Numerical Model of Groundwater Flow in the southern portion of the Trinity Aquifer

Stakeholder Advisory Forum #2
August 16, 2024

Thank you for signing in early.

The meeting will begin at 10:00 am, Central Daylight Time

Please stay muted during the meeting and use the chat box to submit questions

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Meeting information

- An audio and video recording of the meeting, presentation, and the report summarizing the meeting will be made available on the project's TWDB website

- http://www.twdb.texas.gov/groundwater/models/gam/trnt_h/trnt_s.asp

Why Stakeholder Advisory Forums?

Keep stakeholders updated about progress of the modeling project

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

Agenda

Numerical Model for the southern portion of the Trinity Aquifer

Question and Answer

Numerical Model of Groundwater Flow in the southern portion of the Trinity Aquifer

Introduction

Lead Modeler : Jevon Harding, P.G.

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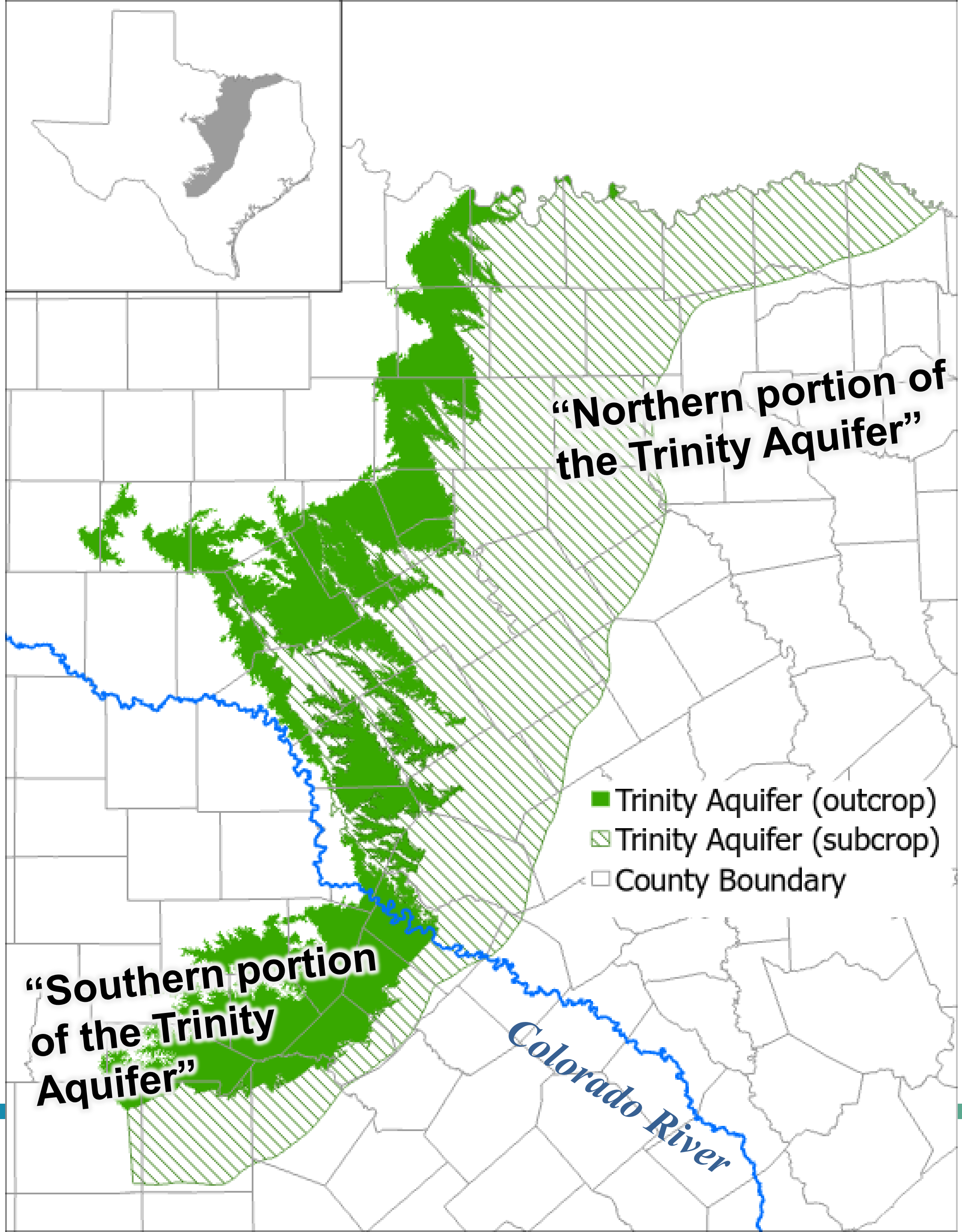
Updated TWDB Naming Convention



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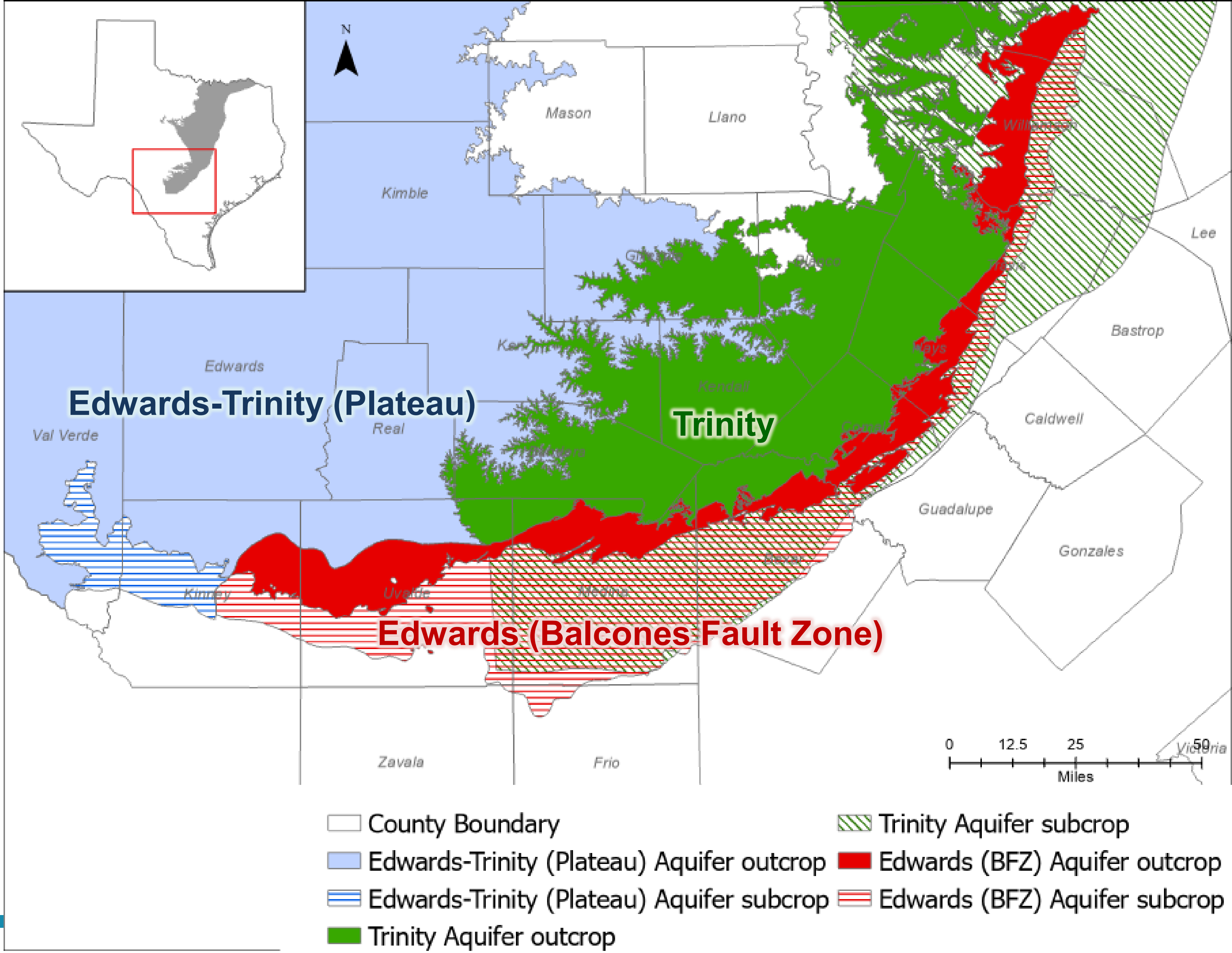
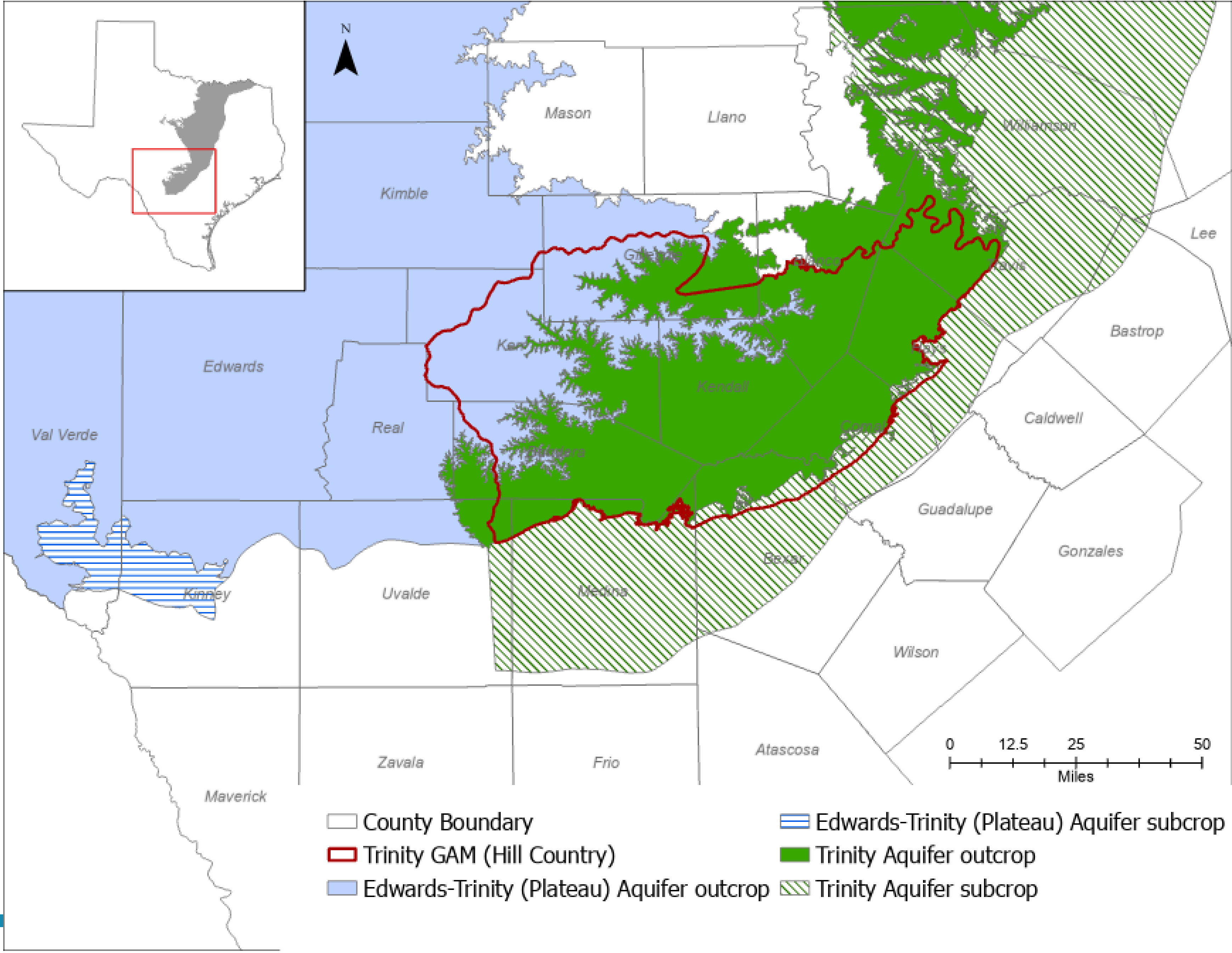
Major Aquifers

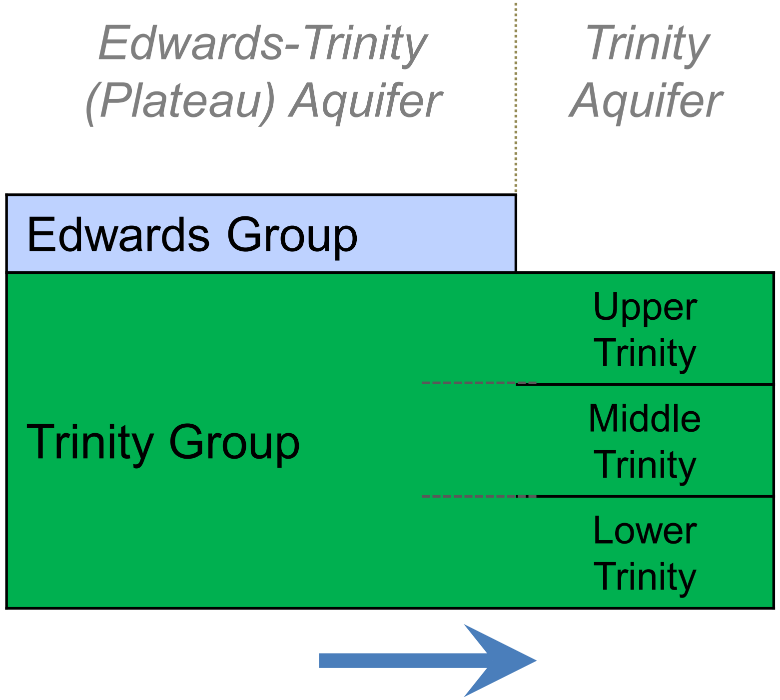


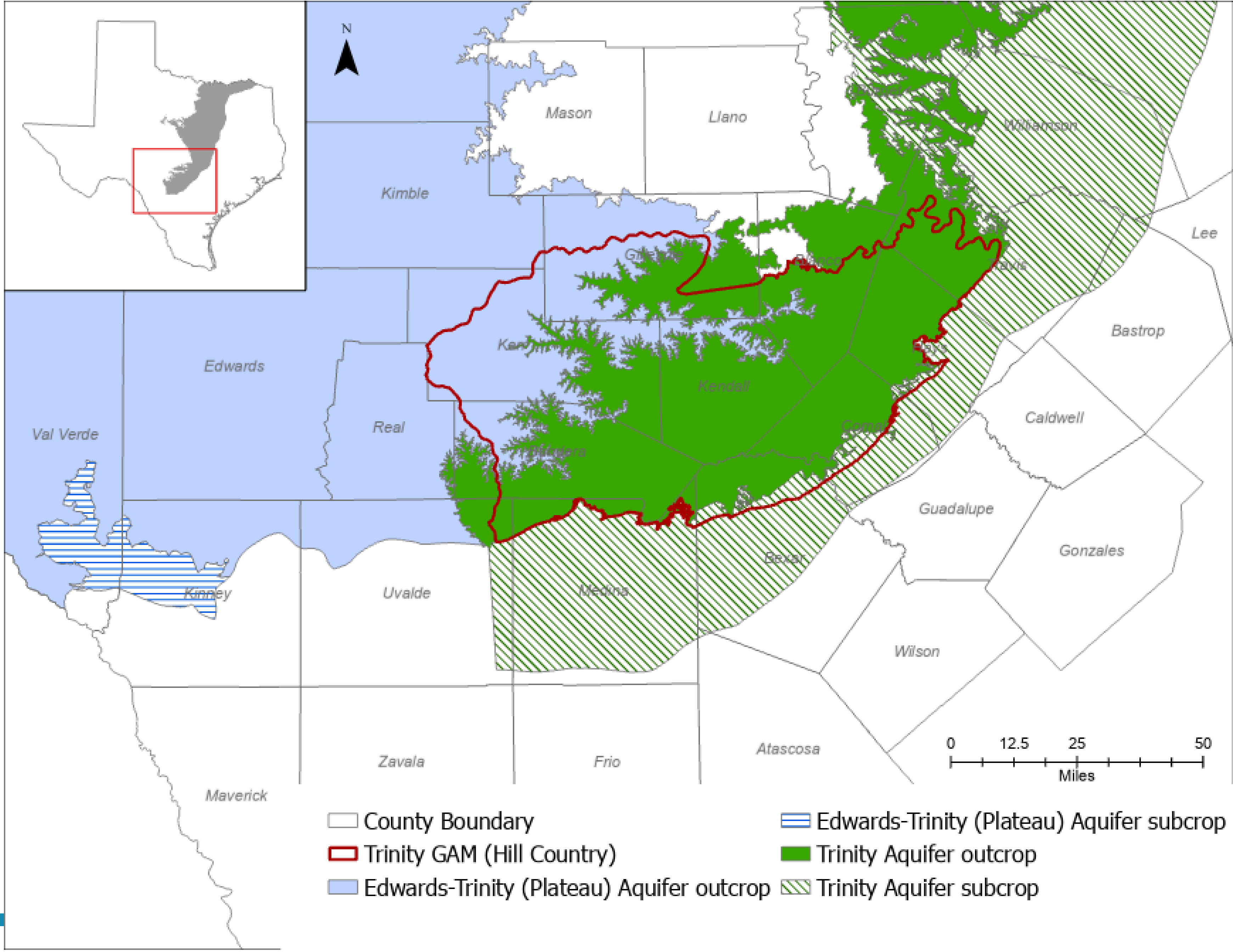
Existing GAM

- Trinity (Hill Country) GAM *v2.01*
- 4 layers
- MODFLOW-96
- Updated in 2011
- Calibrated to 1997
- Used in **GMA 9**



Existing GAM





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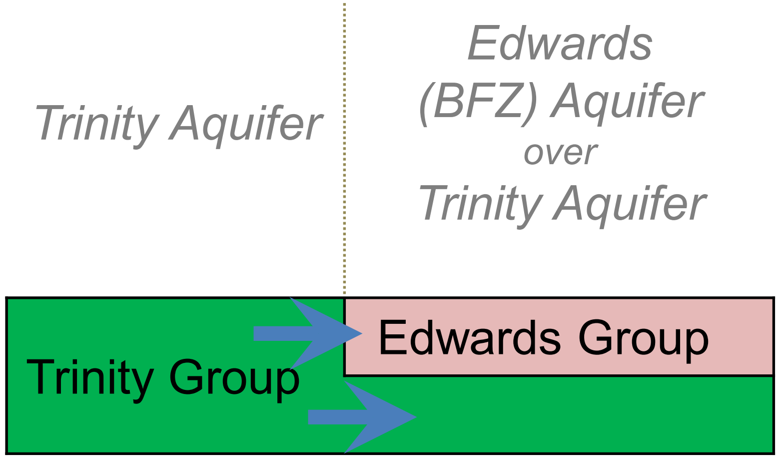
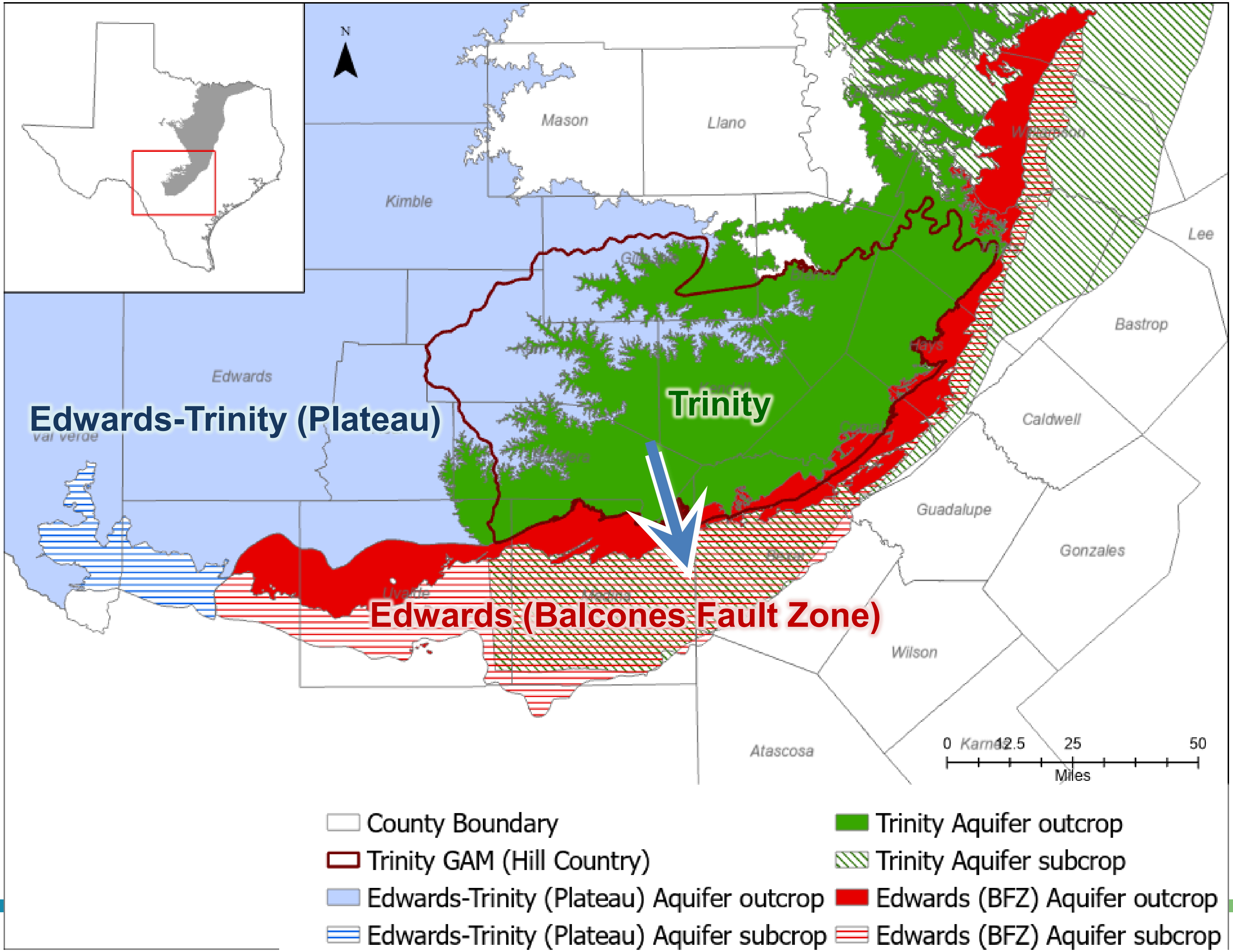
Existing GAM

Inter-aquifer flow Considerations:

- Does not include Edwards (BFZ)





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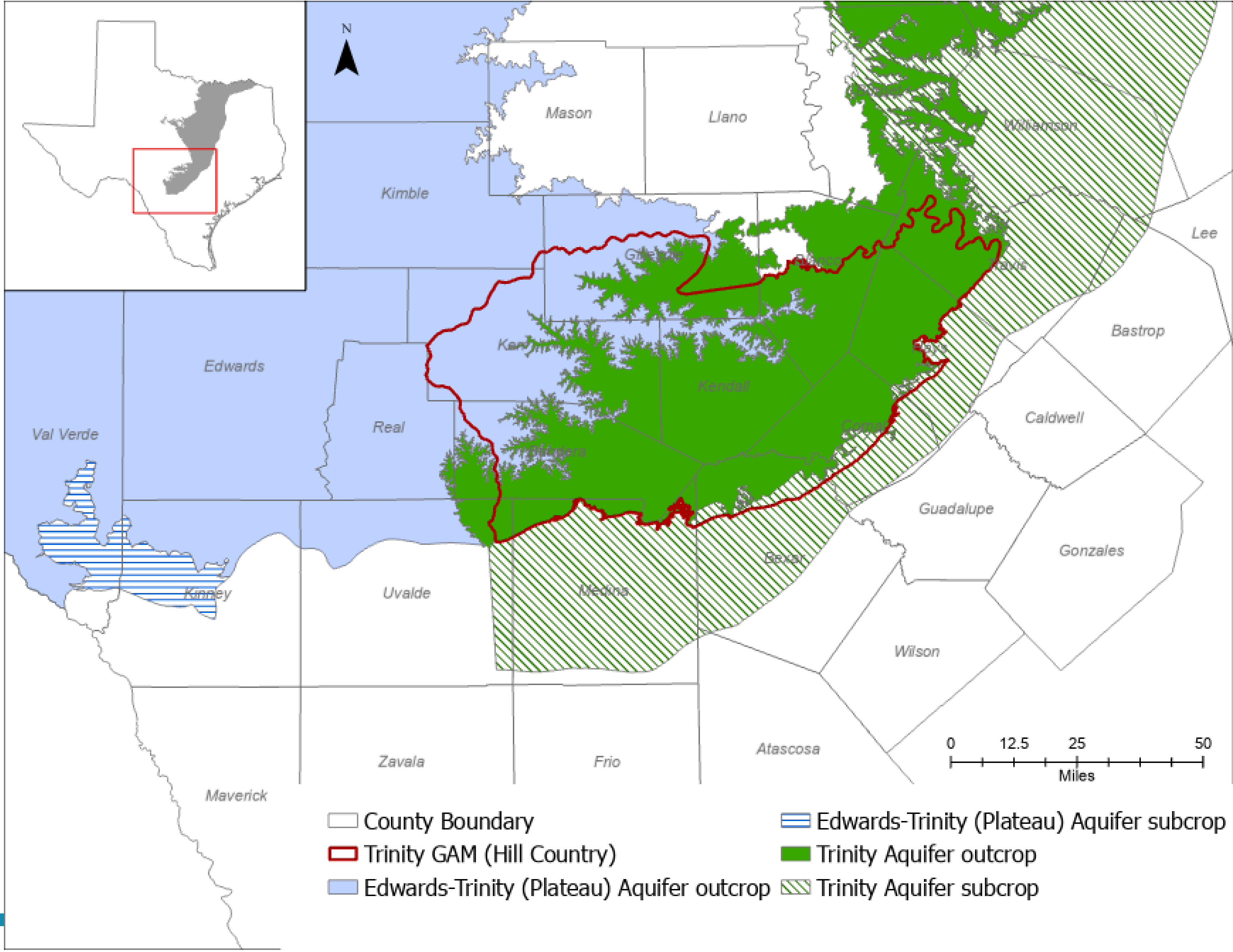
Existing GAM

General Considerations:

- Does not include underlying downdip Trinity
- No current GAM covers entire Trinity aquifer
- No current GAM able to evaluate brackish interactions



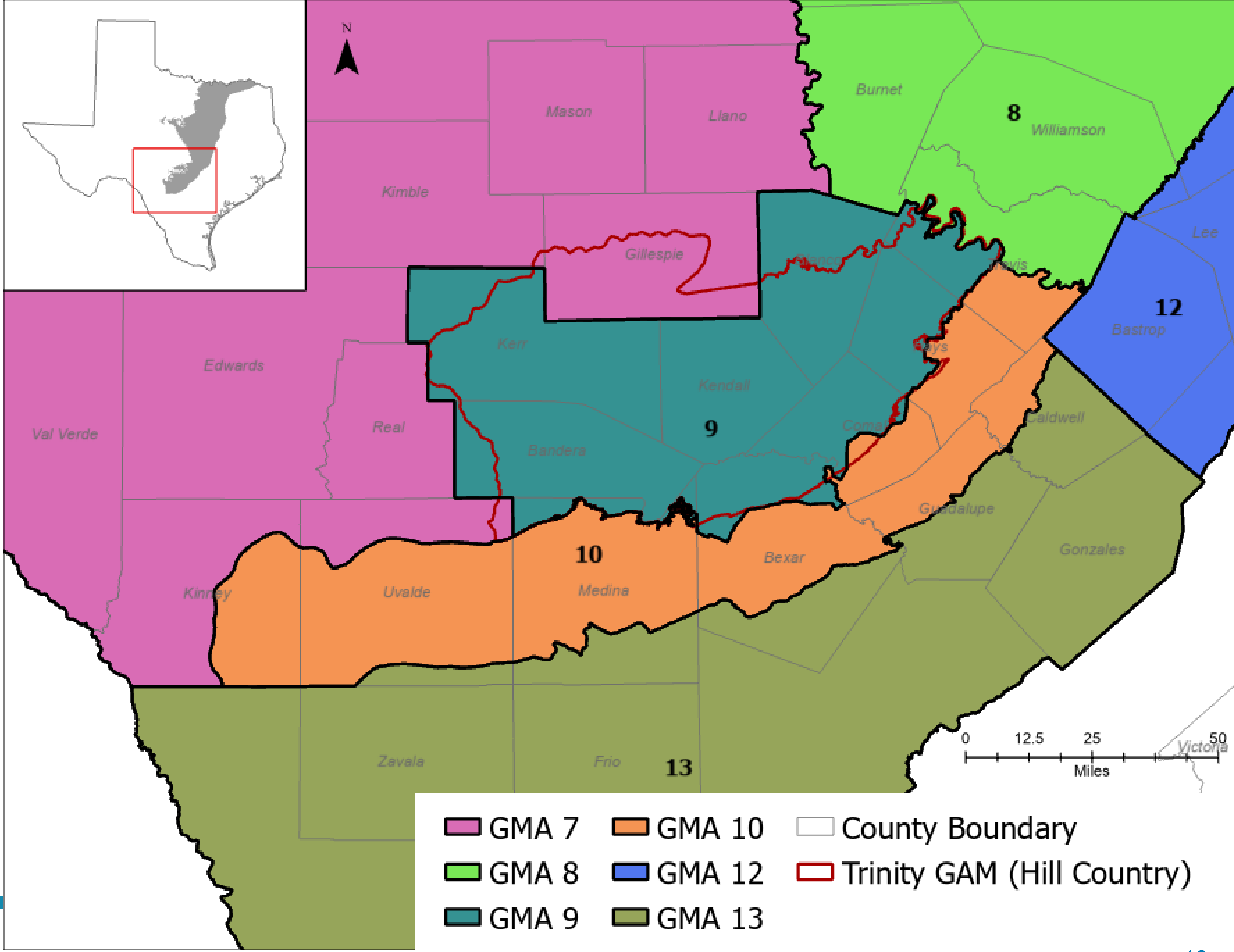
Existing GAM

Analysis Considerations:

- Splits counties/GCD
- Missing portions of Aquifer

Joint Planning considerations:

- Missing portions of GMA 9
- Cannot be used in GMA 10



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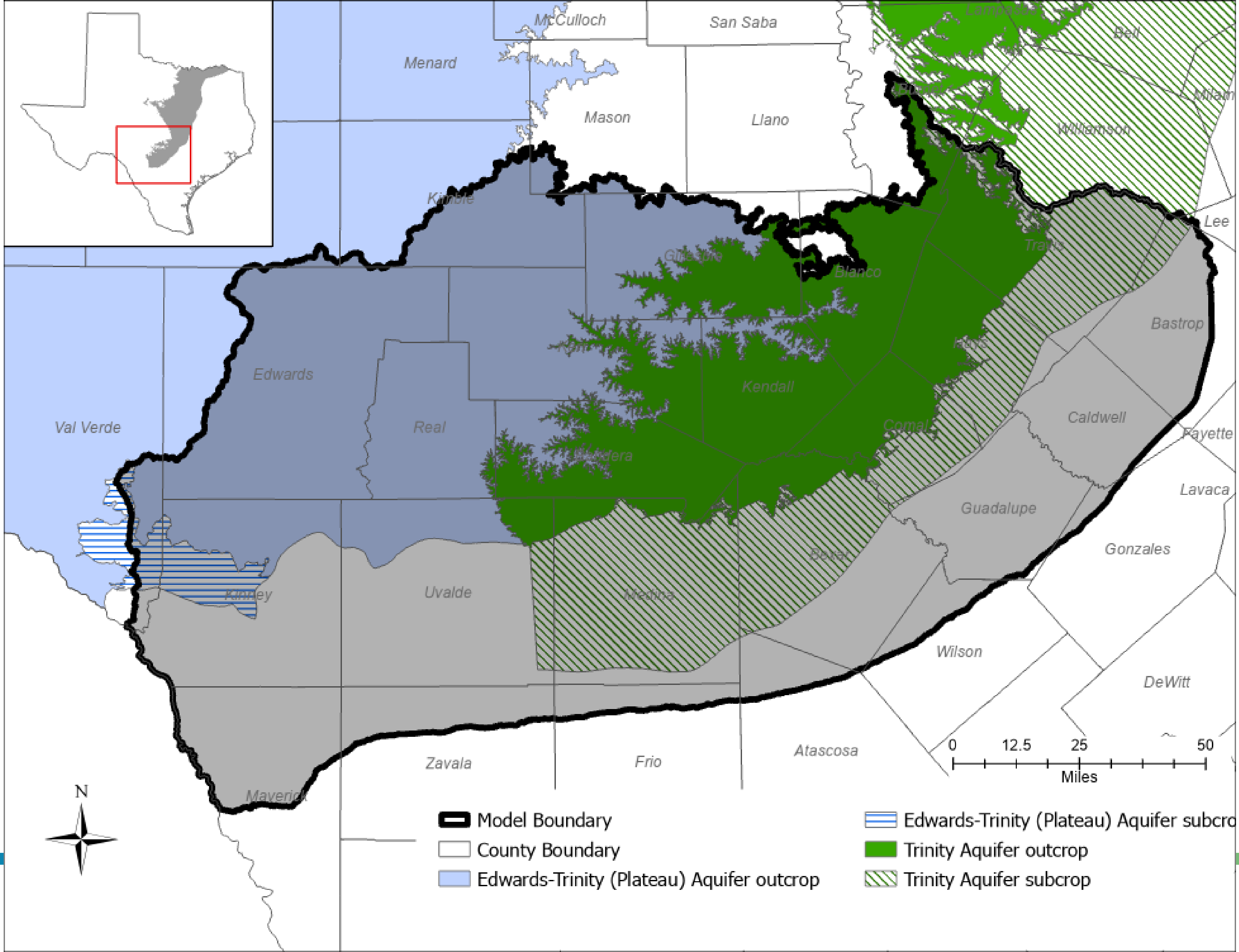
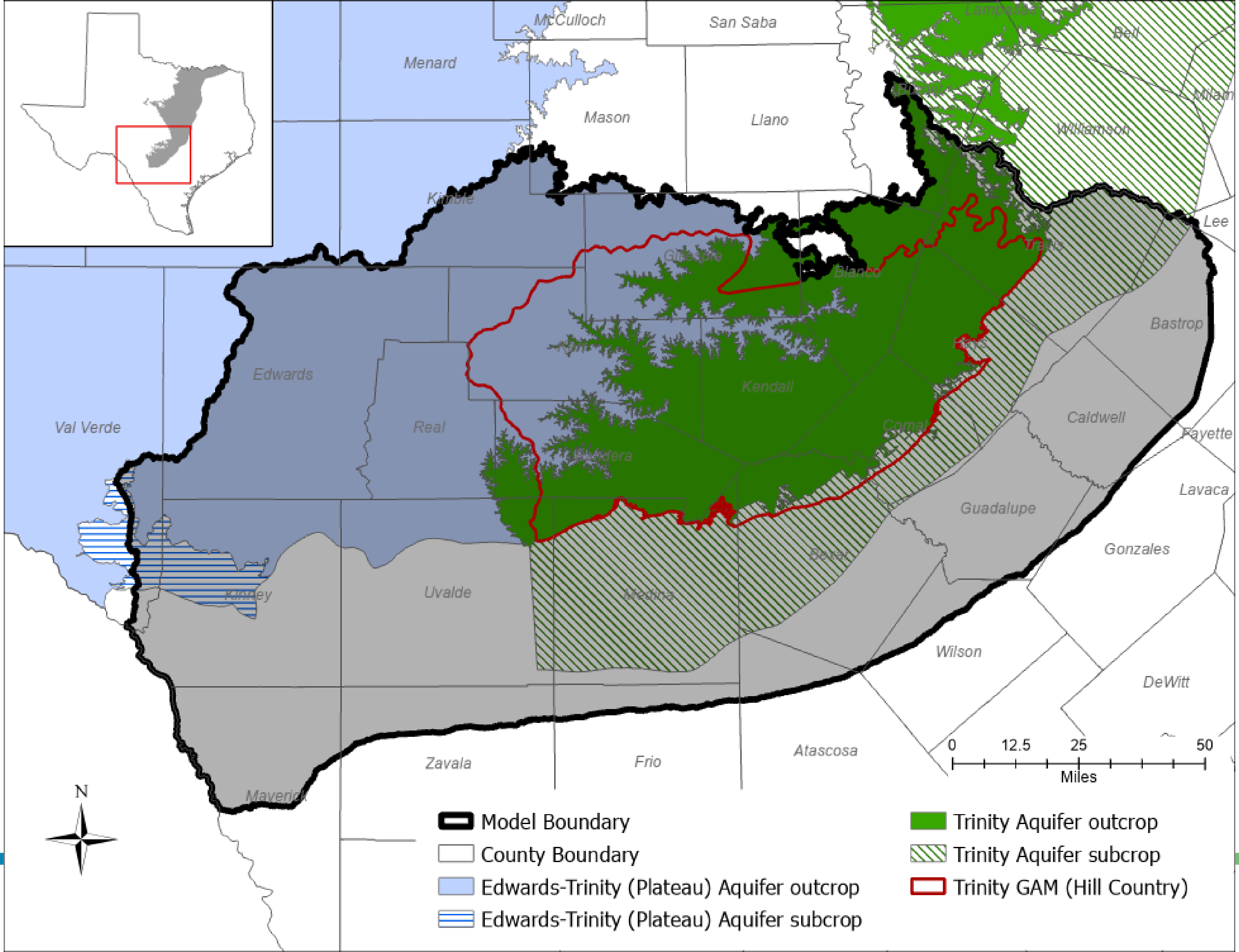
Model Boundary

