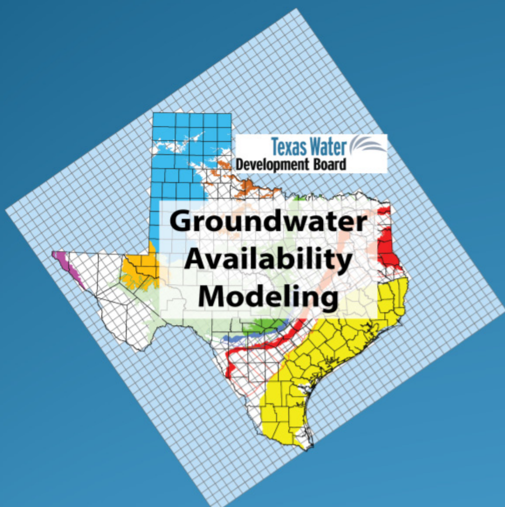
Capitan Reef Complex Aquifer GAM Stakeholder Advisory Forum Number 1



Fort Stockton, Texas

October 25, 2012

Ian C. Jones, Ph.D., P.G.

Texas Water Development Board

Outline

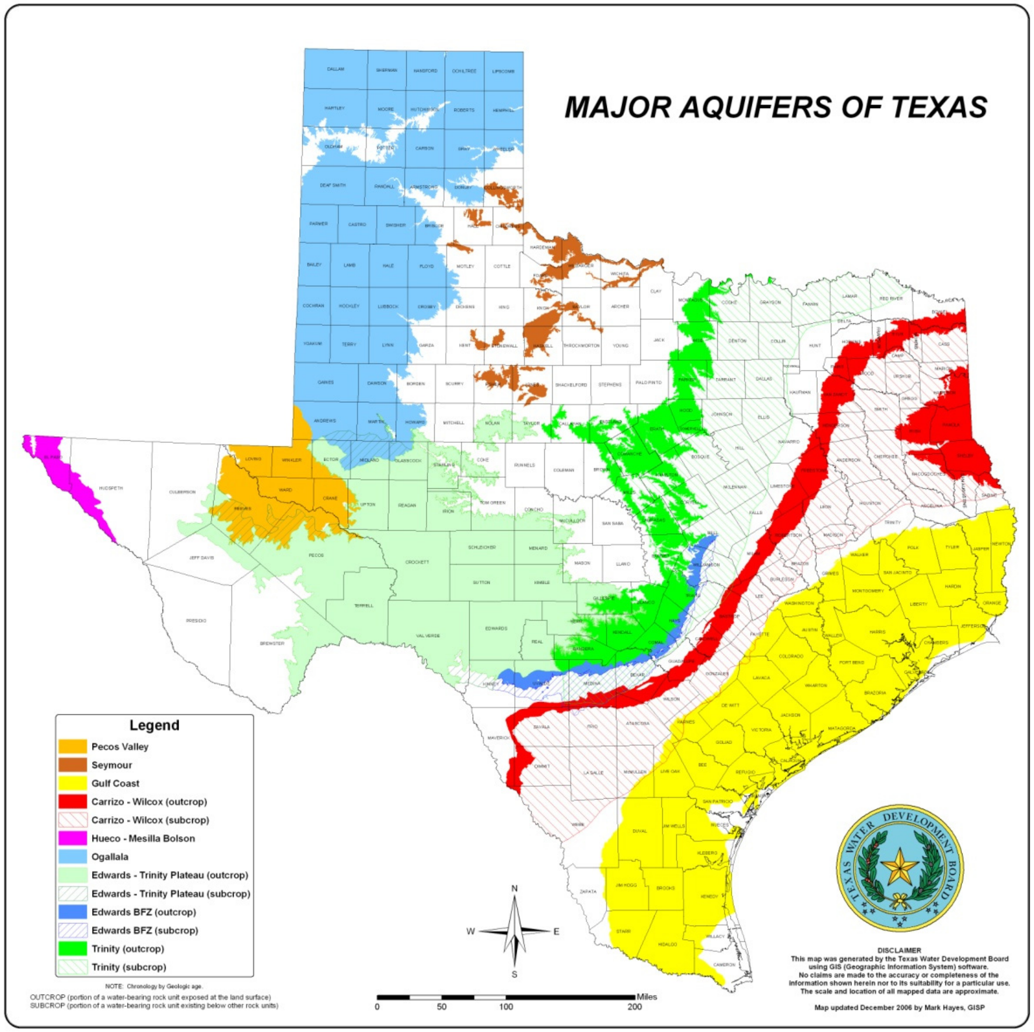
- Introduction
- Regional overview
- Basics of groundwater flow
- Overview of Capitan Reef Complex Aquifer
- Groundwater modeling
- Data collection
- Project schedule

INTRODUCTION

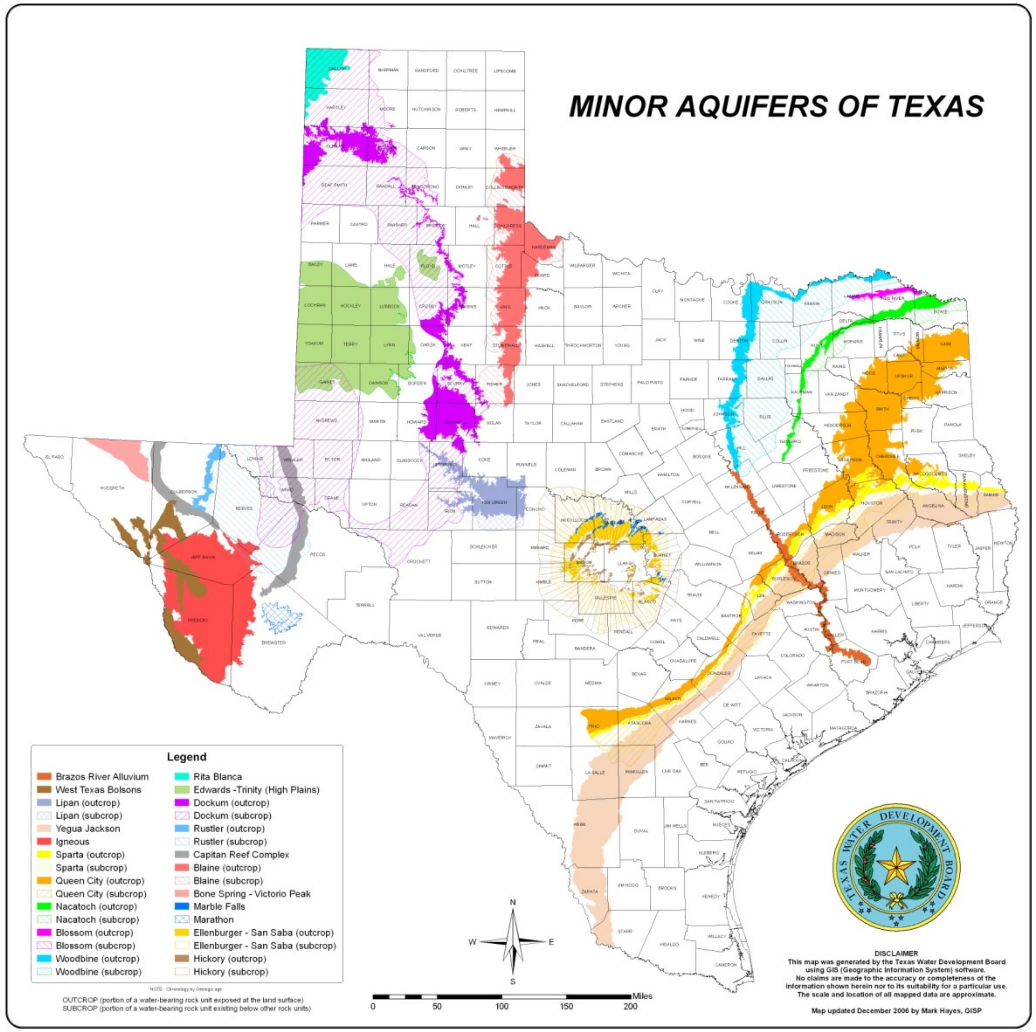
Groundwater Availability Modeling Program

- **Aim**: Develop groundwater flow models for the major and minor aquifer of Texas.
- **Purpose**: Tools that can be used to aid in groundwater resources management by stakeholders.
- **Public process**: Stakeholder involvement during model development process.
- **Models**: Freely available, standardized, thoroughly documented. Reports available over the internet.
- **Living tools**: Periodically updated.

Major Aquifers



Minor Aquifers



How we use Groundwater Models?

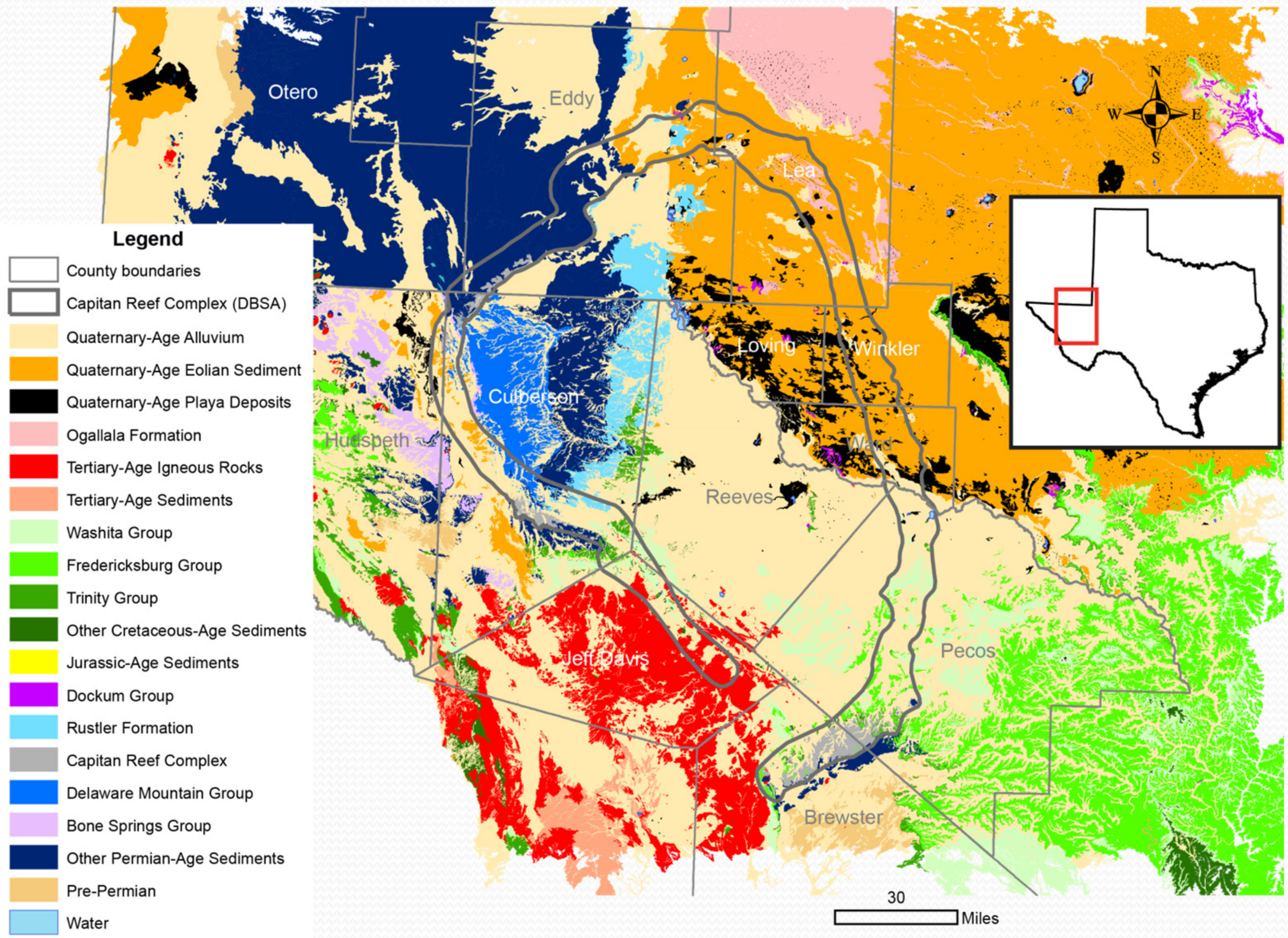
- Provide groundwater conservation districts with water budget data for their management plans.
- Assisting groundwater management areas in determining desired future conditions.
- Calculating Modeled Available Groundwater.

Stakeholder Advisory Forums

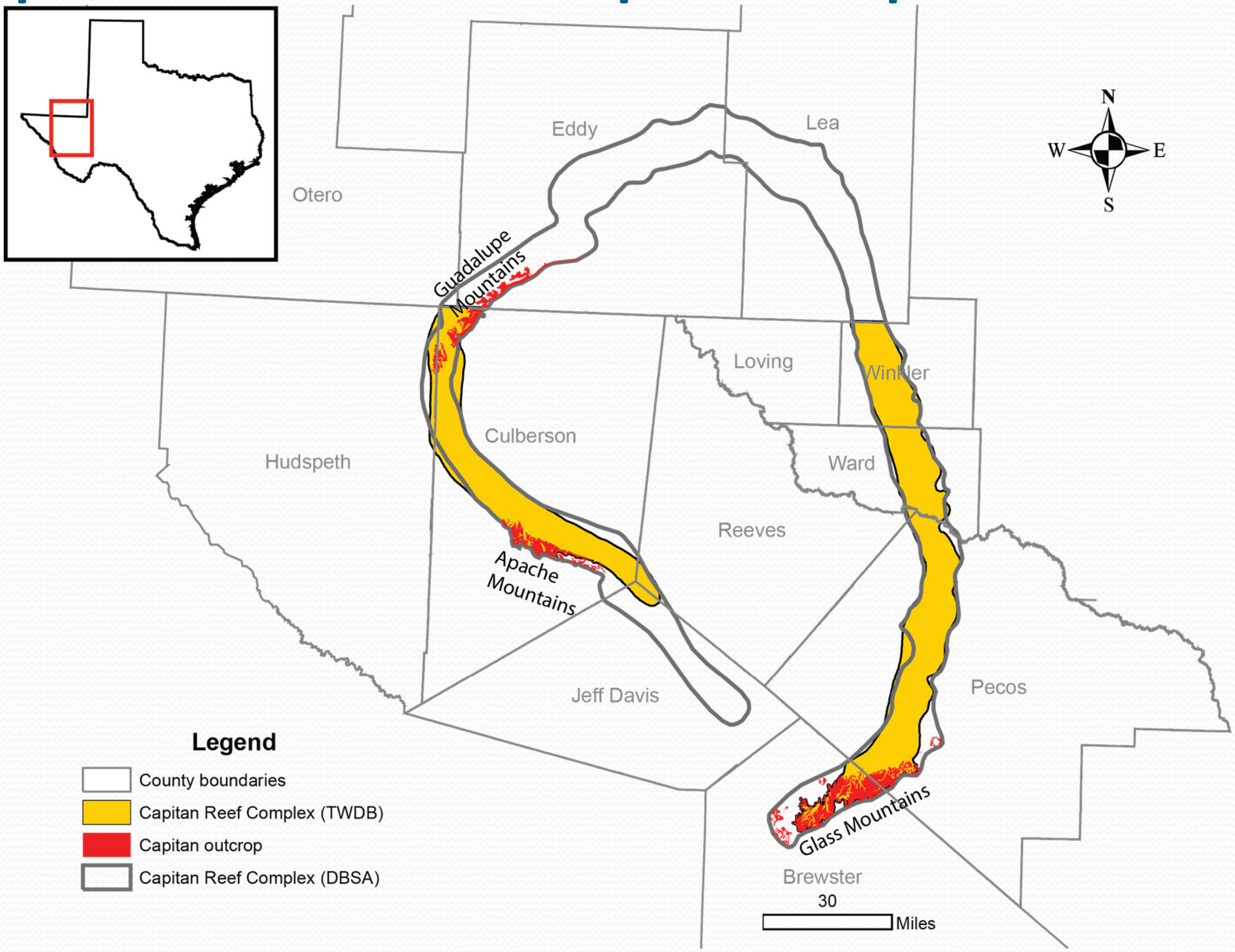
- Keep stakeholders updated about progress of the model
- Inform how the groundwater model can, should, and should not be used
- Provide stakeholders with the opportunity to provide input and data to assist with model development

