Conceptual Model for the Brazos River Alluvium Aquifer GAM

Stakeholder Advisory Forum #2
Milano, TX

Presented By:

INTERA
GEOSCIENCE & ENGINEERING SOLUTIONS

Texas Water Development Board

January 22, 2015

Today's Topics

- The Brazos River Alluvium Aquifer GAM team
- Introduction to the GAM program
- Conceptual Model for the Brazos River Alluvium Aquifer

Project Team and Responsibilities

Introduction of Texas Water Development Board (TWDB) Groundwater Availability Modeling (GAM) Program

Cindy Ridgeway, P.G.

Manager of Groundwater Availability Modeling

Texas Water Development Board

Texas Water Development Board

Disclaimer

The following presentation is based upon professional research and analysis within the scope of the Texas Water Development Board's statutory responsibilities and priorities but, unless specifically noted, does not necessarily reflect official Board positions or decisions.

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Groundwater Availability Modeling Program

- **Aim**: Develop groundwater flow models for the major and minor aquifers 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.

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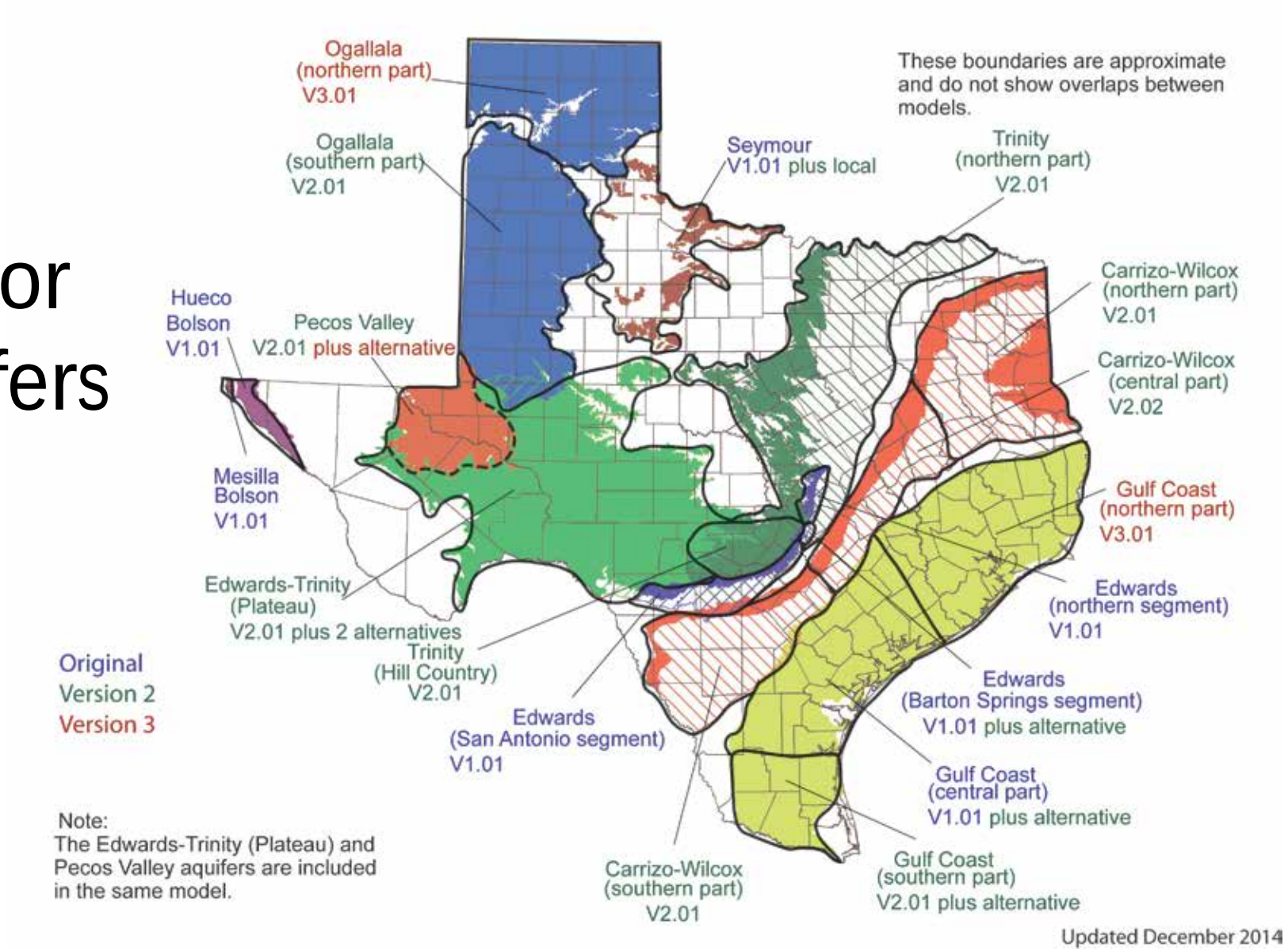
Major Aquifers



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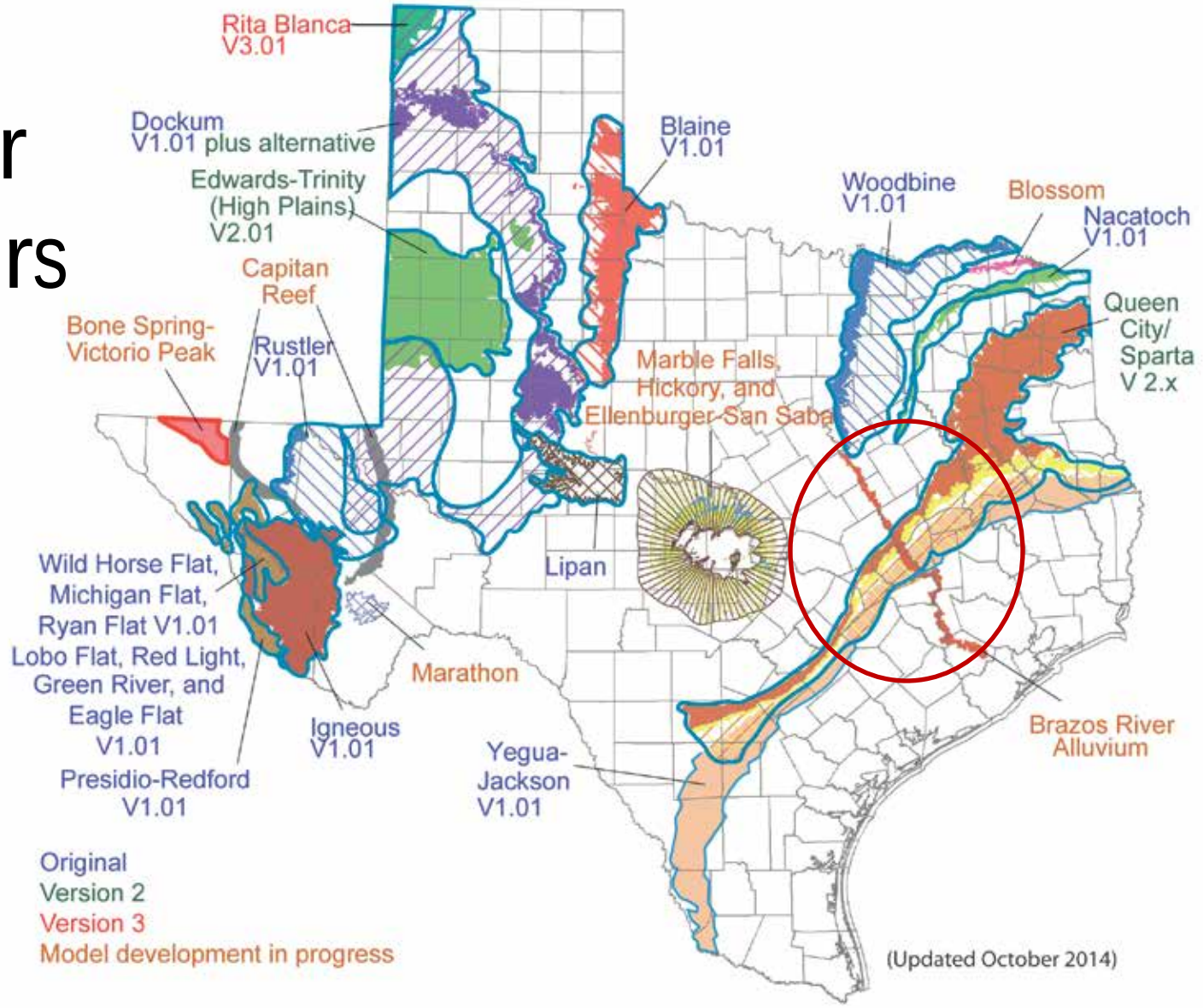
Minor Aquifers



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How we use Groundwater Models?

Per Statute:

- TWDB provides groundwater conservation districts with water budget data for their management plans.
- Groundwater management areas can use to assist in determining desired future conditions.
- TWDB uses when calculating estimated Modeled Available Groundwater.
- TWDB uses when calculating Total Estimated Recoverable Storage.

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Why 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

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Contact Information

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Texas Water Development Board
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Austin, Texas 78711-3231

Web information:
http://www.twdb.texas.gov/groundwater/models

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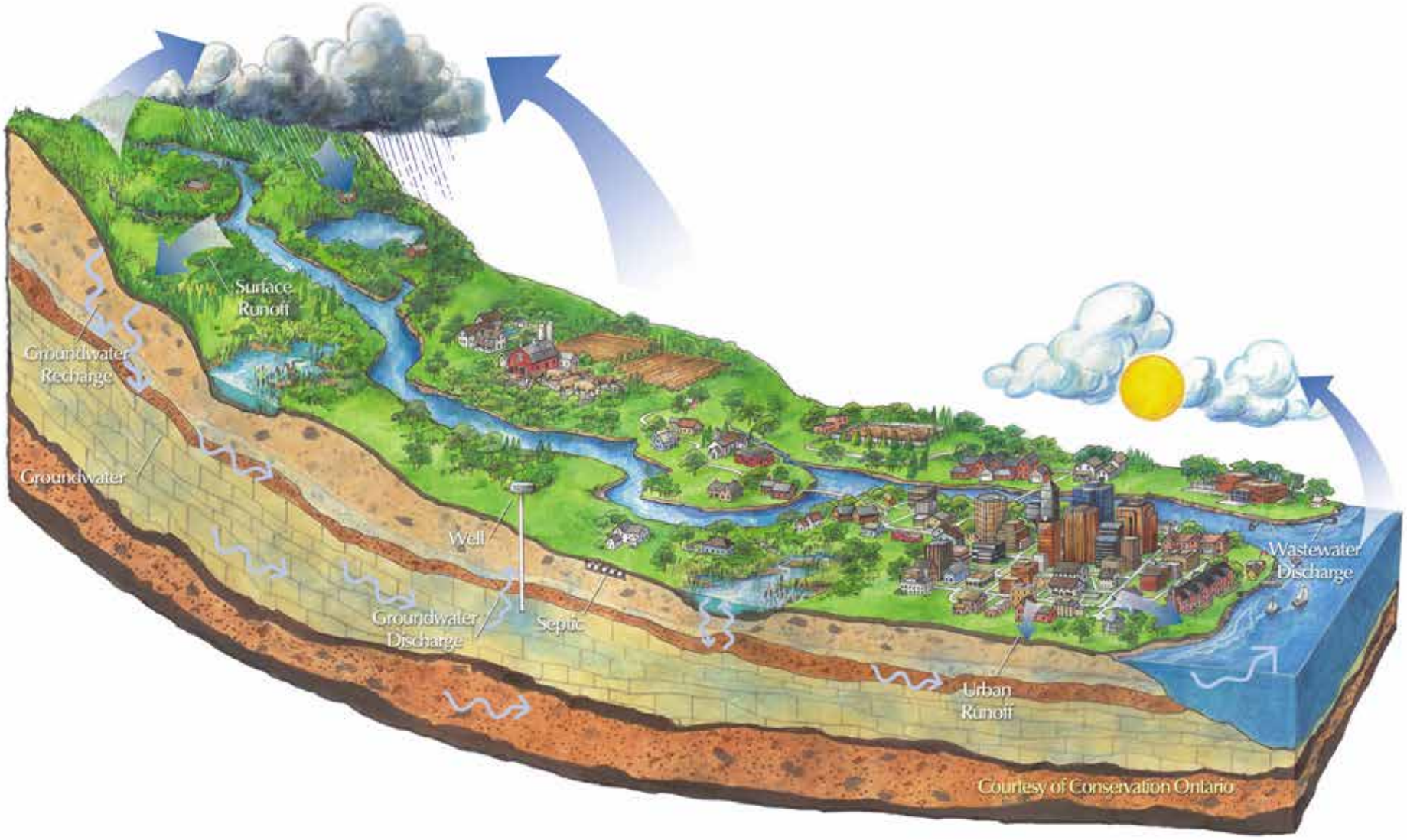
Conceptual Model

A **Conceptual Model** is a simplified description of the various hydrogeologic and structural components of an aquifer system and their interactions.



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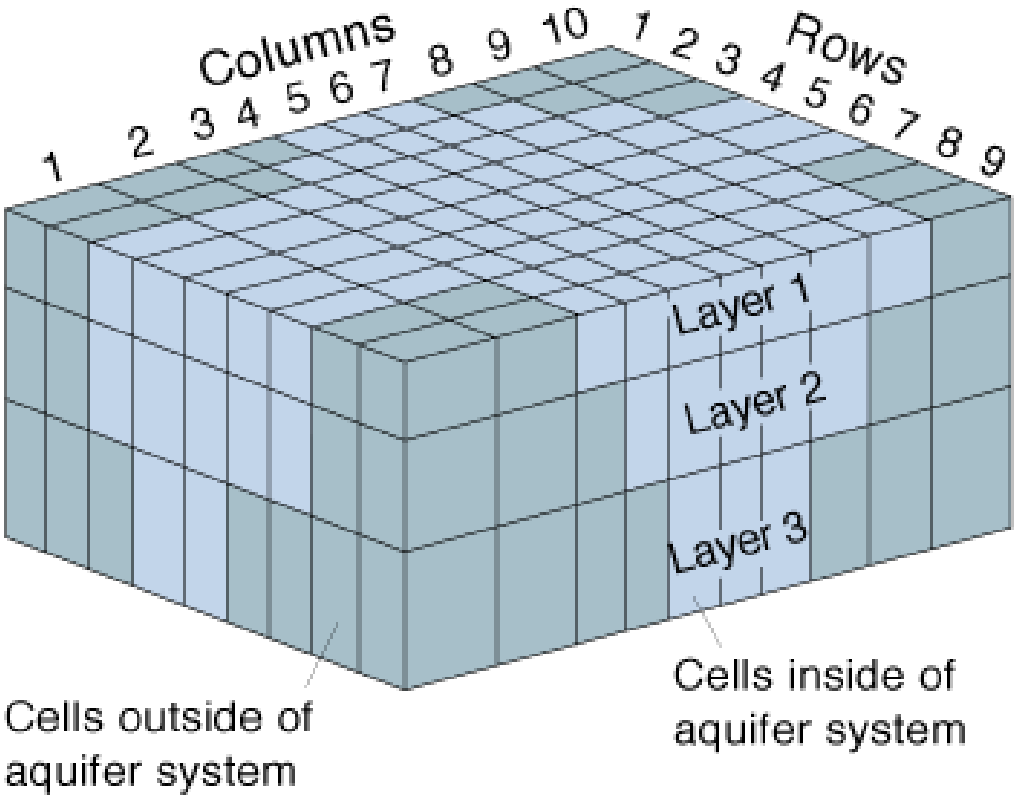

http://pubs.usgs.gov/fs/FS-121-97/images/fig2.gif

Key Aspects of Conceptualization

- Extent and hydrostratigraphy
- Structure
- Water Levels
- Hydraulic/storage properties
- Recharge/discharge
- Groundwater production
- Cross-formational flow
- Water quality

Key Aspects of Conceptualization

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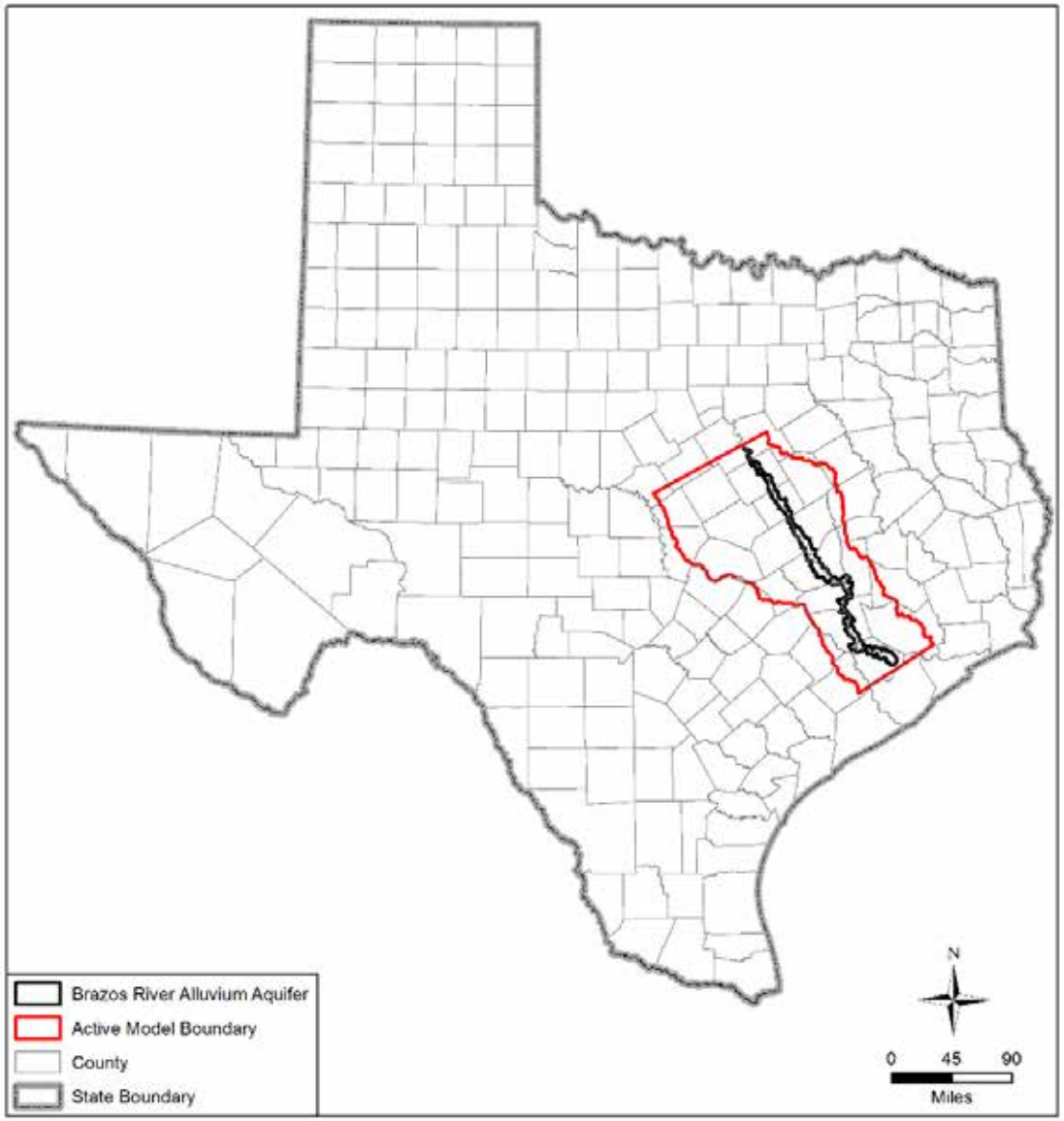
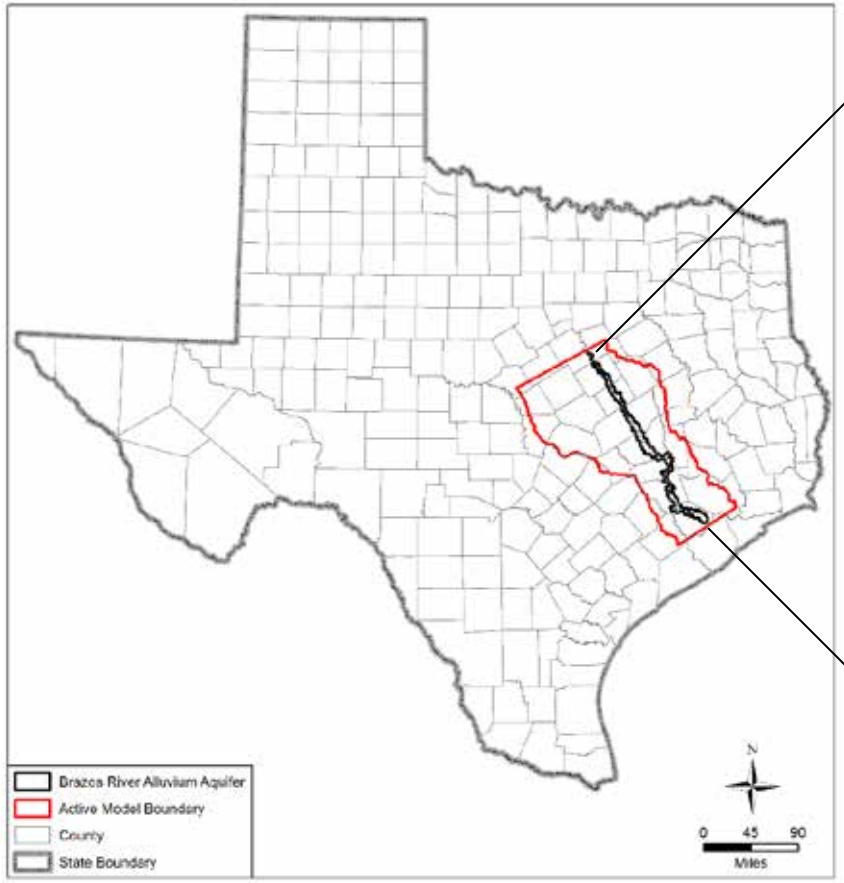
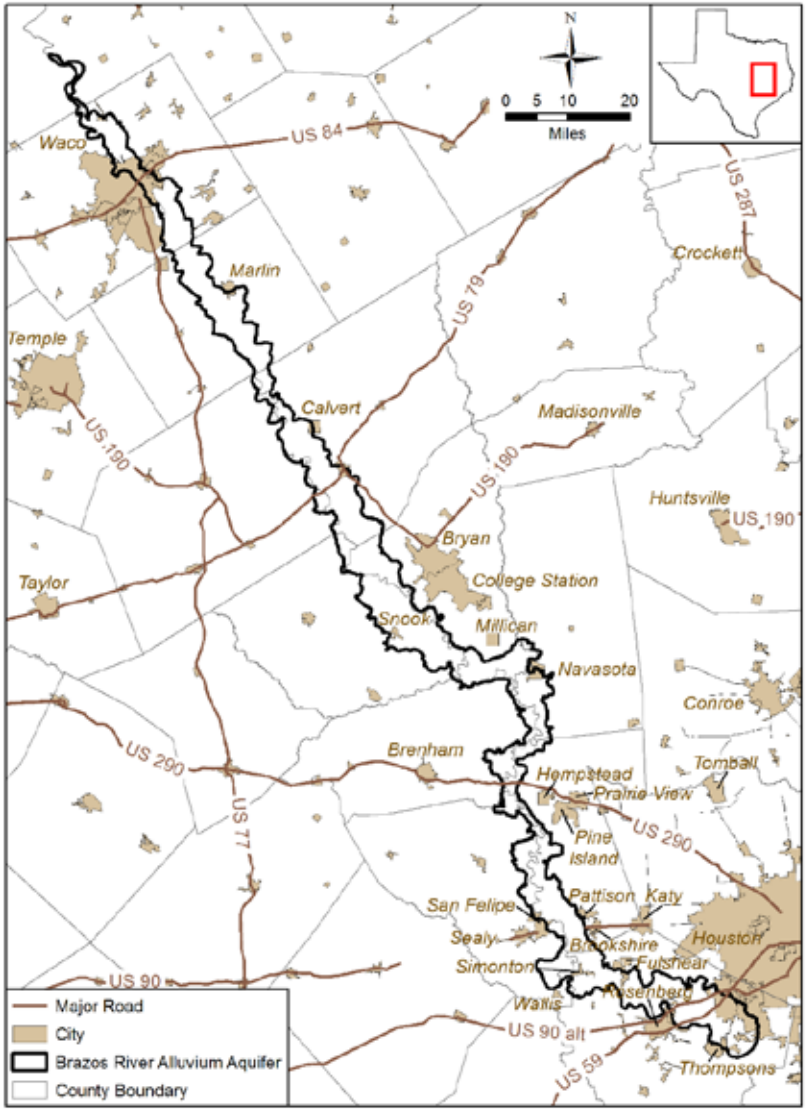
Study Area