Model Boundary

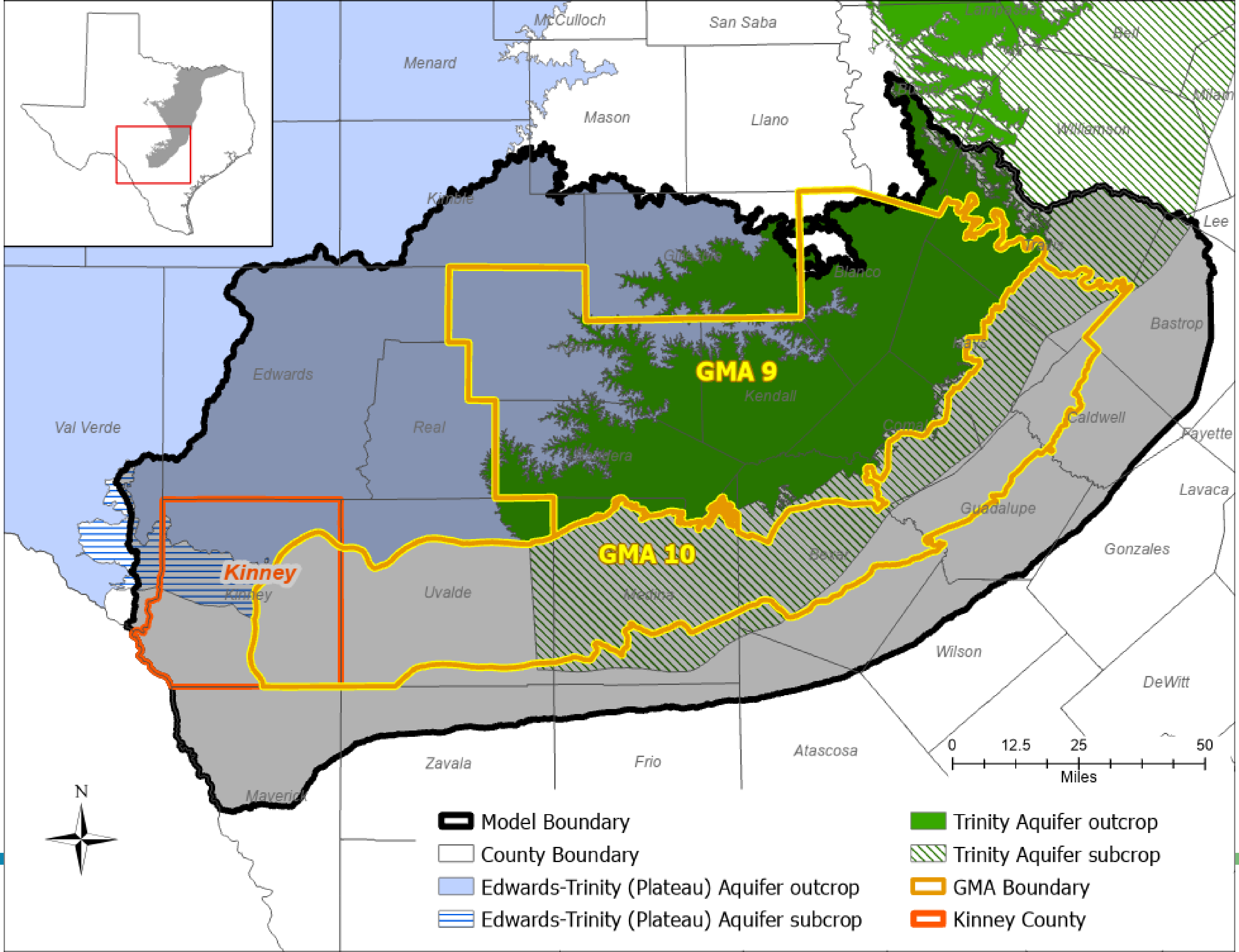


Model Boundary



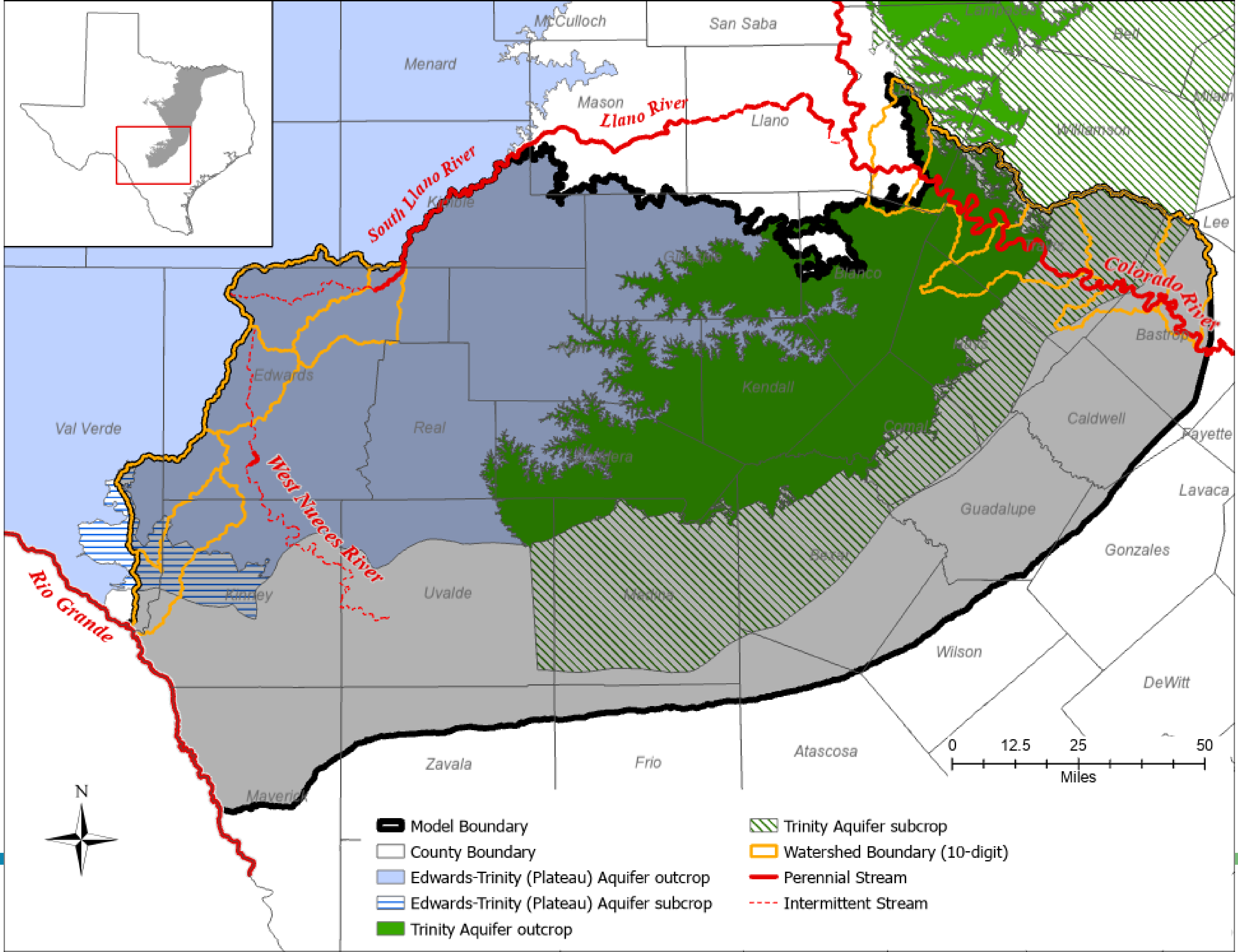
Planning Boundaries

- GMAs 9 & 10
- Kinney County



Natural Boundaries

- Rivers
- Surface watersheds
- Surface Geology



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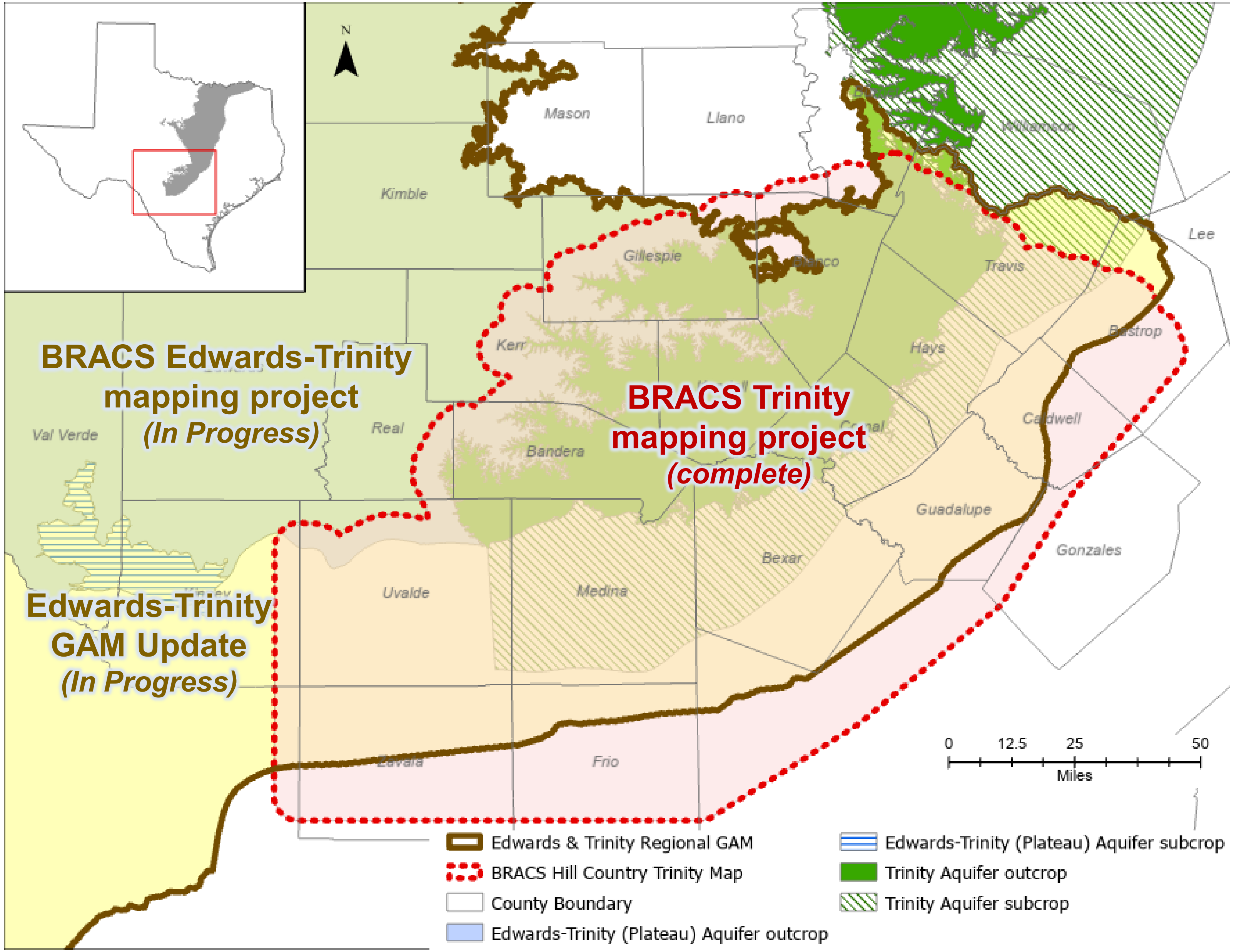
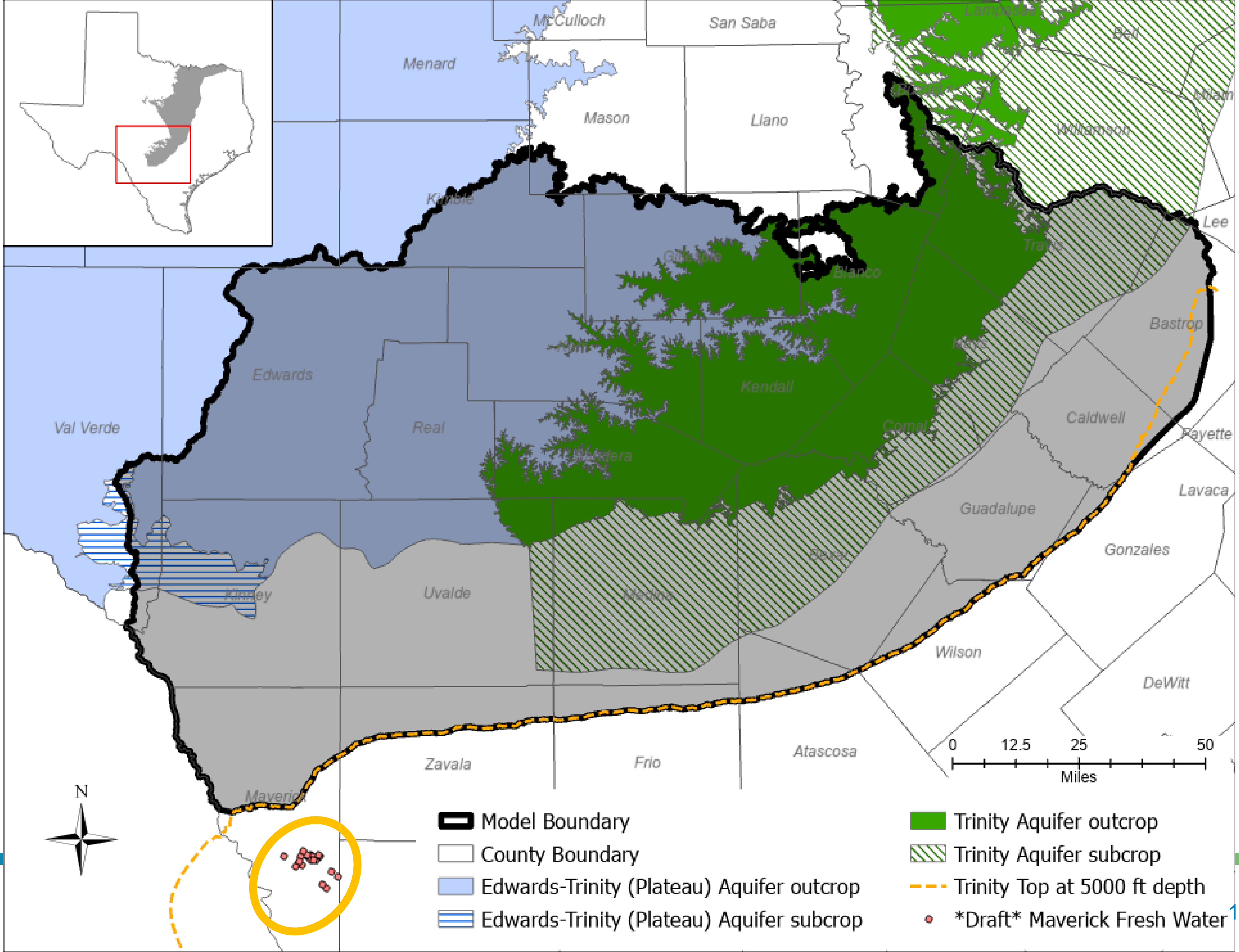
Coordination with other TWDB Projects

- Edwards and Trinity Regional GAM *(in progress)*
- BRACS Hill Country Trinity geologic surfaces *(complete)*
- BRACS Edwards-Trinity (Plateau) geologic surfaces *(in progress)*



Coordination with BRACS

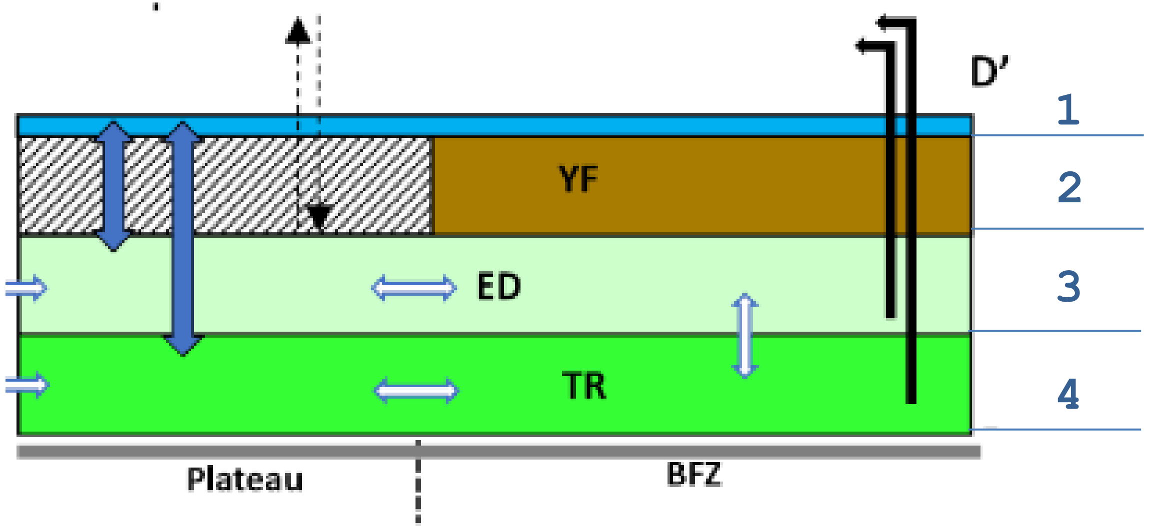
- Include *DRAFT* Brackish Groundwater Production Zones (BGPZ)
- Avoid *DRAFT* Maverick Basin fresh water area



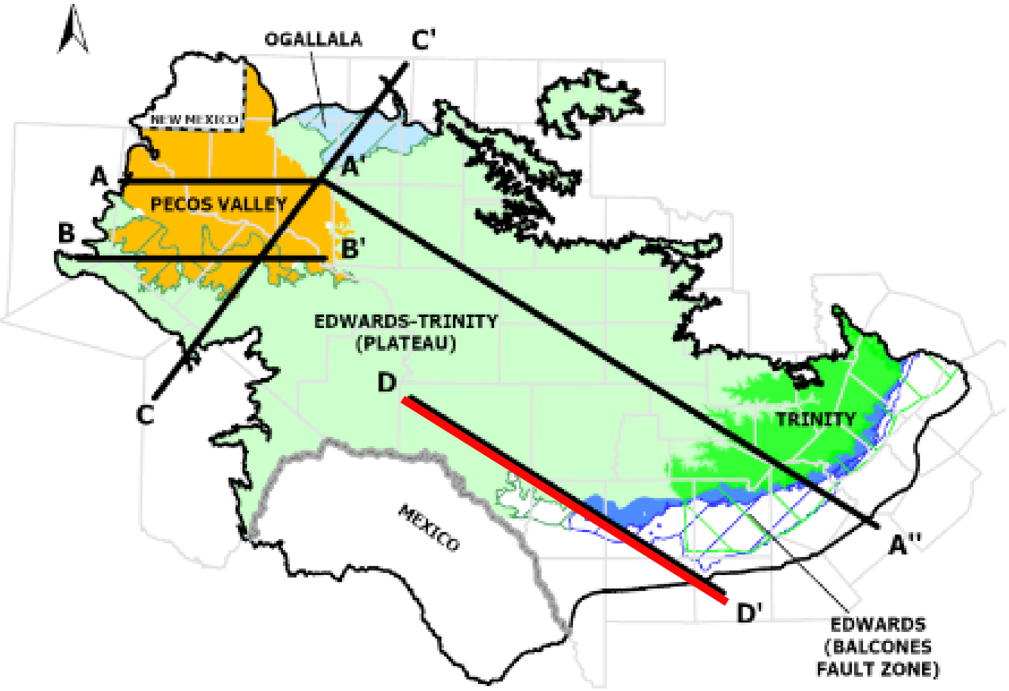
Model Layers

Stratigraphy

(Edwards & Trinity Regional GAM - Conceptual Model)

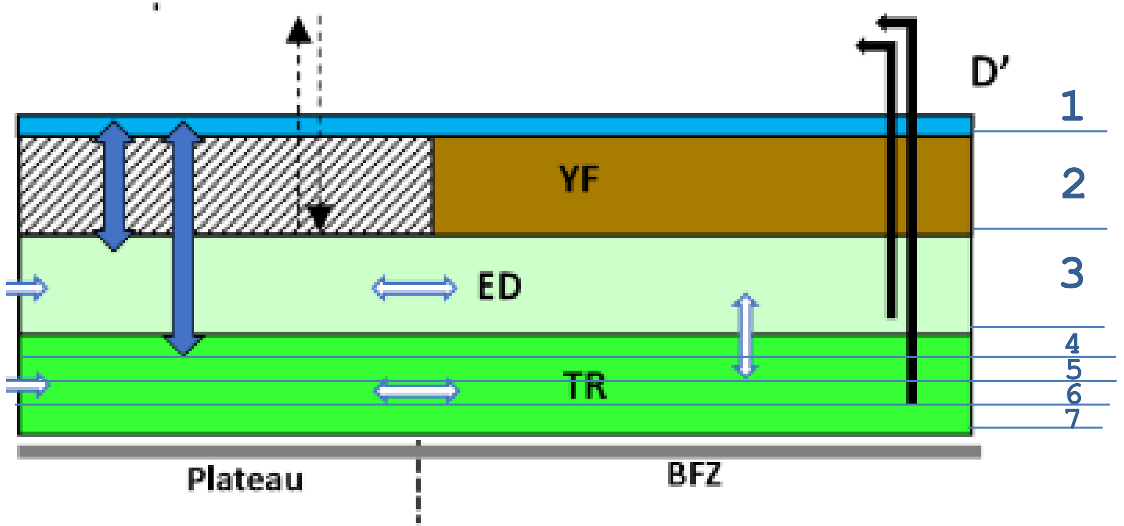


Edwards & Trinity Regional GAM Conceptual Model, 2022



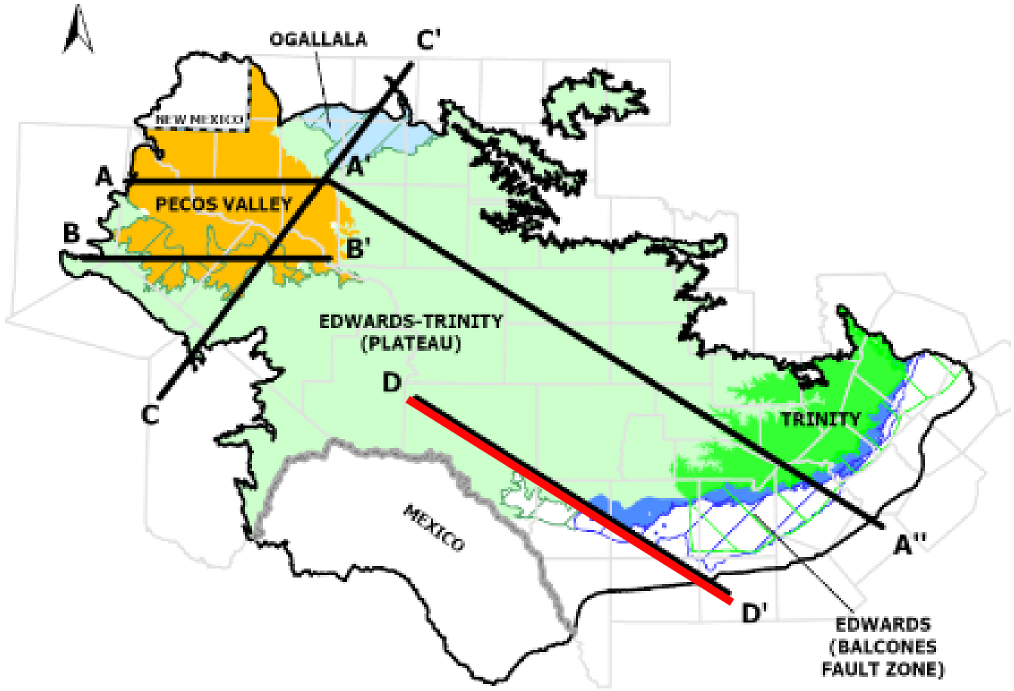
Plateau (West)	Hill Country (Central)	Edwards BFZ (Southeast)	Model Layer
Rivers/Alluvium	Rivers/Alluvium	Rivers/Alluvium	1
	--	Younger Units*	2
Edwards	--	Edwards	3
Trinity	Trinity	Trinity	4

**Upper Cretaceous + Overlying units*



Stratigraphy

(Southern Trinity GAM)

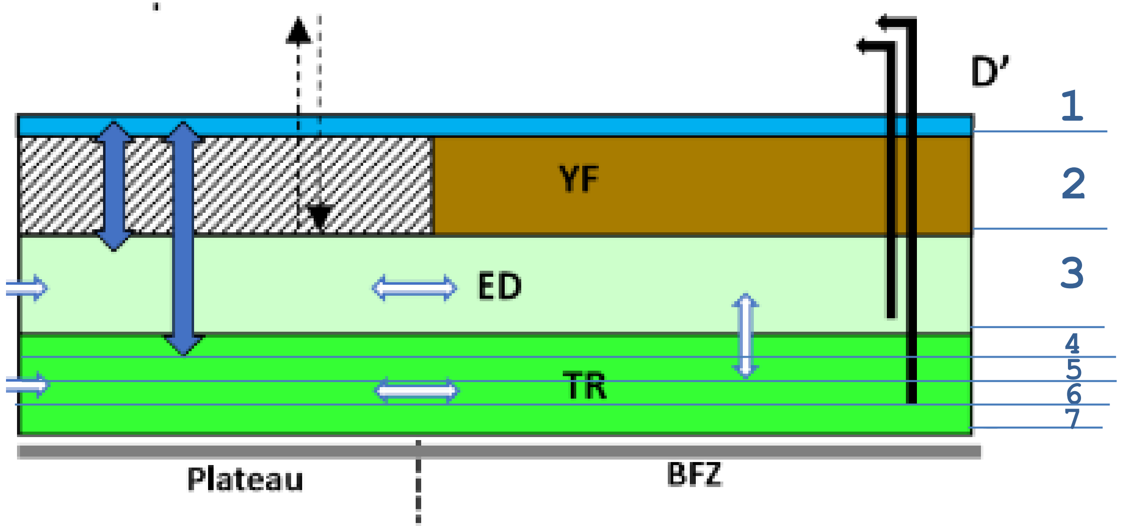


Plateau (West)	Hill Country (Central)	Edwards BFZ (Southeast)	Model Layer
Rivers/Alluvium	Rivers/Alluvium	Rivers/Alluvium	1
	--	Younger Units*	2
Edwards	--	Edwards	3
Upper Trinity	Upper Trinity	Upper Trinity	4
Middle Trinity	Middle Trinity	Middle Trinity	5
Hammett Shale	Hammett Shale	Hammett Shale	6
Lower Trinity	Lower Trinity	Lower Trinity	7

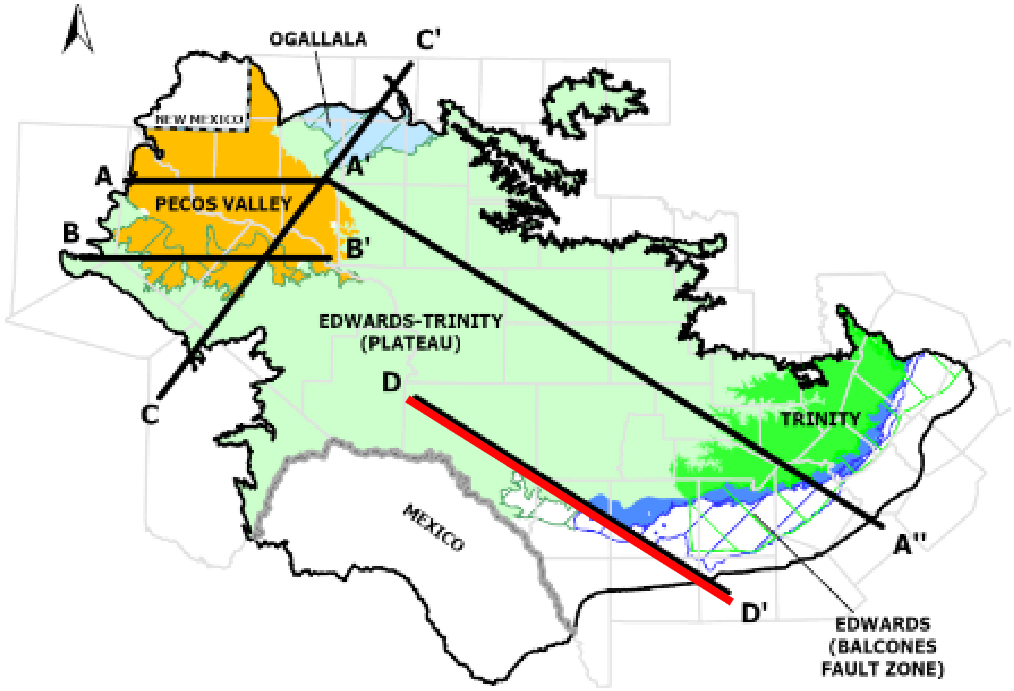
**Upper Cretaceous + Overlying units*

Stratigraphy

(Southern Trinity GAM)



Handled through RIV & RCH package (eliminate extra cells)



Plateau (West)	Hill Country (Central)	Edwards BFZ (Southeast)	Model Layer
~~Rivers/Alluvium~~	~~Rivers/Alluvium~~	~~Rivers/Alluvium~~	~~1~~
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**Upper Cretaceous + Overlying units*

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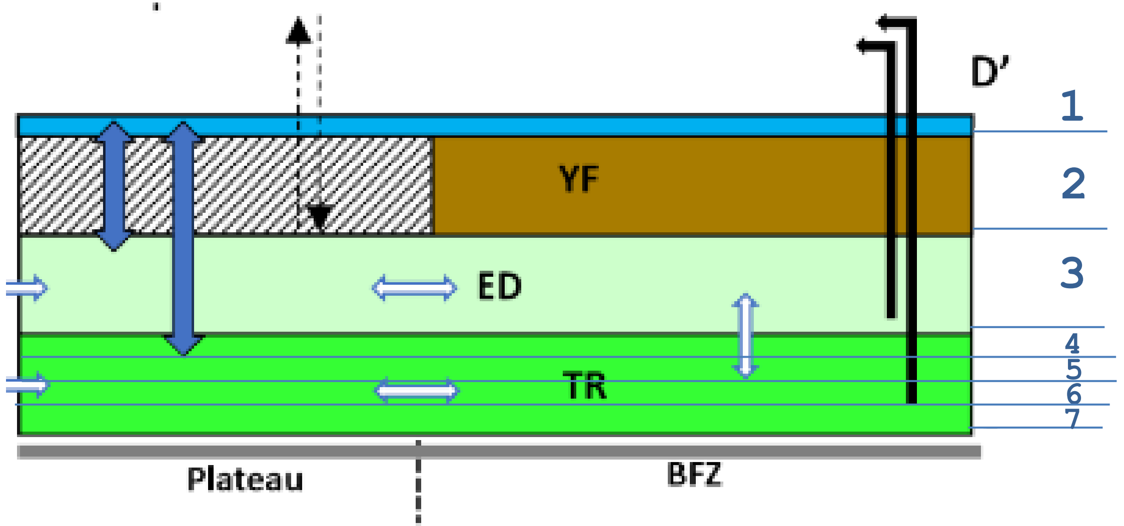
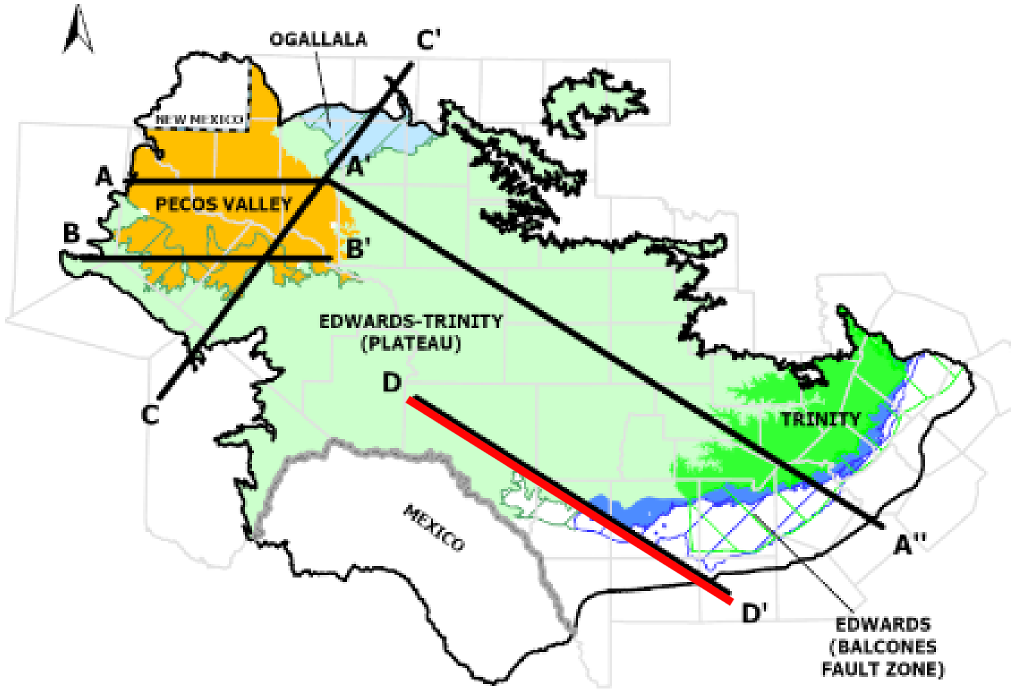
Stratigraphy

(Southern Trinity GAM)





Handled through GHB package (eliminate placeholder cells)

Plateau (West)	Hill Country (Central)	Edwards BFZ (Southeast)	Model Layer
~~Rivers/Alluvium~~	~~Rivers/Alluvium~~	~~Rivers/Alluvium~~	~~1~~
	~~--~~	~~Younger Units*~~	~~2~~
Edwards	--	Edwards	3
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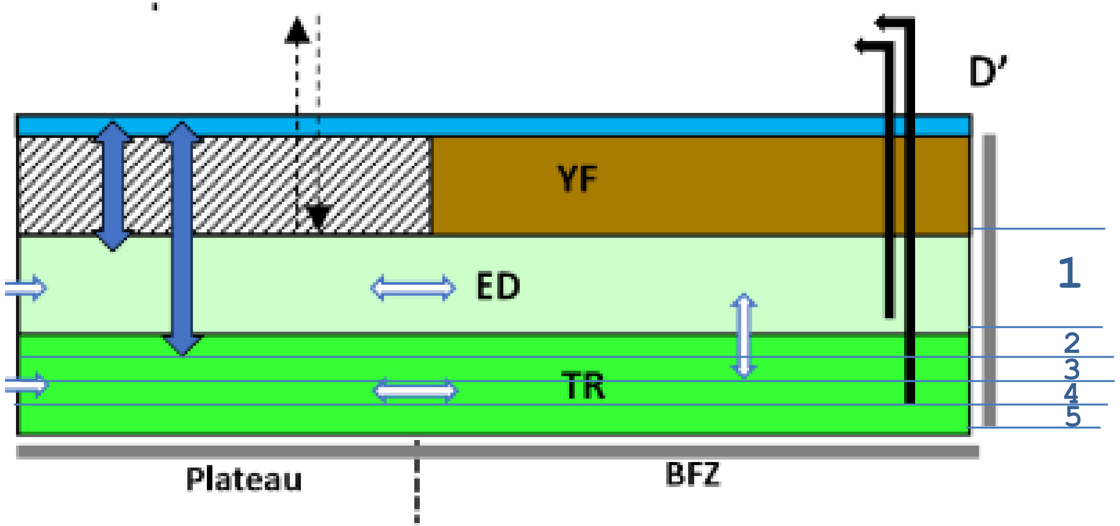
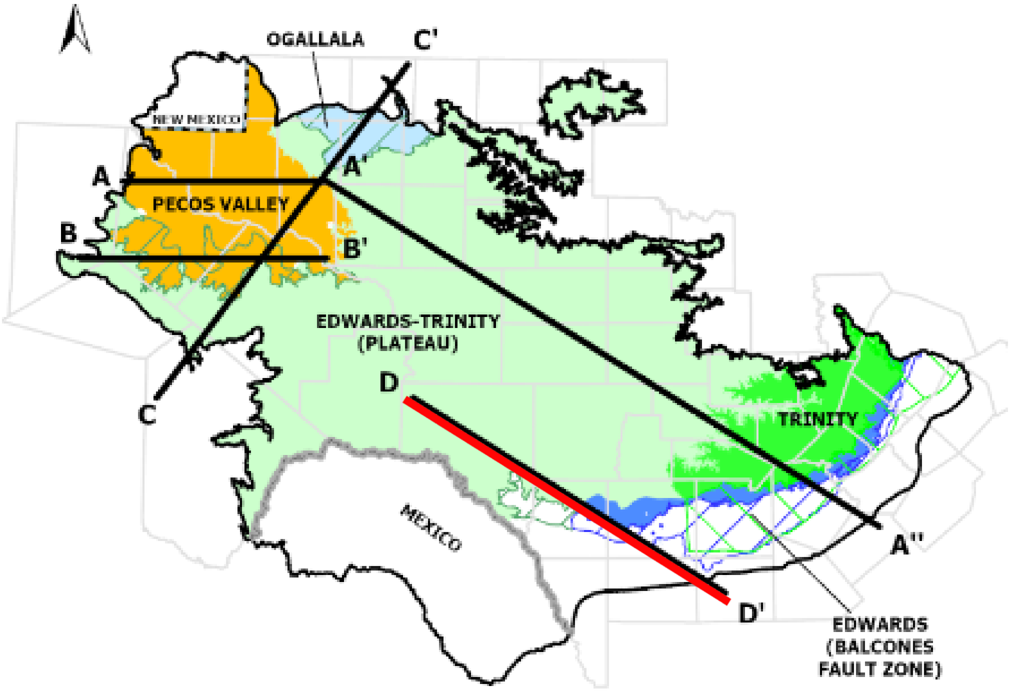
**Upper Cretaceous + Overlying units*

