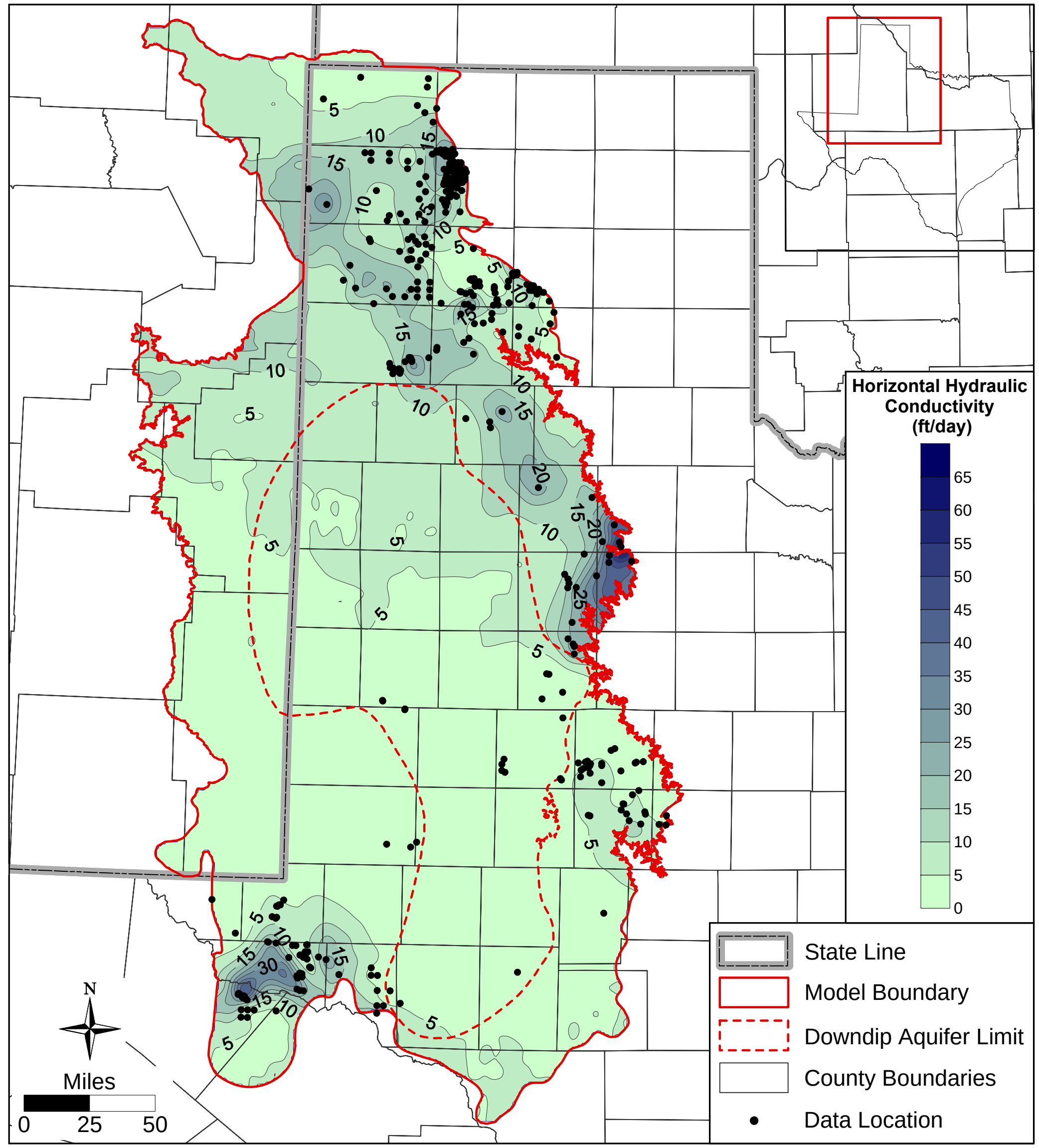
Horizontal Hydraulic Conductivity

Upper Dockum



Horizontal Hydraulic Conductivity

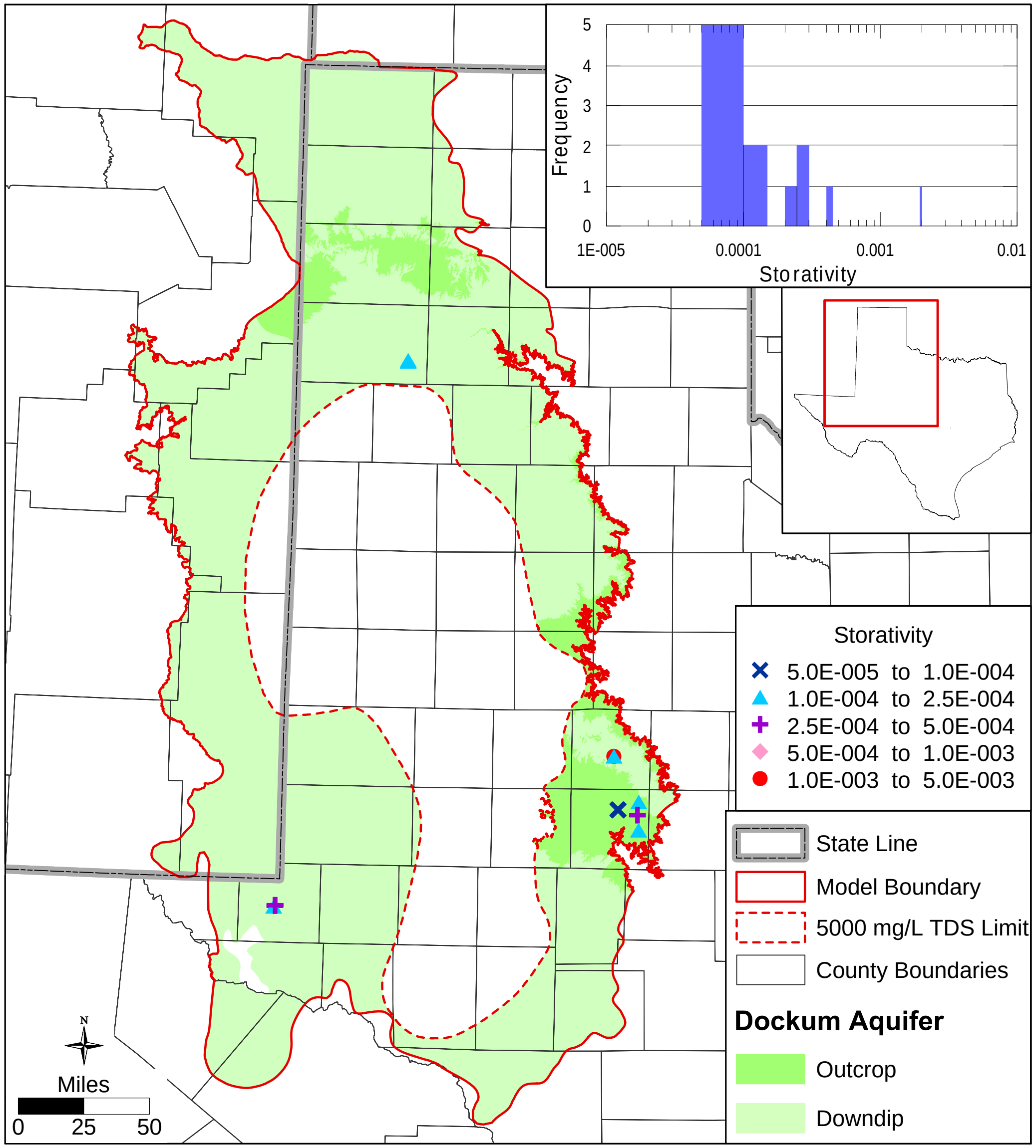
Lower Dockum



Vertical Conductivity

- Will be estimated in the Dockum using
  - Literature values for sand and clay K_v
  - Percentage of sand and clay in upper and lower Dockum

Storativity

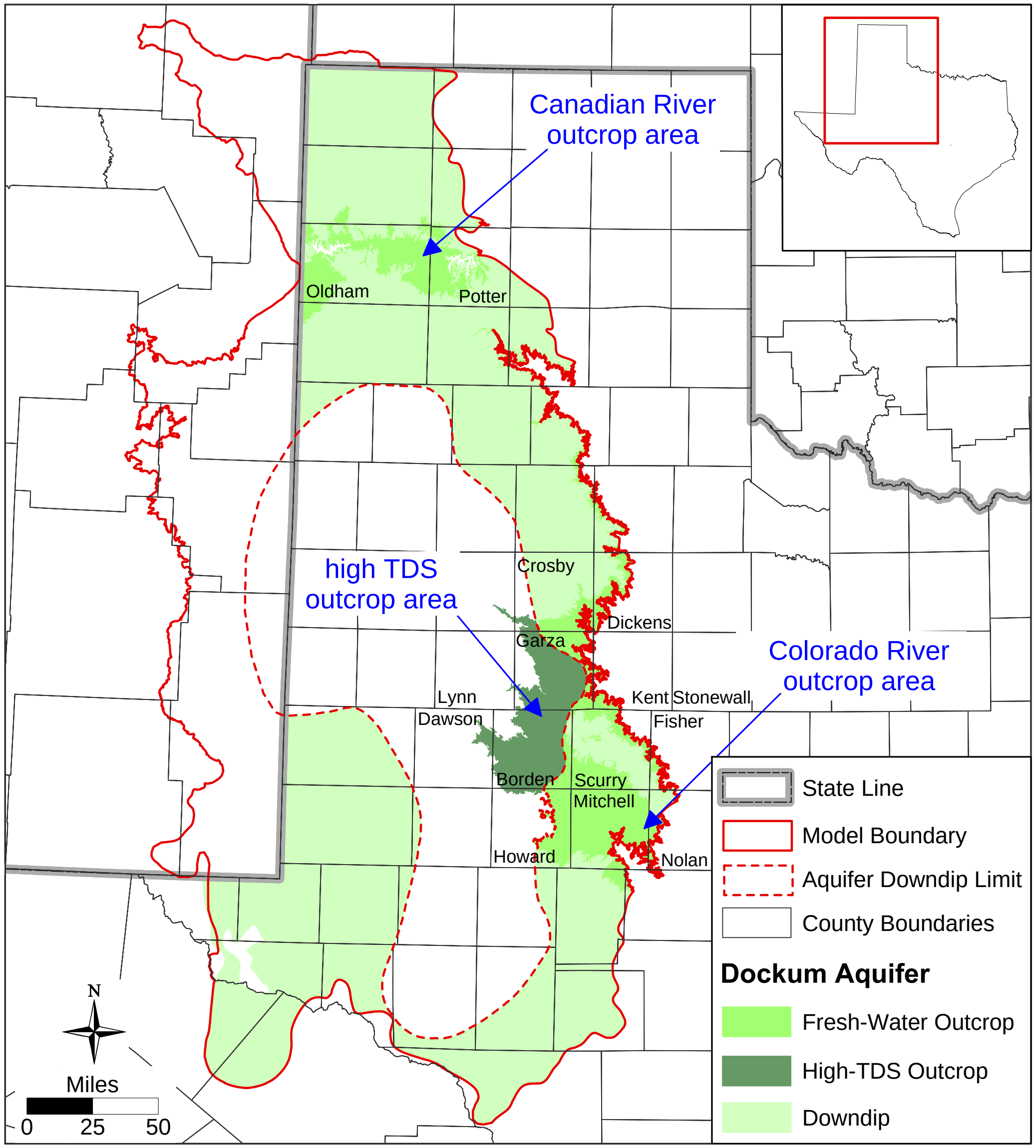


Recharge

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
  - Depth to water
- Recharge is not directly measurable on a model scale
- Recharge varies as a function of time and location

Recharge – Outcrop Areas



Recharge

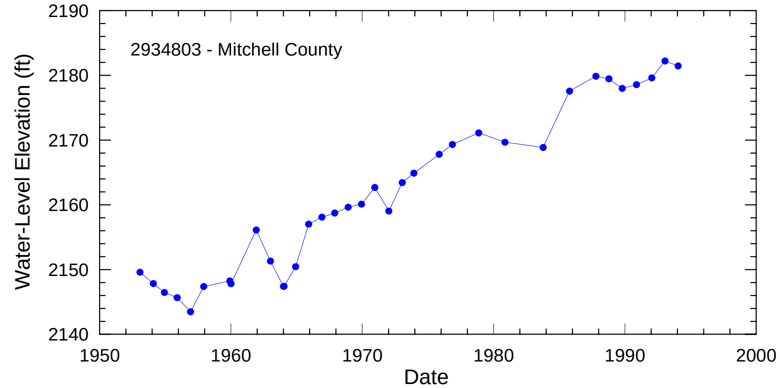
- All precipitation recharge in Dockum outcrops is shallow recharge
  - Canadian River outcrop area – recharge flows to Canadian River and its tributaries
  - Colorado River outcrop area – recharge flows to streams or springs
- Proposed Approach:
  - Vary recharge temporally based on precipitation
  - Vary recharge spacially based on soil type
- Some irrigation return flow

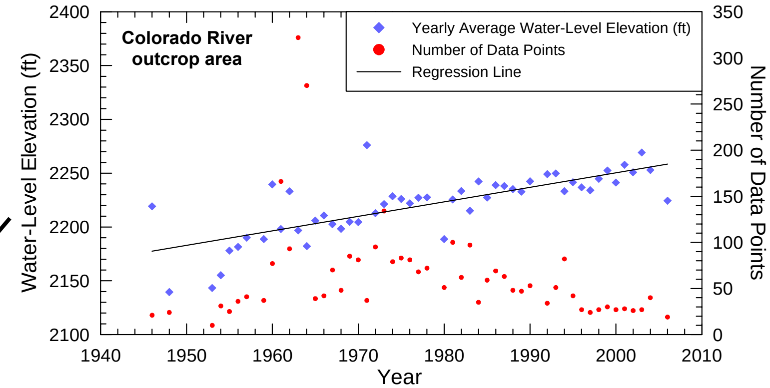
Recharge – Literature Review

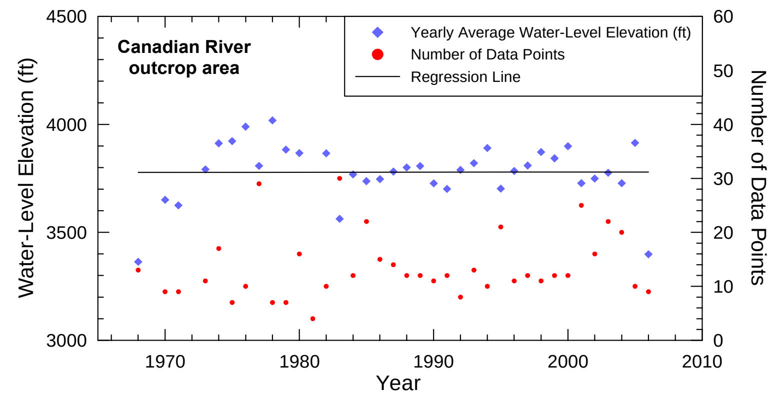
- Dockum Aquifer
  - 0.16 in/yr (Bradley and Kalaswad, 2003)
  - 0.12 in/yr (2006 Panhandle Regional Water Plan)
  - Unsaturated zone numerical modeling
    - 0.08 to 0.2 in/yr (Colorado River Outcrop area)
    - < 0.08 in/yr (Canadian River Outcrop area)
- Ogallala Aquifer (for comparison)
- Seymour Aquifer (for comparison)

Methods Used to Estimate Recharge

- **Playa influx (predevelopment)**
  - 0.02 to 0.04 in/yr
- **Linear water level rise in wells in the Colorado River Outcrop area (postdevelopment)**
  - 0 to 0.43 in/yr
- **Regional water level rise (postdevelopment)**
  - 2.2 in/yr (Colorado River Outcrop area)
  - not applicable for Canadian River Outcrop area)