REGIONAL OVERVIEW

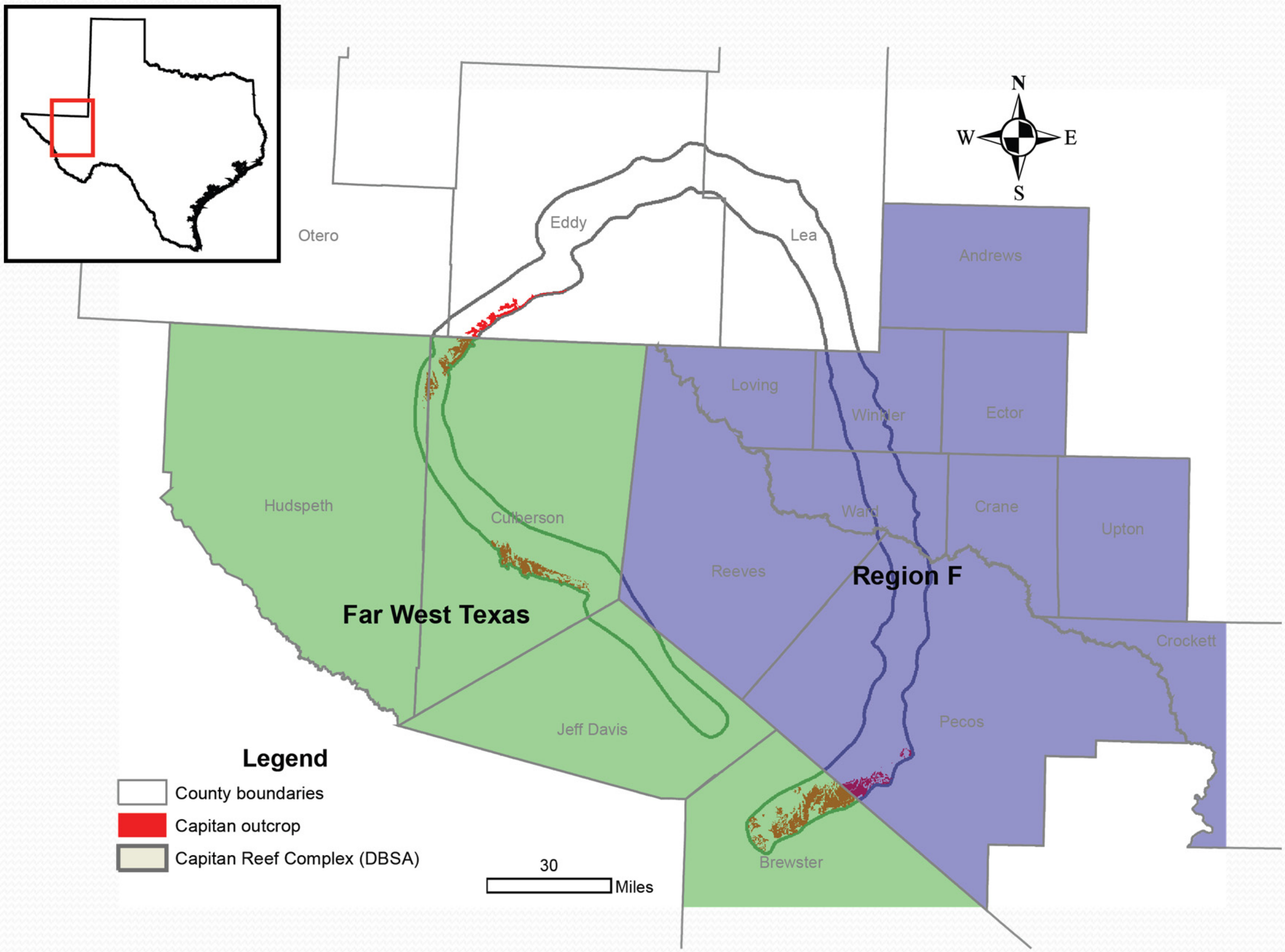
Surface Geology



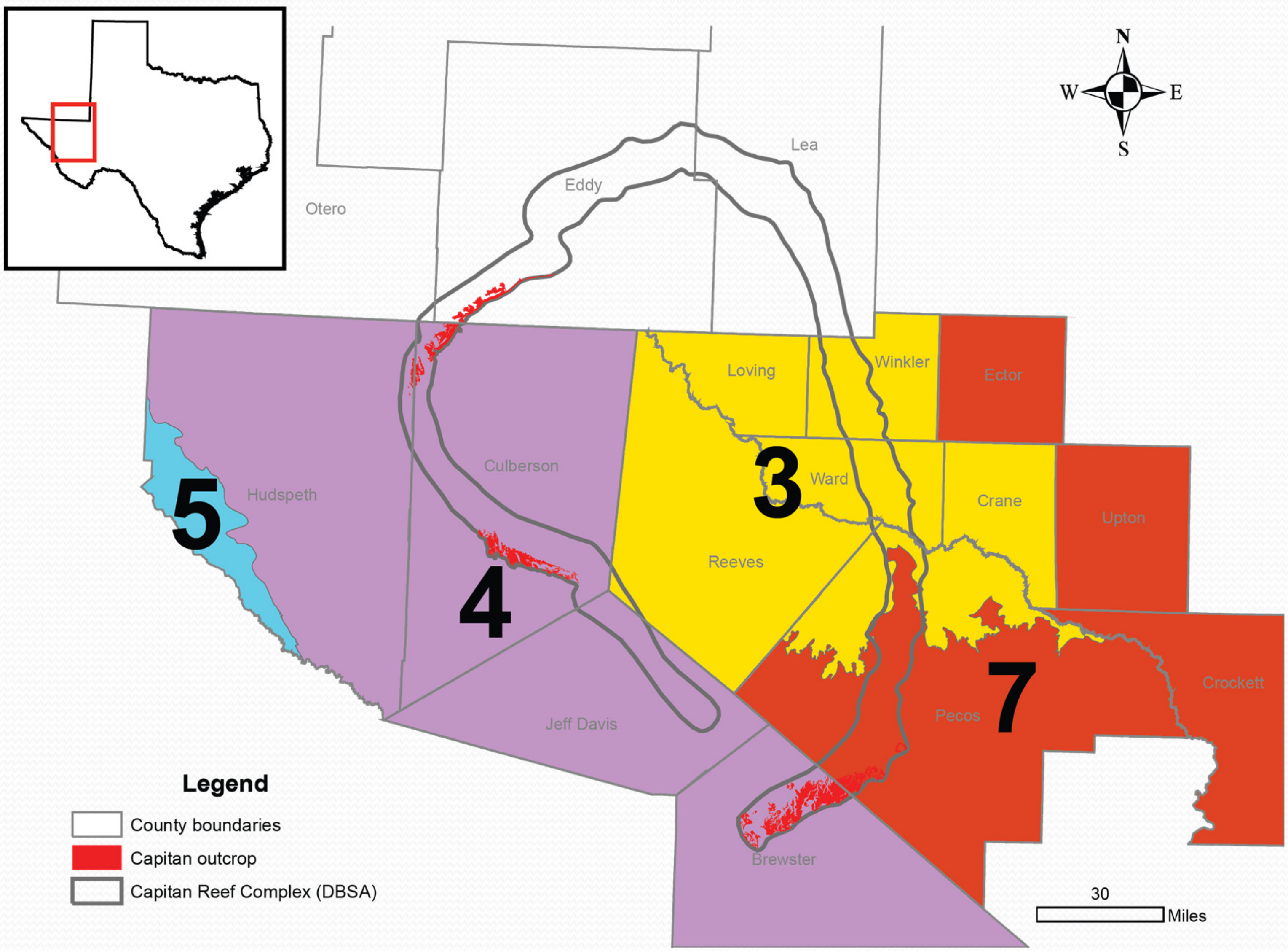
Capitan Reef Complex Aquifer



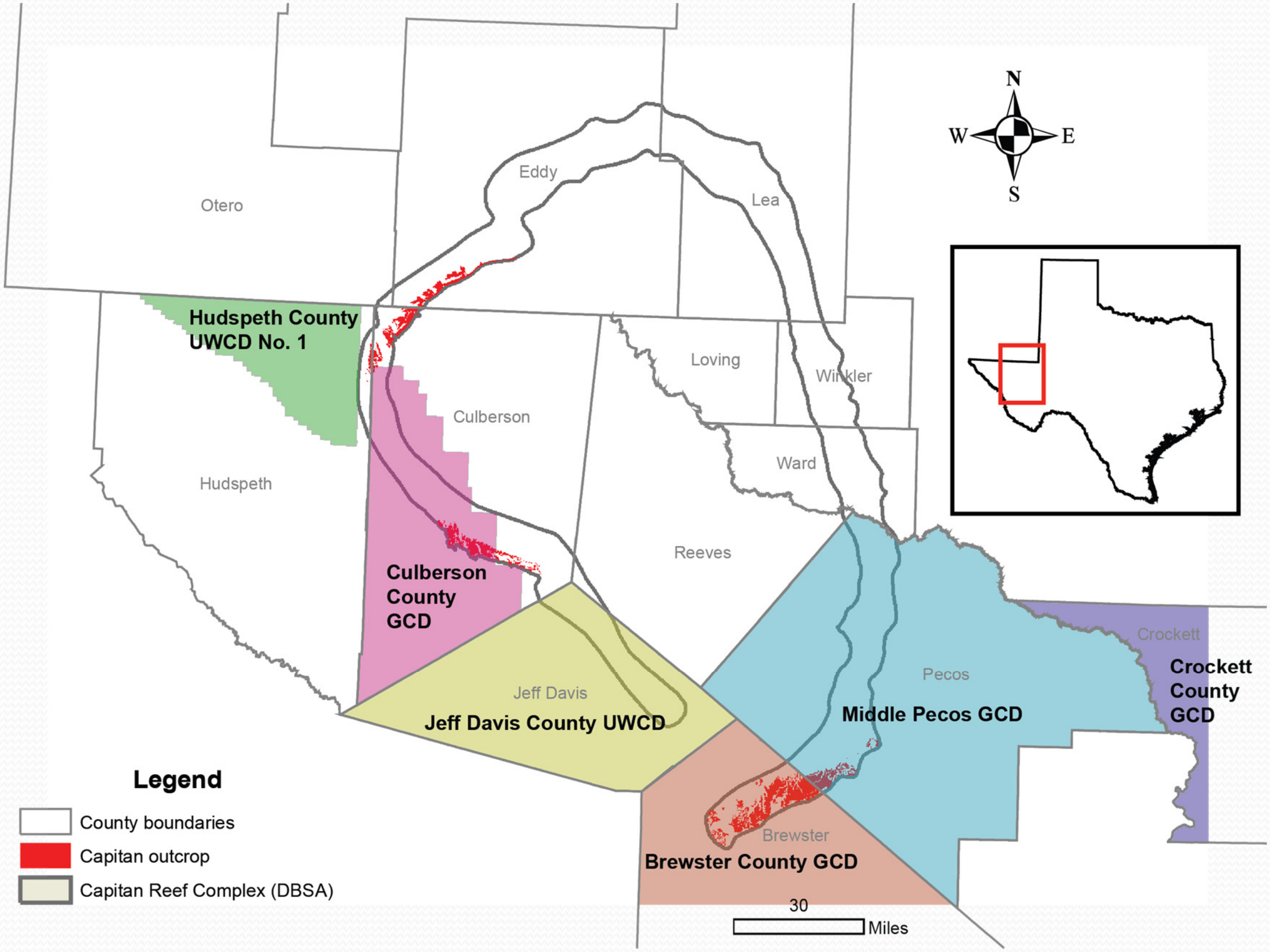
Regional Water Planning Areas



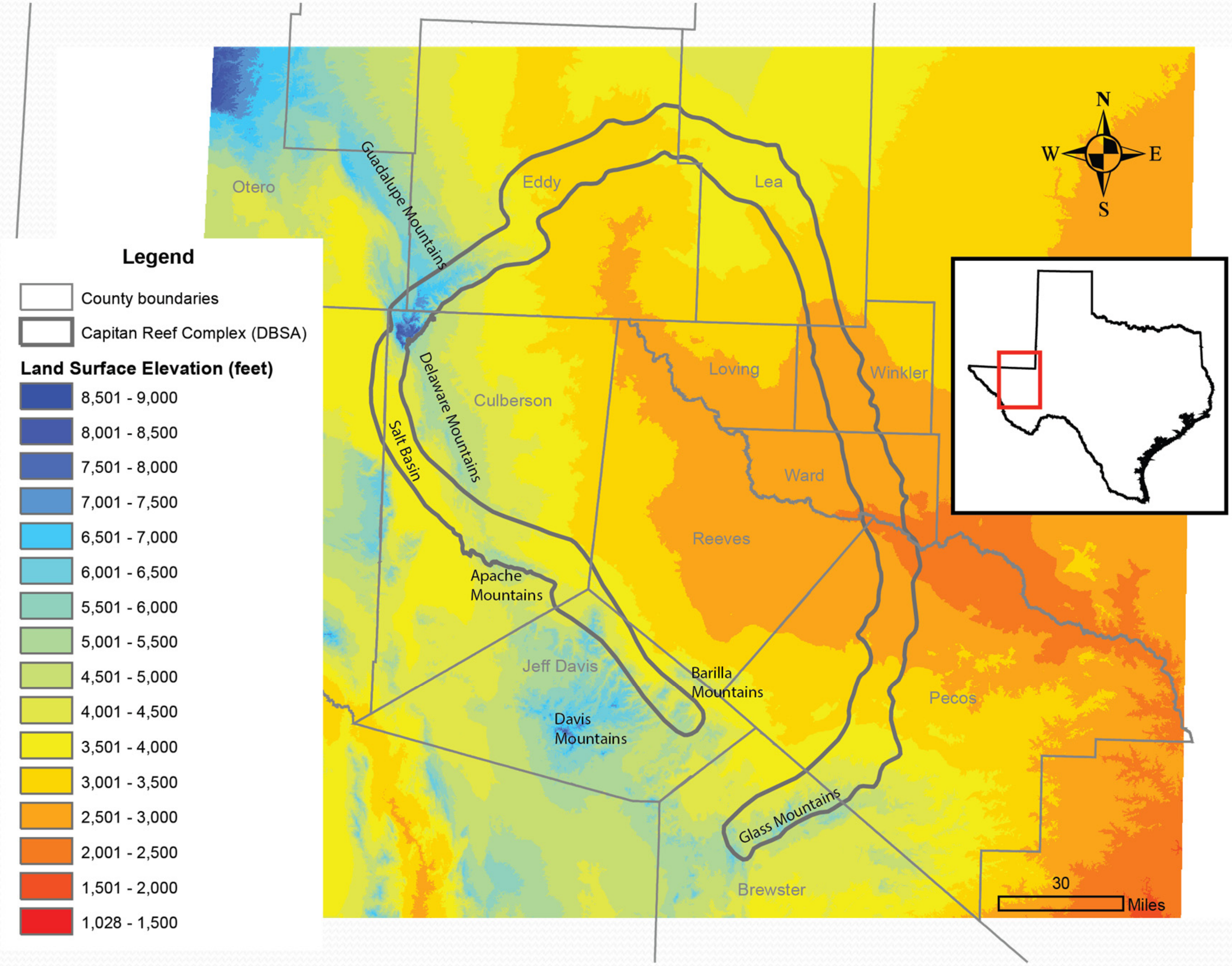
Groundwater Management Areas



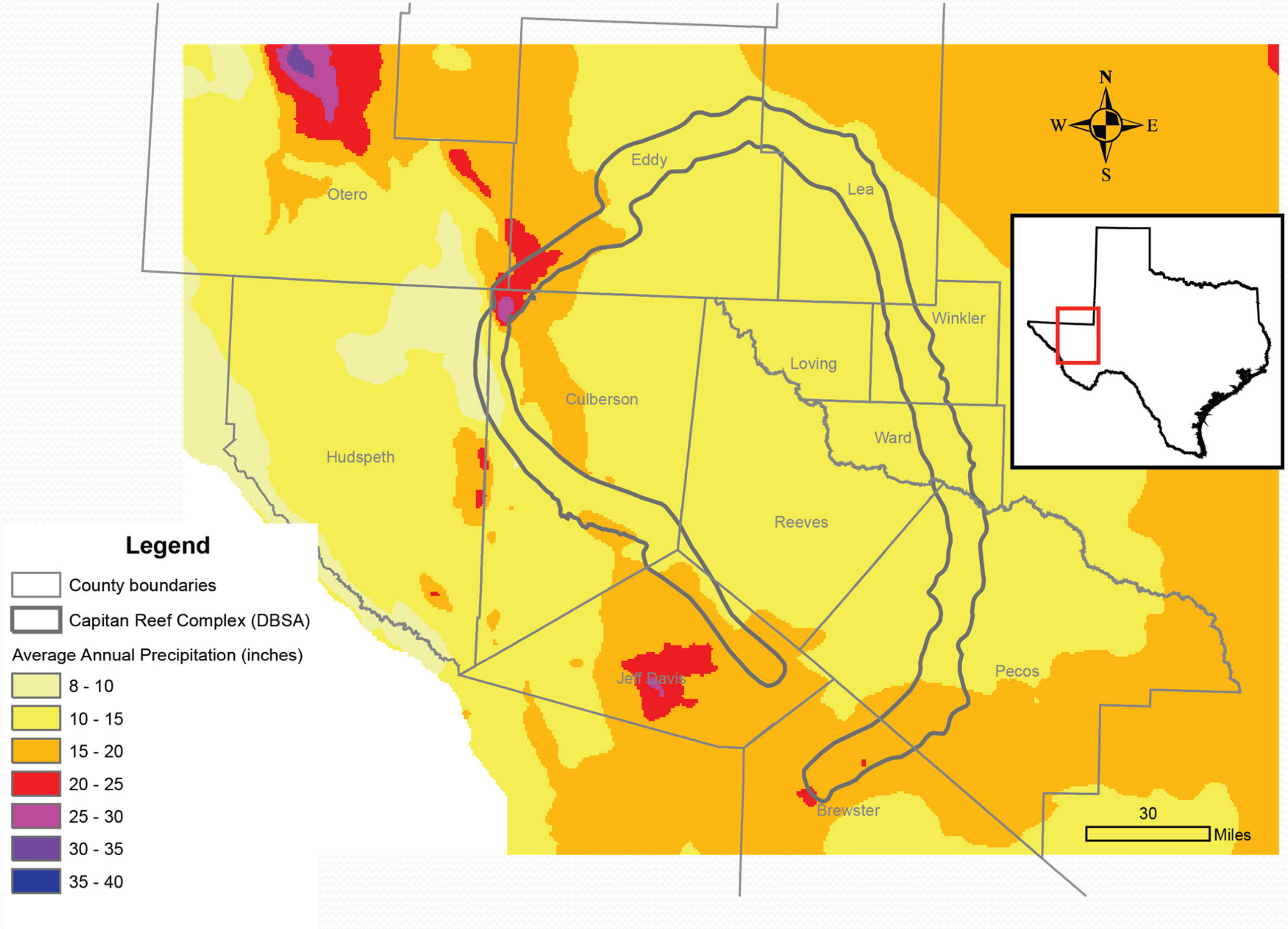
Groundwater Conservation Districts



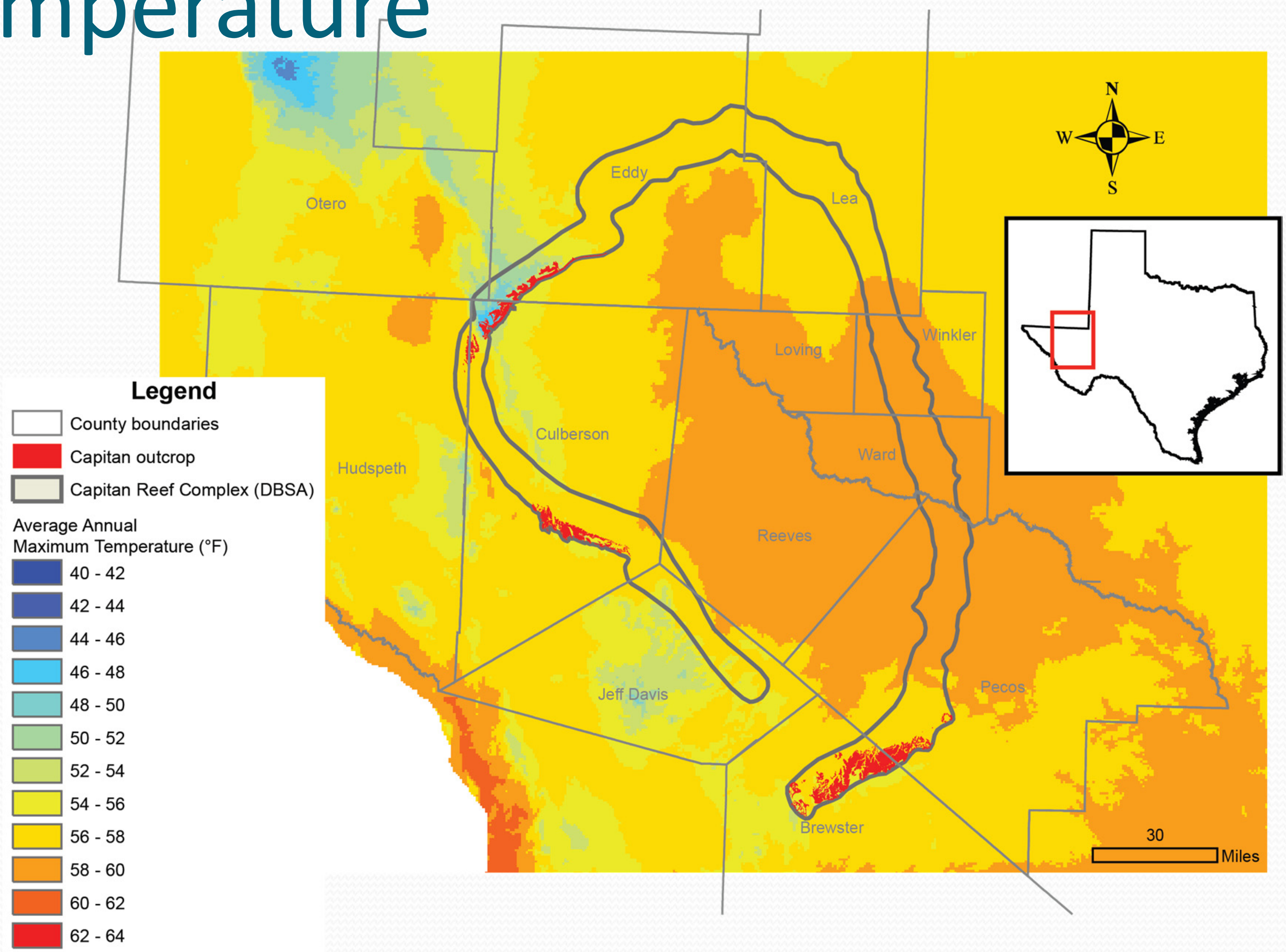
Land Surface Elevation



Average Annual Precipitation



Average Annual Maximum Temperature



BASICS OF GROUNDWATER FLOW

Groundwater Flow: Definitions

- **Aquifer** — Geologic unit that can transmit useable amounts of water to a well
  - **Unconfined** — water table forms the upper boundary
  - **Confined** — upper boundary is low permeability layer
- **Water table** — boundary between saturated and unsaturated zones
- **Hydraulic head** — water level in a well expressed as an elevation

Groundwater Flow: Definitions

- **Hydraulic conductivity** — A measurement of the ability of material to transmit groundwater