Stratigraphy

(Southern Trinity GAM)





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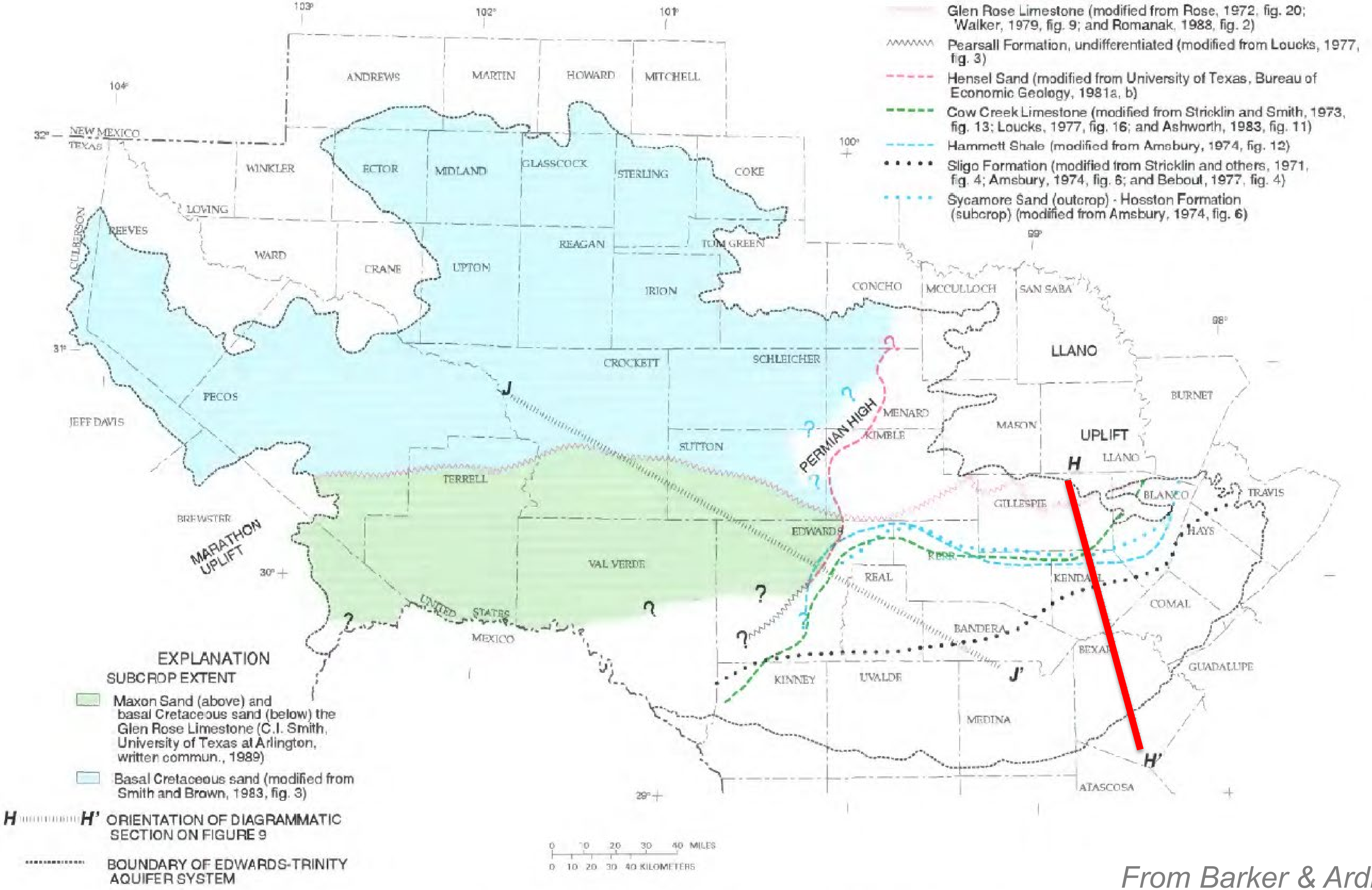
Edwards	--	Edwards	1
Upper Trinity	Upper Trinity	Upper Trinity	2
Middle Trinity	Middle Trinity	Middle Trinity	3
Hammett Shale	Hammett Shale	Hammett Shale	4
Lower Trinity	Lower Trinity	Lower Trinity	5

Model Structure

- Model surfaces are based on
  - BRACS Hill Country Trinity project *(completed)*: surfaces for all Trinity subunits
  - BRACS Edwards-Trinity (Plateau) project *(in progress)*: picks for Trinity top/bottom

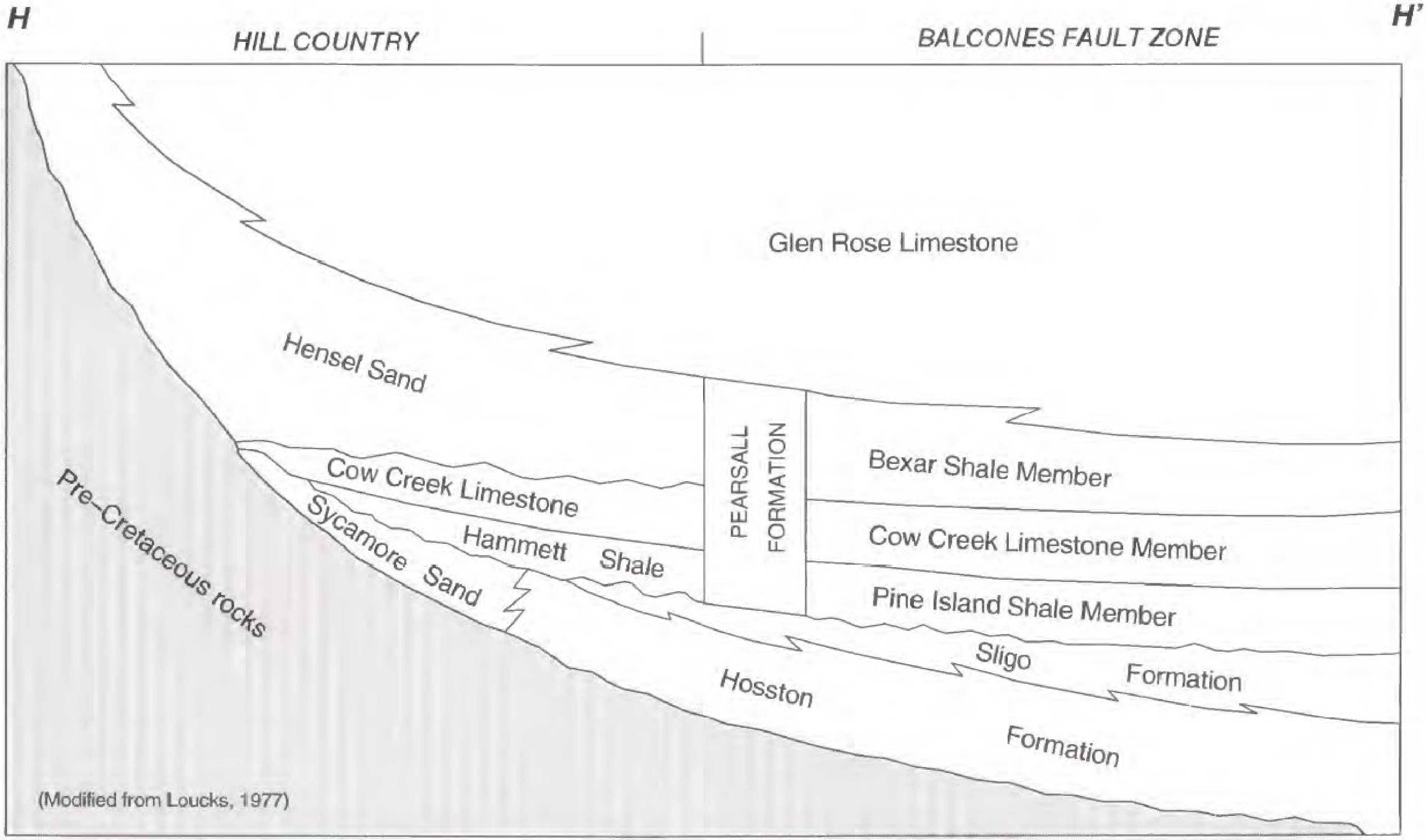
- Model surfaces were adjusted to model-specific land surface

- In Edwards-Trinity (Plateau) area:
  - subunit divisions are placeholders to avoid pinchouts
  - hydraulic properties used for transition from differentiated Trinity subunits → Undifferentiated Trinity



From Barker & Ardis 1996

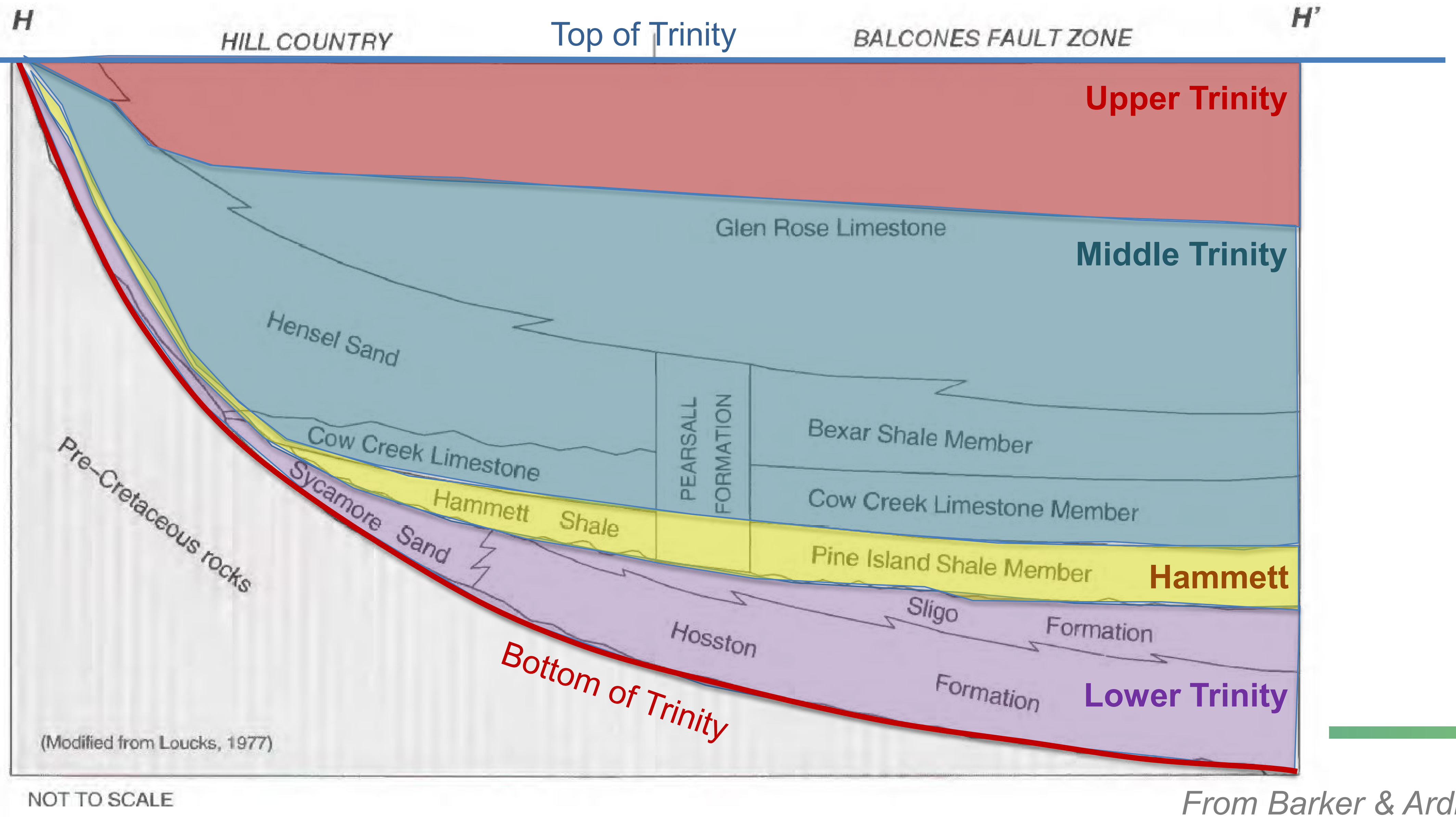
Southern Trinity units do pinch out in the North against Llano Uplift



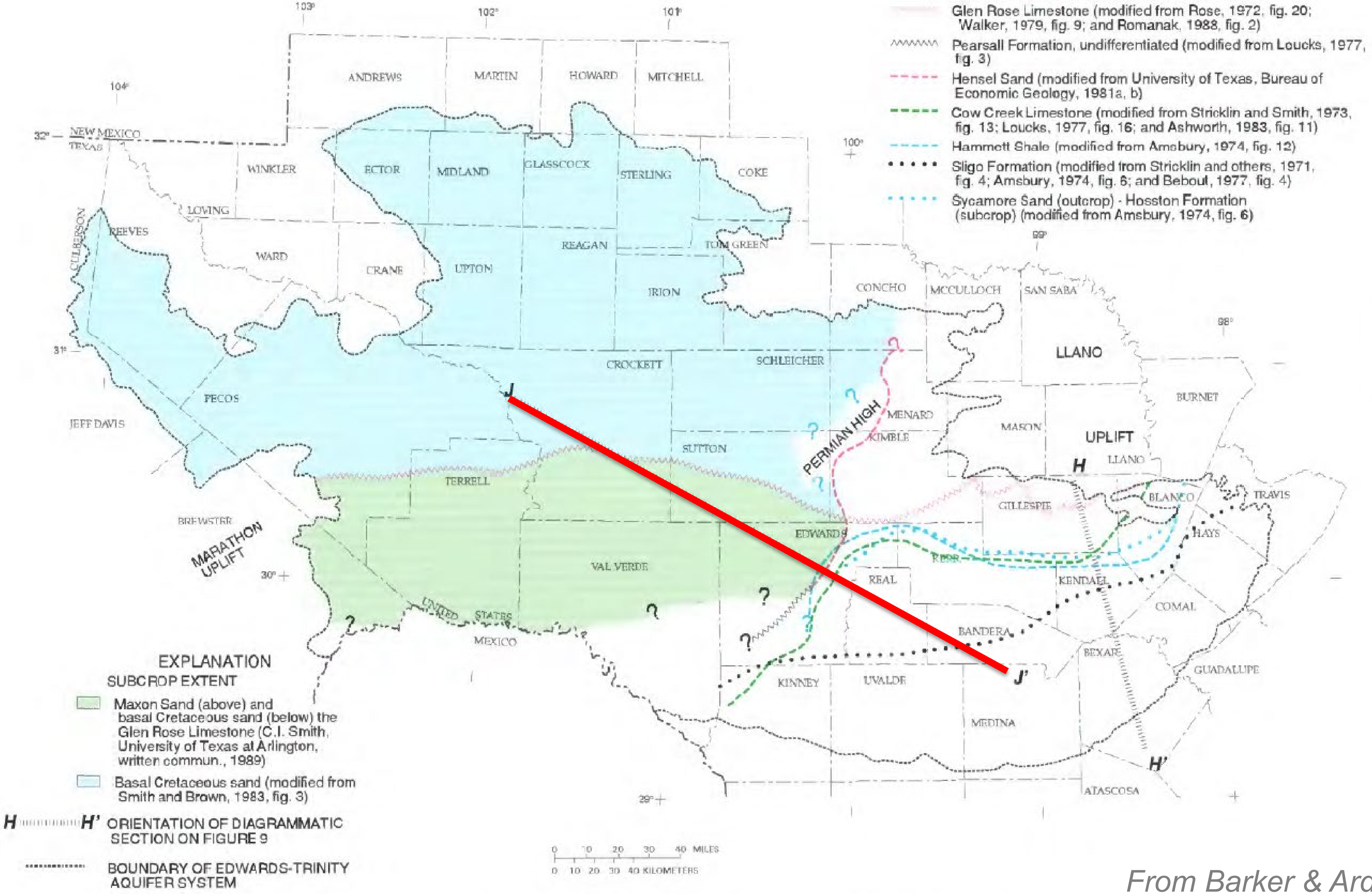
NOT TO SCALE

From Barker & Ardis 1996

Southern Trinity units do pinch out in the North against Llano Uplift

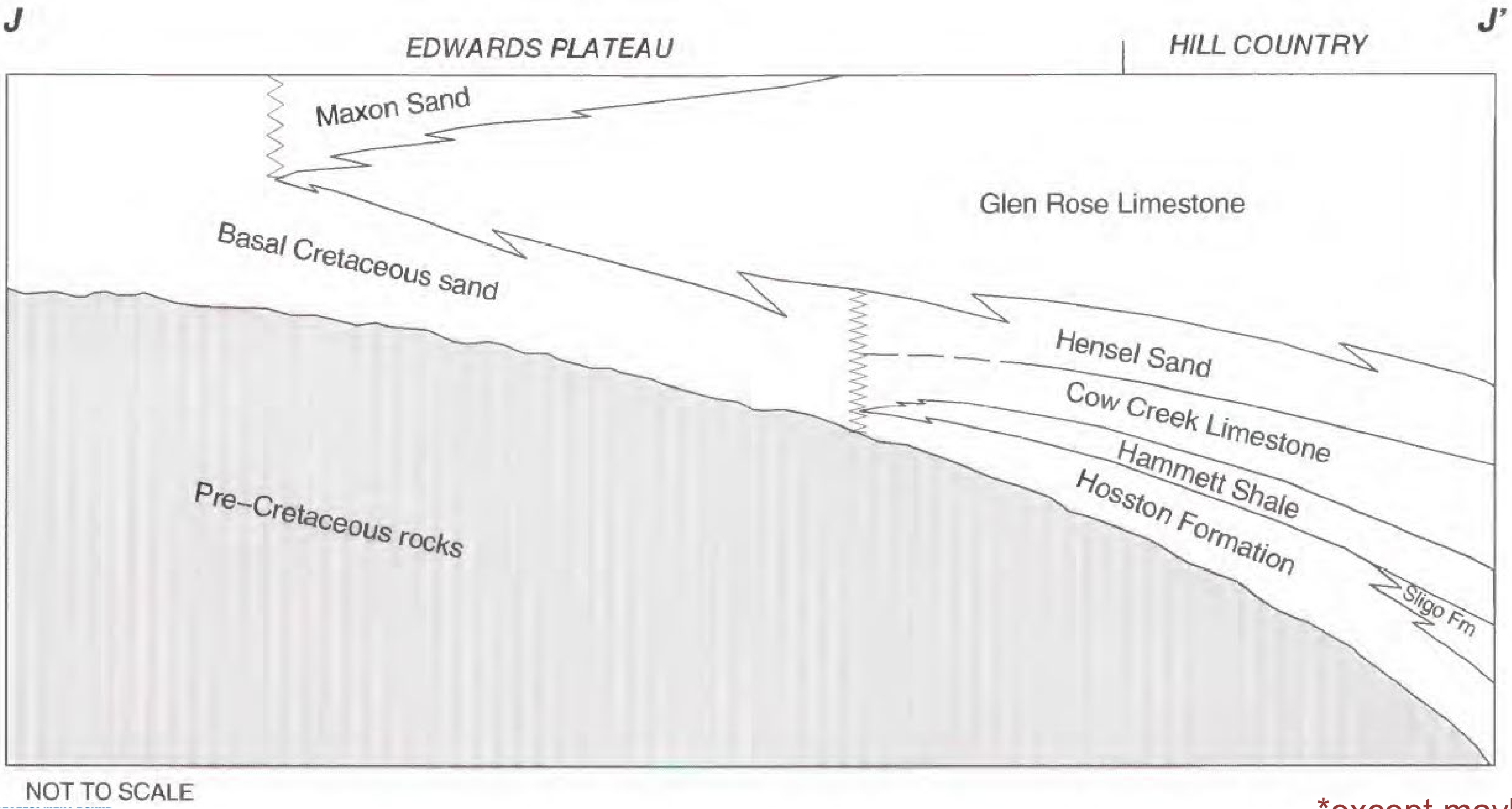


From Barker & Ardis 1996



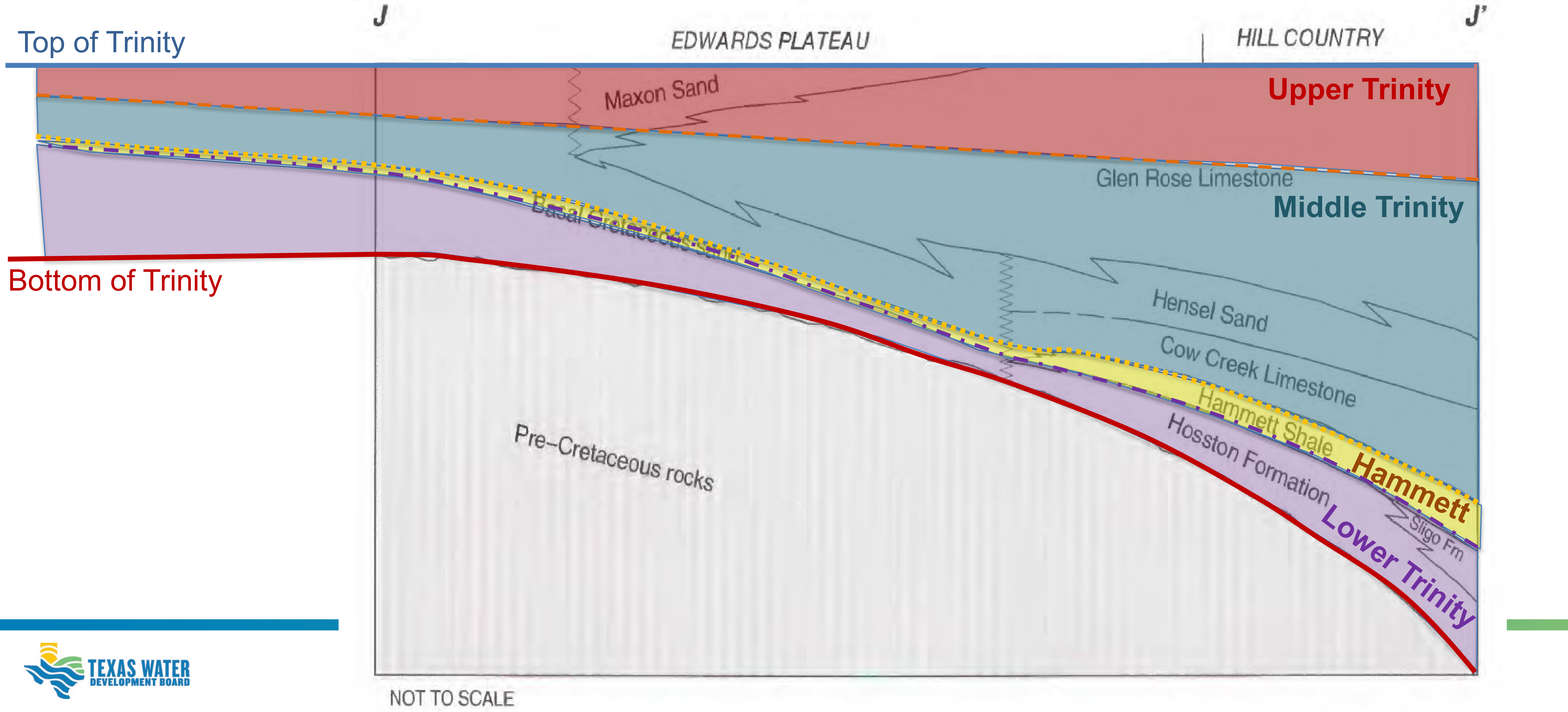
From Barker & Ardis 1996

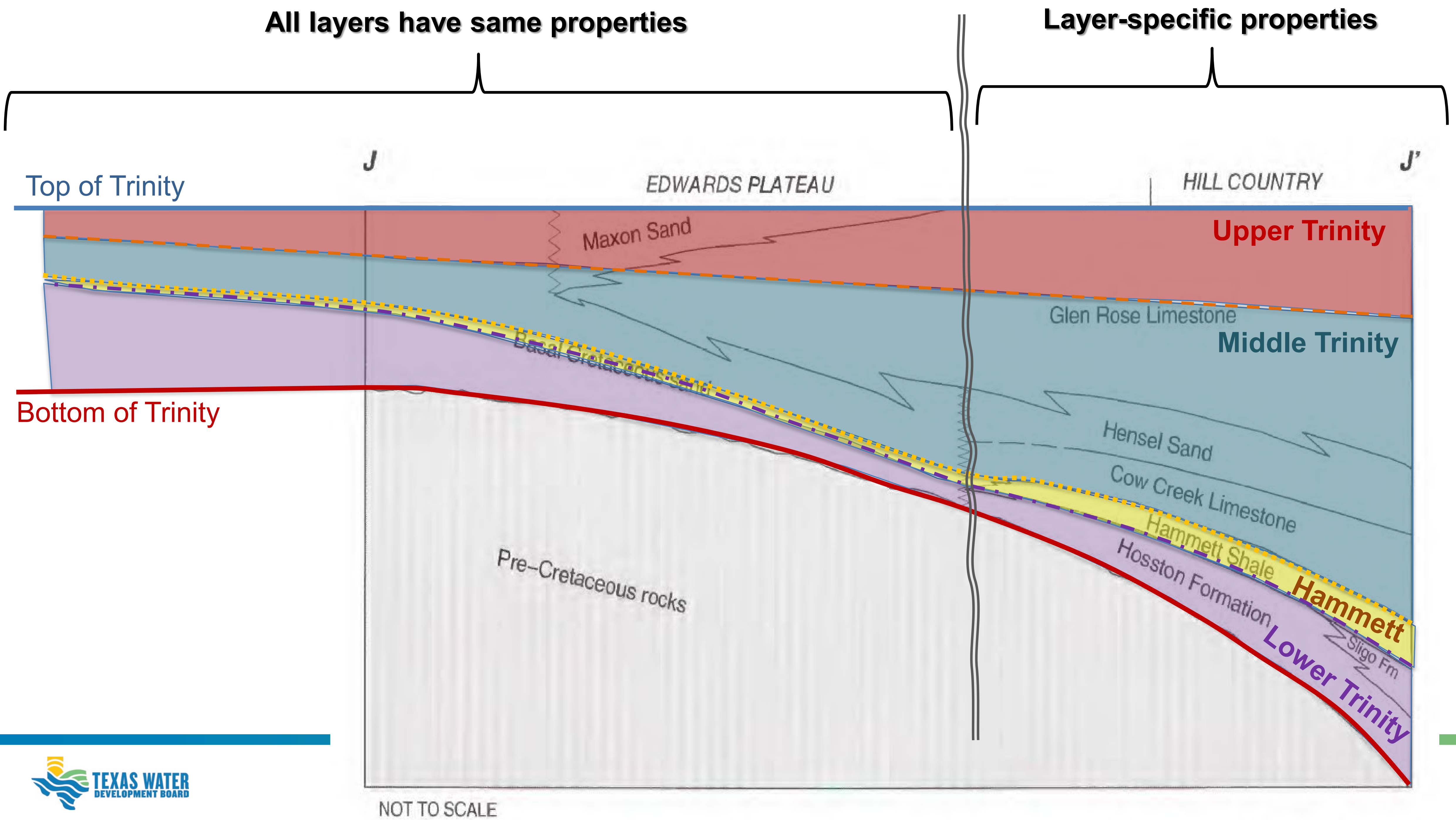
Southern Trinity units do NOT pinch out in the West* – they grade into “Basal Cretaceous sand”



From Barker & Ardis 1996

*except maybe Hammett


Top of Trinity
J
EDWARDS PLATEAU
HILL COUNTRY
J'
Maxon Sand
Upper Trinity
Glen Rose Limestone
Middle Trinity
Basal Cretaceous sand
Hensel Sand
Cow Creek Limestone
Hammett Shale
Hammett
Bottom of Trinity
Hosston Formation
Sligo Fm
Lower Trinity
Pre-Cretaceous rocks
NOT TO SCALE



All layers have same properties
Layer-specific properties
J
J'
EDWARDS PLATEAU
HILL COUNTRY
Top of Trinity
Upper Trinity
Maxon Sand
Glen Rose Limestone
Middle Trinity
Basal Cretaceous sand
Bottom of Trinity
Hensel Sand
Cow Creek Limestone
Hammett Shale
Hammett
Hosston Formation
Sligo Fm
Lower Trinity
Pre-Cretaceous rocks
NOT TO SCALE

Model Design: MODFLOW 6

Model Design

- MODFLOW
  - Open-source software from U.S. Geological Survey (USGS)
  - Ability to automate model setup and analysis with “flopy” Python package

- MODFLOW 6
  - Ability to completely exclude cells outside model area
  - Ability to add extra refinement to areas of interest (streams, springs, etc.)
  - Fully unstructured grid
  - Future potential:
    - Ability to run nested local models
    - Can connect packages through Mover (MVR) Utility *(ex. Springs to streams for SW-GW interactions)*

Model Packages: Grid (DISU)

Model Packages: DISU

- DISU package defines the model grid:
  - Size and location of cells *(including level of refinement)*
  - Whether cells are active/inactive
  - Specify which cells are connected to which

Model Packages: DISU

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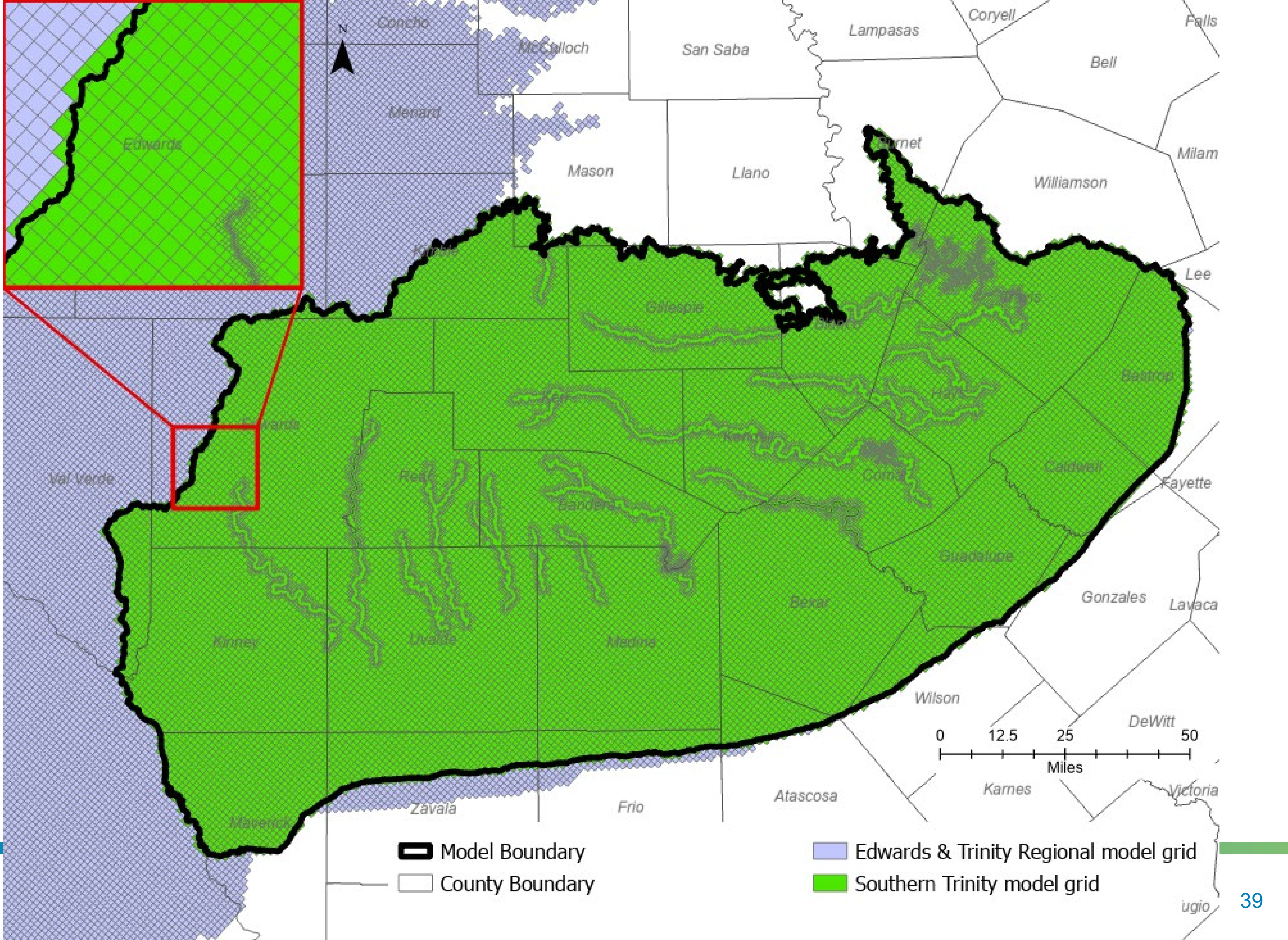
Model Grid



N
Concho
McCulloch
San Saba
Lampasas
Coryell
Falls
Bell
Menard
Mason
Llano
Williamson
Milam
Lee
Edwards
Val Verde
Kinney
Uvalde
Medina
Bexar
Gillespie
Bastrop
Caldwell
Fayette
Guadalupe
Gonzales
Lavaca
Wilson
DeWitt
Karnes
Victoria
Atascosa
Frio
Zavala
Maverick
0
12.5
25
50
Miles
Model Boundary
County Boundary
Edwards & Trinity Regional model grid
Southern Trinity model grid

Model Grid

- 453,940 total cells *(357,197 active)*
- Quadtree refinement
  - Max: *1 mile x 1 mile*
  - Min : $^{1}/_{16}$ *mile x* $^{1}/_{16}$ *mile*
- 5 layers
  - All layers have same number of total cells & same level of refinement
  - Eroded areas are inactive
  - No pinchouts

