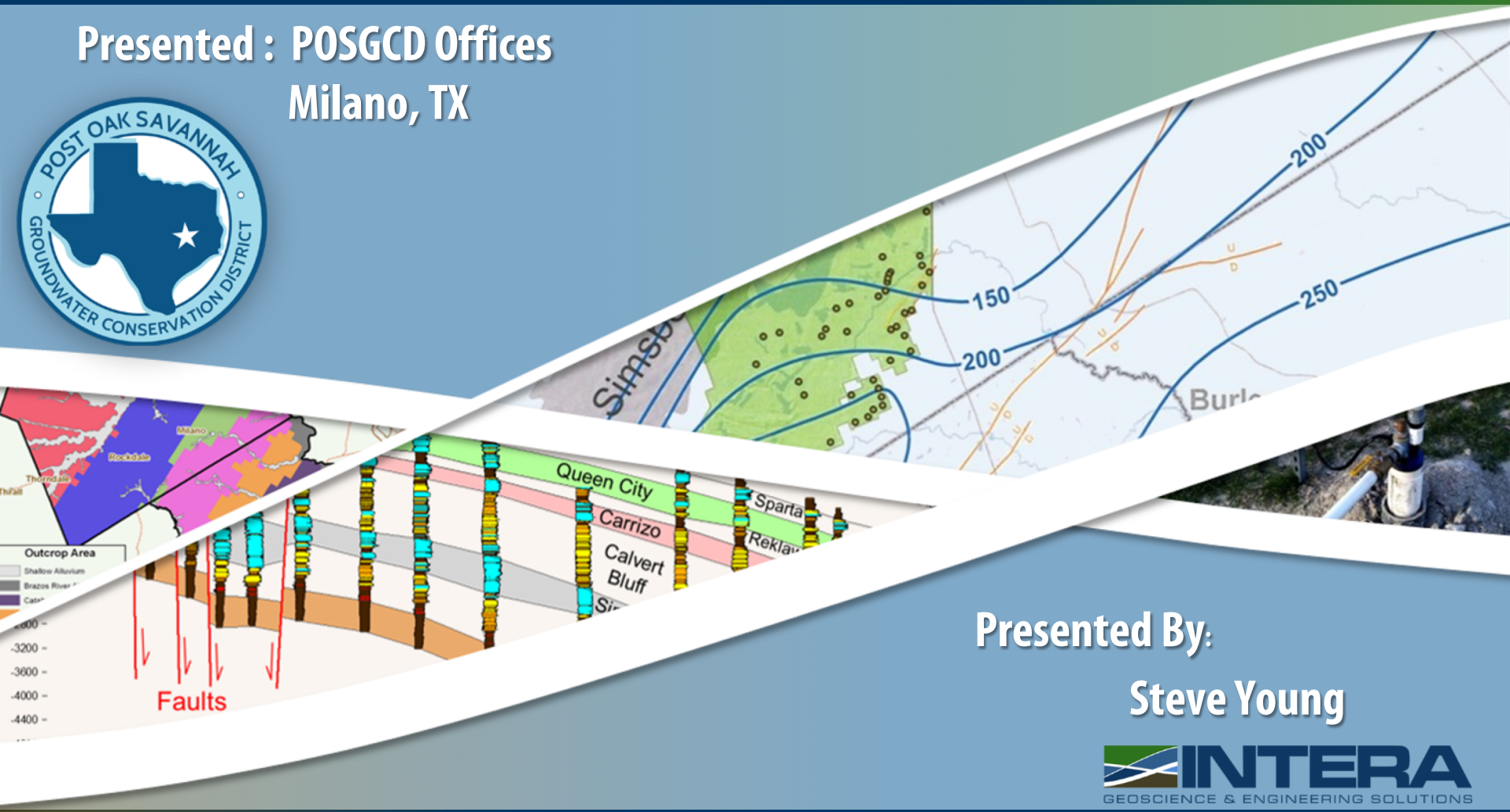
Assessment and Management of Groundwater Resources

Presented : POSGCD Offices
Milano, TX



Presented By:
Steve Young
INTERA
GEOSCIENCE & ENGINEERING SOLUTIONS

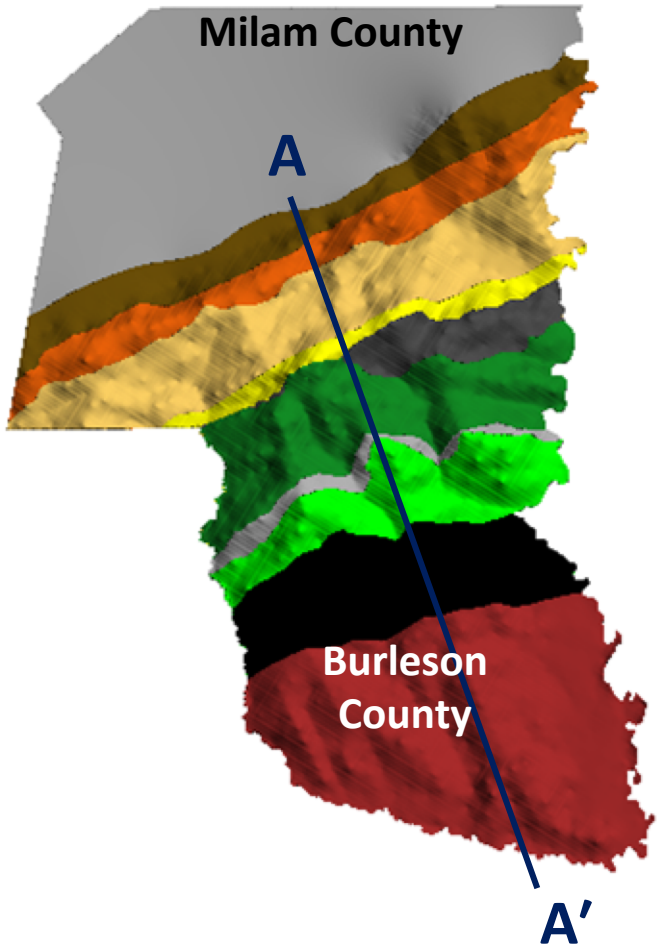
October 23, 2018

Introduction to Carrizo-Wilcox Aquifer

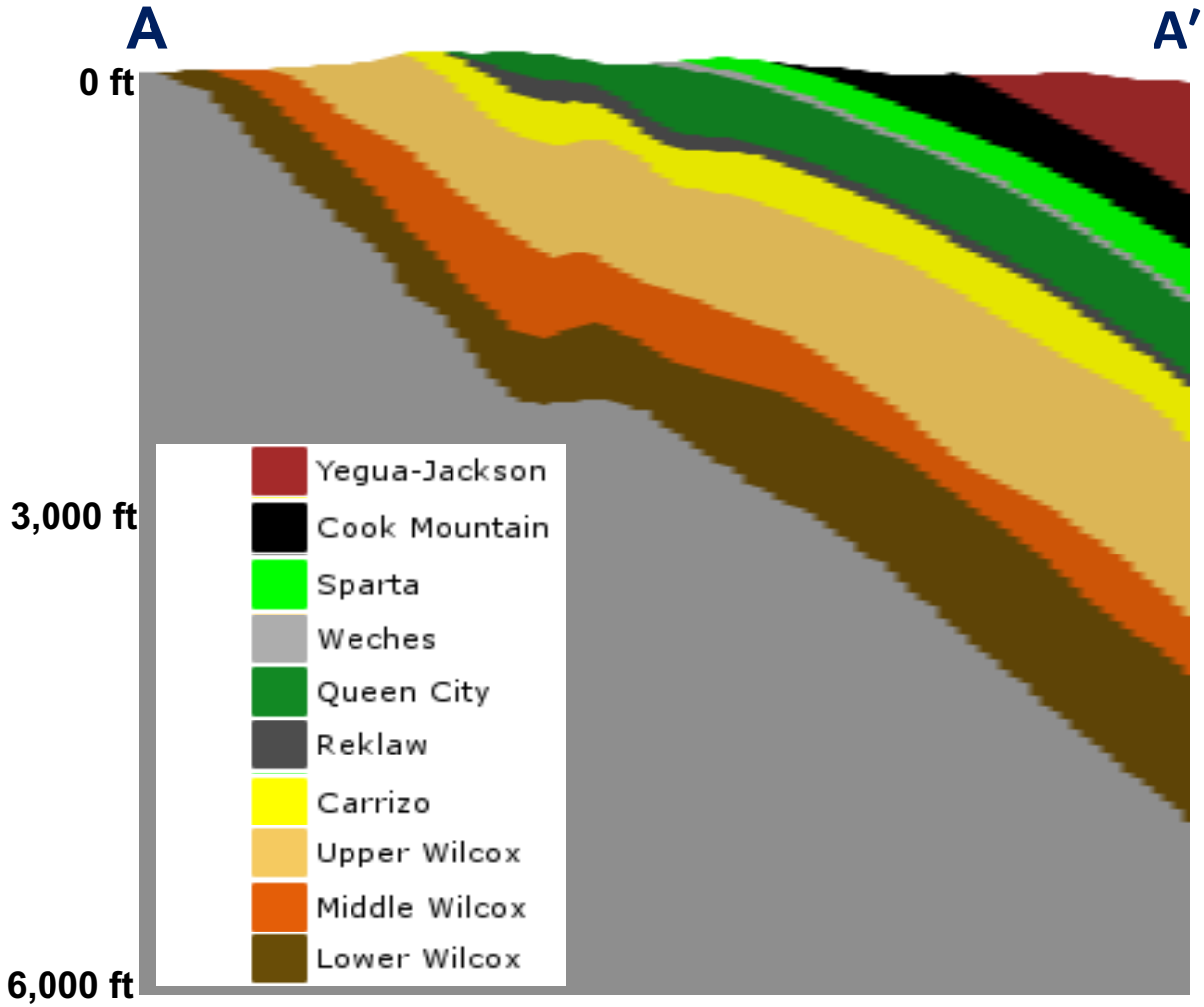
- Structure
- Faults
- Hydraulic Properties

POSGCD Aquifers

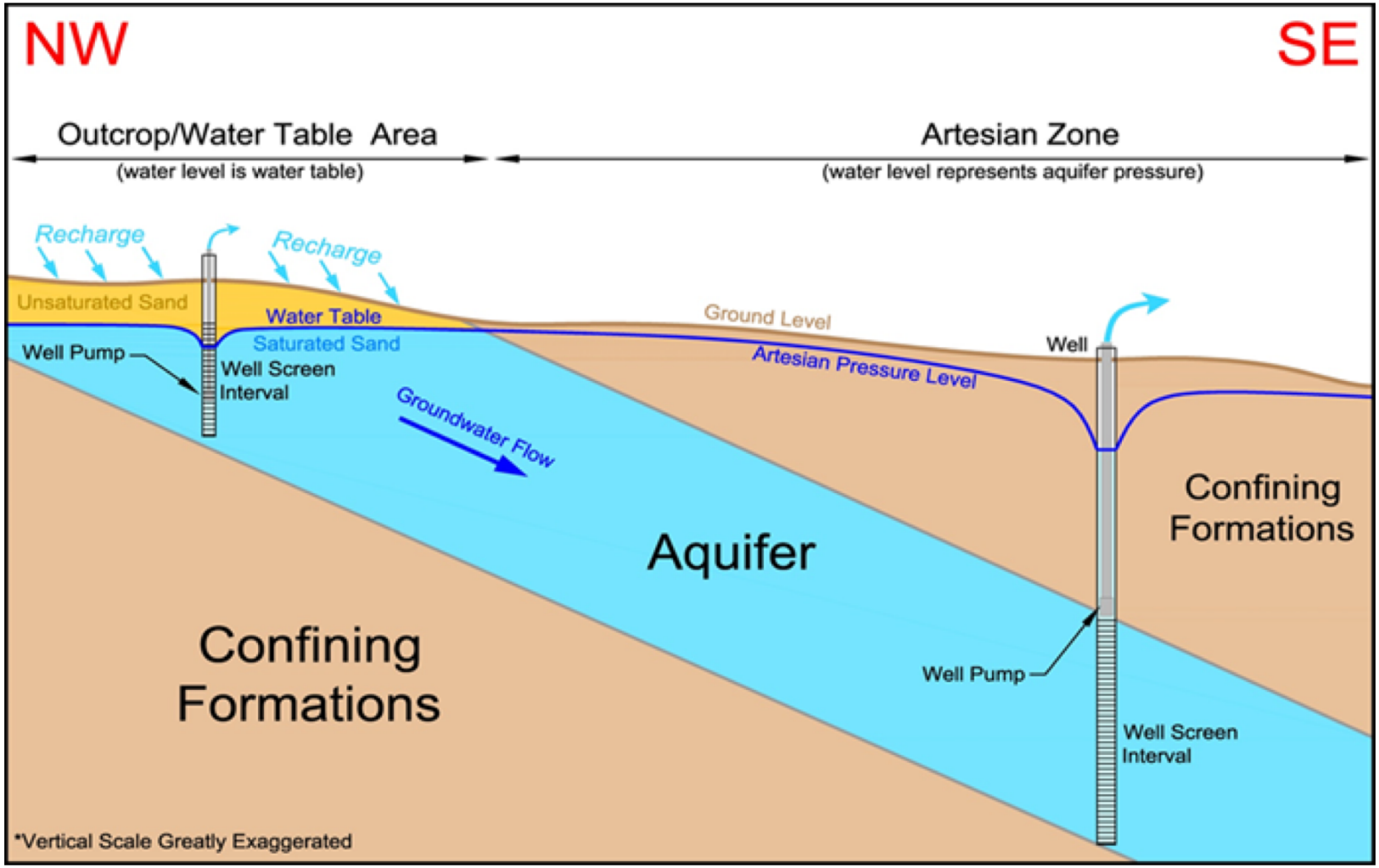
Aerial View
Outcrop of Different Aquifers