- **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 of head

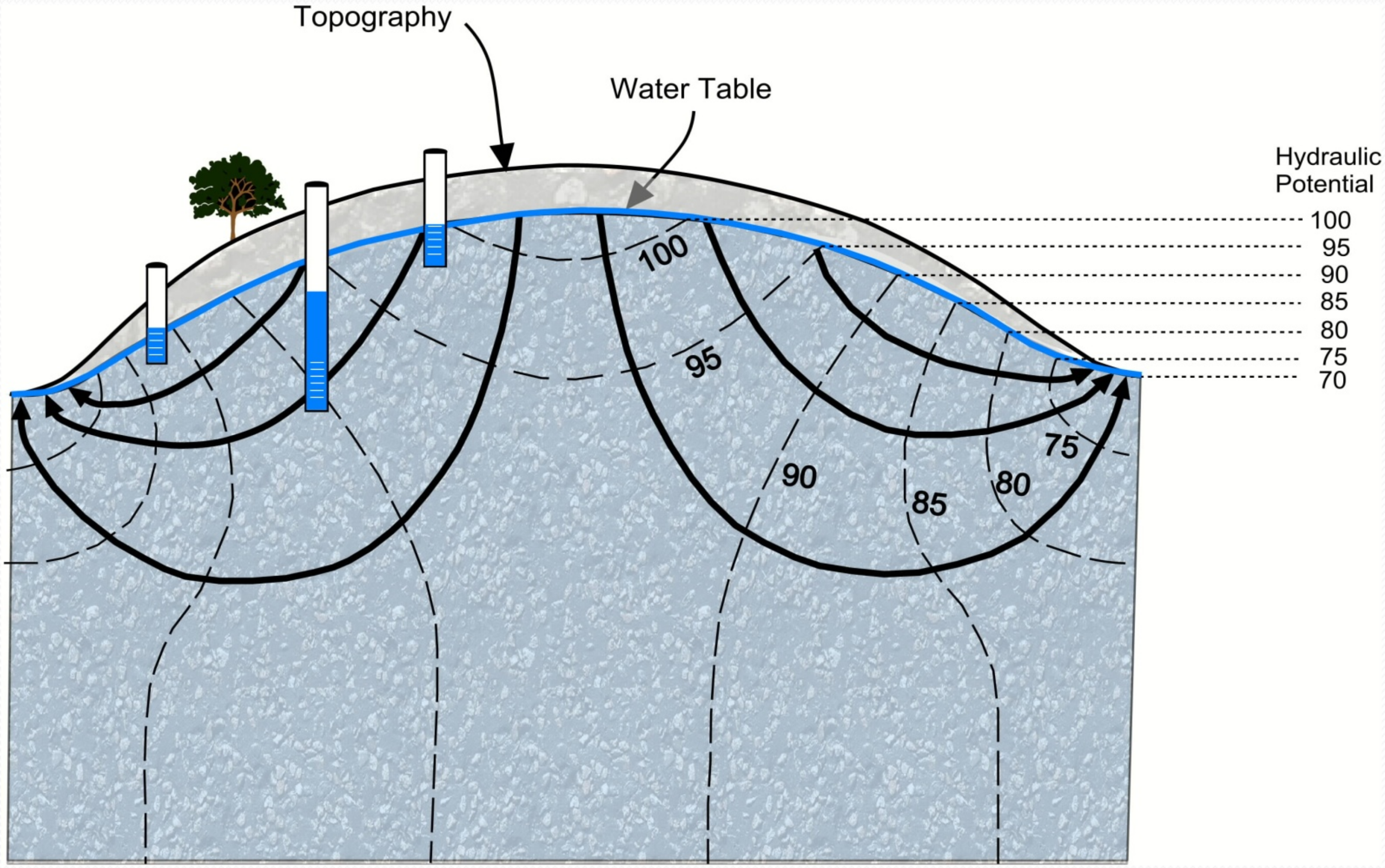
Groundwater Flow: Definitions

- **Recharge** — The processes involved in the addition of water to the saturated zone
- **Discharge** – The processes involved in water leaving an aquifer
- **Cross-formational flow** – Groundwater flow between geologic formations (aquifers)
- **Stream loss or gains** – The water that is lost or gained through the base of a stream due to interaction with an aquifer

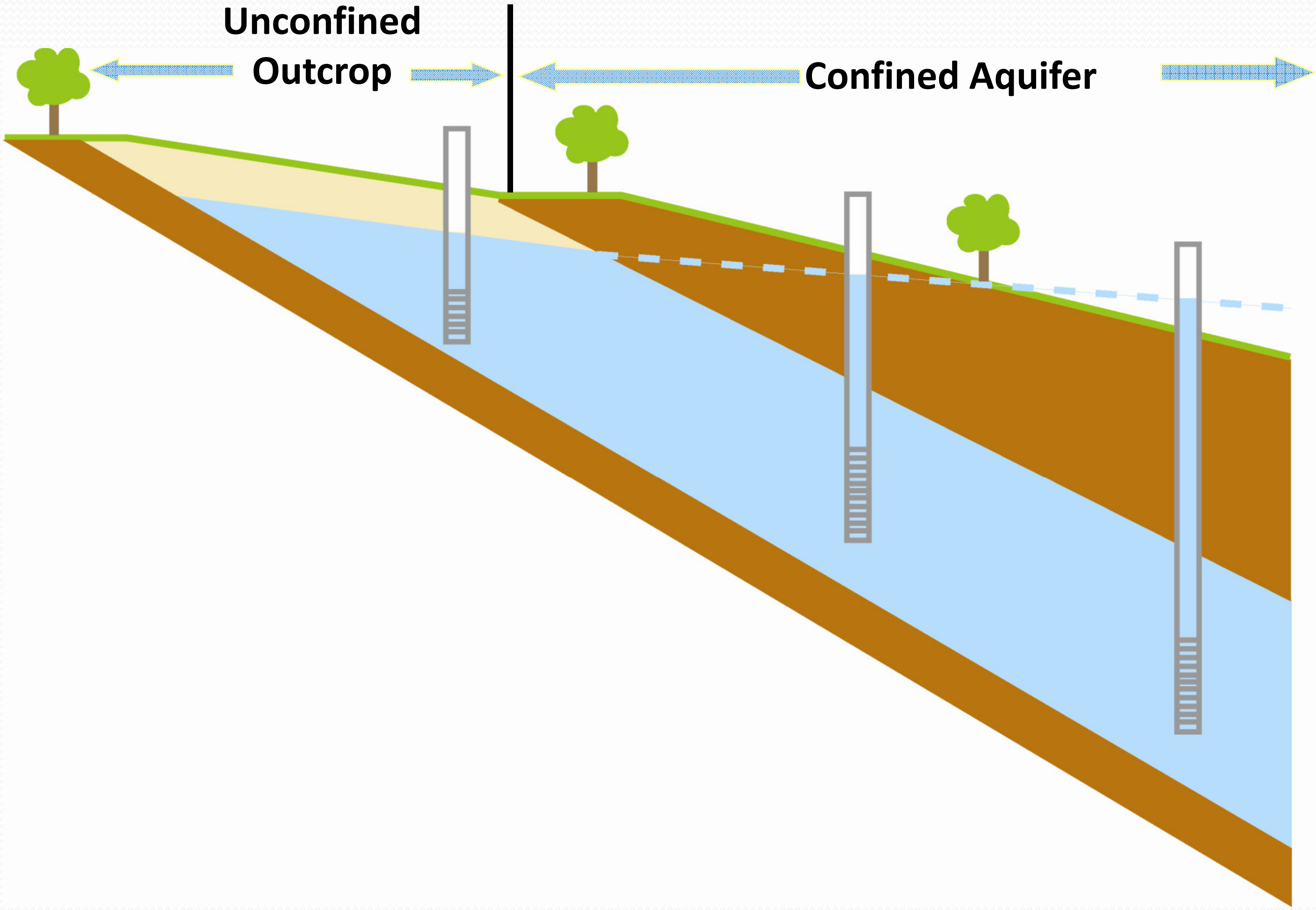
Basic Principles of Groundwater Flow

- The primary observable quantity describing groundwater flow is the hydraulic head as measured in a well
- The difference in hydraulic head between adjacent wells determines the direction of groundwater flow
  - From higher heads towards lower heads
- The water table is typically a subdued replica of the topography
- The thickness and hydraulic conductivity of the aquifer define volumetric flow rates
  - The larger the hydraulic conductivity and thickness, the greater the flow