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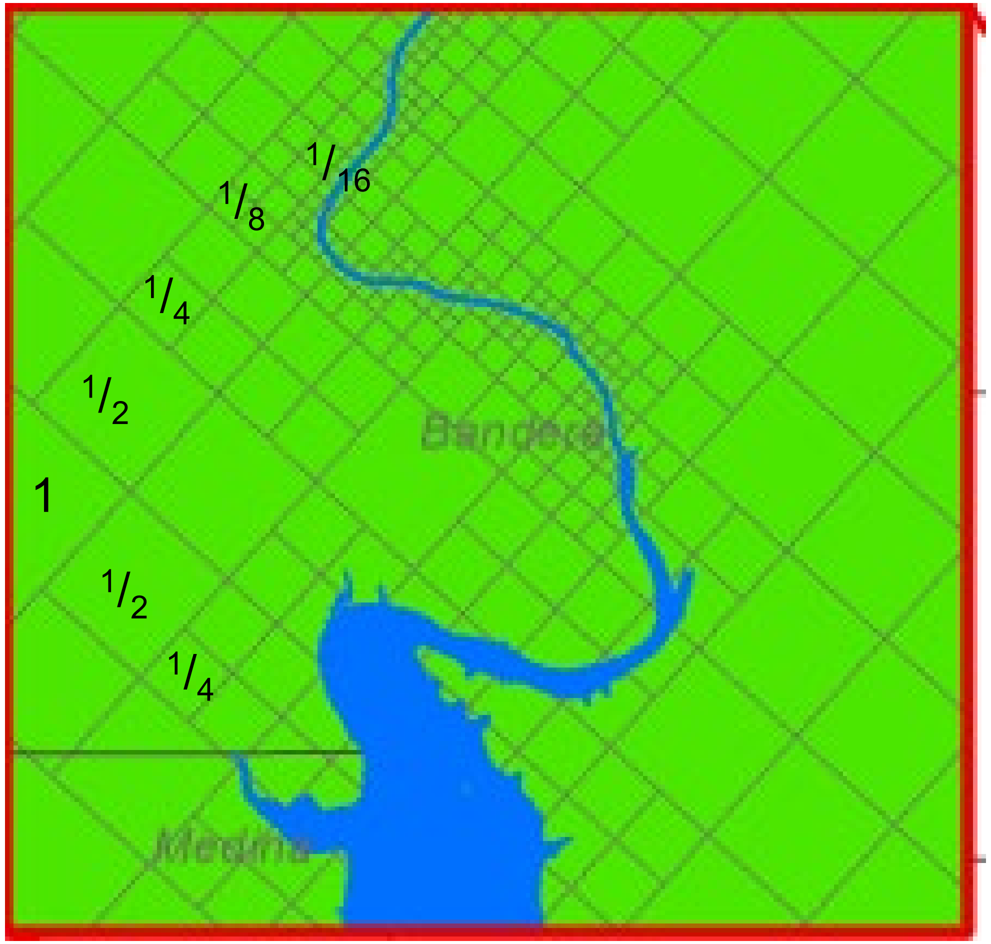
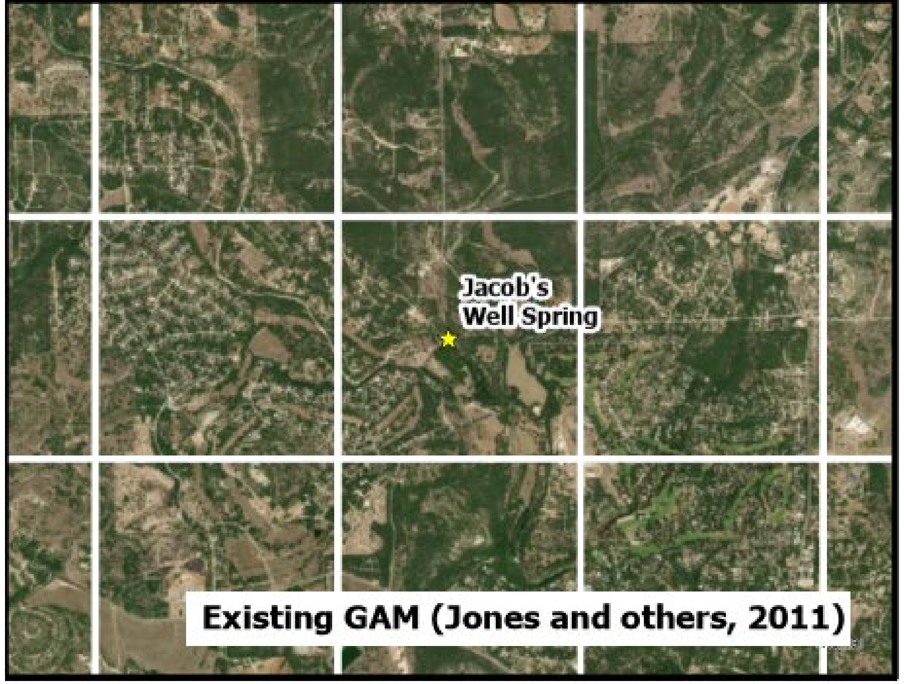
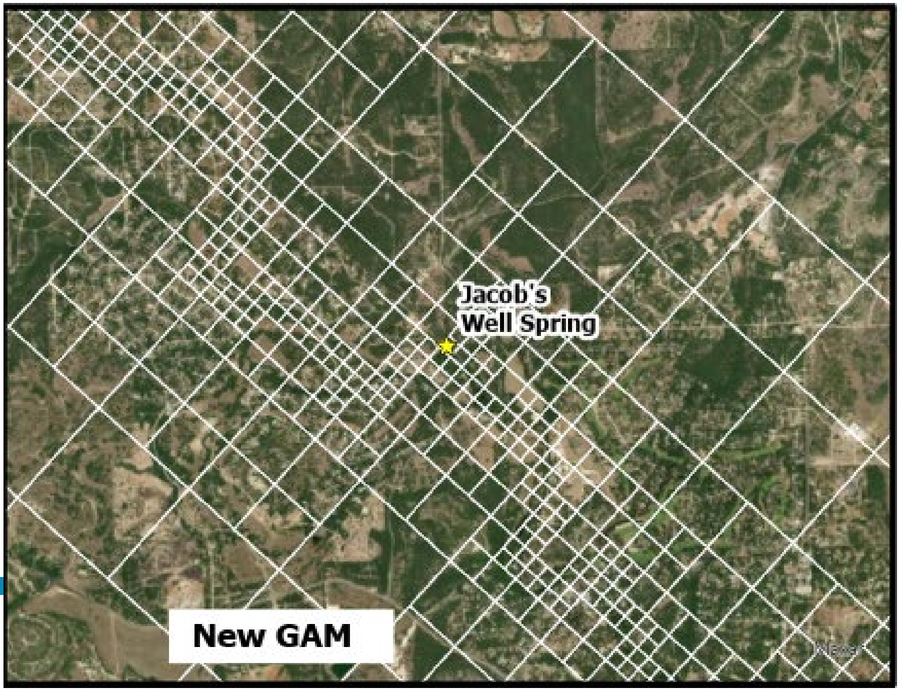
Model Refinement

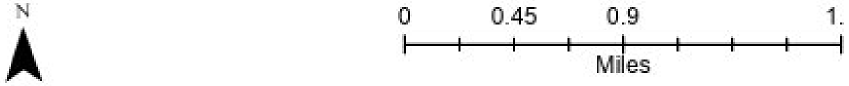
- Quadtree refinement progressively divides cells into 4 equal parts
- Refinement around streams ($^{1}/_{16}$ mile) and lakes ($^{1}/_{4}$ mile)
- Most major springs also refined because near streams



Model Refinement







Grid comparison between Southern Trinity models

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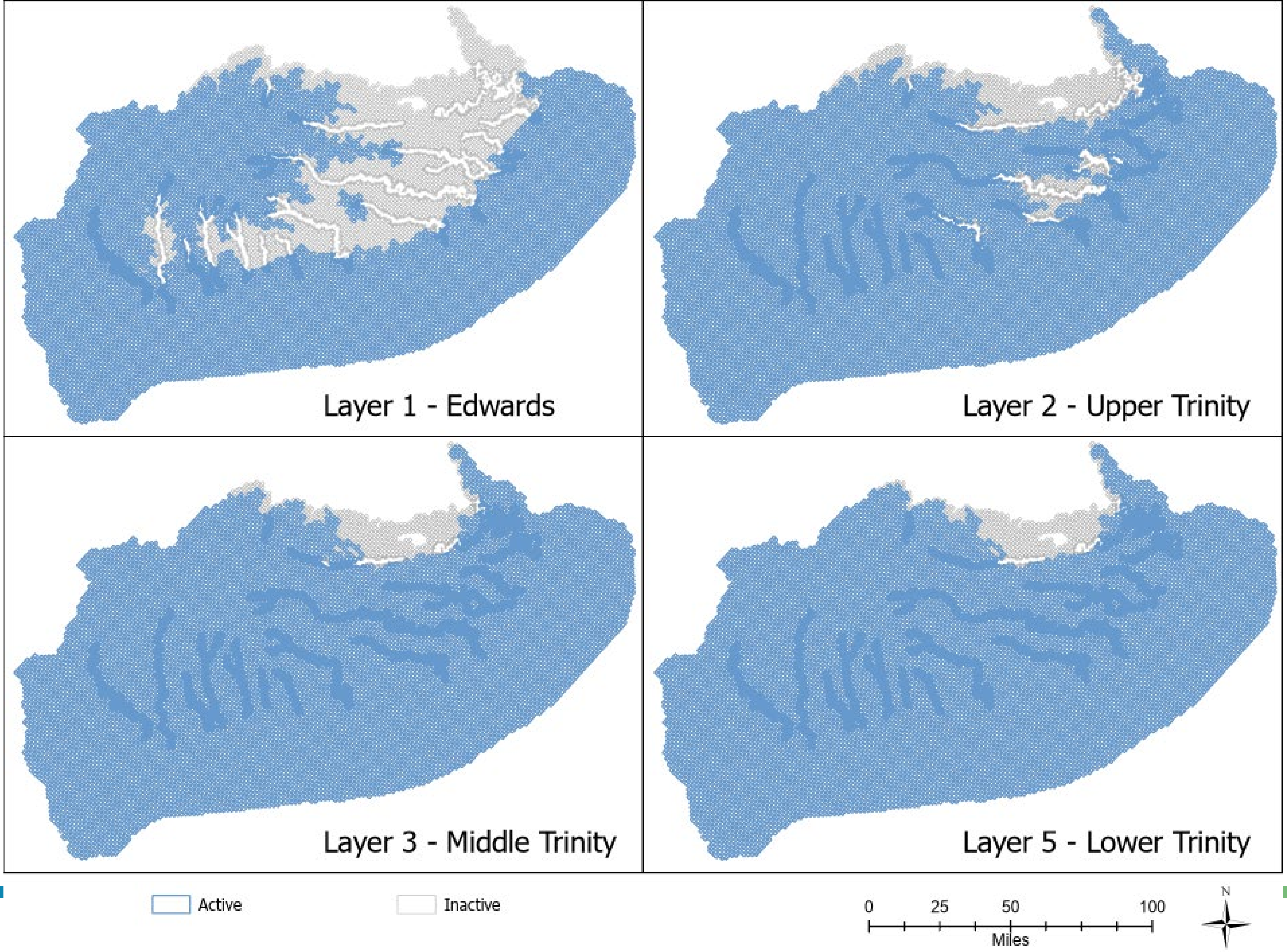
Model Packages: DISU

- DISU package defines the model grid:
    - Size and location of cells *(including level of refinement)*
    - **Whether cells are active/inactive**
    - Specify which cells are connected to which

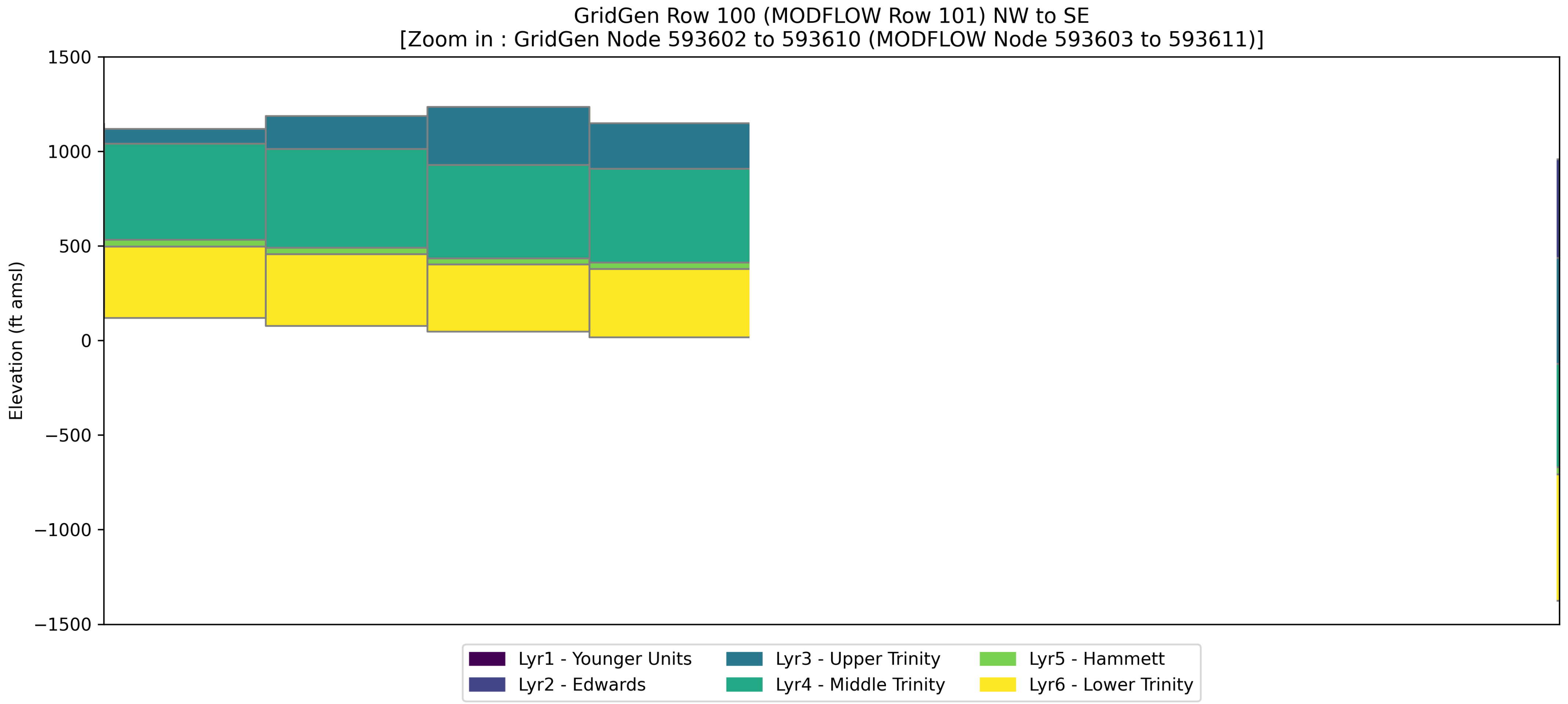
Model Grid



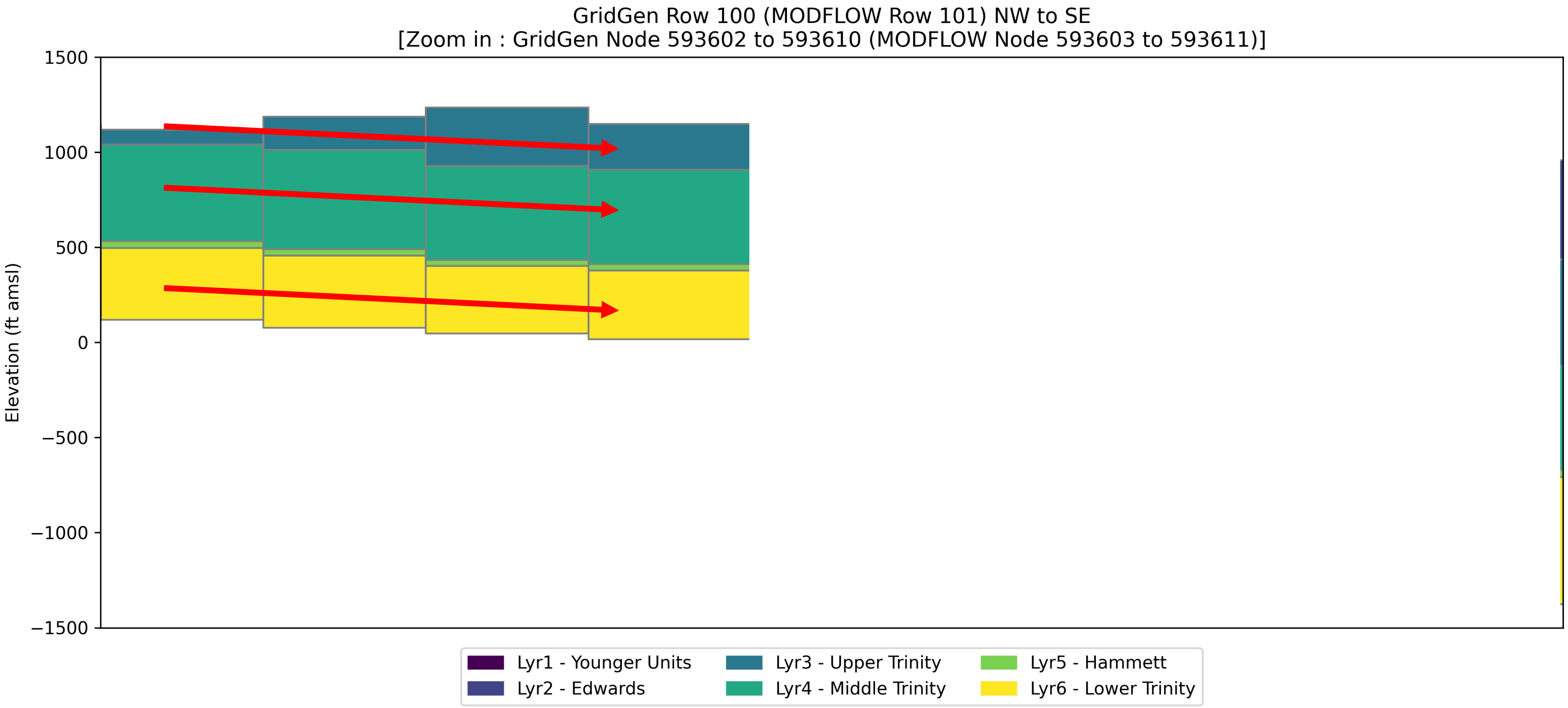
* Layer 4 Hammett Shale extent approximately same as Layer 5

Model Packages: DISU

- DISU package defines the model grid:
  - Size and location of cells *(including level of refinement)*
  - Whether cells are active/inactive
  - **Specify which cells are connected to which**



GridGen Row 100 (MODFLOW Row 101) NW to SE
[Zoom in : GridGen Node 593602 to 593610 (MODFLOW Node 593603 to 593611)]
Elevation (ft amsl)
1500
1000
500
0
−500
−1000
−1500
Lyr1 - Younger Units
Lyr2 - Edwards
Lyr3 - Upper Trinity
Lyr4 - Middle Trinity
Lyr5 - Hammett
Lyr6 - Lower Trinity



- Typical model assumes that horizontal flow mostly follows model layers
- Decent simplifying assumption for most geology in Texas
- Easy for structured grid models to replicate

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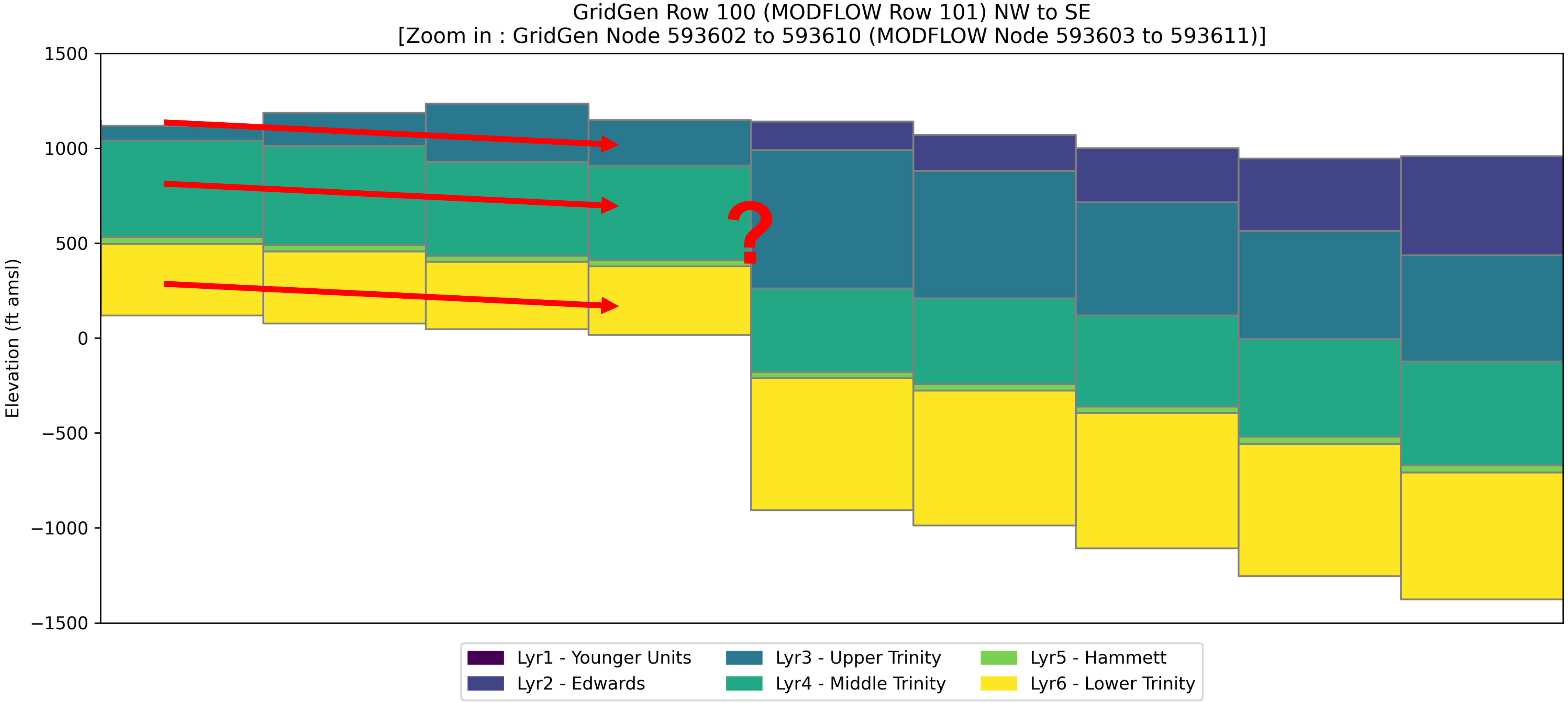
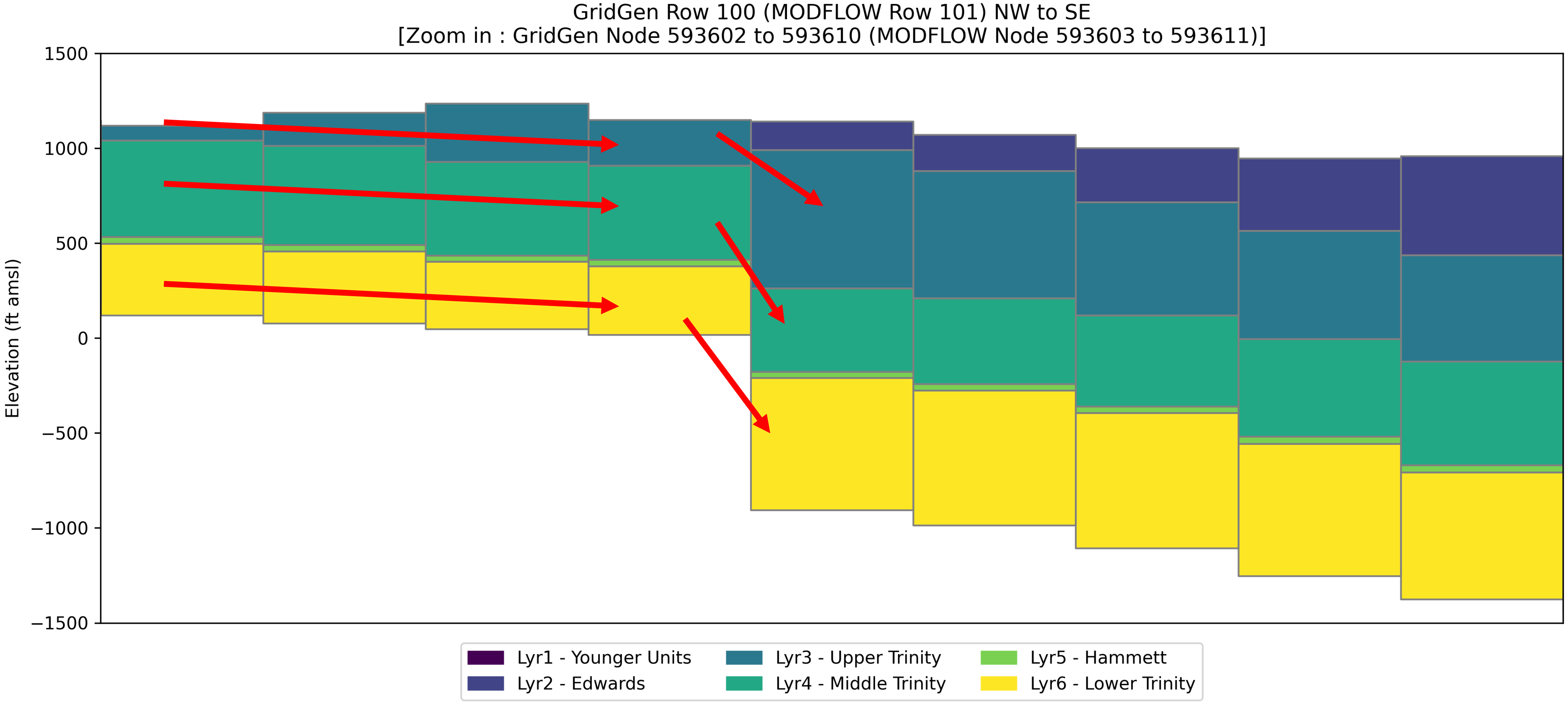
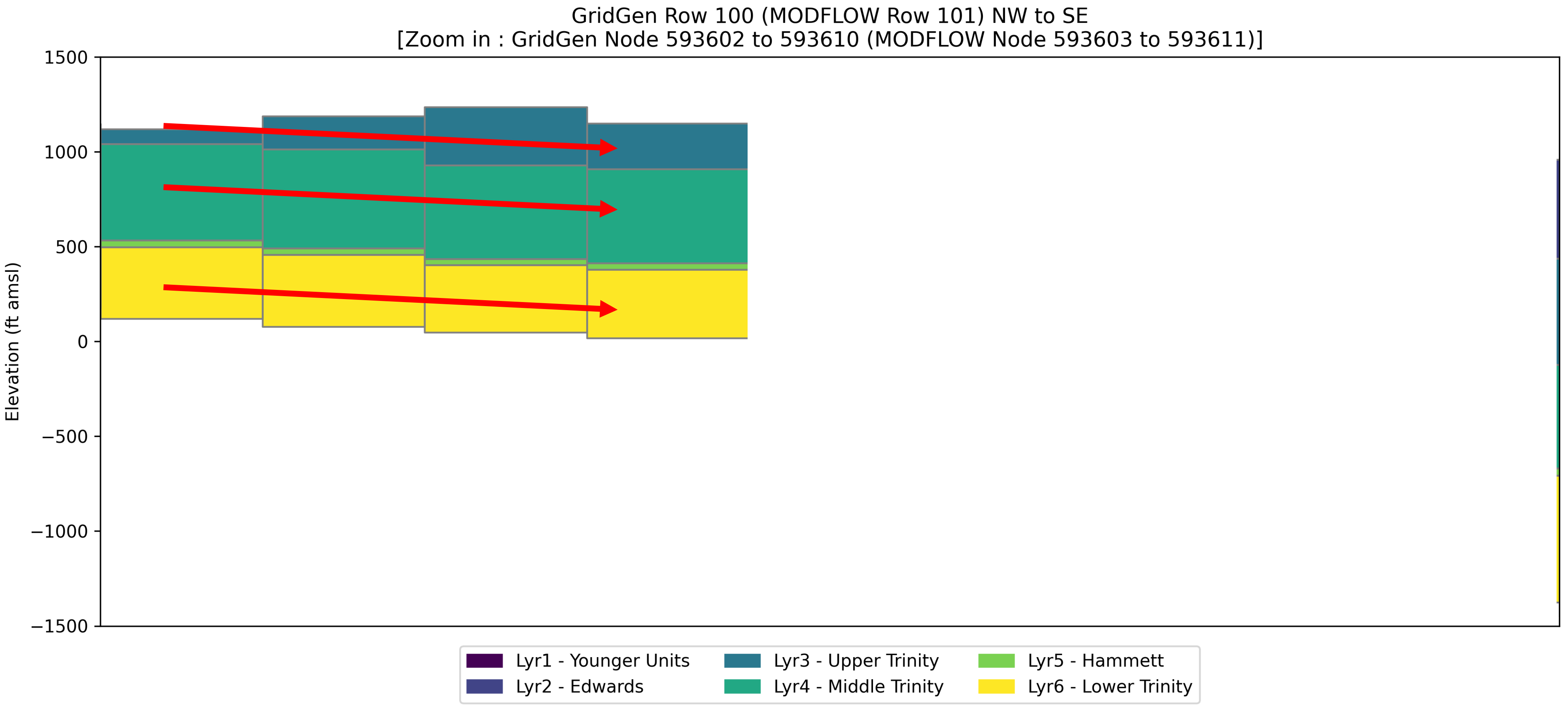


- Fault blocks & disconnected geology are more complicated



- Structured grid will automatically connect model layers even if elevations don’t overlap



- Typical solution : Don’t include complicated geology!
- This is why original “Hill Country” Trinity GAM does NOT include Edwards Balcones Fault Zone

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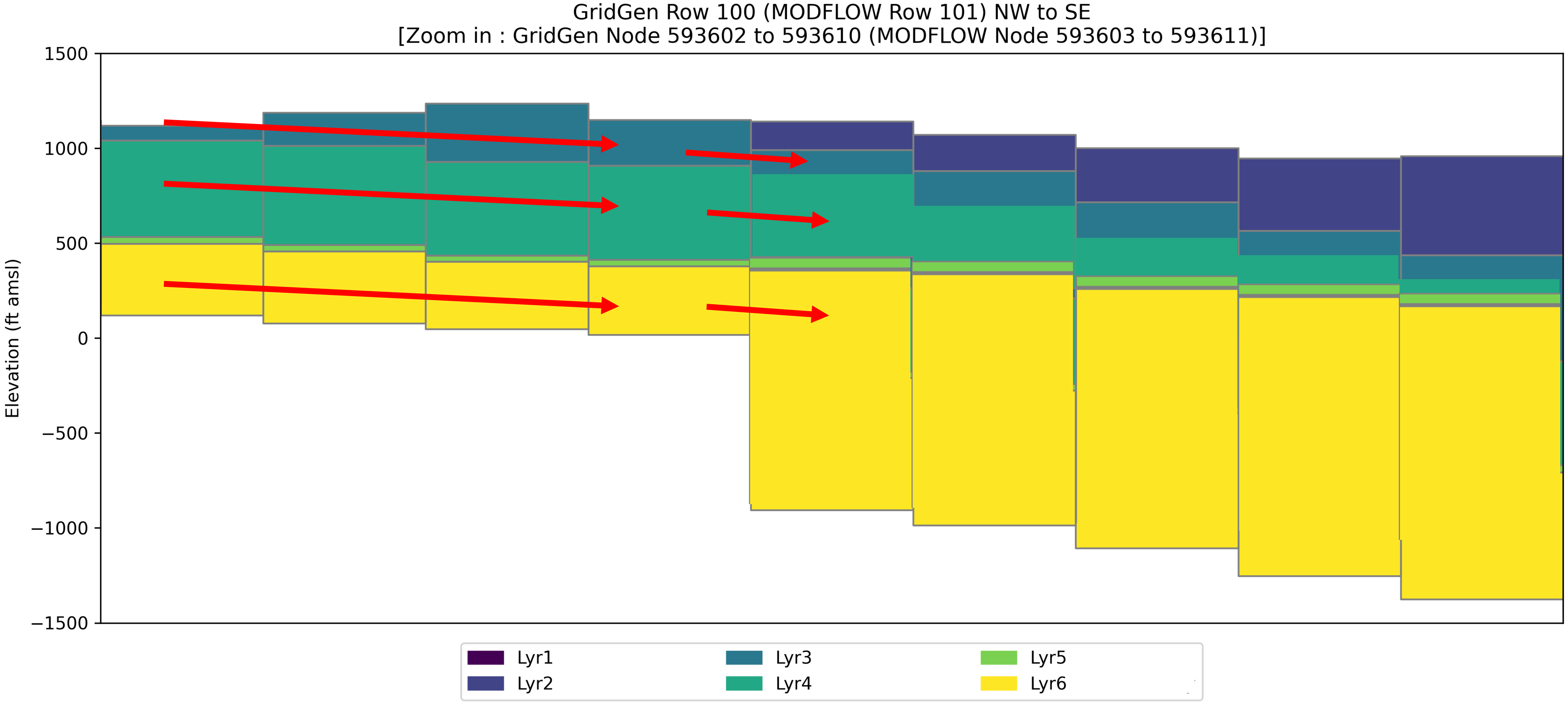

- Other more complicated solution : Define Model layers separately from Geology
- Requires simplifications & assumptions
- Makes post-processing by geologic layer difficult