Vertical Cross-Section View Looking From Side

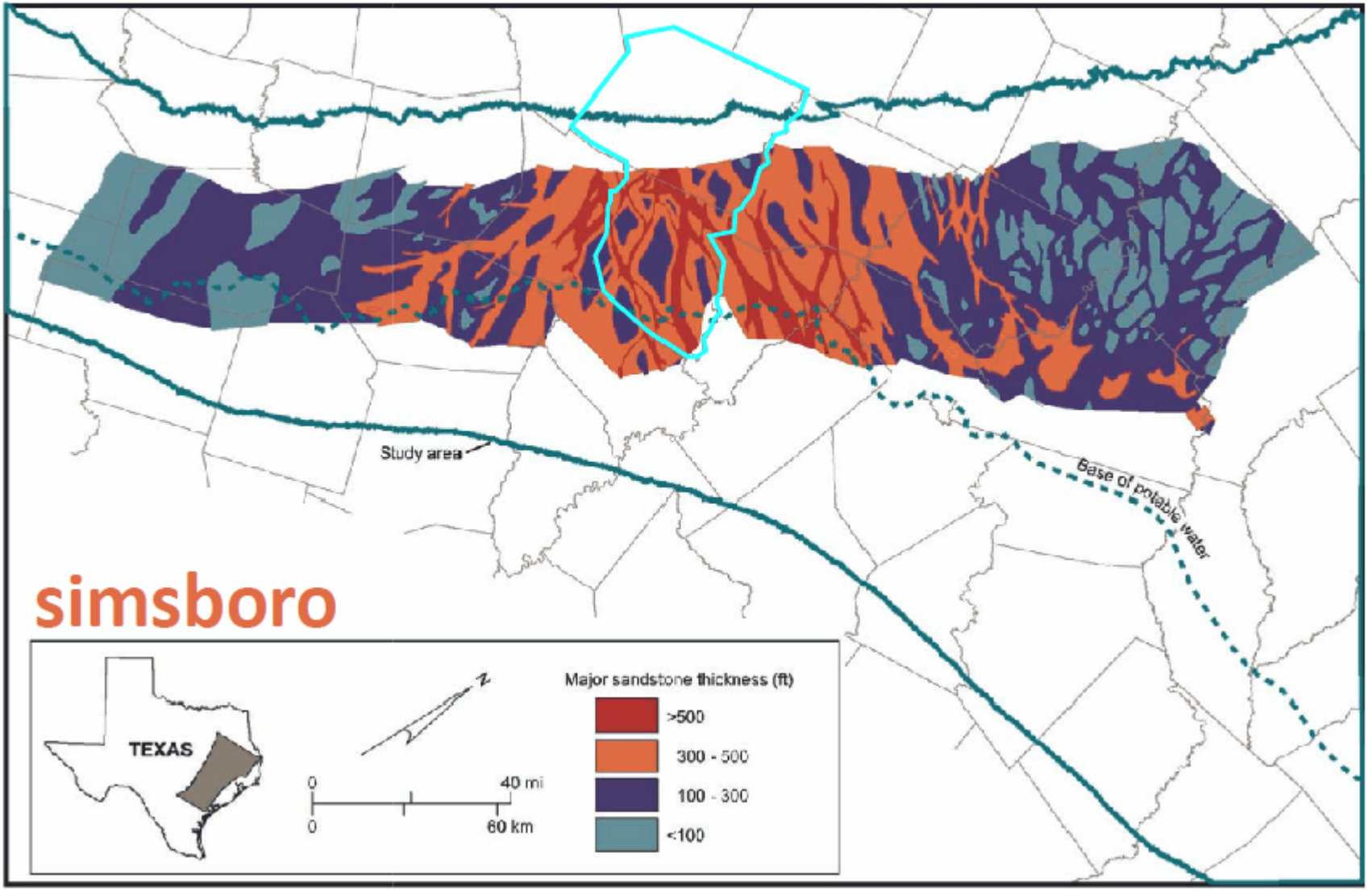


Unconfined and Confined Aquifer Conditions



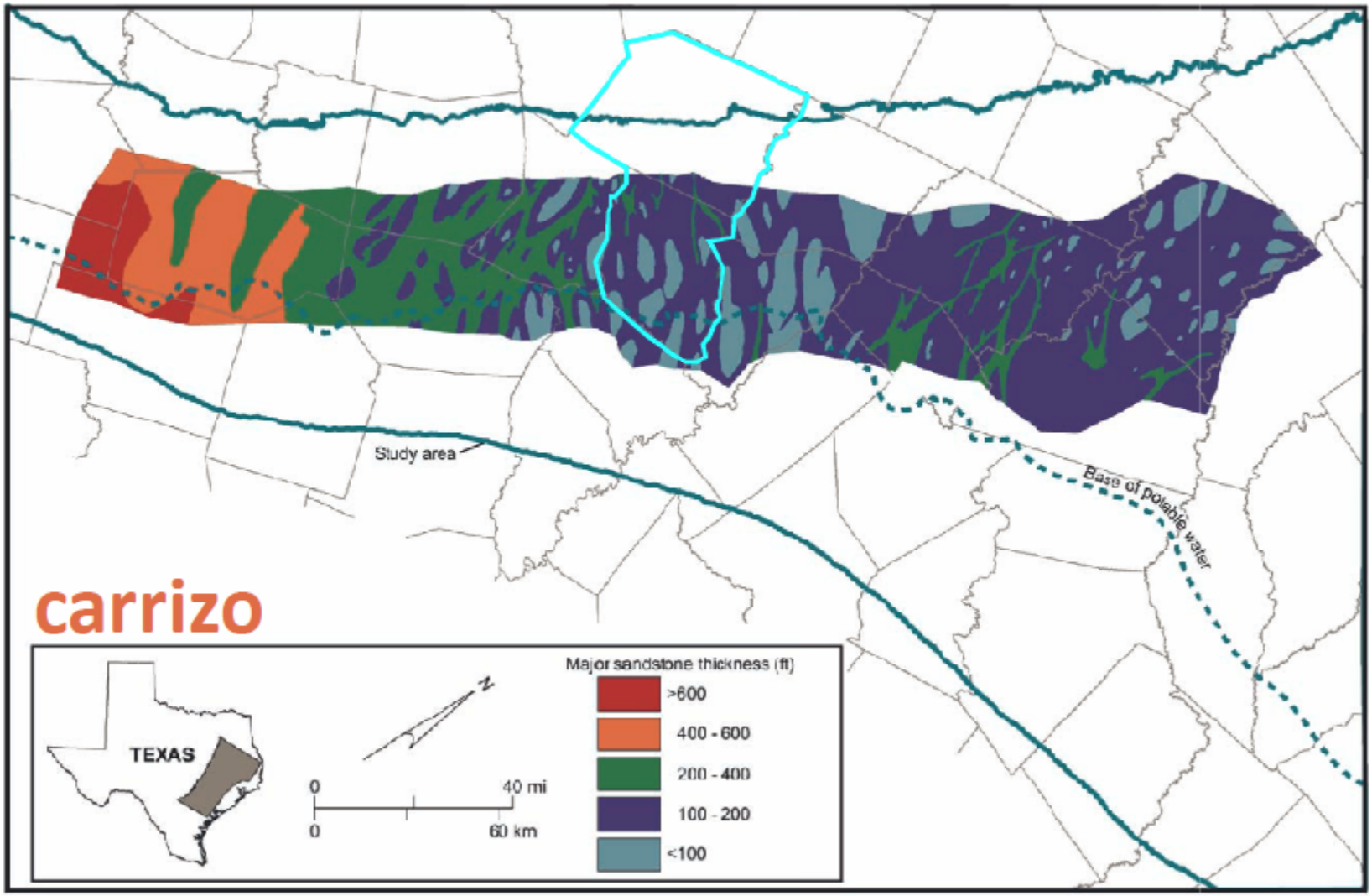
Modified from RW Harden (June, 2016)

Simsboro (Middle Wilcox) Thickness*



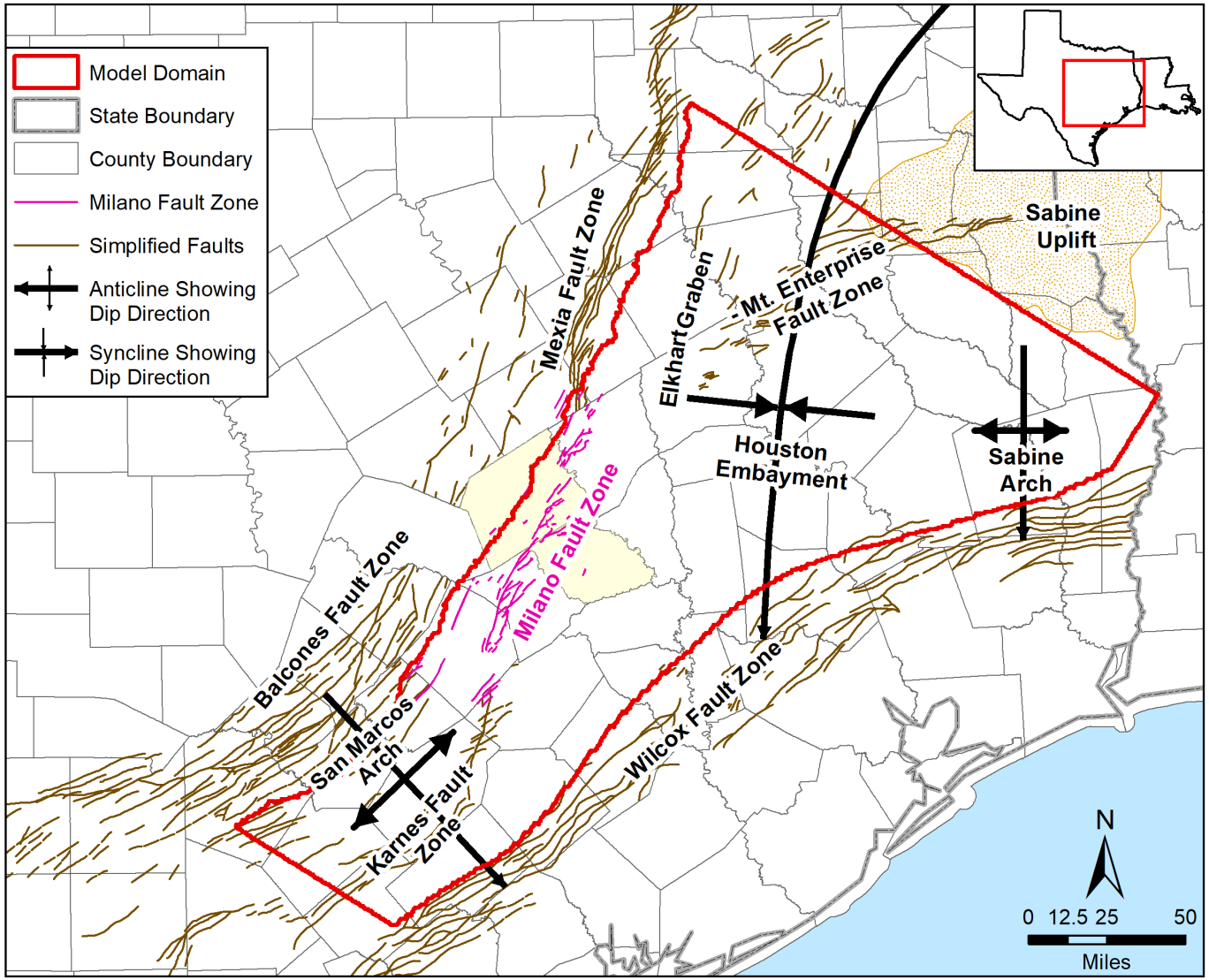
* From Dutton and others (2003)

Carrizo Thickness*

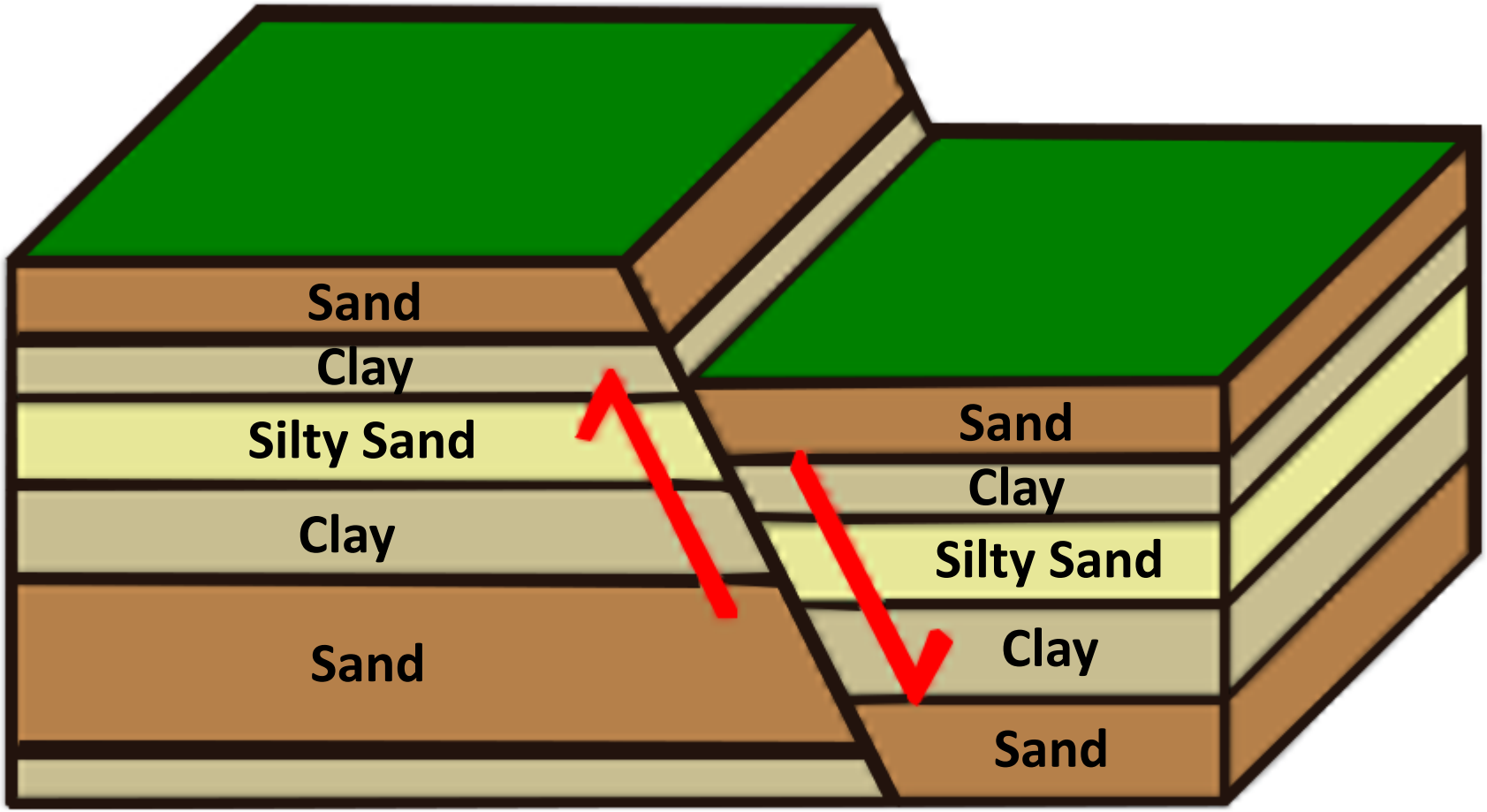


* From Dutton and others (2003)