Schematic Cross Section of Groundwater Flow

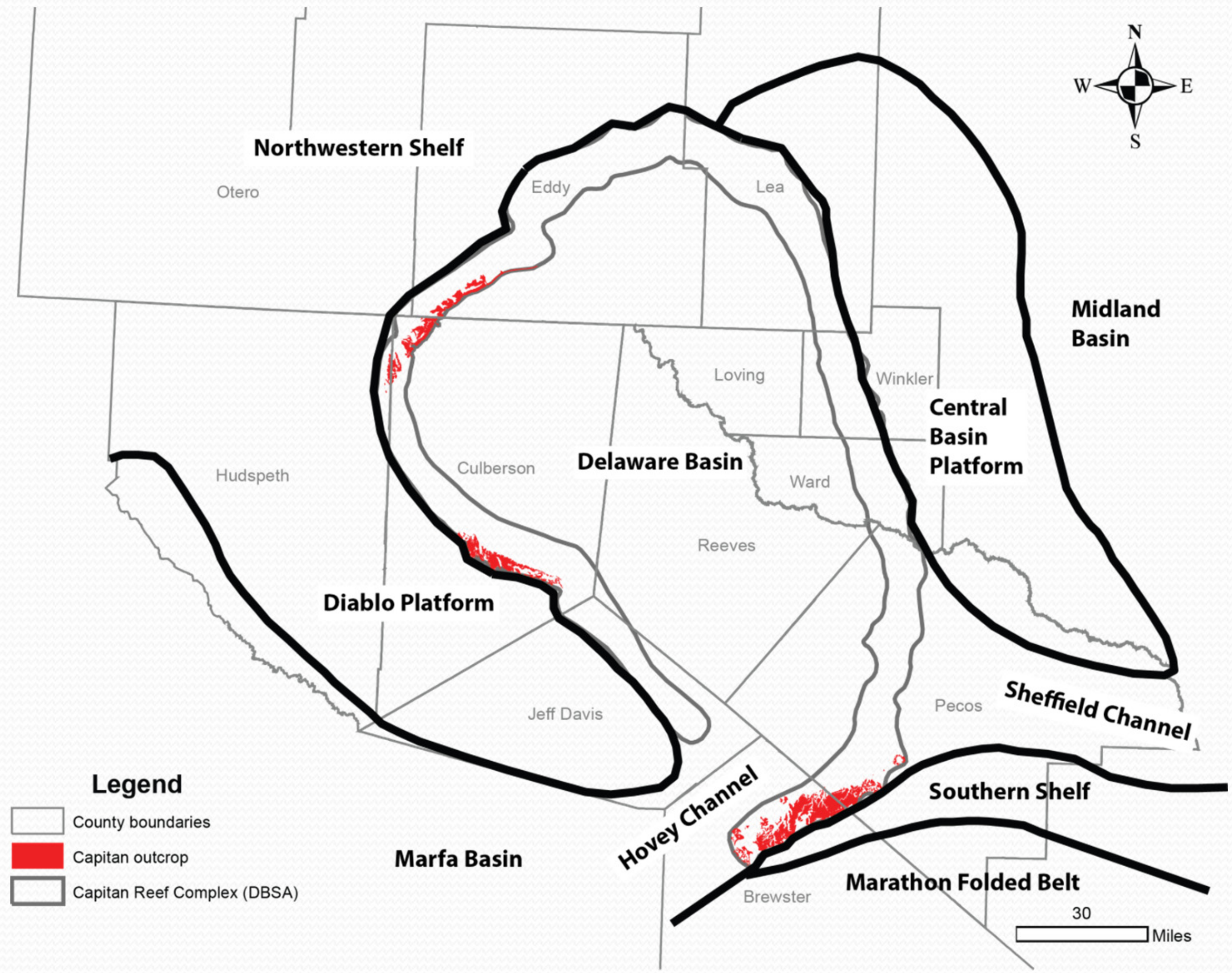


Confined/Unconfined Aquifer

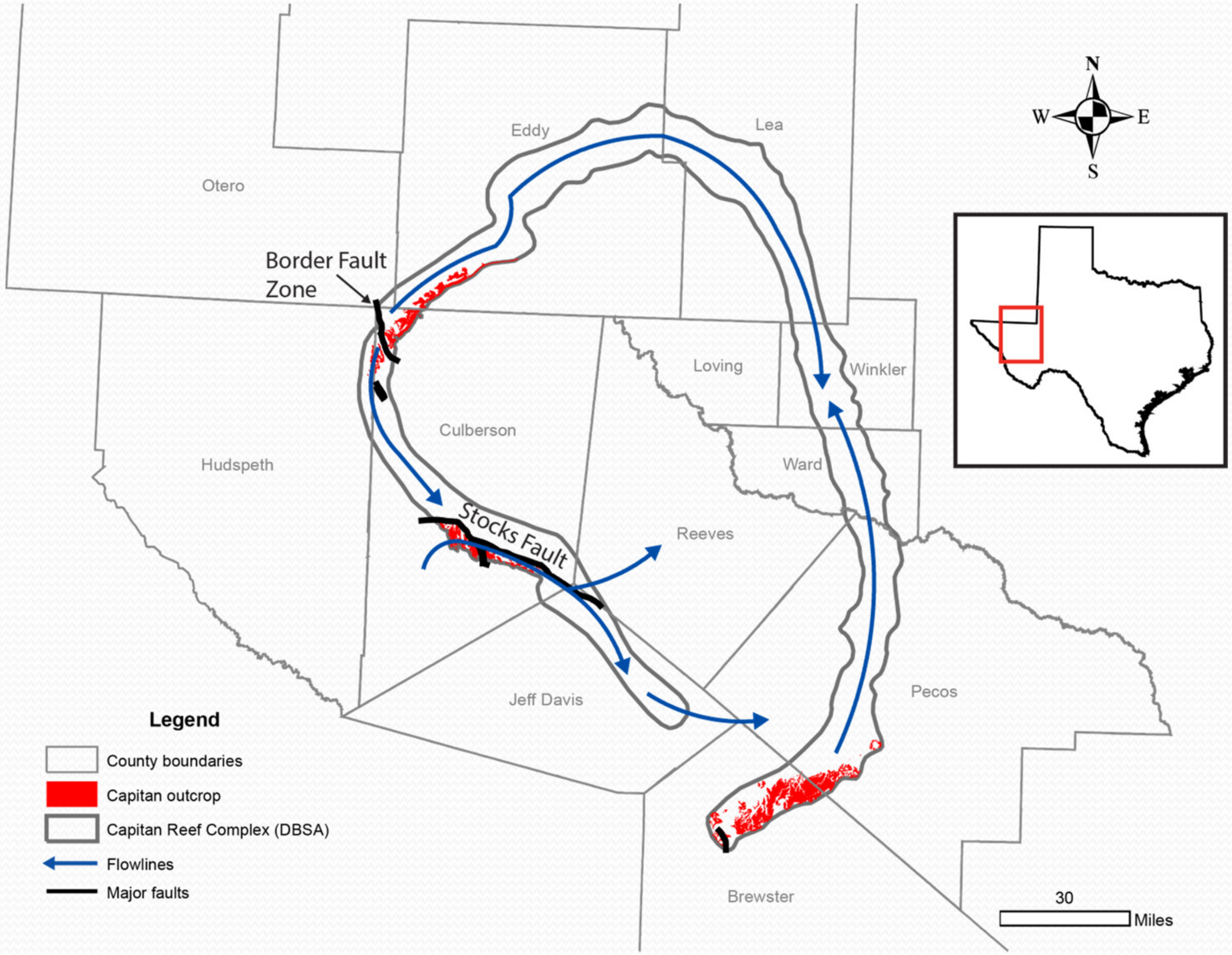


CAPITAN REEF COMPLEX AQUIFER

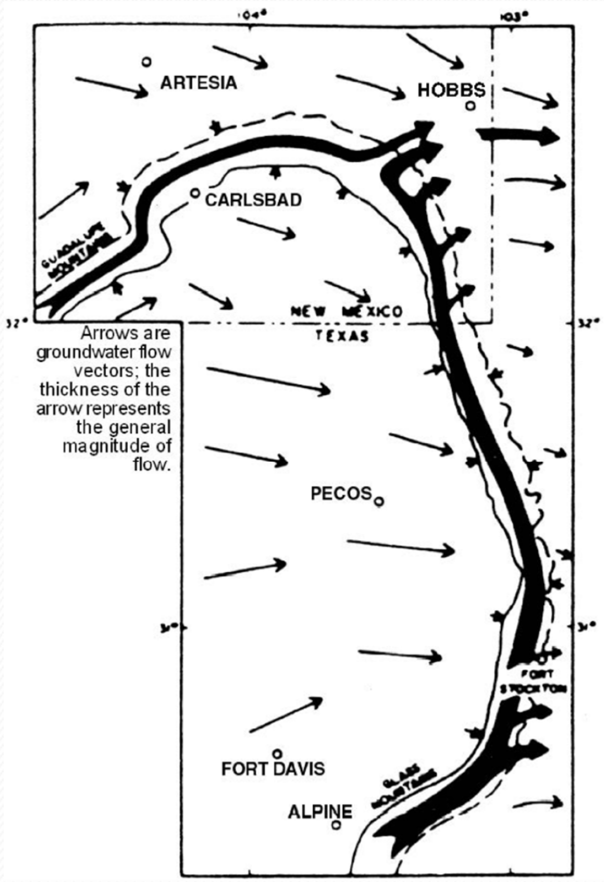
Structural Setting



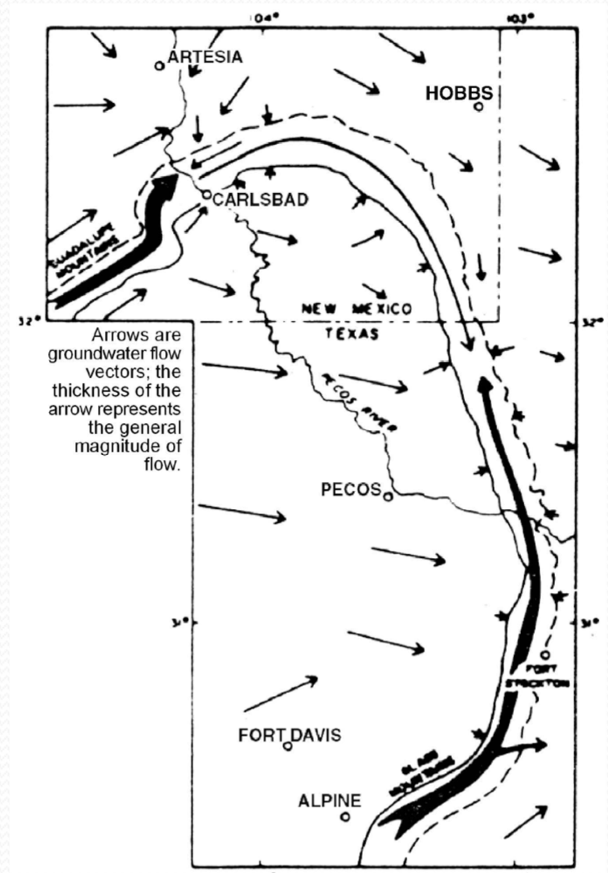
Conceptual Flow System



Conceptual Flow System



(a)



(b)

Generalized Stratigraphy

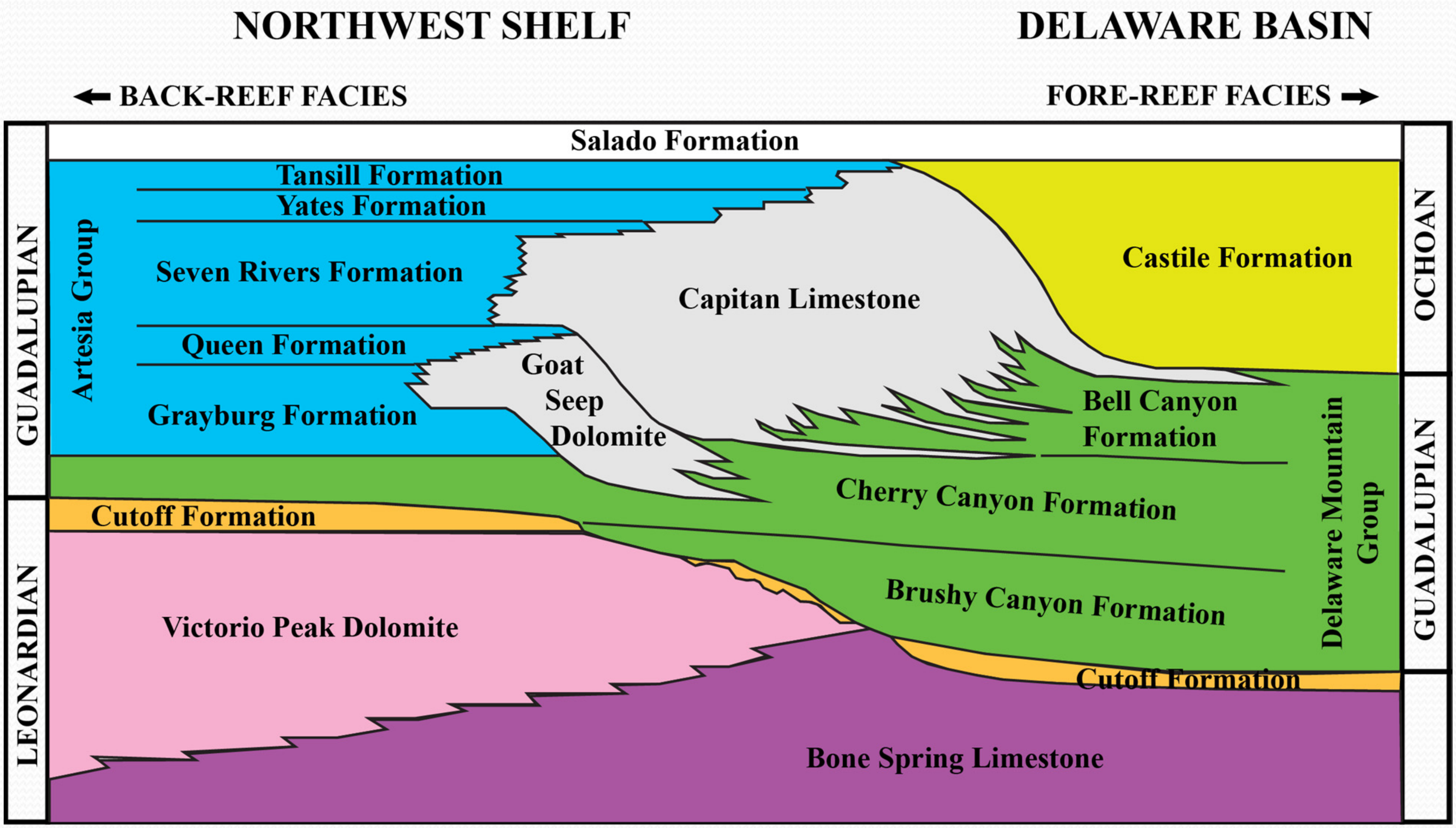
Summary of geologic formations and groups forming the Capitan Reef Complex and Delaware Basin

Period/Epoch or Series	Apache Mountains (Wood, 1968; Uliana, 2001) — Back Reef	Apache Mountains — Reef	Guadalupe Mountains (King, 1948; Hiss, 1975; Kerans and others, 1994; Kerans and Tinker, 1999) — Back Reef	Guadalupe Mountains — Reef	Glass Mountains (King, 1930; Hill, 1999) — Back Reef	Glass Mountains — Reef	Delaware Basin
Quaternary to Tertiary	Quaternary Tertiary Deposits		Quaternary Tertiary Deposits		Quaternary Tertiary Deposits		Quaternary Tertiary Deposits
Cretaceous					Cretaceous		
Triassic					Bissett		
Permian/Ochoan				Rustler[a]			Rustler
				Salado[a]			Salado
				Castile[a]			Castile
Permian/ Guadalupian	Artesia Group: Tansill	Capitan Reef Complex; Capitan Limestone	Artesia Group: Tansill	Capitan Reef Complex; Carlsbad and Capitan Limestones	Gilliam	Capitan Reef Complex; Tessey	Delaware Mountain Group: Bell Canyon
	Artesia Group: Yates		Artesia Group: Yates				
	Artesia Group: Seven Rivers		Artesia Group: Seven Rivers			Vidrio	Cherry Canyon
	Artesia Group: Munn		Artesia Group: Queen/ Grayburg	Capitan Reef Complex; Goat Seep Dolomite			
	Cherry Canyon		Upper San Andres	Cherry Canyon	Word Formation (Cherry and Brushy Canyon Equivalent)		Brushy Canyon
			Lower San Andres (equivalent to Brushy Canyon)				
	Cutoff Shale (Member of Bone Spring Limestone) [spans Apache and Guadalupe Mountains]						Pipeline Shale Member
Permian/ Leonardian	Yeso	Victorio Peak (Member of the Bone Spring Limestone) [spans to Guadalupe Mountains]			Leonard and Hess Member of Leonard Formation		Bone Spring Limestone

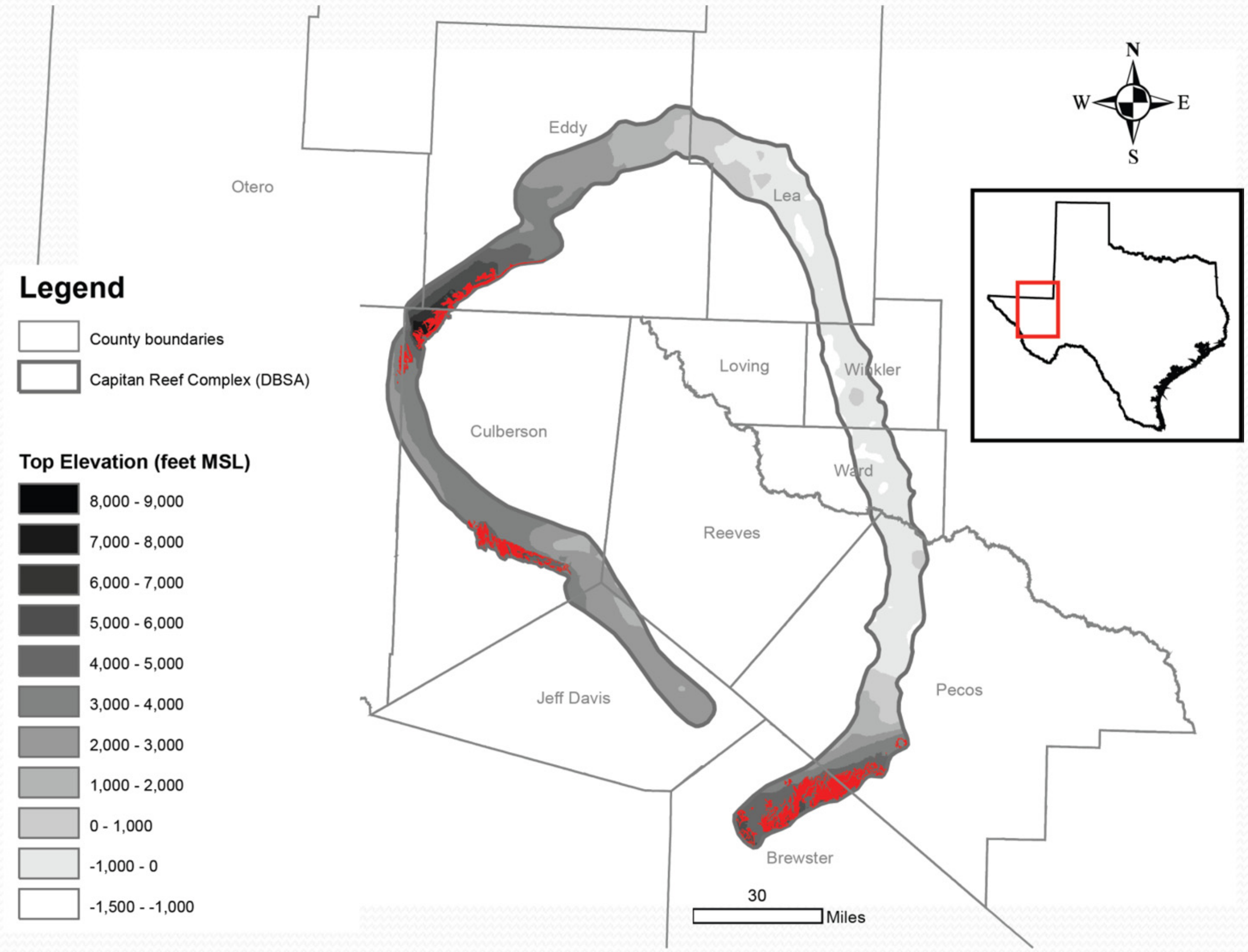
Sources: From Standen and others (2009): Modified after King, 1930, 1948; Wood, 1968; Hiss, 1975; Uliana, 2001; Hill, 1999; Kerans and others, 1994; Kerans and Tinker, 1999

[a] Formations overlie Capitan Reef Complex between the Guadalupe and Glass Mountains