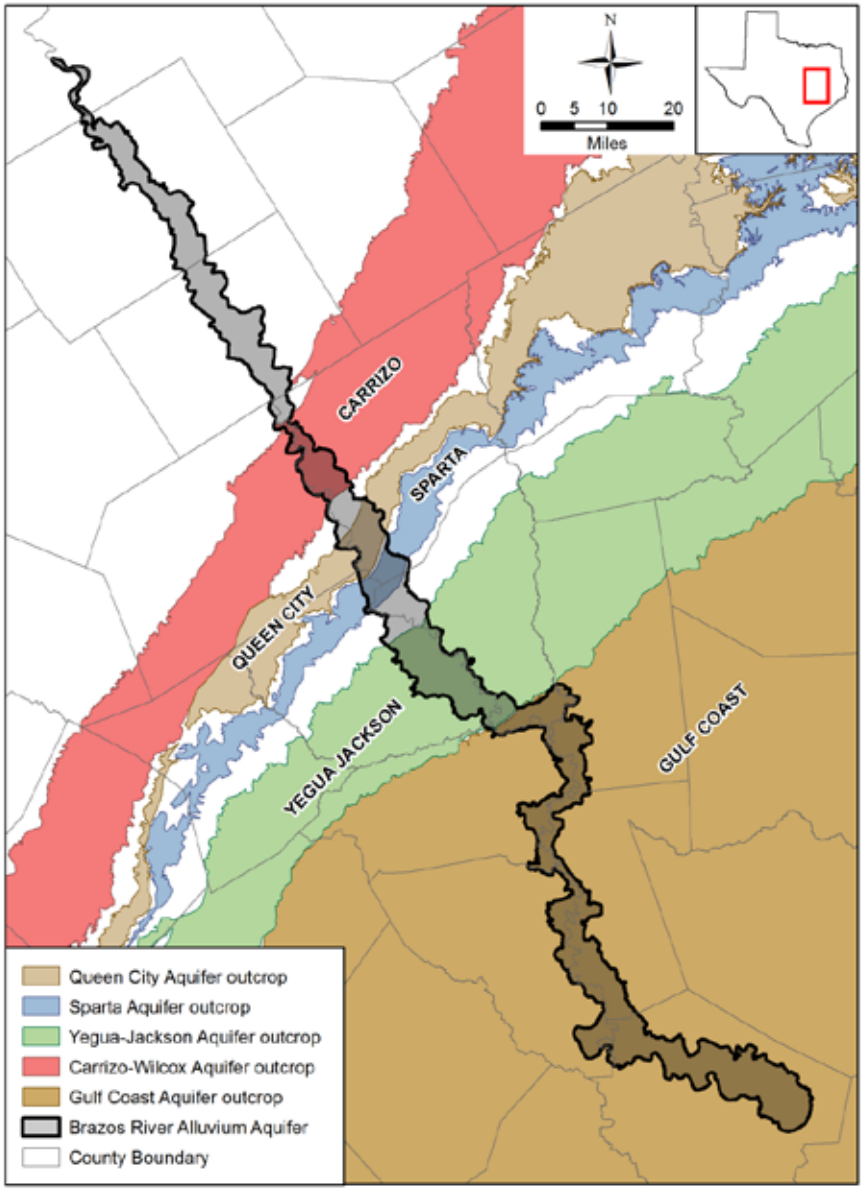

Brazos River Alluvium Aquifer
Active Model Boundary
County
State Boundary
N
0
45
90
Miles

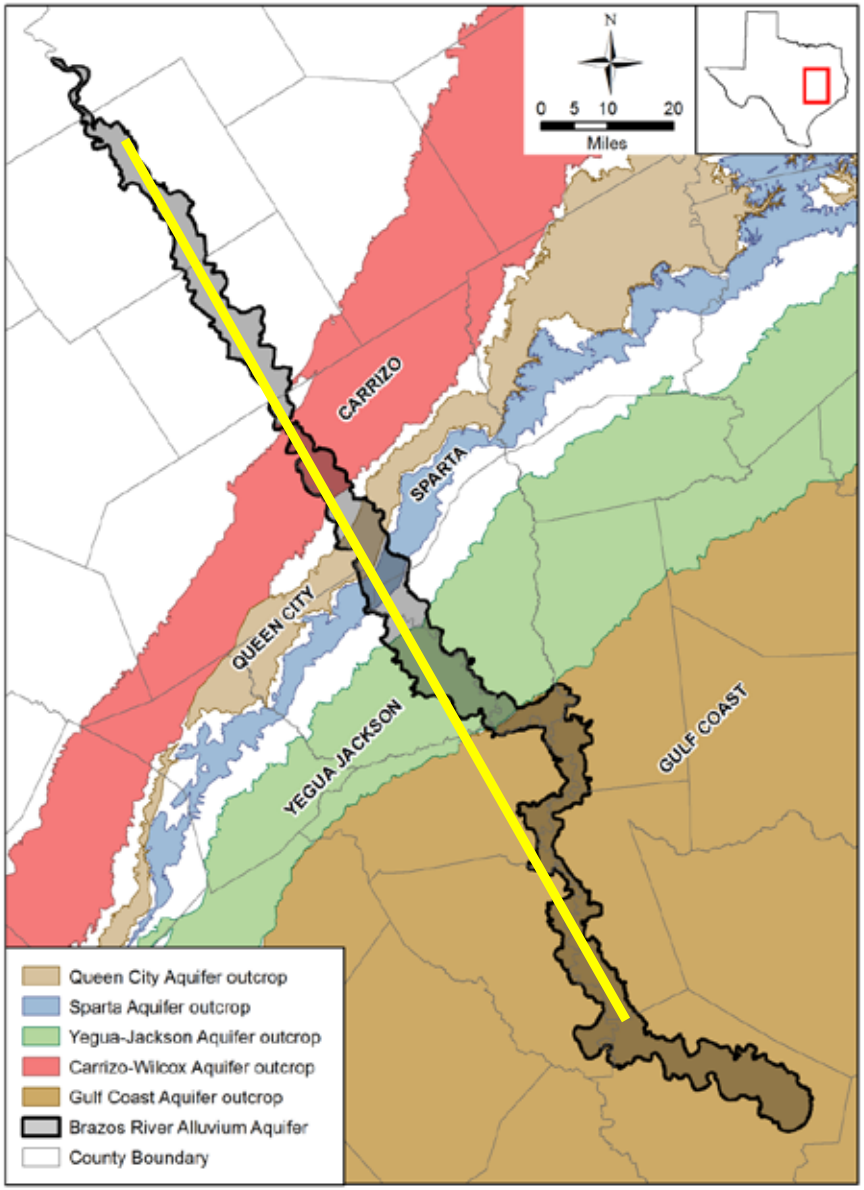
Study Area

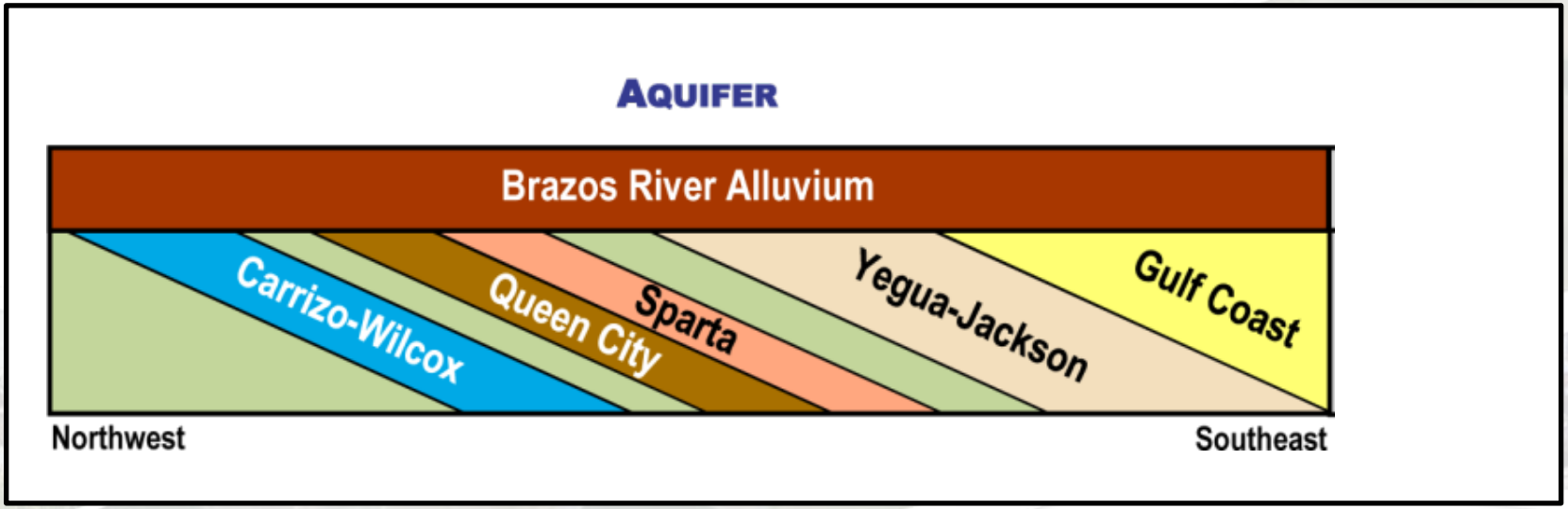

Brazos River Alluvium Aquifer
Active Model Boundary
County
State Boundary
N
0 45 90
Miles

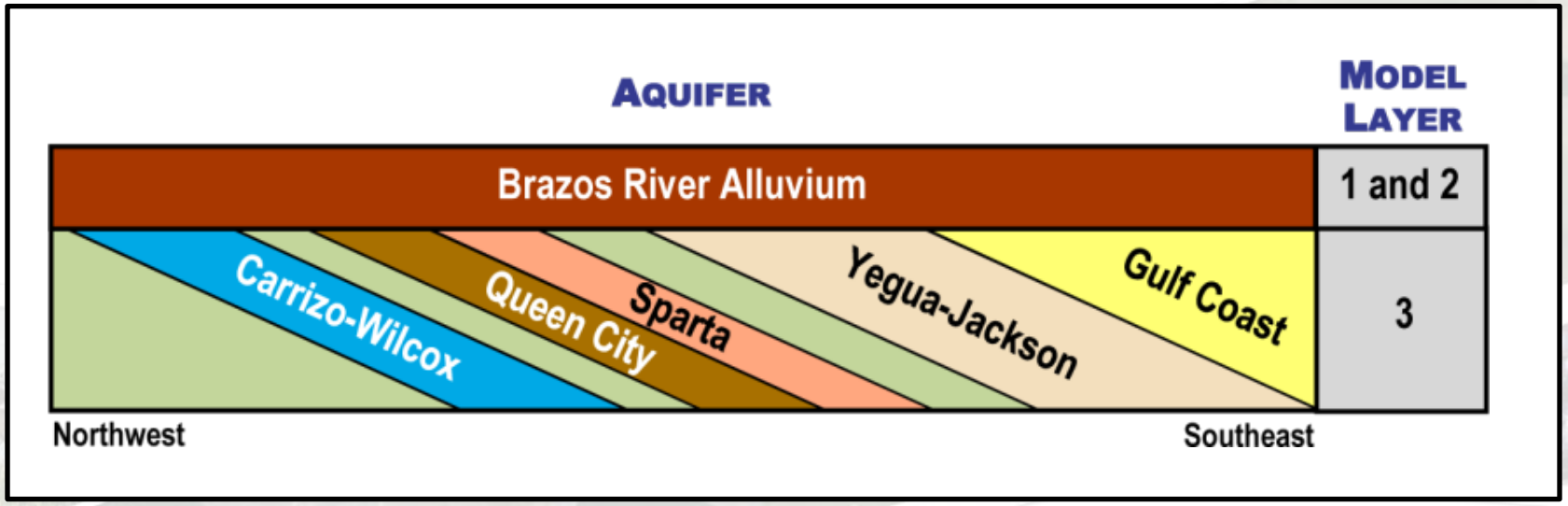

N
0 5 10 20
Miles
Waco
US 84
Marlin
Temple
US 79
US 287
Crockett
Calvert
Madisonville
US 190
Huntsville
Bryan
College Station
Taylor
Snook
Millican
Navasota
Conroe
Brenham
US 290
Hempstead
Prairie View
Tomball
US 77
Pine Island
Pattison
Katy
San Felipe
Sealy
Brookshire
Houston
Simonton
Fulshear
Rosenberg
Wallis
US 90 alt
US 59
Thompsons
Major Road
City
Brazos River Alluvium Aquifer
County Boundary

Extent and Hydrostratigraphy




N
0 5 10 20
Miles
CARRIZO
SPARTA
QUEEN CITY
YEGUA JACKSON
GULF COAST
Queen City Aquifer outcrop
Sparta Aquifer outcrop
Yegua-Jackson Aquifer outcrop
Carrizo-Wilcox Aquifer outcrop
Gulf Coast Aquifer outcrop
Brazos River Alluvium Aquifer
County Boundary


AQUIFER
Brazos River Alluvium
Carrizo-Wilcox
Queen City
Sparta
Yegua-Jackson
Gulf Coast
Northwest
Southeast


AQUIFER
MODEL LAYER
Brazos River Alluvium
1 and 2
Carrizo-Wilcox
Queen City
Sparta
Yegua-Jackson
Gulf Coast
3
Northwest
Southeast

Key Aspects of Conceptualization

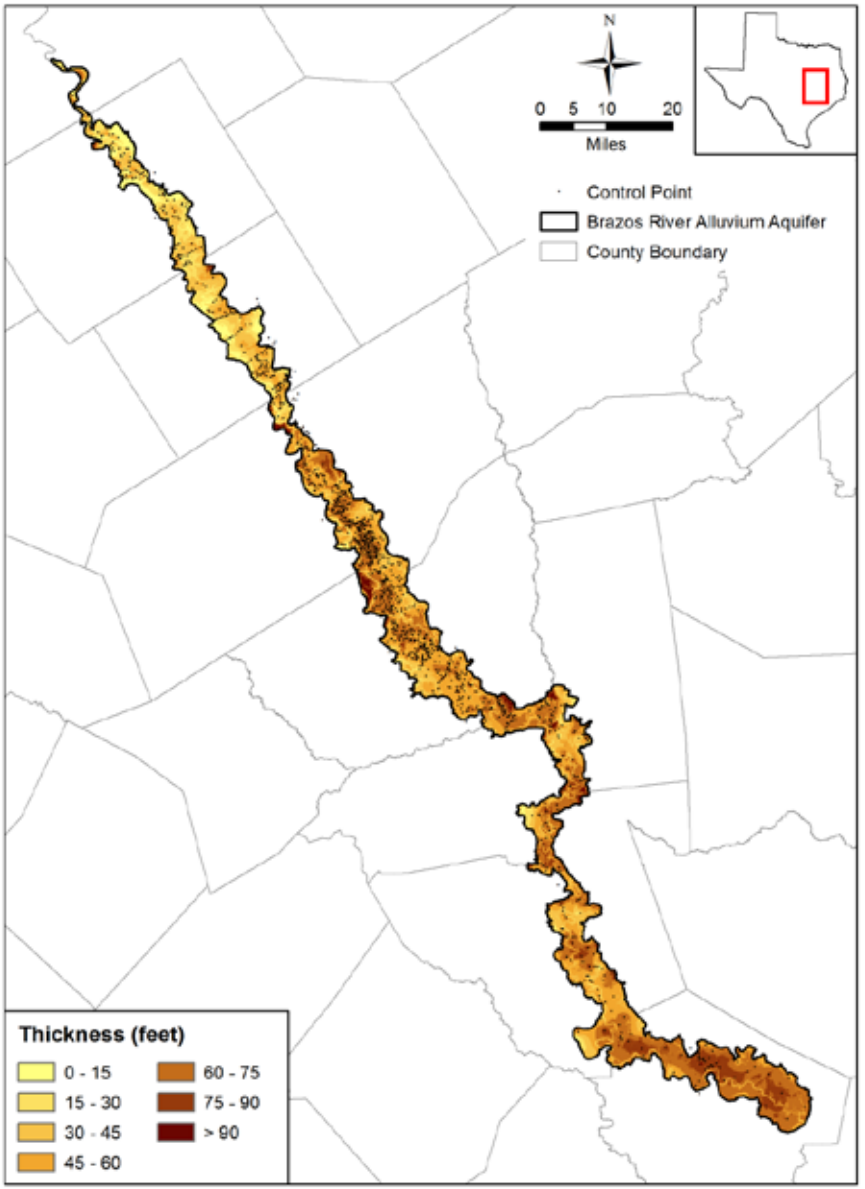
- Extent and hydrostratigraphy
- **Structure**
- Water Levels
- Hydraulic/storage properties
- Recharge/discharge
- Groundwater production
- Cross-formational flow
- Water quality

Structure

- Re-evaluated structural raster and control points from Shah and others (2007)
- Re-calculated thickness for near-boundary anomalies with no nearby control points.
- Filled in gaps between current and previous model extent.
- Re-created Base of Aquifer using the newest 10m resolution DEM and new thickness raster.

Brazos Thickness

- Thickness increases to the South
- Thinnest portion corresponds with the Brazos River



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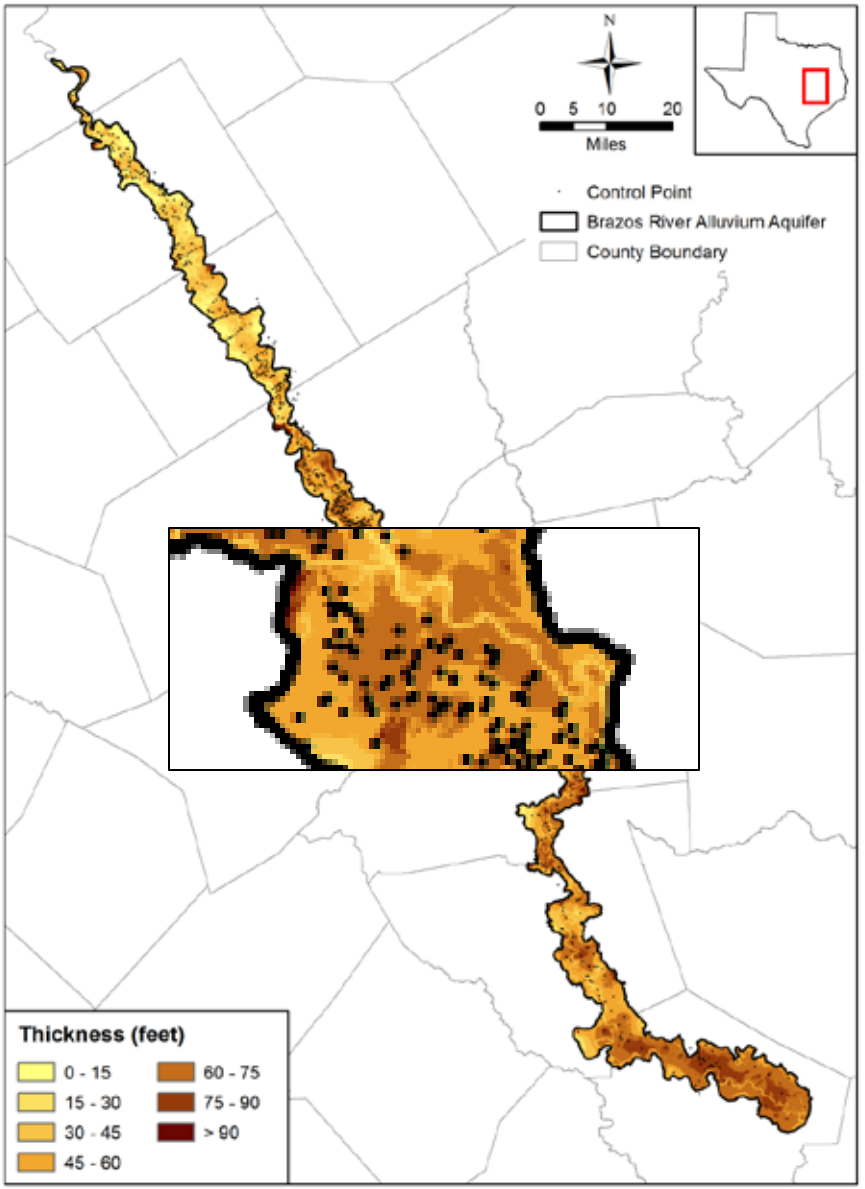

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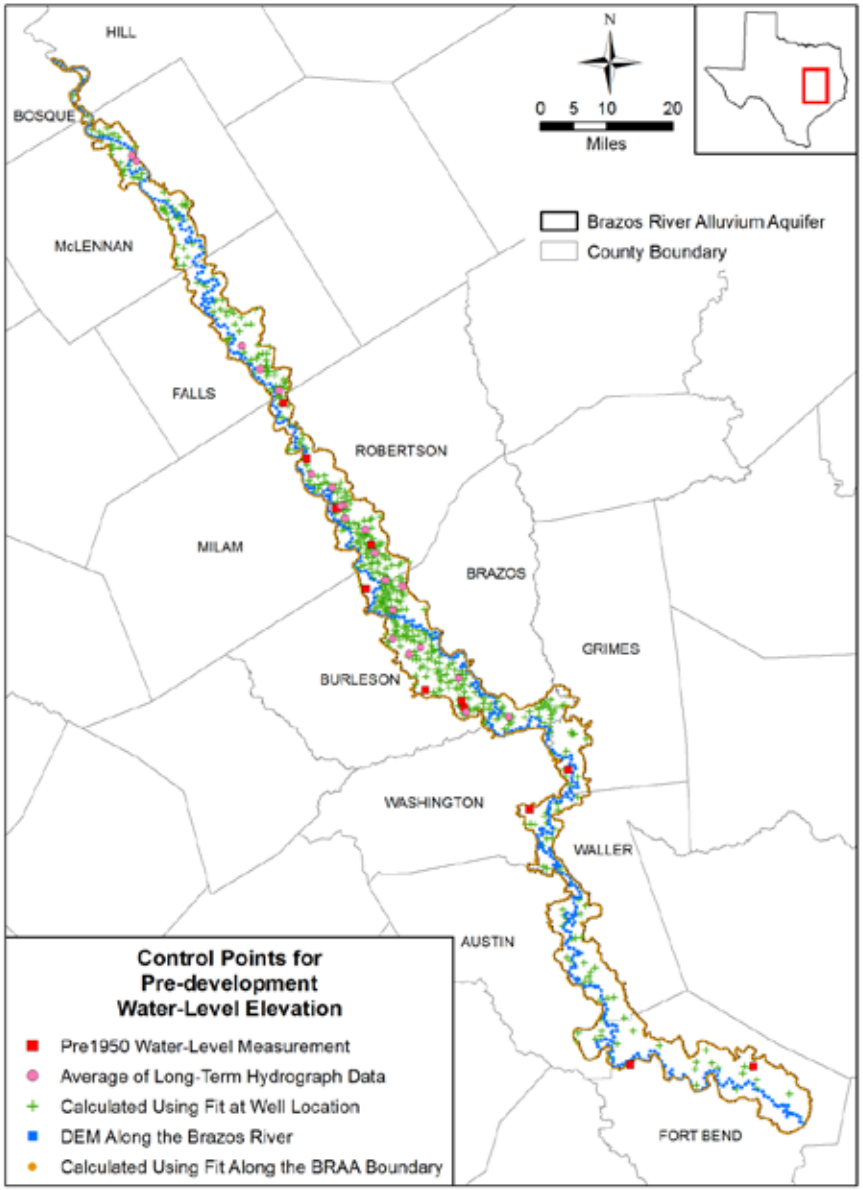
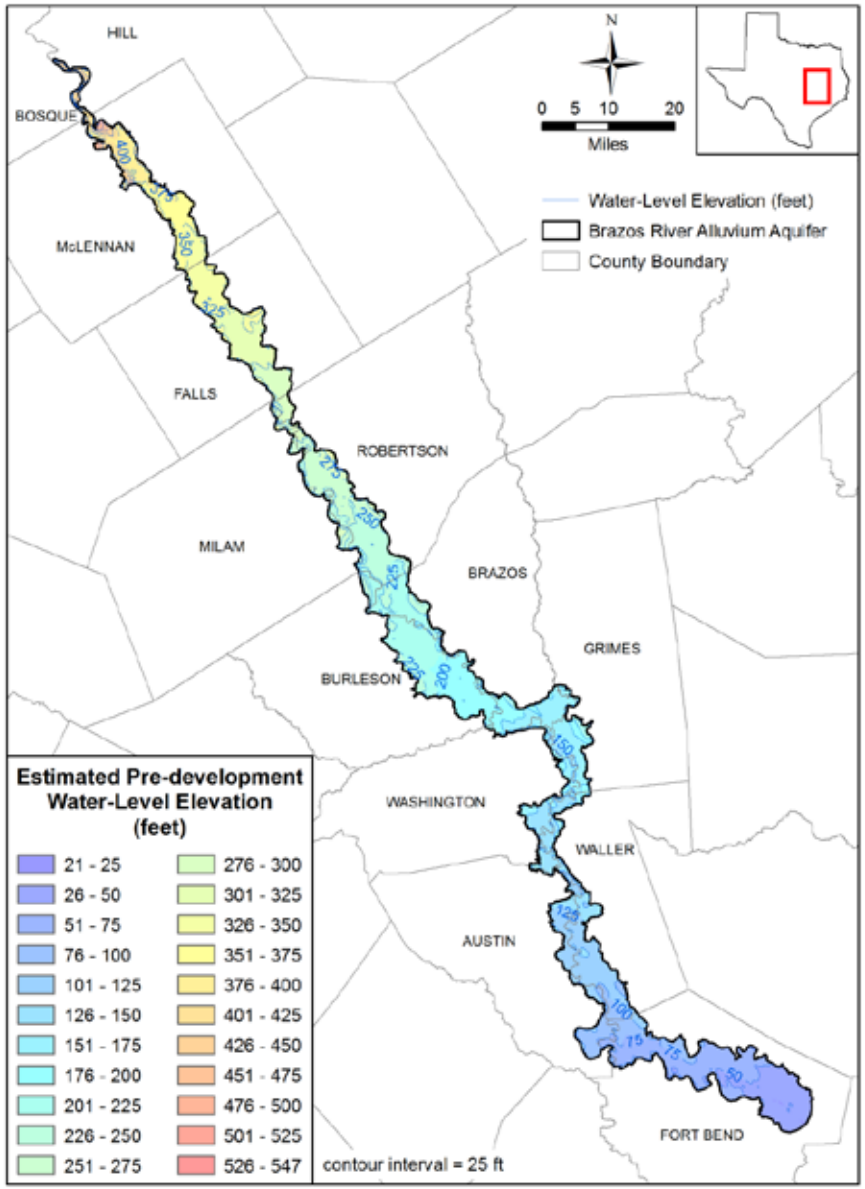
Water Levels