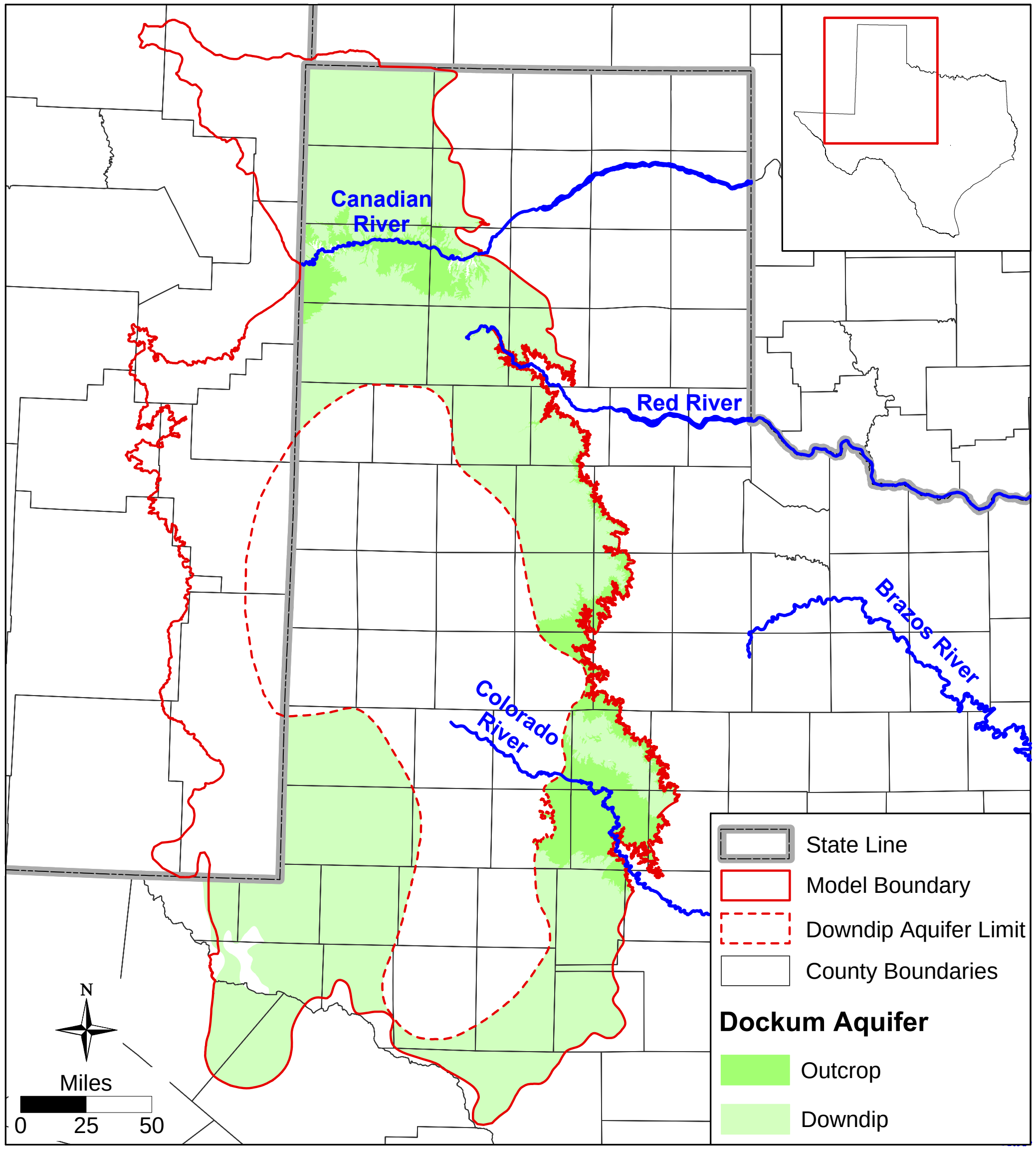




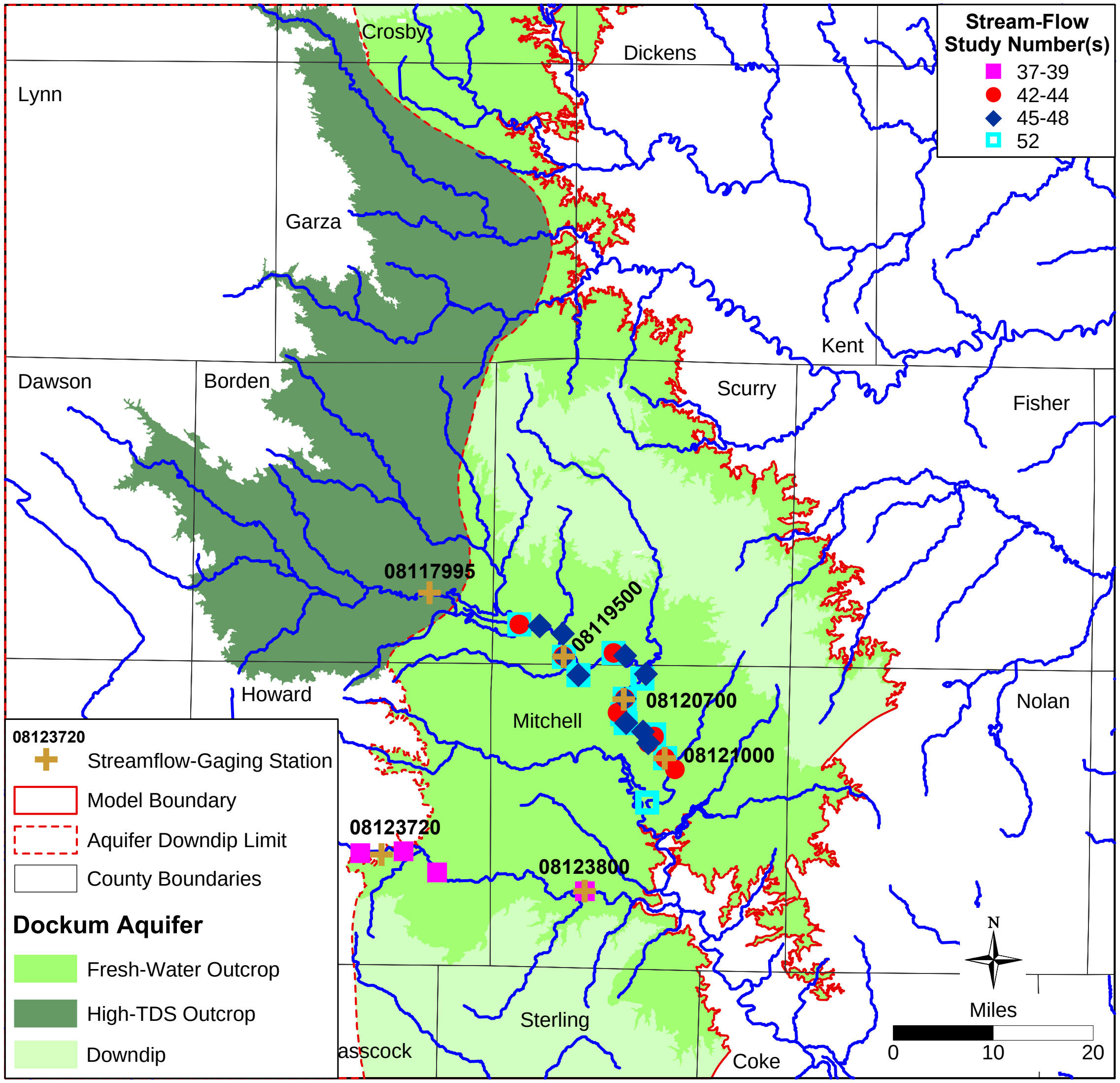


Surface Water

Major Rivers

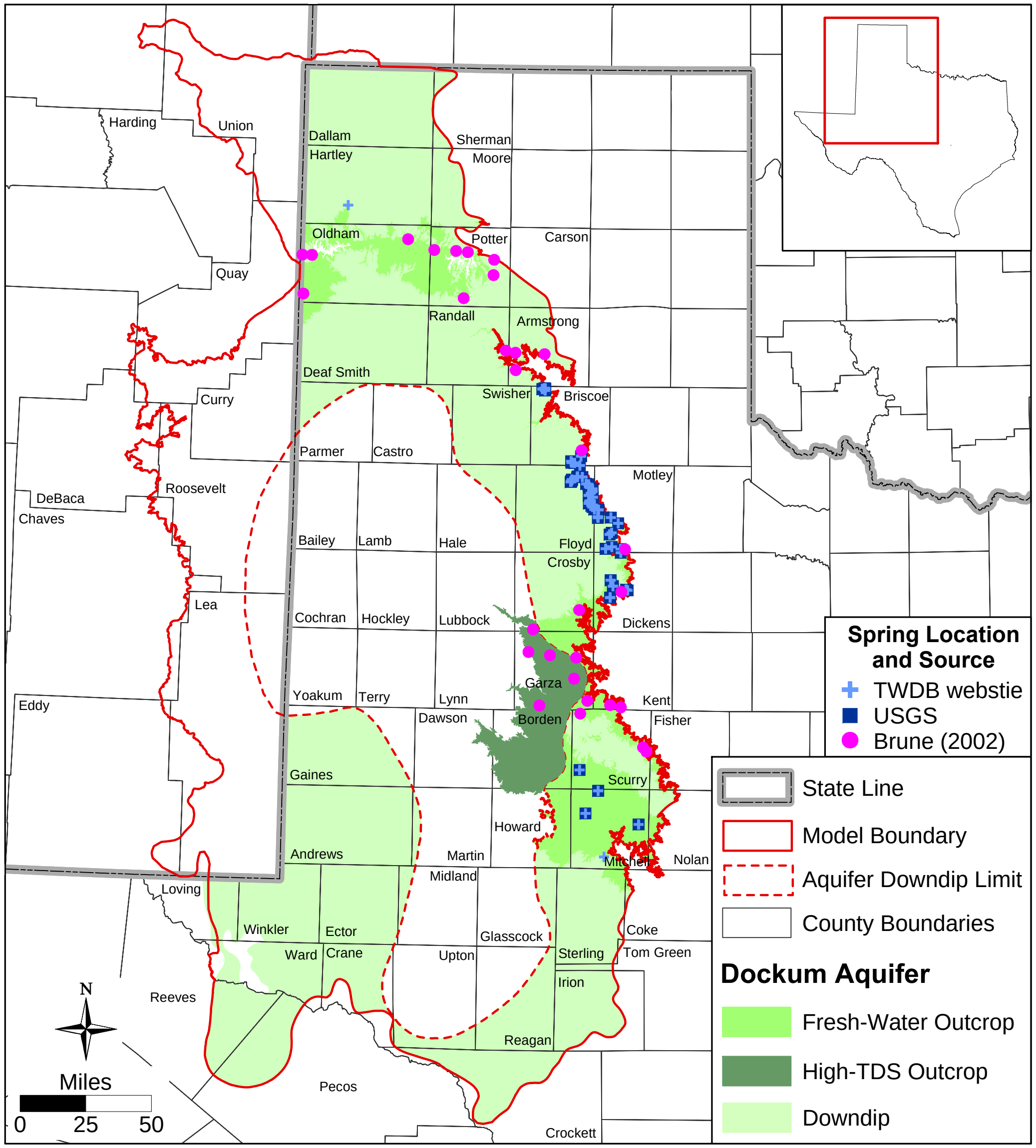


Gain/Loss Studies

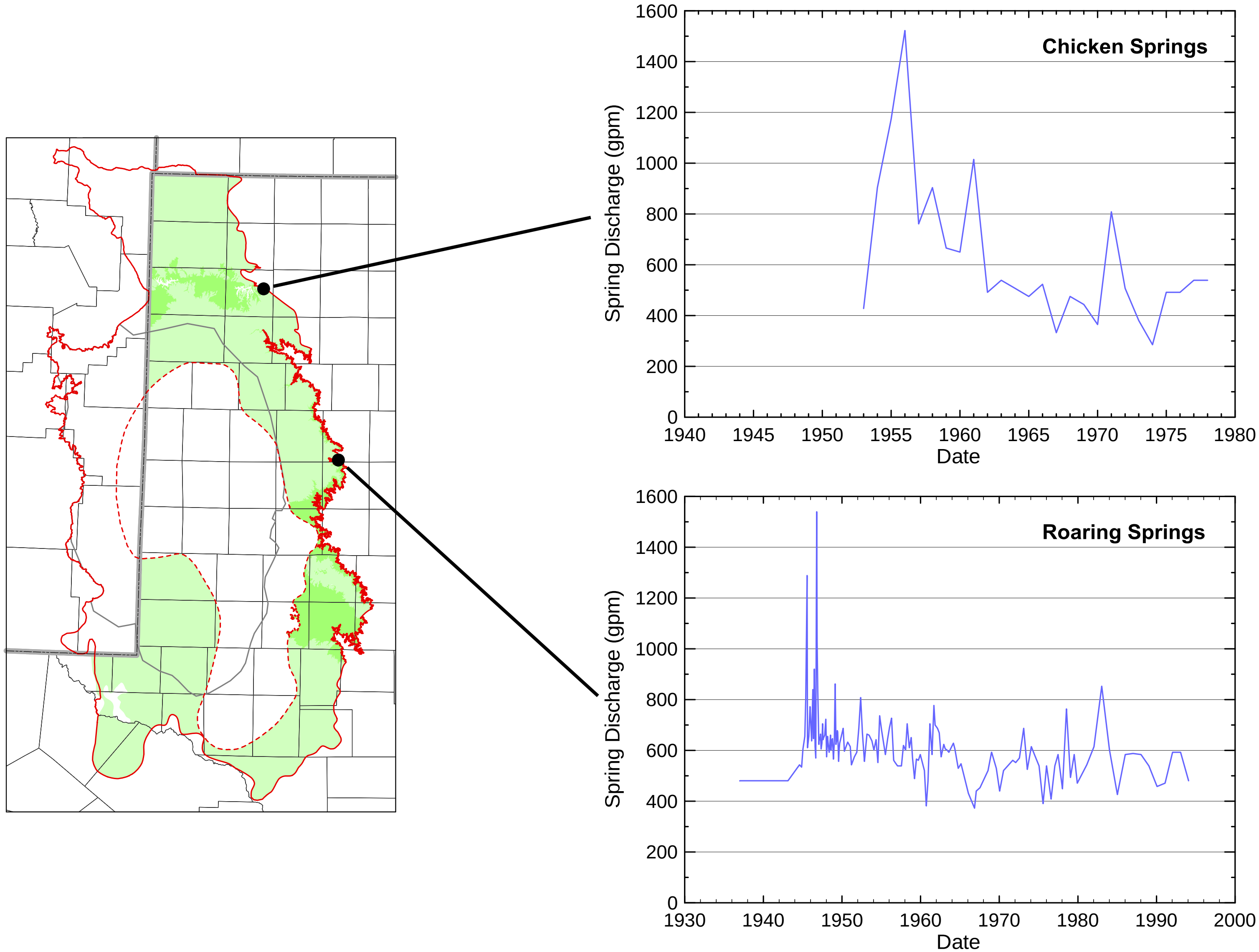


Slade et al., (2002)