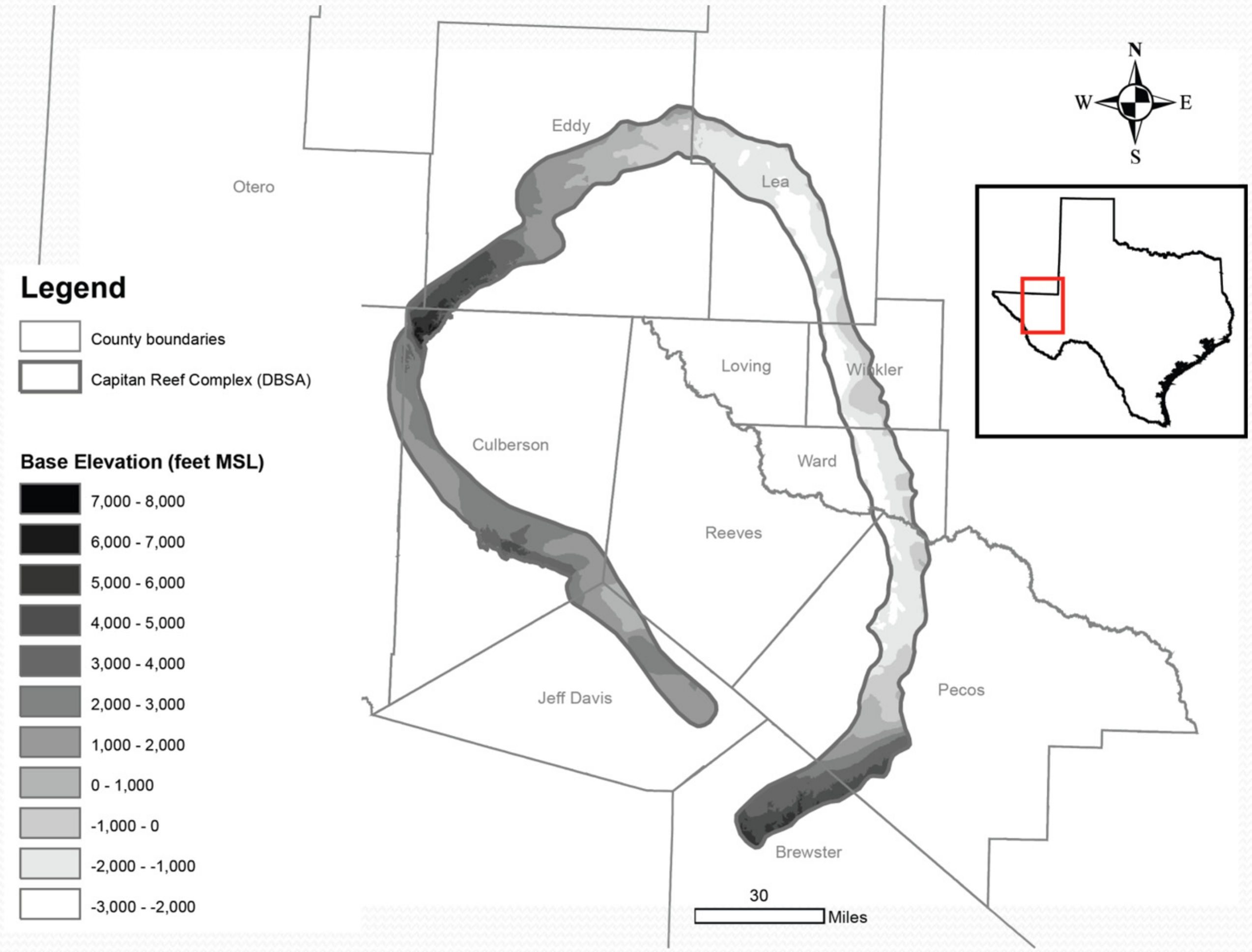
Generalized Cross-Section



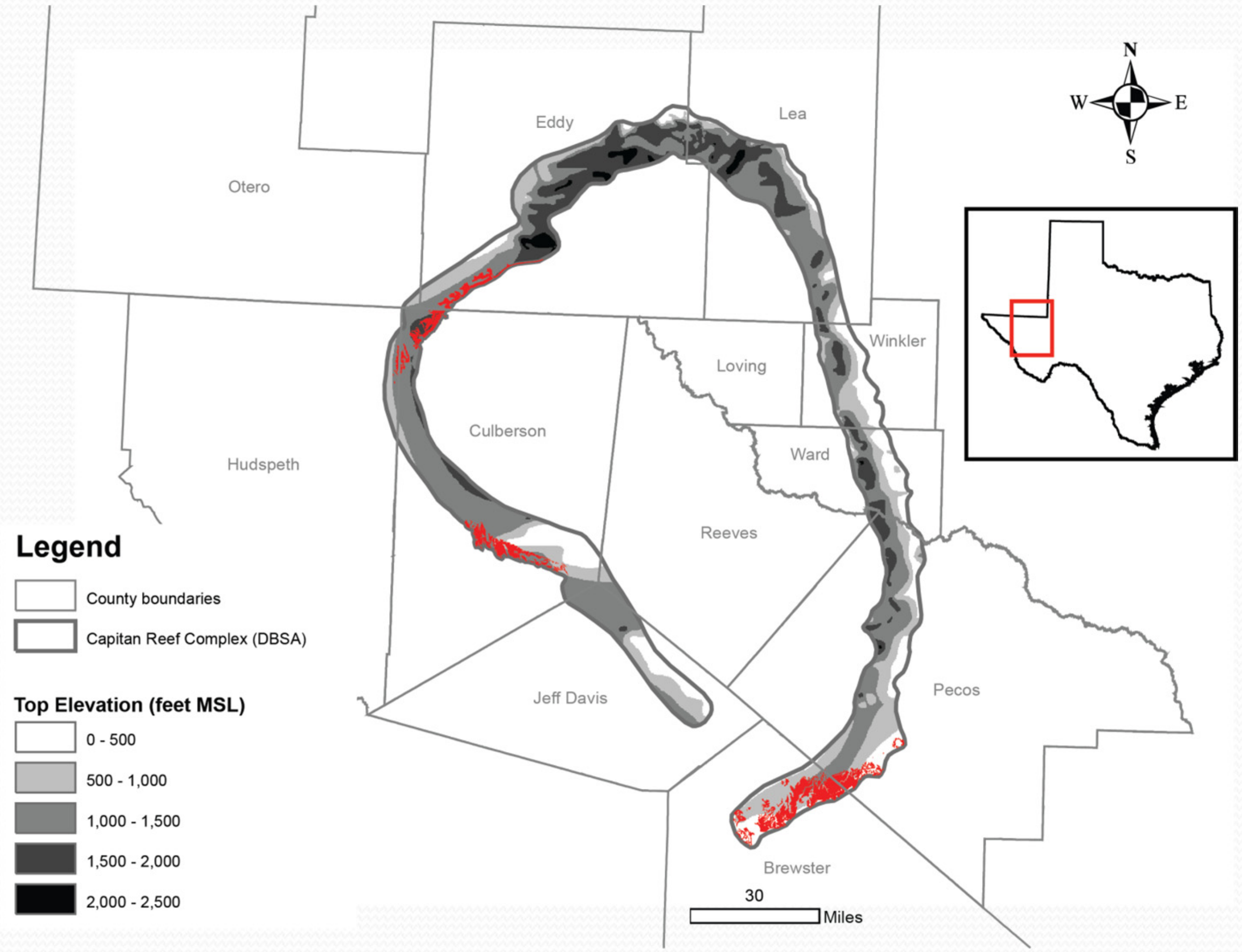
Aquifer Top Elevation



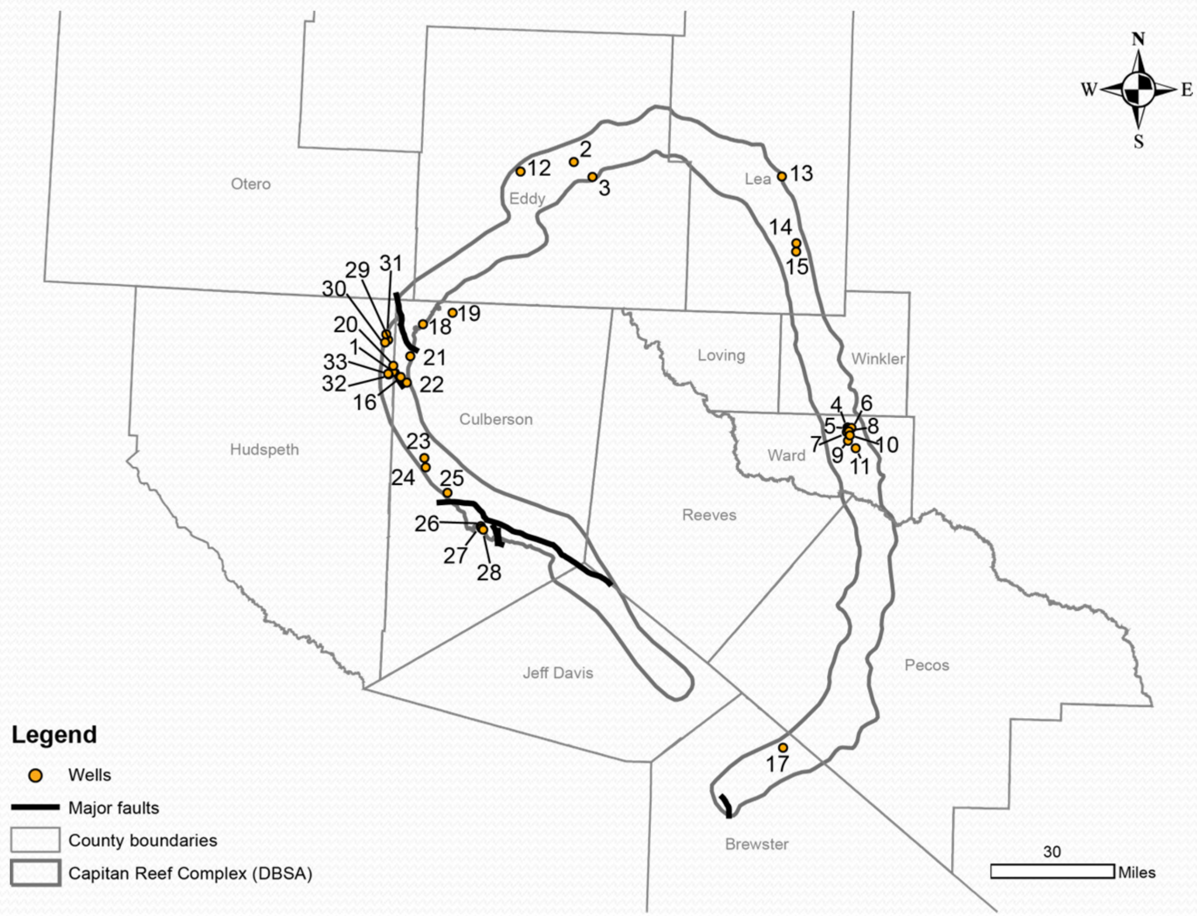
Aquifer Base Elevation



Aquifer Thickness



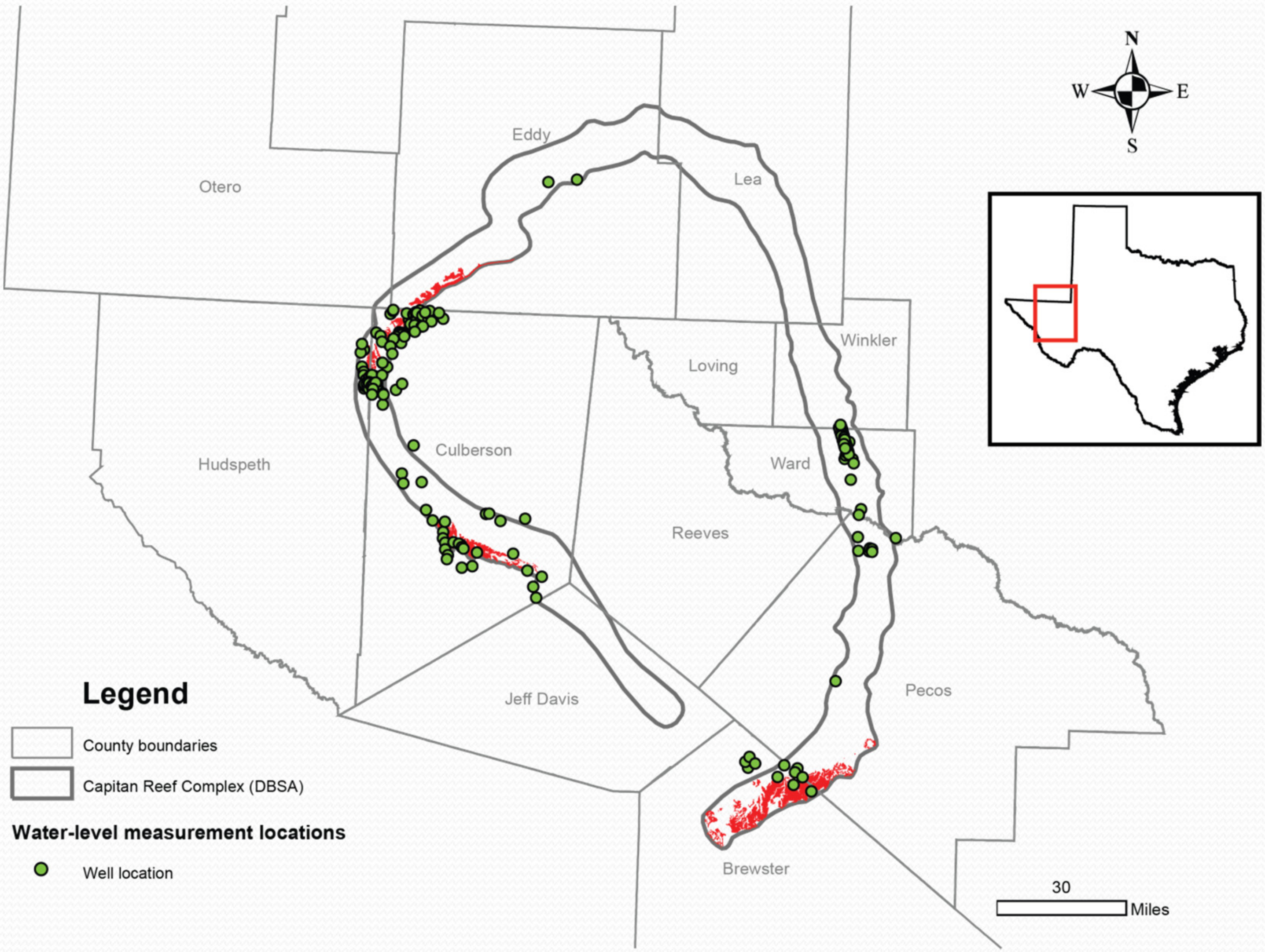
Hydraulic Properties



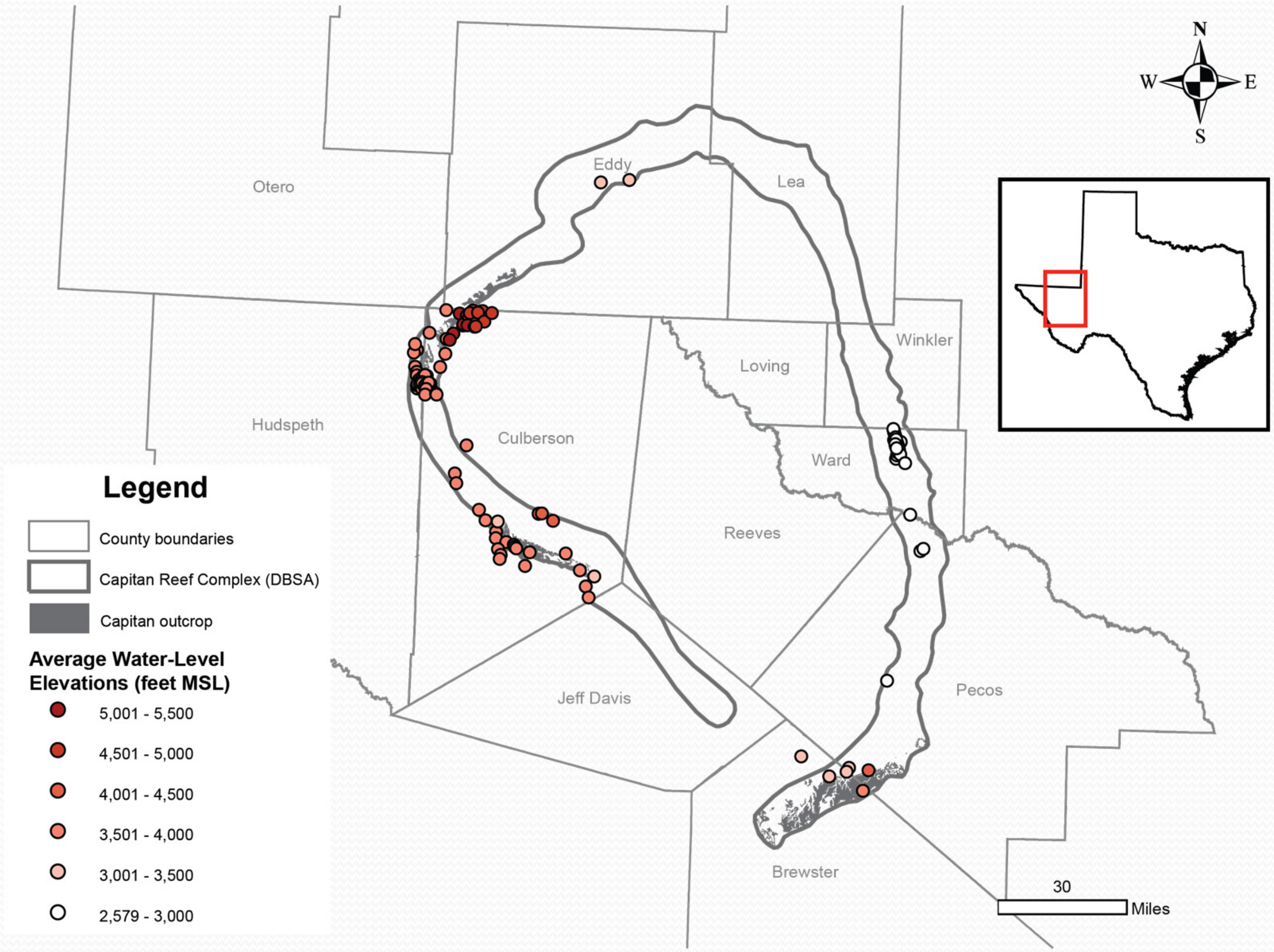
Hydraulic Properties

- Problem
  - General lack of hydraulic data, especially in Texas part of aquifer
  - Currently no data from Winkler or Pecos counties