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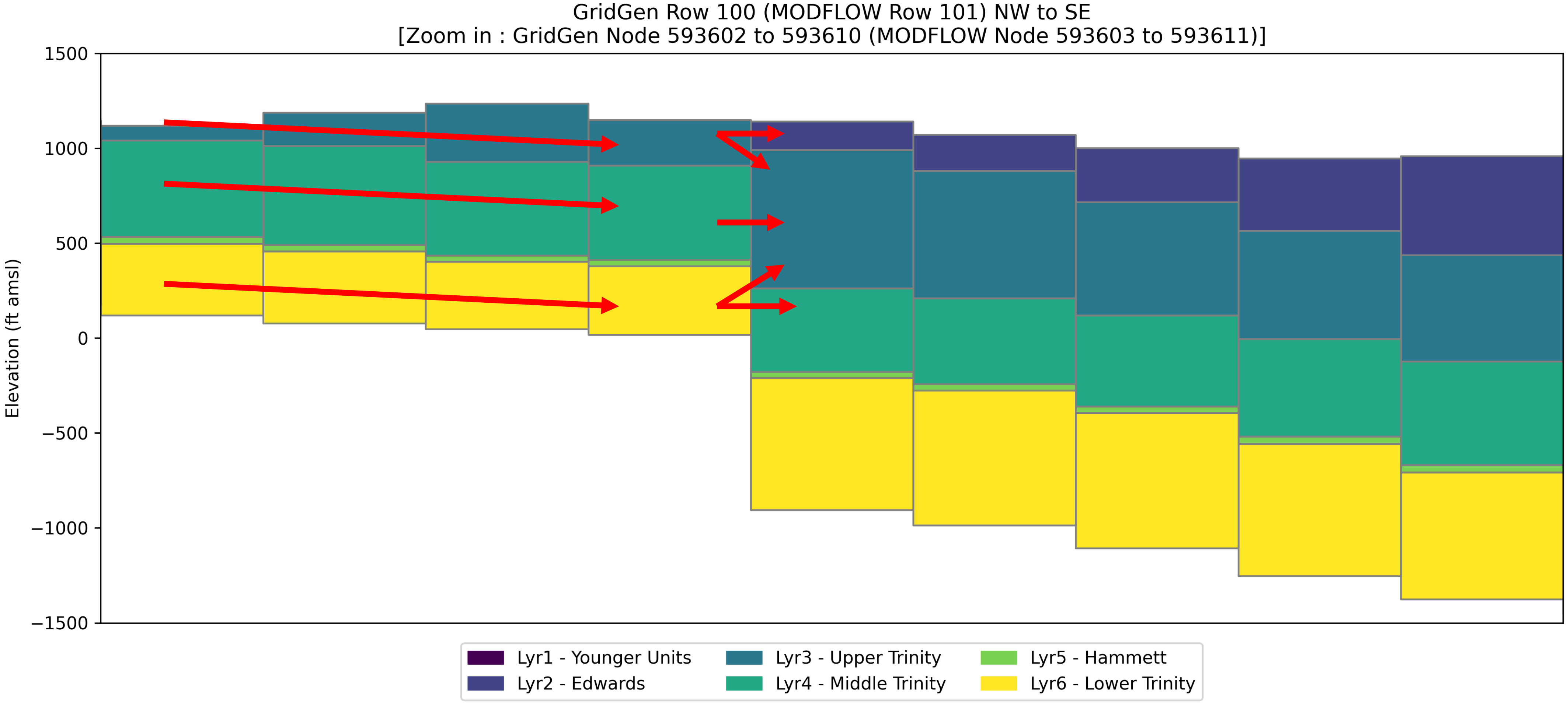
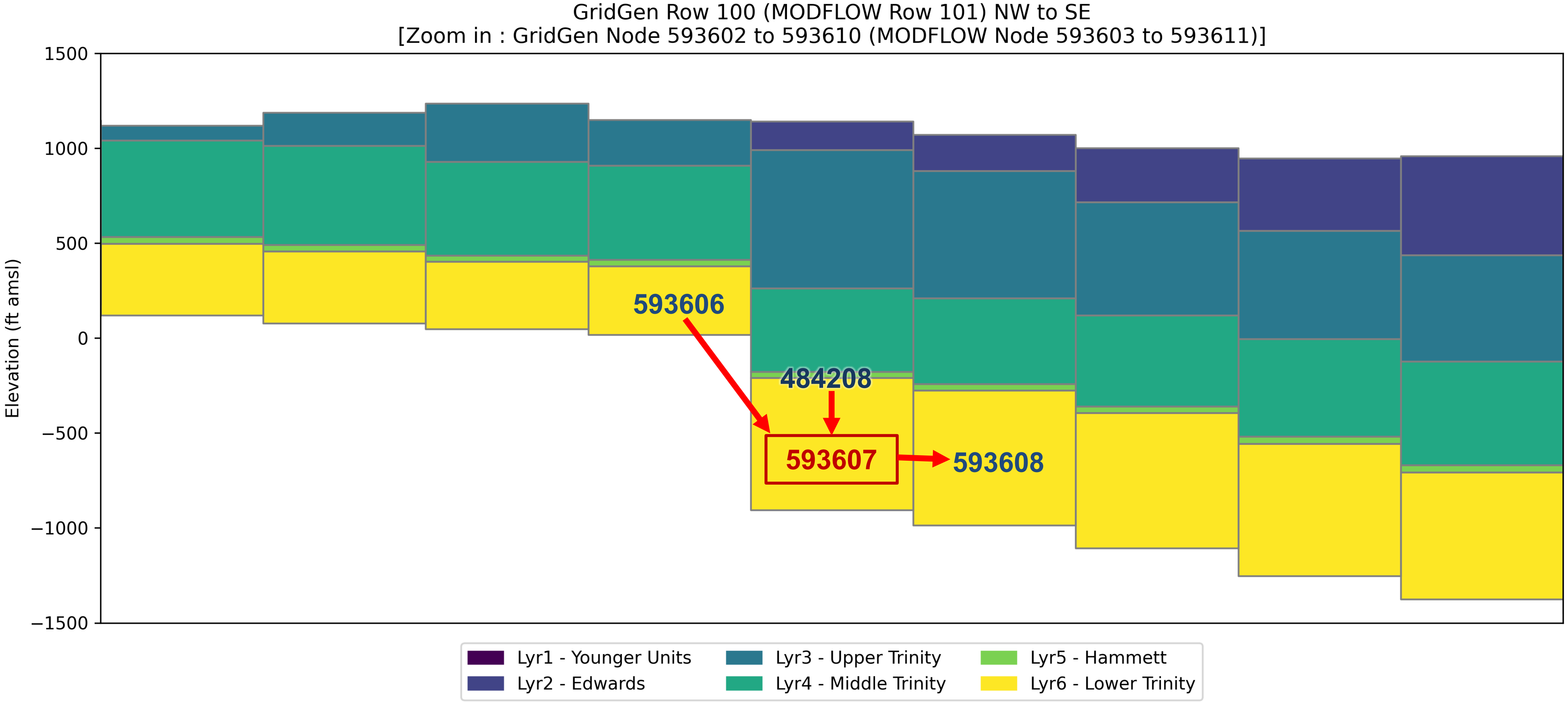
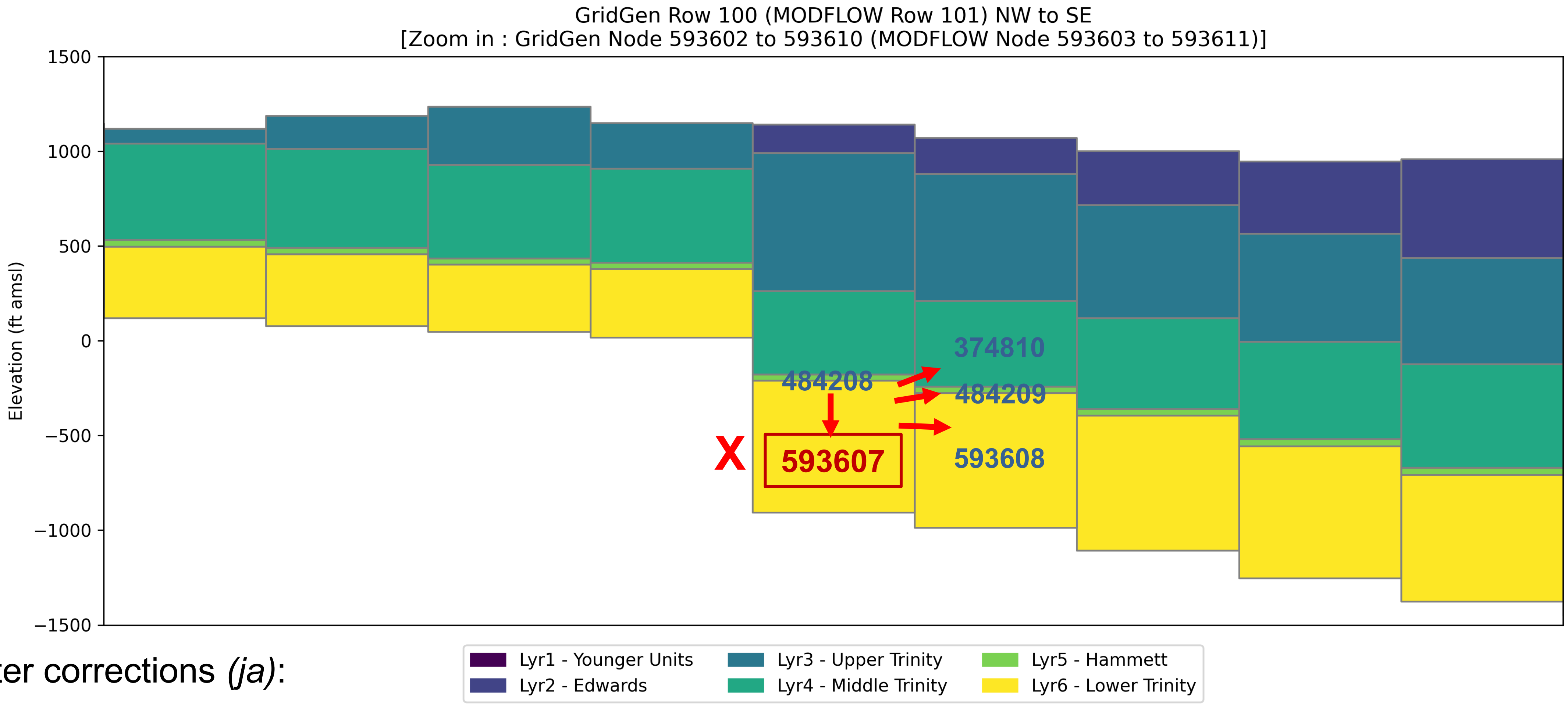


- Fully unstructured grid – less reliant on model “layers”
- Can specify flow connections for individual model cells



Before corrections *(ja)*:

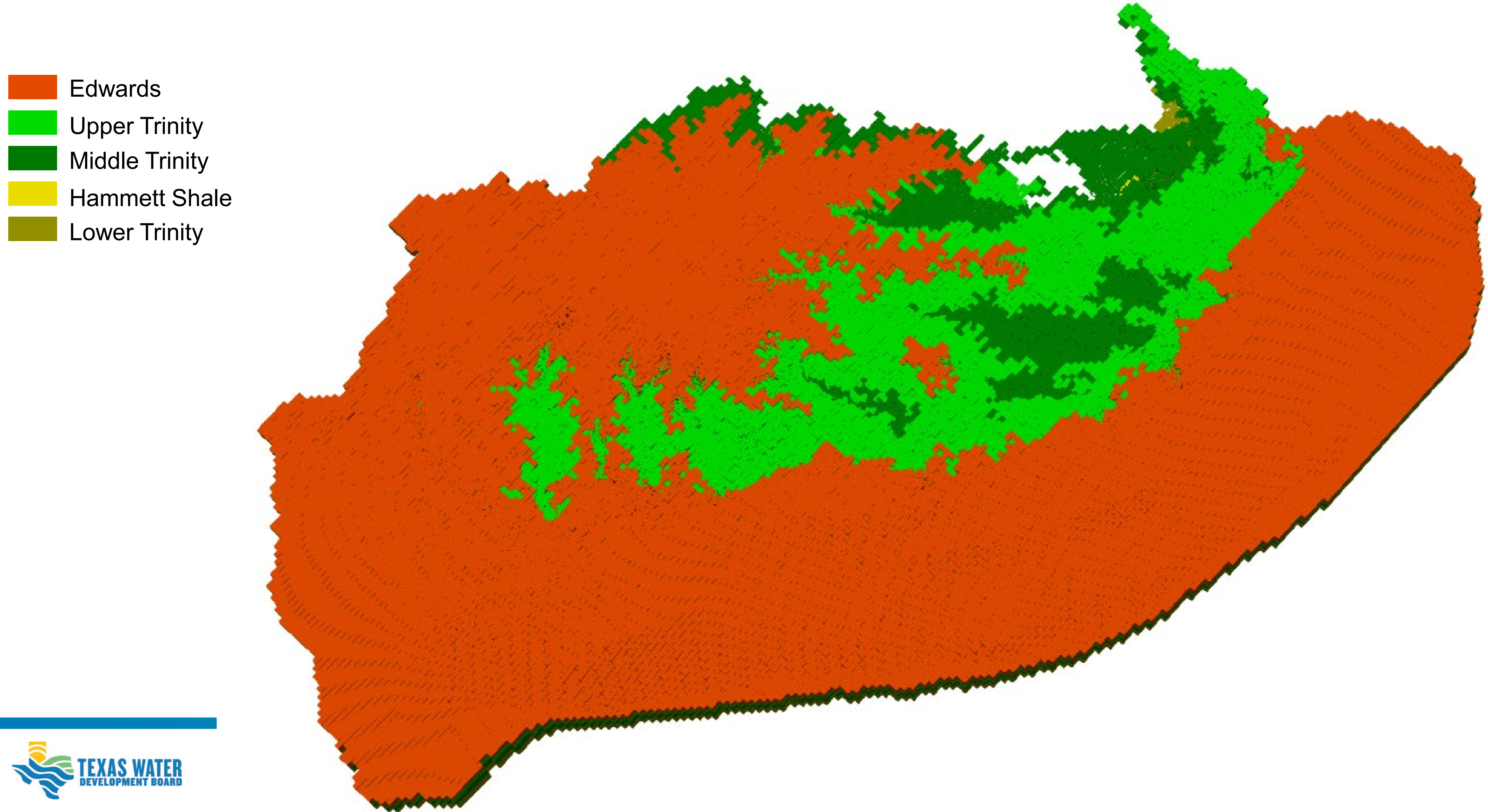
<u>**593607**</u> → **484208** 593223 **593606** **593608** 594050



After corrections *(ja)*:

593607 → **374810 484208 484209 593608** 594050

Model Structure



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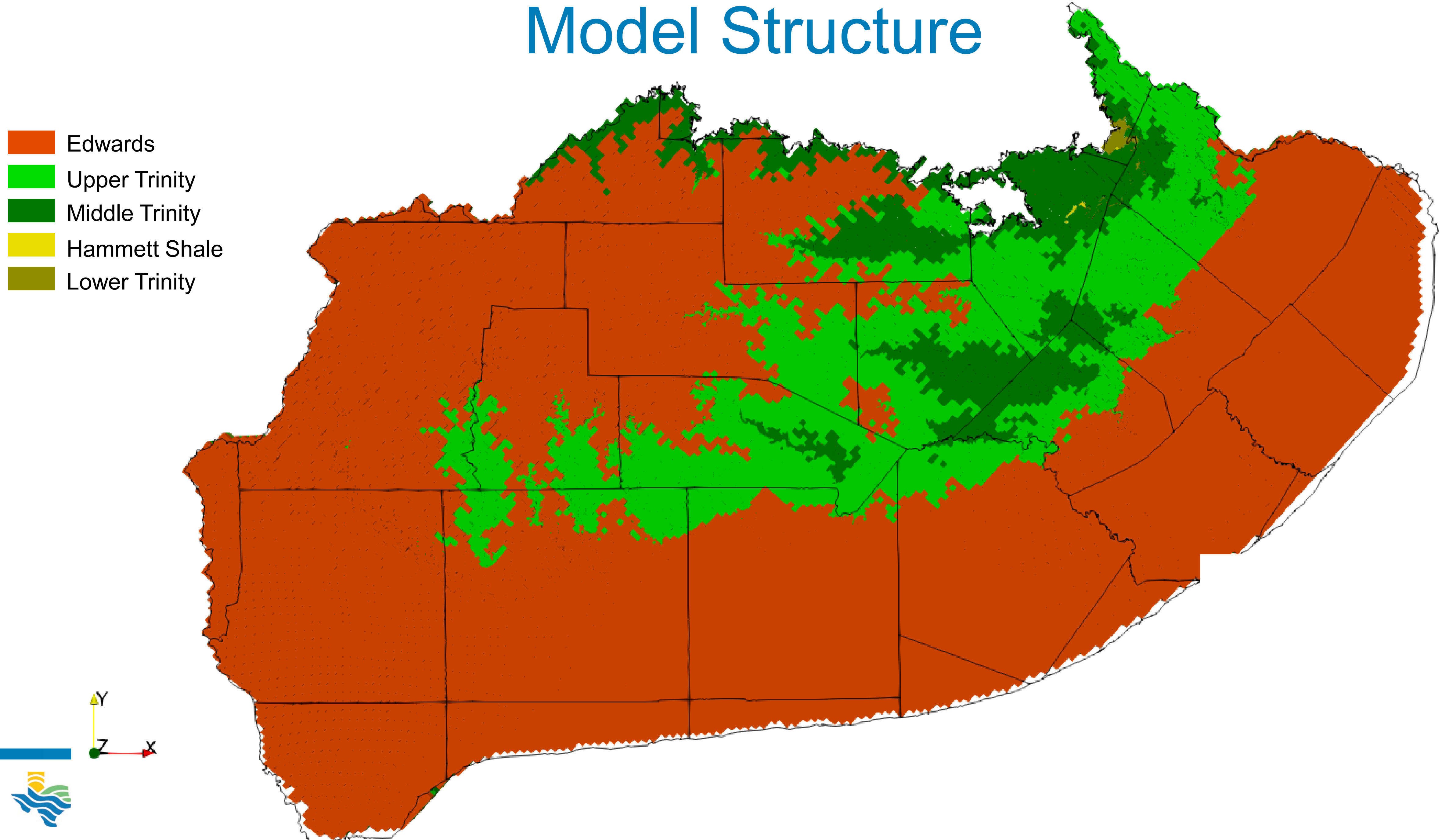
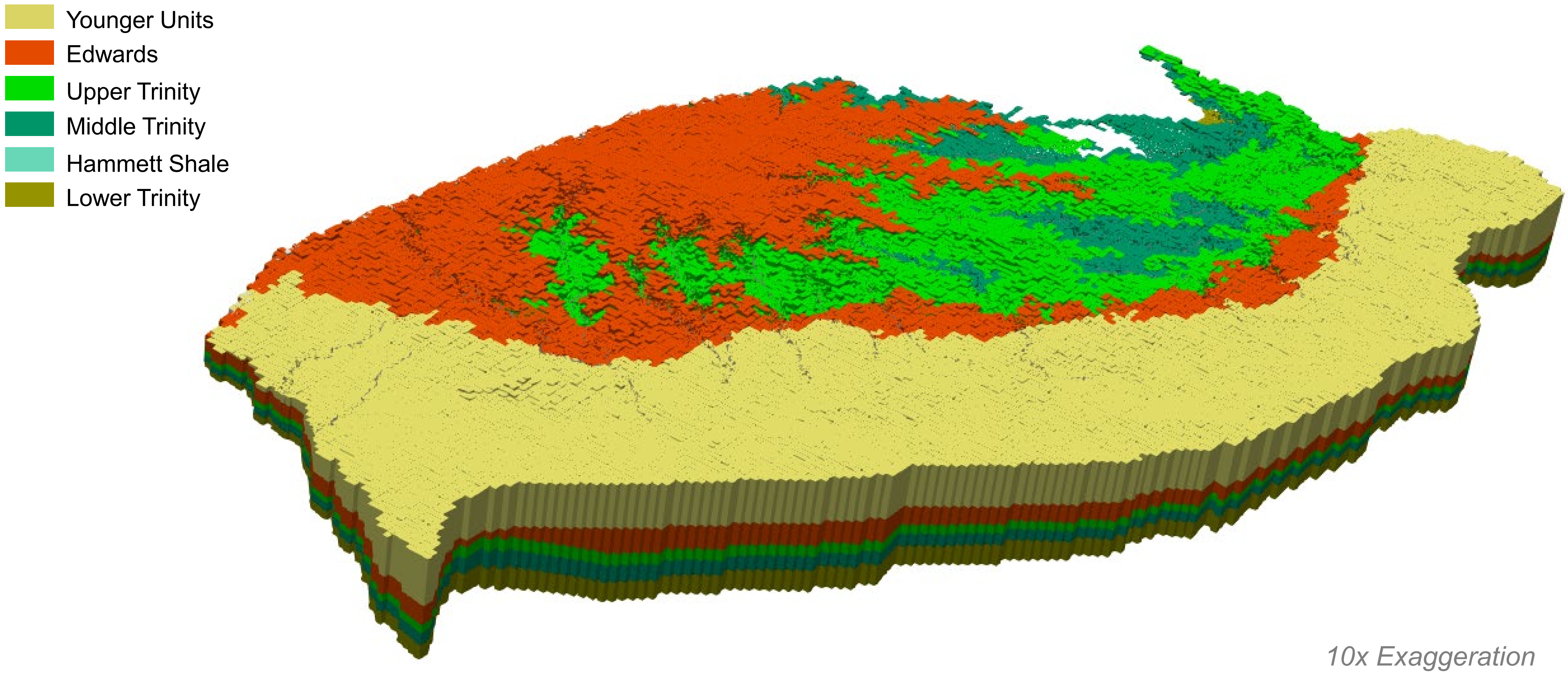
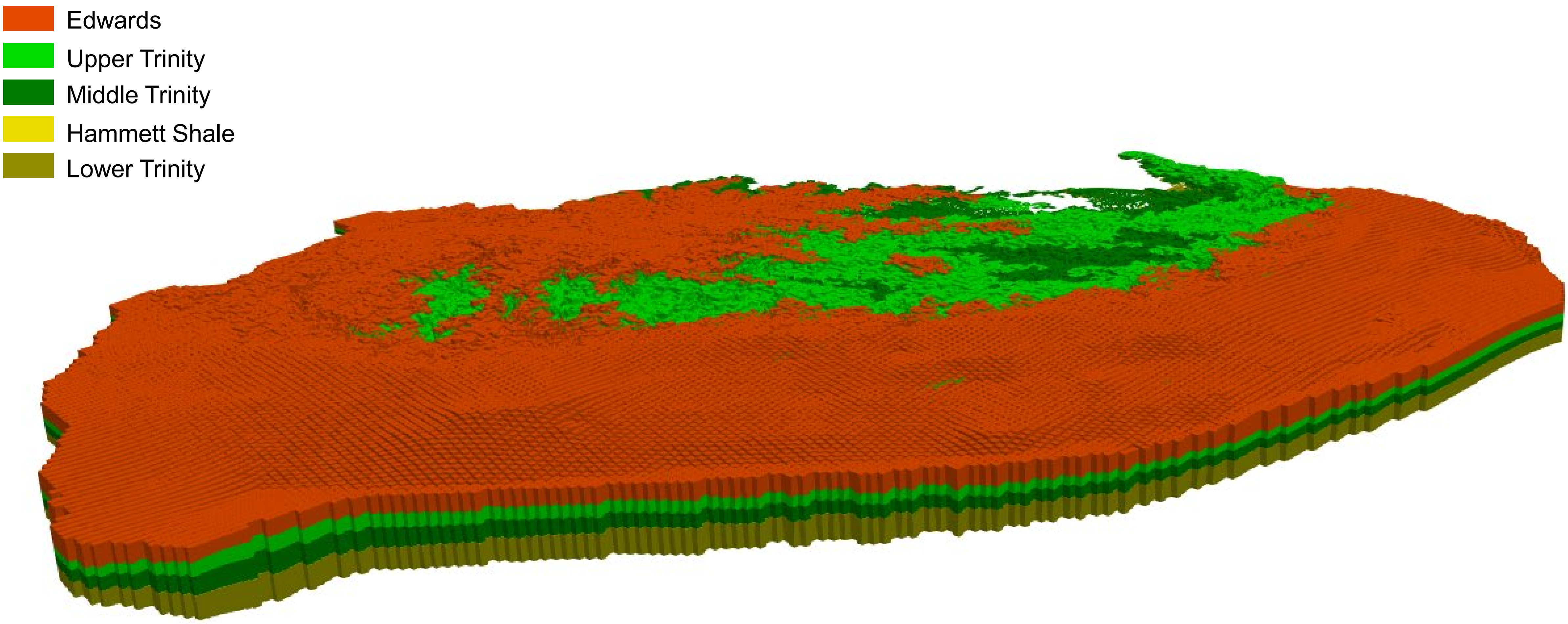
Model Structure



Model Structure

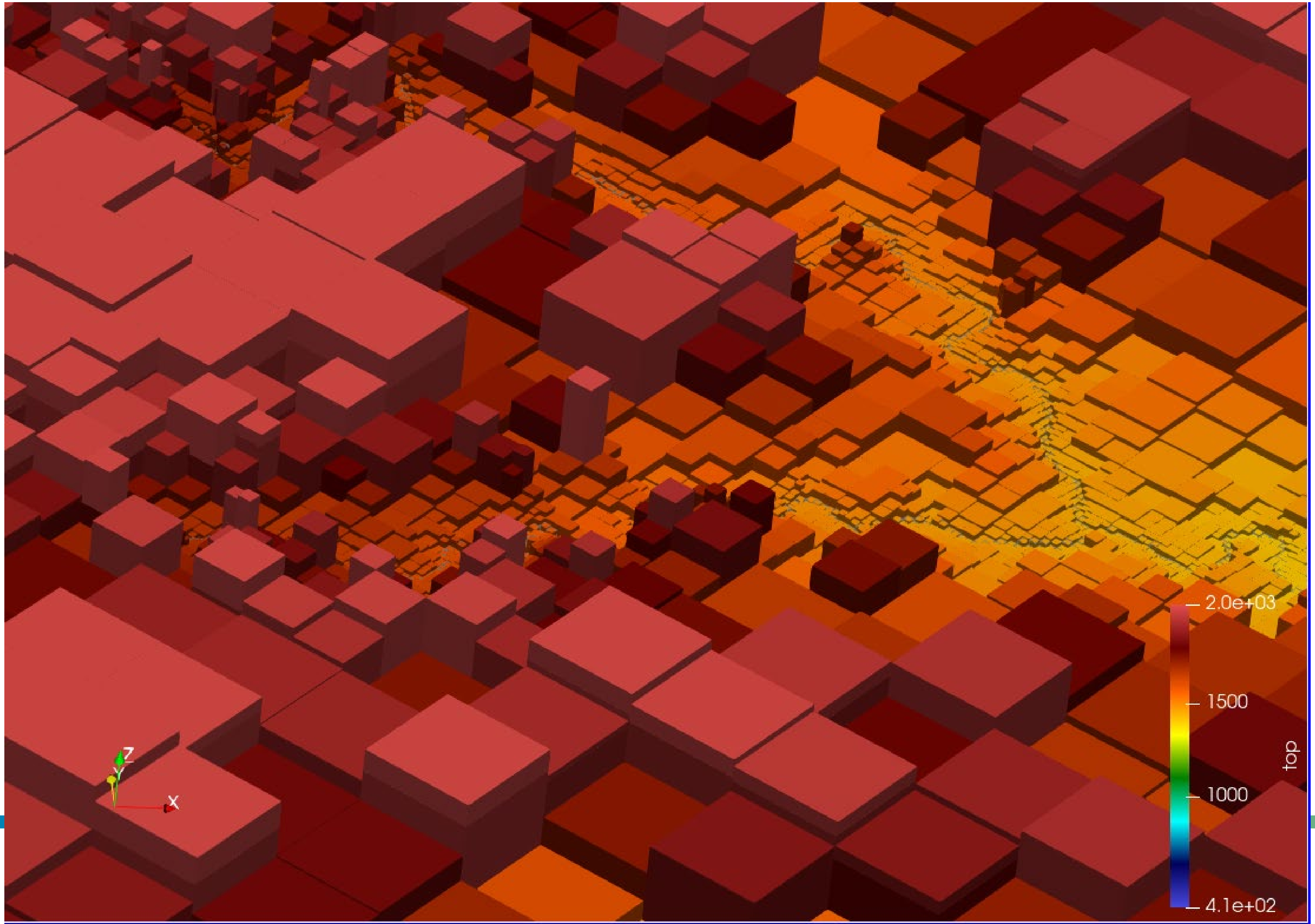


Model Structure

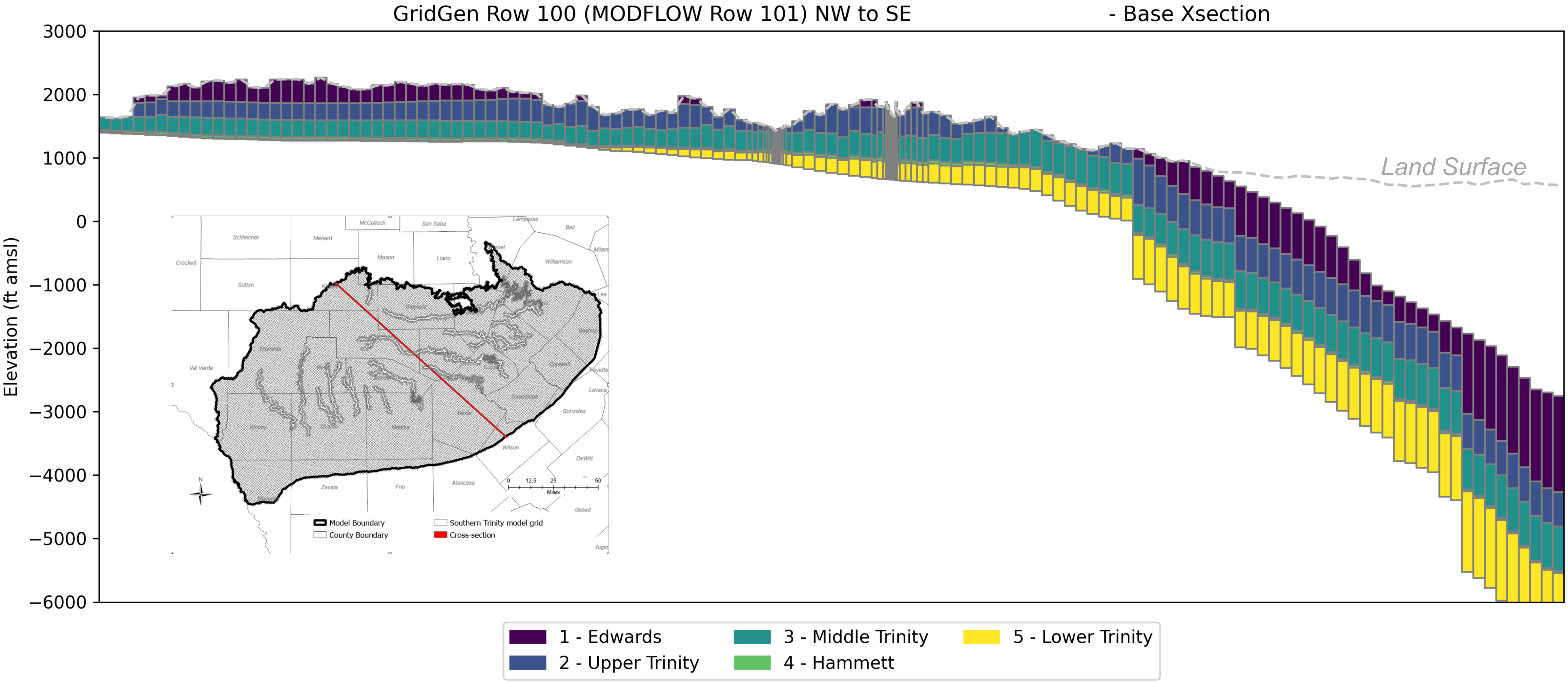


10x Exaggeration

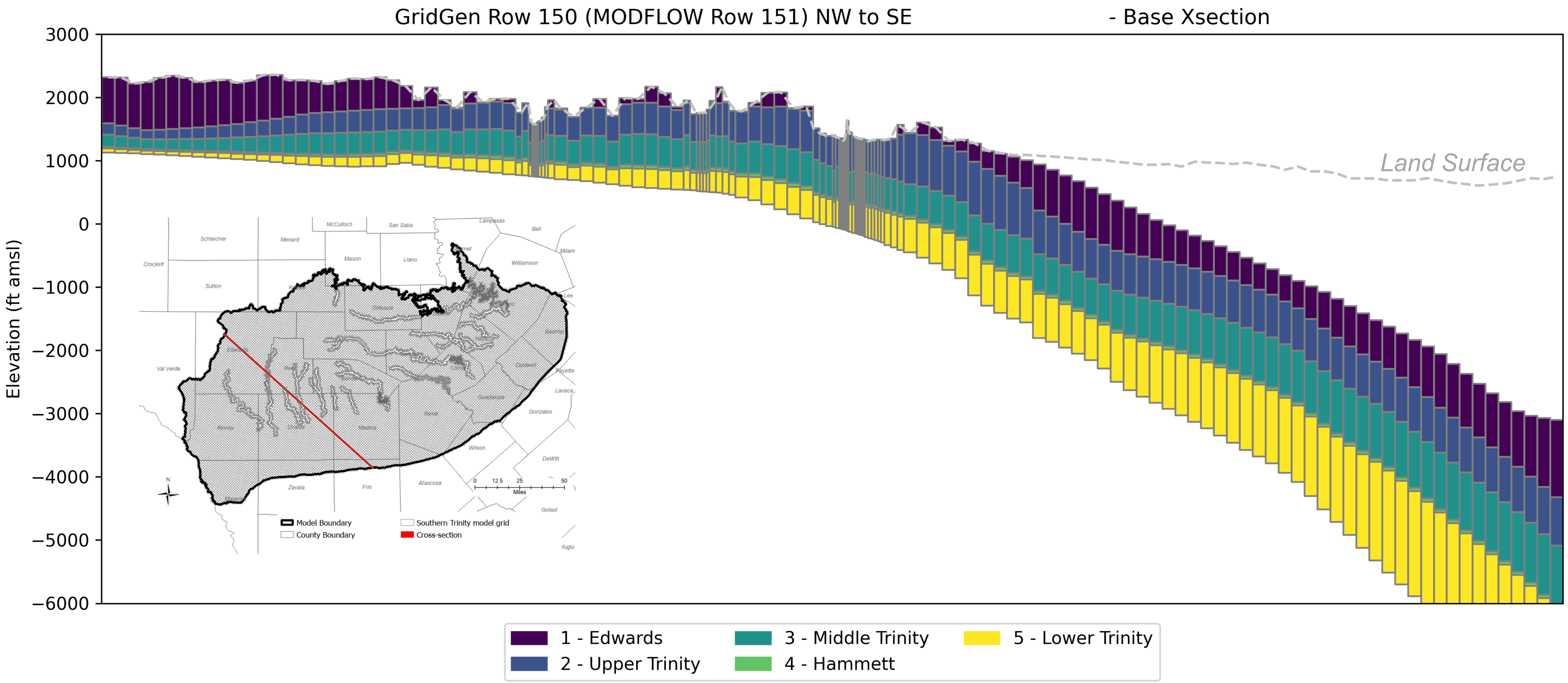
Model Structure



Model Structure



Model Structure



Model Packages: Properties (NPF)

Model Packages: NPF

- NPF package defines model properties:
  - Cell type (confined/unconfined)
  - Hydraulic conductivity
  - Storage properties

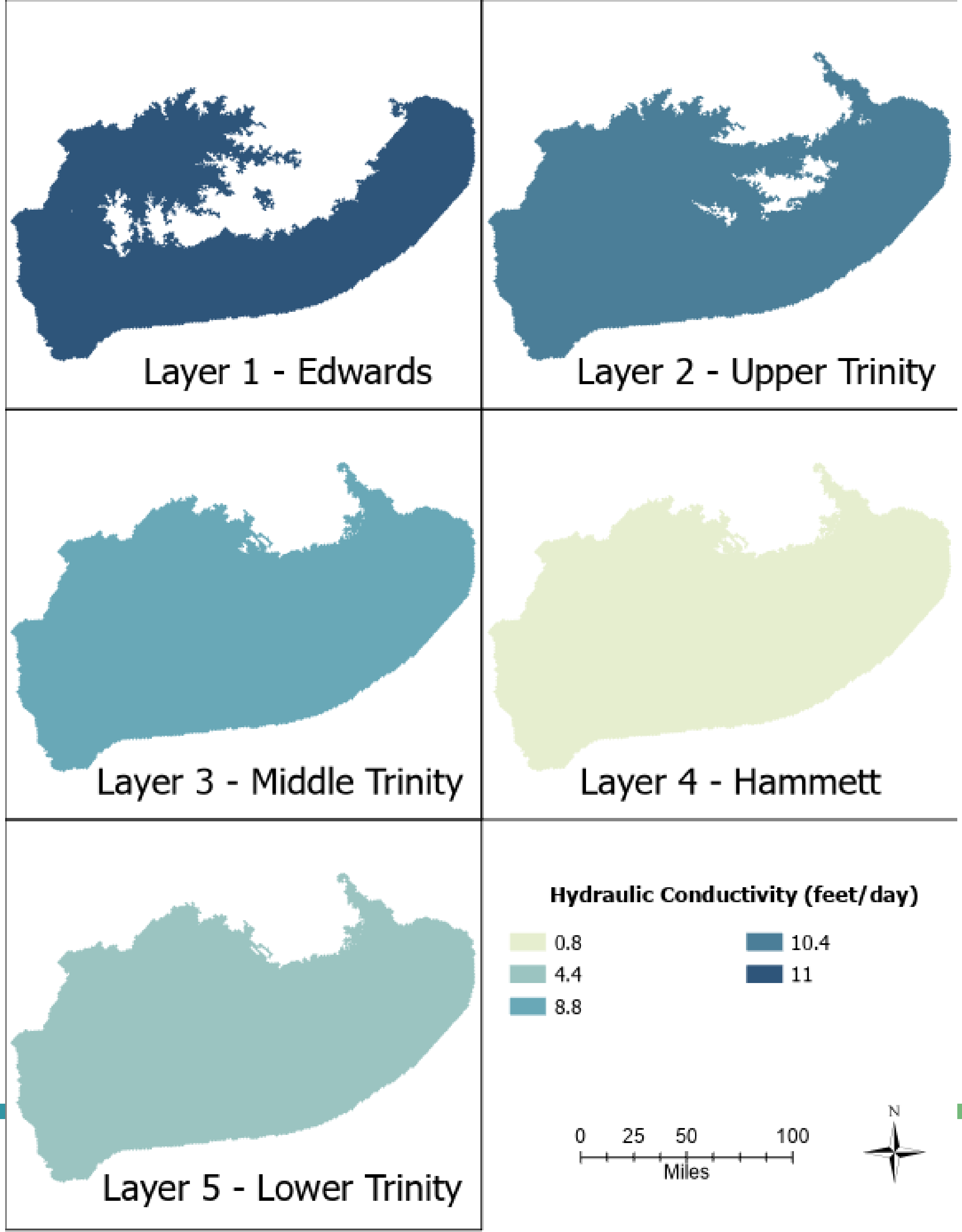
Model Packages: NPF

- Input Values by Variable:
  - Cell type: all cells convertible (confined/unconfined based on head)
  - Hydraulic conductivity:
    - Horizontal : uniform values by layer from previous GAM
    - Vertical : 1/10 of Horizontal
  - Storativity: not defined for SS model