- Water-level data from 1,208 wells were retrieved from
  - TWDB groundwater database
  - TWDB submitted drillers reports database
  - Brazos Valley Groundwater Conservation District
  - Post Oak Savannah Groundwater Conservation District

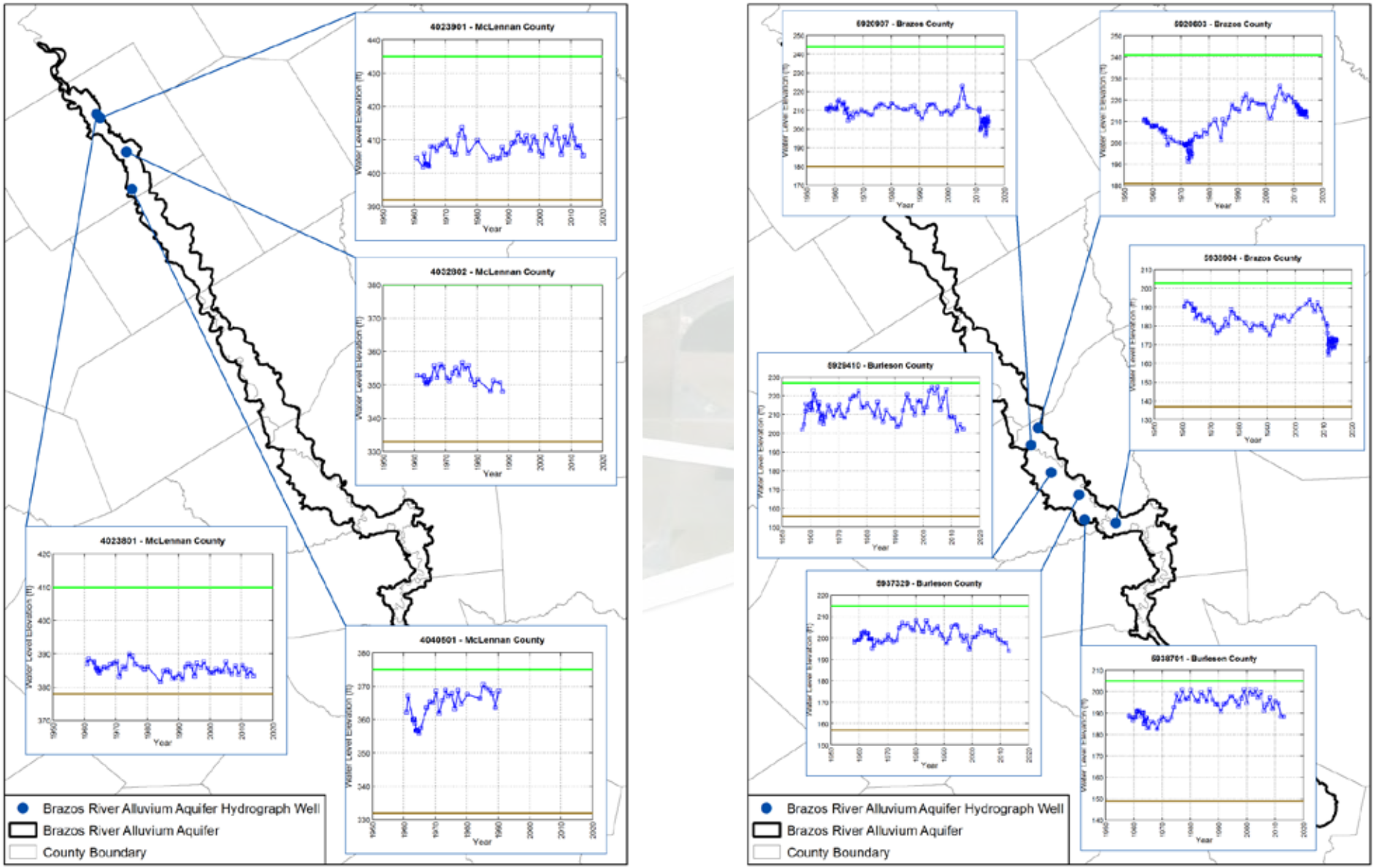
- Wells were assigned to aquifers based on the current study's new structural surfaces

Pre-development Water Levels

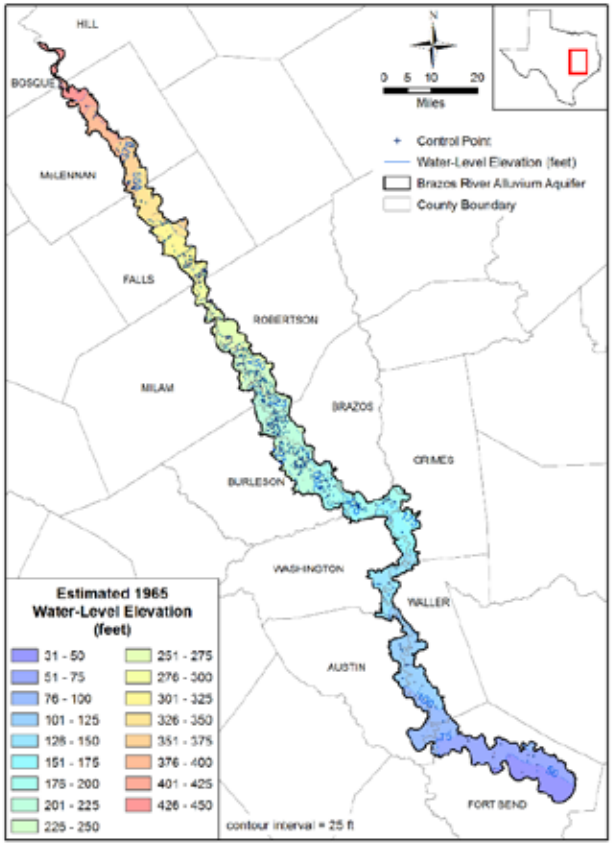


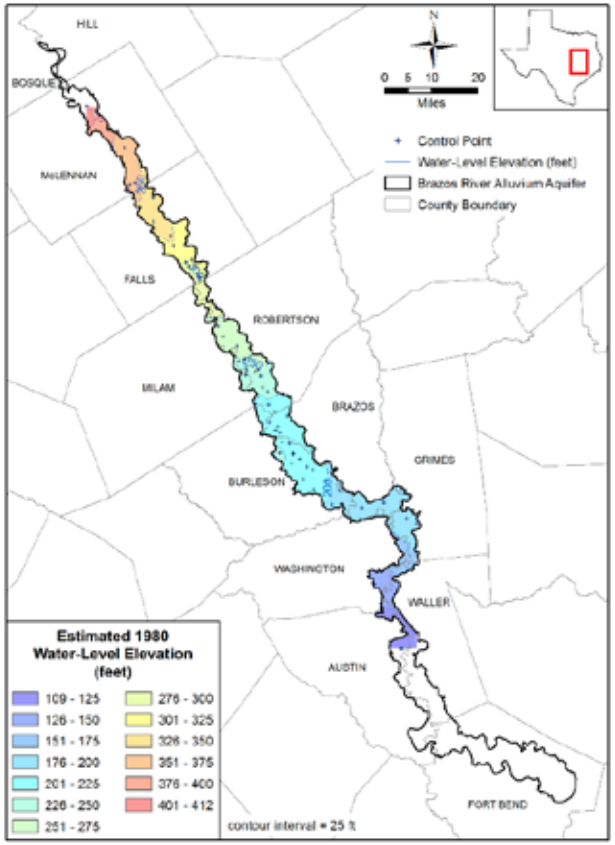


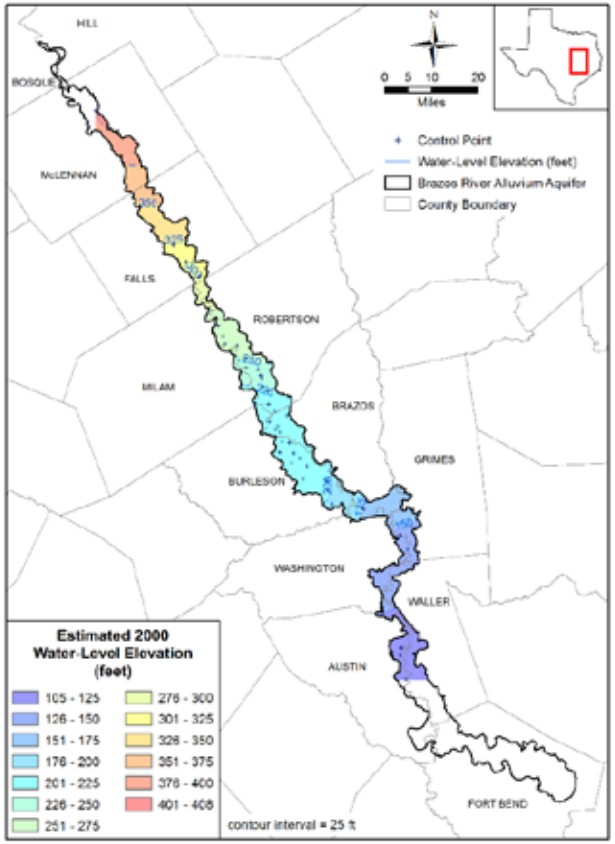
Post-development Water Levels



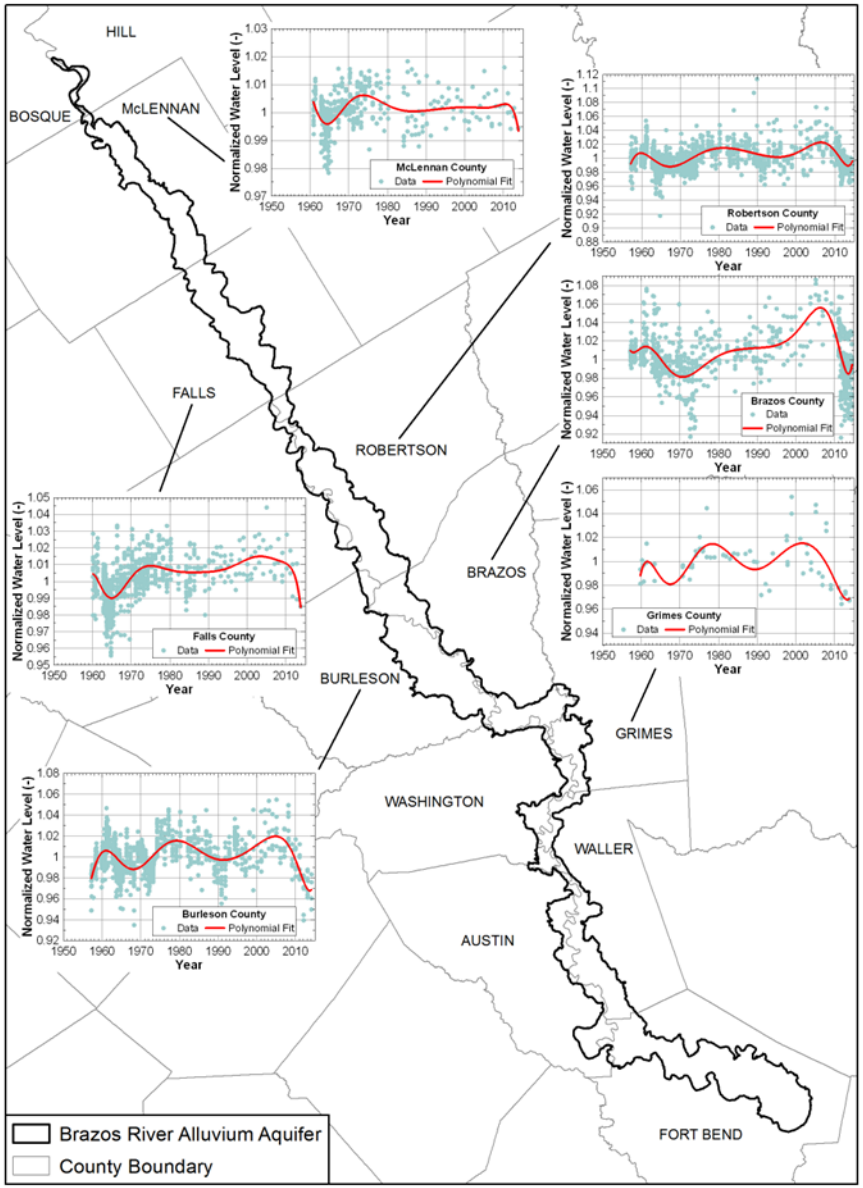
Water Level Decline







- Water-levels stay relatively constant across time with no notable long-term declines


HILL
BOSQUE
McLENNAN
FALLS
ROBERTSON
BRAZOS
BURLESON
GRIMES
WASHINGTON
WALLER
AUSTIN
FORT BEND
McLennan County
Robertson County
Brazos County
Grimes County
Falls County
Burleson County
Data
Polynomial Fit
Normalized Water Level (-)
Year
Brazos River Alluvium Aquifer
County Boundary

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Hydraulic Parameters

§ Sources:

- Previous literature including Cronin & Wilson (1967), O'Rourke (2006), Follett (1974), Wrobelski (1996), Munster & others (1996), Dutton & others (2003)

- Shah and Houston (2007) database

- TWDB Groundwater database

- TWDB Submitted Drillers' Reports database

- Newly scanned logs from :

  TCEQ Public Water Supply program (394 well logs)

  TWDB WIID database (282 well logs)

Hydraulic Parameters

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- Newly scanned logs from :
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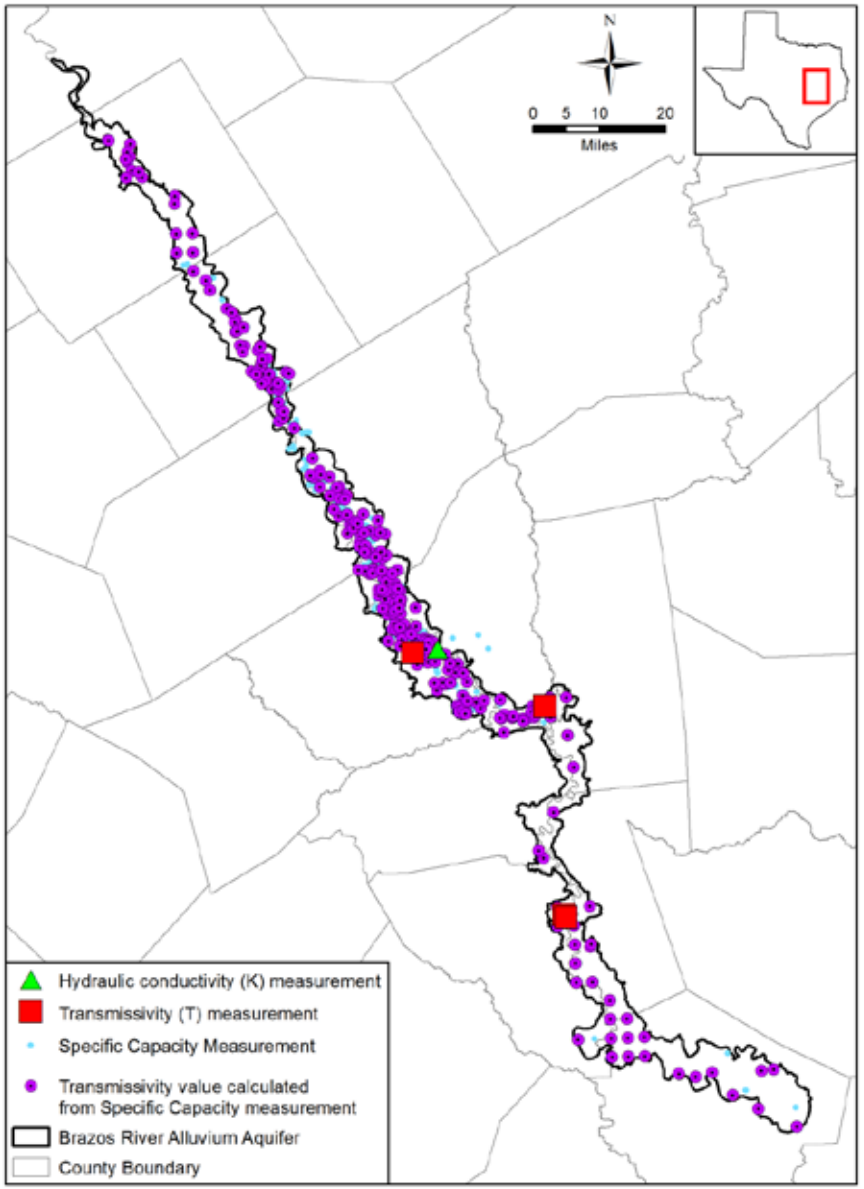
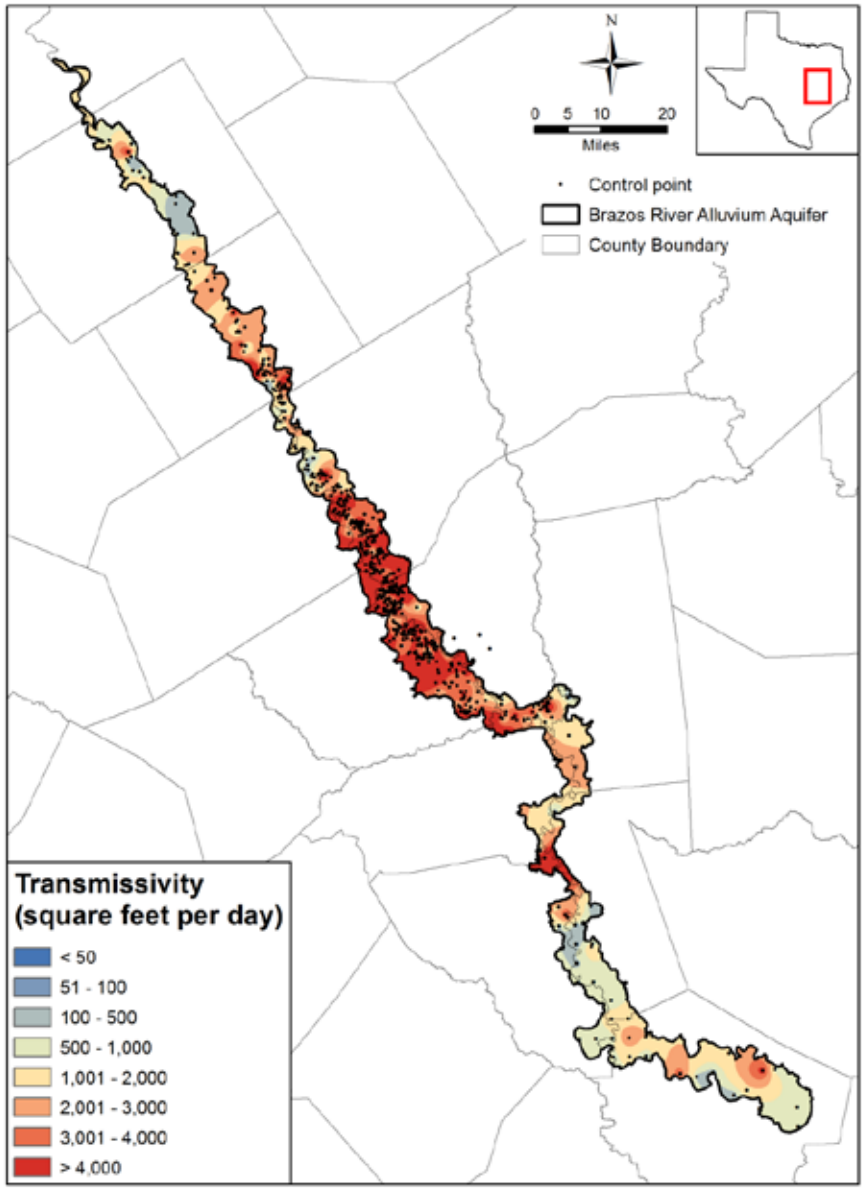
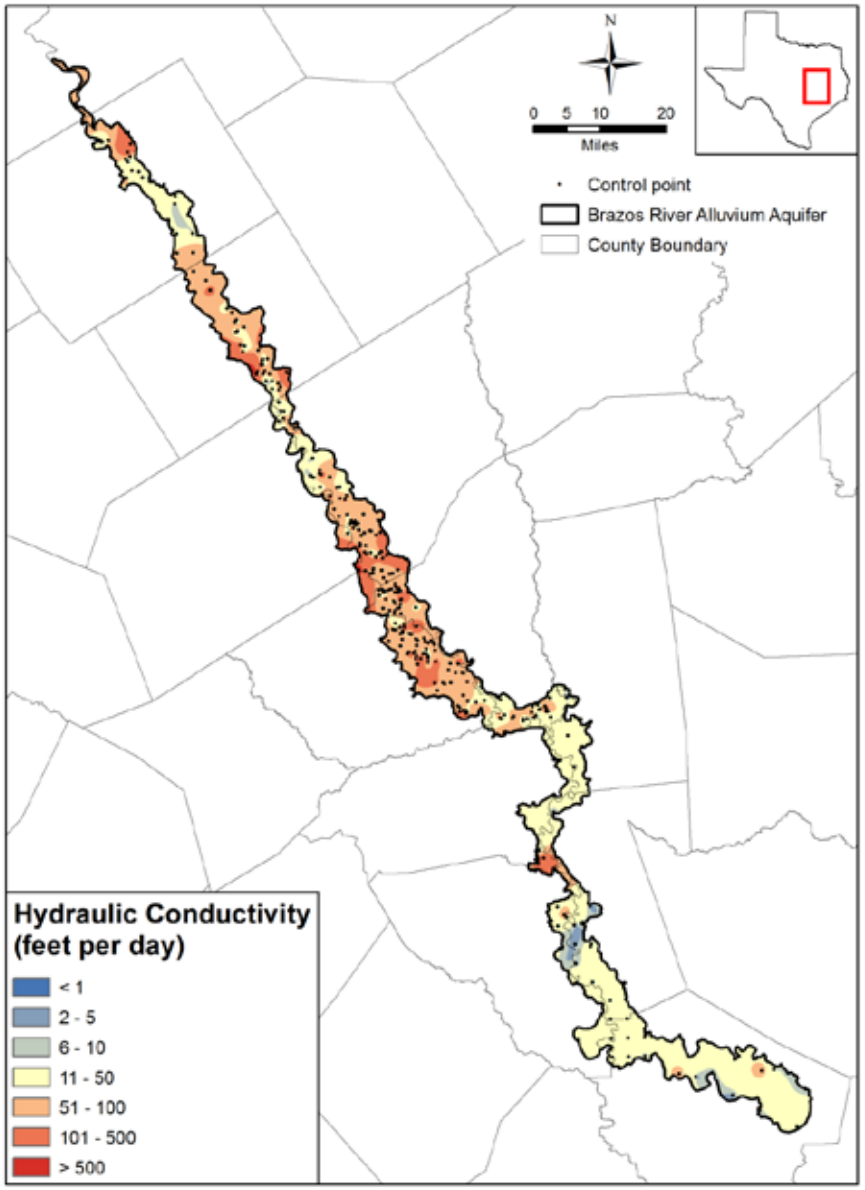
Hydraulic Parameters

- Very few K or T values available from long duration pump tests (4)
- Used the Theis nonequilibrium equation to calculate Transmissivity from Specific Capacity



Hydraulic Parameters





Hydraulic Parameters

§ Vertical Hydraulic Conductivity

- No literature values for vertical hydraulic conductivity are available
- Assume that the alluvium is not highly stratified outside of some isolated clay layers.
- Vertical flow will be governed primarily by the difference in conductivity between the BRAA and underlying units.