Water-Level Data



Water-Level Data



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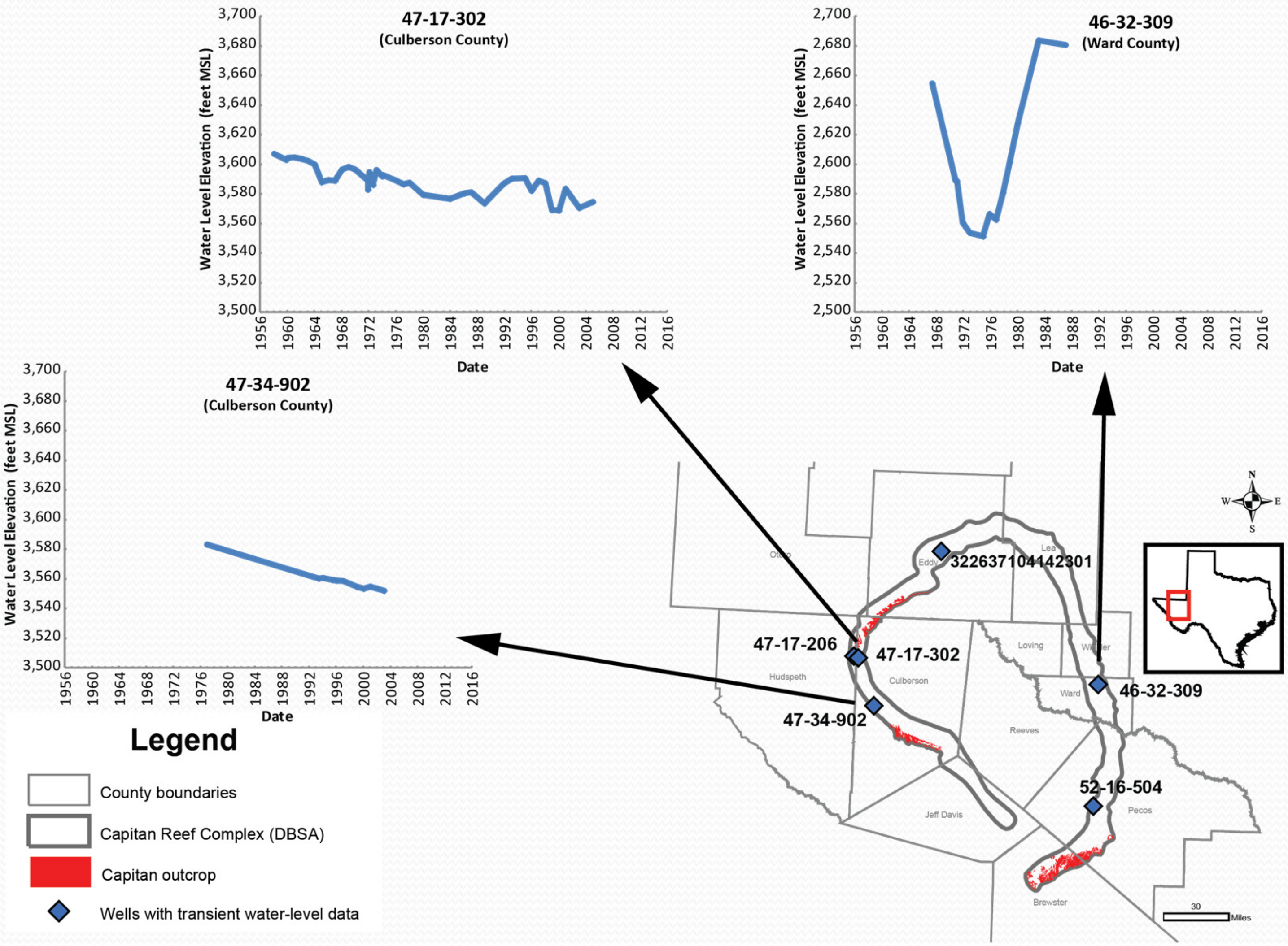

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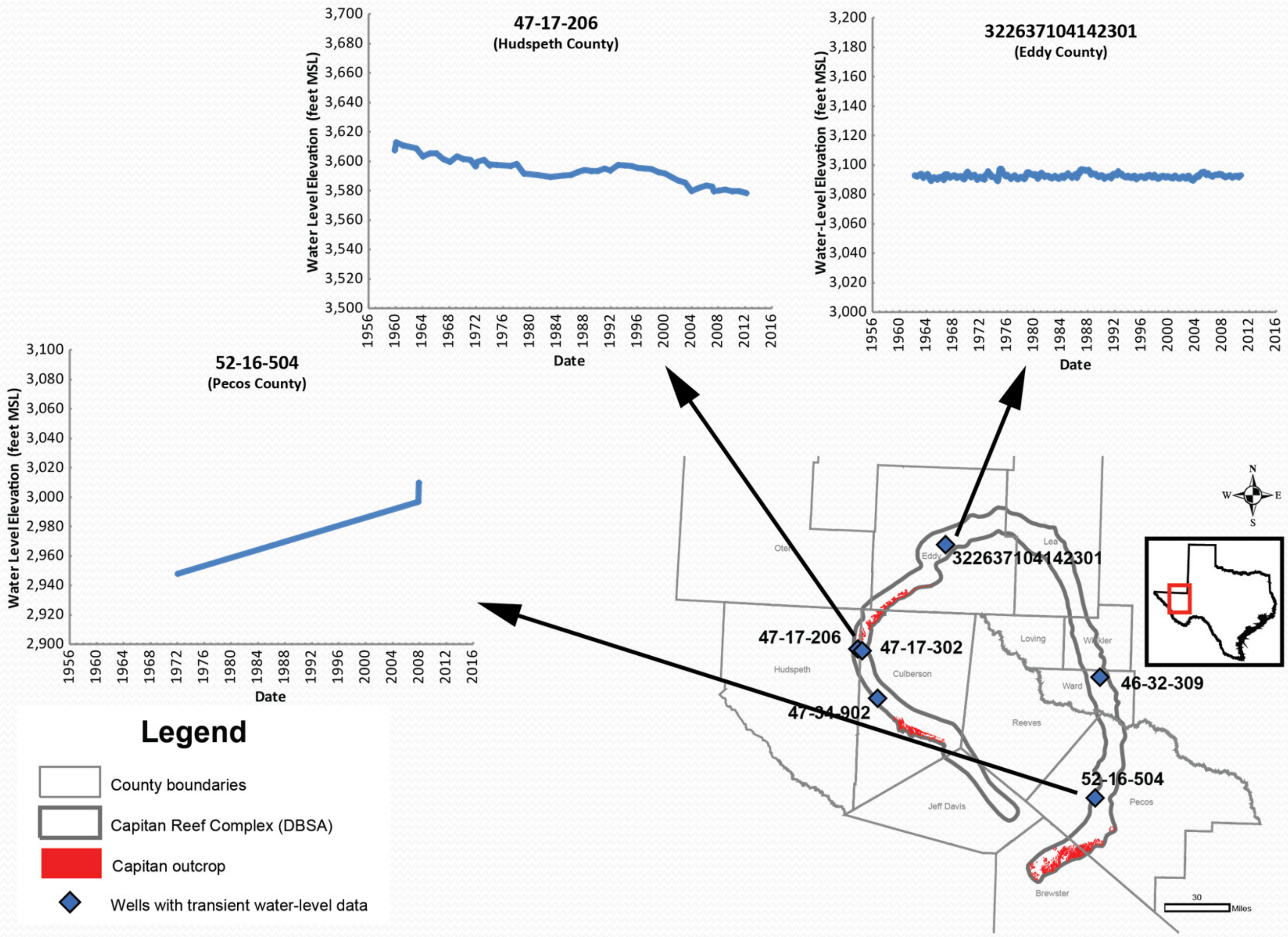
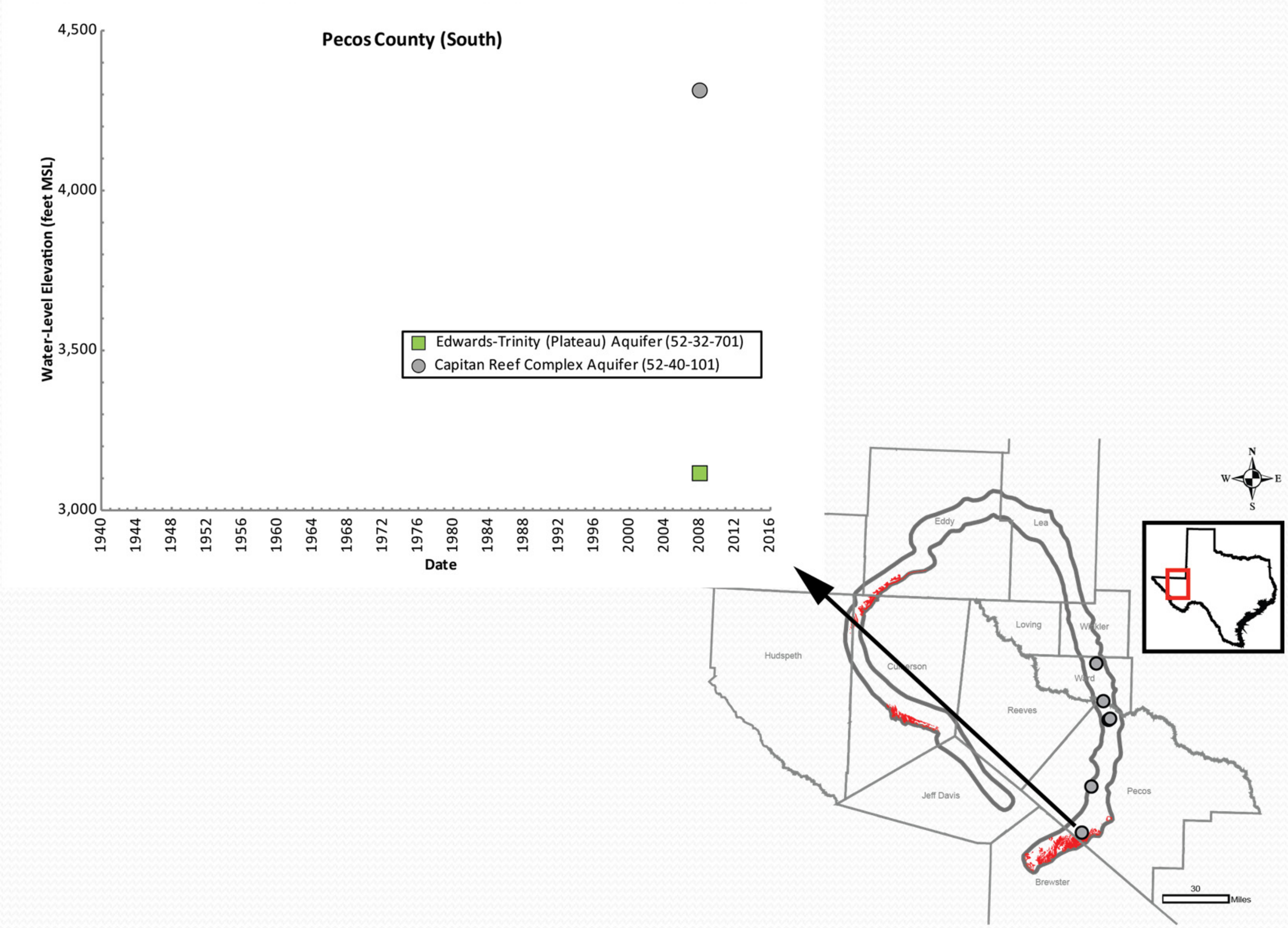
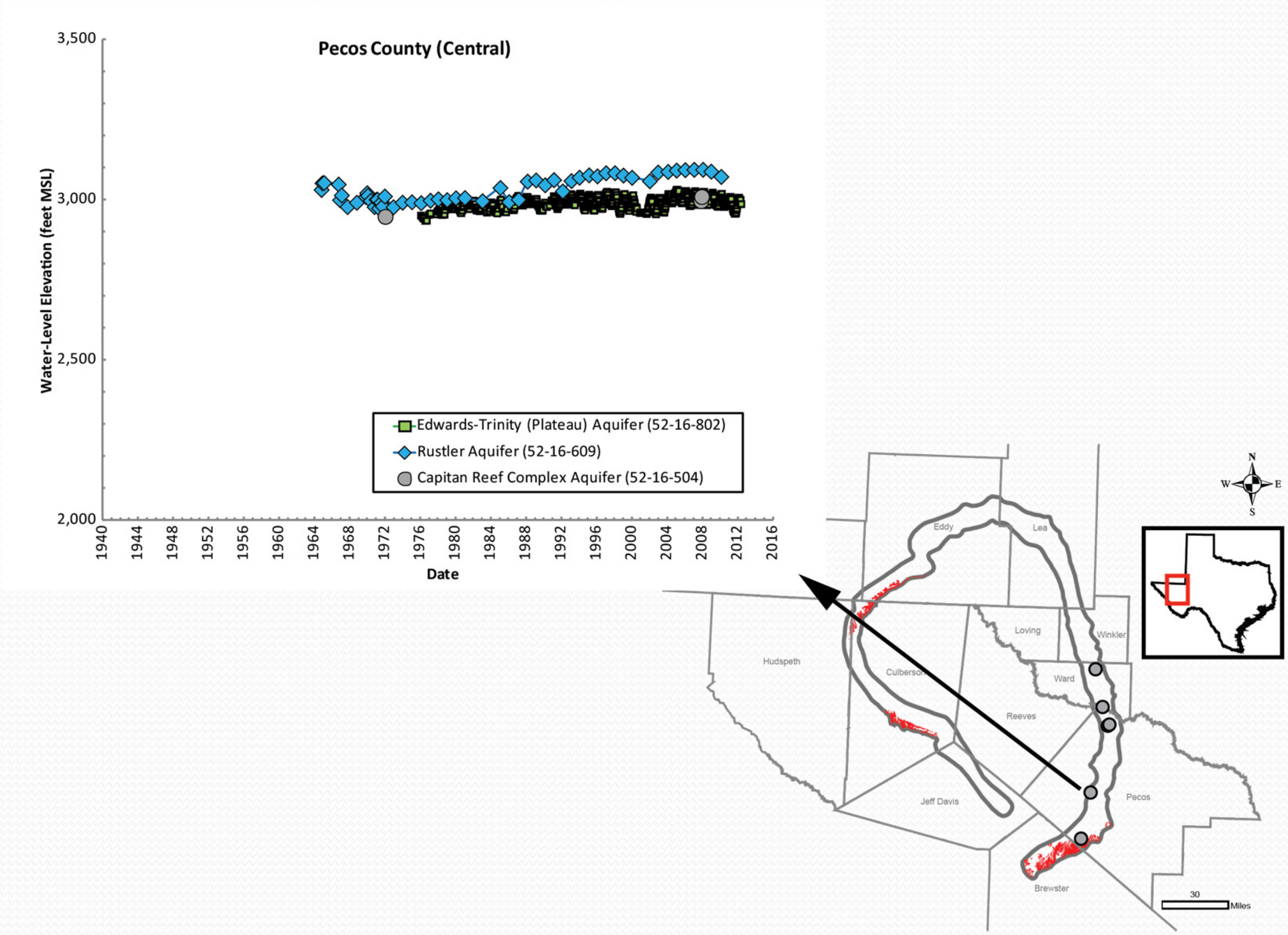