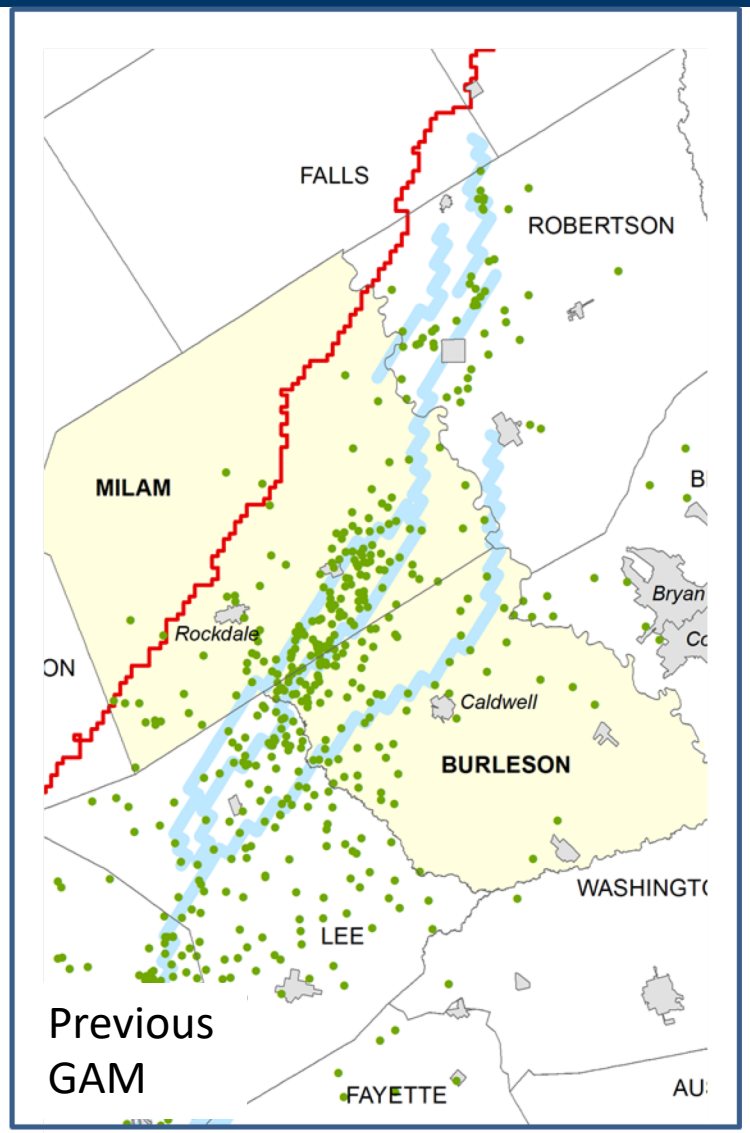
Fault Zone of Interest

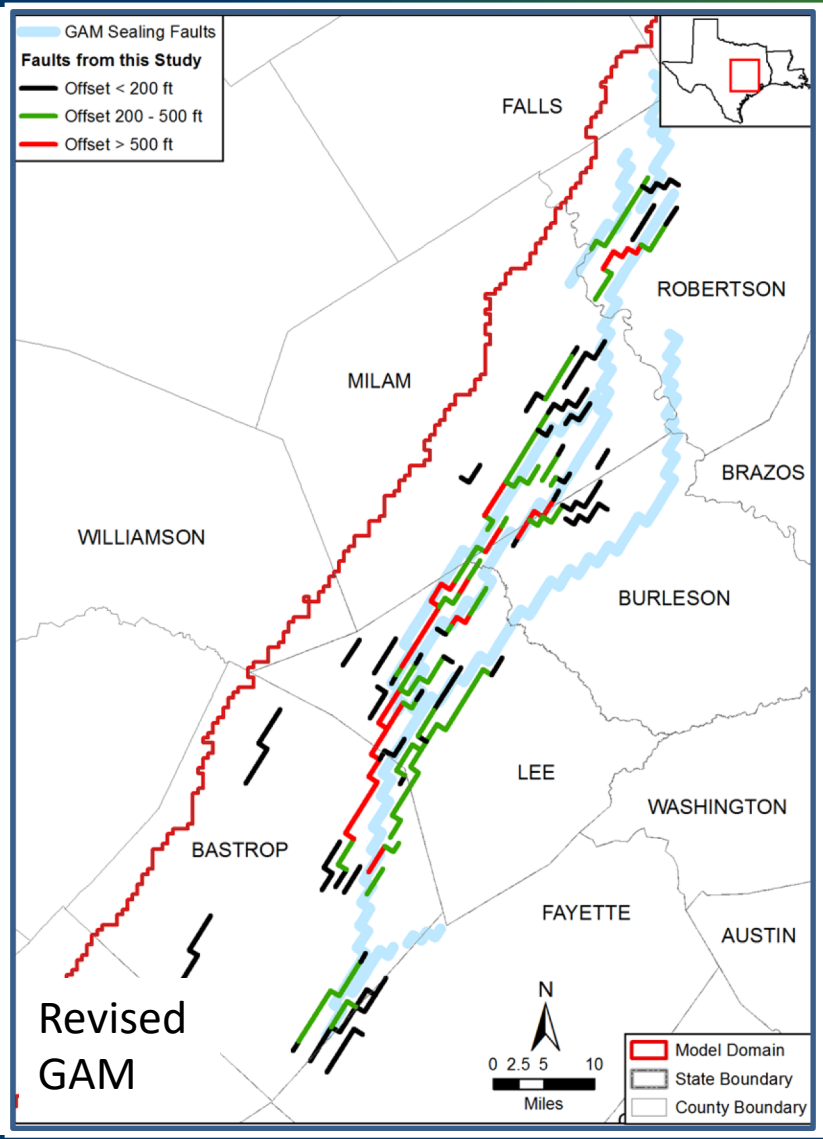


Normal Fault



Fault Locations





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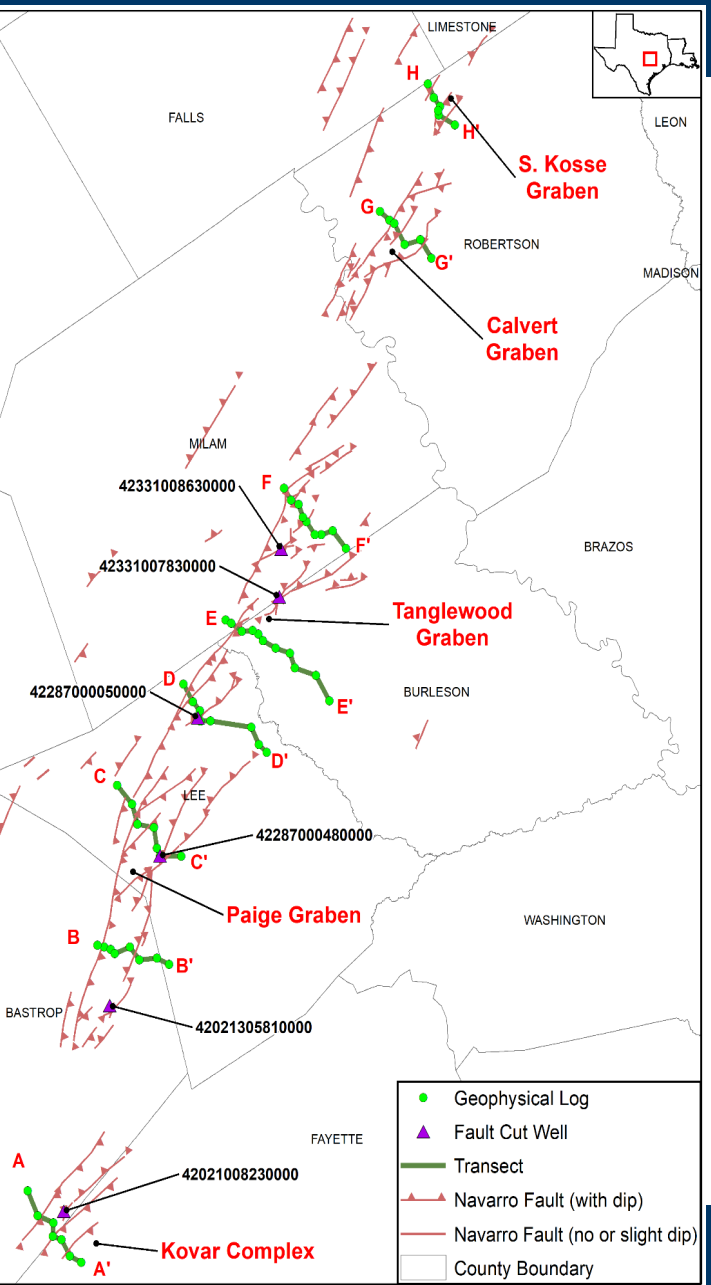
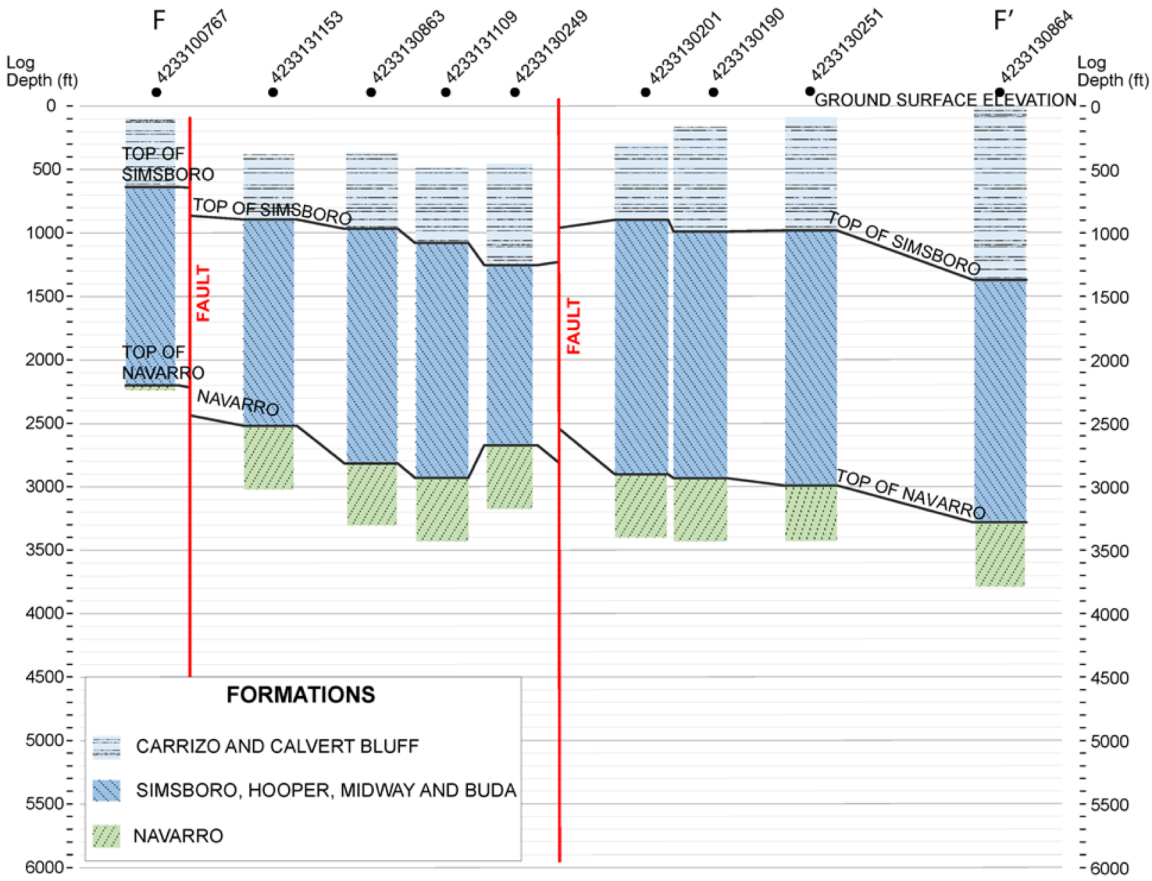
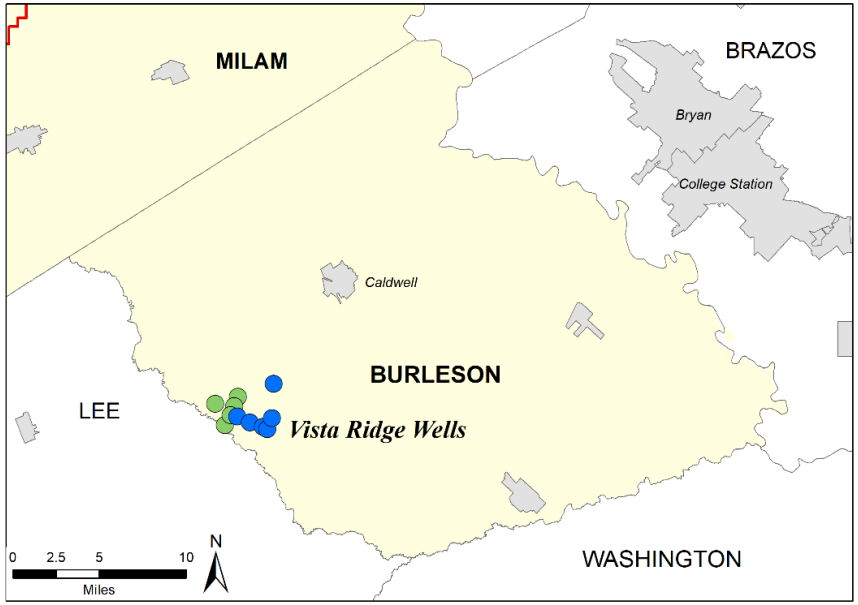
Estimated Fault Locations





Vista Ridge Pumping Tests

Well	Aquifer	Estimated Transmissivity (gpd per foot)
CW-2	Carrizo	25,600
CW-3	Carrizo	17,700
CW-5	Carrizo	25,000
CW-7	Carrizo	28,000
CW-9	Carrizo	23,000
PW-10	Simsboro	127,000
PW-11	Simsboro	117,000
PW-13	Simsboro	137,000
PW-15	Simsboro	115,000
PW-16	Simsboro	100,000
PW-17	Simsboro	128,000



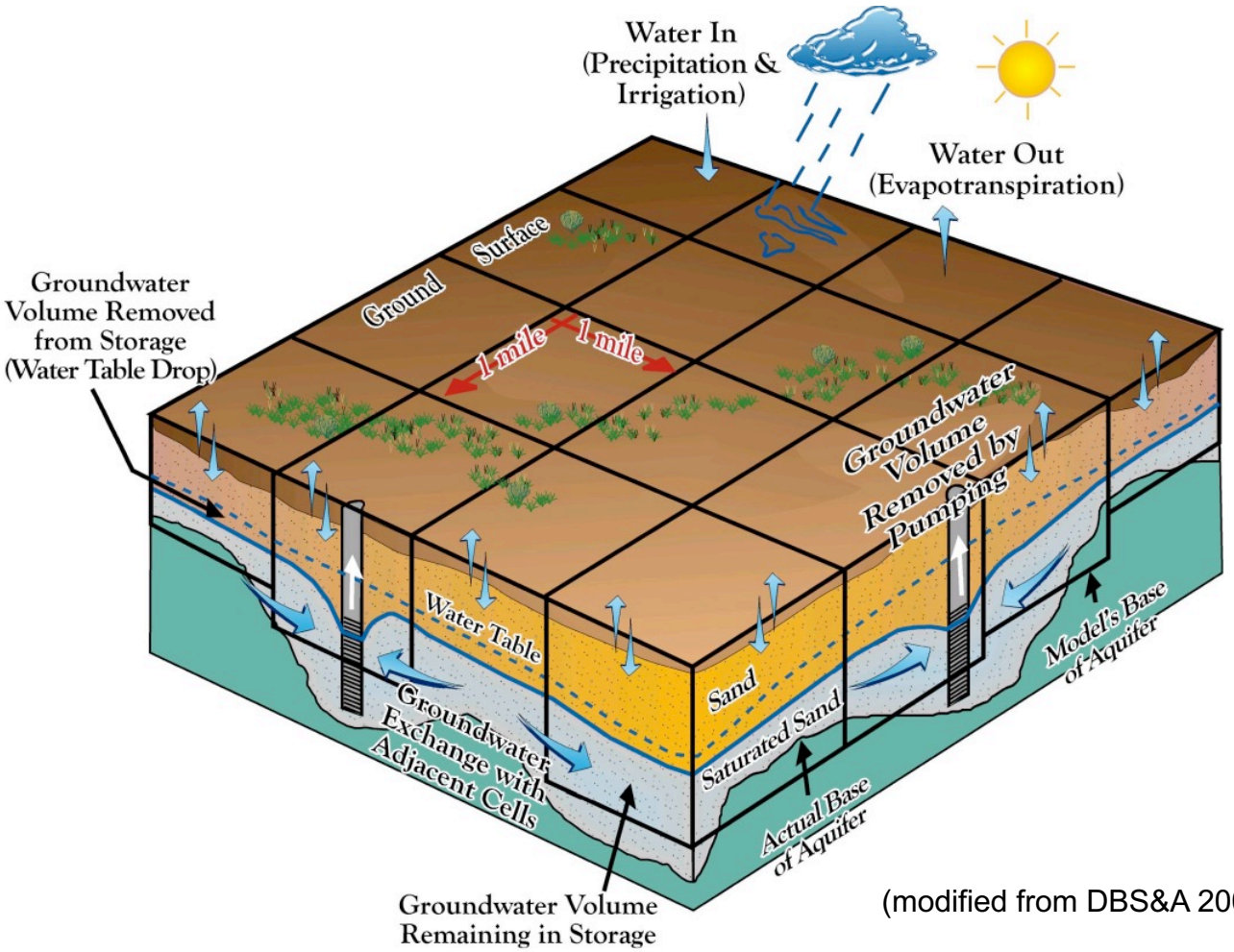
- **Pumping 100 gpm for 1 year**
  - 57 ft of drawdown in Carrizo
  - 15 ft of drawdown in Simsboro
- **Pumping 1,000 gpm for 1 year**
  - 570 ft of drawdown in Carrizo
  - 150 ft of drawdown in Simsboro

Carrizo-Wilcox Aquifer Groundwater Availability Model

- What is a Groundwater Availability Model
- Recent Updates to Groundwater Availability Model
  - Data
  - Model Calibration

What is a Groundwater Availability Model

- Simplified Representation of Real System
- Consists of grids representing blocks of aquifer
- Flow equations link blocks together like an Excel Spreadsheet



(modified from DBS&A 2001)

Groundwater Availability Models are "Living Tools"

- GAMs are updated periodically to incorporate new data as it becomes available
- "Living Tools" is a benefit that promotes continual data collection and analysis
- POSGCD Required to Use Four GAMs
  - Brazos River Alluvium GAM
  - Northern Trinity and Woodbine GAM
  - Yegua-Jackson GAM
  - Central Portion of Sparta, Queen City, and Carrizo-Wilcox GAM

Updates to Central Sparta, Queen City and Carrizo-Wilcox GAM

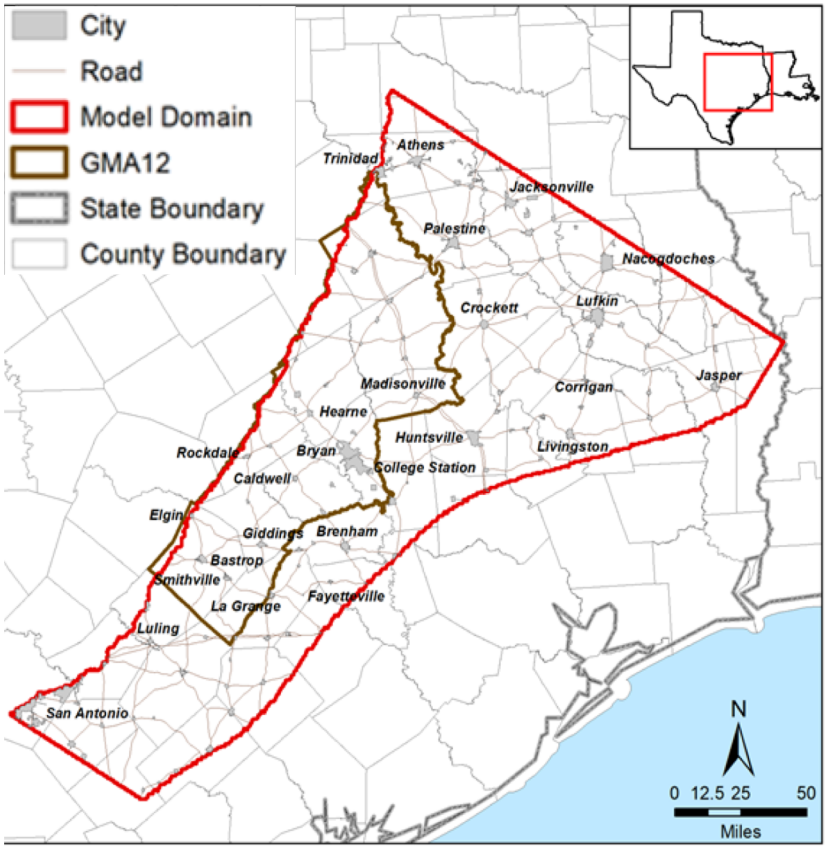
Component	Additional Information
Conceptual Model	Fault locations and types
	Recharge estimated from rainfall and surface geology
	Groundwater-surface water interaction
	Storage properties with depth and aquifer type
Data	Aquifer properties from pumping tests
	Historical pumping rates and locations
	Well locations
	Historical water levels
	Geophysical logs to check aquifer tops and bottoms
Groundwater Code	MODFLOW USG (2017) replaces MODFLOW96 (1996)
Model Construction and Calibration	Small grid cell sized near rivers
	Additional model layers
	Advance calibration software running on a supercomputer at TACC

Improved GAM Capability to Help Answer

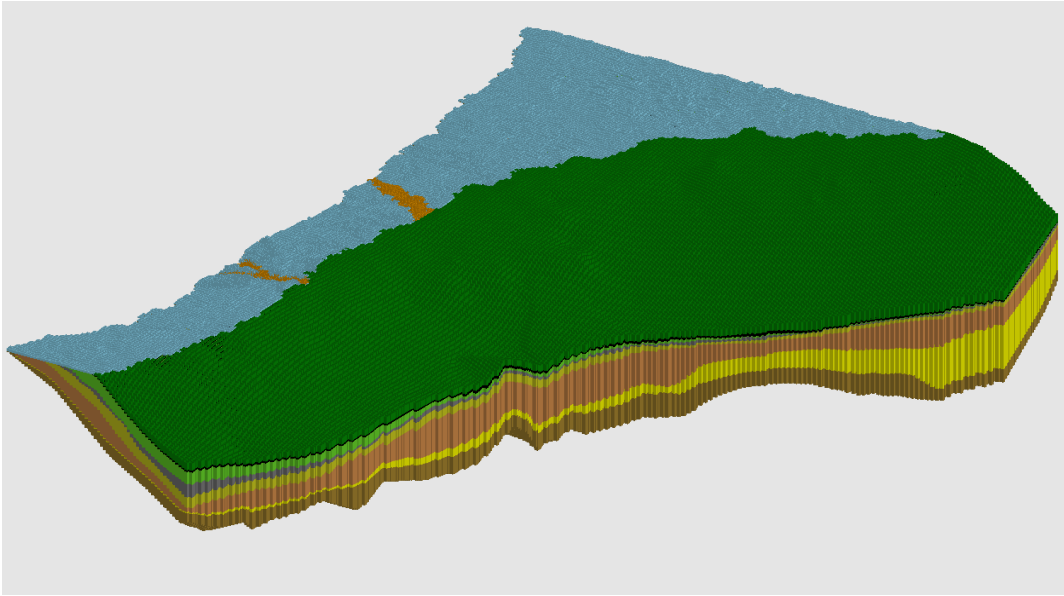
1. How productive are the aquifers?
2. How much water is stored in the aquifers?
3. How much and how fast will pumping cause water levels to change in response to pumping?
4. How much do the aquifers interact with surface water?
5. How much do the aquifers interact with adjacent aquifers?
6. How will drought impact aquifer water levels and aquifer productivity?