§ Storage

- Specific yield estimated at 15% by Cronin & Wilson (1967)

Key Aspects of Conceptualization

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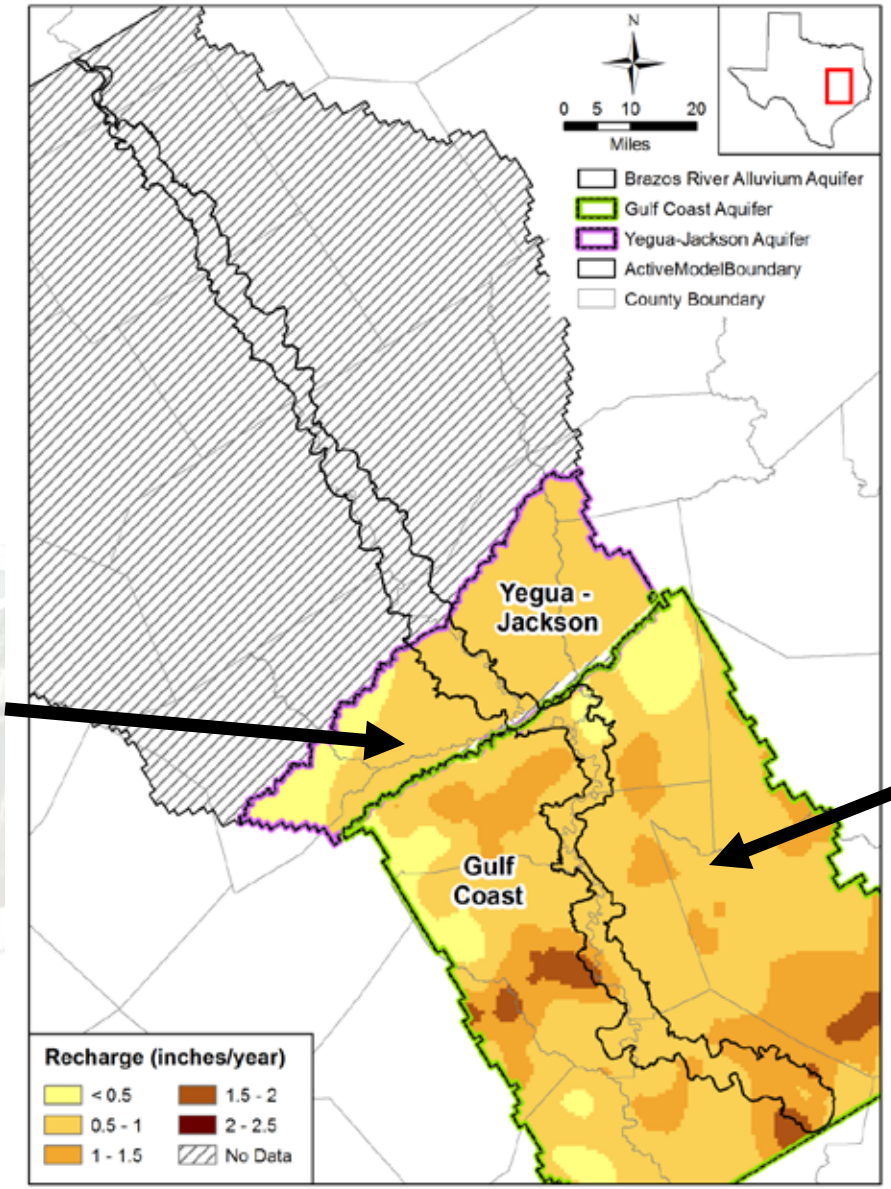
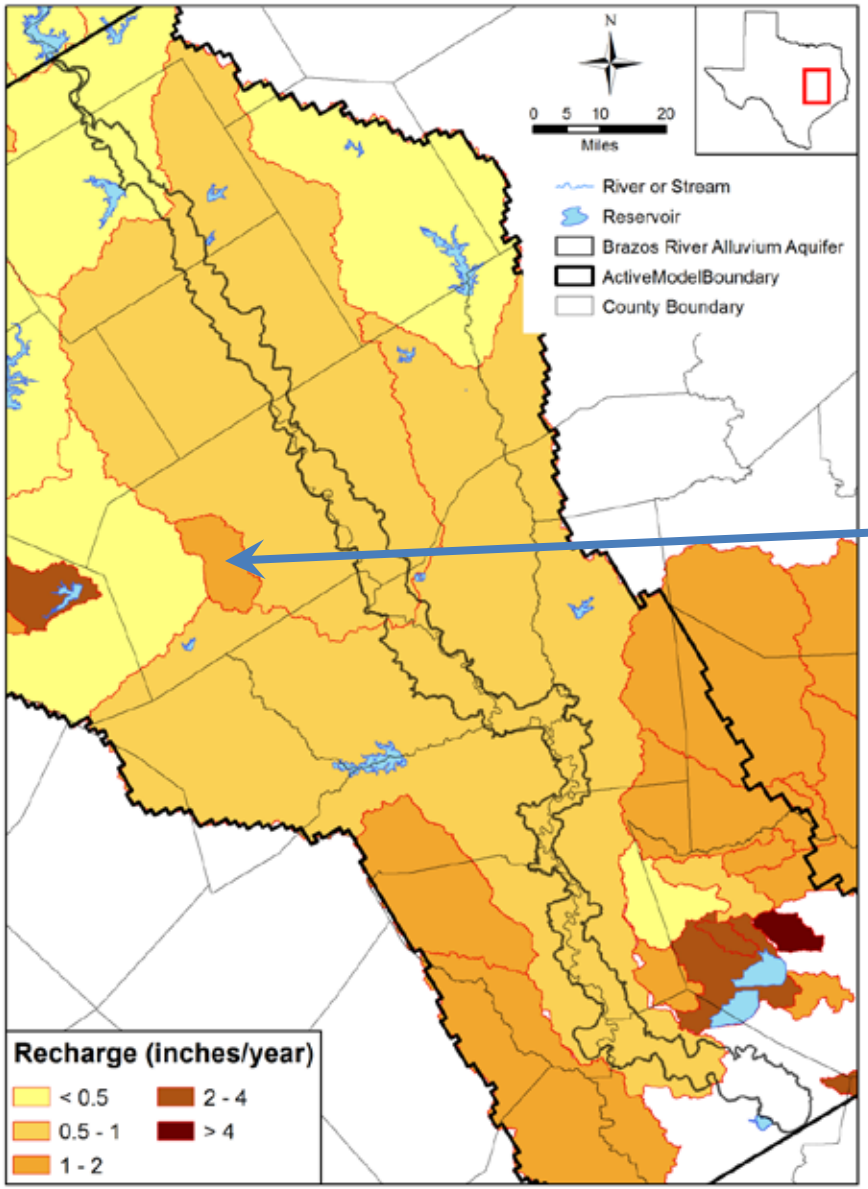
Recharge – Previous Work

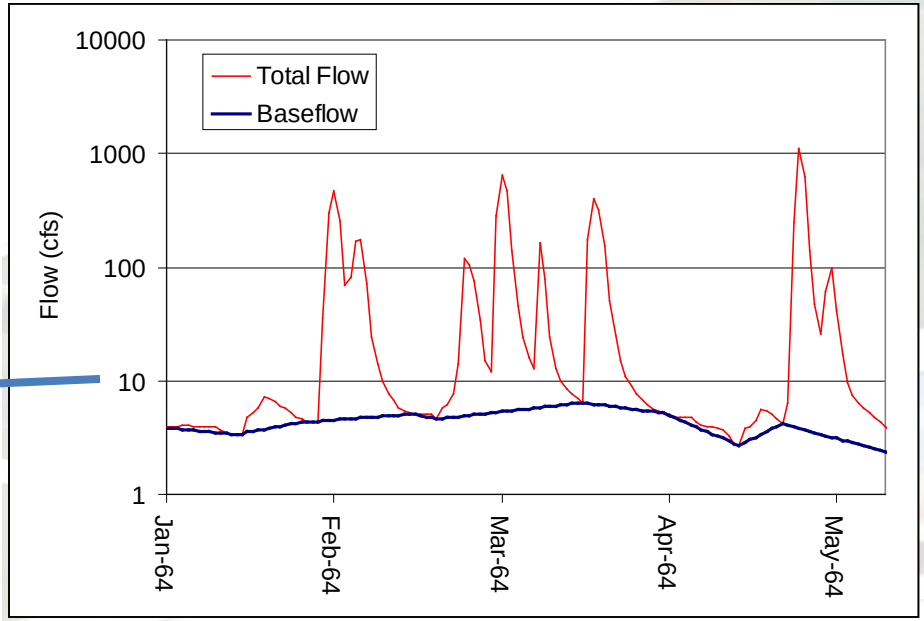
Yegua – Jackson GAM
(Deeds et al., 2010)



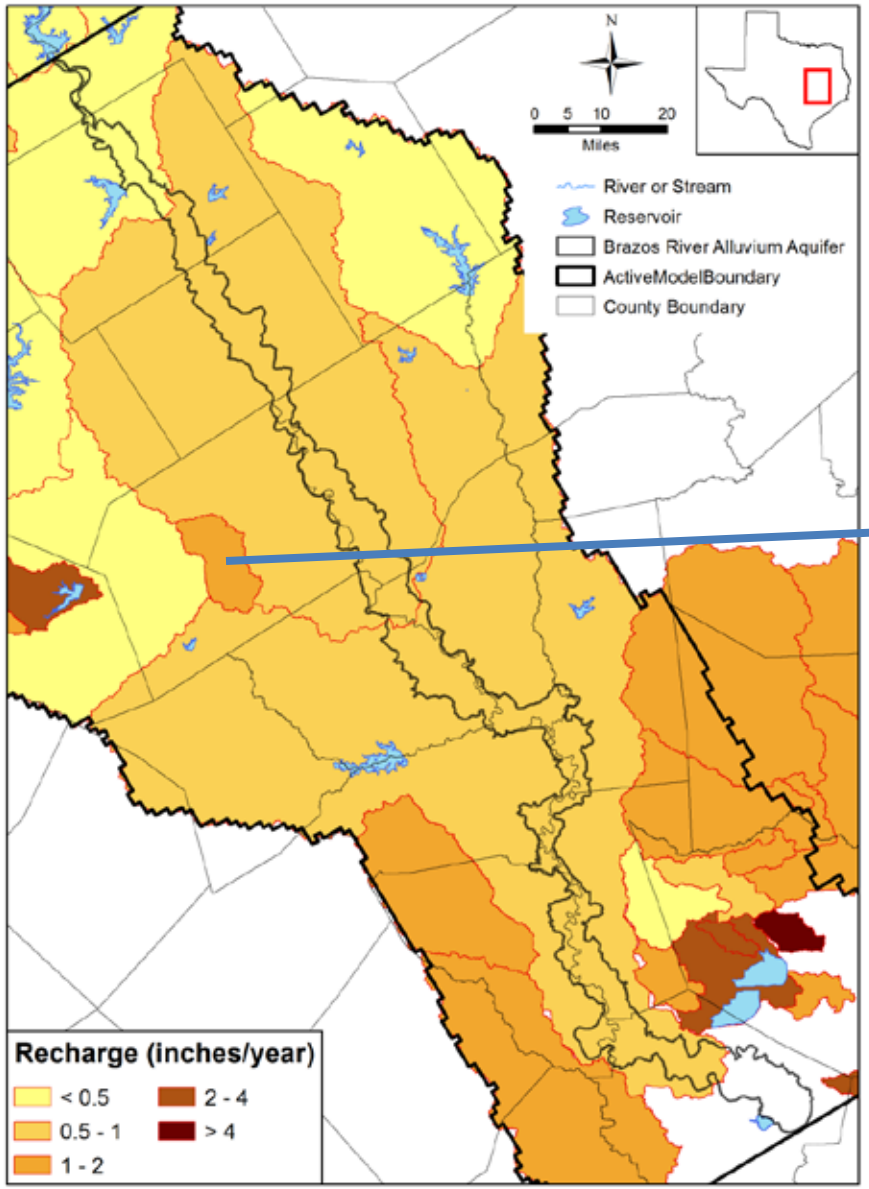
Gulf Coast
Recharge Study
(Scanlon et al., 2012)

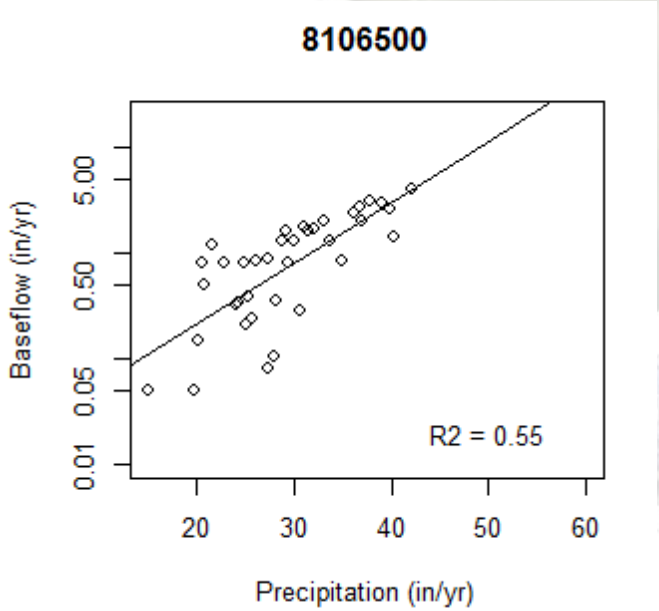
Recharge


N
0 5 10 20
Miles
River or Stream
Reservoir
Brazos River Alluvium Aquifer
ActiveModelBoundary
County Boundary
Recharge (inches/year)
< 0.5
0.5 - 1
1 - 2
2 - 4
> 4


Total Flow
Baseflow
Flow (cfs)
10000
1000
100
10
1
Jan-64
Feb-64
Mar-64
Apr-64
May-64

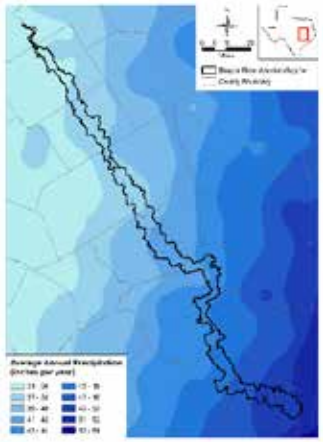
Recharge


N
0 5 10 20
Miles
River or Stream
Reservoir
Brazos River Alluvium Aquifer
ActiveModelBoundary
County Boundary
Recharge (inches/year)
< 0.5
0.5 - 1
1 - 2
2 - 4
> 4


8106500
Baseflow (in/yr)
0.01
0.05
0.50
5.00
R2 = 0.55
20
30
40
50
60
Precipitation (in/yr)

Recharge

Precipitation



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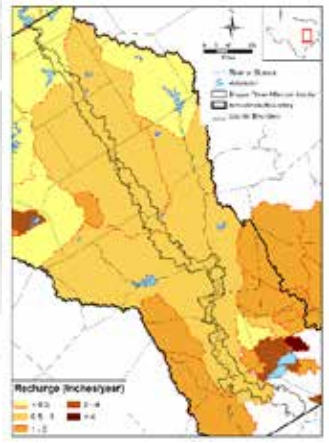
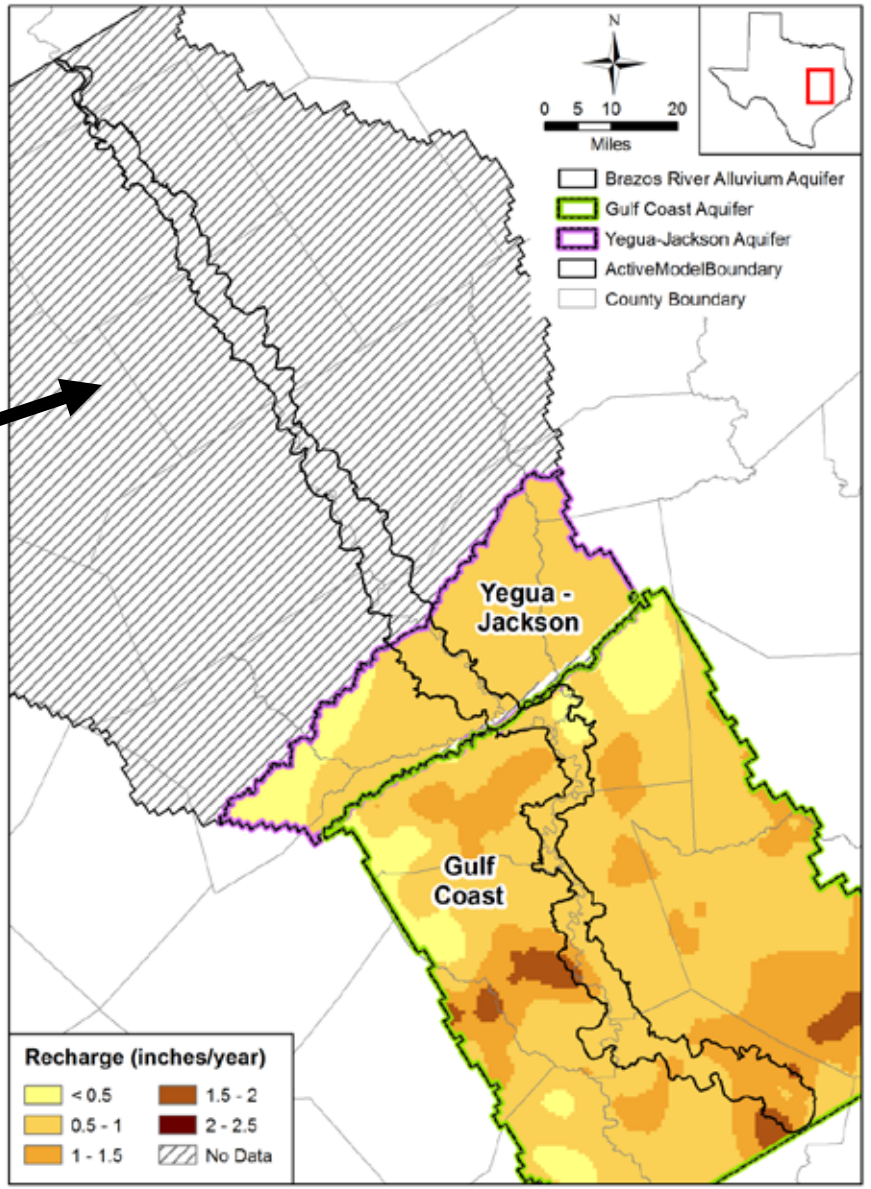
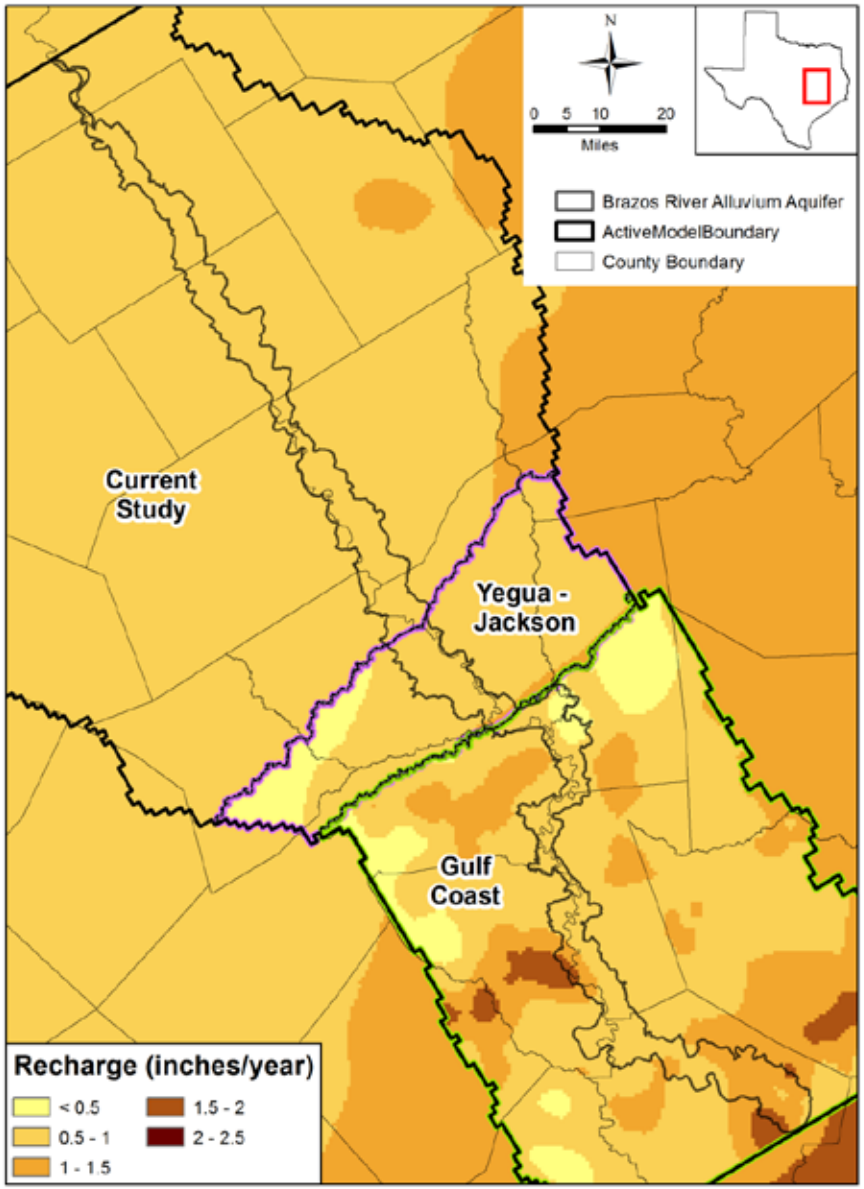


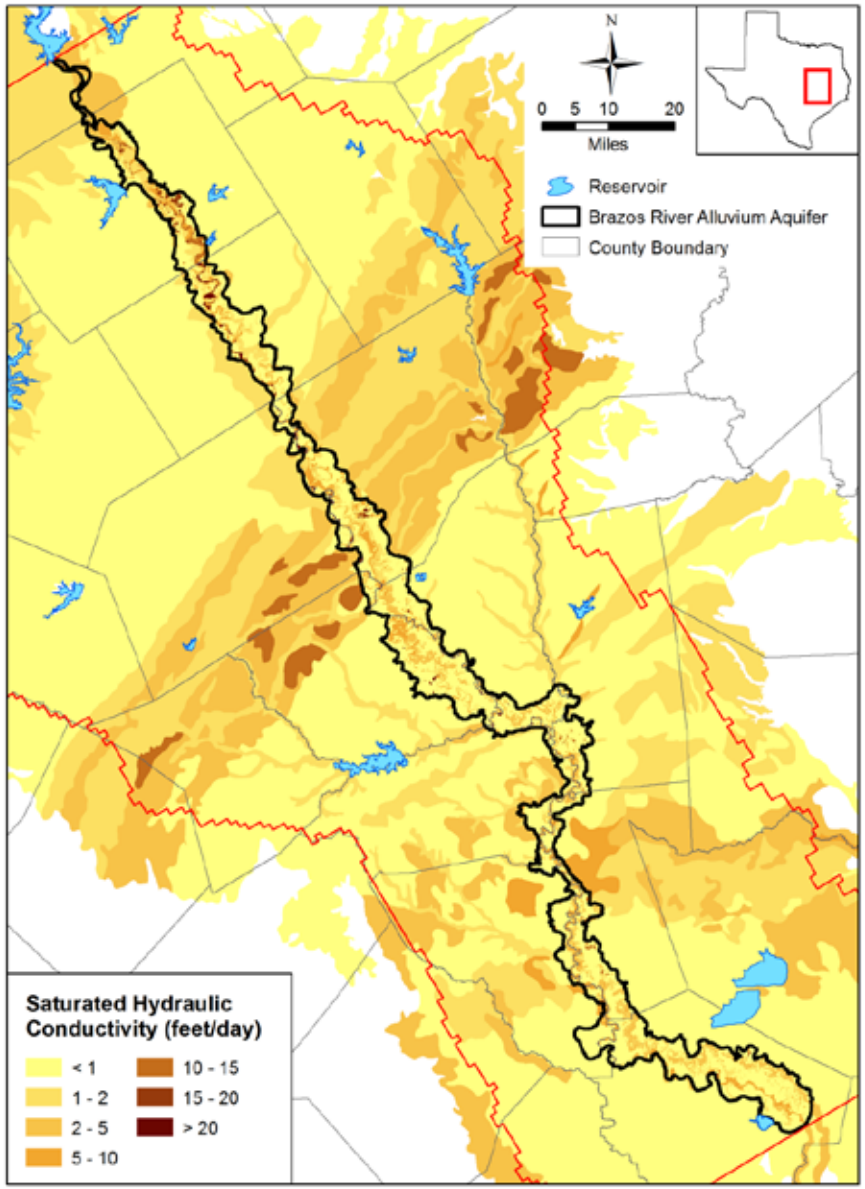
Baseflow Analysis

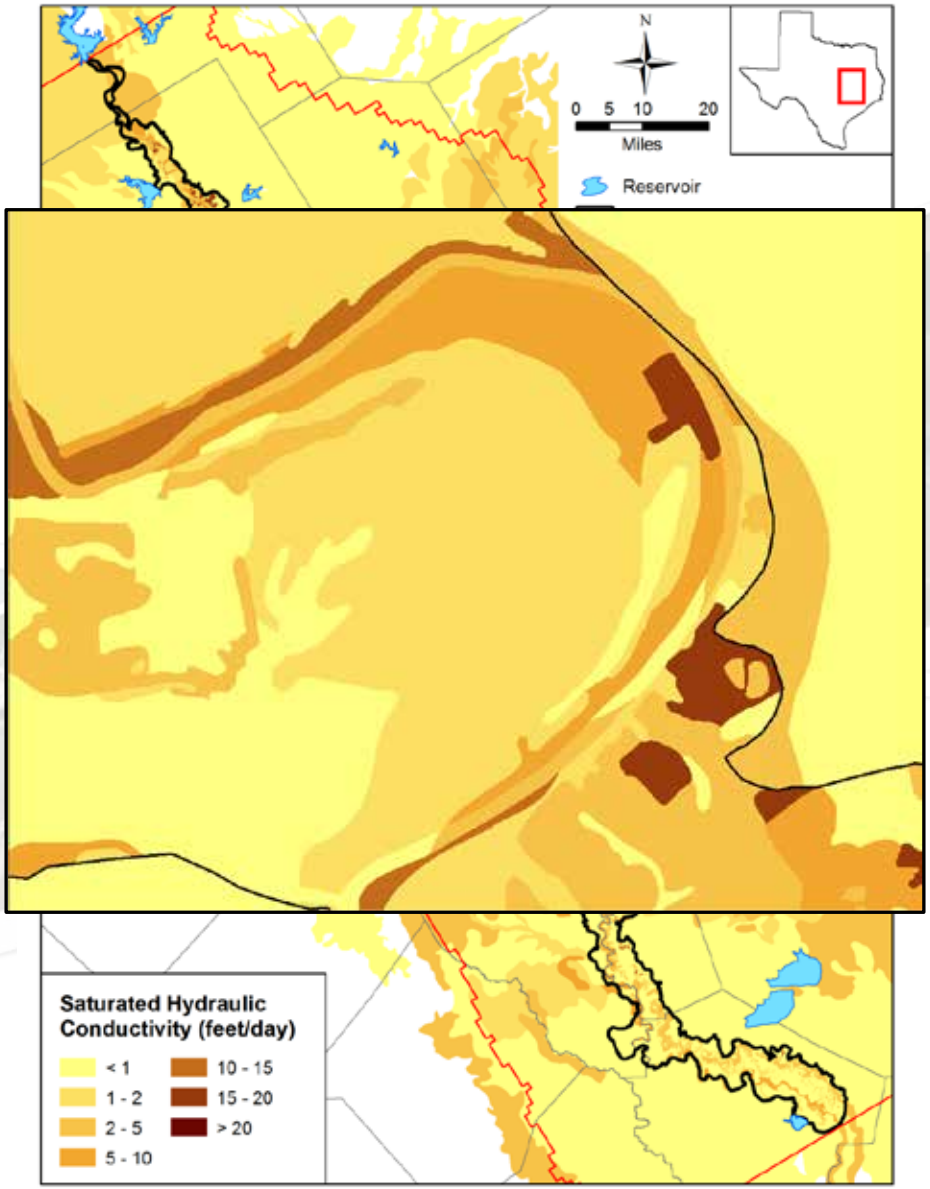



N
0 5 10 20
Miles
Brazos River Alluvium Aquifer
ActiveModelBoundary
County Boundary
Current Study
Yegua - Jackson
Gulf Coast
Recharge (inches/year)
< 0.5
0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5