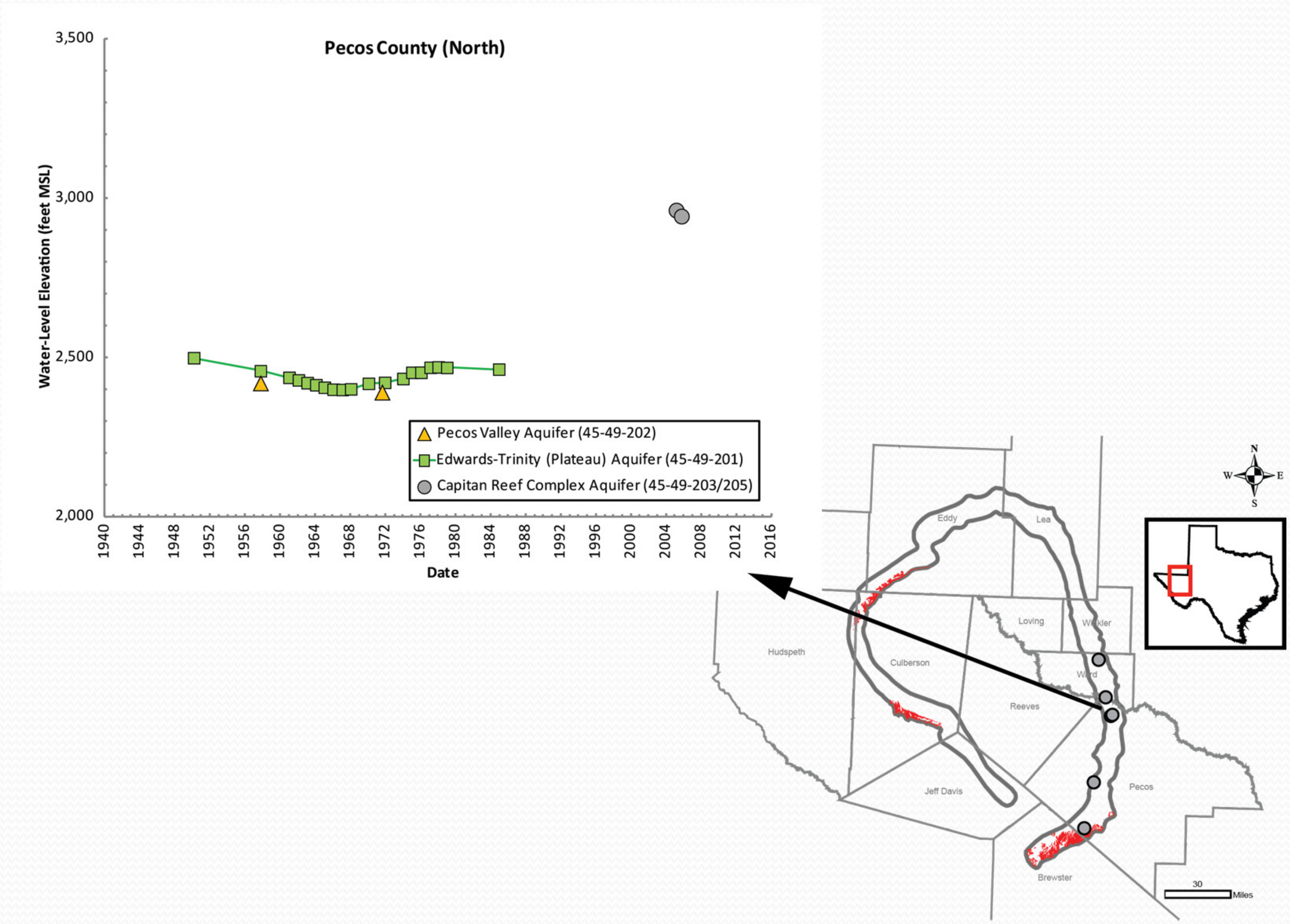
Water-Level Data



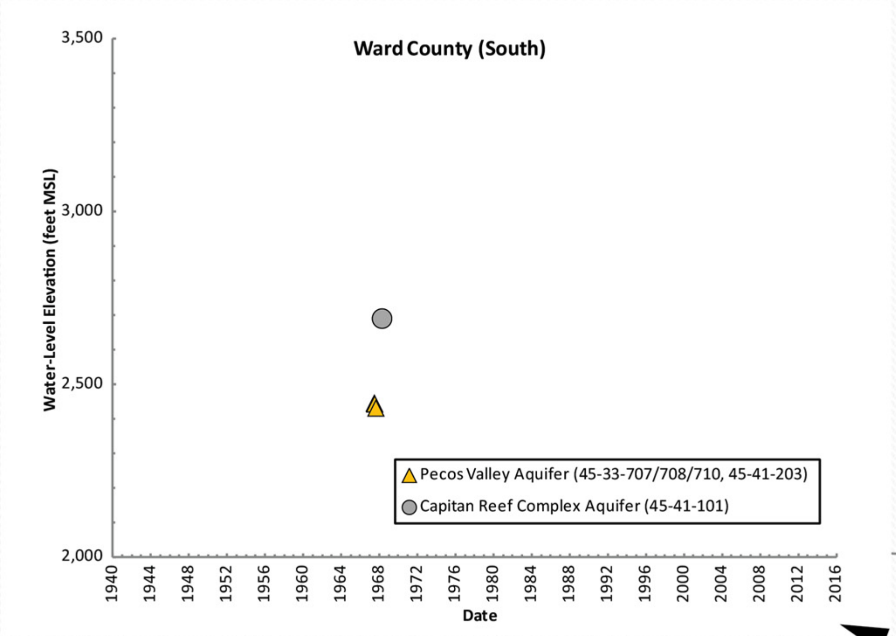
Water-Level Data

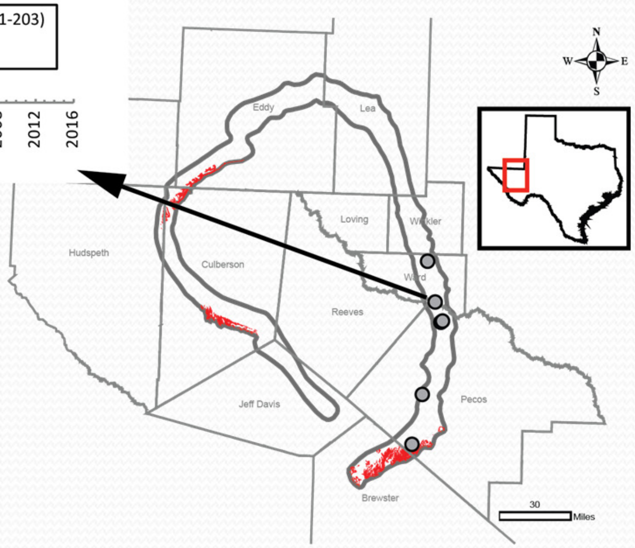


Water-Level Data



Water-Level Data





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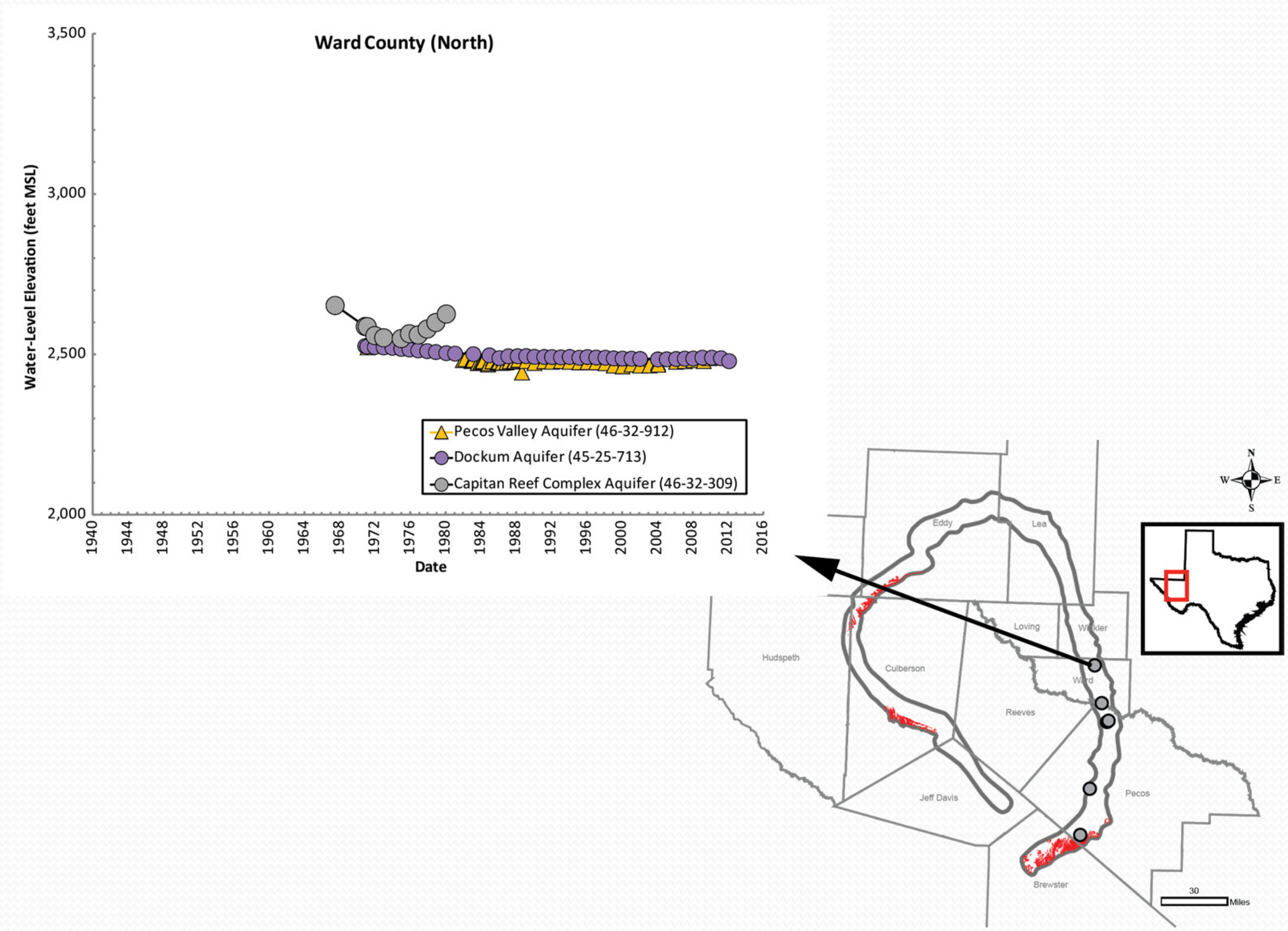
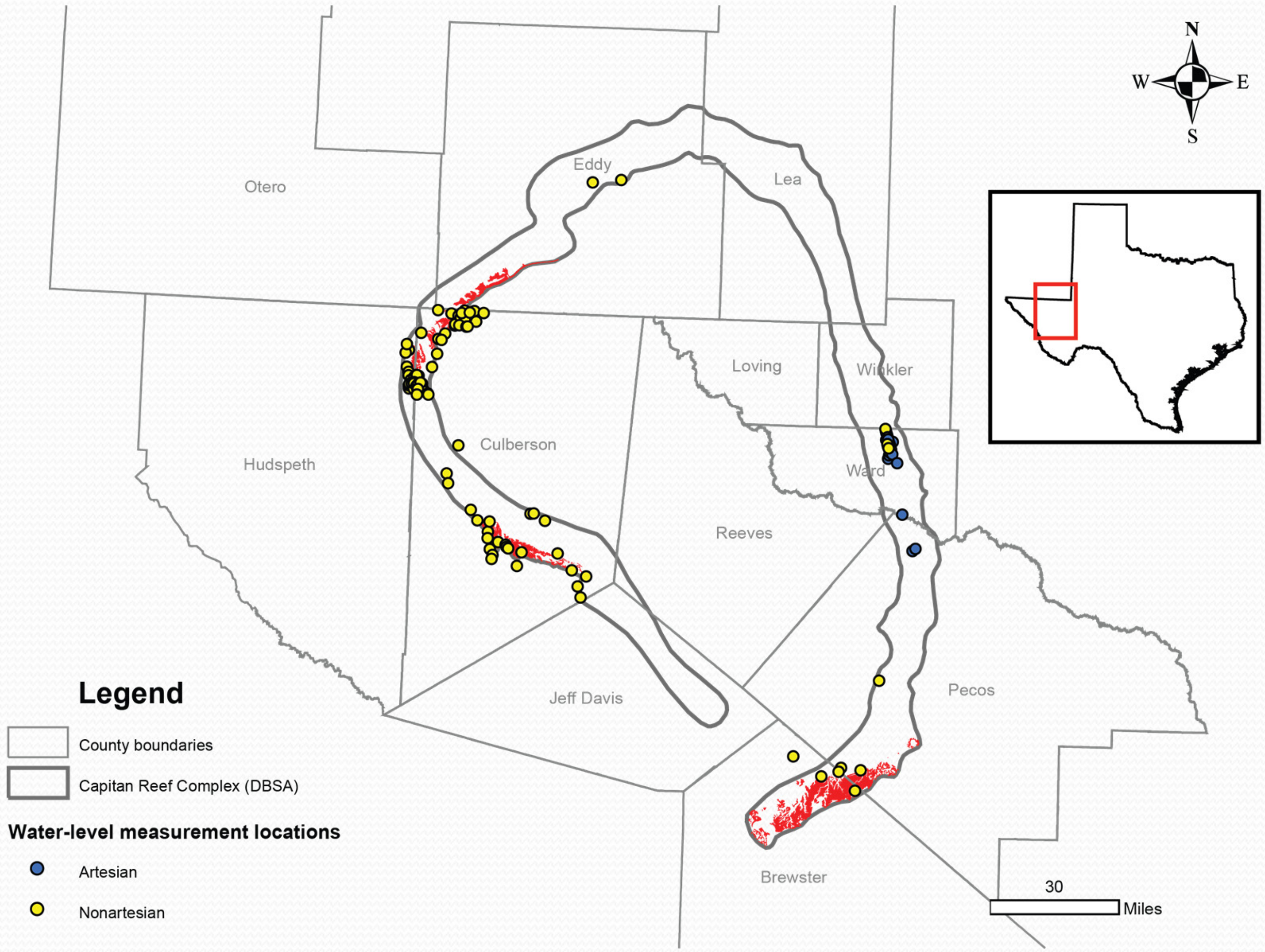