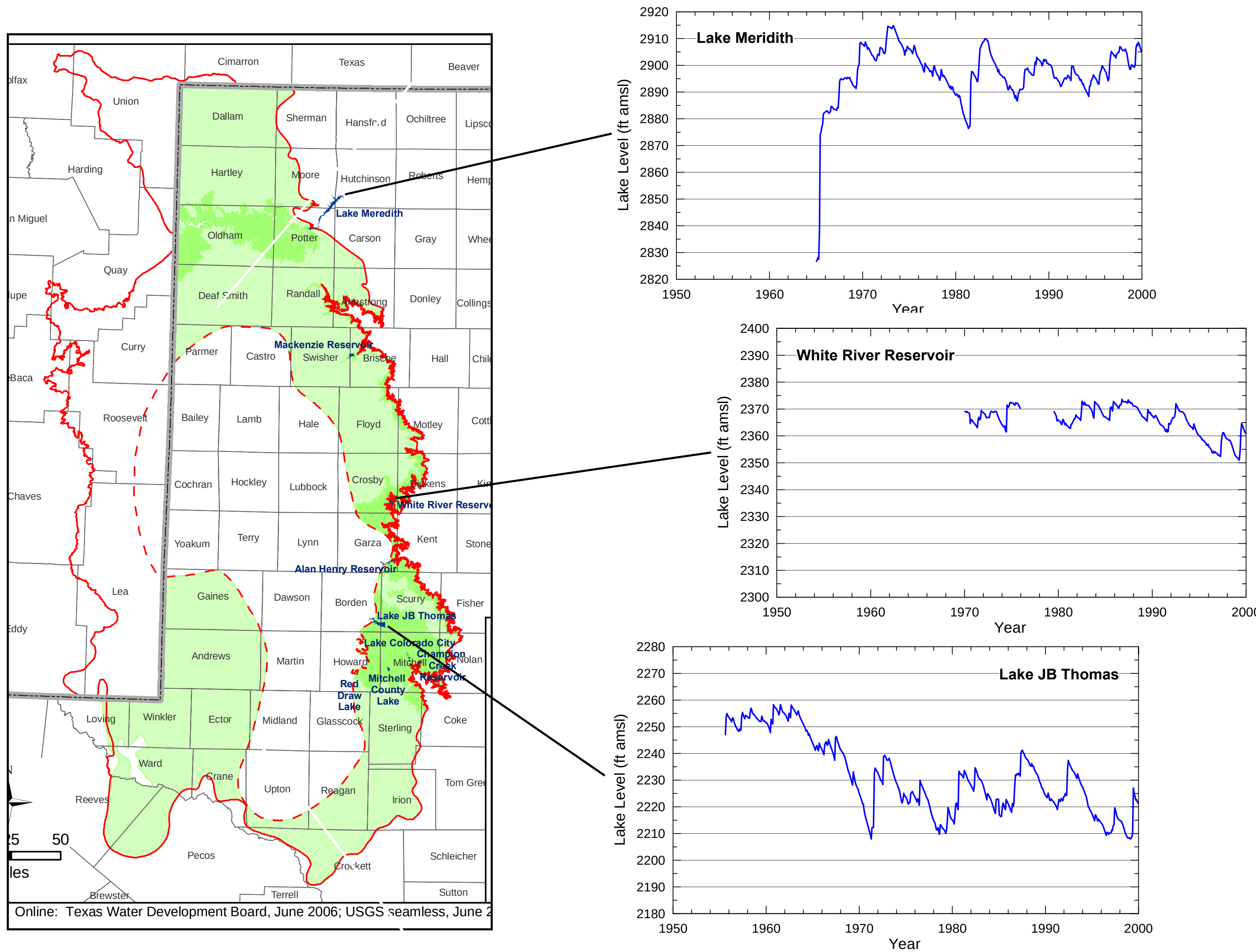
Spring Locations



Spring Hydrographs



Lake Locations and Hydrographs

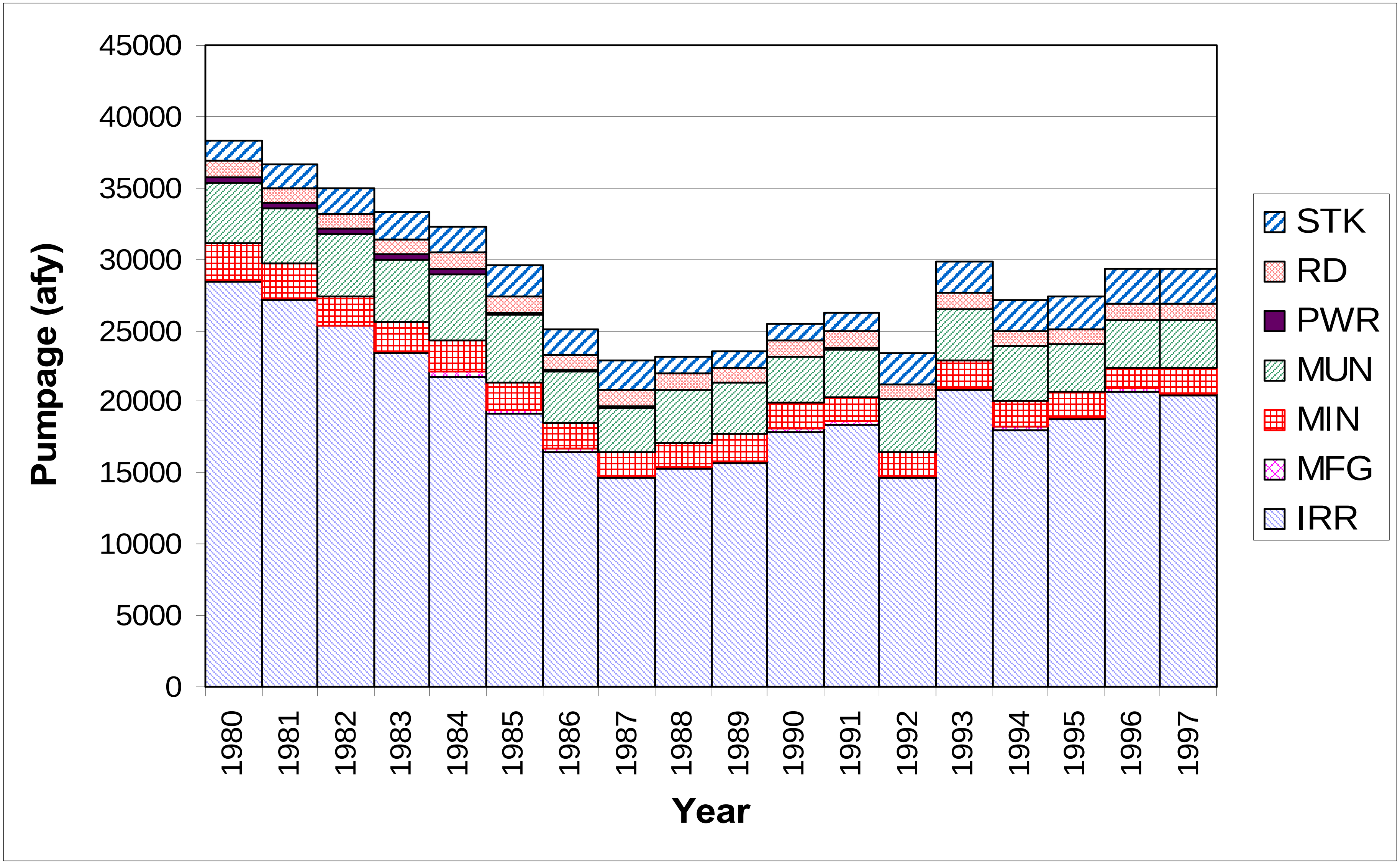


Pumping

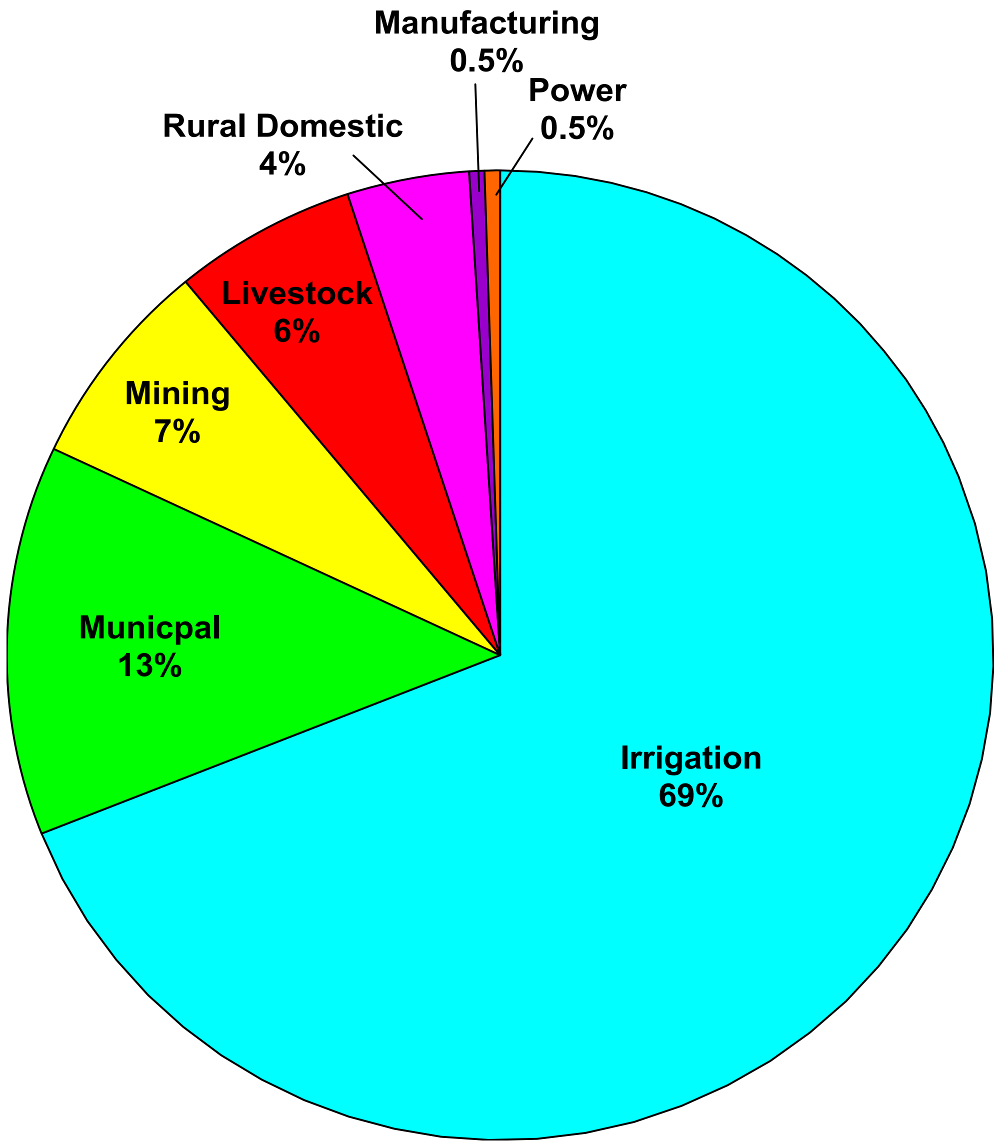
Transient Period (1980-1997)

- Irrigation, manufacturing, mining, municipal, power, and stock pumping summed by county from Pumpamatic Master Pumping tables from the TWDB
- Rural domestic pumping was calculated by county from 1990 census block population data

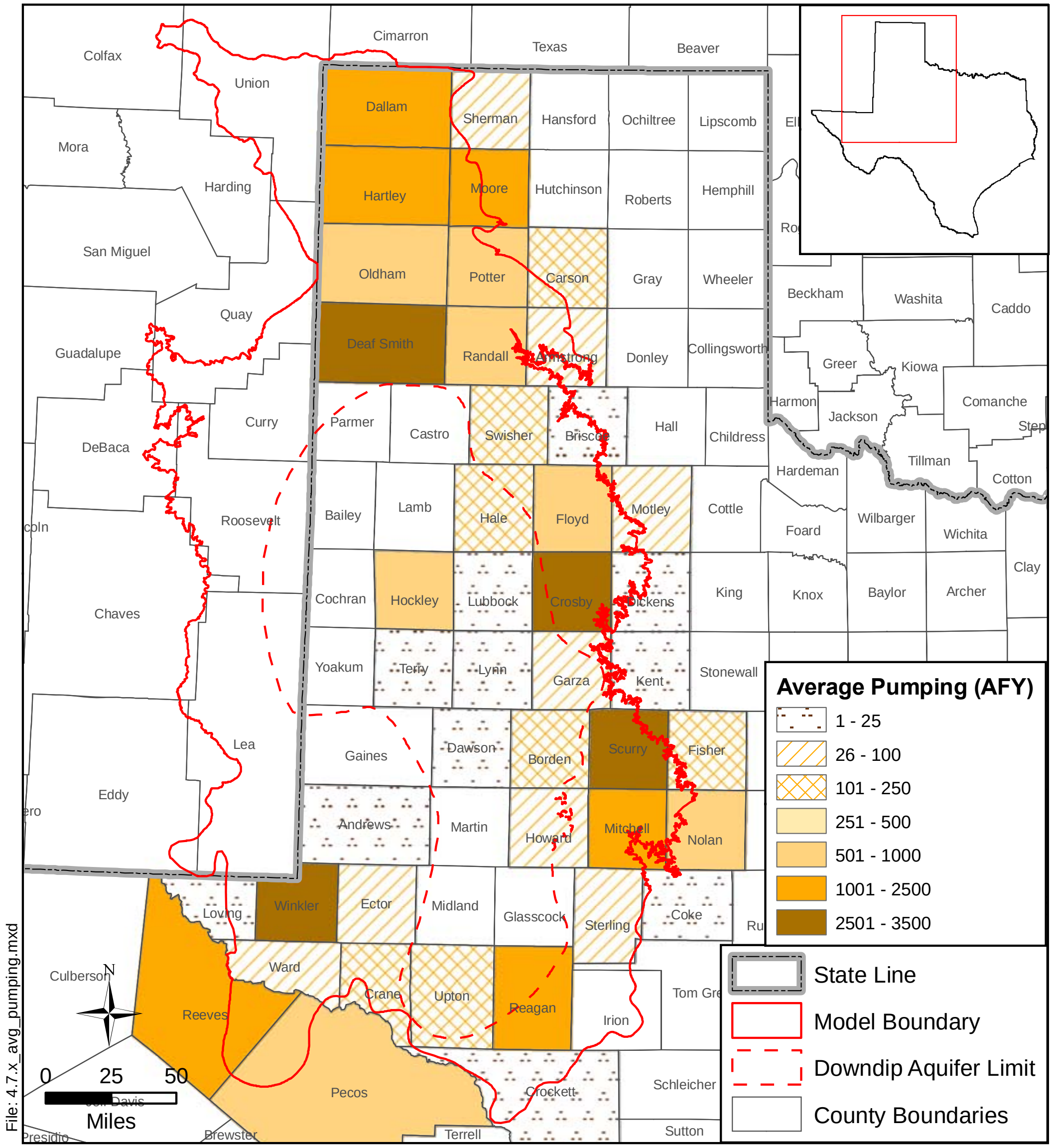
1980 – 1997 Pumpage



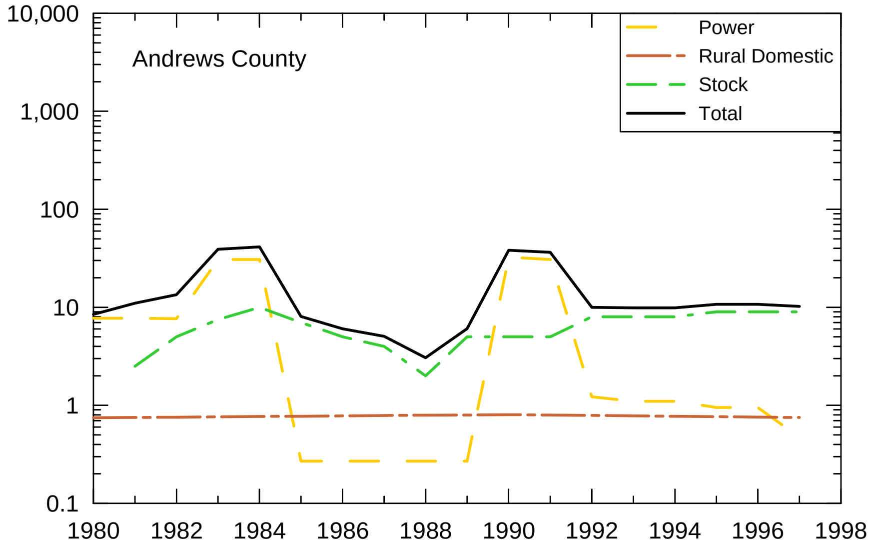
Uses of Water (1980 – 1997 Average)