Model Construction

Areal Extent



Three-Dimensional View



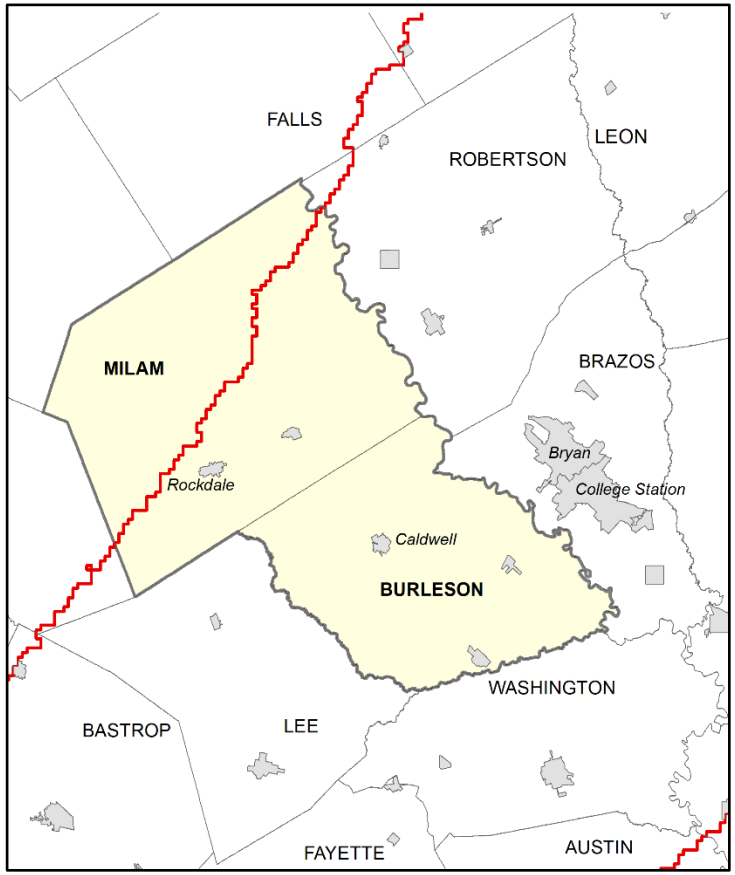
How Model was Improved

- Conducted detailed investigation of fault locations and behavior
- Updated aquifer properties using recent aquifer pumping tests
- Increased model time period for comparison to observed water levels
  - Required collection of historical pumping date for a longer time period
- Enhanced model predictive capabilities near streams
- Enhanced representation of recharge

Reason for Historical Pumping and Pumping Plots

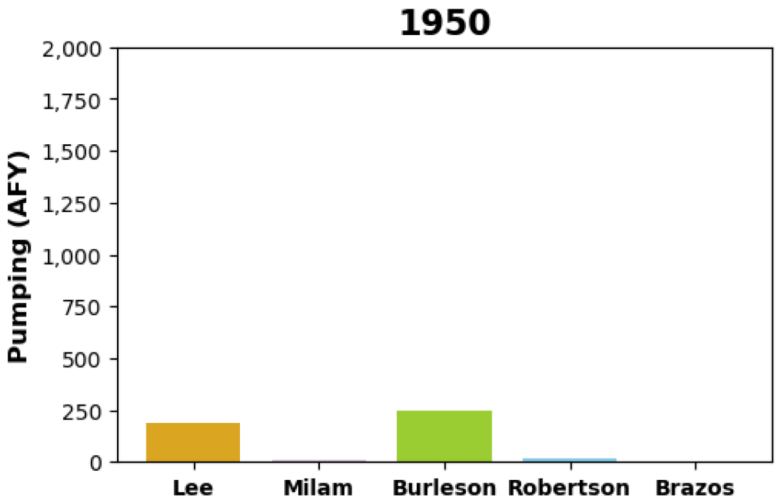
- Previous model simulated 20 years
  - 1980 through 1999
- Updated model simulates 80 years
  - 1930 through 2010
- Pumping needed for all 80 years

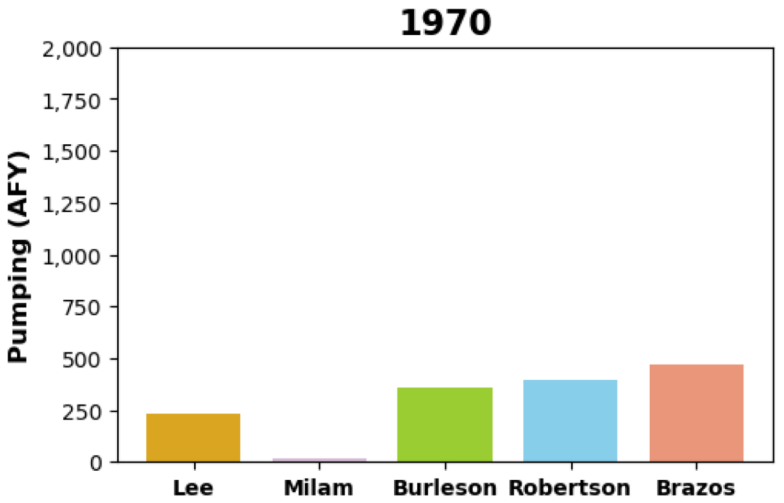
- Plots show the total pumping calculated by summing the pumping for all entities for that year

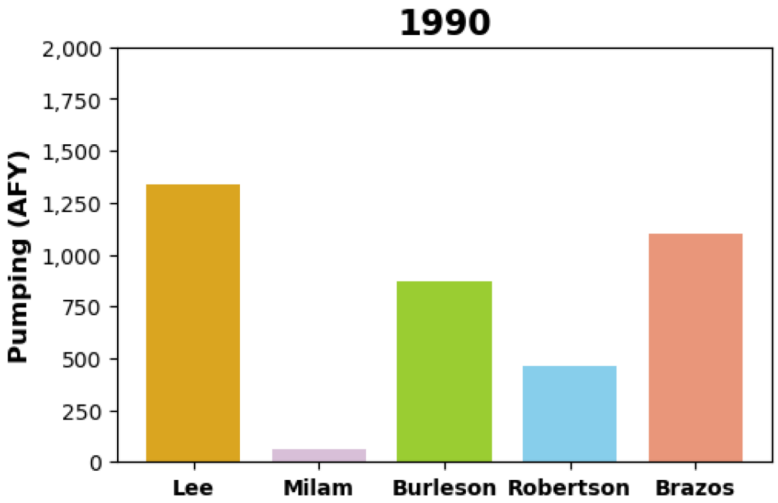


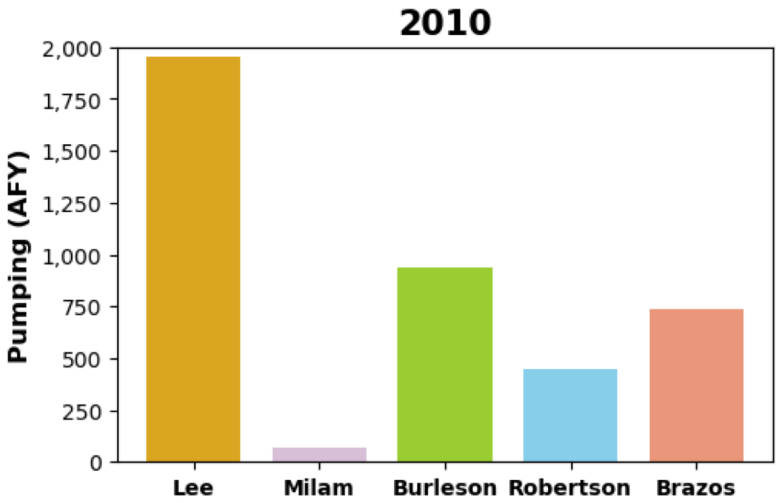
* 2016 Region C Water Plan

Historical Pumping from Carrizo Aquifer

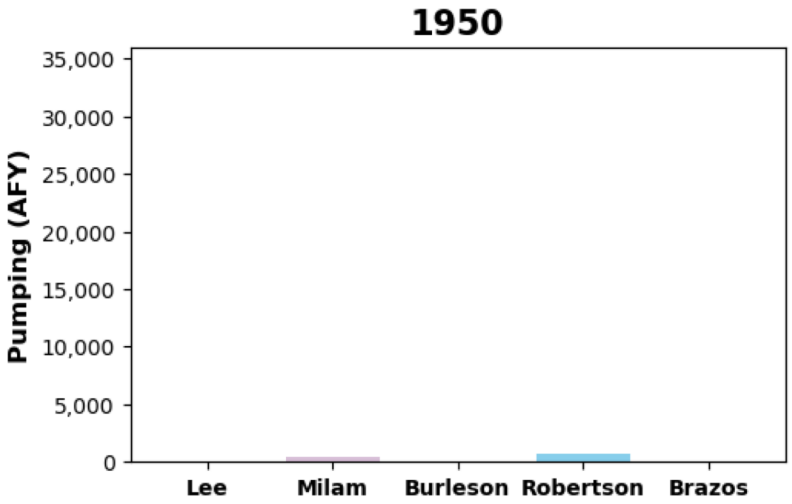


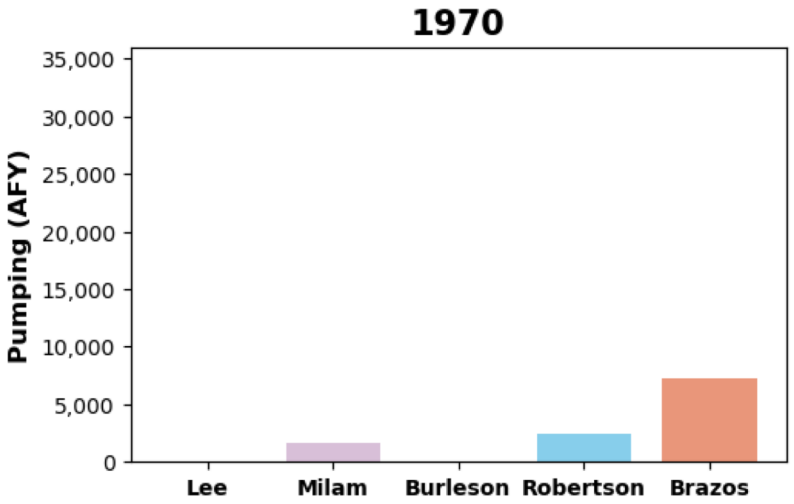


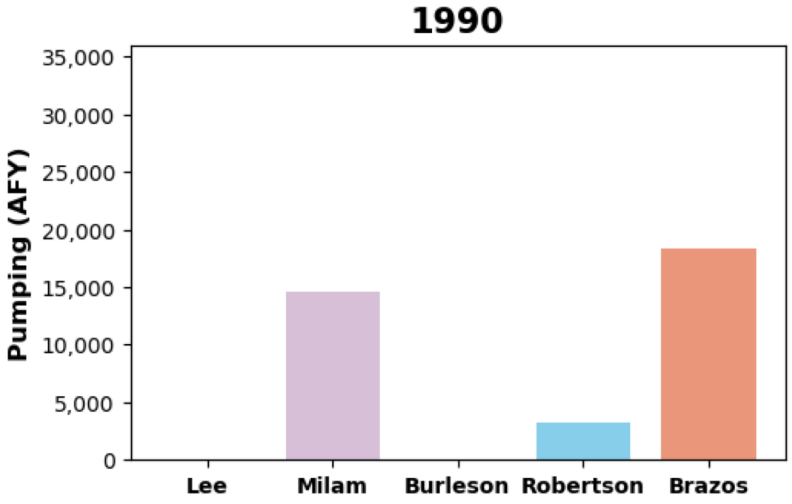


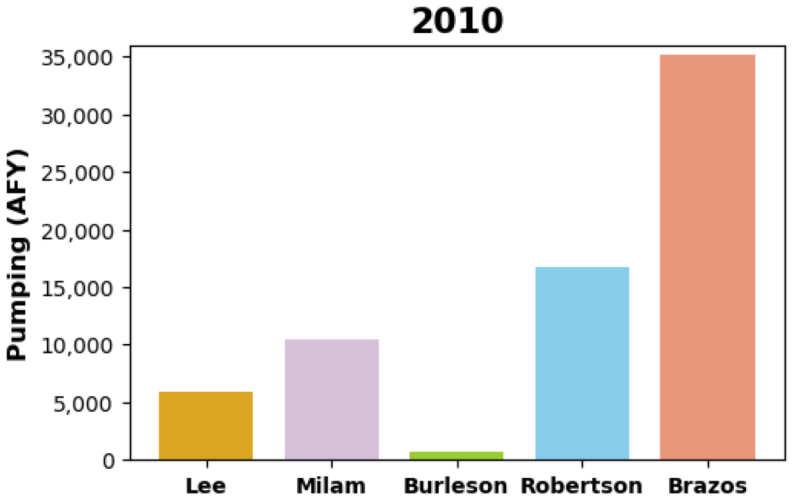


Historical Pumping from Simsboro Aquifer

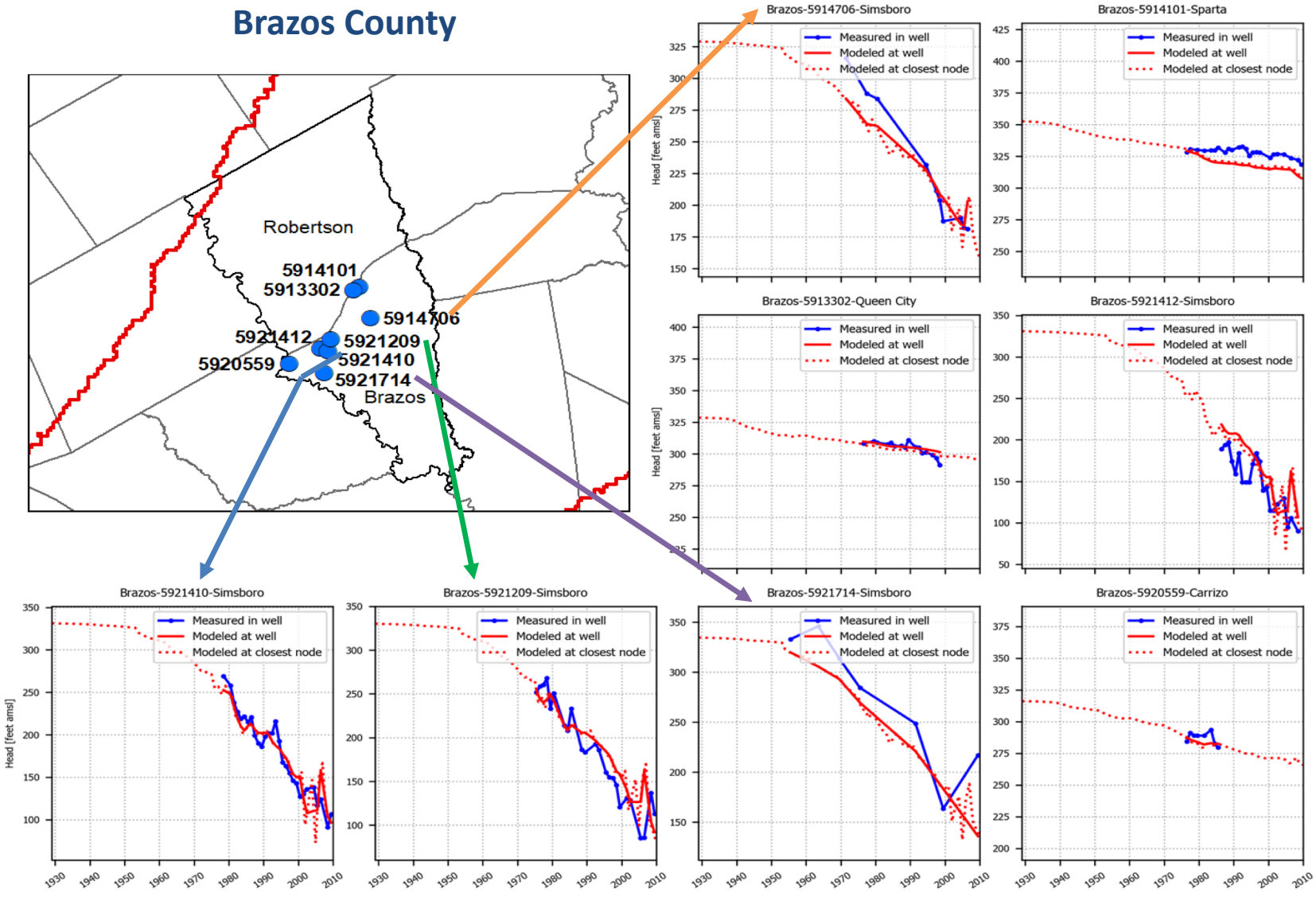






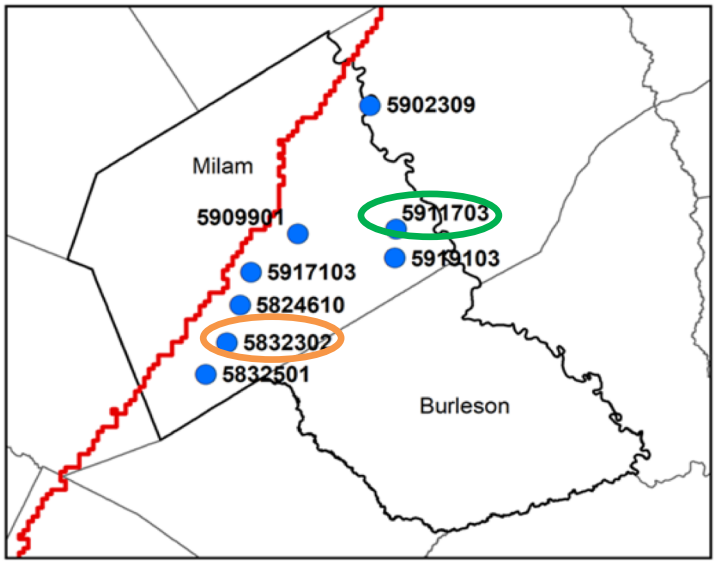


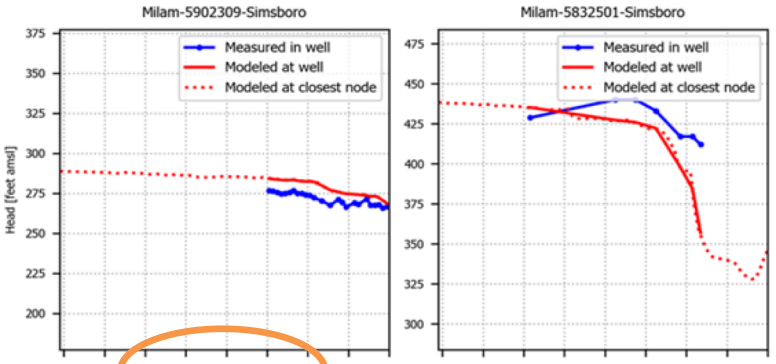
Updated GAM Provides Good Matches to Historical Water Levels in Regions of High Pumping in Simsboro Aquifer