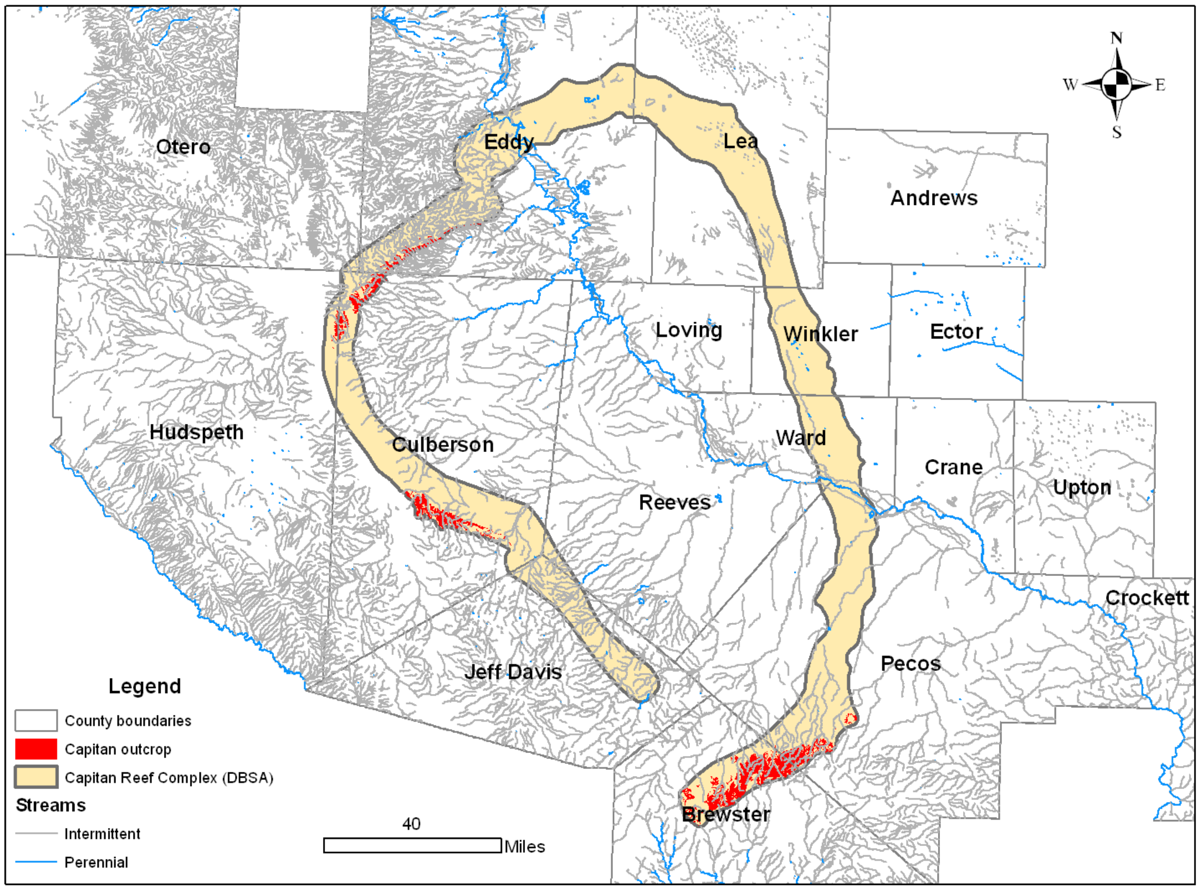
Artesian Wells



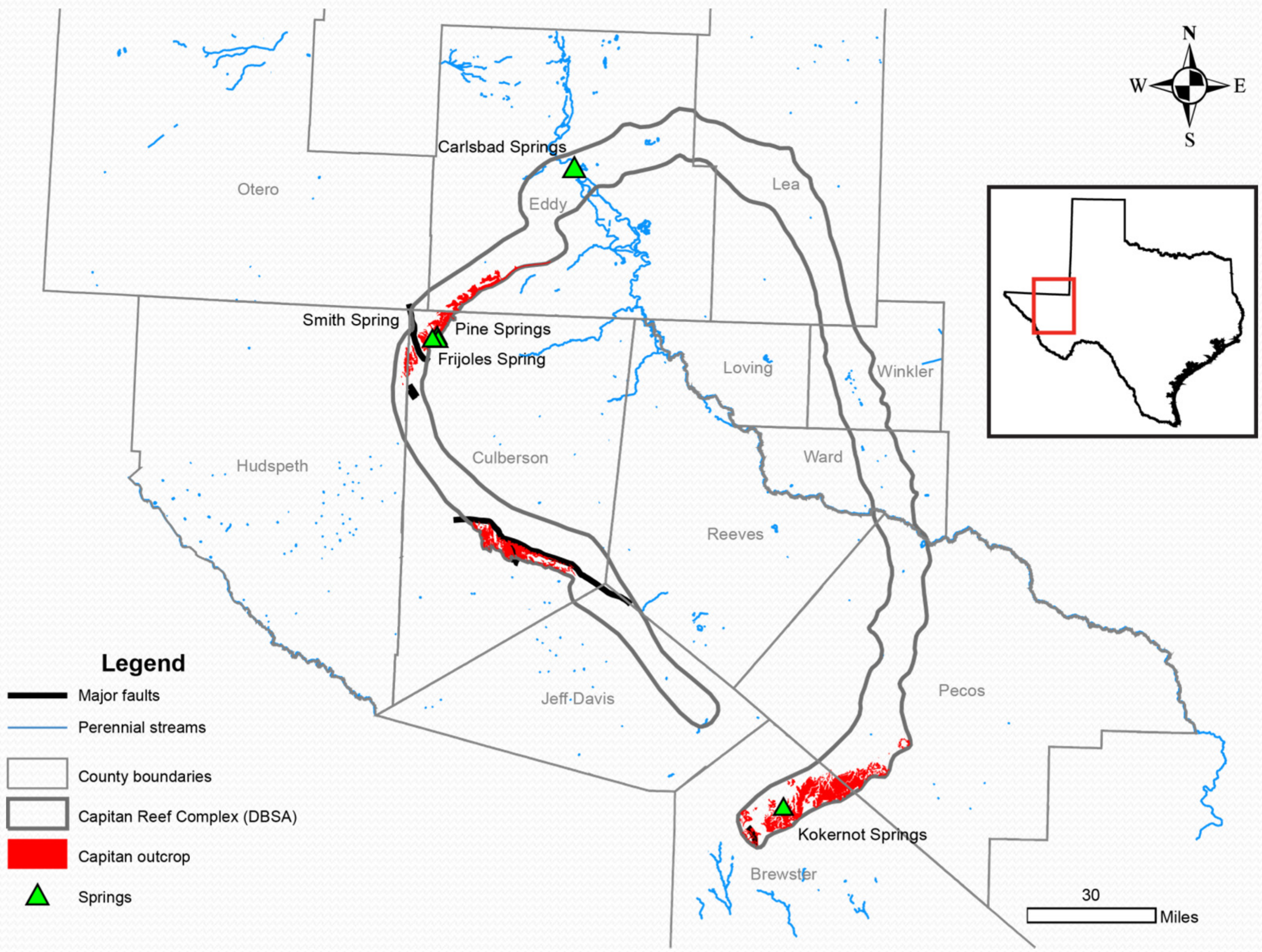
Recharge/Discharge

- Used to develop a conceptual water balance as part of conceptual model development
  - Outcrop water balance
  - Boundary flows and spring flow
  - Groundwater chemistry
    - Flow paths
    - Recharge distribution

Surface Water



Springs


N
W
E
S
Carlsbad Springs
Otero
Eddy
Lea
Smith Spring
Pine Springs
Frijoles Spring
Loving
Winkler
Hudspeth
Culberson
Ward
Reeves
Pecos
Jeff-Davis
Kokernot Springs
Brewster
30
Miles
Legend
Major faults
Perennial streams
County boundaries
Capitan Reef Complex (DBSA)
Capitan outcrop
Springs

Groundwater Isotopes

- Carbon-14 (^{14}C)
  - Relative age of groundwater
  - Indicates recent recharge
- Carbon-13 ($\delta^{13}C$)
  - Progressively changes from soil to rock compositions along flow paths
- Stable Hydrogen (δD) and Oxygen ($\delta^{18}O$)
  - Seasonal and/or spatial distribution of recharge
  - Source of recharge water
- Tritium (^{3}H)
  - Relative age of groundwater
  - Indicates recent recharge

GROUNDWATER MODELING

Definition

- A mathematical device that represents an approximation of an aquifer *(The Compendium of Hydrogeology)*
- Simulation of groundwater flow by means of a governing equation used to represent the physical processes that occur in the aquifer, together with equations that describe heads or flows along the boundaries of the model *(Anderson and Woessner, 2002)*

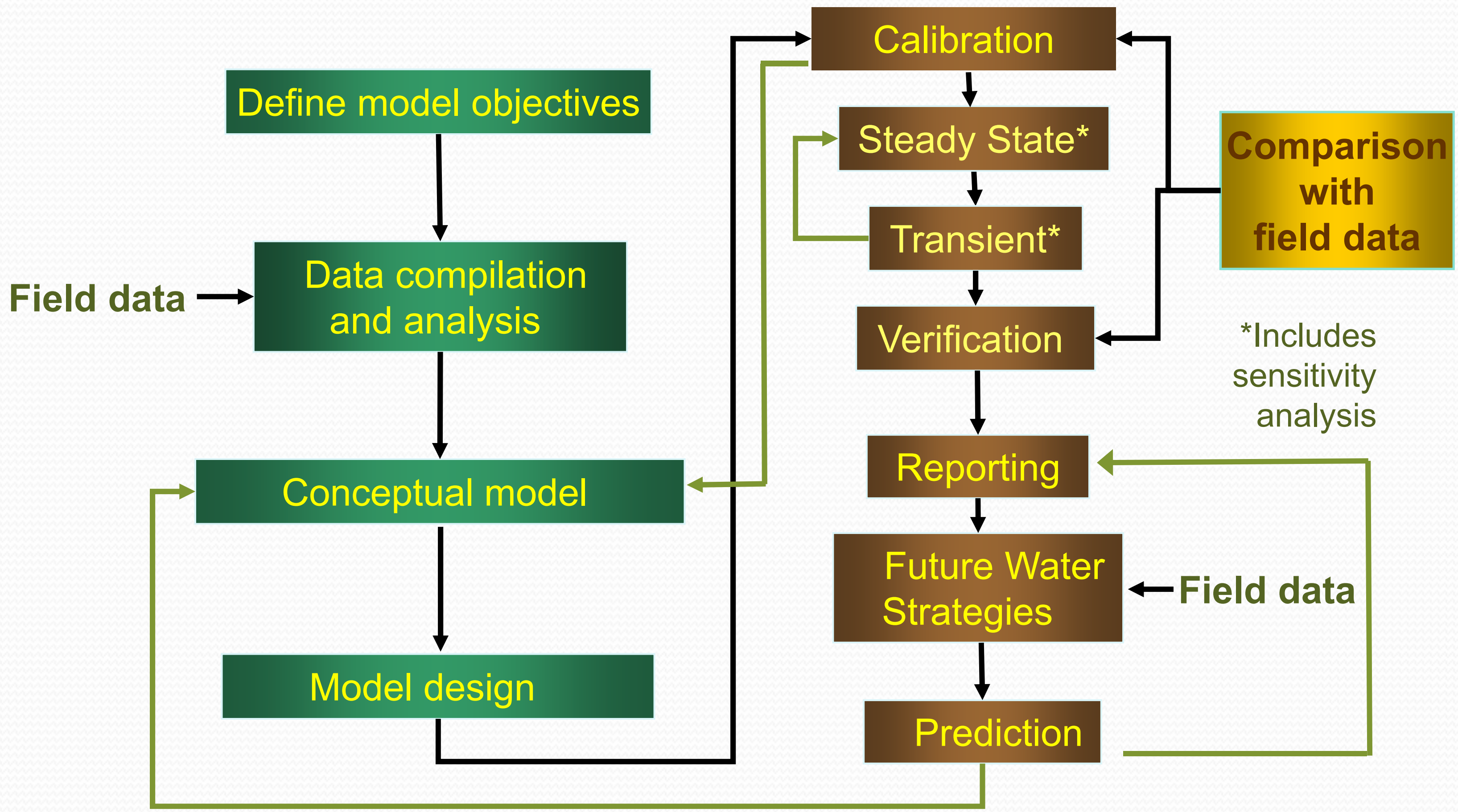
Why Groundwater Flow Models?

- 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 only means for integrating available data for the prediction of groundwater flow at the scale of interest

Numerical Flow Model

- A numerical groundwater flow model is the mathematical representation of an aquifer
- It uses basic laws of physics that govern groundwater flow
- In the model domain, the numerical model calculates the hydraulic head at discrete locations (determined by the grid)
- The calculated model heads can be compared to hydraulic heads measured in wells

Modeling Process



Model Specifications

- Three dimensional (MODFLOW-2005 or later)
- Regional scale (1000’s of square miles)
  - Eastern arm of the Capitan Reef Complex Aquifer
- Grid spacing
  - Uniform grid – ¼ miles proposed
- Implement
  - recharge
  - groundwater/surface water interaction
  - pumping
- Calibration to observed water levels/fluxes

MODFLOW

- Code developed by the U.S. Geological Survey (USGS)
- Selected by TWDB for all GAMs
- Handles the relevant processes
- Comprehensive documentation
- Public domain – non-proprietary
- Most widely used groundwater model
  - USGS had 12,261 downloads of MODFLOW computer code in 2000
- Supporting interface programs available
  - Groundwater Vistas to be used in all GAMs

DATA COLLECTION

Data Collection

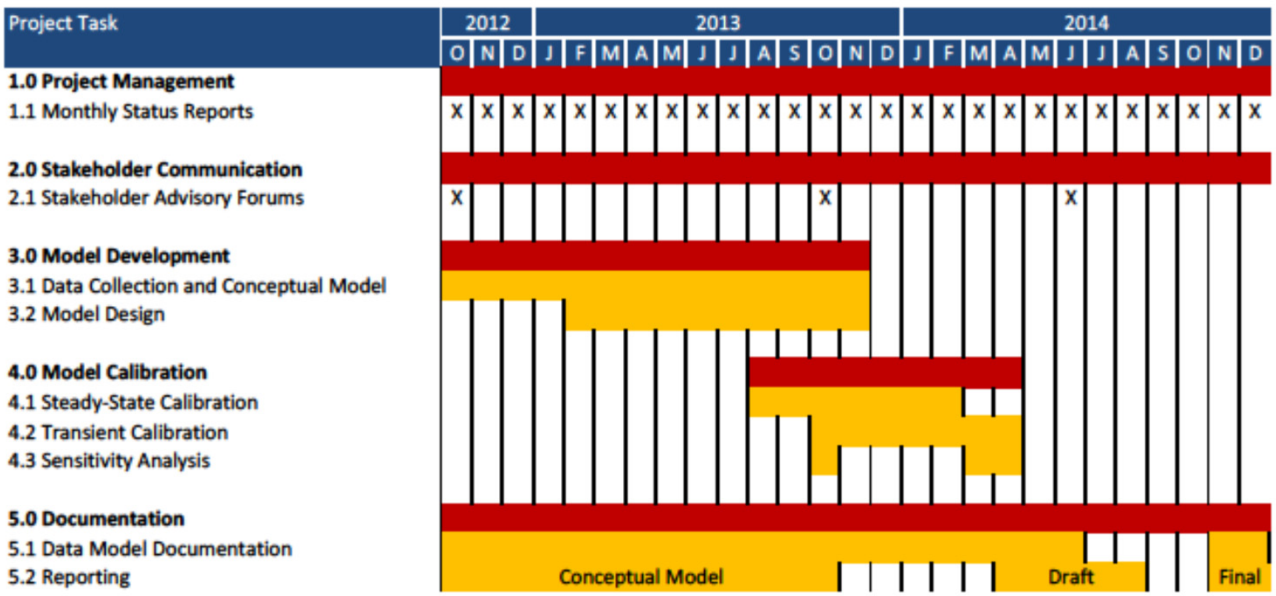
- Heads, Discharge & Water Quality Data
  - County Reports (predevelopment)
    - Evidence of artesian wells
    - Evidence of flowing springs
  - TWDB groundwater database
  - GCDs
  - Thesis work
  - Other literature

Data Collection

- Hydraulic Properties
  - County reports
  - Meyers
  - TCEQ Surface Casing Database
    - Typically specific capacity tests
  - GCD
  - Literature/Thesis
  - Stakeholders

PROJECT SCHEDULE

Project Tasks and Proposed Schedule



Data Request

- Request:
  - Unpublished data to support the model
    - Water levels
    - Pump test results
- Deadline:
  - February 2013

Contact Information

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Texas Water Development Board

P.O. Box 13231

Austin, Texas 78711-3231

Web information:

www.twdb.texas.gov/groundwater

Meeting Minutes for the First Capitan Reef Complex Aquifer Groundwater Availability Model Stakeholder Advisory Forum

October 25, 2012

Pecos County Courthouse, Fort Stockton, Texas

The first Stakeholder Advisory Forum (SAF) for the Capitan Reef Complex Aquifer Groundwater Availability Model (GAM) was held on Thursday, October 25, 2012 at 11:00 AM at the Pecos County Courthouse located at 103 West Callaghan Street in Fort Stockton. A list of meeting participants is provided at the end of this meeting note.

The purpose of the first SAF was to provide an introduction to the Capitan Reef Complex Aquifer and to solicit input from stakeholders including any available data that could be made public in support of this modeling project. The meeting also provided a forum for discussing the project schedule and provided an opportunity for feedback from stakeholders.

SAF Presentation: Ian Jones, Ph.D., P.G., TWDB

Dr. Jones presented a prepared presentation structured according to the following outline:

1. Introduction to Groundwater Availability Modeling Program;
2. Regional Overview;
3. Basics of Groundwater Flow;
4. Overview of Capitan Reef Complex Aquifer;
5. Groundwater Modeling;
6. Data Collection; and
7. Project Schedule.

Questions and Answers:

Question: What does Modeled Available Groundwater (MAG) equal?

Answer: The Groundwater Management Areas (GMAs) determine Desired Future Conditions (DFCs) for their aquifer(s), and based on these DFCs we run the model, and come up with the MAG, which is basically a pumping rate, which is based on that determined DFC.

Follow-up Question: Yes, but what is that used for? I don't think many in this room [know] what the MAGs are, and how they're used.

Follow-up Answer: [The MAGs are used by the regional planning groups as the amount of water available to use in the planning process i.e. total supply values. The MAGs are also provided to the GCDs to consider when issuing permits. The MAGs and the groundwater availability models are not regulatory: they should be considered more like tools for planning purposes.]

Question: So, if the permitting is based on it, it then becomes a regulatory model?

Answer: Yes.

Question: Is there a general [unintelligible] now?

Answer: These are regional models, so you don't want to use a regional model to address some very localized issue. So, they're more big-picture models not for, let's say, trying to simulate flow to, say, a small spring. That would not be appropriate.

Follow-up Question: At what level of area is it appropriate or inappropriate?

Follow-up Response: The Texas-wide answer would be county-scale. Where there are very large counties – it'd be less than that. So over, let's say, several square miles. Not a very small area.

Question: Can you determine that based on the data that you have, that build the model on? Can you do sensitivity to determine what size, what level is appropriate or not?

Answer: During the process? Yes. It all depends on the resolution that you get from the grid size, also there's a certain amount of uncertainty associated with how much data you are able to collect to input into the model. All of that goes into determining what scale is appropriate.

Question: So will you all make that determination?

Answer: During the process, yes.

Question: What would the head of a flowing Capitan well be?

Answer: It's the elevation that the water in the artesian well would rise to. Many times one ends up getting some sort of pressure measurement, which then gets converted ultimately into a water level elevation.

Question: Why are you modeling only the Eastern arm of the Capitan reef?

Answer: There is a model of the Bone Spring/Victorio Peak, which included parts of the western arc. We'll have to make a final determination as to where the cutoff will be. That hasn't been decided yet.

Question: You haven't decided on the boundary of the model yet, as far as the northern extent?

Answer: We haven't made a final decision on the northern extent.

Comment: The flow coming out of the Guadalupe Mountains and coming all the way around down into Ward County – that actually comes out to Pecos River there, there's a saline barrier, so there is no flow across that. That's water coming in from the northwest shelf that feeds into the reef. It's a more brackish water. Throughout that section one of your biggest challenges will be the cross-formational flow, and also getting all the pumping from the O&G industry – the only real stress on this system, so far. There's been a lot of it.

Question: What about karst, of which there is a lot in this system? Do you have any ideas on modeling that?

Answer: Again, it depends on how much data we have. Right now, it's too scattered to be very specific in terms of where you have specific conduits and stuff like that. So, probably karst will be represented based on just relatively high hydraulic conductivities of the limestone versus the surrounding rocks.

Follow-up Response: There is a lot of data that *(William)* Hiss never used in his publications on the Capitan Reef Complex.

Question: You said the projected package deal will be available in 2014?

Answer: The final report, yes.

Question: When will your next SAF meeting be held?

Answer: The next stakeholder meeting will be tentatively in October of next year. That meeting is to discuss the conceptual model. That meeting will be held just before the conceptual model report is submitted.

Question: Are you equally going to address the recharge implications of the Capitan just as aggressively as water levels and such?

Answer: Yes.

Capitan Reef Complex Aquifer GAM Stakeholder Advisory Forum 1

October 25, 2012

Attendance

Name	Affiliation
Steve Finch	John Shoemaker & Associates
Jeff Williams	Williams Ranch
Darrell Peckham	Water Quest, Inc.
Gil Van Deventer	Trident Environmental
Glenn Honaker	Belding Farms
John Brocksch	Aquifer Group LLC
Paul Weatherby	Middle Pecos GCD
Cole Walker	CRMWD
Mitch Holmes	CRMWD
Mark Dobson	DNA Geosciences, Inc.
George Riggs	Pecos County
Janet Groth	Middle Pecos GCD
Radu Boghici	Texas Water Development Board
Ian Jones	Texas Water Development Board