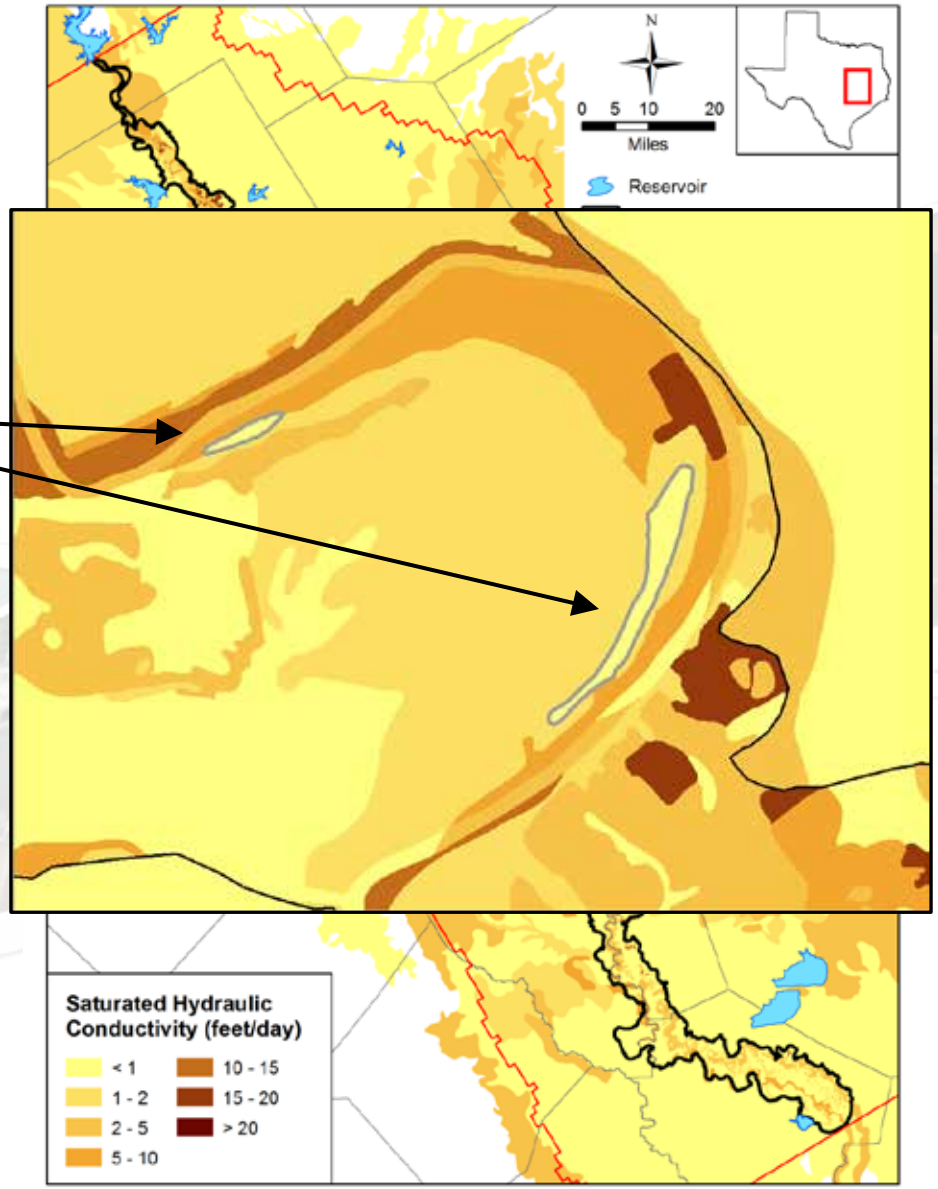
Recharge

	Other Model Areas
PRE-development	Baseflow-derived recharge + previous models
POST-development	Baseflow-derived recharge + previous models

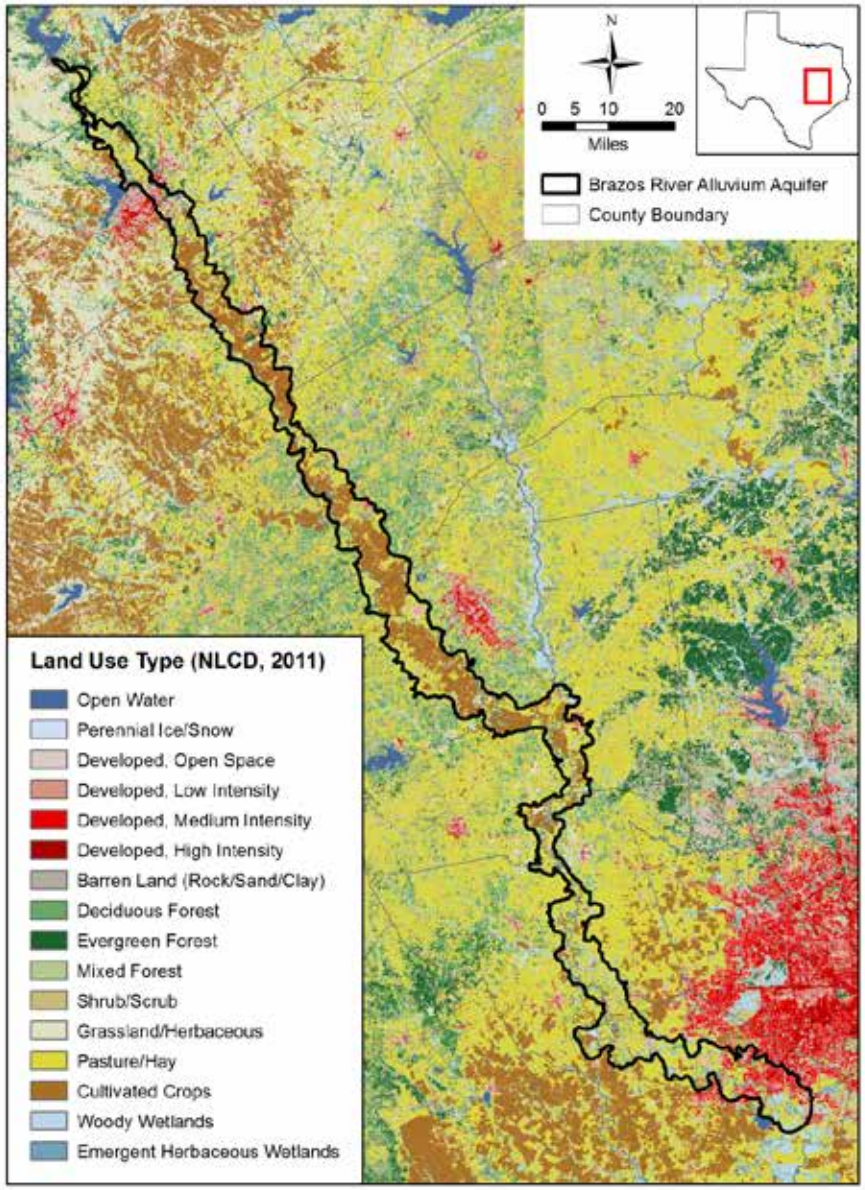

N
0 5 10 20
Miles
Reservoir
Brazos River Alluvium Aquifer
County Boundary
Saturated Hydraulic Conductivity (feet/day)
< 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
> 20


N
0 5 10 20
Miles
Reservoir
Saturated Hydraulic Conductivity (feet/day)
< 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
> 20

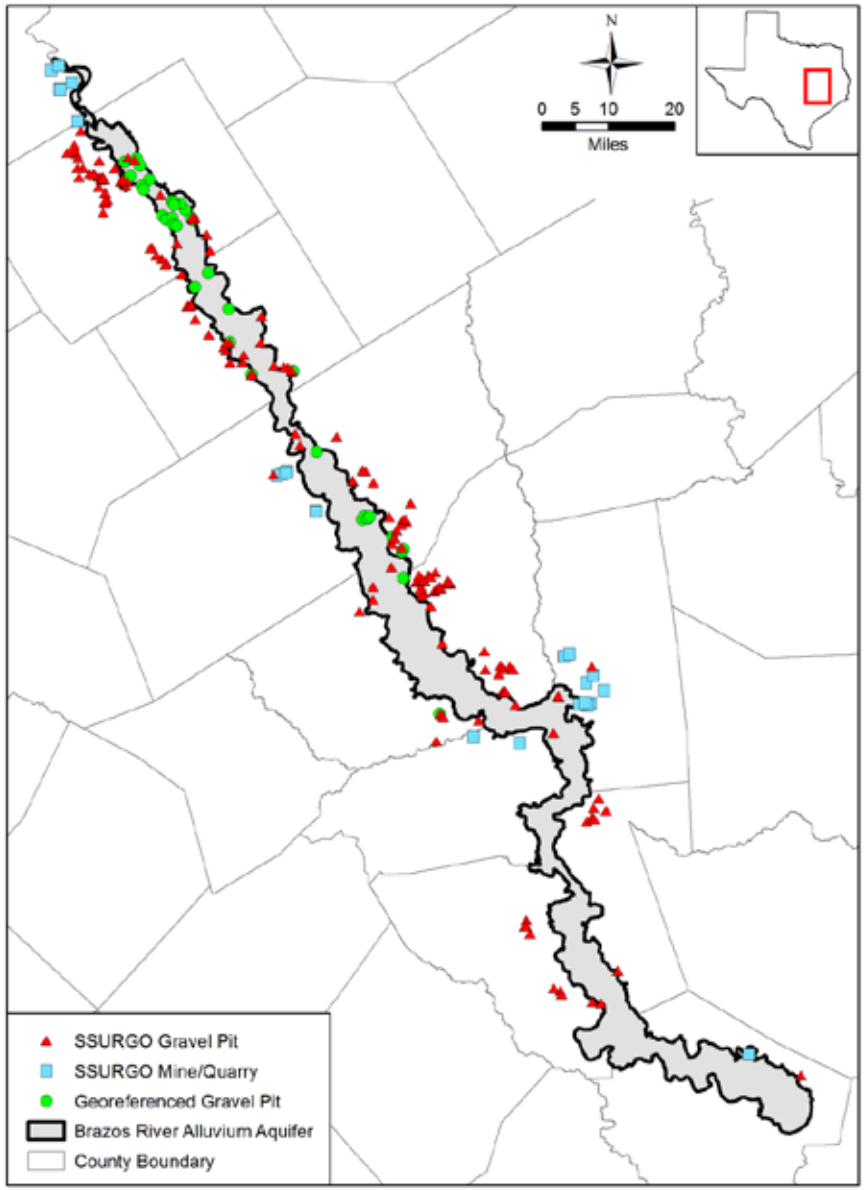
Ships Clay


N
0 5 10 20
Miles
Reservoir
Saturated Hydraulic Conductivity (feet/day)
< 1
1 - 2
2 - 5
5 - 10
10 - 15
15 - 20
> 20

Recharge


N
0 5 10 20
Miles
Brazos River Alluvium Aquifer
County Boundary
Land Use Type (NLCD, 2011)
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land (Rock/Sand/Clay)
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands

Recharge


N
0 5 10 20
Miles
SSURGO Gravel Pit
SSURGO Mine/Quarry
Georeferenced Gravel Pit
Brazos River Alluvium Aquifer
County Boundary

Recharge

	Brazos River Alluvium Aquifer
PRE-development	Baseflow-derived recharge + soil type
POST-development	Baseflow-derived recharge + soil type + land use/irrigation + focused recharge

Natural Discharge

§ Discharge to Brazos River from the Brazos River Alluvium Aquifer is likely a large portion of water balance.

§ Re-evaluated USGS Gain/Loss Studies (Turco & others, 2007)

- Added diversions and return flows
- Adjusted error analysis

§ Performed hydrograph separation analyses for sequential gages on the Brazos River to determine baseflow trends

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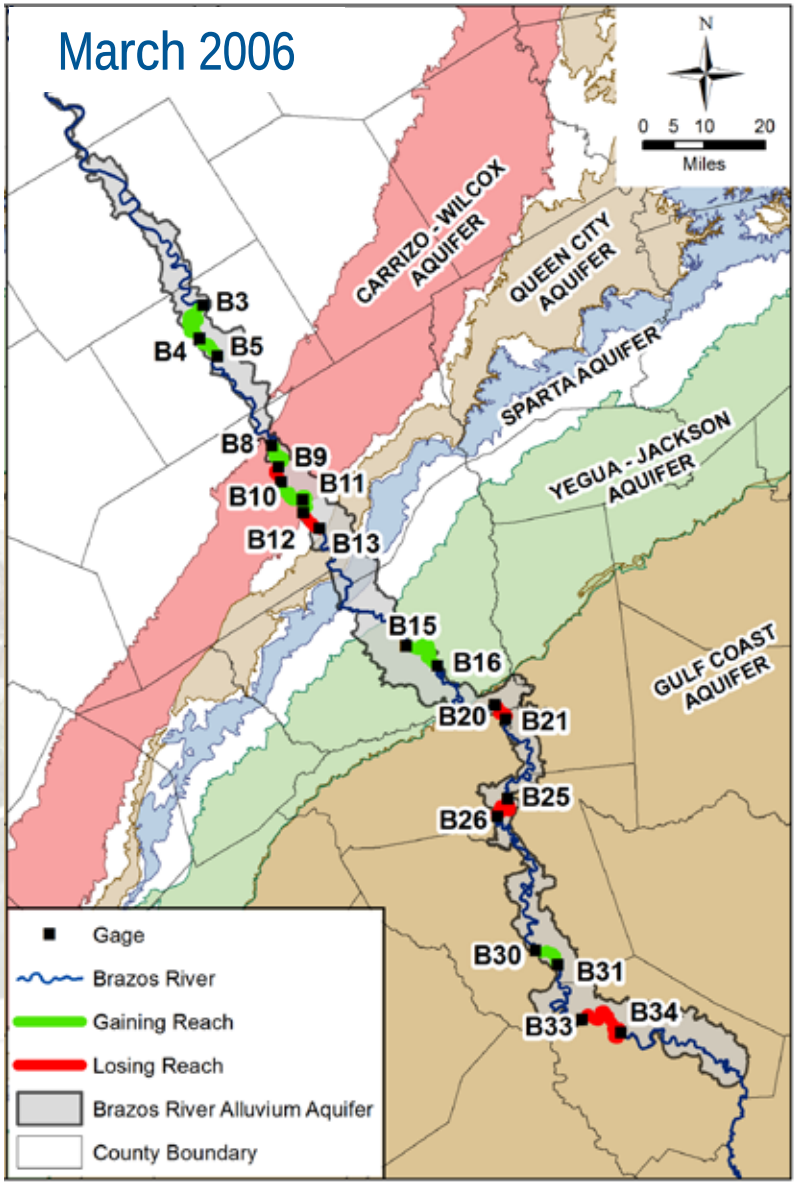

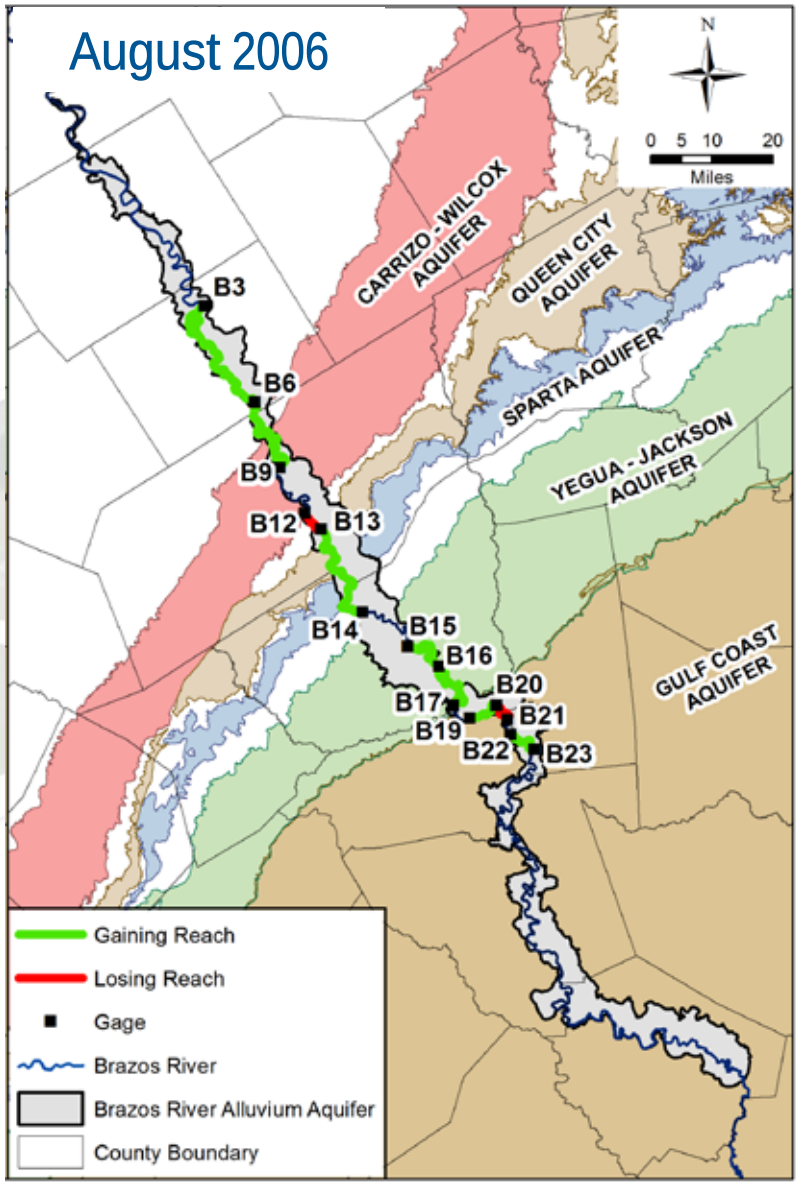

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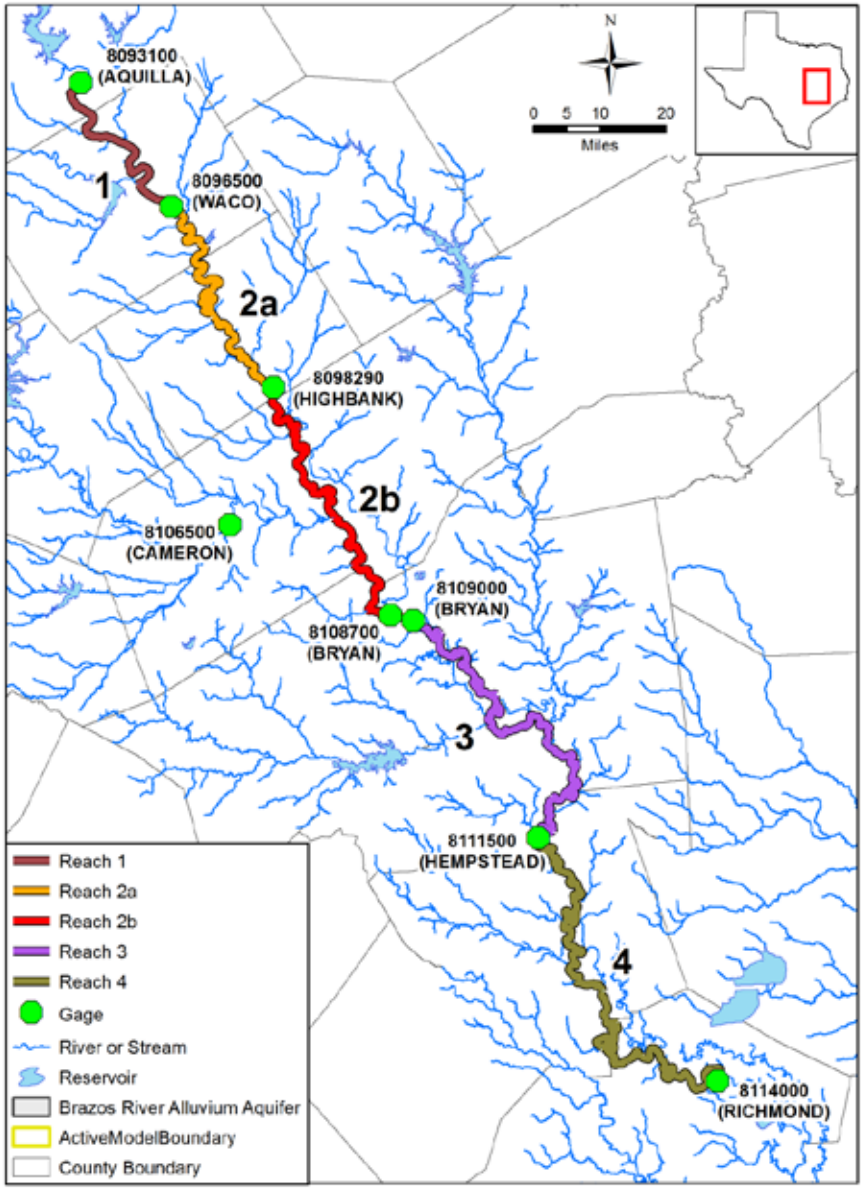
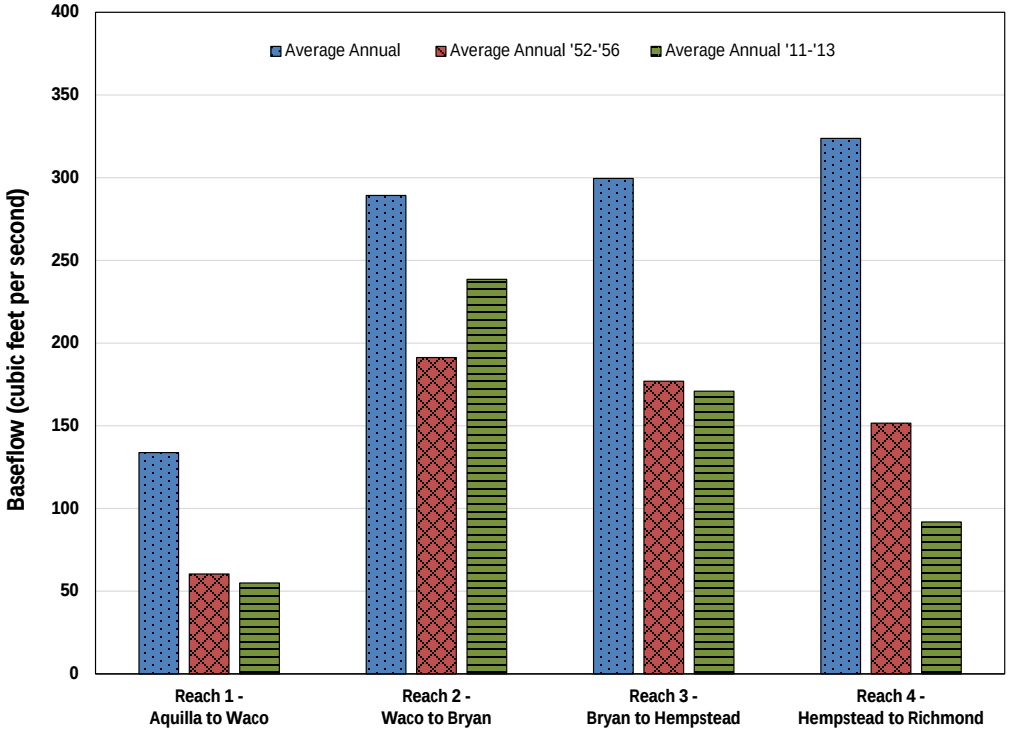
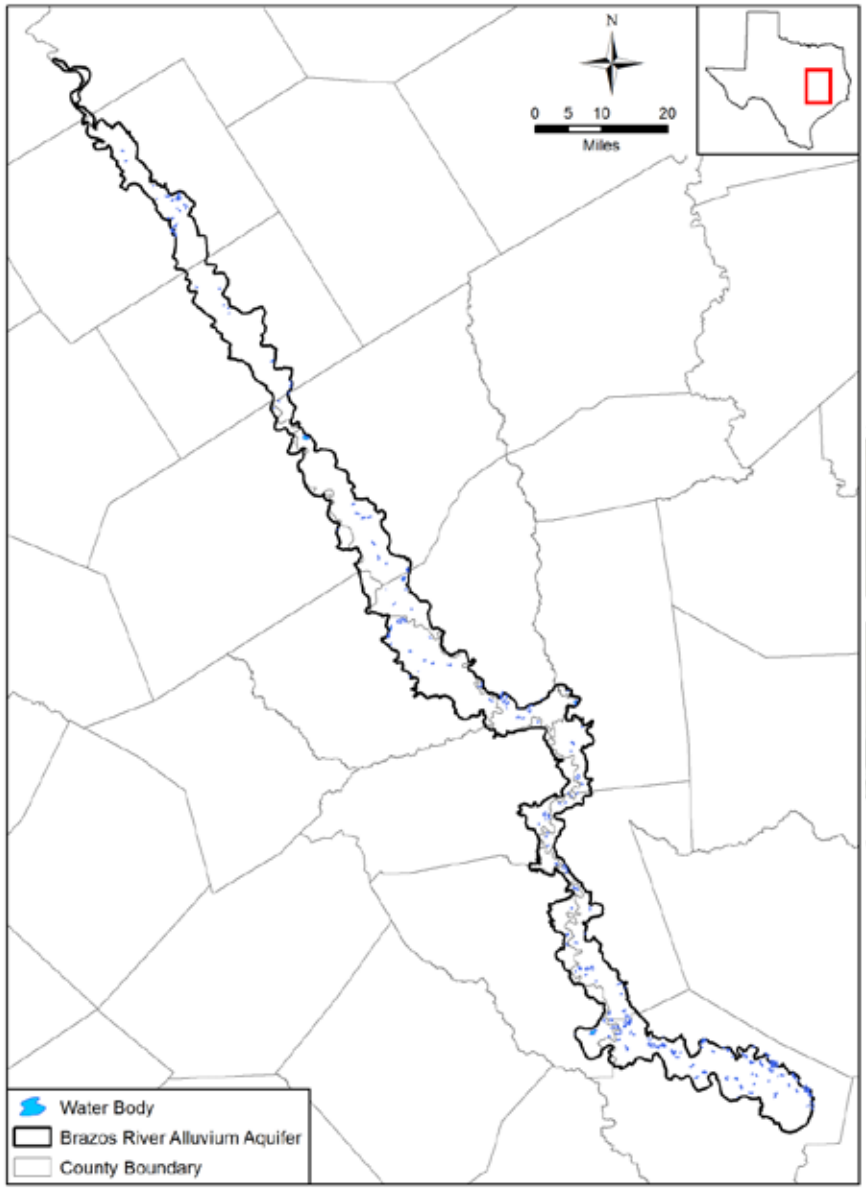
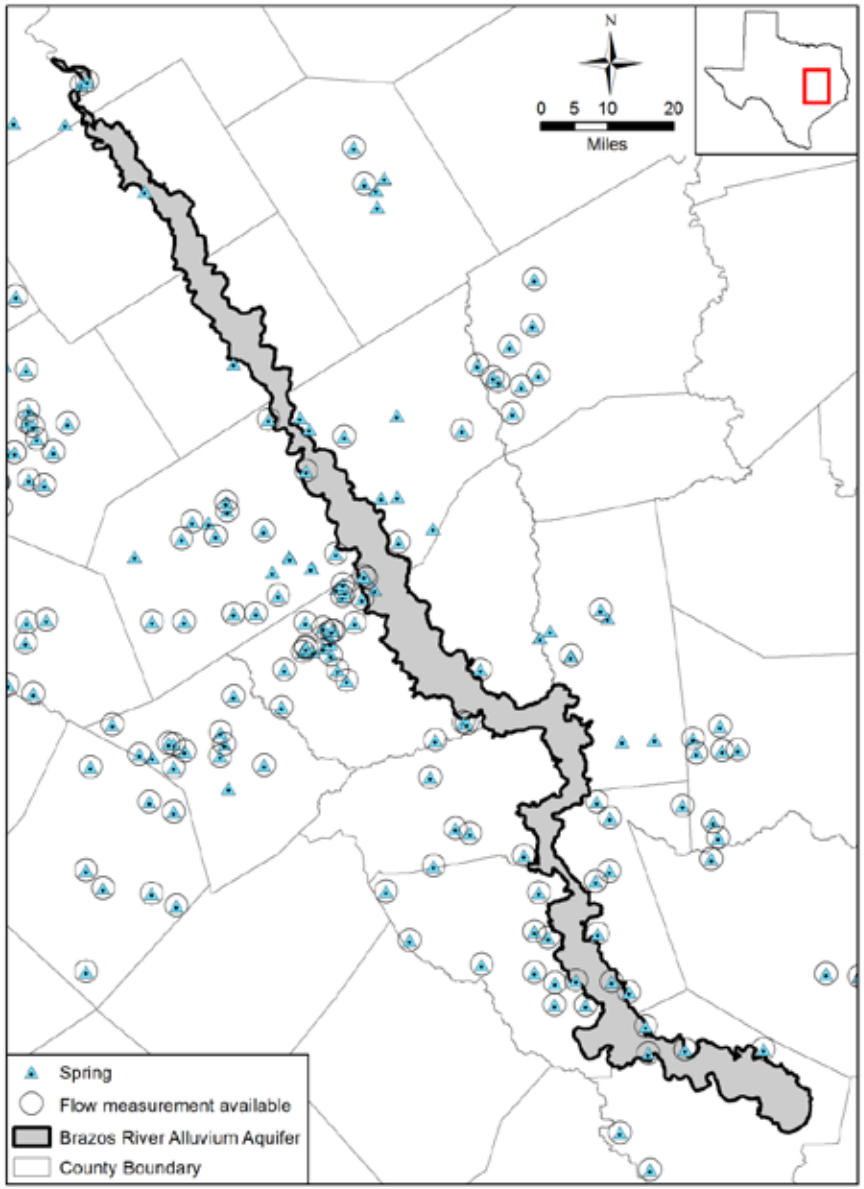