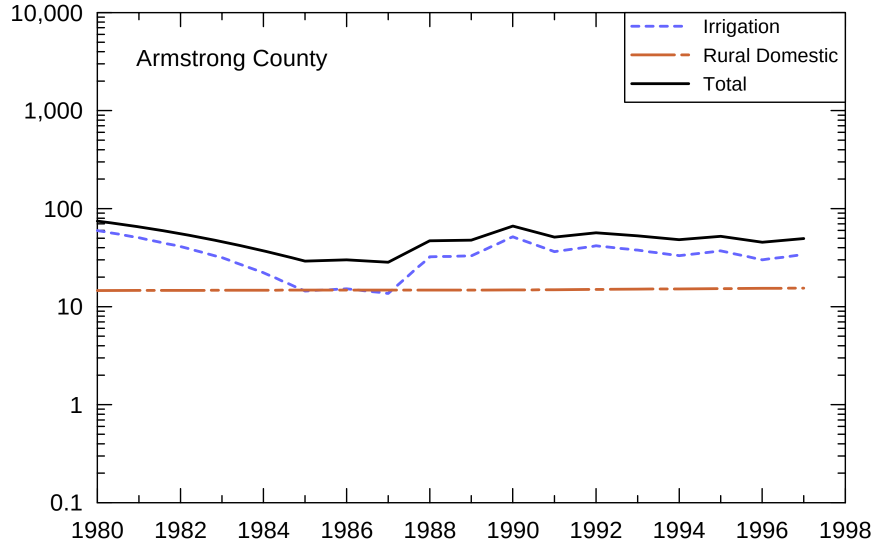


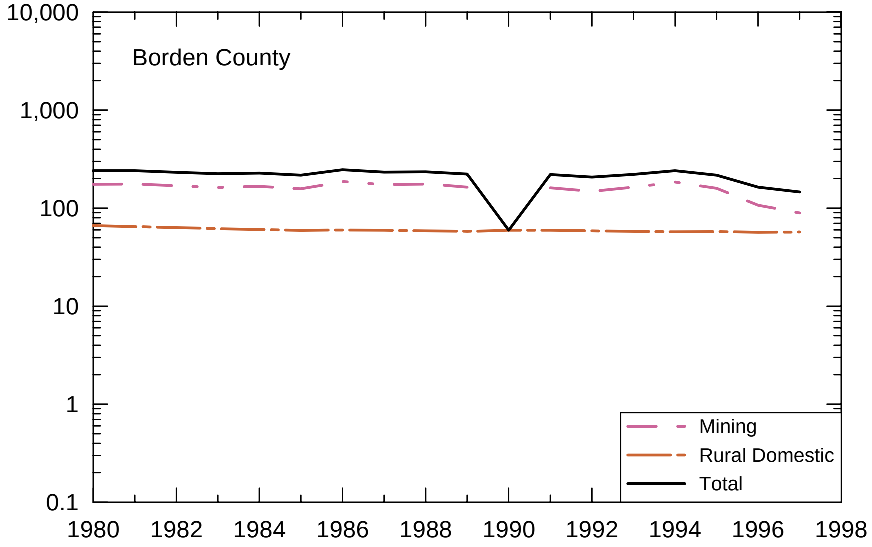
1980 – 1997 Average Pumpage

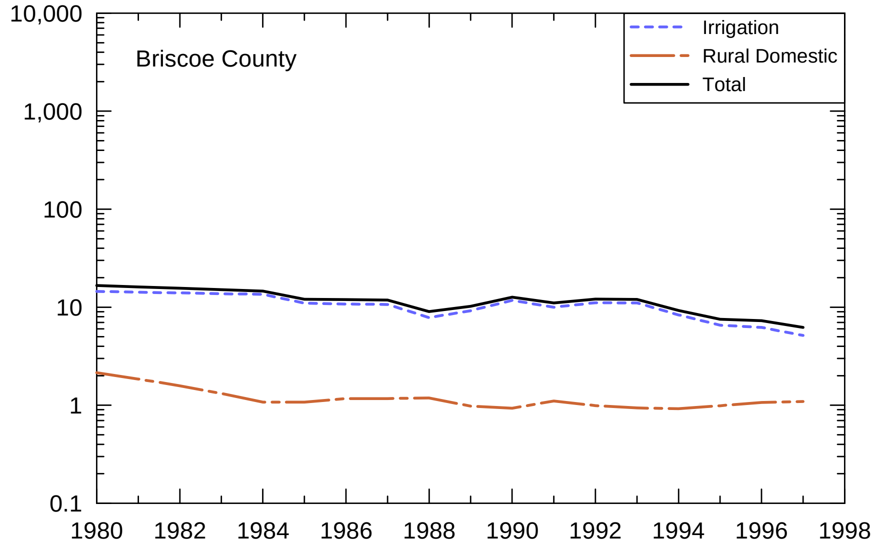


County Pumping

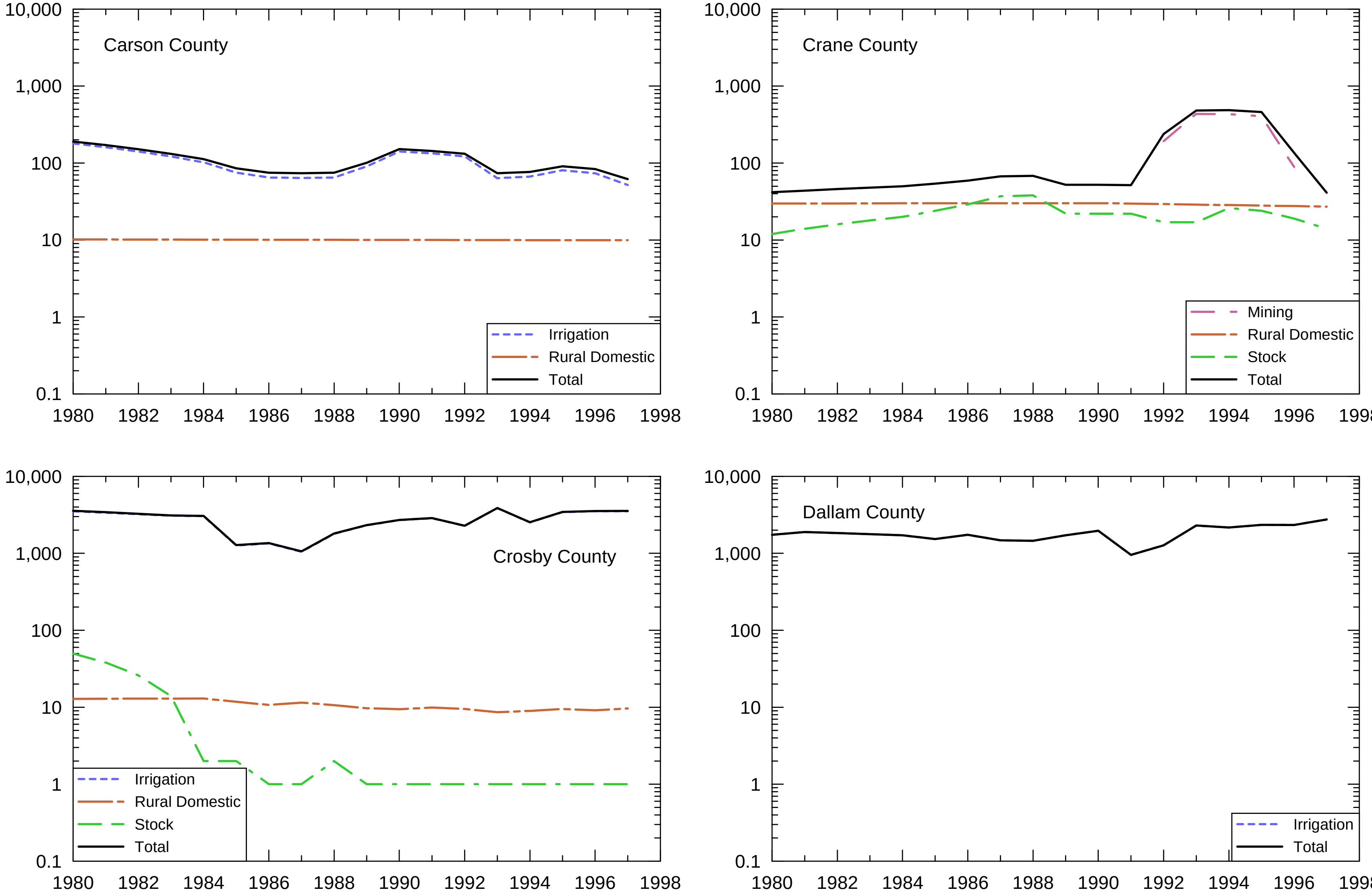




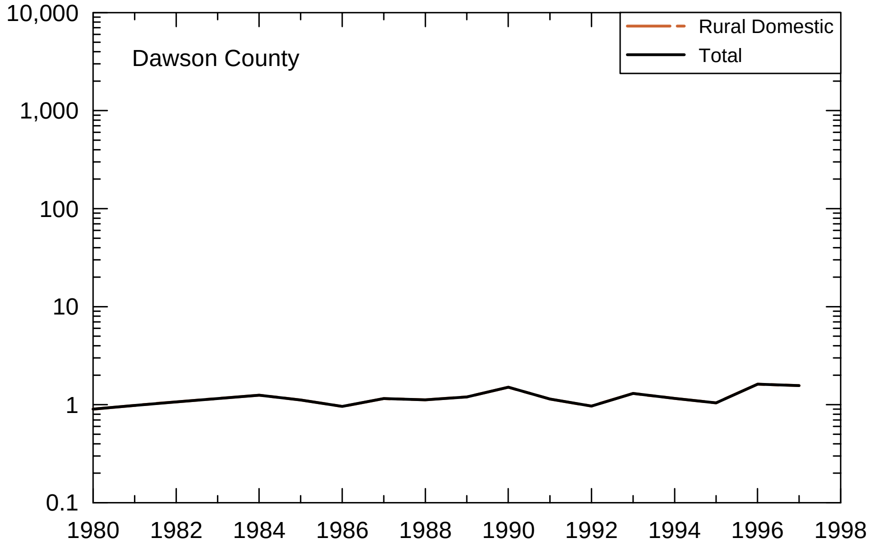


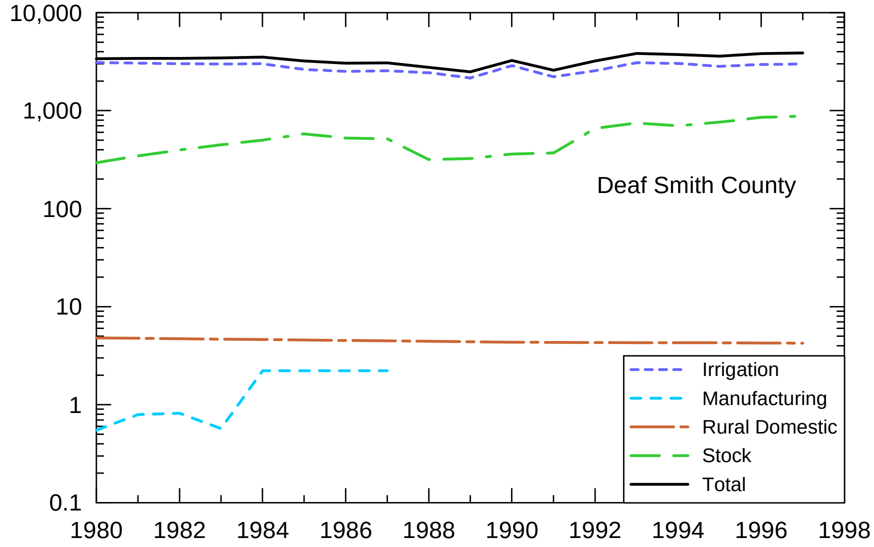


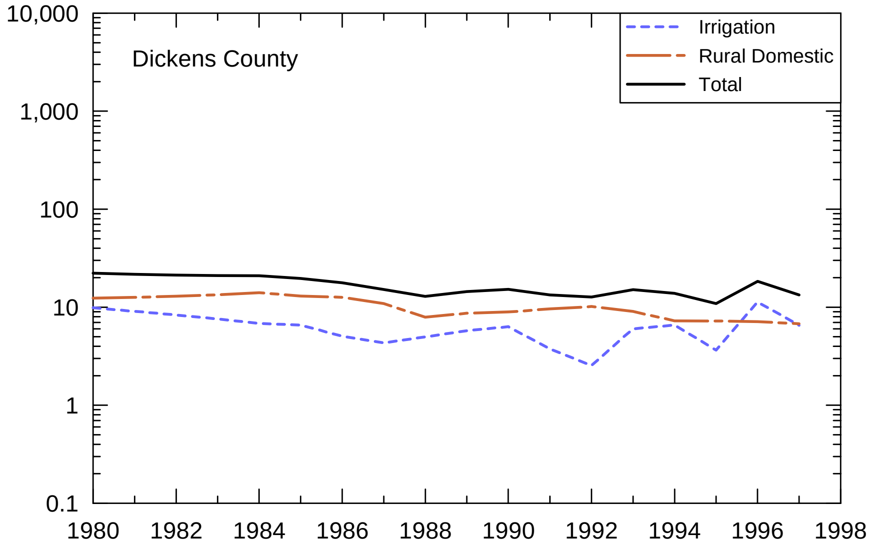
County Pumping

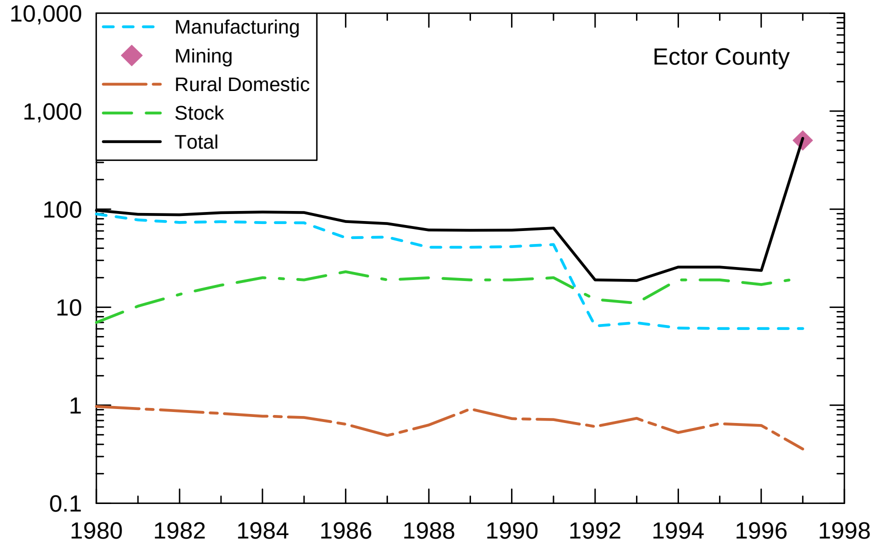


County Pumping

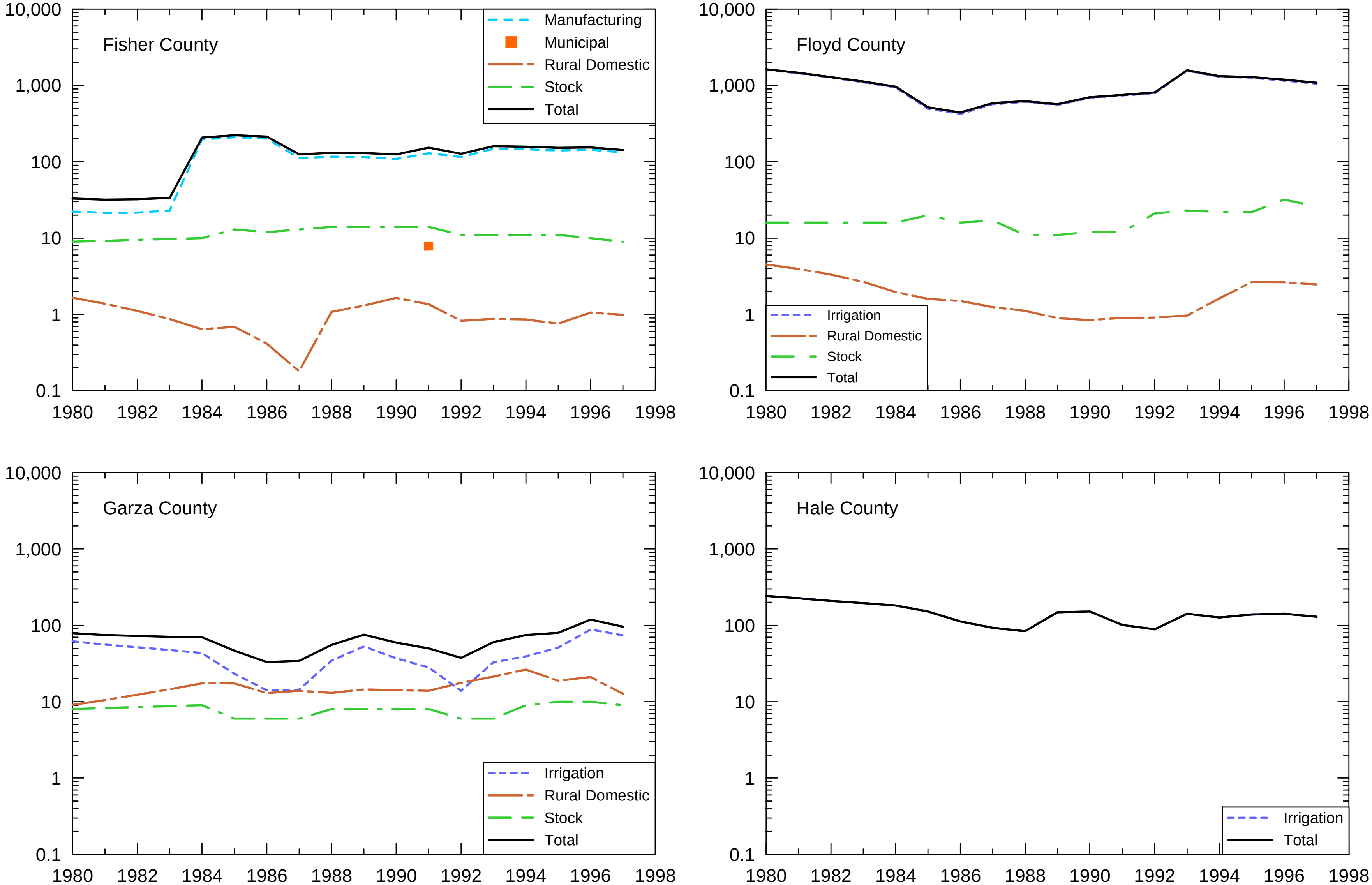




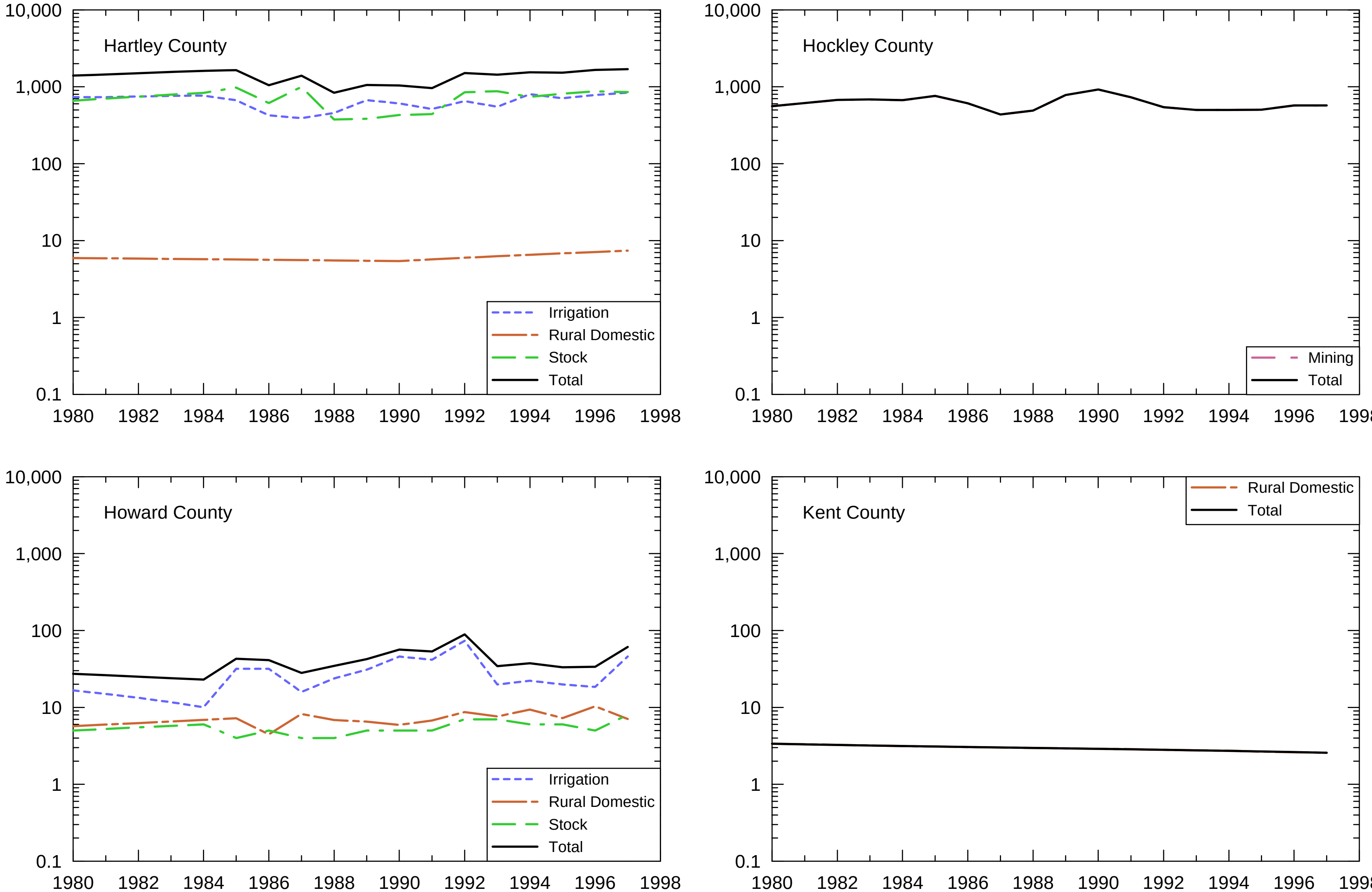




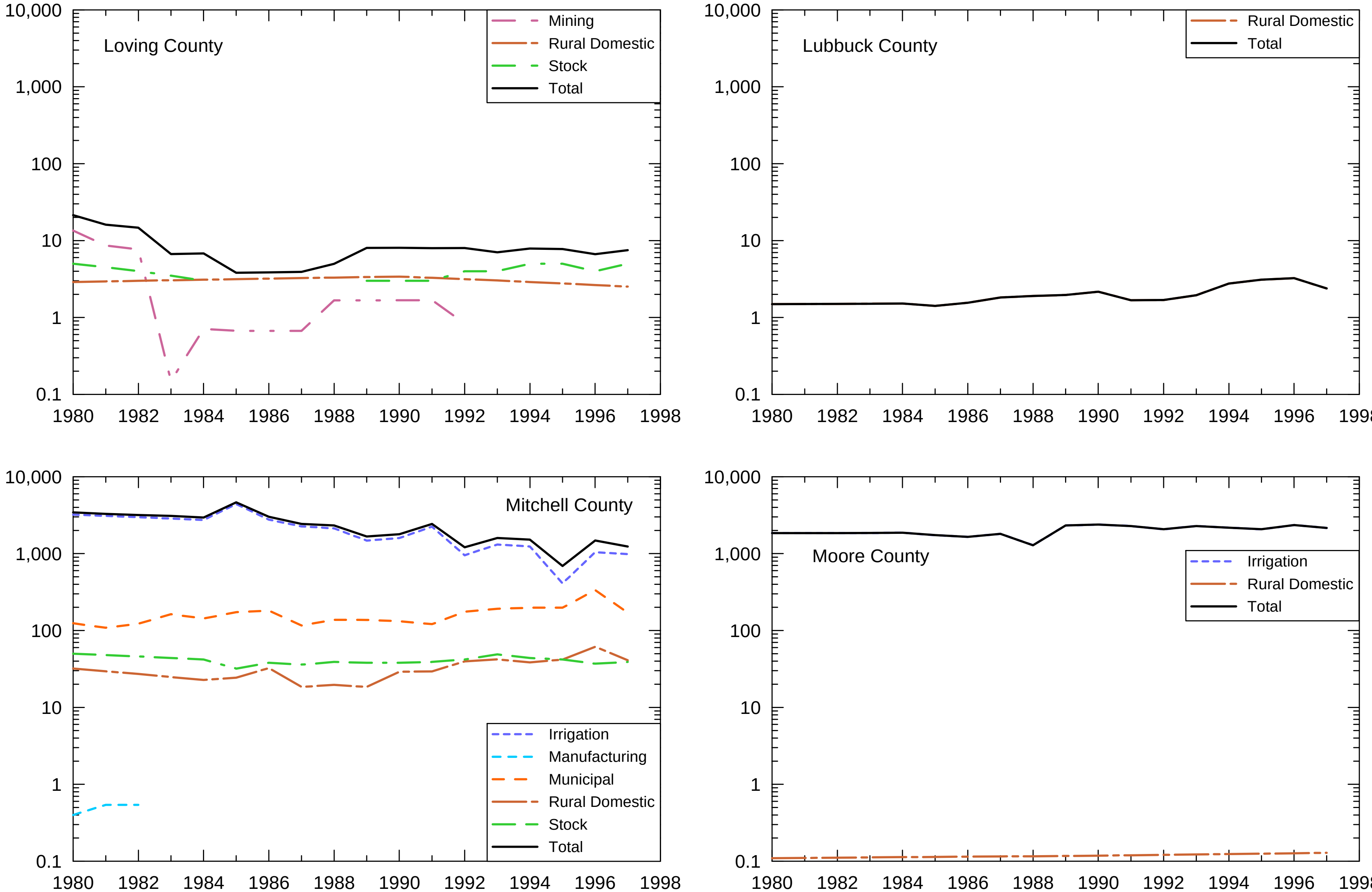
County Pumping



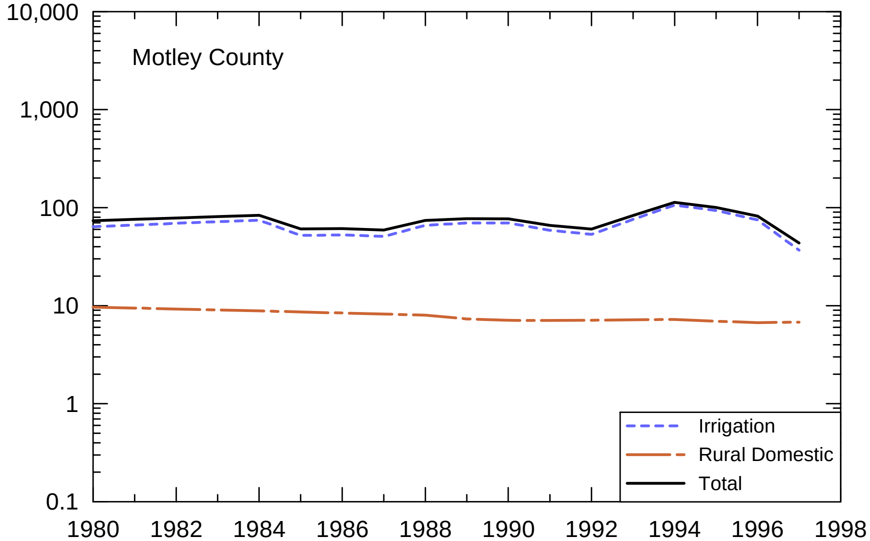
County Pumping