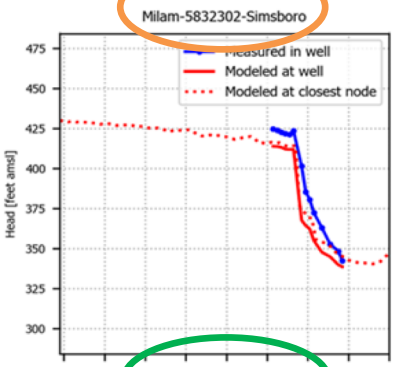


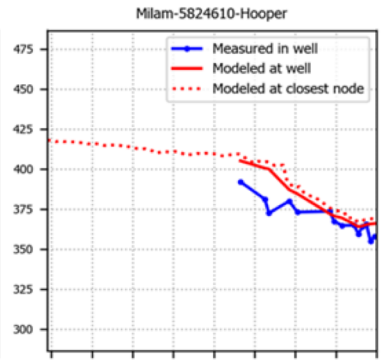
Updated GAM Provides Good Matches to Historical Water Levels in Simsboro Affected by “Alcoa” and “Bryan” Pumping

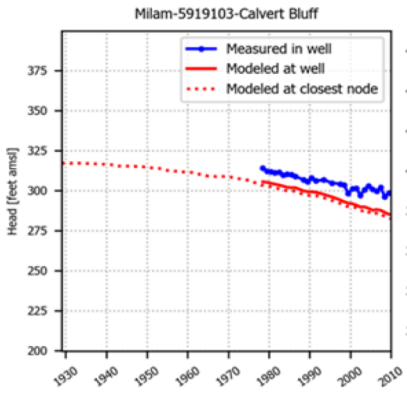
Milam County

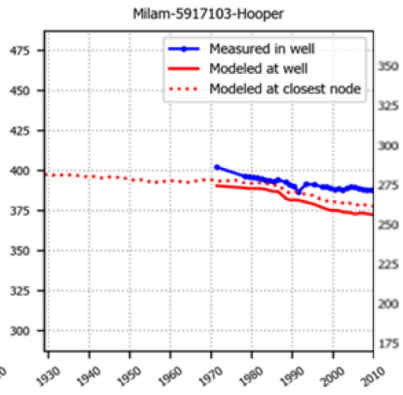


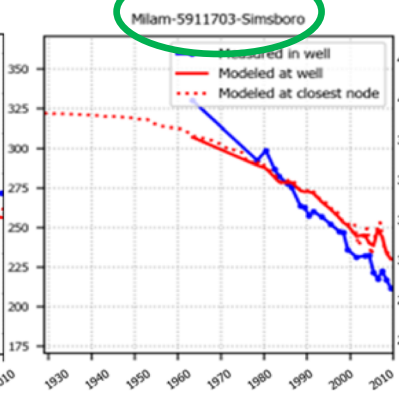


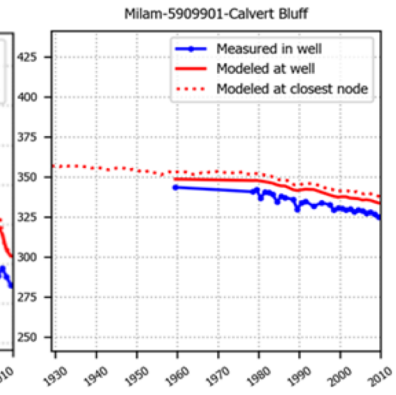










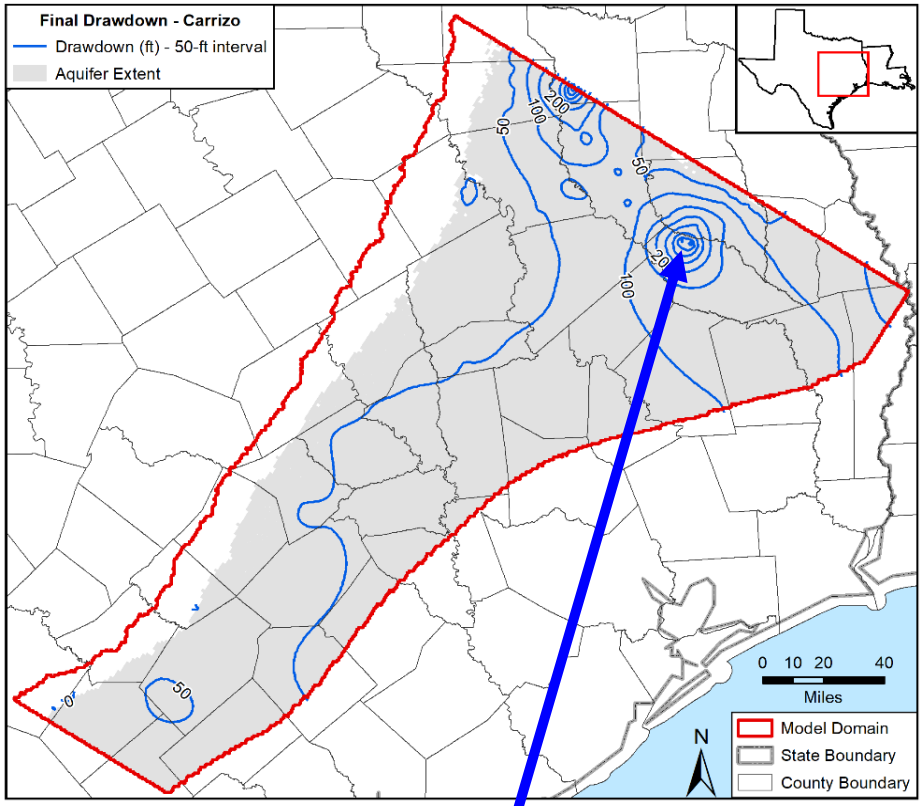


Groundwater Availability Model as a Tool to Support Groundwater Management

- Aquifer Response to Pumping
  - Measured versus Simulated Drawdowns
  - Simulated Saturated Thickness and Artesian Pressures
- Monitoring of Groundwater Levels
  - Monitoring Network
  - Compliance Calculations

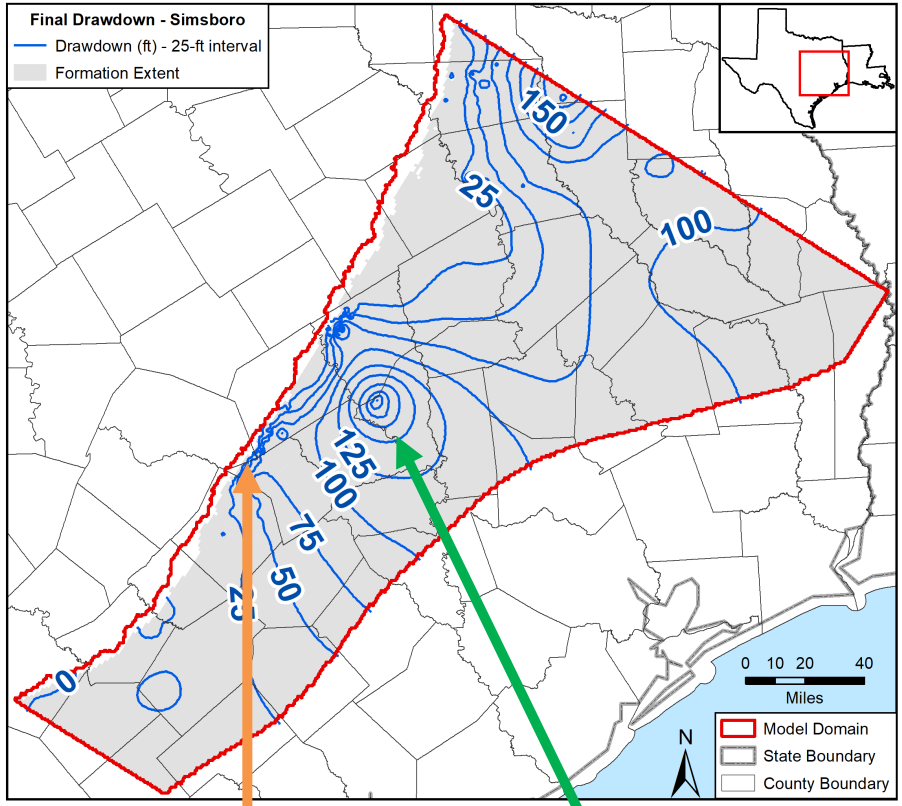
Simulated Drawdown from 1930 to 2010

Carrizo Aquifer



Lufkin

Simsboro Aquifer



Alcoa

City of Bryan

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Approved GMA 12 Desired Future Conditions (DFCs)

GCD or County	Average Aquifer Drawdown (ft) measured from January 2000 through December 2069					
	Sparta	Queen City	Carrizo	Calvert Bluff	Simsboro	Hooper
BVGCD	12	12	61	125	295	207
FCGCD	47	64	110	Declared as non-relevant		
LPGCD	5	15	62	100	240	165
METGCD	5	2	80	90	138	125
POSGCD	28	30	67	149	318	205
Falls	--	--	--	--	-2	27
Limestone	--	--	--	11	50	50
Navarro	--	--	--	-1	3	3
Williamson	--	--	--	-11	47	69
GMA-12	***16***	***16***	***75***	***114***	***228***	***168***

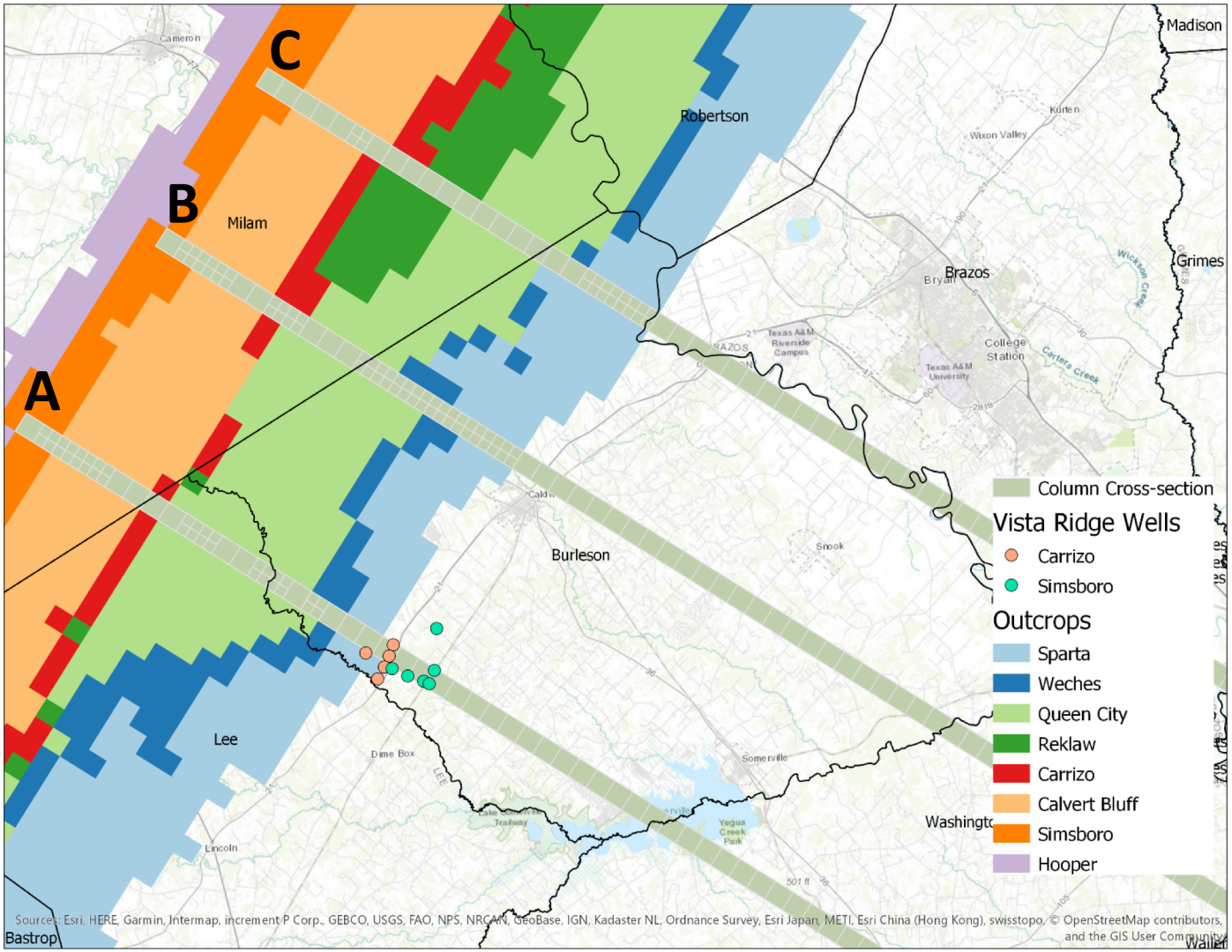
From GMA 12 Consultant Team (2018)

Preliminary Results Based on Pumping Rates Used to Produce Current DFCs

GCD or County	Average Aquifer Drawdown (ft) modeled from January 2011 through December 2070					
	Sparta	Queen City	Carrizo	Calvert Bluff	Simsboro	Hooper
BVGCD	~40	~35-40	~65-75	~80-85	~145-150	~115-125
FCGCD	~35	~65	~135	Declared as non-relevant		
LPGCD	~25	~30	~100	~85-90	~140-145	~105
METGCD	~25	~20	~40	~40	~50	~50
POSGCD	~60-65	~30-35	~105-110	~110-115	~190-200	~150
Falls	--	--	--	--	~10-15	~5
Limestone	--	--	--	~10	~10	~5
Navarro	--	--	--	~0	~0	~0
Williamson	--	--	--	~30	~25-30	~15
GMA 12	***~35***	***~35***	***~80-85***	***~80-85***	***~125-130***	***~105***

From GMA 12 Consultant Team (2018)

Location of Cross-sections Through Carrizo and Simsboro Aquifers



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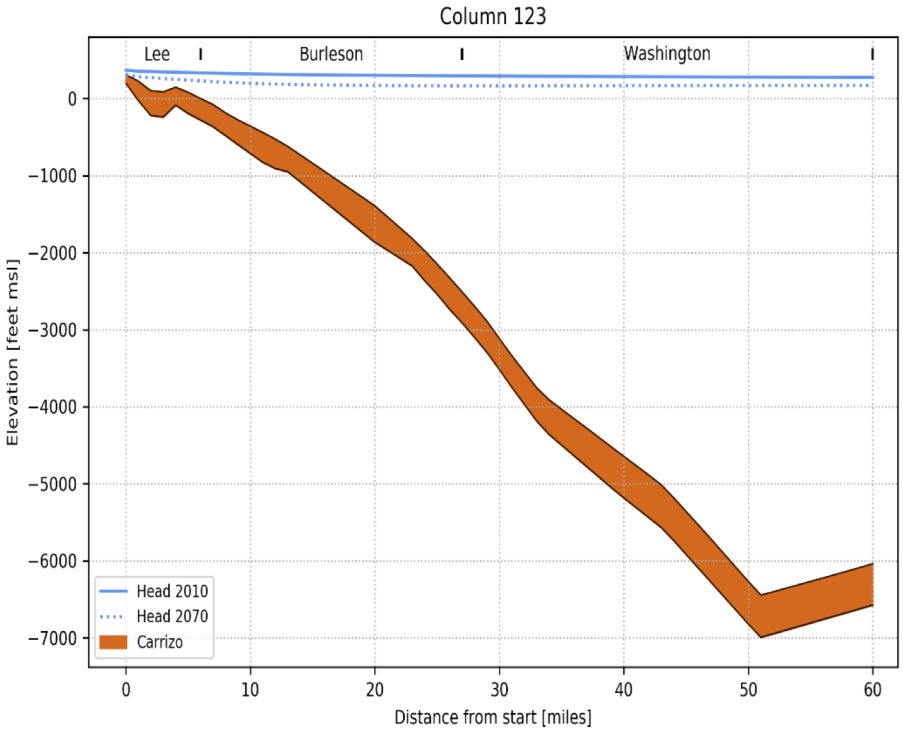
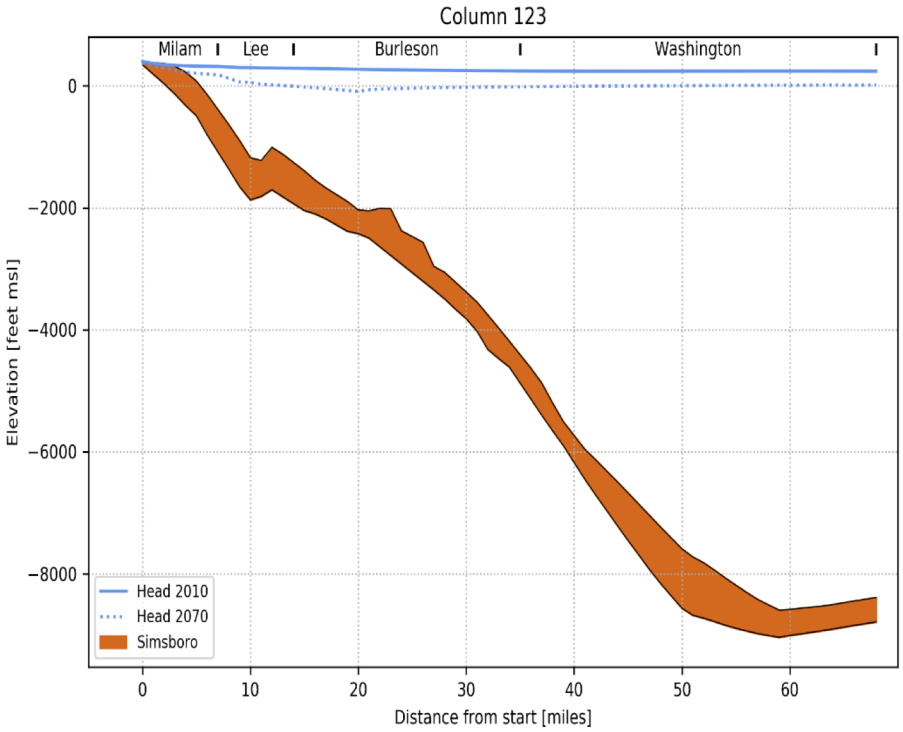
Cross-section A: Saturated Thickness & Water Levels for Carrizo and Simsboro Aquifer