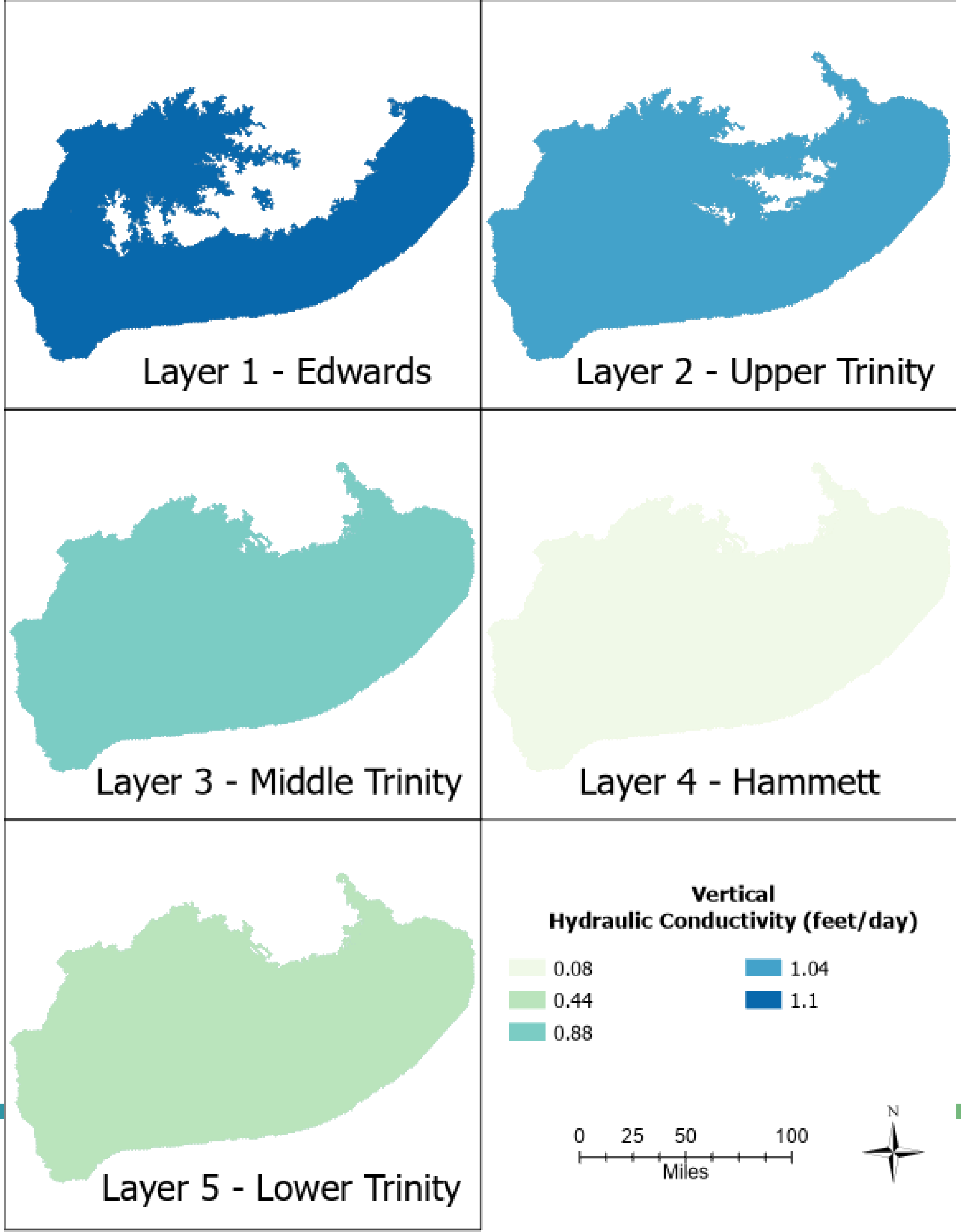
- To be updated during calibration:
  - Hydraulic conductivity (Multipliers based on Zones)

- Other potential considerations:
  - Might need localized K Zones to account for behavior around Faults

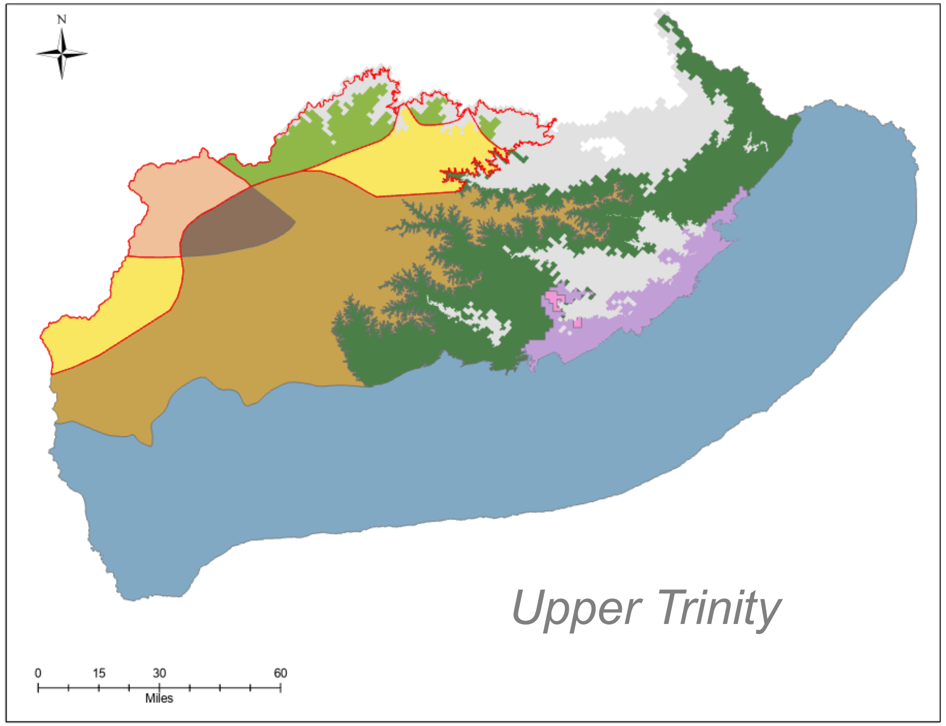
Horizontal Hydraulic Conductivity

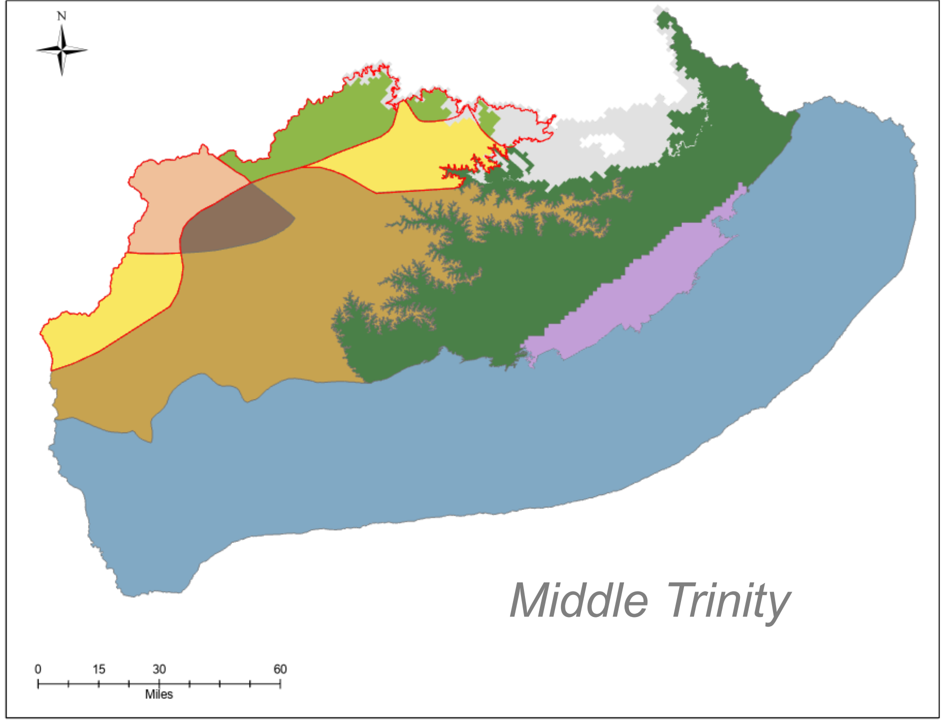


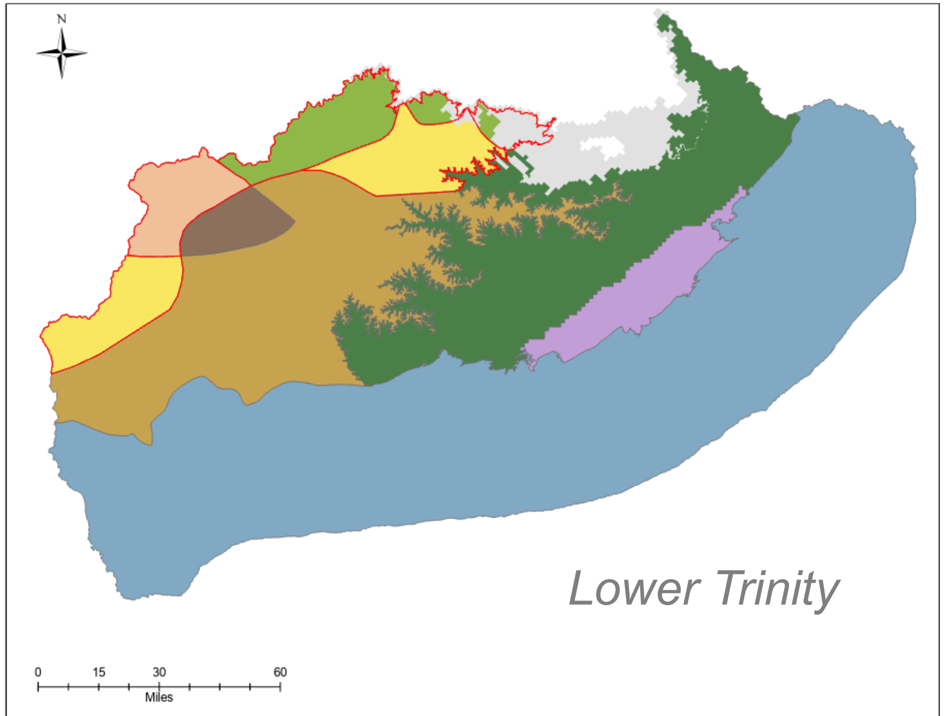
Vertical Hydraulic Conductivity



K Zones







Permeability Zone

- Balcones Fault Zone (downdip)
- Balcones Fault Zone (outcrop)
- Cibolo Creek
- Glen Rose
- Glen Rose w Hammett
- Hill Country outcrop
- Maxon Sand
- Maxon Sand w Hammett
- Trinity Sands
- Inactive
- No Hammett

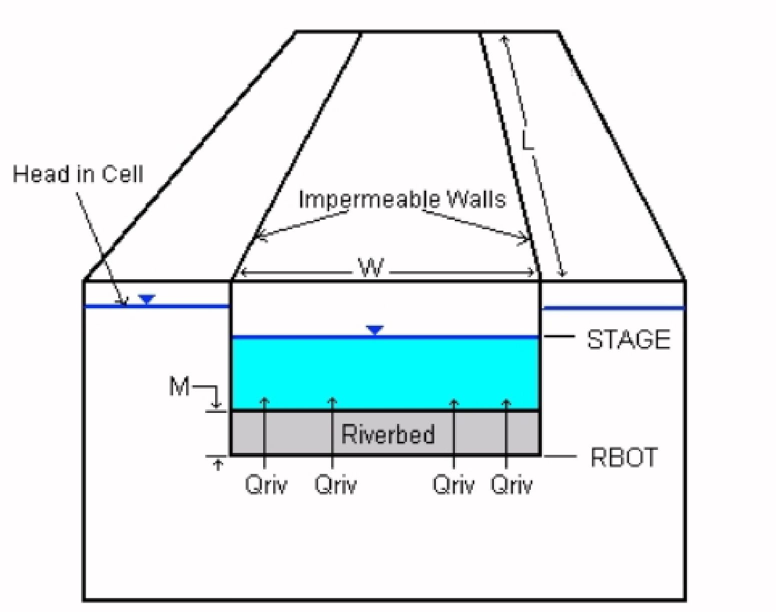
Model Packages: Rivers (RIV)

Model Packages: RIV

- RIV package represents:
  - Perennial streams/rivers
  - Major Lakes *(Lake Travis, Lake Austin, Canyon Lake, Medina Lake)*

- Water can **leave** or **enter** Aquifer

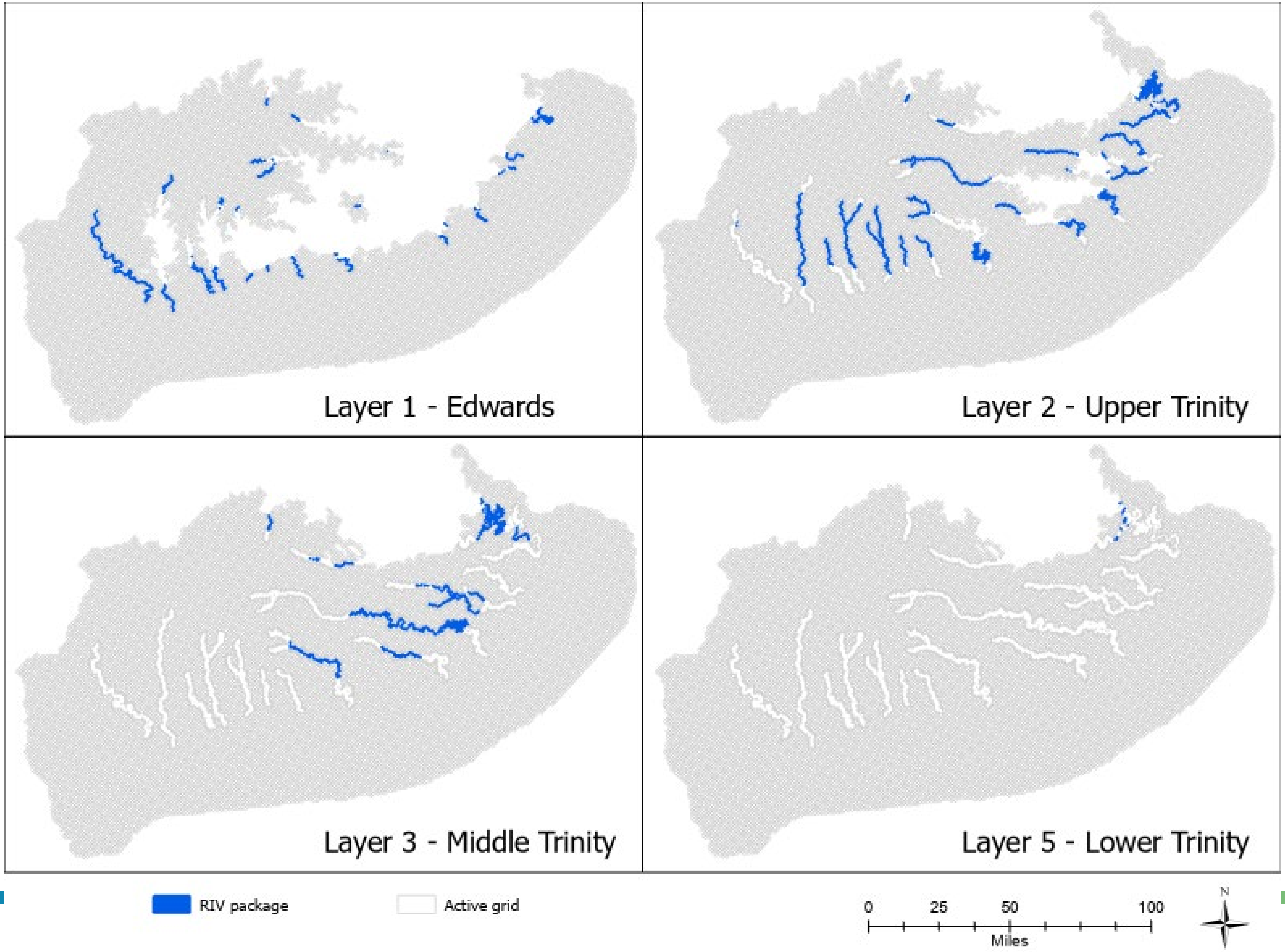
- Variables:
  - Stream stage (elevation)
  - Stream bottom (elevation)
  - Conductance



Schematic of River Boundary

https://www.waterloohydrogeologic.com/help/vmod/index.html?vm_ch4_input7.htm

Model Packages: RIV



TEXAS WATER DEVELOPMENT BOARD

Model Packages: RIV

- Input Values by Variable:
  - Stream stage (elevation) – land surface elevation
  - Stream bottom (elevation) – 0.5 feet below land surface elevation
  - Conductance – 100 feet/day

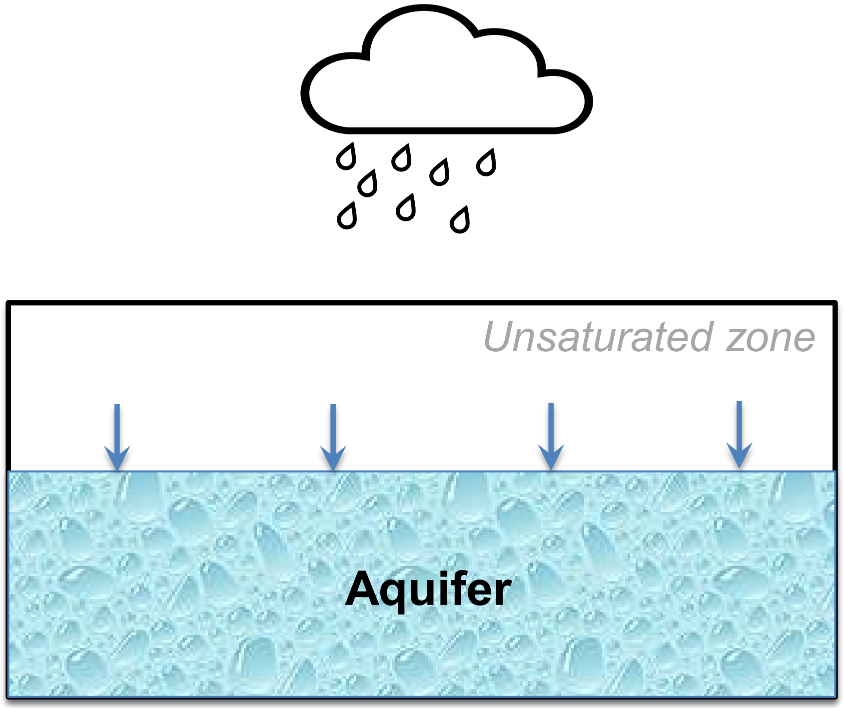
- To be updated during calibration:
  - Conductance

- Other potential considerations:
  - Would like to use USGS River stage values instead of land surface
  - If possible, would like to replace this with SFR package

Model Packages: Recharge (RCH)

Model Packages: RCH

- RCH package represents:
  - Precipitation that infiltrates to water table
- Water can only **enter** Aquifer
- Variables:
  - Recharge flux (usually % of Precipitation)



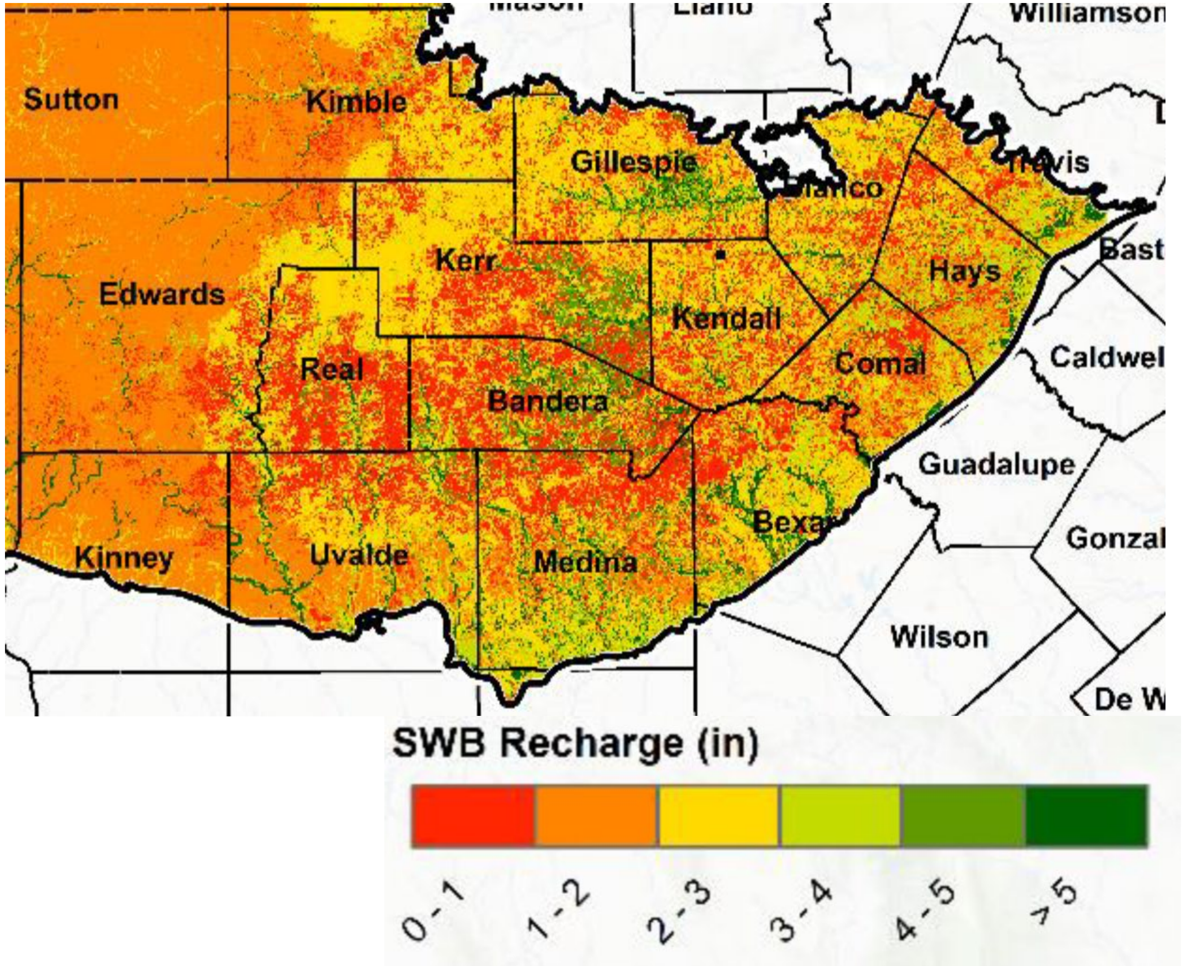
Model Packages: RCH

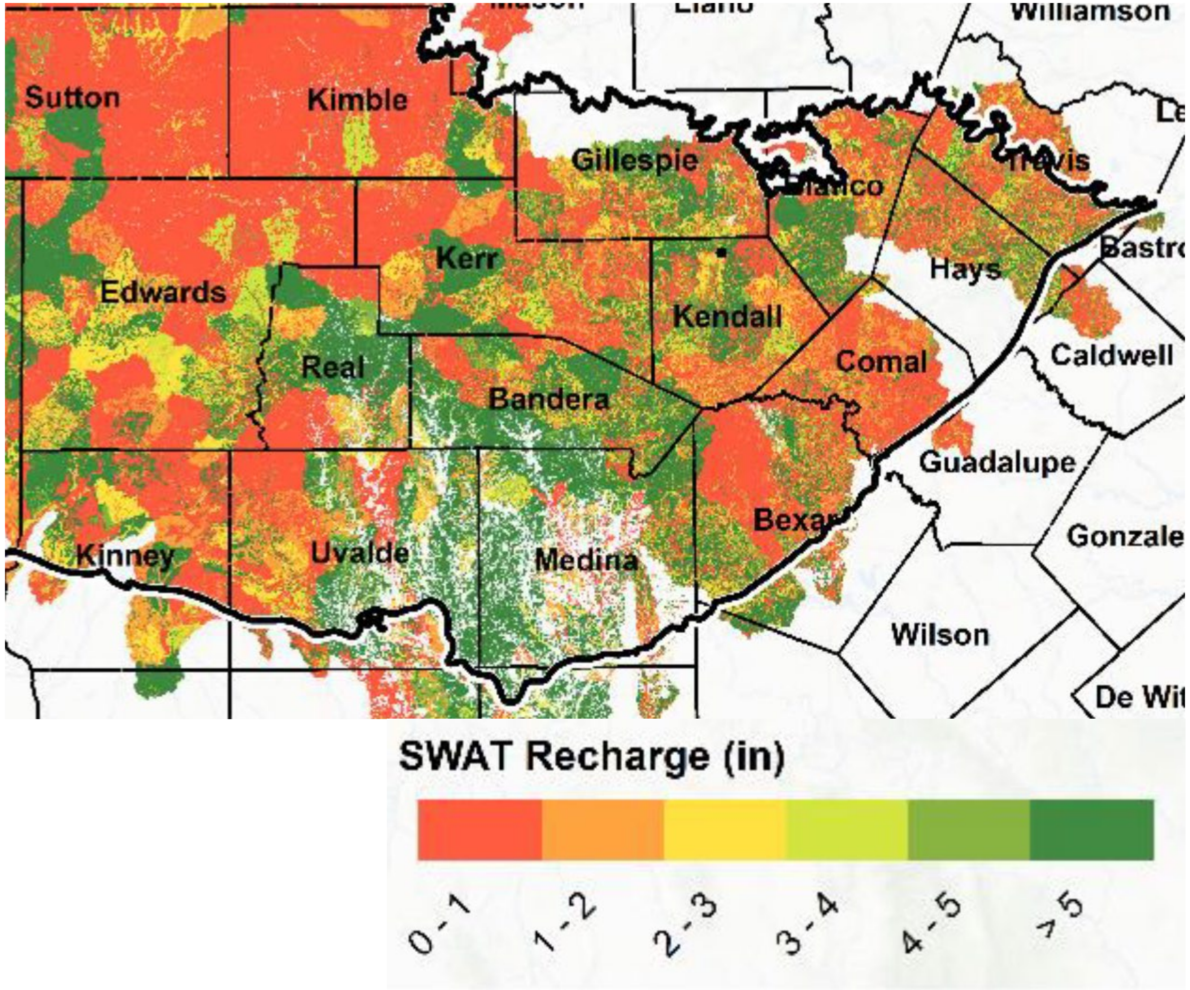
- Recharge flux from contracted WSP Recharge study
  - Annual recharge values based on PRISM precipitation data
  - Several methods/distributions created
  - Soil-water-balance (SWB) method shows most realistic spatial distribution

Expected Range
(based on Table 5-1 [Jones & others, 2011])

Literature source	Recharge rate (inches per year)
Muller and Price (1979)	0.5
Ashworth (1983)	1.3
Kuniansky (1989)	3.6
Bluntzer (1992, calculated)	2.2
Bluntzer (1992, estimated)	1.7
Kuniansky and Holligan (1994)	2.3
Mace and others (2000)	1.3
Mace (2001)	2.2
Wet Rock Groundwater Services (2008)	3.1
Anaya and Jones (2009)	1.4

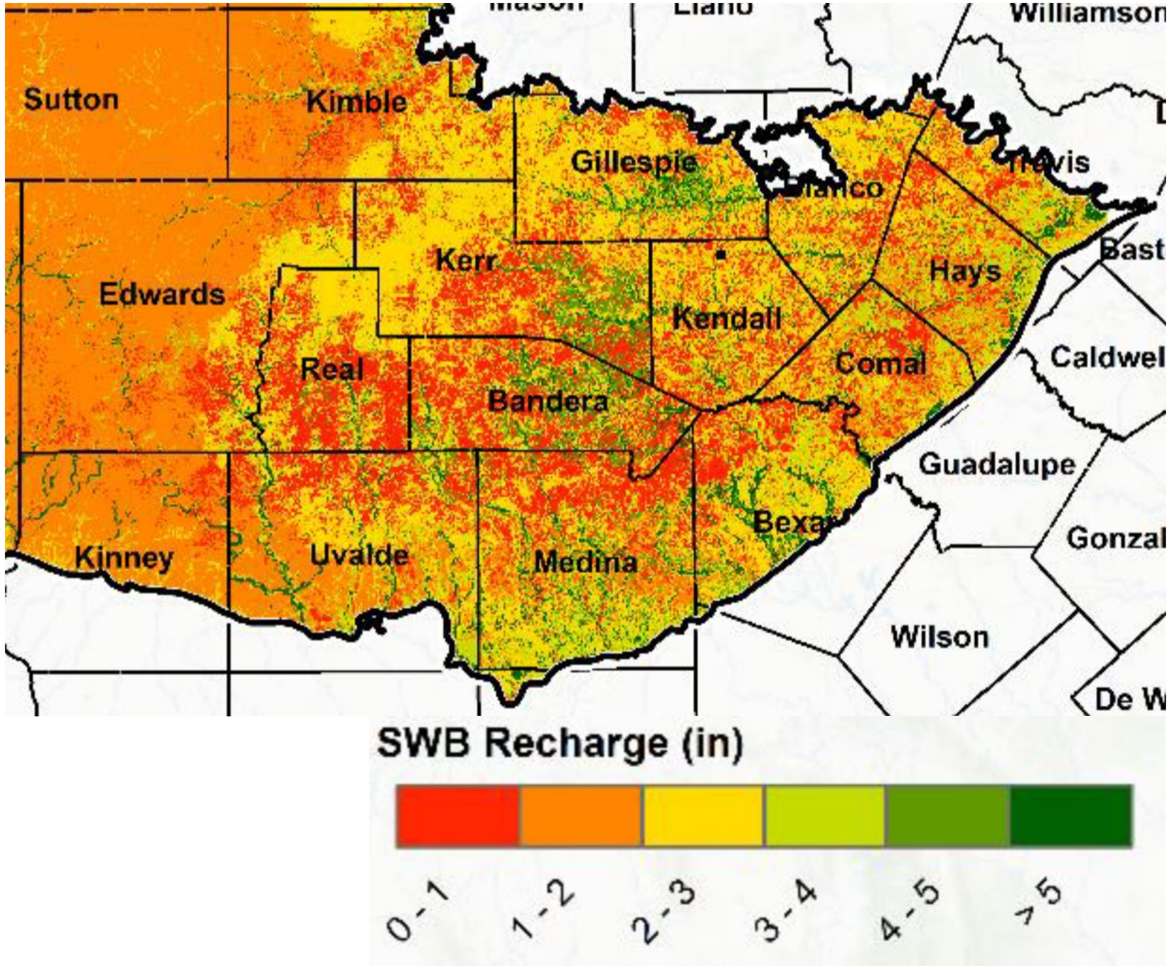
Recharge Distribution

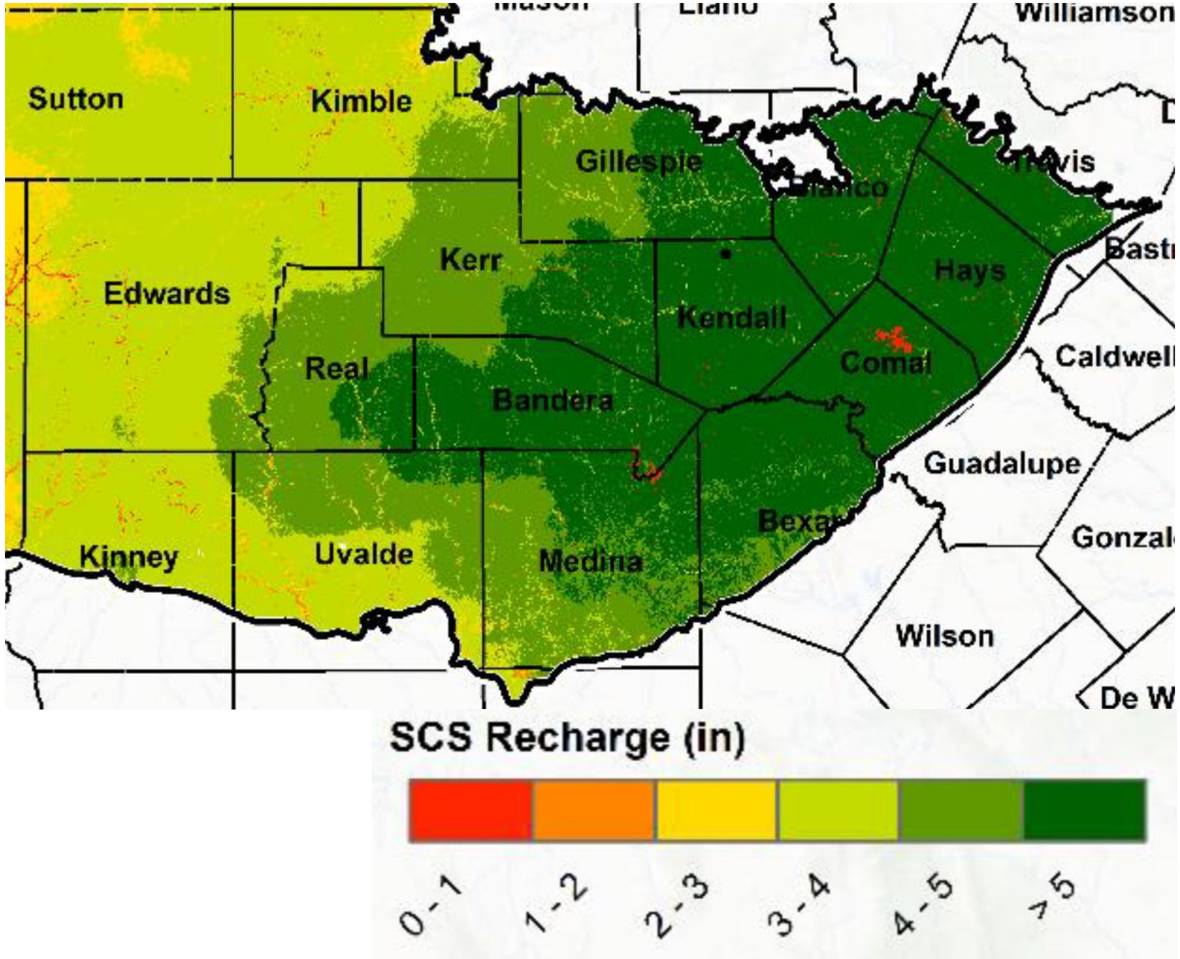




modified from:
Estimates of Recharge and Surface Water – Groundwater Interactions for Aquifers in Central and West Texas (TWDB Contract #2048302455)

Recharge Distribution

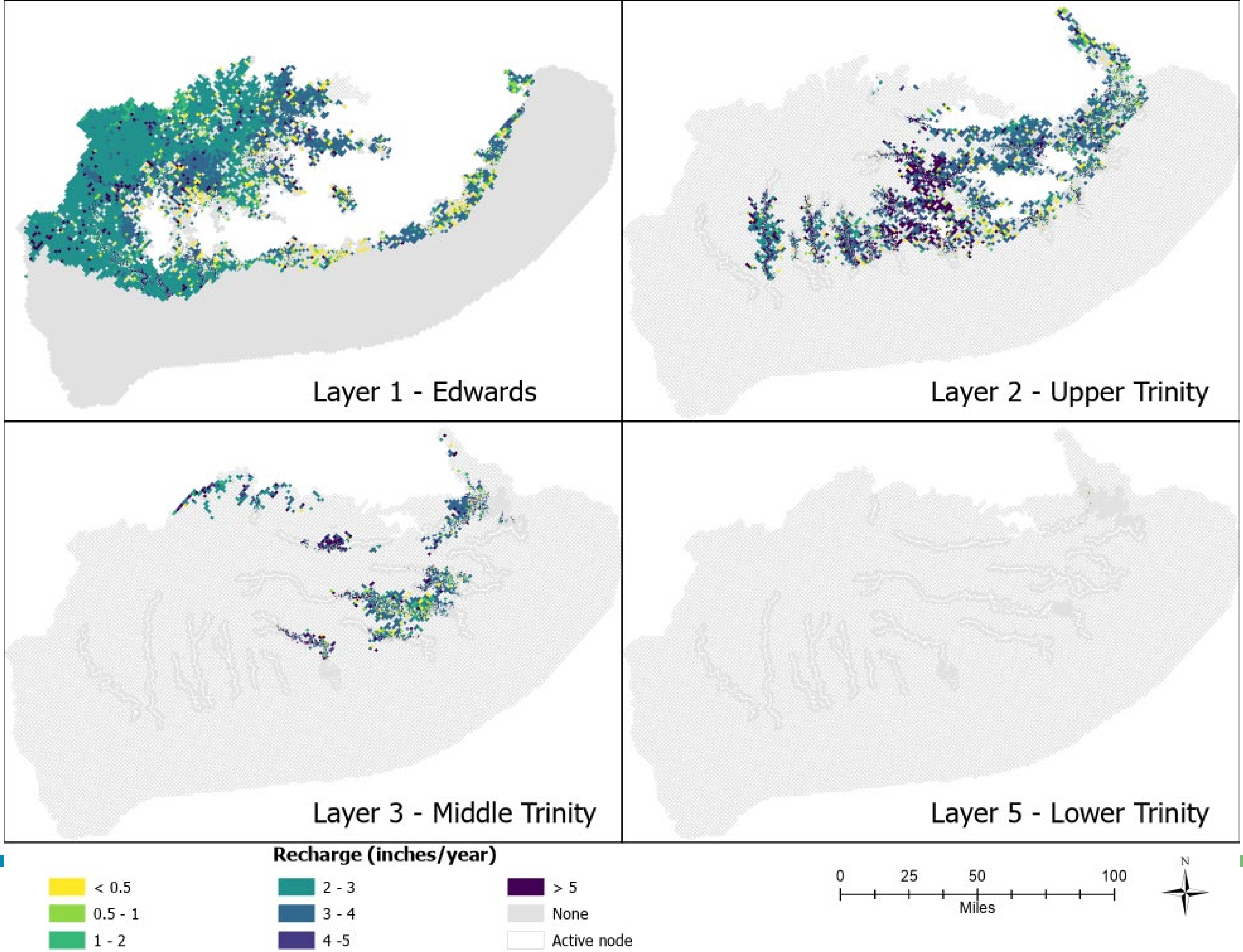




modified from:
Estimates of Recharge and Surface Water – Groundwater Interactions for Aquifers in Central and West Texas (TWDB Contract #2048302455)