Natural Discharge: Springs and Oxbow Lakes





Key Aspects of Conceptualization

- Extent and hydrostratigraphy
- Structure
- Water Levels
- Hydraulic/storage properties
- Recharge/discharge
- **Groundwater production**
- Cross-formational flow
- Water quality

Groundwater Production

§ Pumping data sources:

- Previous literature including Cronin & Wilson (1967), Wilson (1967) Baker and others (1974), Follett (1974), and TWDB (2001)

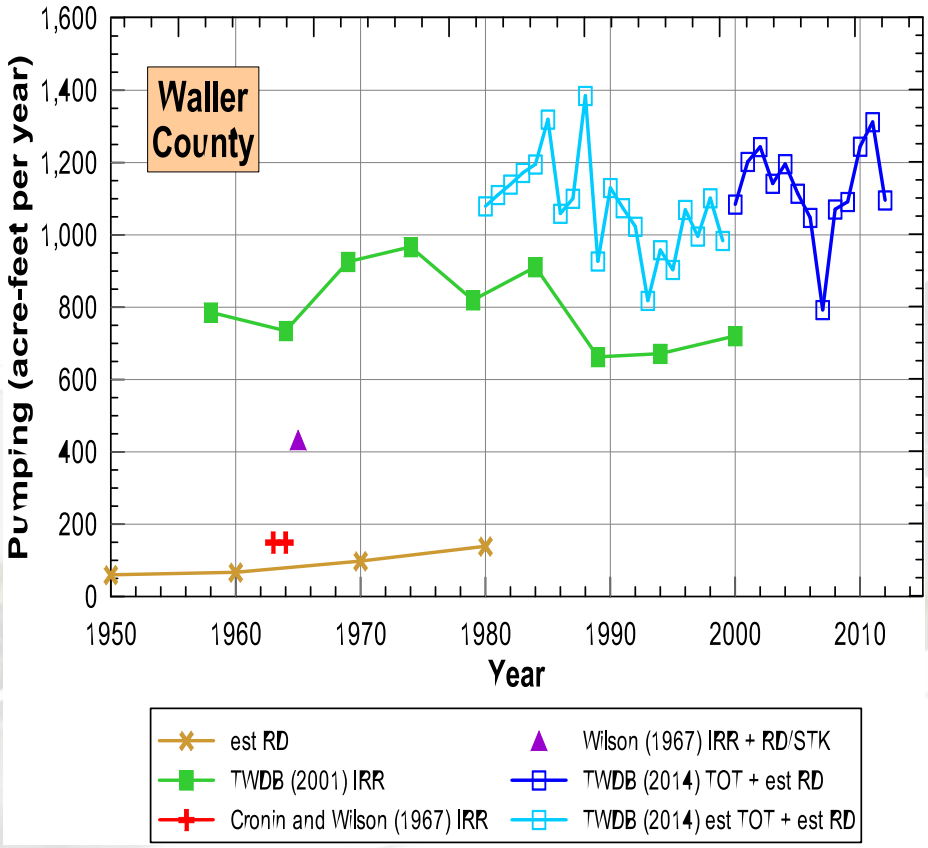
- TWDB Water Use Survey

- Brazos Valley Groundwater Conservation District

- Post Oak Savannah Groundwater Conservation District

- Calculated rural domestic pumping based on Census data and per capita water use

Groundwater Production



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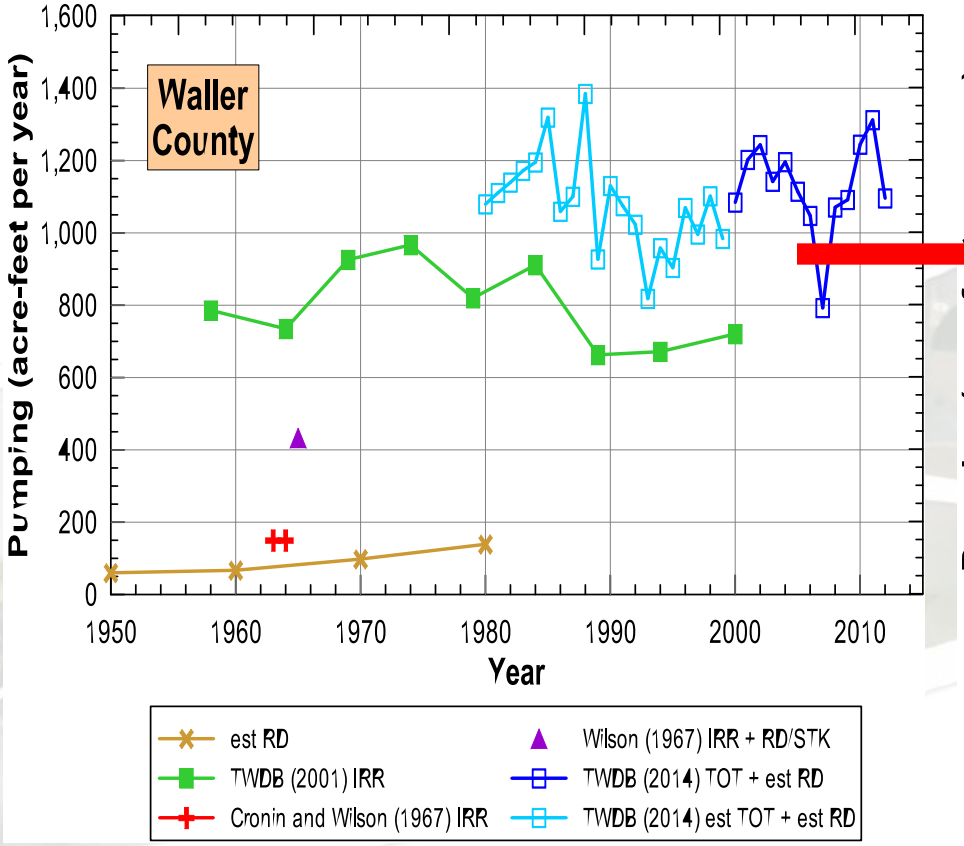
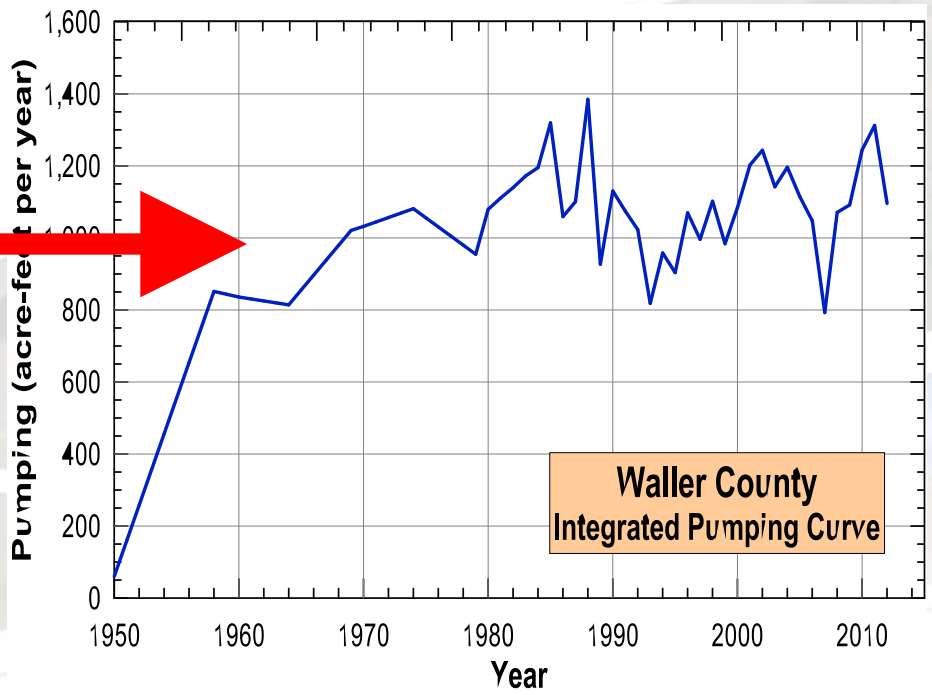
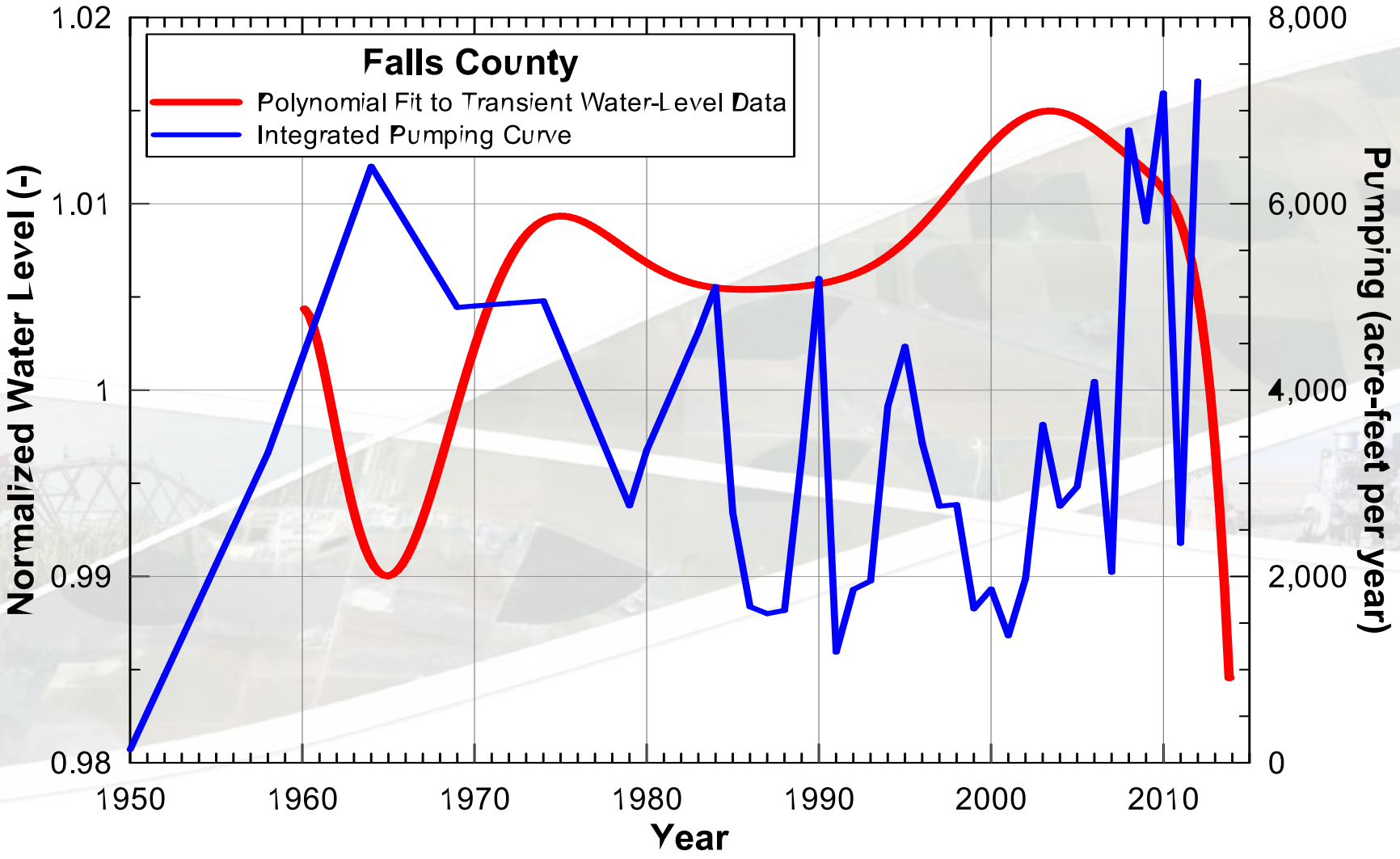




Effect of Pumping on Water Levels



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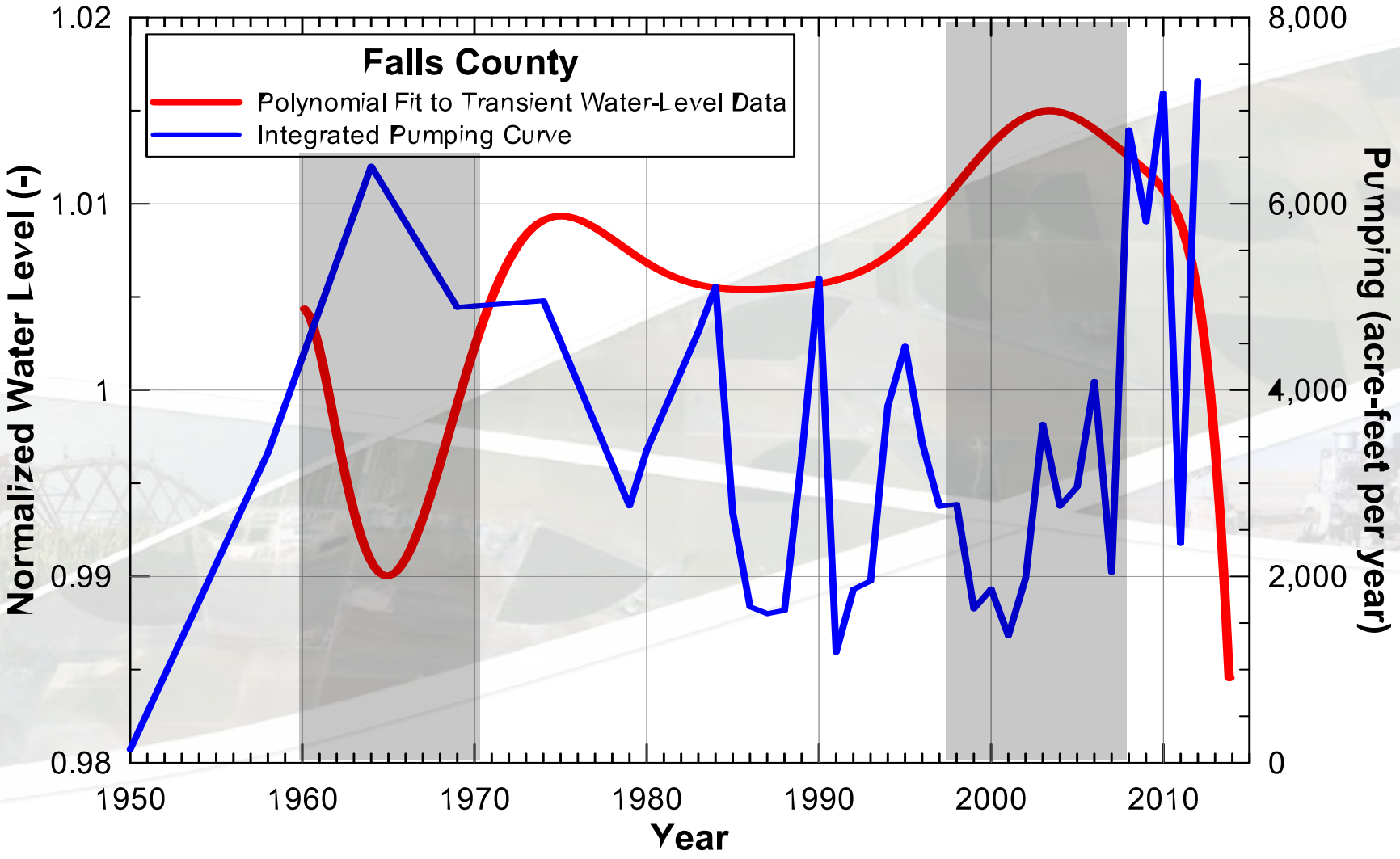

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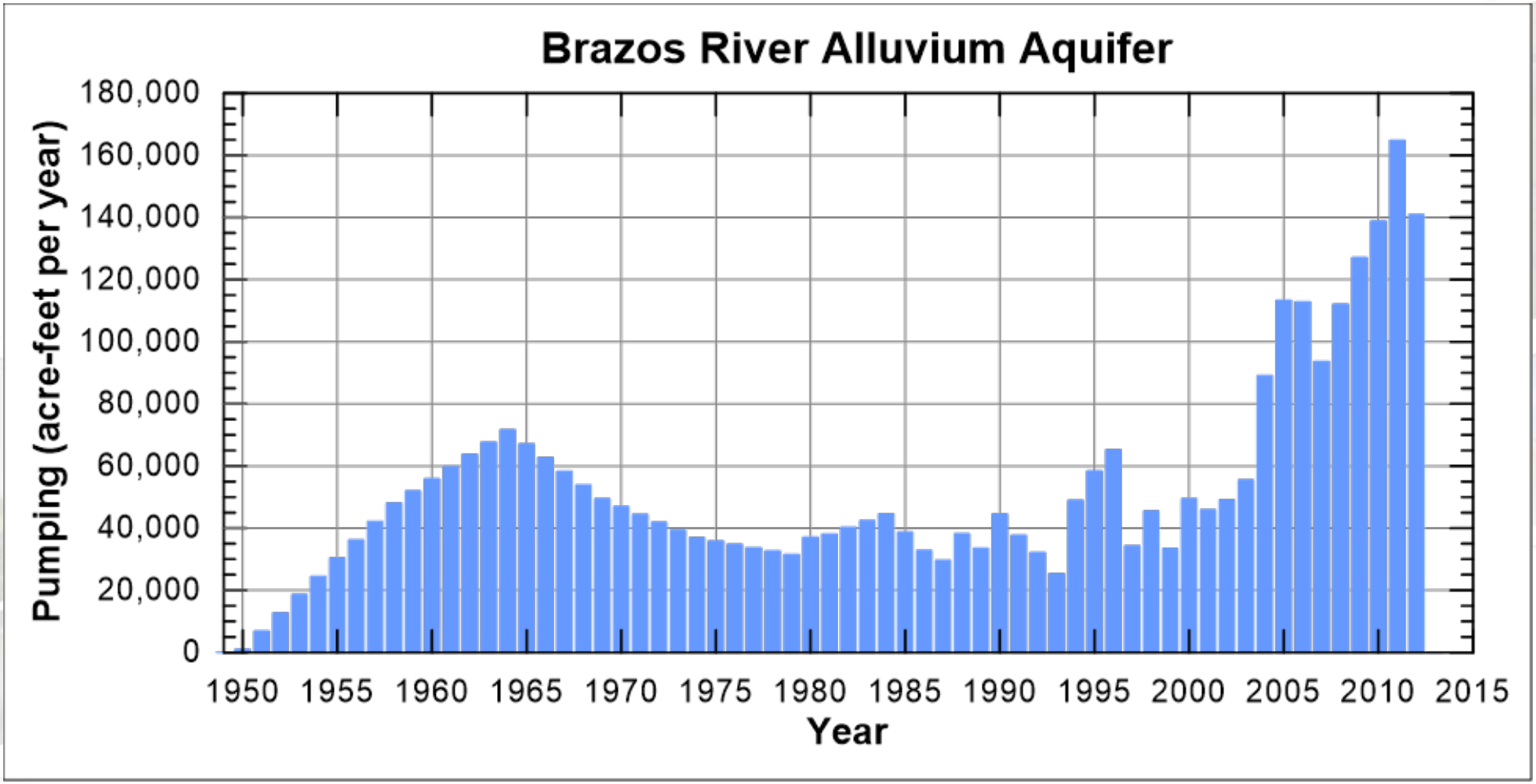

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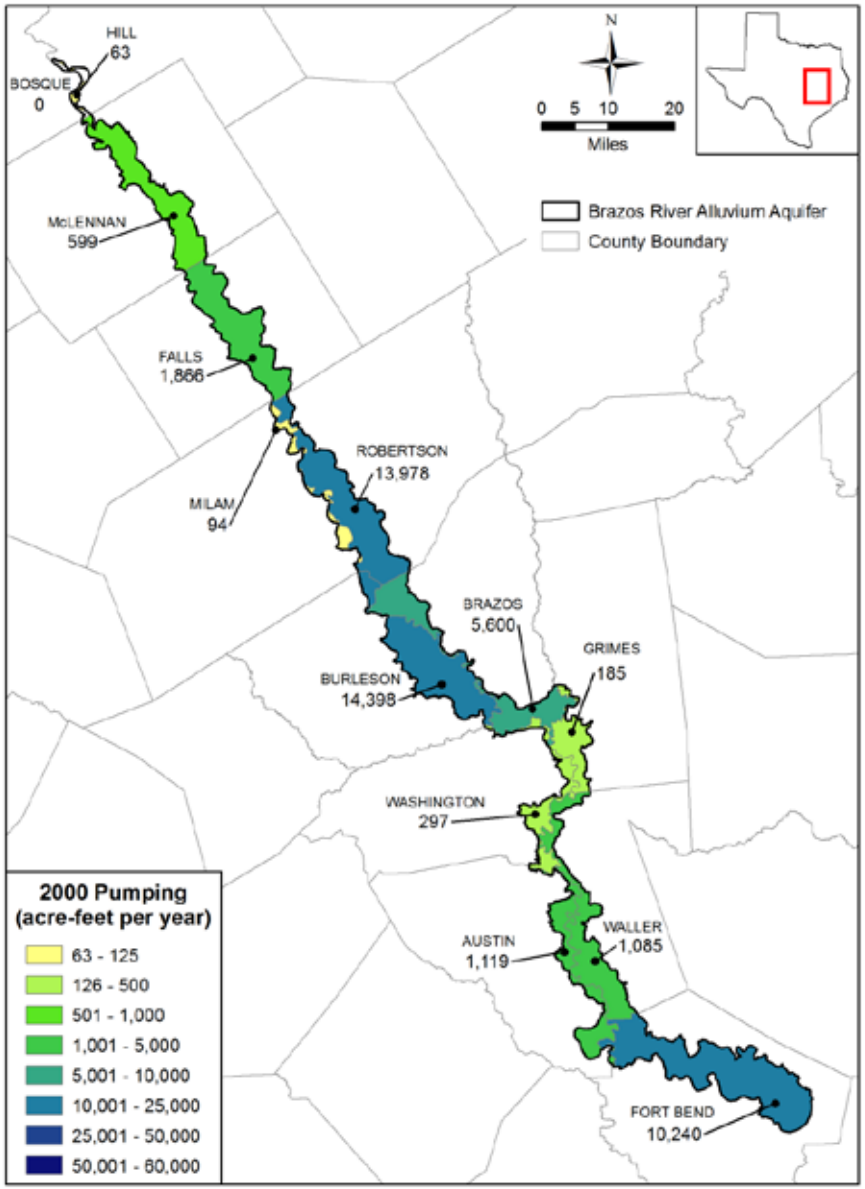