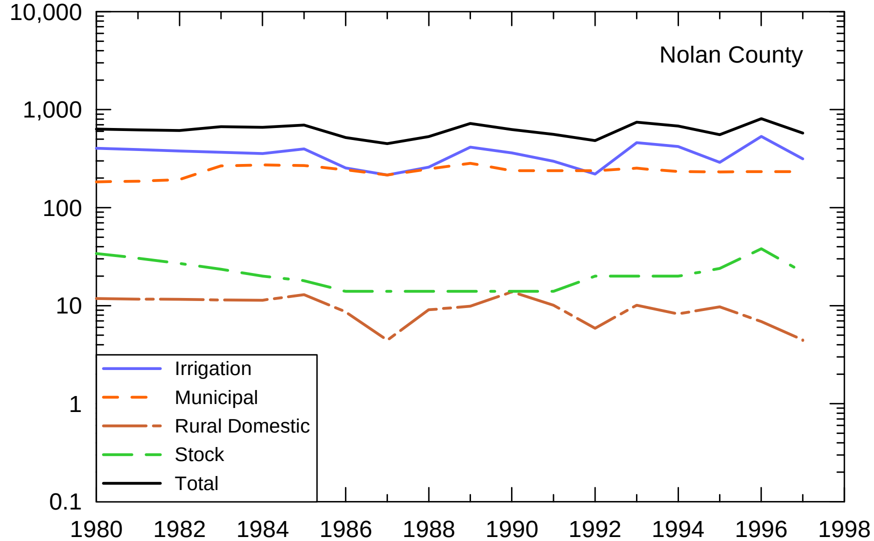


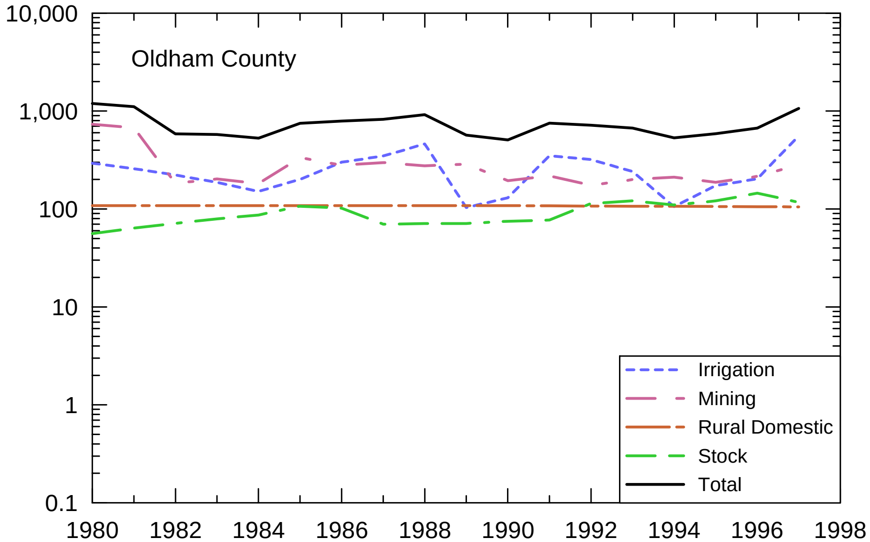
County Pumping

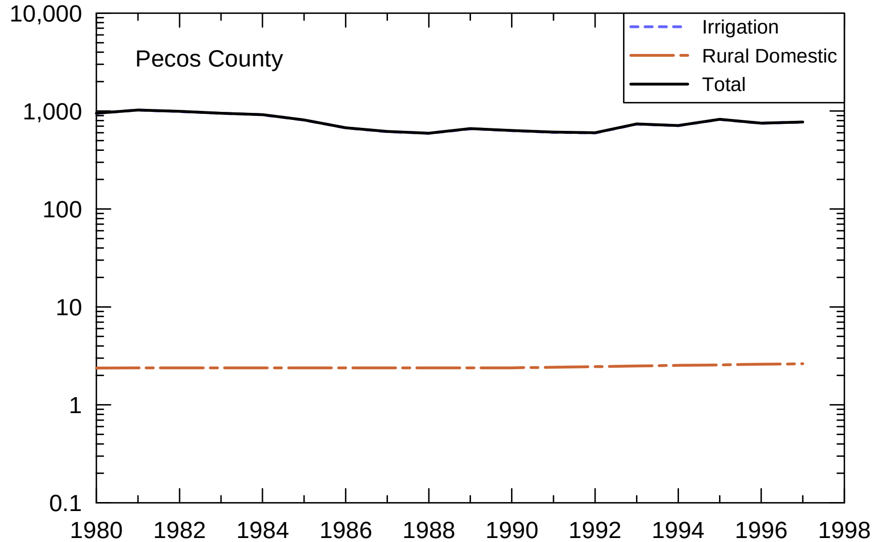


County Pumping

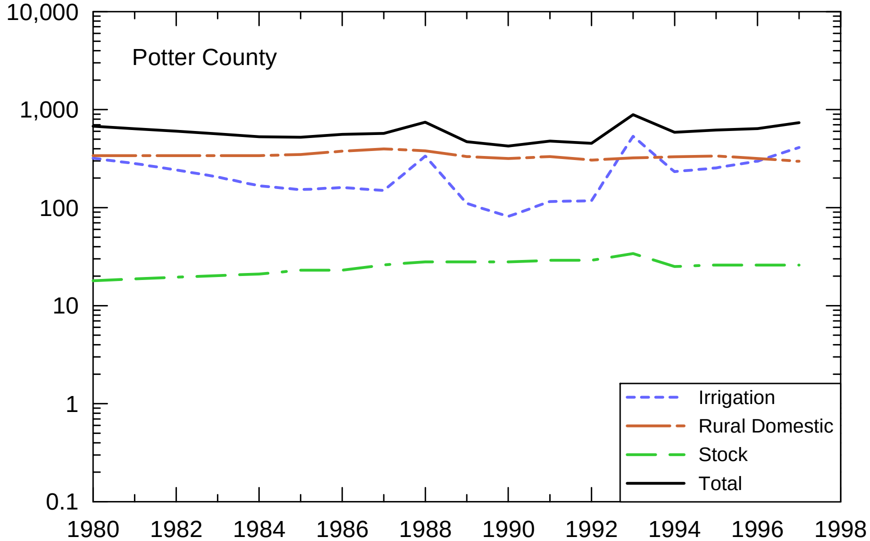


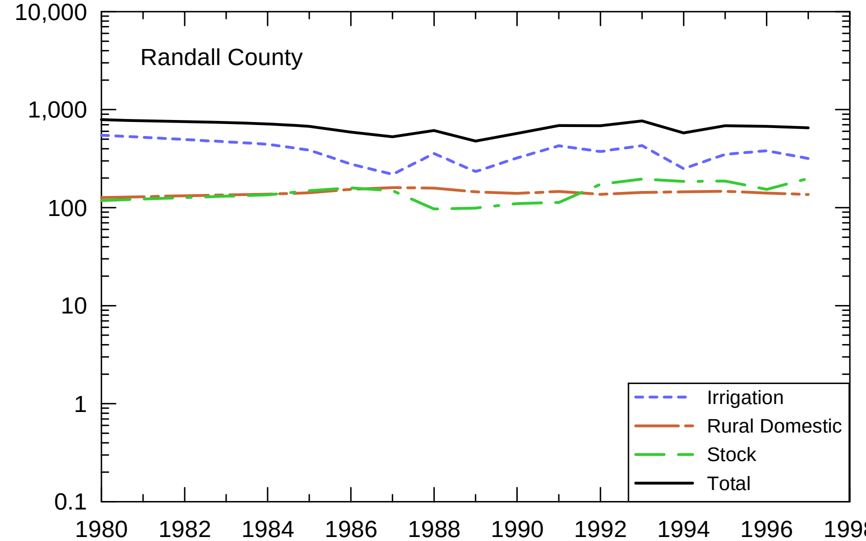


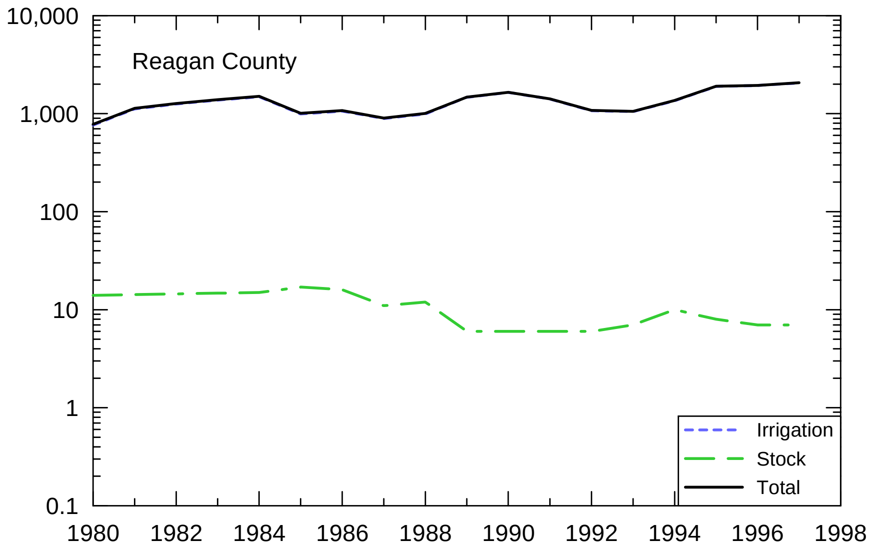


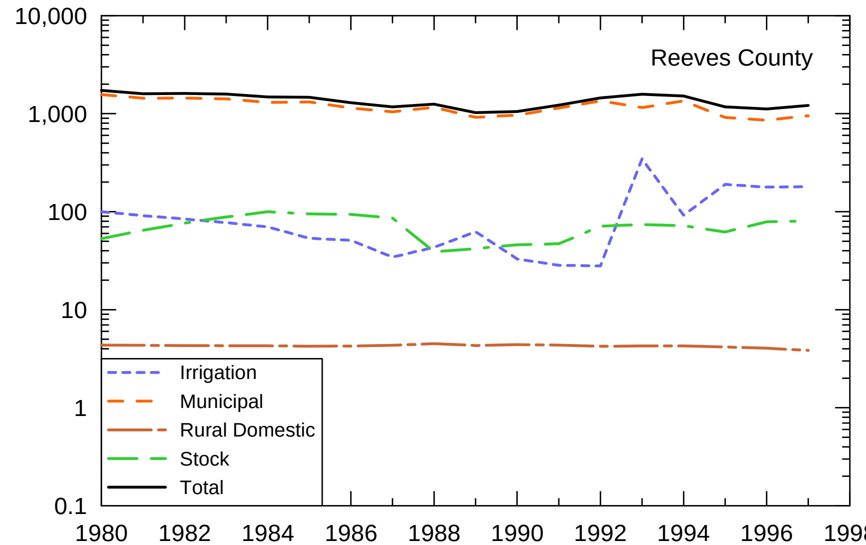


County Pumping

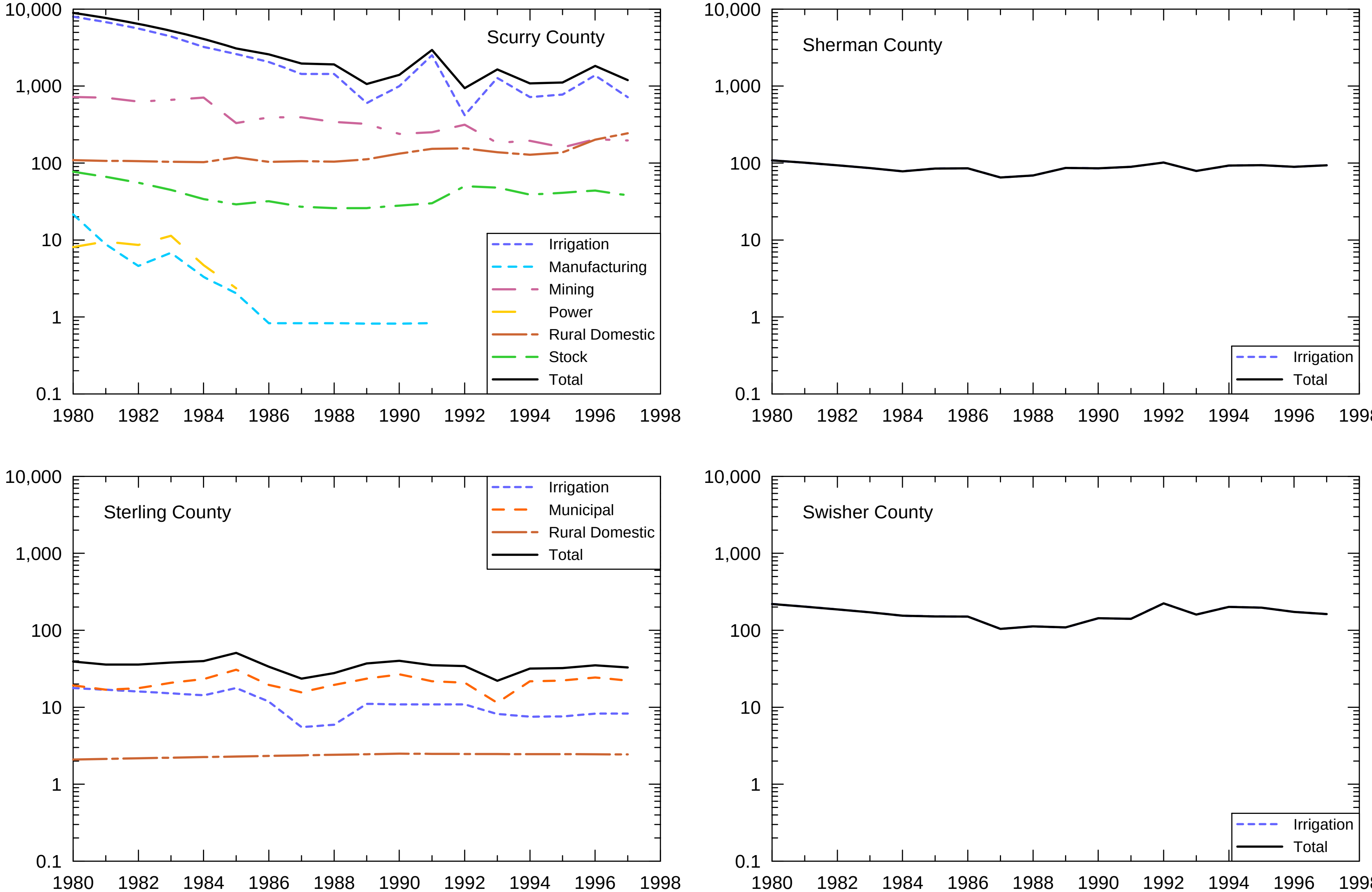




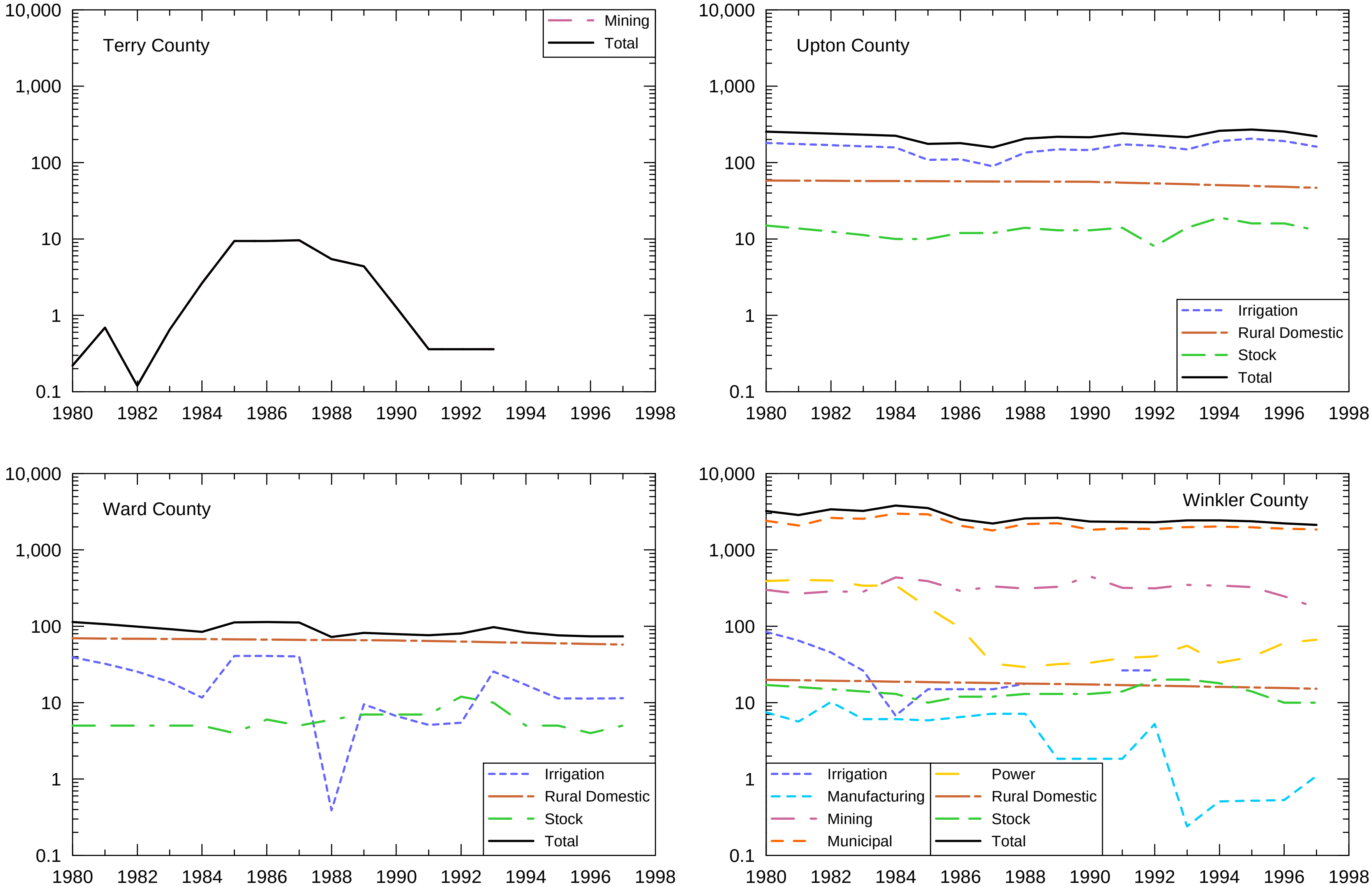




County Pumping



County Pumping

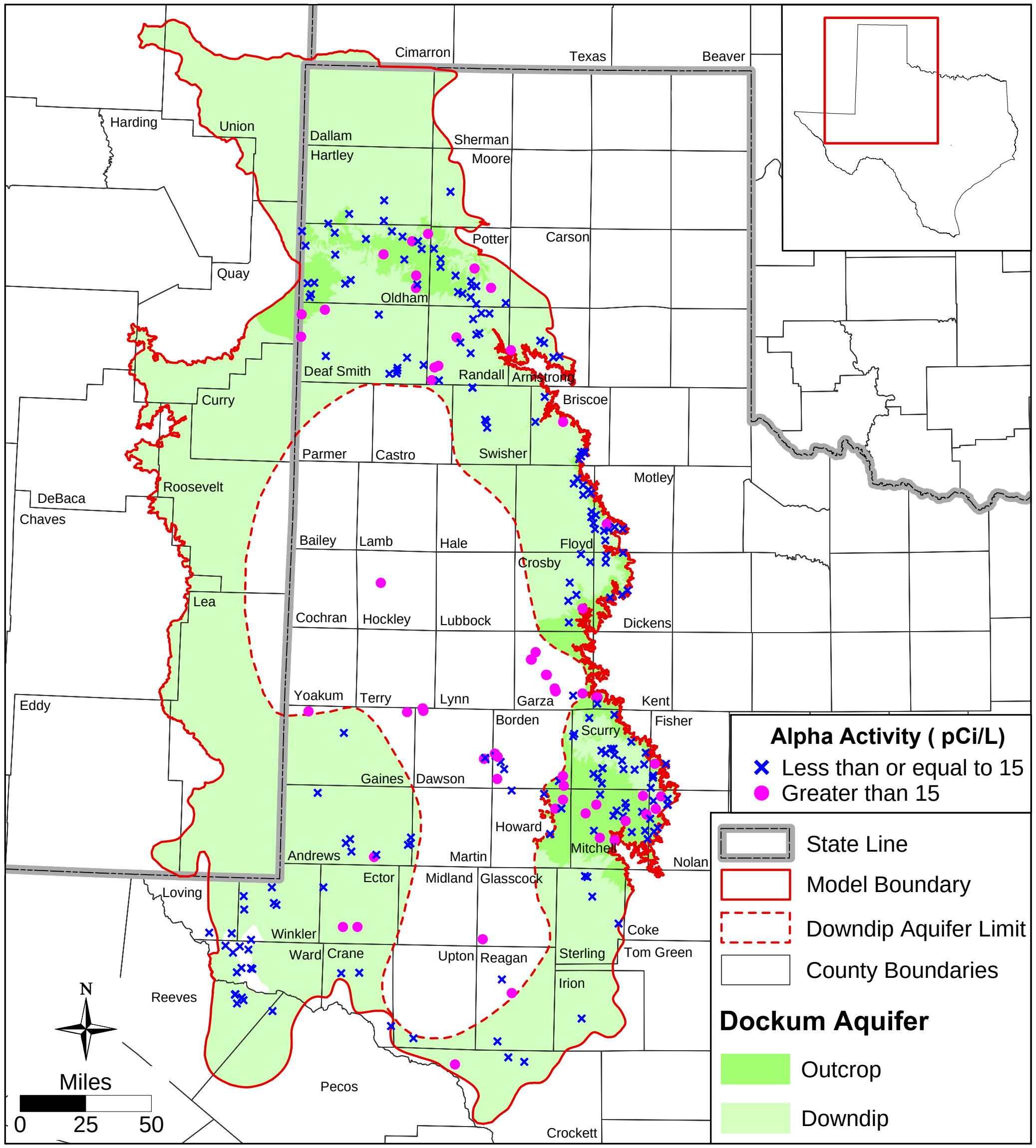


Groundwater Quality

Selected Primary MCLs

Water Quality Constituent	Wells Monitored	Screening Level	Wells > S.L.
Alpha Activity	262	15 pCi/L	20%