Model Packages: RCH

1981 Recharge



TEXAS WATER DEVELOPMENT BOARD

Model Packages: RCH

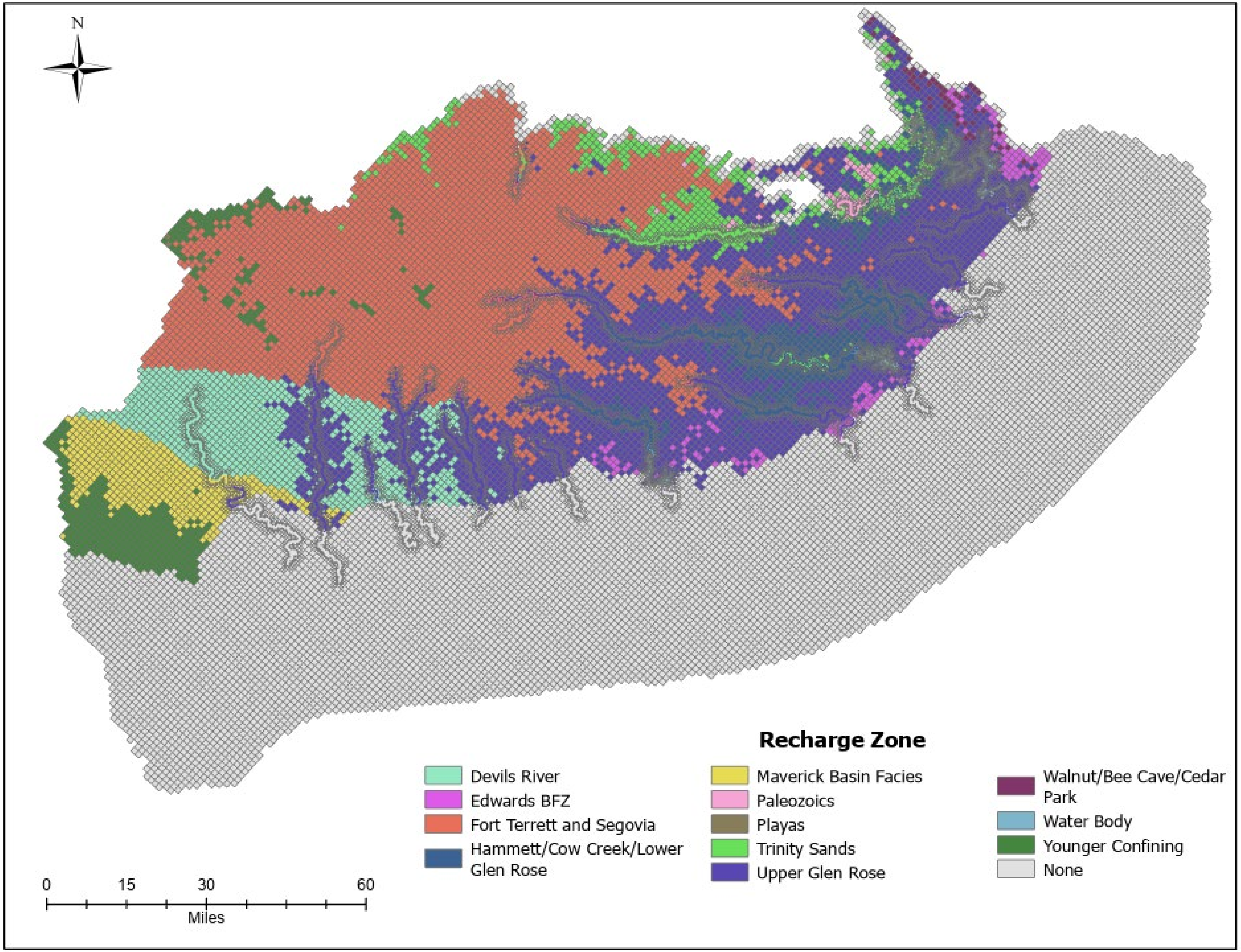
- Input Values by Variable:
  - Recharge flux : SWB Recharge values

    Note: did not apply Recharge to RIV cells (avoid double-counting)

- To be updated during calibration:
  - Flux Multipliers based on Surface Geology Zones

- Other potential considerations:
  - Will likely need to limit Maximum Recharge based on percent of Precipitation

Recharge Zones



TEXAS WATER DEVELOPMENT BOARD

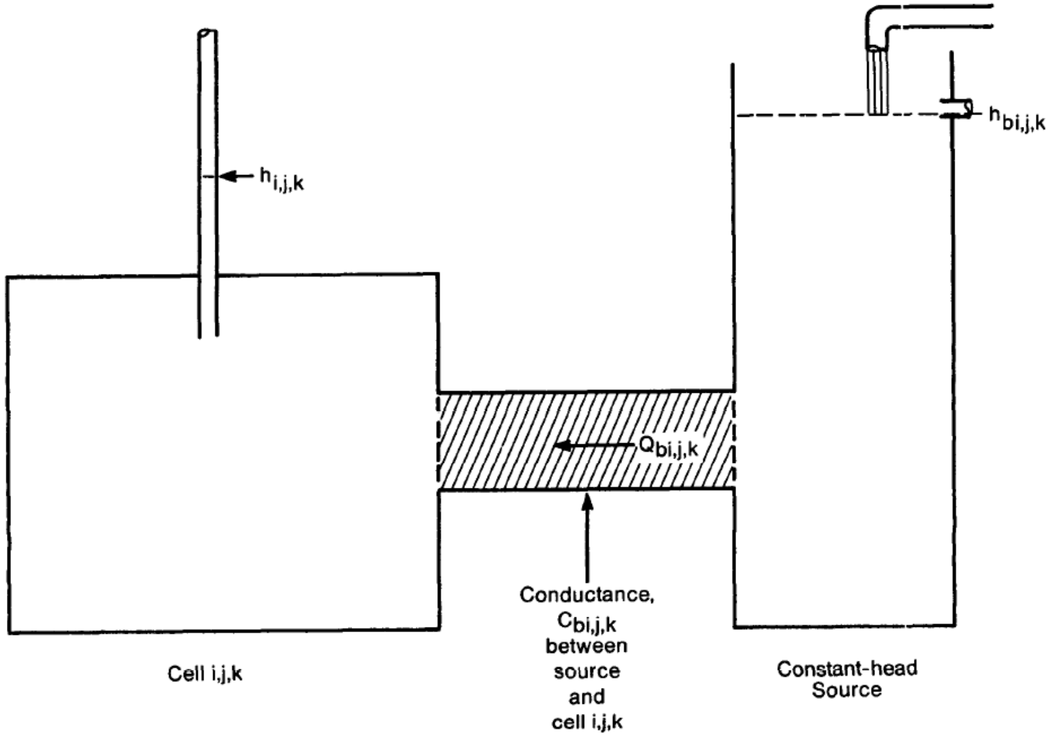
Model Packages: Boundary Flow (GHB)

Model Packages: GHB

- GHB package represents:
  - Western Boundary (lateral flow between models in Edwards-Trinity [Plateau] Aquifer
  - Southeastern Boundary (vertical flow between Edwards [BFZ] Aquifer & younger units)

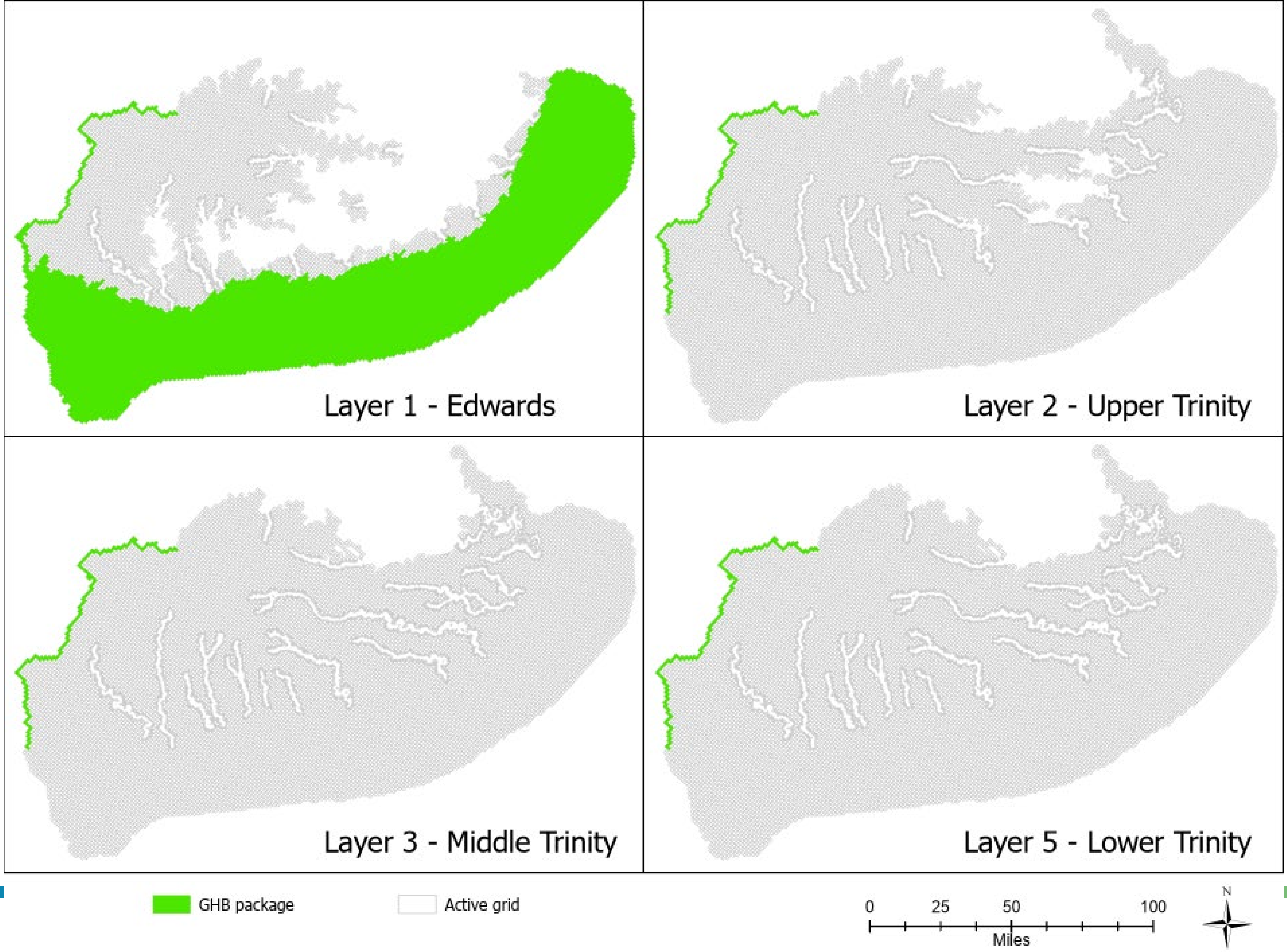
- Water can **leave** or **enter** Aquifer

- Variables:
  - Boundary Head (elevation)
  - Conductance



(McDonald and Harbaugh, 1988)

Model Packages: GHB



Model Packages: GHB

- Initial Values by Variable:
  - Boundary Head (Western Boundary) – from Edwards-Trinity [Plateau] GAM
  - Boundary Head (Southeastern Boundary) – DEM or EAA (2004) model
  - Conductance – 15 feet/day

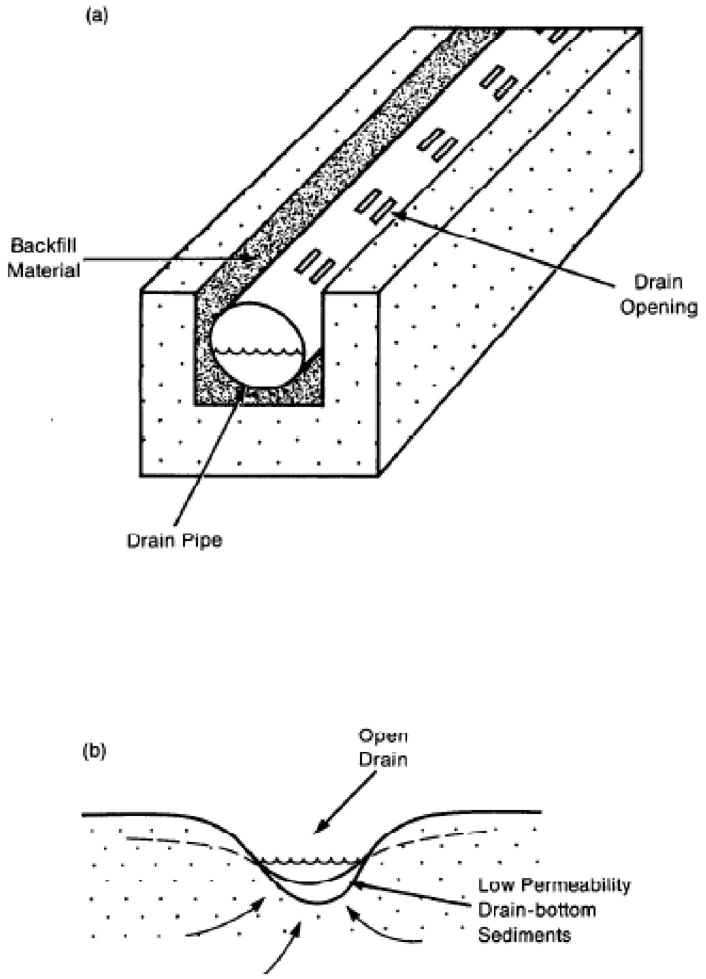
- To be updated during calibration
  - Conductance

- Other potential considerations
  - EAA (2004) heads are not consistent with current model structure
  - May need to introduce calibration parameter that varies % saturated thickness above Edwards top

Model Packages: Drains (DRN)

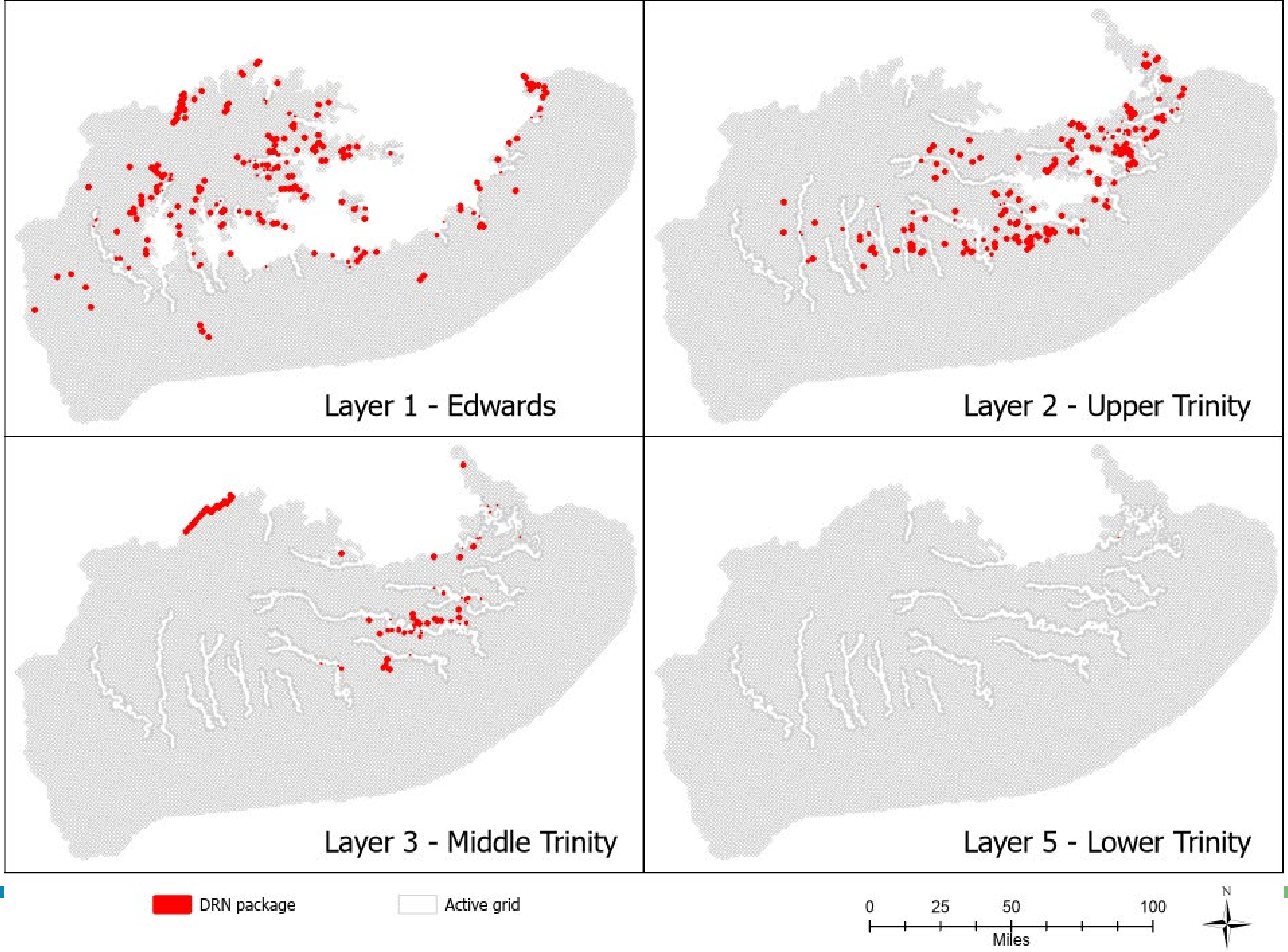
Model Packages: DRN

- DRN package represents:
  - Springs
  - Llano River
- Water can only **leave** Aquifer
- Variables:
  - Head (elevation)
  - Conductance



(McDonald and Harbaugh, 1988)

Model Packages: DRN



Model Packages: DRN

- Initial Values by Variable:
  - Head (elevation) – land surface elevation at spring/drain location
  - Conductance – calibrated value from EAA (2015) or 5 feet/day

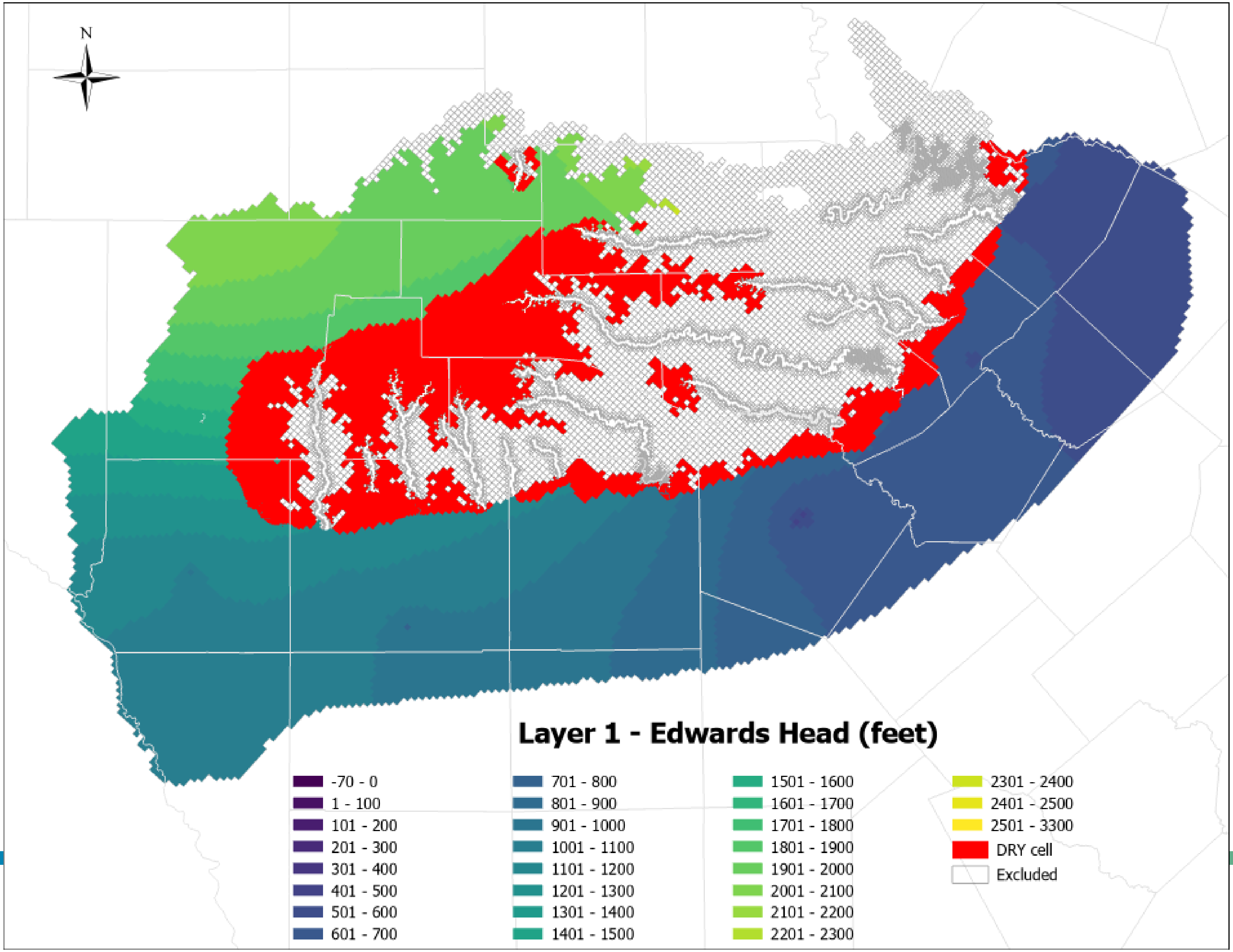
- To be updated during calibration
  - Conductance for each major spring
  - Conductance for spring category (very small, small, medium)

- Other potential considerations
  - Calibrated EAA (2015) conductances may not be consistent with current model structure

(McDonald and Harbaugh, 1988)

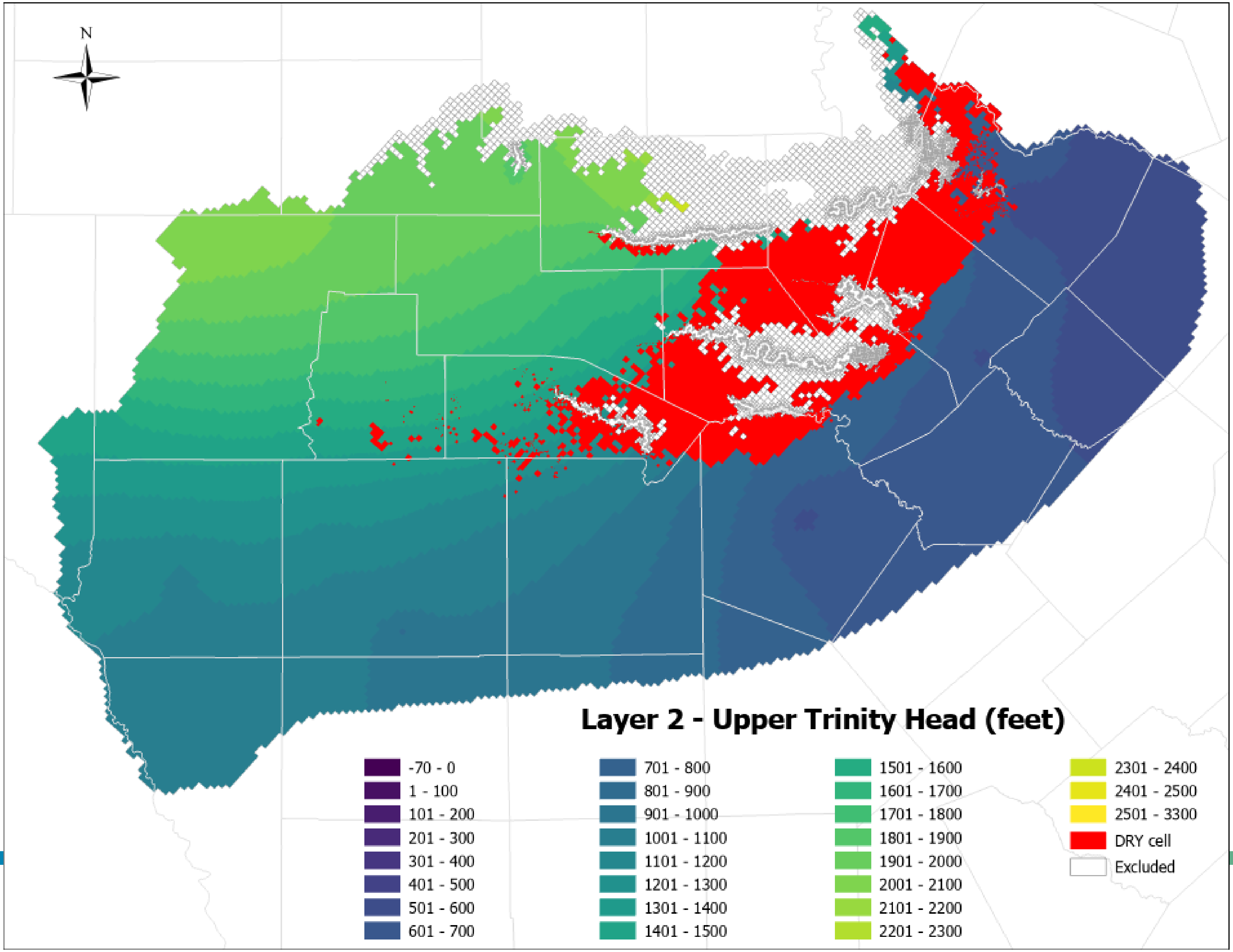
Model Results: Steady-State

Model Results

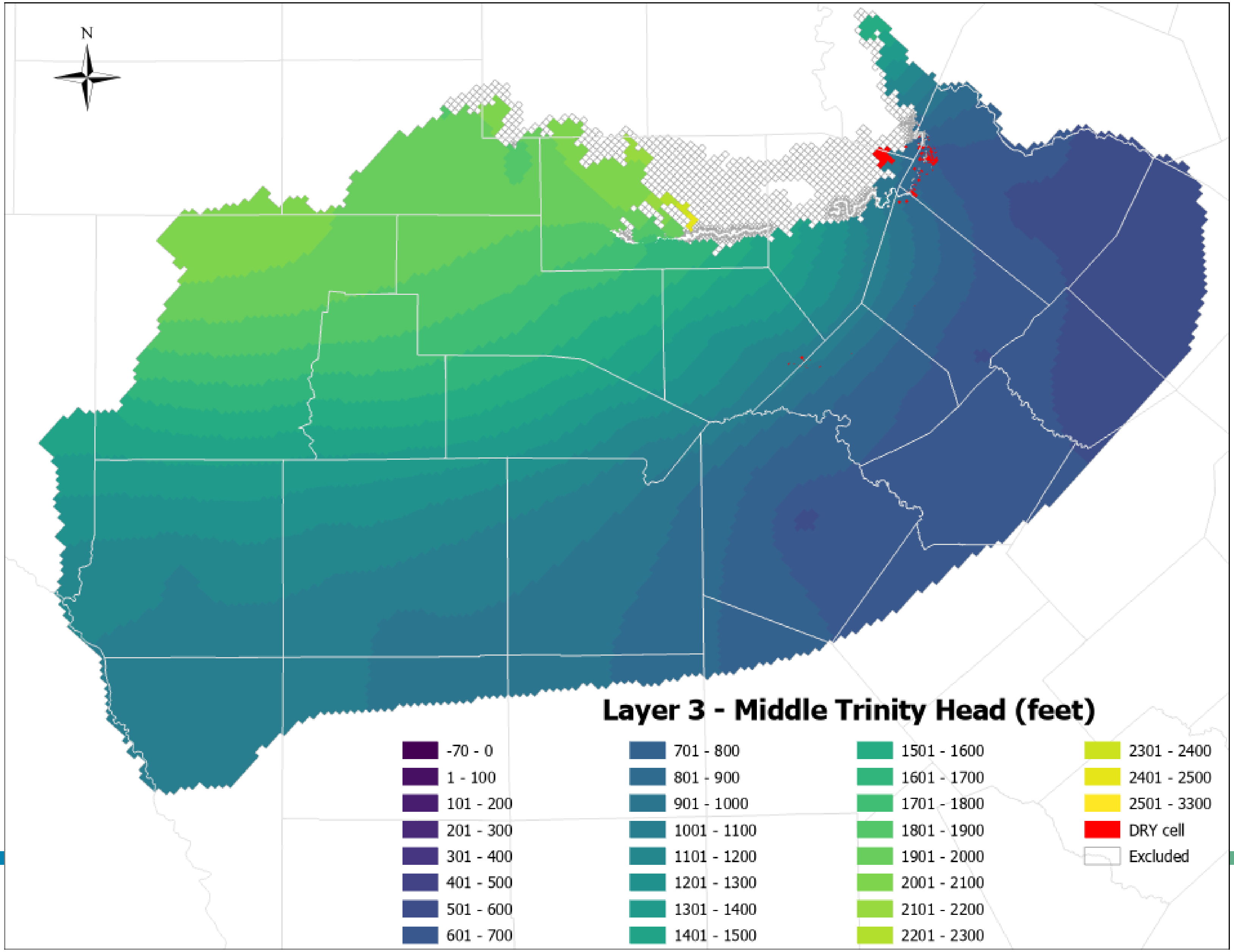


TEXAS WATER DEVELOPMENT BOARD

Model Results

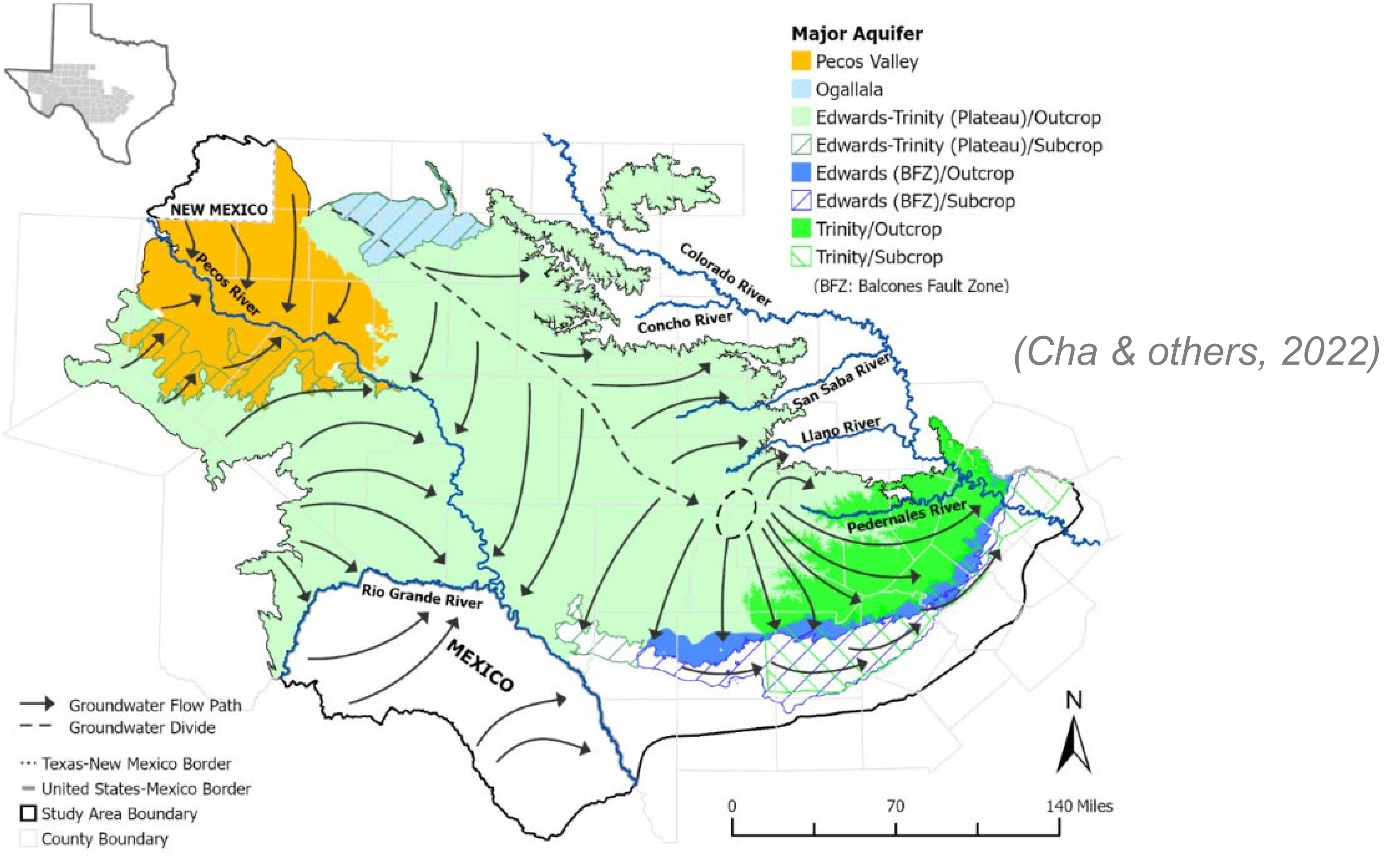


Model Results



TEXAS WATER DEVELOPMENT BOARD

Model Results

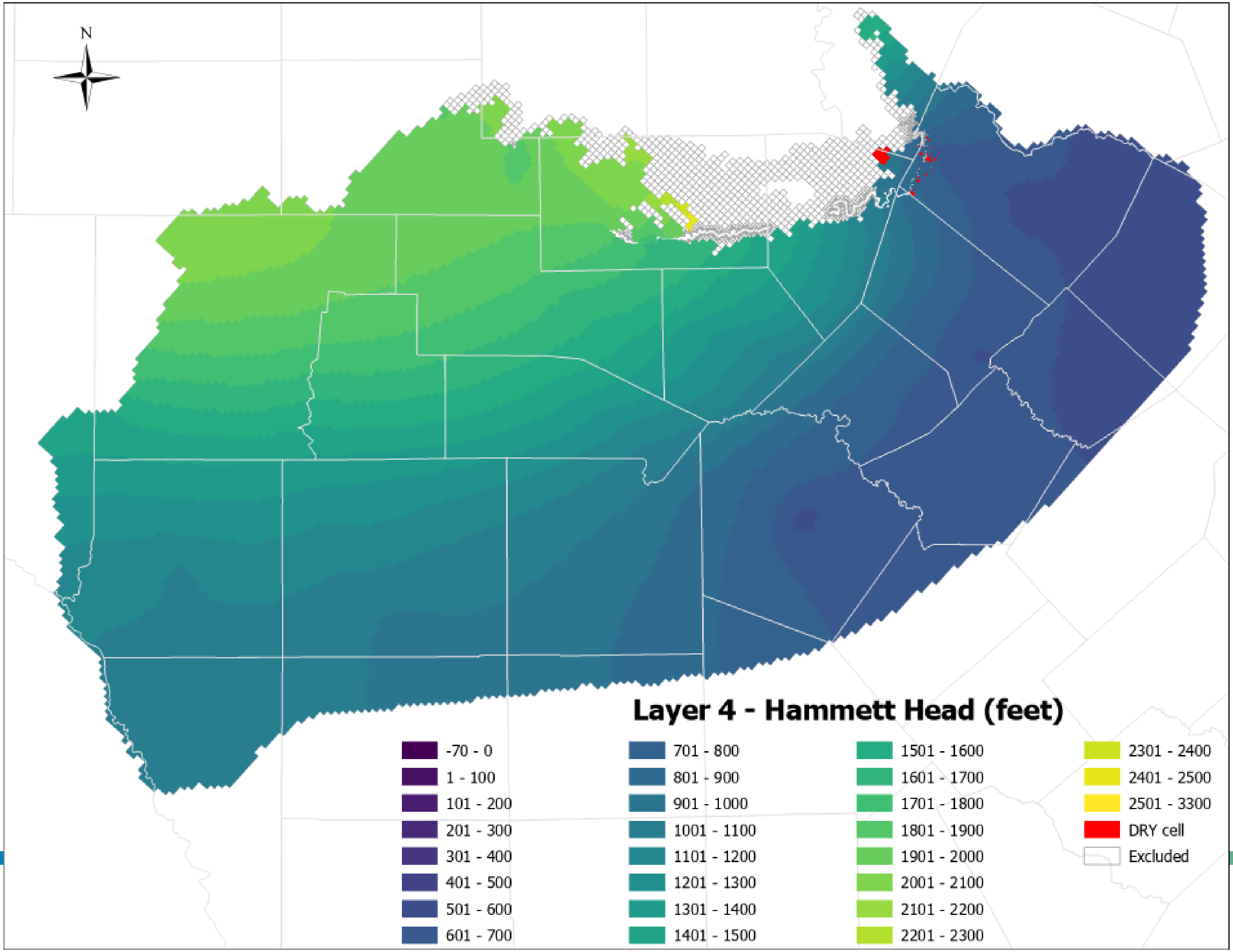


(Cha & others, 2022)

Figure 4.3-17. Generalized regional groundwater flow path for the Pecos Valley and Edwards-Trinity (Plateau) Region (modified from Anaya and Jones, 2009; Edwards Aquifer Authority, 2021).