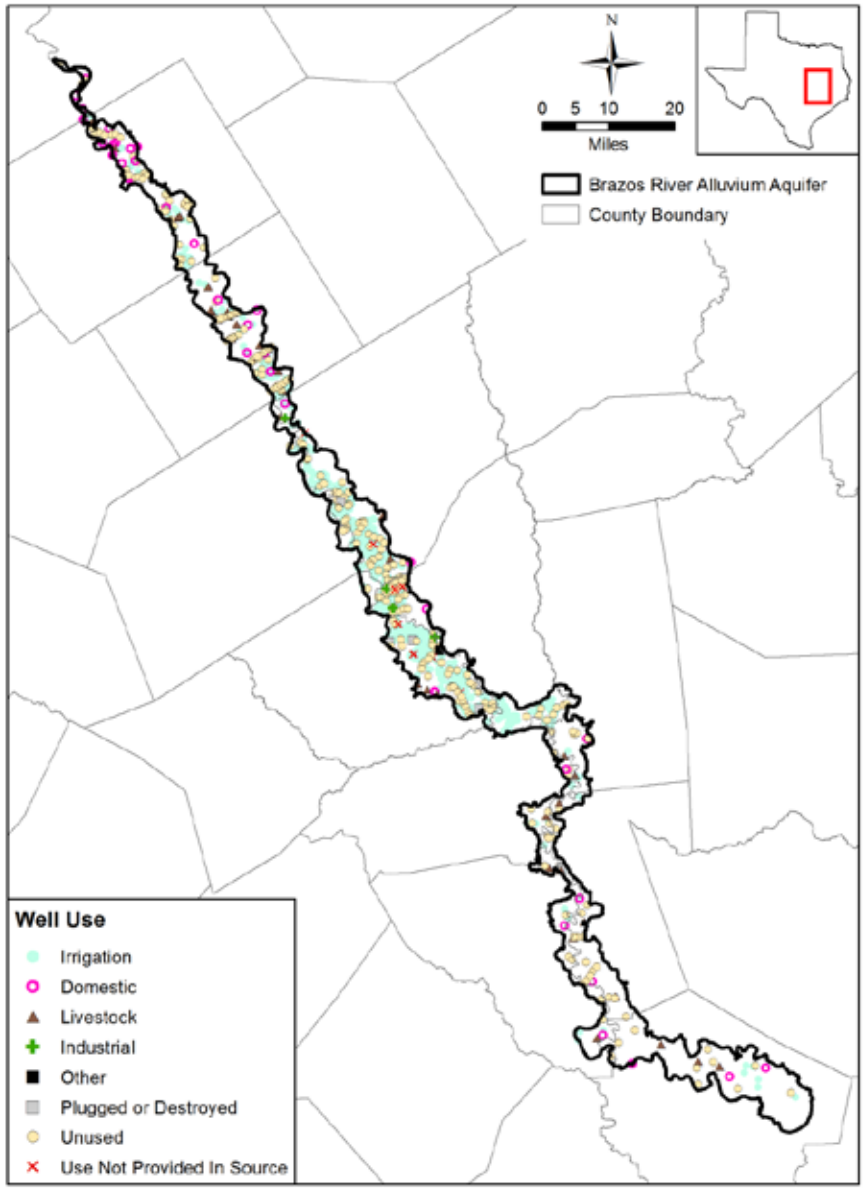

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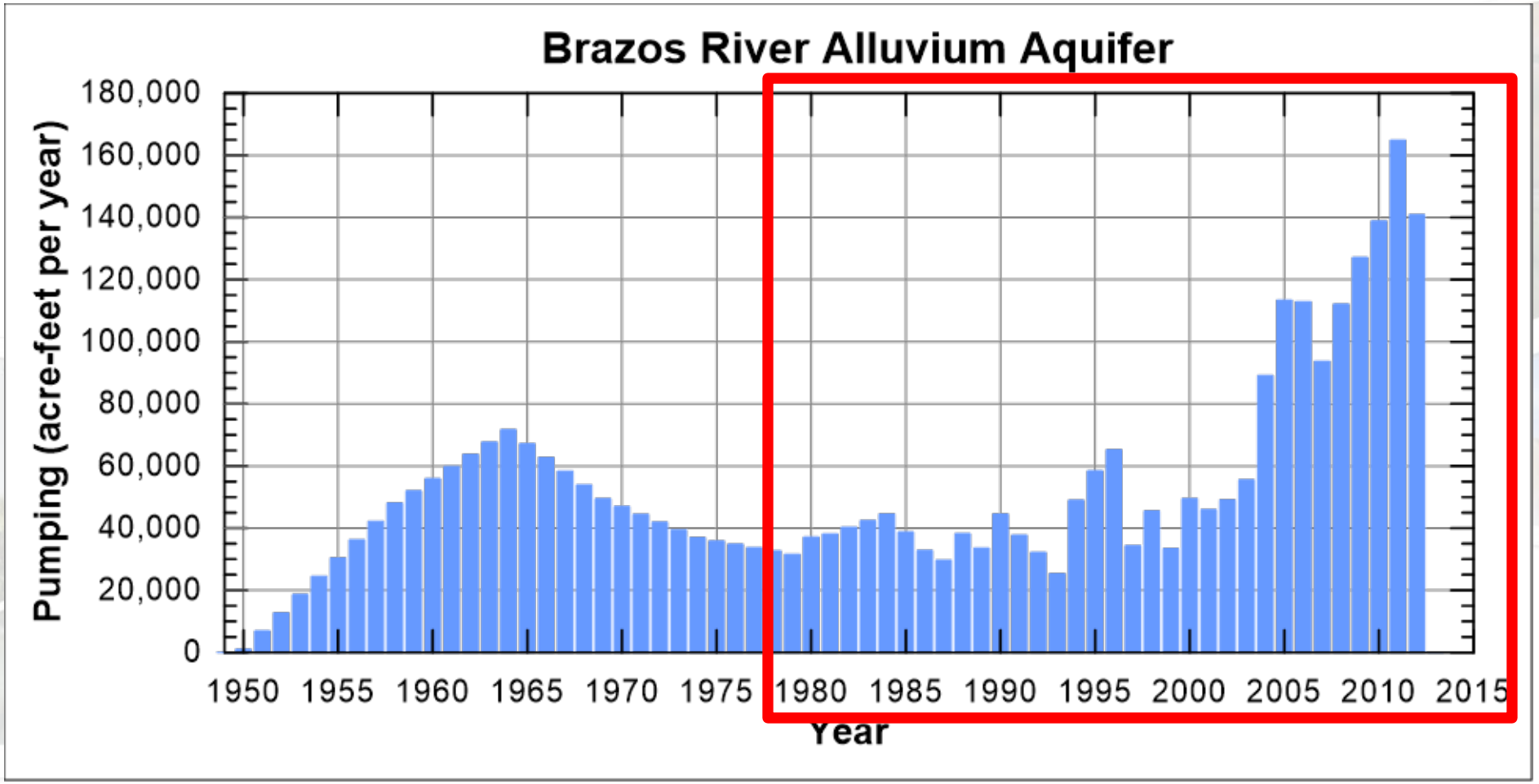

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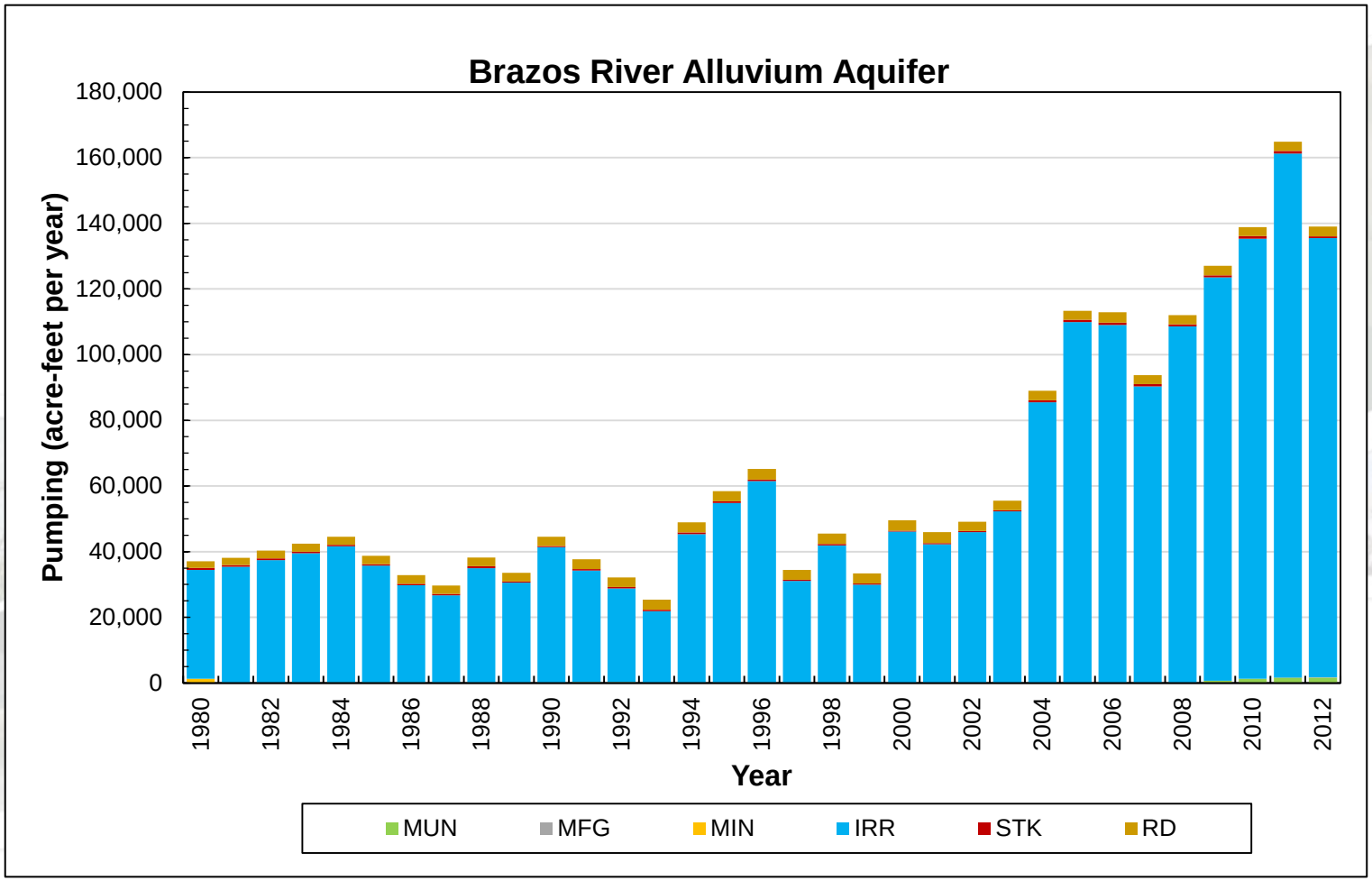

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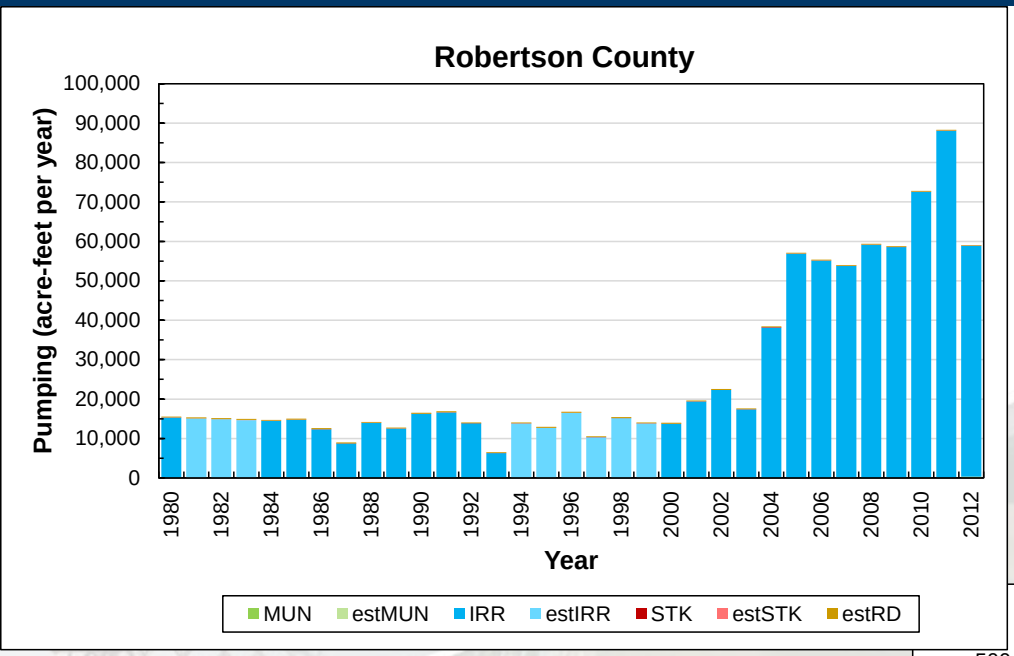

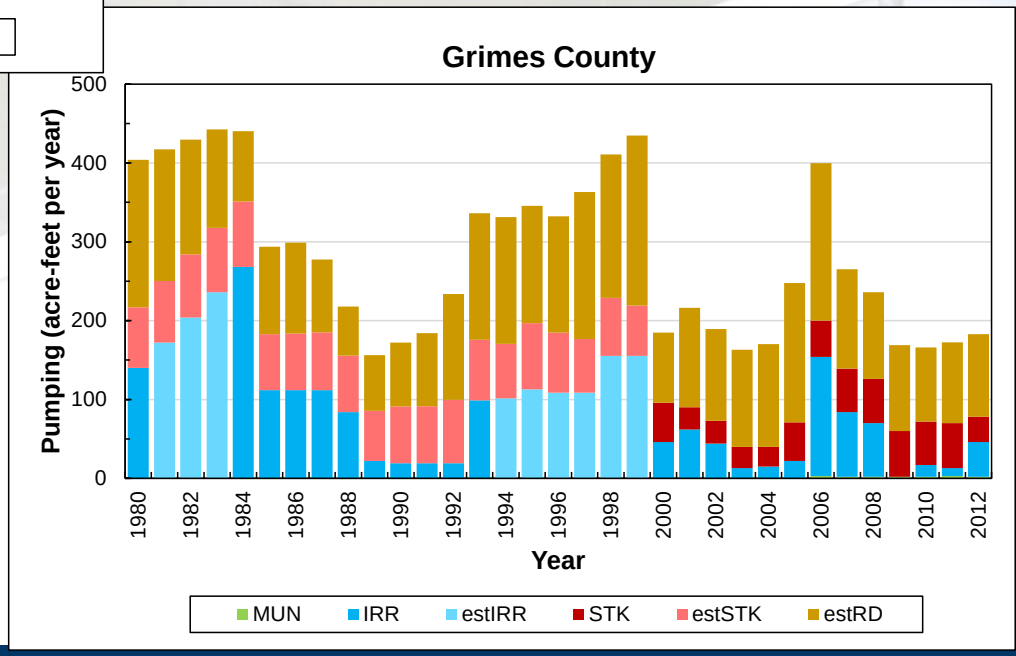

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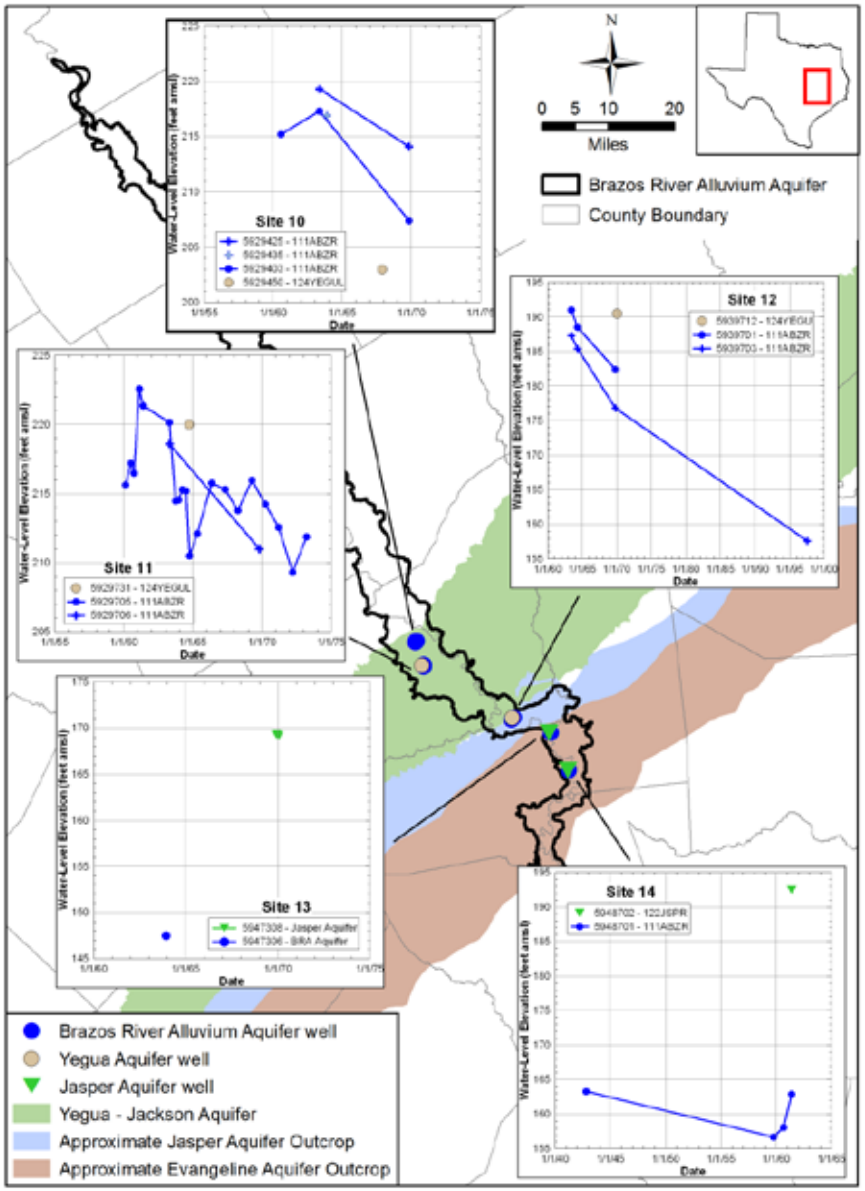
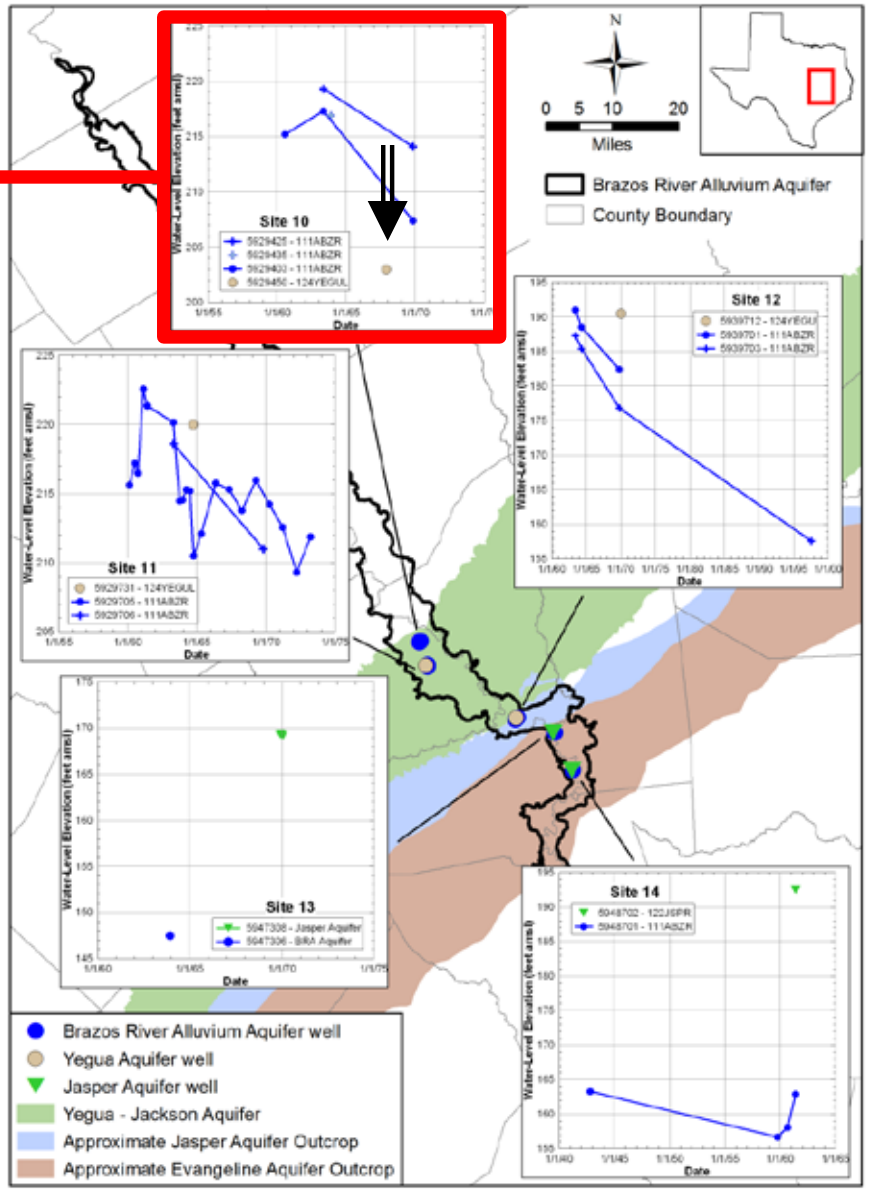
Cross-formational Flow