Carrizo

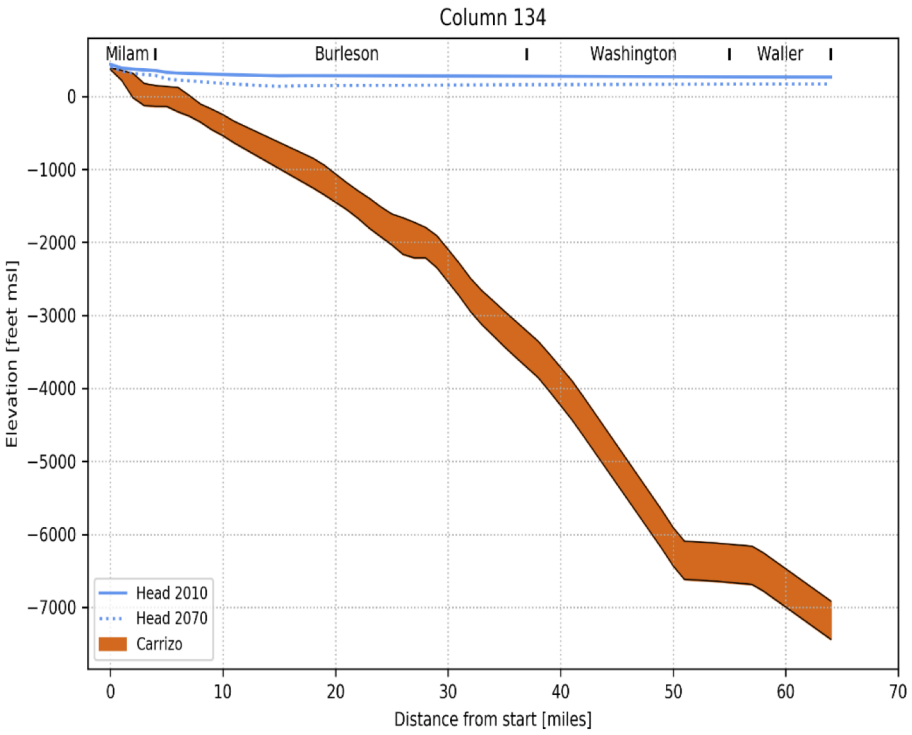


Simsboro

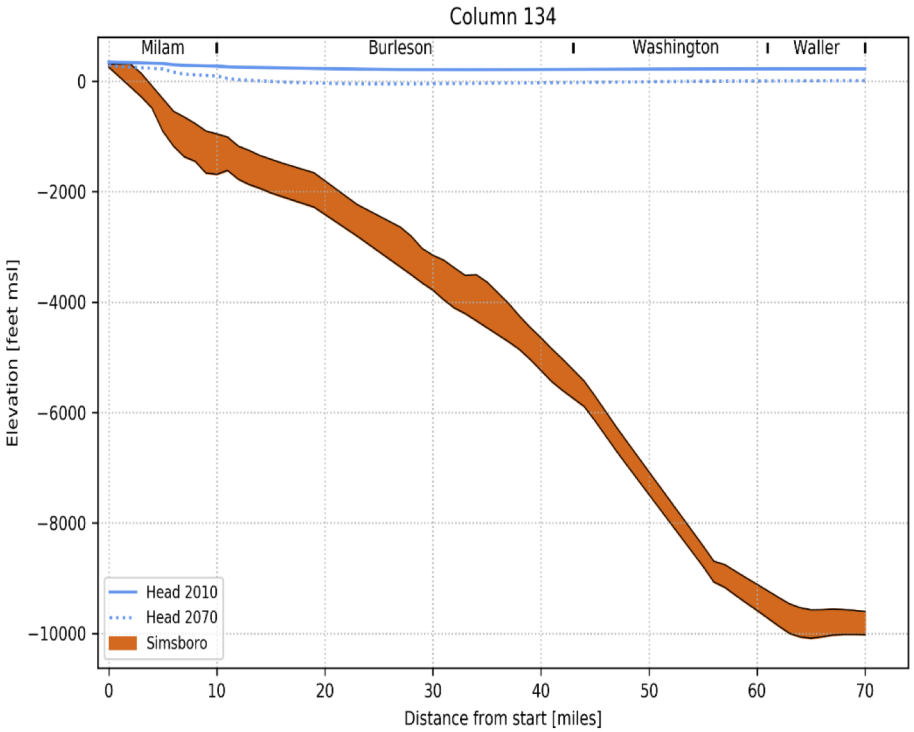


Cross-section B: Saturated Thickness & Water Levels for Carrizo and Simsboro Aquifer

Carrizo

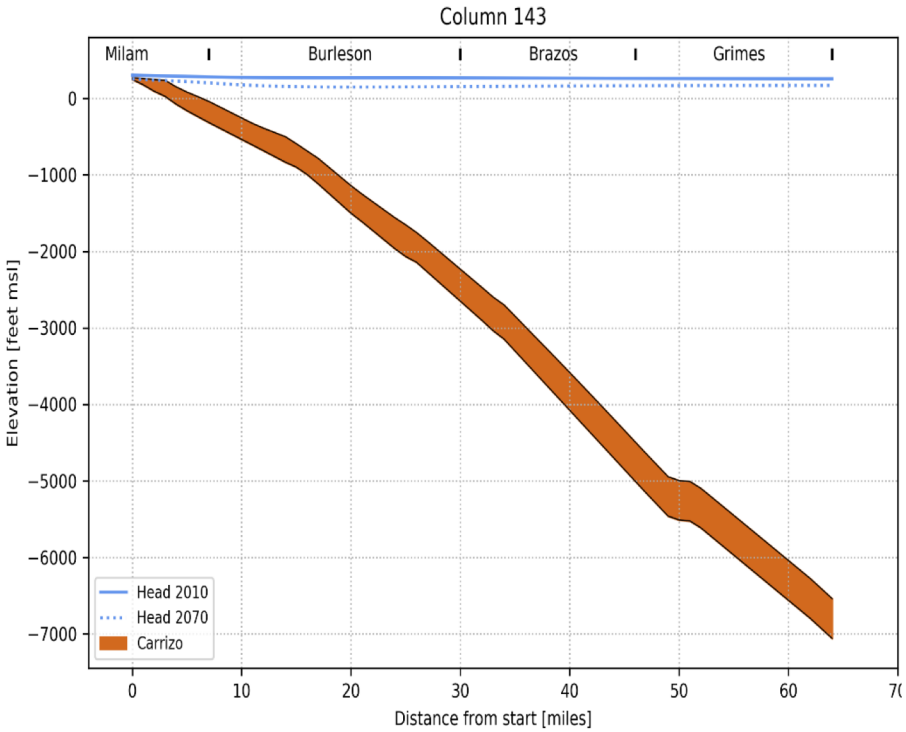


Simsboro

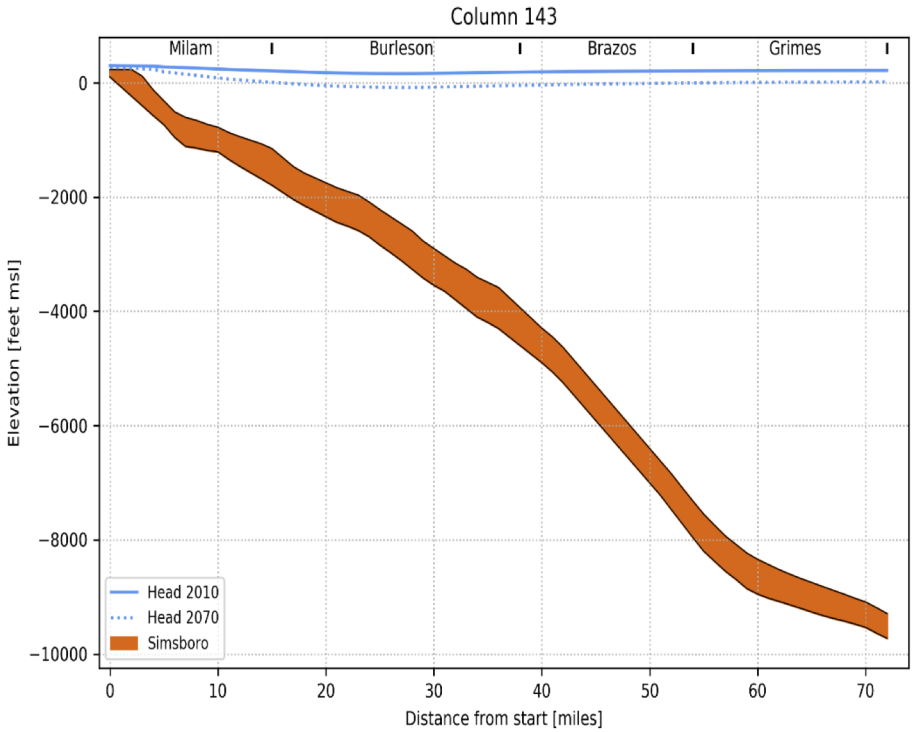


Cross-section C: Saturated Thickness & Water Levels for Carrizo and Simsboro Aquifer

Carrizo



Simsboro



POSGCD Approach for Aquifer Protection

- Groundwater Management Zones
- Groundwater Monitoring Program
- POSGCD Rules for Aquifer Protection

5. Management Zones

The District is divided into groundwater management zones for the purpose of evaluating and managing groundwater resources recognizing the different characteristics and anticipated future development of the aquifers in the District.

The District will establish and enforce Rules for the spacing of wells, the maximum allowable production of groundwater per acre of land located over an aquifer, require permits for production, regulate drawdown and provide for a reduction in the maximum allowable production and permitted production of groundwater per acre of land based on the different surface and subsurface characteristics and different evaluation and monitoring within the Management Zones.

Designated Management Zones

- **Aquifers:** Brazos River Alluvium, Trinity, Sparta, Queen City, Carrizo, Upper Wilcox, Middle Wilcox, Lower Wilcox, Yegua/Jackson Management Zone
- **Shallow Zones for Aquifers:** All deposits that occur at a depth of 400 feet or less for aquifers above except for Brazos River Alluvium … purpose is to characterize the water levels in the unconfined portions of the aquifers

Guidance Document for Collection and Analysis of Monitoring Data

TABLE OF CONTENTS

Post·Oak·Savannah·Guidance·Document·for·Evaluating· Compliance·with·Desired·Future·Conditions·and·Protective· Drawdown·Limits·¶

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Prepared·for:¶

¶

Post·Oak·Savannah·Groundwater·Conservation·District↵
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Prepared·by:¶

¶

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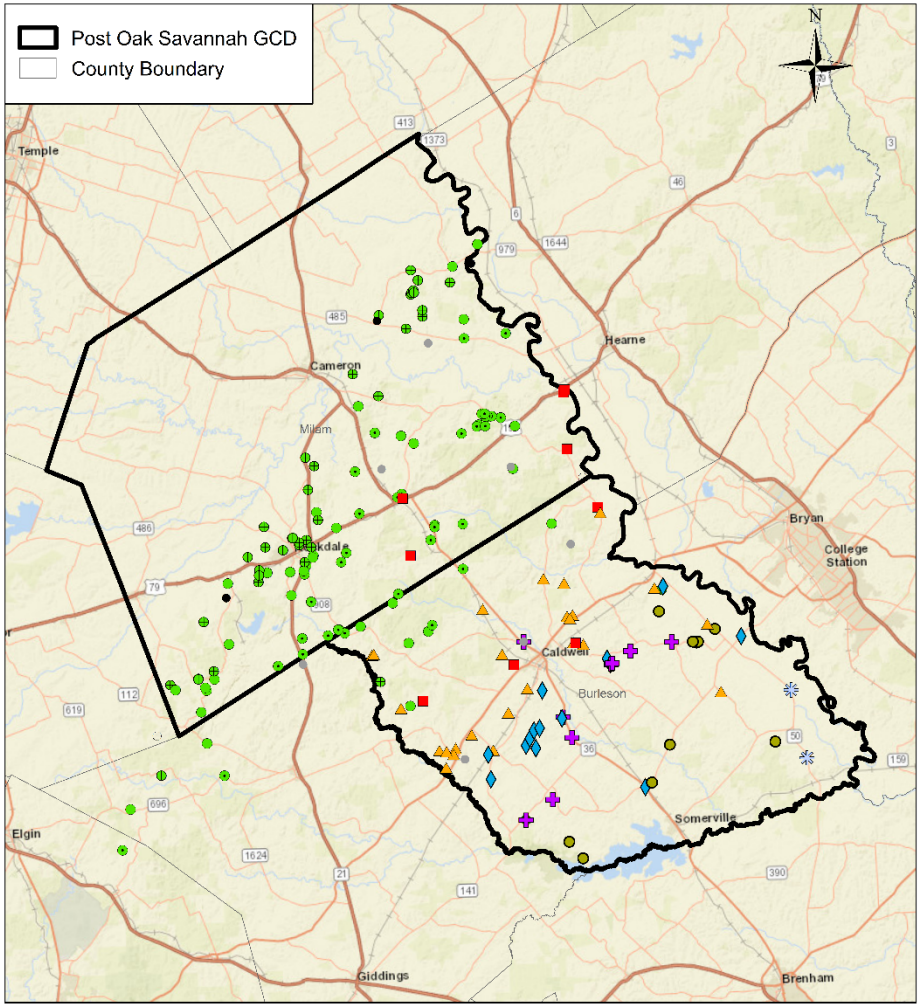
¶
August·2018¶

Monitoring Well Network



Status of PDF Compliance

Management Zone	PDL	Drawdown from 2000 to 2012	Drawdown from 2000 to 2013	Drawdown from 2000 to 2014	Drawdown from 2000 to 2015	Drawdown from 2000 to 2016	Drawdown from 2000 to 2017
		Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)	Calculated Drawdown (% of DFC)
Yegua Jackson	20	5.7 (29%)	6.4 (32%)	6.8 (34%)	7.3 (36%)	4.1 (21%)	3.1 (15%)
Sparta	20	4 (20%)	4.5 (22%)	4.9 (25%)	4.5 (22%)	3.1 (15%)	2.4 (12%)
Queen City	20	3.4 (17%)	4.1 (20%)	4.6 (23%)	4.1 (20%)	2.2 (11%)	1.2 (6%)
Carrizo	20	4.7 (23%)	5.8 (29%)	6.2 (31%)	5.6 (28%)	3.5 (18%)	2.2 (11%)
Calvert Bluff (Upper Wilcox)	20	5.9 (29%)	7 (35%)	7.2 (36%)	6.7 (34%)	5.5 (27%)	4.5 (22%)
Simsboro (Middle Wilcox)	20	6 (30%)	6.6 (33%)	6.7 (33%)	6.1 (31%)	5 (25%)	4 (20%)
Hooper (Lower Wilcox)	20	6 (30%)	6.2 (31%)	6.3 (32%)	6.2 (31%)	5.1 (26%)	4.3 (22%)

Rule 16.4- Actions Based on Monitoring Results

- Threshold 1
  - Criteria (60% of MAG, 50% of DFC or PDL, DFC projected using GAM to be exceeded in 15 years)
  - Initial Required Action (addition study to identify the source of impacts and/or improve site data or analysis tools)
- Threshold 2
  - Criteria (70% of MAG, 60% of DFC or PDL)
  - Initial Required Action(review of MP and rules, initiation of public process to discern preventive and/or protective actions including but limited to Rules 16.5 and 16.6, initiate development of response and action workplan)