Arsenic	305	10 µg/L	4%
Fluoride	840	4 mg/L	4%
Mercury	198	2 µg/L	2%
Nitrate (as Nitrogen)	896	10 mg/L	1.3%
Selenium	305	50 µg/L	5%

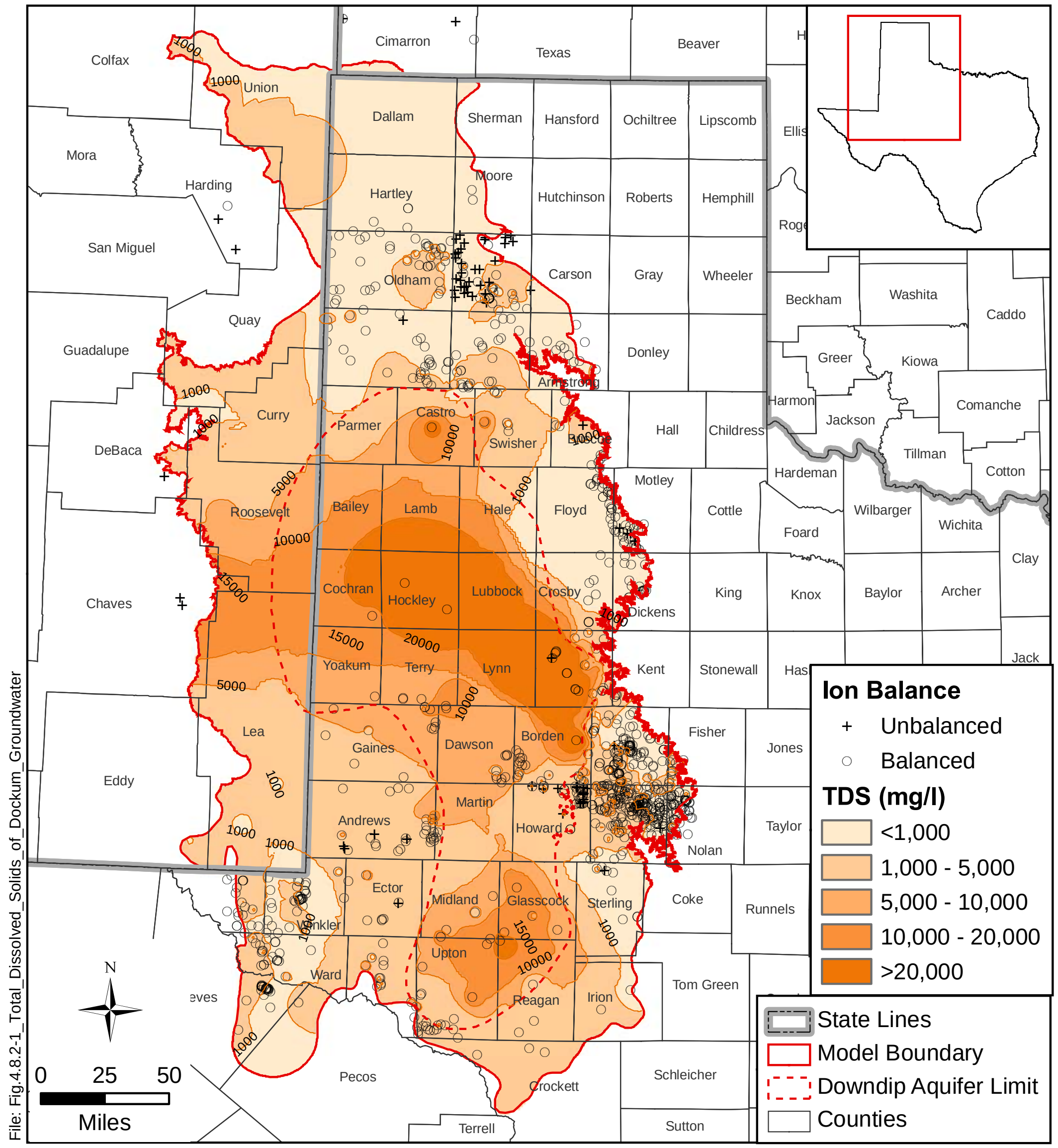
Alpha Activity



Selected Secondary MCLs

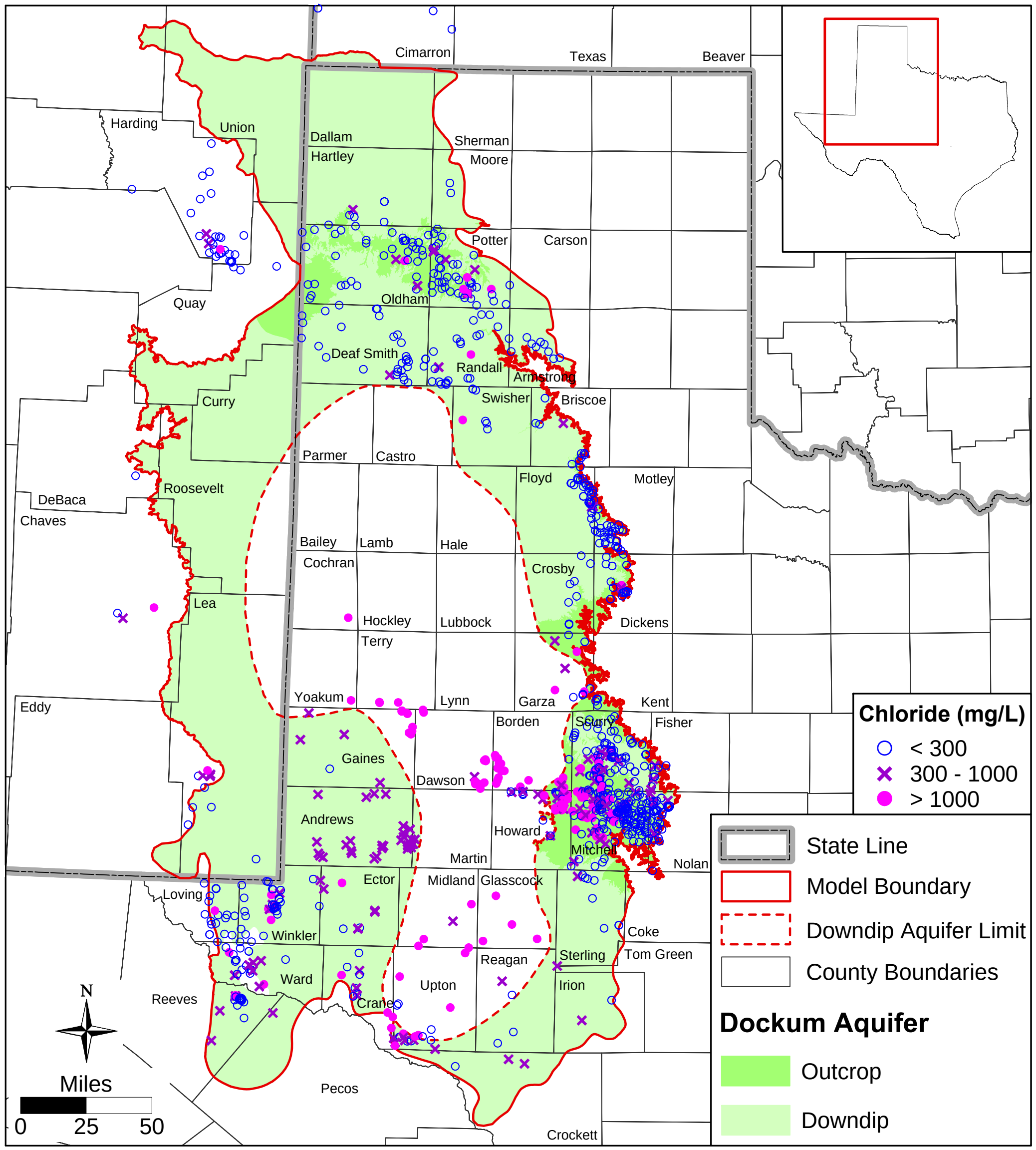
Water Quality Constituent	Wells Monitored	Screening Level	Wells > S.L.
Total Dissolved Solids	959	1000 mg/L	43%
Chloride	1000	300 mg/L	30%
Fluoride	840	2 mg/L	30%
Iron	337	300 µg/L	27%
Manganese	328	50 µg/L	16%
Sulfate	1000	300 mg/L	41%
Aluminum	133	0.2 mg/L	1.5%

Total Dissolved Solids



Source: TWDB, Panhandle GCD; USGS/New Mexico; Hart et al. (1976)

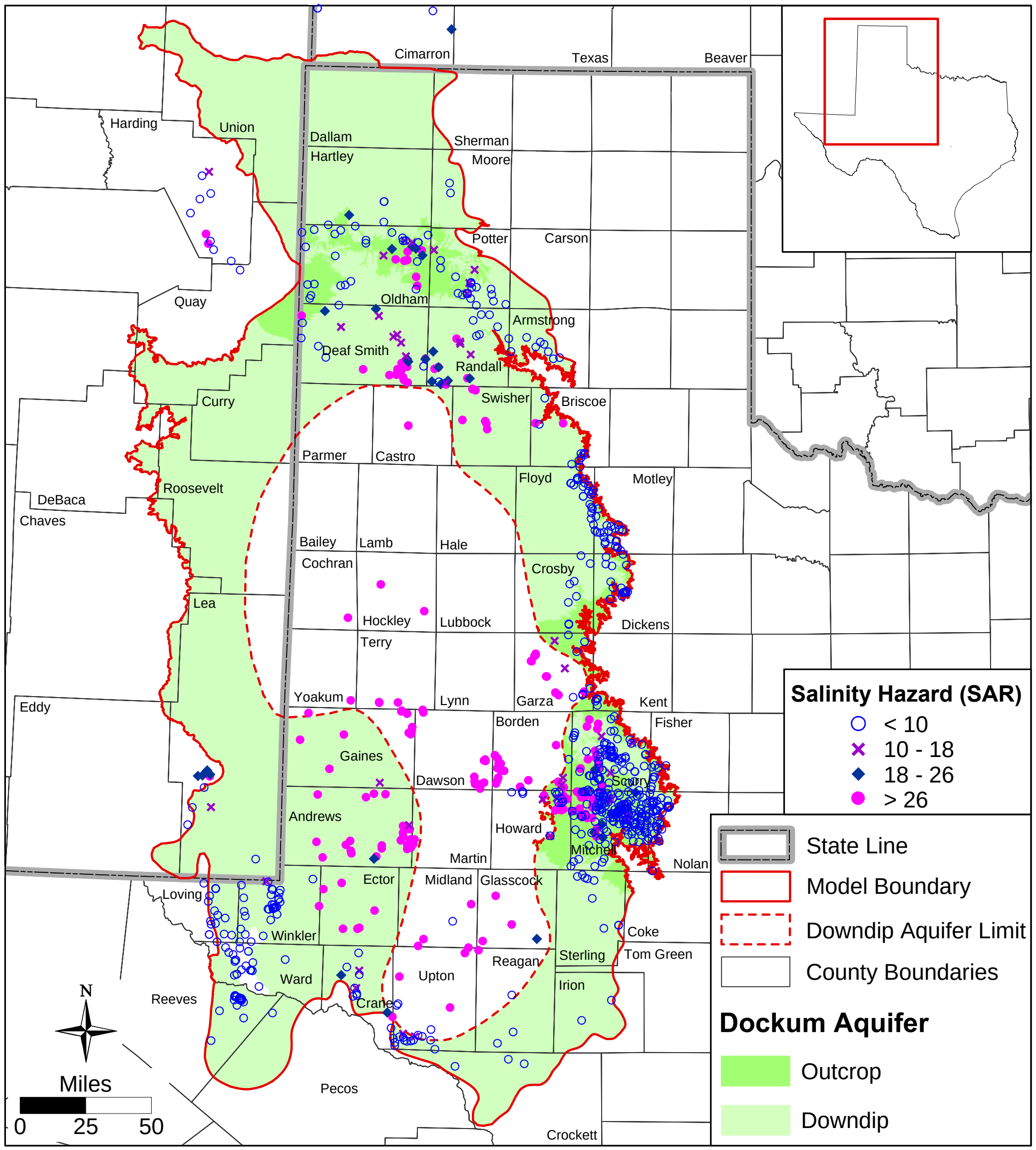
Chloride


Cimarron
Texas
Beaver
Harding
Union
Dallam
Hartley
Sherman
Moore
Potter
Carson
Quay
Oldham
Deaf Smith
Randall
Armstrong
Curry
Swisher
Briscoe
Parmer
Castro
Floyd
Motley
Roosevelt
DeBaca
Chaves
Bailey
Lamb
Hale
Cochran
Crosby
Lea
Hockley
Lubbock
Dickens
Terry
Yoakum
Lynn
Garza
Kent
Eddy
Borden
Scurry
Fisher
Gaines
Dawson
Andrews
Howard
Mitchell
Martin
Nolan
Loving
Ector
Midland
Glasscock
Winkler
Coke
Reagan
Sterling
Tom Green
Ward
Upton
Irion
Reeves
Crane
Pecos
Crockett
N
Miles
0 25 50
Chloride (mg/L)
< 300
300 - 1000
> 1000
State Line
Model Boundary
Downdip Aquifer Limit
County Boundaries
Dockum Aquifer
Outcrop
Downdip