Cross-formational Flow

Head gradient favors flow from Brazos River Alluvium Aquifer into Yegua



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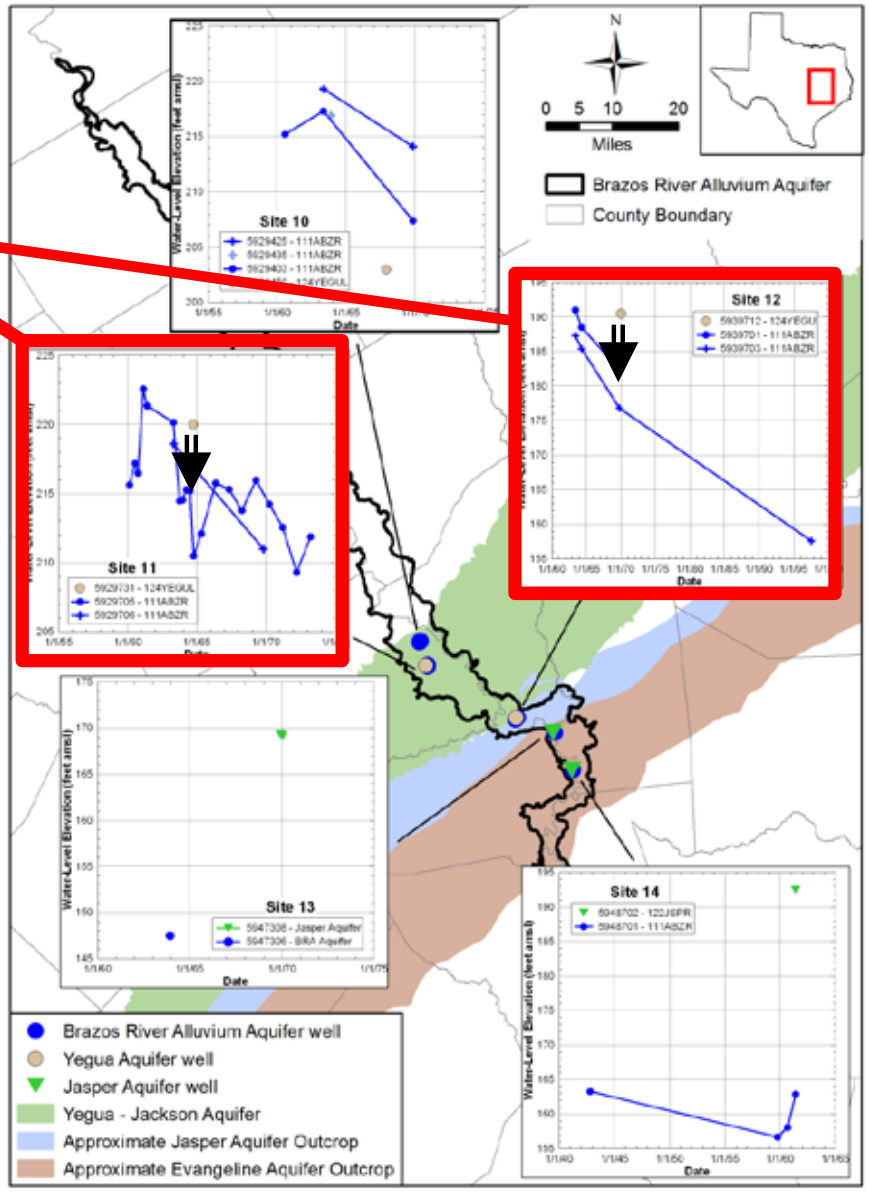
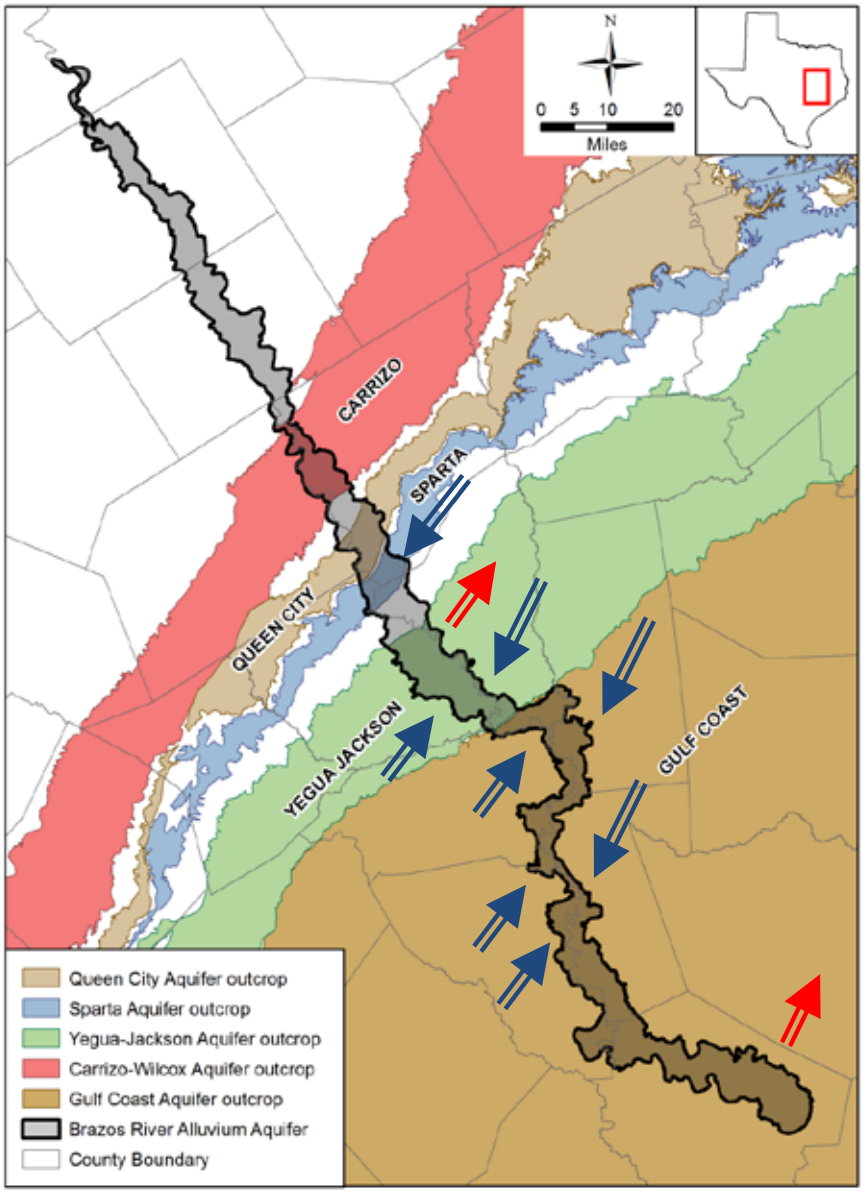


Cross-formational Flow

- Flow upward into BRAA:
  - Sparta : 1 site
  - Yegua : 2 sites
  - Jasper : 2 sites
  - Evangeline: 3 sites
- Flow downward from BRAA:
  - Yegua: 1 sites
  - Chicot: 1 site
- Unclear
  - Carrizo-Wilcox
  - Queen City



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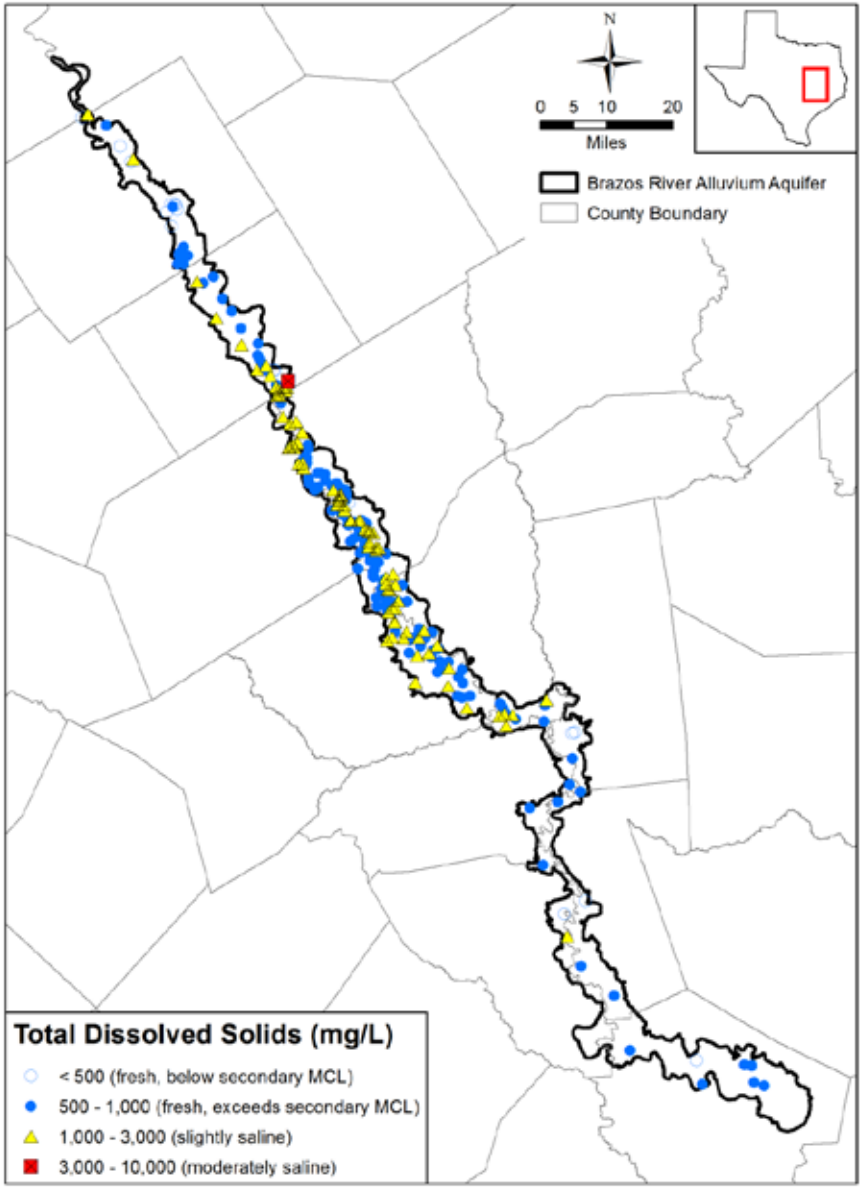
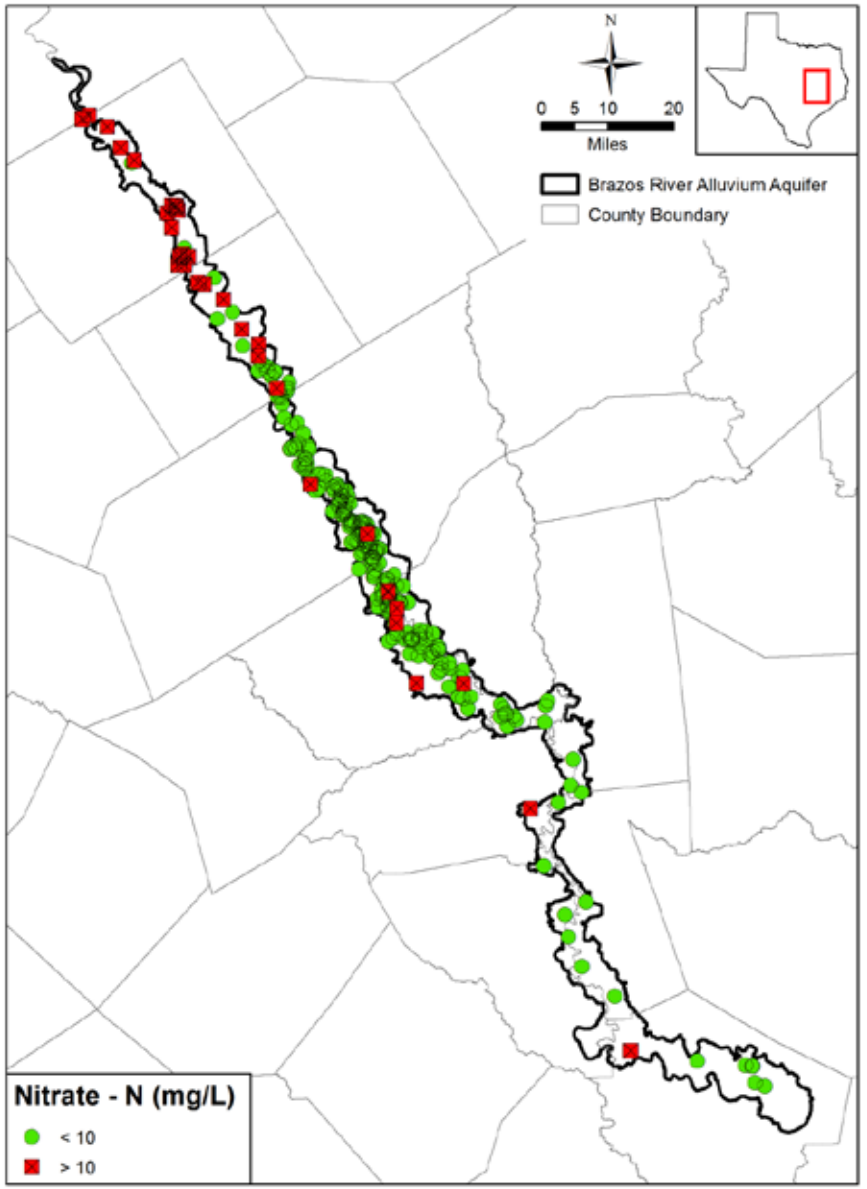
- **Water quality**

Water Quality

- Groundwater water quality analysis included 262 wells retrieved from the TWDB Groundwater Database
- Wells were assigned to aquifers based on the current study's new structural surfaces.
- Only the most recent sampling event for a given parameter was chosen from each well.

Water Quality



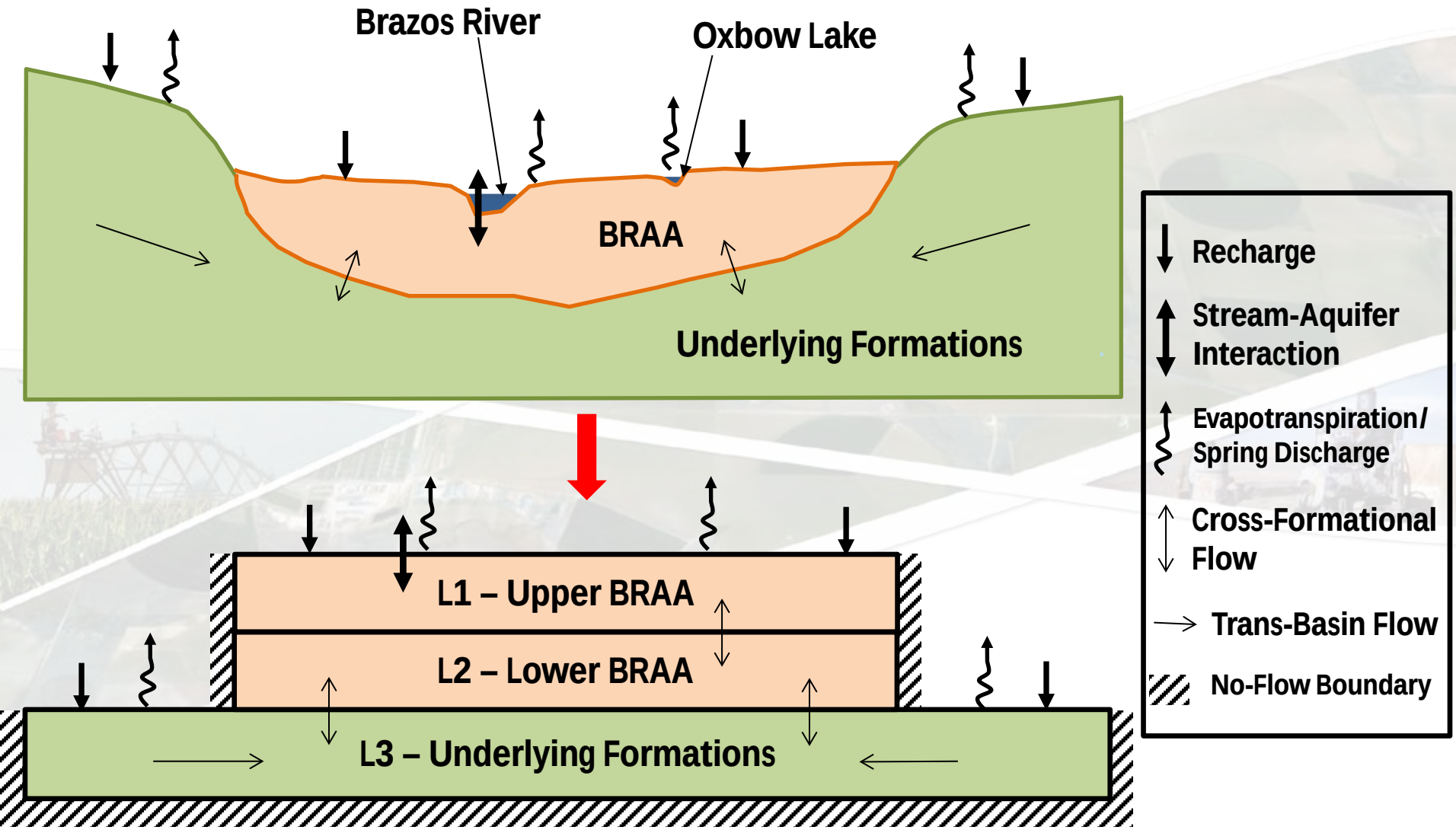


Summing It Up

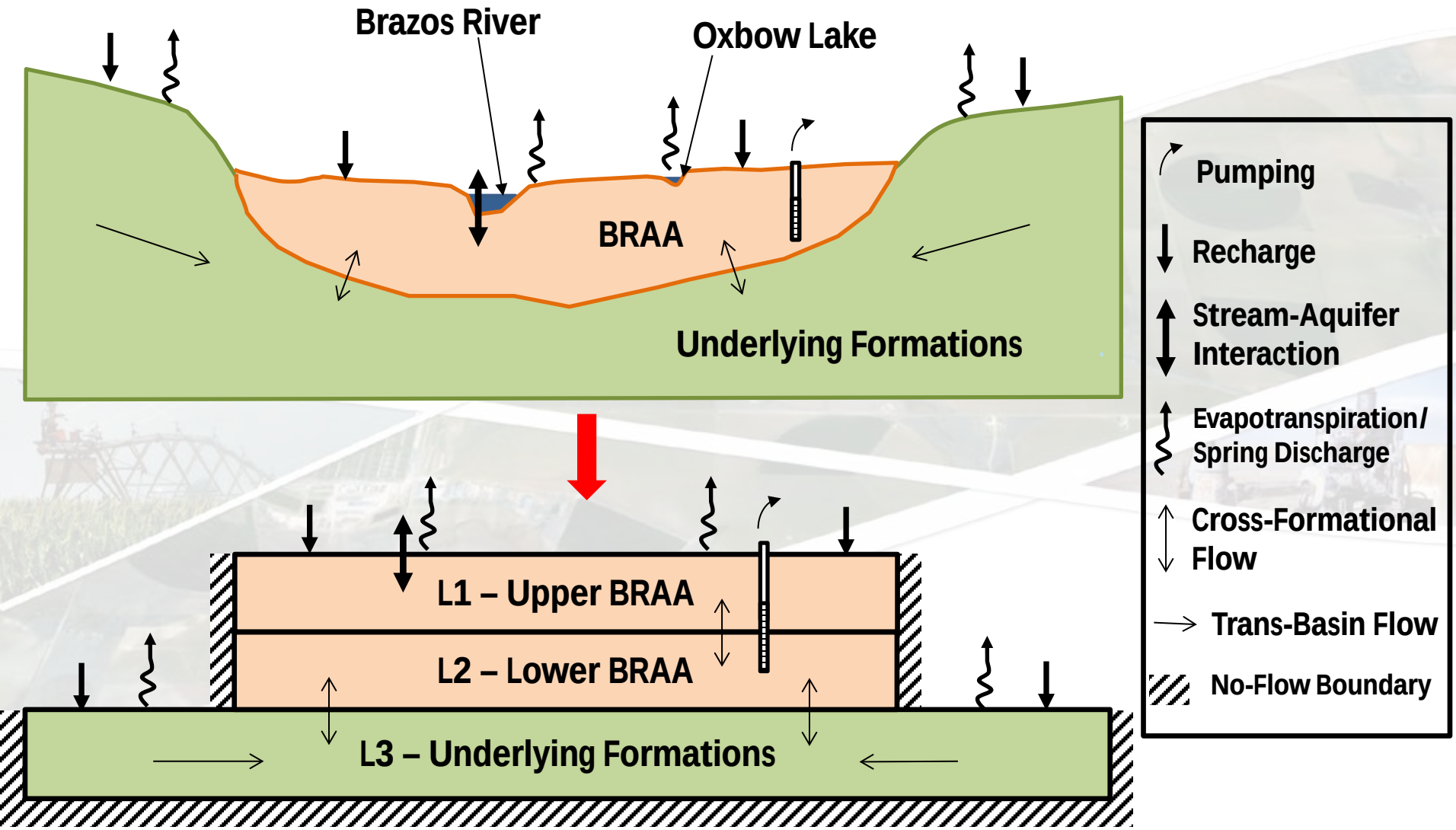
Conceptual Model

- Pre-development
  - recharge balances discharge
  - no net change in groundwater storage
- Post-development
  - increased discharge from pumping
  - locally increased recharge from irrigation
  - overall reduction in natural discharge
  - no apparent reduction in GW storage
  - potential reduction/reversal in cross-formational flow from pumping underlying layers

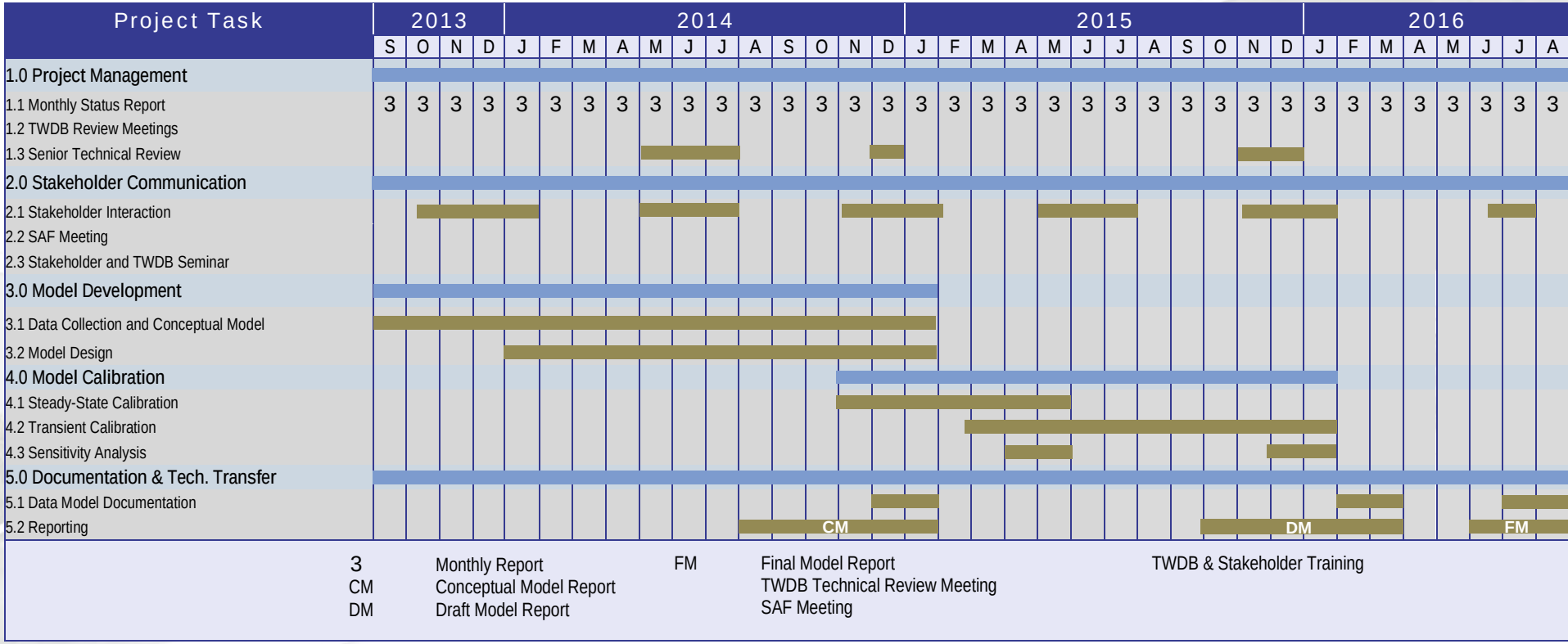
Conceptual Model – Pre-development



Conceptual Model – Post-development



Schedule


Project Task
2013
2014
2015
2016
S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
1.0 Project Management
1.1 Monthly Status Report
1.2 TWDB Review Meetings
1.3 Senior Technical Review
2.0 Stakeholder Communication
2.1 Stakeholder Interaction
2.2 SAF Meeting
2.3 Stakeholder and TWDB Seminar
3.0 Model Development
3.1 Data Collection and Conceptual Model
3.2 Model Design
4.0 Model Calibration
4.1 Steady-State Calibration
4.2 Transient Calibration
4.3 Sensitivity Analysis
5.0 Documentation & Tech. Transfer
5.1 Data Model Documentation
5.2 Reporting
CM
DM
FM
3 Monthly Report
CM Conceptual Model Report
DM Draft Model Report
FM Final Model Report
TWDB Technical Review Meeting
SAF Meeting
TWDB & Stakeholder Training

Brazos Alluvium Aquifer GAM -- Stakeholder Advisory Forum #2
Milano, Texas, January 22, 2015
Questions and Answers

Question: Is the conceptual model cartoon figure meant to represent the Brazos River Alluvium Aquifer?
Answer: No, it is just a picture to show what a conceptual model is.

Question: Did you account for gravel veins or variability in production abilities in the Brazos River Alluvium Aquifer?
Answer: Yes, and we will talk about hydraulic properties later in the presentation.

Question: What are the black dots on the plot of the aquifer structure?
Answer: They are the control points i.e., driller's logs or wells.

Question: Are you using the most recent TWDB groundwater database?
Answer: Yes, we are using the 2014 database as well as driller's logs.

Question: Which hydrographs are for the Brazos River Alluvium Aquifer?
Answer: The three at the top are. We have many other hydrographs that will be included in the report and associated geodatabase.

Question: Is there interaction between the Brazos River and the alluvium?
Answer: Yes.
Question: Which study?
Answer: There are several studies. Turco (2007), Baldys and Schalla (2011), and this study.

Question: Is this particular oxbow in Brazos County?
Answer: No, it is in one of the counties in the northern portion of the study area.

Question: Did you take into account irrigation water?
Answer: Yes, we try incorporate irrigation return flow in the recharge we apply to the alluvium.
Question: What about overland flow to the river.
Answer: We don't account for that.

Question: What percent of streamflow comes from the aquifer?
Answer: That varies spatially but it's maybe as high as 30 percent is some areas.

Question: Do you have actual pumping data or an estimate?
Answer: Mostly estimates. We can attach metered data to wells though if we have it.

Question: Is that maximum pumping in 2011 about 160,000 acre-feet?
Answer: Yes.

Question: How do you distribute pumping over time?
Answer: We have estimates for the different time periods.

Question: If estimated pumping differs from permit, will they have to change the permit?
Answer: No, this is not a regulatory tool. It is just used to inform.

Question: Did you identify data gaps where monitor wells could be put in?
Answer: We will show where we have data and where the gaps are. Part of modeling is a sensitivity analysis which shows the importance (or lack thereof) of any data gaps.

Question: Are you using interpolation?
Answer: Yes, that is how we fill in between measurement points.

Question: How will you calibrate?
Answer: We will alter model inputs in an attempt to match observed water level and baseflow estimates.

Question: How will you incorporate gravel pits?
Answer: We have maps of the gravel pit locations. They can act either as focused recharge or focused discharge points depending on the operation of the pit.

Attendance

Name	Affiliation
Bobby Bazan	POSGCD
David Stratta	Farmer
John Melvin	BVGRA
Philip Price	Brazos River Authority
Robert Thompson	Harris-Galveston Subsidence District
Alan M. Day	BVGCD
Evan Cook	Brazos River Authority
Cindy Ridgeway	TWDB
Jevon Harding	INTERA
John Ewing	INTERA