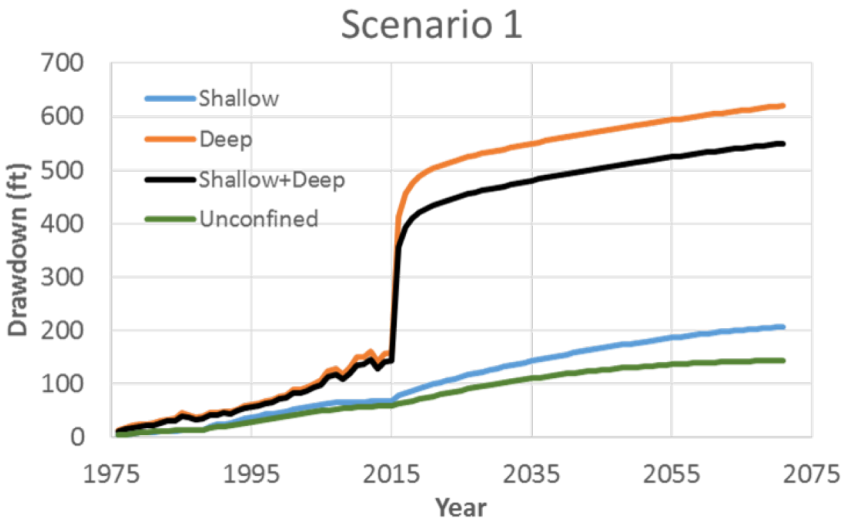
Rule 16.4- Actions Based on Monitoring Results (con't)

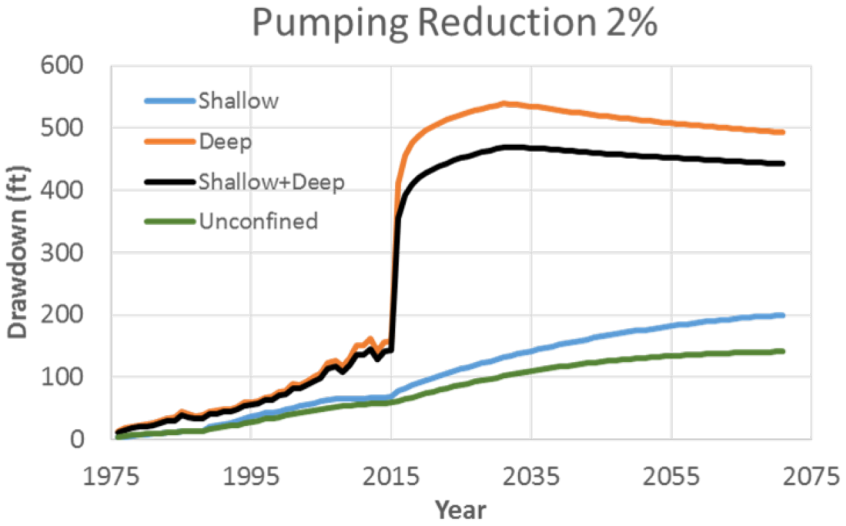
- Threshold 3
  - Criteria (75% of DFC or PDL)
  - Initial Required Action(consider and adopt amendments to MP and rules, conduct public hearings, develop and implement a Response and Action Workplan)
    - Reduce permitted production and/or maximum allowable production

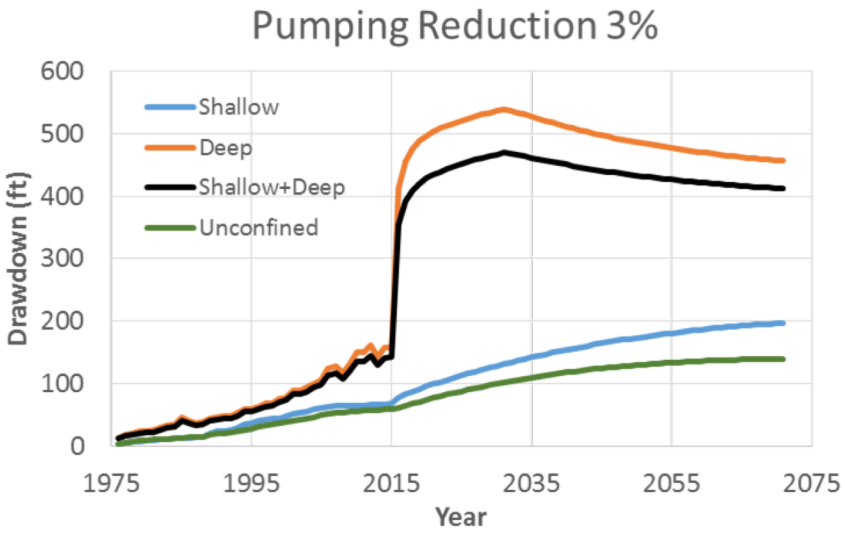
Rule 16.5 Reductions Required by Regulatory Action

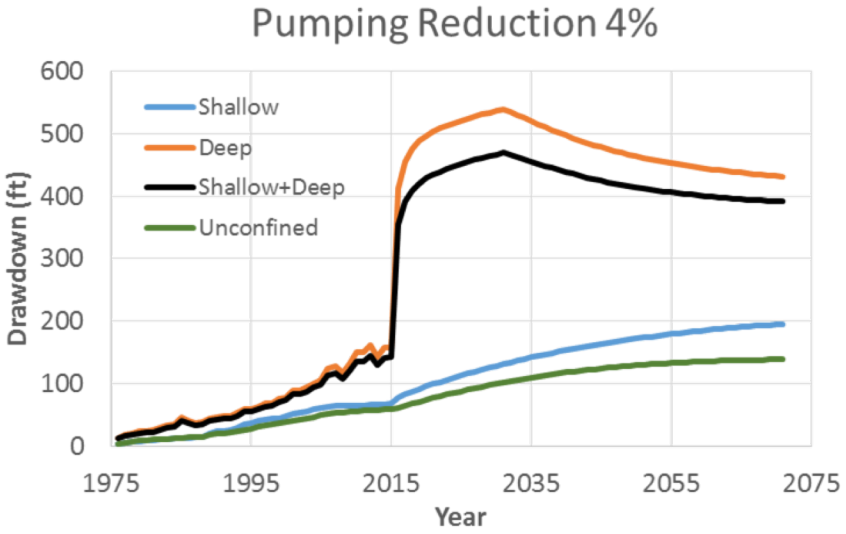
- "Board may proportionately reduce the maximum amount of water that may be permitted per acre and the volume of water authorized to be produced under any permit issued by the District"
- "Board will adjust the thresholds established in Rule 16.4…"

Investigation of Reduced Pumping Rates: POSGCD Simsboro Deep Pumping









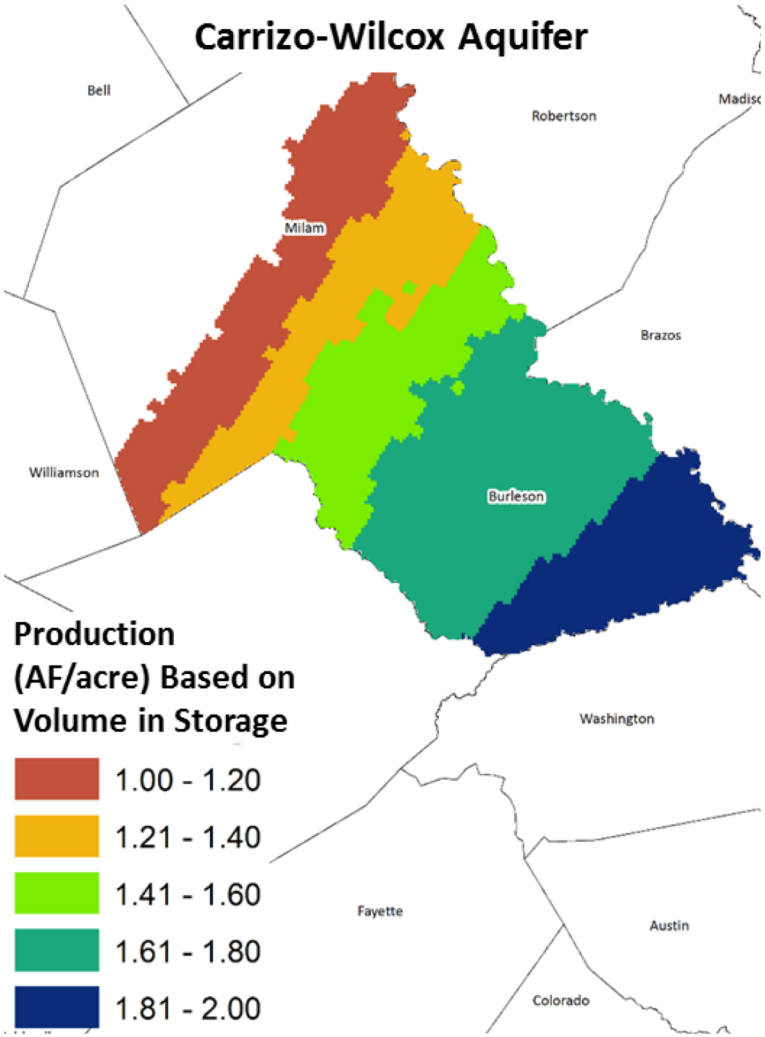
Rule 16.6 Adjusting Maximum Production Permitted

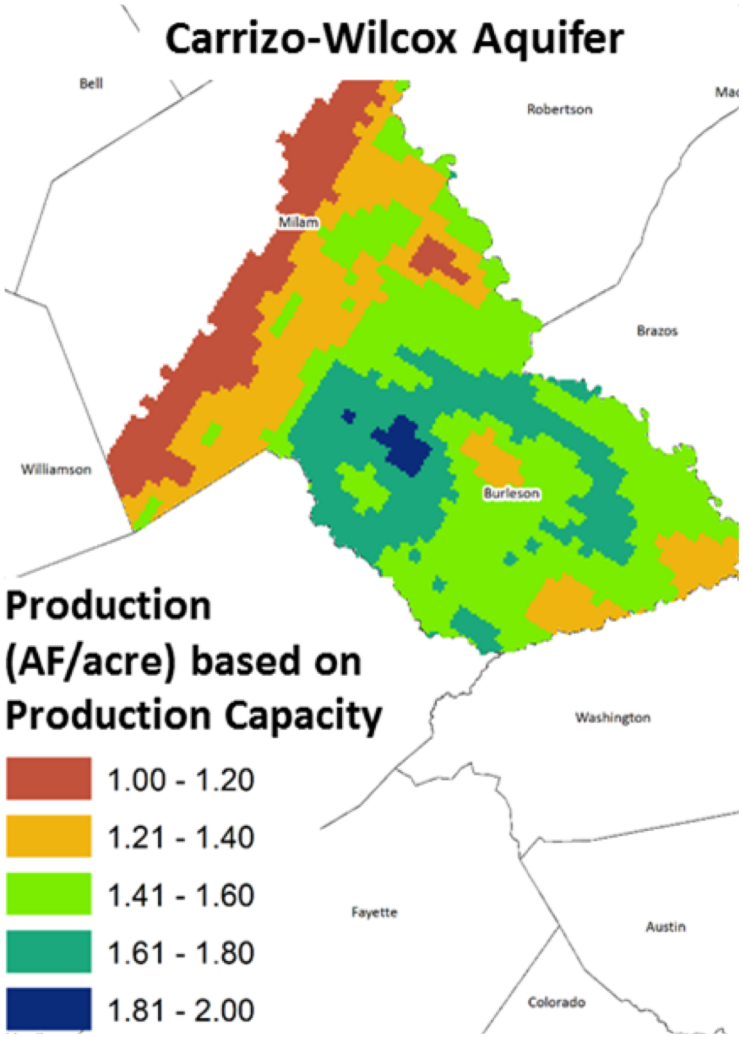
- "District shall adjust the maximum groundwater production permitted per acre and/or the permitted production under any permit issued by the District as follows:"
  - "the maximum water production permitted per acre for the Management Zone and the water authorized to be produced under any permit issued by the District for that zone will be reduced"
  - "production in a Management Zone may be reduced to the extent that production in that Management Zone is impacting water drawdown levels in any Management Zone in the District"
  - "The maximum allowable production of 2 acre feet of groundwater per acre of land, provided in Rule 5.1.2, may be reduced, and the maximum allowable production may be established or reduced for any one, or more than one, Management Zone"

Adjustments to the 2 AFY/acre Maximum Production Rate

- Factors that Could be used for Basis of Fair Share
  - Surface acreage
  - Groundwater in storage underlying acreage
  - Aquifer production capacity underlying acreage
  - A combination of the three factors above
- Review Several Mathematical Options for Transforming (or Scaling) Factors to Production Rate (af/acre)
- Example Maps of Production Rates
  - Single aquifers
  - All aquifers

Example for Carrizo-Wilcox Aquifer: Max Production Rate (af/acre) based on Groundwater in Storage or Production Capacity



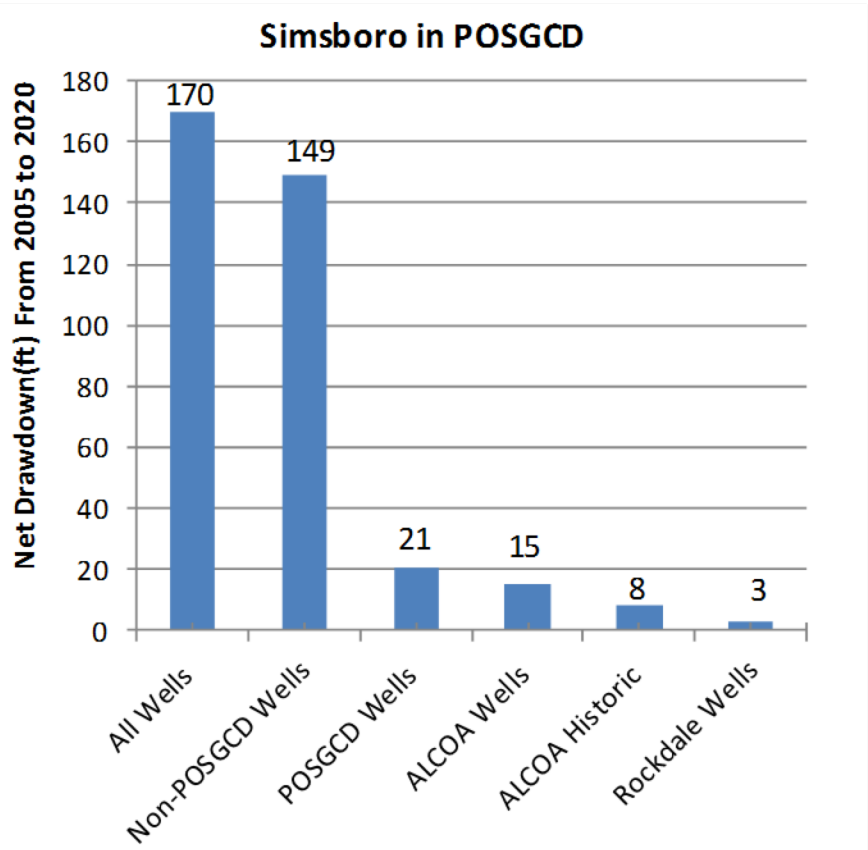


Identify the Impact of Pumping in a Management Zone to Drawdown in another Management Zone

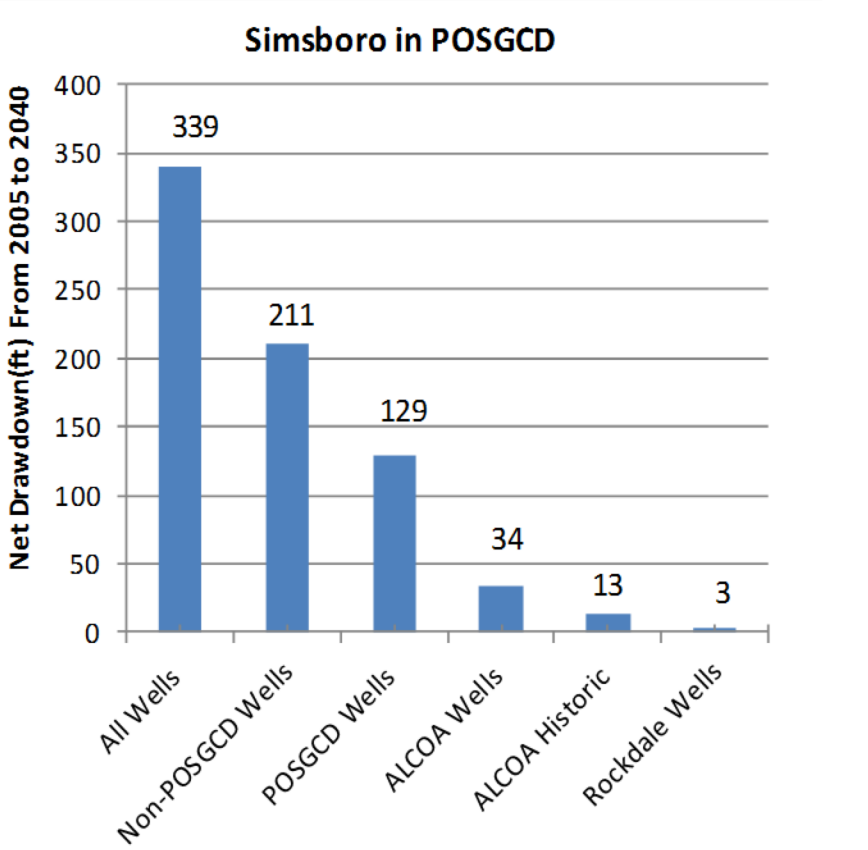
- Cross-flow is groundwater that flows across aquifer boundaries
- Pumping in a aquifer reduces the water level in the adjacent aquifers and causes an increase in cross flow to the aquifer
- POSGCD has investigated methods of how determine:
  - How pumping in a well A affects drawdown in another well B
  - How pumping in management zone A affects drawdown in management zone B