Irrigation Screening Levels

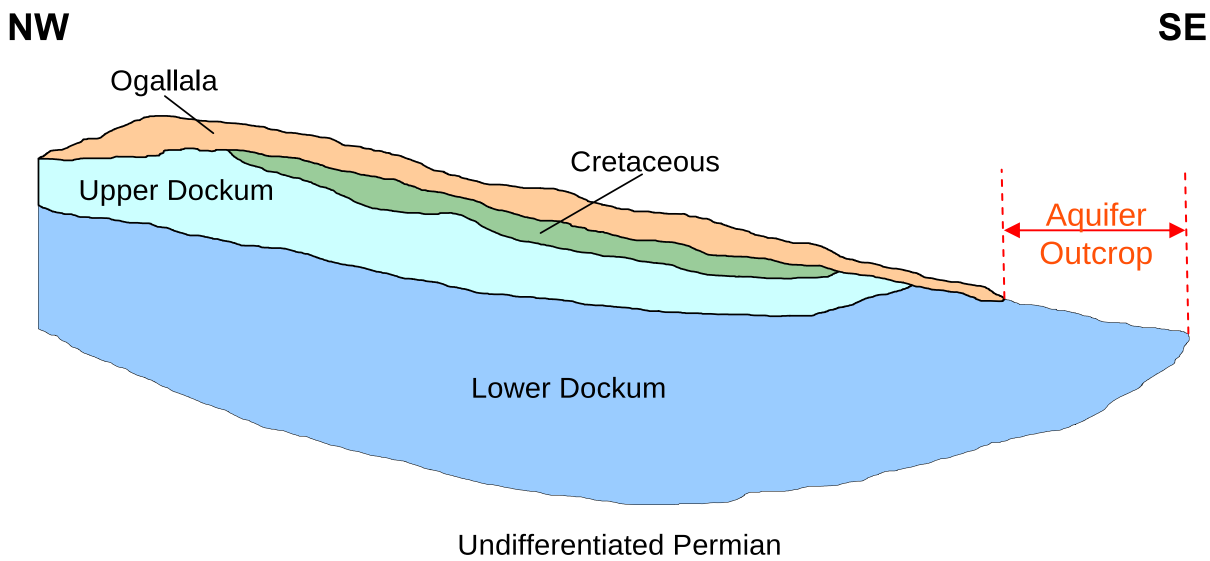
Water Quality Constituent	Wells Monitored	Screening Level	Wells > S.L.
Salinity Hazard	848	High	75%
		Very High	33%
Sodium Hazard	902	High	3%
		Very High	21%
Boron	400	2 mg/L	3%
		0.75 mg/L	25%
Chloride	1000	1000 mg/L	15%

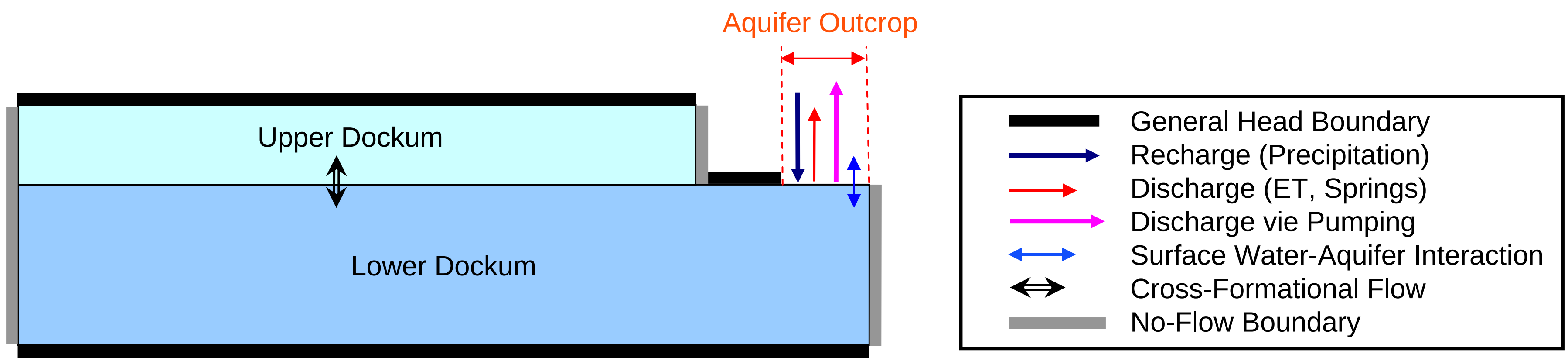
Sodium Hazard (SAR)



Conceptualization of Groundwater Flow

Conceptualization of Groundwater Flow





Conceptualization of Groundwater Flow

- Outcrop Areas
  - Recharge by precipitation and stream loss
  - Discharges to springs and streams and by ET
- Subcrop with TDS < 5,000 mg/L
  - Portion of Dockum Group defined as an aquifer
  - Only lower Dockum present
  - Fresh water enters via cross-formational flow from overlying Ogallala and Pecos Valley aquifers
  - Flow is towards the Canadian River in the northern portion of the model area
  - Flow is towards the southeast along the eastern side of the model area and discharge to springs or overlying formations

Conceptualization of Groundwater Flow

- Subcrop with TDS < 5,000 mg/L (cont)
  - Flow is likely towards the trough in southwestern portion of model area
  - Flow is likely into the Permian in the southeastern portion of the model area
- Subcrop with TDS > 5,000 mg/L
  - Correspond to the portion of the Dockum Group not defined as an aquifer
  - Upper and lower Dockum present
  - Little movement of groundwater into or out of the deeper parts of the depositional basin

Conceptualization of Groundwater Flow

Subcrop with TDS > 5,000 mg/L (cont)

- No or insignificant displacement of the original groundwater by fresh water from precipitation recharge
- Connate water from recharge in eastern New Mexico prior to Pleistocene time when Pecos River valley was eroded
- Movement of water out of the deeper parts of the basin is restricted by the high fluid density of the groundwater
- Very little cross-formational flow from overlying aquifers due to the high mudstone content in the upper Dockum

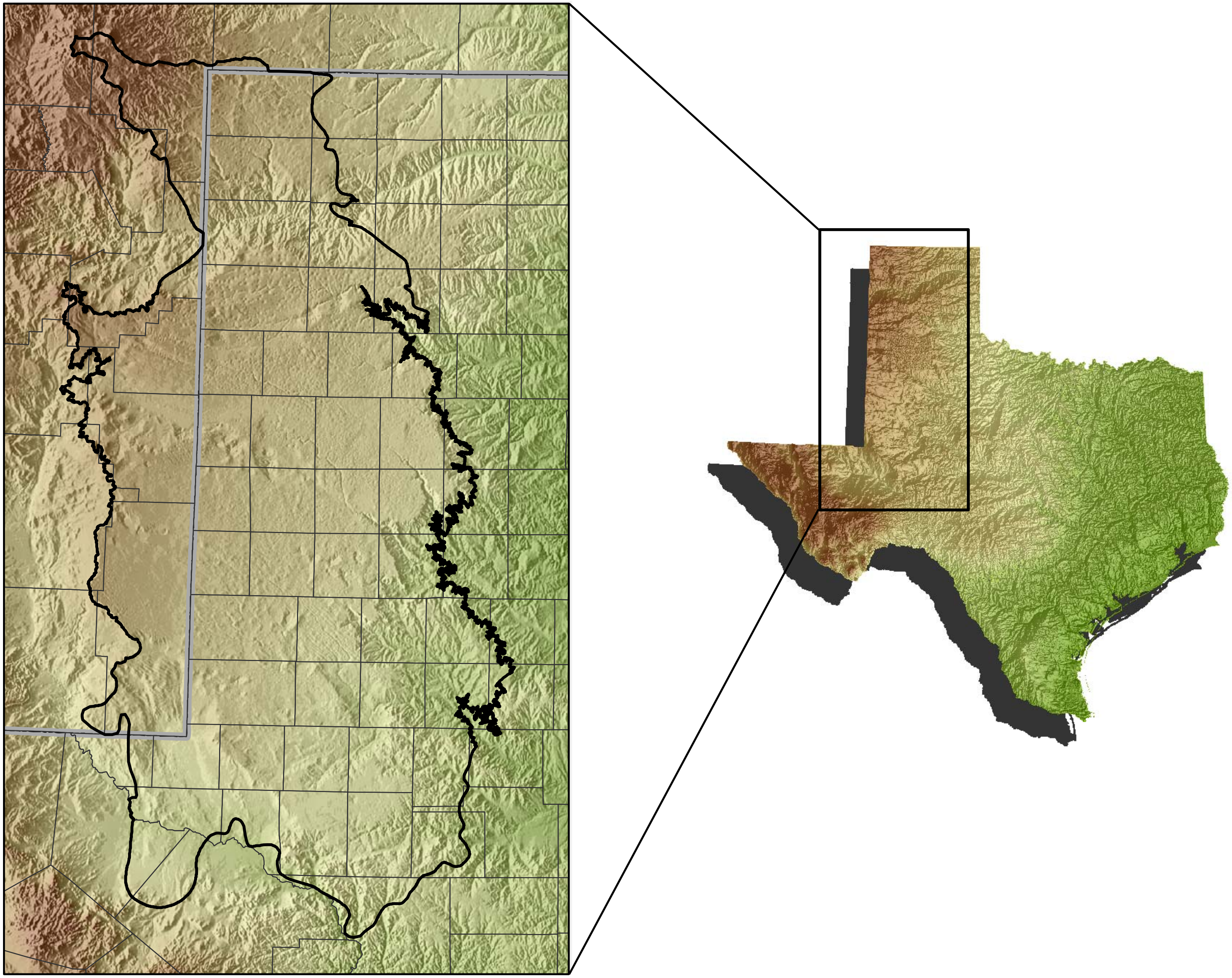
Future Work and Schedule

Numerical Model

- Develop model inputs
- Calibrate model to predevelopment conditions
- Calibrate model to transient (1980 – 1997) conditions
- Perform parameter sensitivity analysis

Dockum GAM Schedule

- Project start – May 2006
- SAF 1 – July 2006
- Draft Conceptual Model Report – May 2007
- SAF 2 – June 2007
- Steady-state & transient model calibration – April 2008
- SAF 3 – May 2008
- Draft final model report – June 2008
- Model training seminar – August 2008
- Final model report – October 2008



Dockum Aquifer GAM
2nd Stakeholder Advisory Forum
June 7, 2007
Lubbock, Texas

Name	Affiliation
Melanie Barnes	League of Women Voters
Ray Brady	
Ken Carver	Permian Basin UWCD
Jason Coleman	South Plains UWCD
Steve Coneway	City of Hereford
Jim Conkwright	High Plains UWCD
Amy Crowell	Panhandle GCD
Harvey Everheart	Mesa UWCD
Kathleen Garrett	TWDB
Kevin S. Hopson	DBS&A
Peggy Hunka	TCEQ
Ian Jones	TWDB
Toya Jones	INTERA Inc.
Mike McGregor	Llano Estacado UWCD
John Pickens	INTERA Inc.
Becky Stewart	Wes-Tex GCD
Gilbert Van Deventer	Trident Environmental
Ben Weinheimer	TCFA
Sue Young	Lone Wolf GCD

Dockum Aquifer GAM
2nd Stakeholder Advisory Forum
Comments and Responses
June 7, 2007
Lubbock, Texas

Questions and Answers:

Q. Is there enough data to define the 5,000 mg/L TDS boundary?
A. Yes. While data is limited or not available in some counties, there is generally sufficient data coverage to allow defining the 5,000 mg/L TDS boundary.

Q. Are the most recent references used for the Dockum boundary? There has been recent work done by students of Thomas Lehman (Texas Tech Univ.)
A. The Dockum geology is based on TWDB aquifer boundary.

Q. Is the entire thickness of the Dockum saturated?
A. Yes, except in the outcrop where the aquifer is unconfined.

Q. What data will be used for calibration?
A. Steady-state calibration will use the best estimate of conditions prior to significant aquifer development. Transient calibration will use time period from 1980 through 1997.

Q. Dual-completion wells not allowed (state law).
A. May be old wells

Q. Don't the GCDs have data for locations with sparse information?
A. Generally no because the Ogallala is the primary aquifer of interested for most of the GCDs. Also, some GCDs are newly formed so they do not have information for the time periods that will be considered by the modeling. The majority of the GCDs were contacted in an attempt to get water level and hydraulic property data for the Dockum aquifer.

Q. How can we have different water levels in the upper and lower Dockum?
A. They are defined as separate hydrogeologic systems for the Dockum GAM.

Q. Is 1980 a legitimate starting point for the transient calibration period?
A. The model run will start earlier (e.g., in the 1950s) before proceeding to the 1980-1997 calibration period.

Q. How many GCDs are in the study area?
A. About 20.

Q. Why is the model calibrated to 1980-1997?
A. This meets the GAM standards. The TWDB has the greatest confidence in pumping data from this period.

Q. Will the model results cover the whole Dockum including the high TDS zone?
A. Yes.

Q. Will the final model report have groundwater availability by county?
A. No, the final model report will give a water budget for the entire aquifer. Future users of the model can use it to estimate groundwater availability for selected regions.

Q. Is there pumping from the upper Dockum
A. Yes.

Q. What will be grid size be for the Dockum GAM?
A. No larger than one square mile. The grid for the Dockum GAM will have the same size, orientation, and reference location as the grid used for the southern Ogallala GAM.

Q. What was used to determine whether a well is located in the upper or lower Dockum?
A. The well's screened interval, or total depth if no screen interval is available, were compared to the elevations of the top and bottom of the upper and lower Dockum to determine in which portion of the Dockum the well is completed.

Q. In looking at groundwater chemistry, was the chemical analysis method considered?
A. In general, specific information regarding the chemical analyses was not available.

Q. How was pumping determined?
A. Pumping was determined by the TWDB and is provided in their Pumpamatic Master Pumping tables and explained in TWDB GAM tech memo 06-01 located on the TWDB website. Note that the pumping presented at this SAF will be used in the modeling unless modifications are recommended by interested parties.

<u>Comments by Stakeholders:</u>

Pumping in Armstrong County is greater than the 25 AFY shown on the figure of average annual pumping by county

The portion of the pumping from the Dockum for wells that are dual completed to the Ogallala and Dockum is probably 75% Dockum rather than the 25% assumed.

The lack of Dockum wells in Dallam and Hartley counties is probably due to all wells being given an Ogallala designation even though they are probably completed to both the Ogallala and Dockum or to just the Dockum.

The presence of red sediments in the Dockum may have lead to confusion in aquifer designations because they have been misinterpreted as Permian redbeds.