Well Contributing to Net Drawdown in Simsboro Aquifer

2020



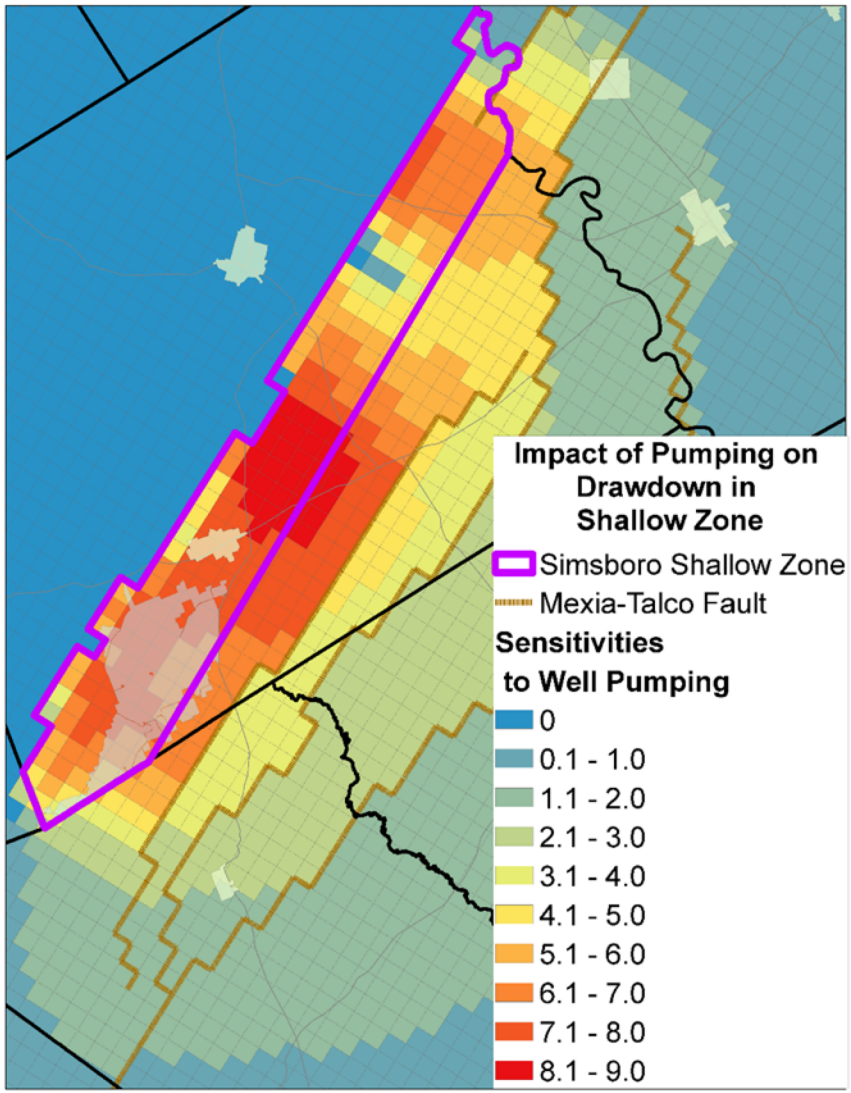
2040



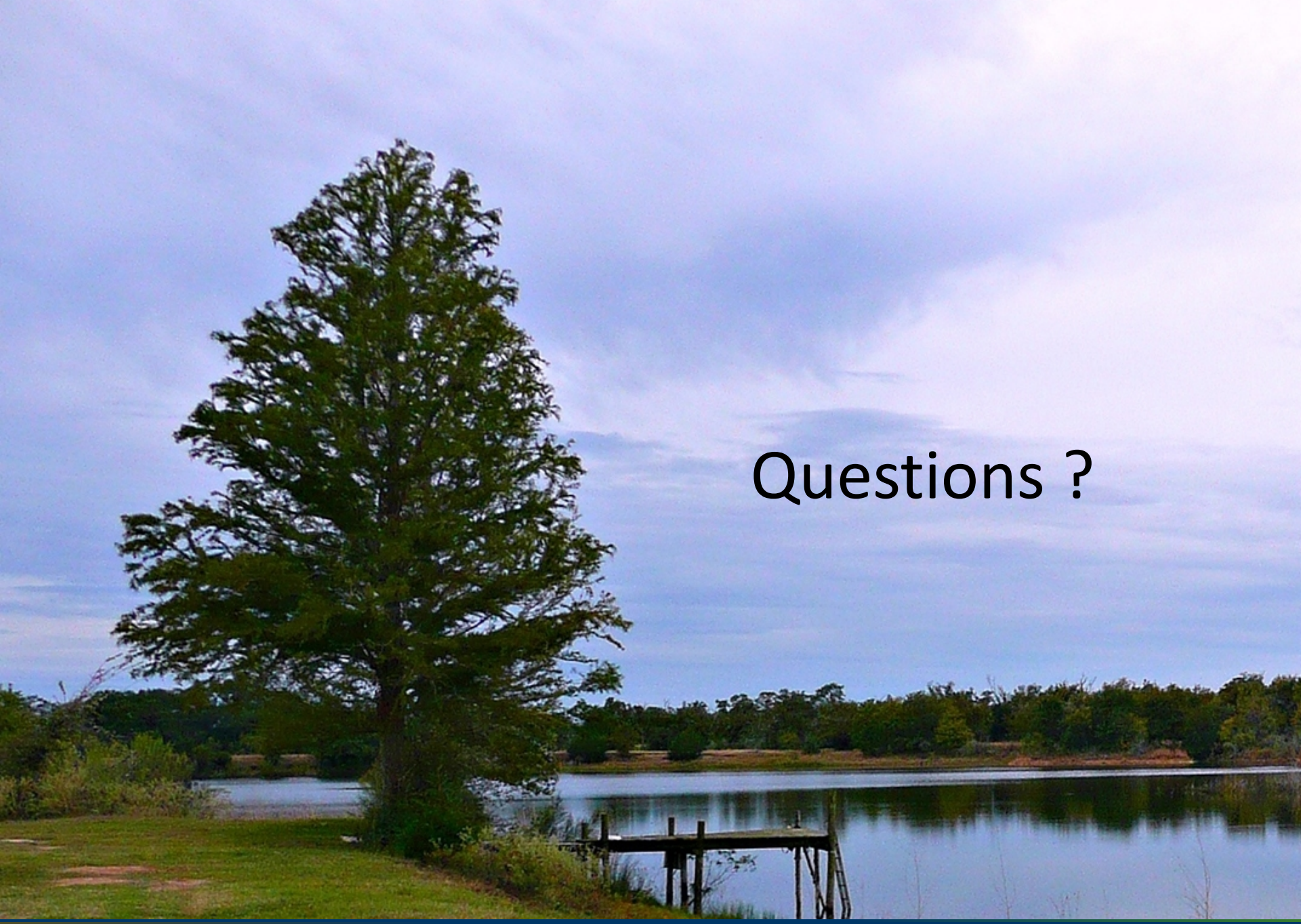
Results are generate by performing series of model runs with different grouping of wells

Sensitivity of Average Drawdown in the Shallow Simboro to Pumping in Each Grid Cell

- The shallow Simboro zone is outlined by purple line
- The color of the grid cell reflects how pumping will affect average drawdown in shallow Simsboro Zone
- Faults are the brown lines

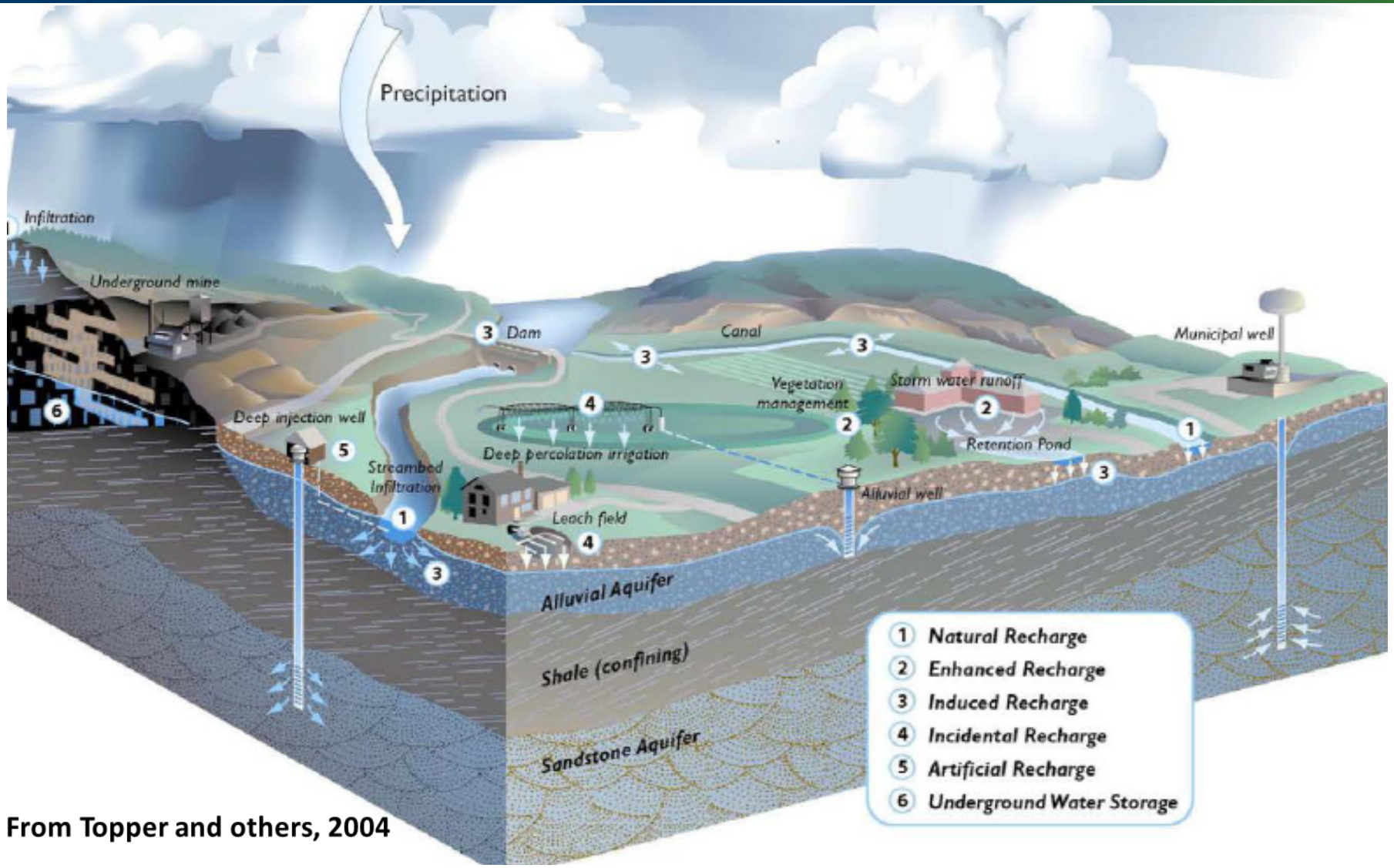


Results are generate by a single model run that is very complex to performed


Questions ?

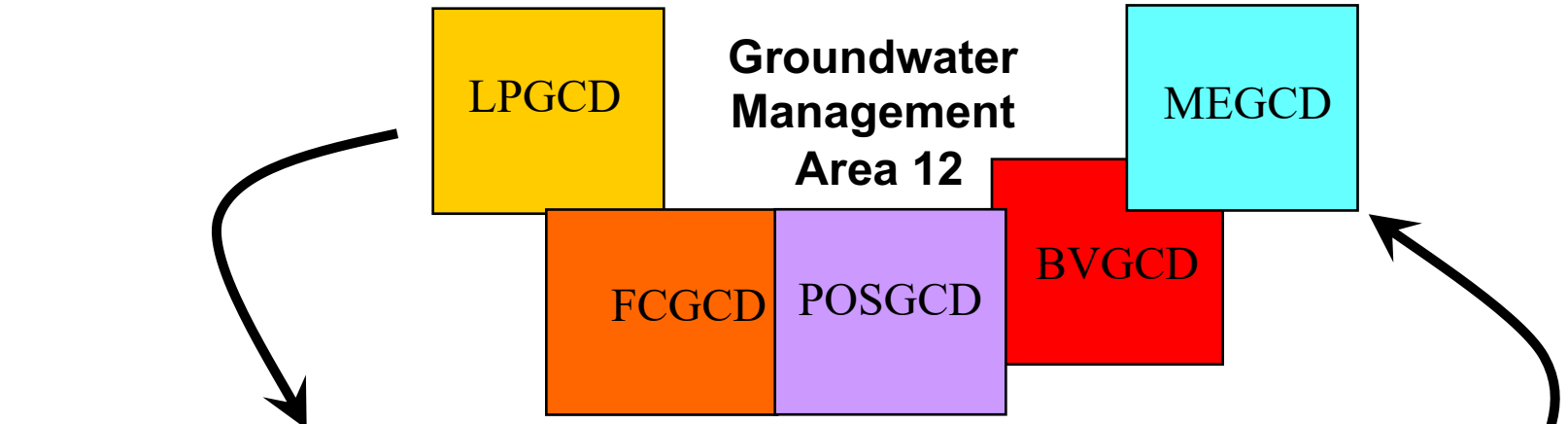
Extra Slides

Application: Evaluate Alternative Water Management Strategies – Example Enhanced Recharge and Aquifer Storage and Recovery



From Topper and others, 2004

Application: GAMs are Used by GMAs and TWDB in Joint Planning Process



DFC

MAG

GAM Groundwater Availability Modeling
xas water development board

TEXAS WATER DEVELOPMENT BOARD

GAM Groundwater Availability Modeling
xas water development board

GMA 12 uses GAM to evaluate various water management strategies, Desired Future Conditions (DFCs), and the future pumping scenarios

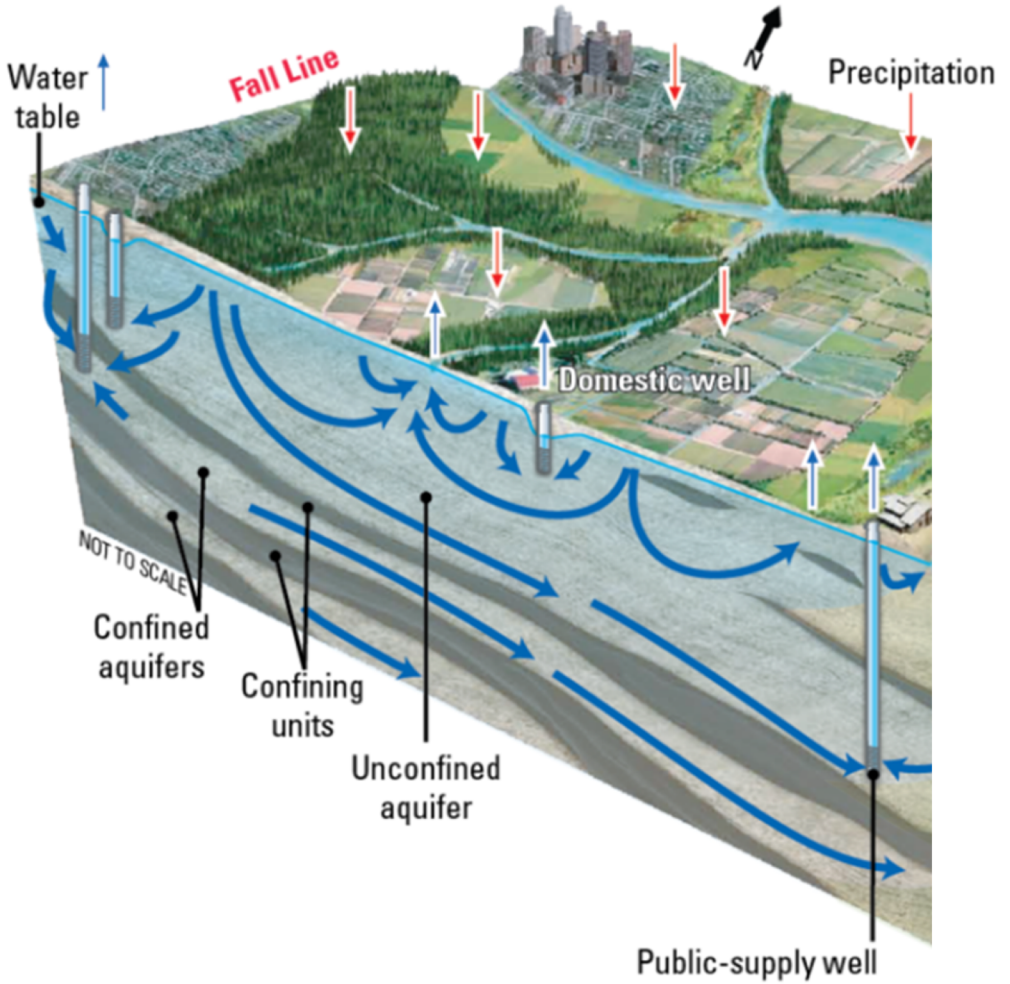
TWDB uses GAM to help determine Modeled Available Groundwater (MAG) from the DFCs

INTERA GEOSCIENCE & ENGINEERING SOLUTIONS

Component Required to Develop a GAM

- Conceptual Model
  - describes relationship and processes
- Data
  - aquifer properties, water level, flow rates
- Groundwater Numerical Code
  - equations that solves for flow and mass balances
- Model Construction and Calibration
  - size of aquifer blocks and methods used to fill data gaps

Schematic of Conceptual Model



Water Budget From 1930 to 2010: Milam County

- Recharge rate values between 40,000 AFY to 100,000 AFY
- Decrease in groundwater flow to streams is shown by green line
- Evidence that pumping in Milam and Brazos is affecting water balance is provided by yellow and brown lines