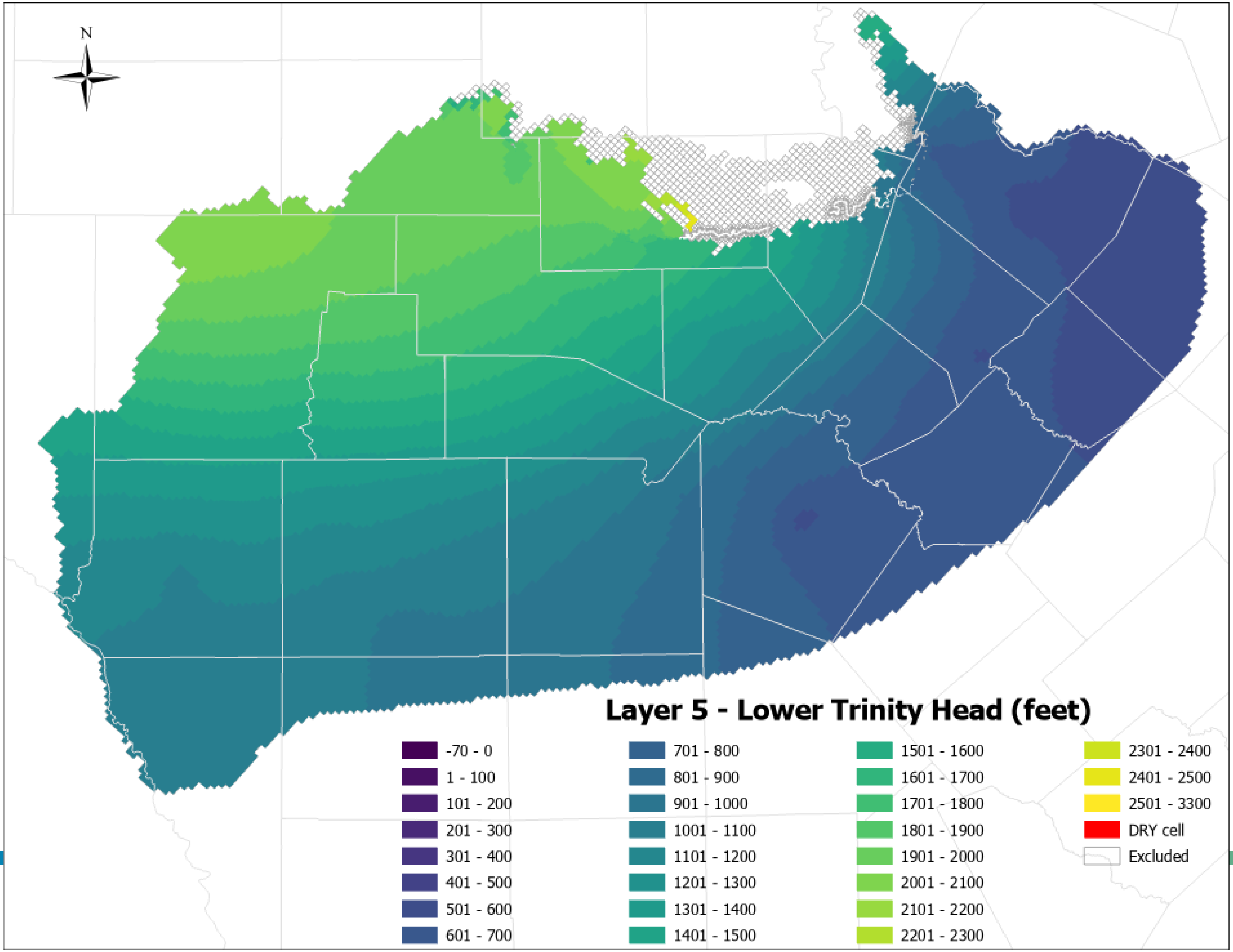
TEXAS WATER DEVELOPMENT BOARD

Model Results



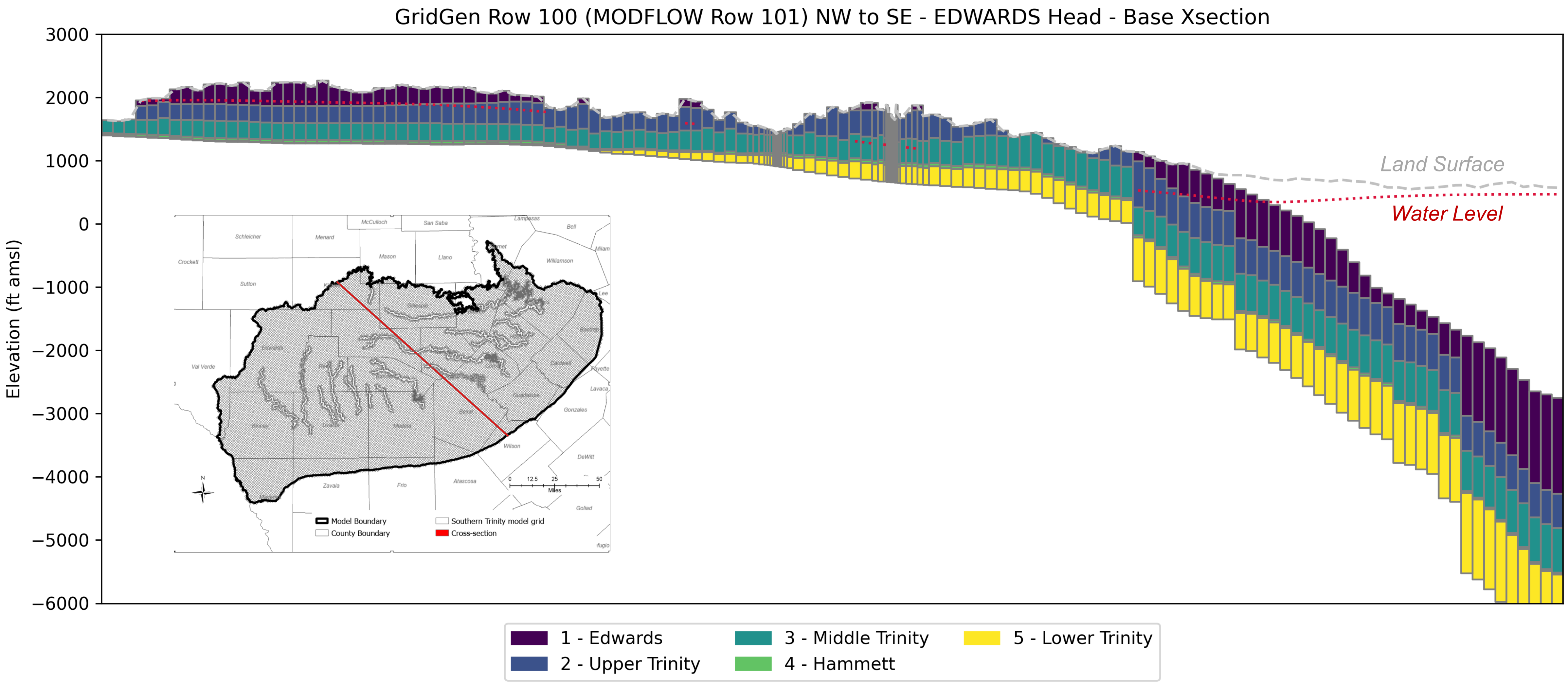
TEXAS WATER DEVELOPMENT BOARD

Model Results

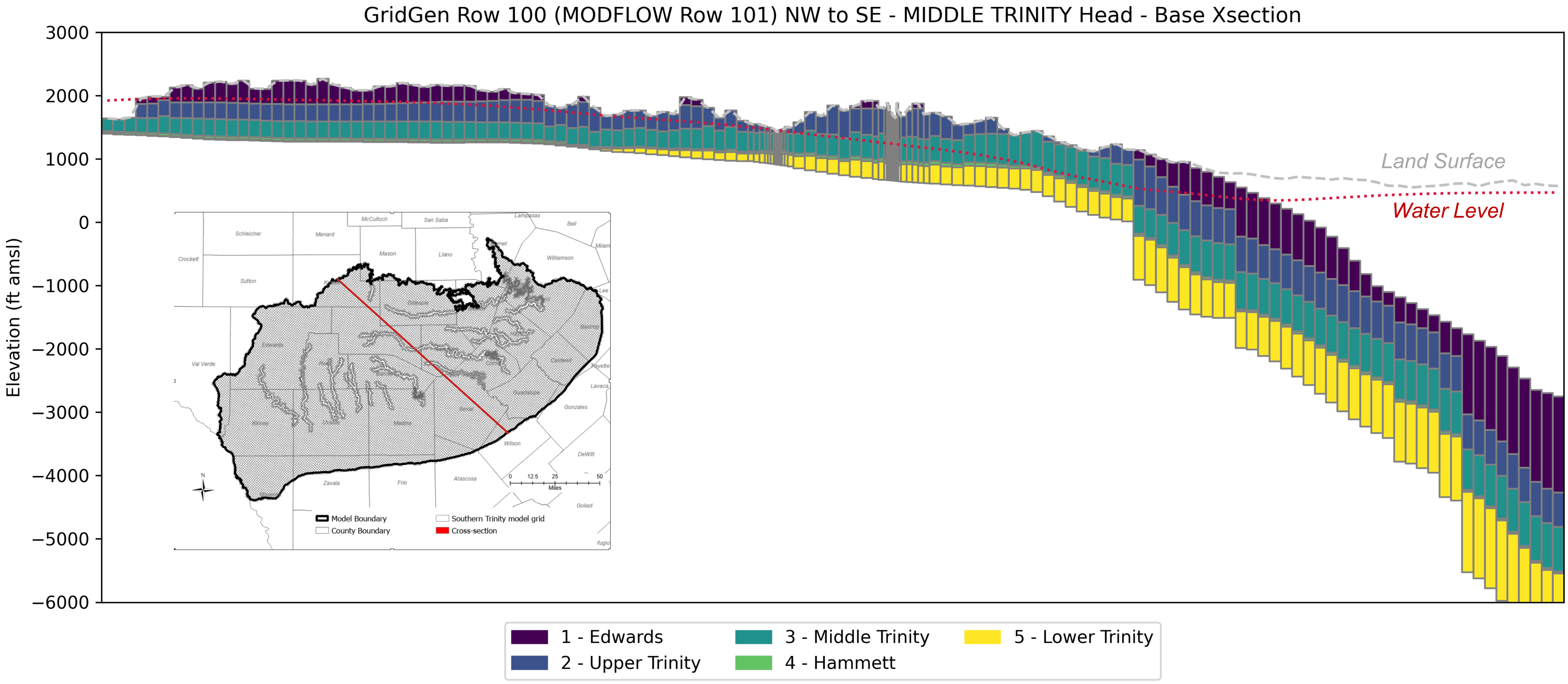


TEXAS WATER DEVELOPMENT BOARD

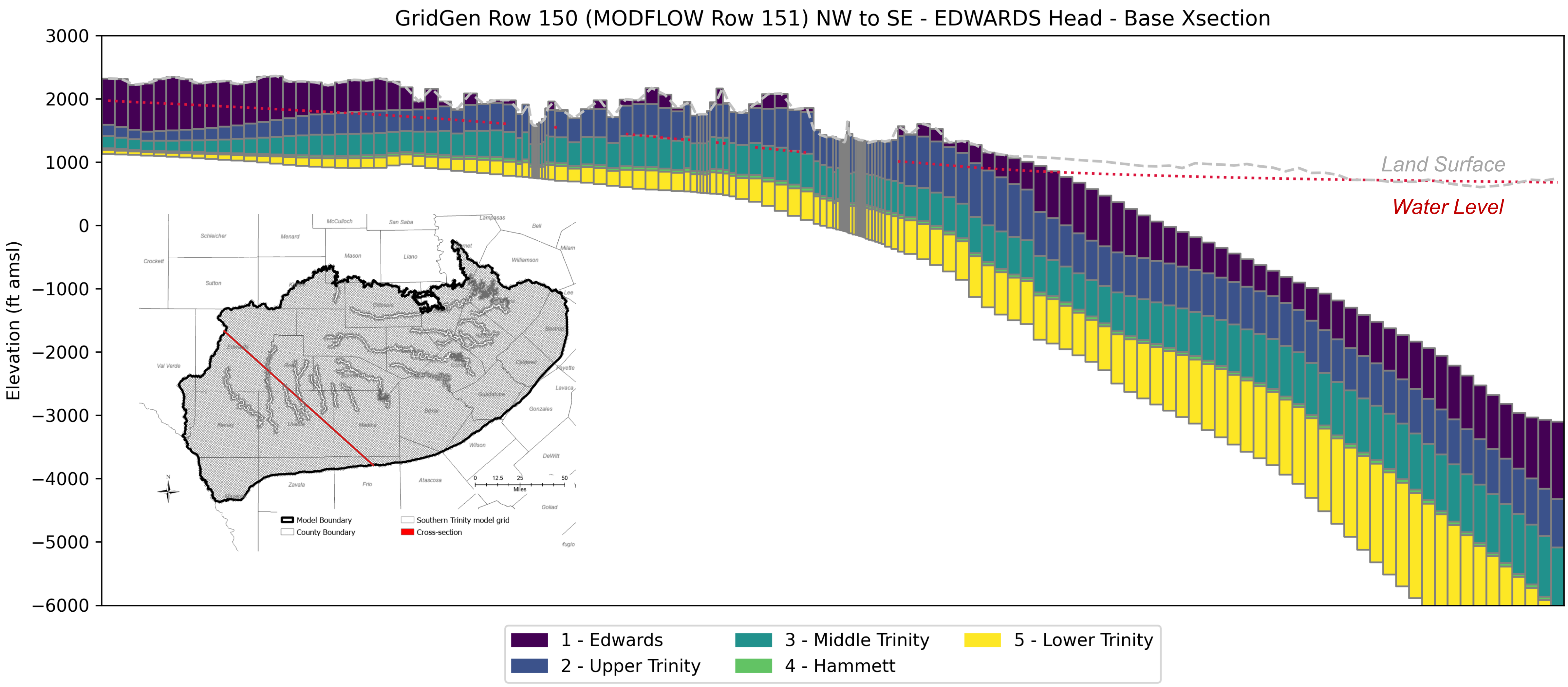
Model Results



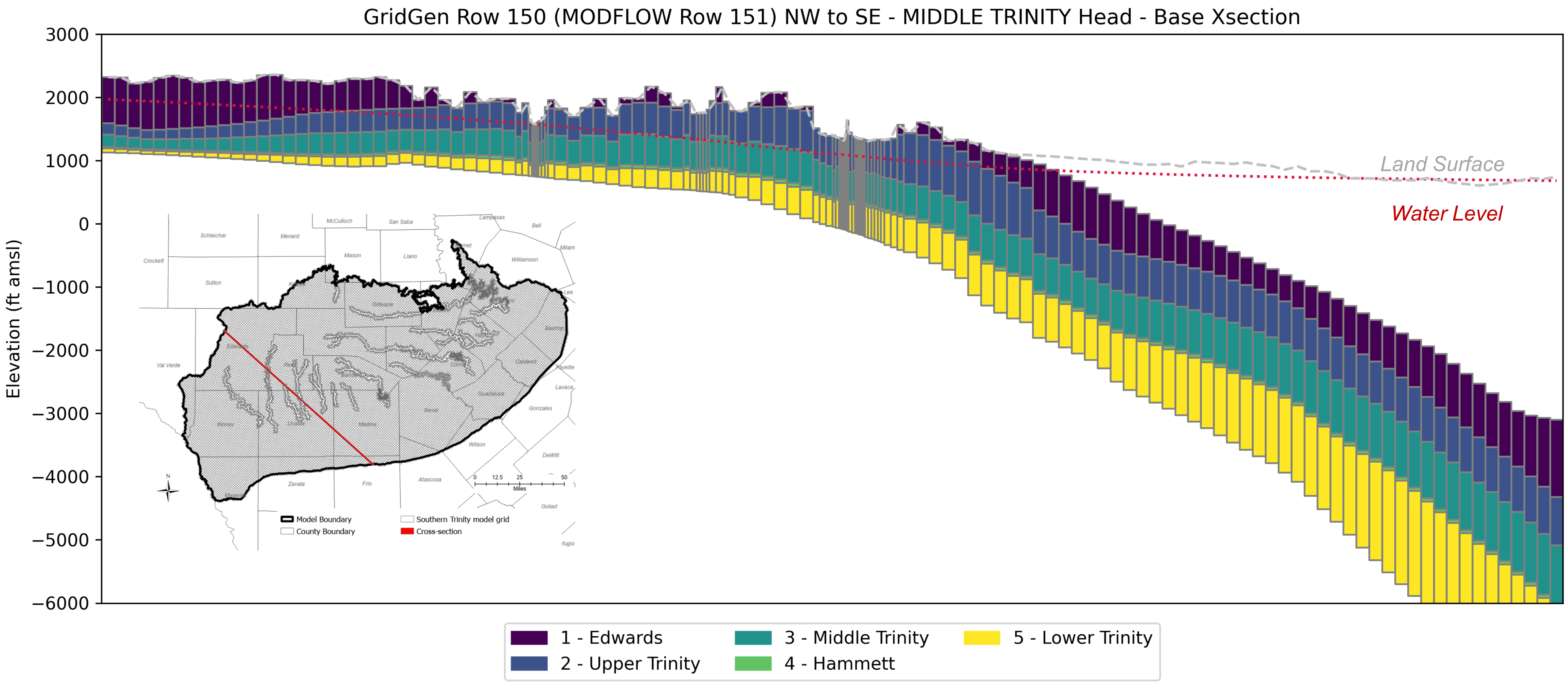
Model Results



Model Results



Model Results

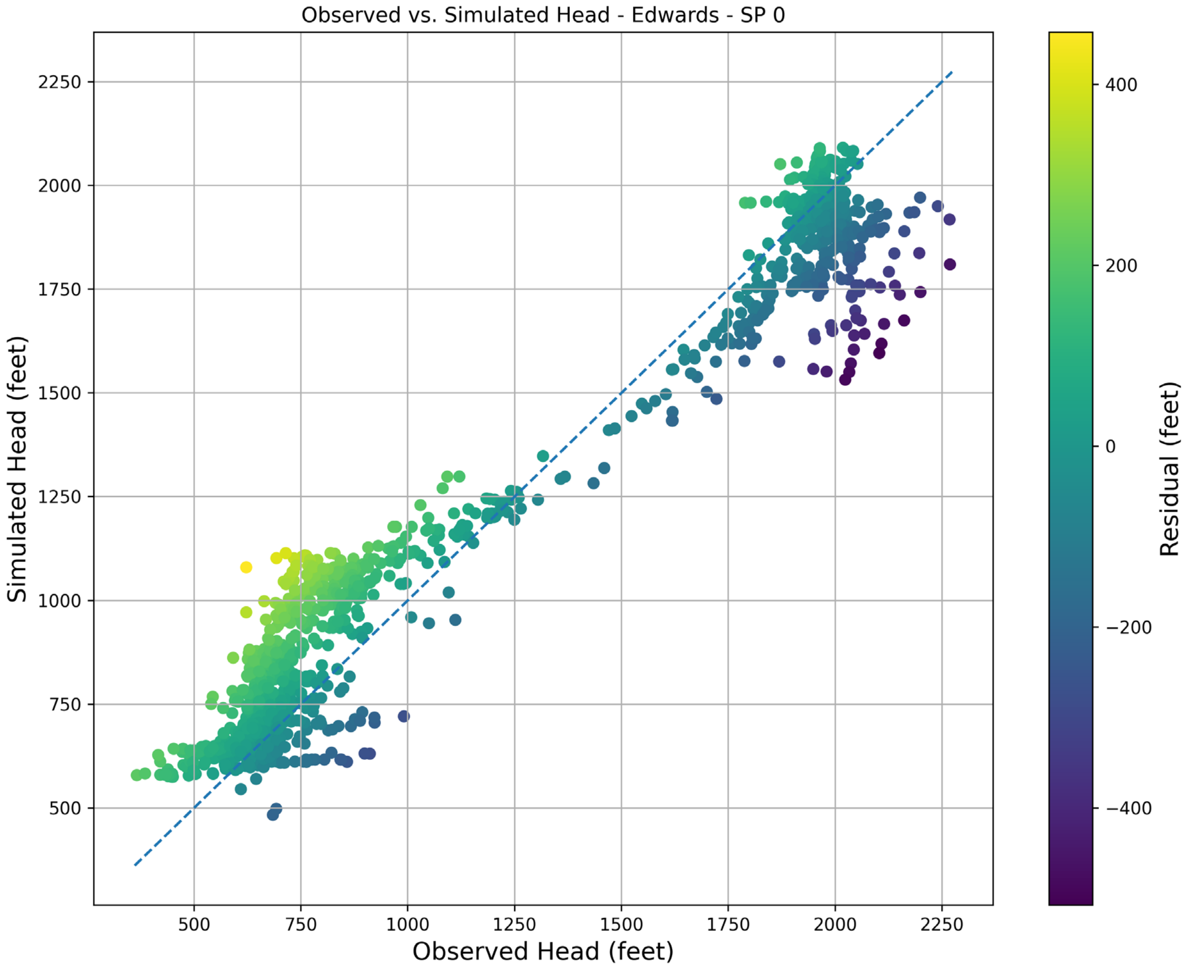


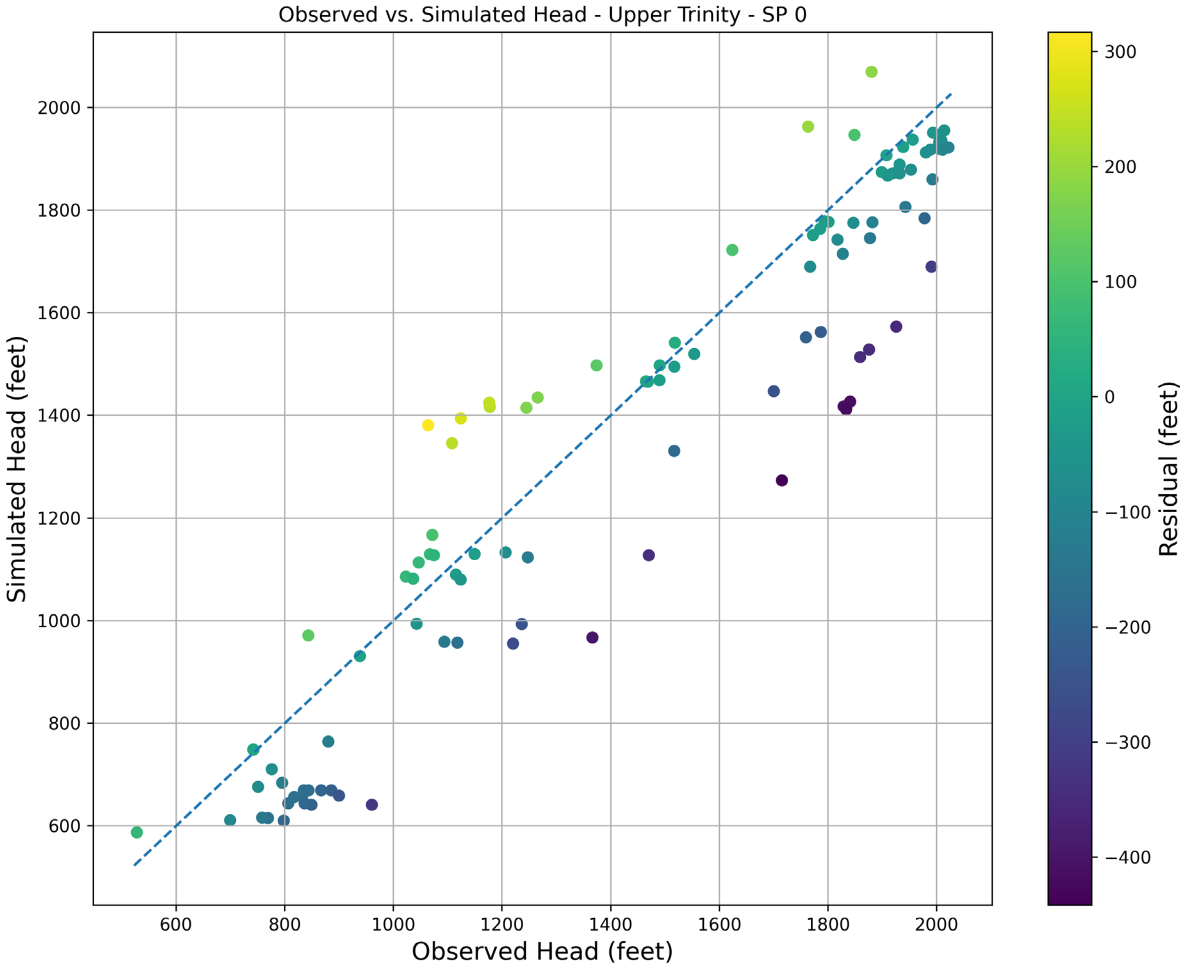
History-matching

- Comparison of field observations to model results
  - Water levels
  - *potentially baseflow/springflow*

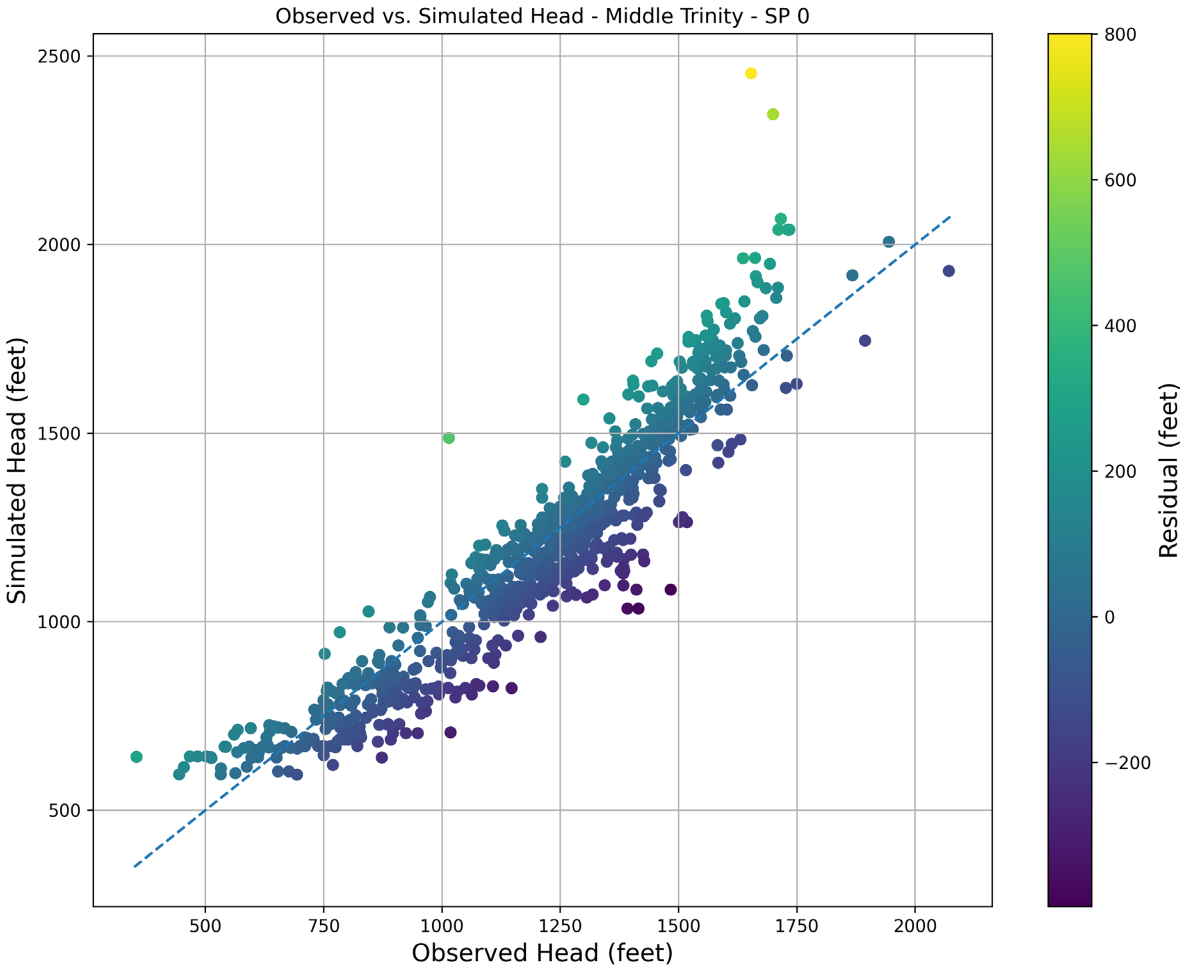
- Steady-state :
  - natural balanced condition
  - often used to represent pre-development conditions
  - Maximum pre-1980 water level

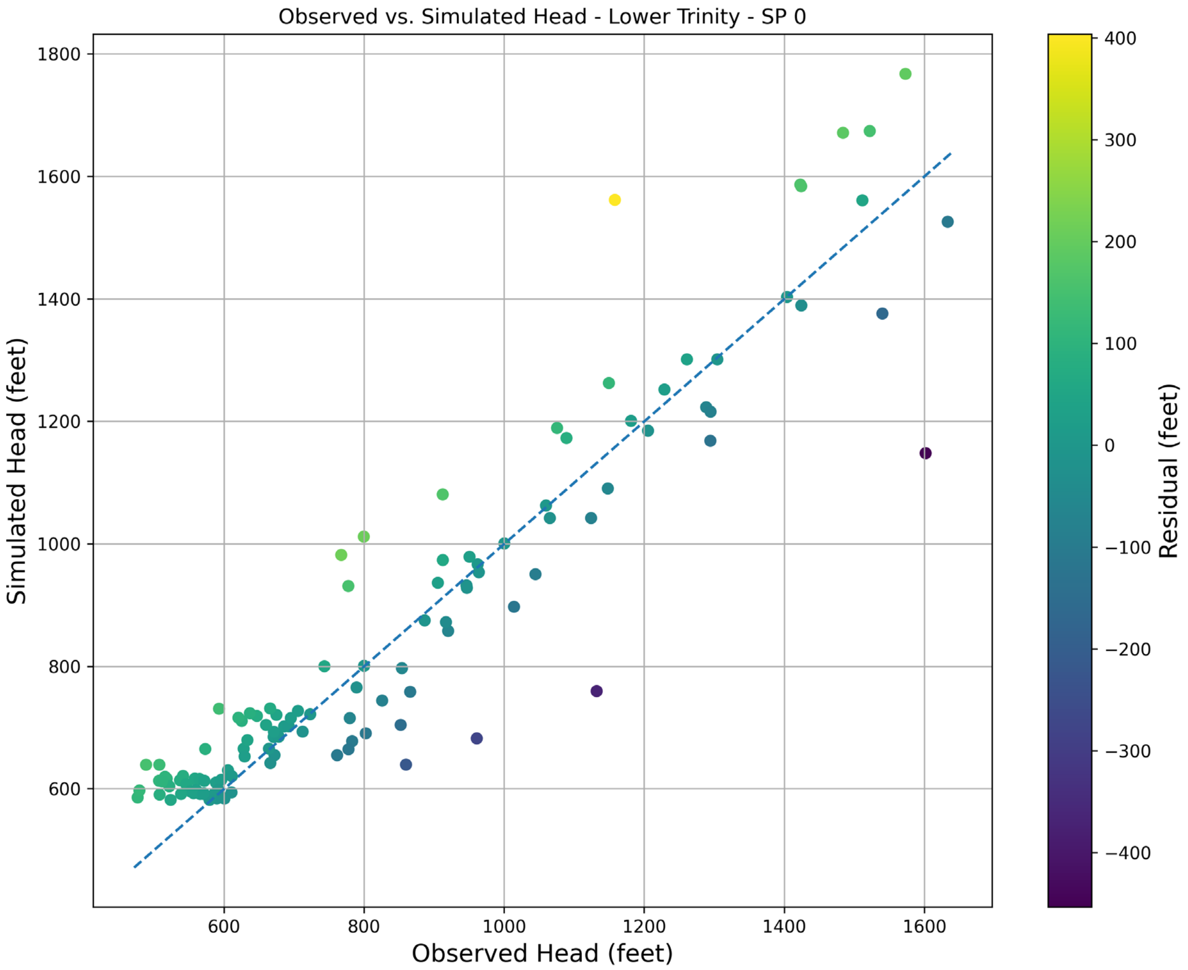
Model Results



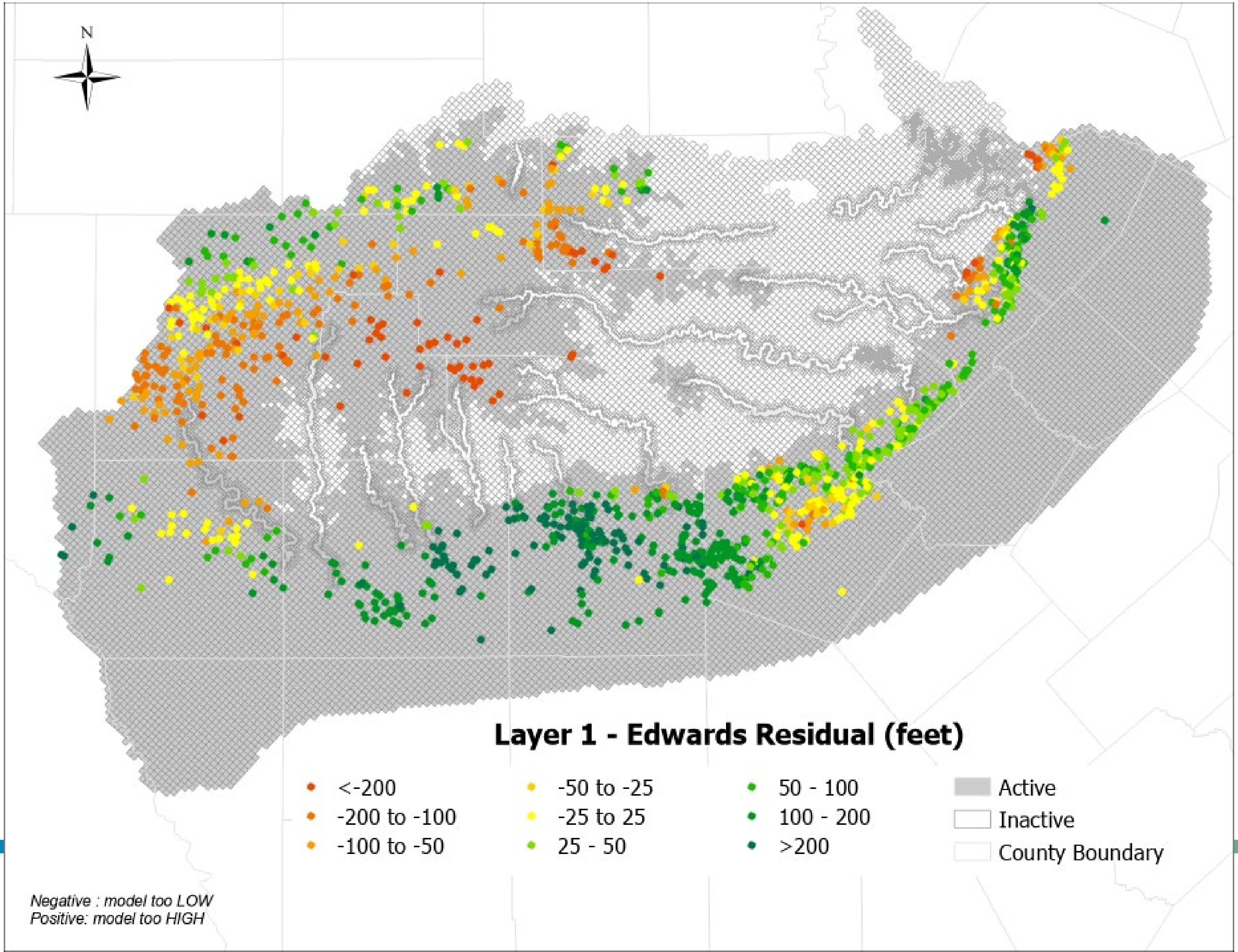


Model Results



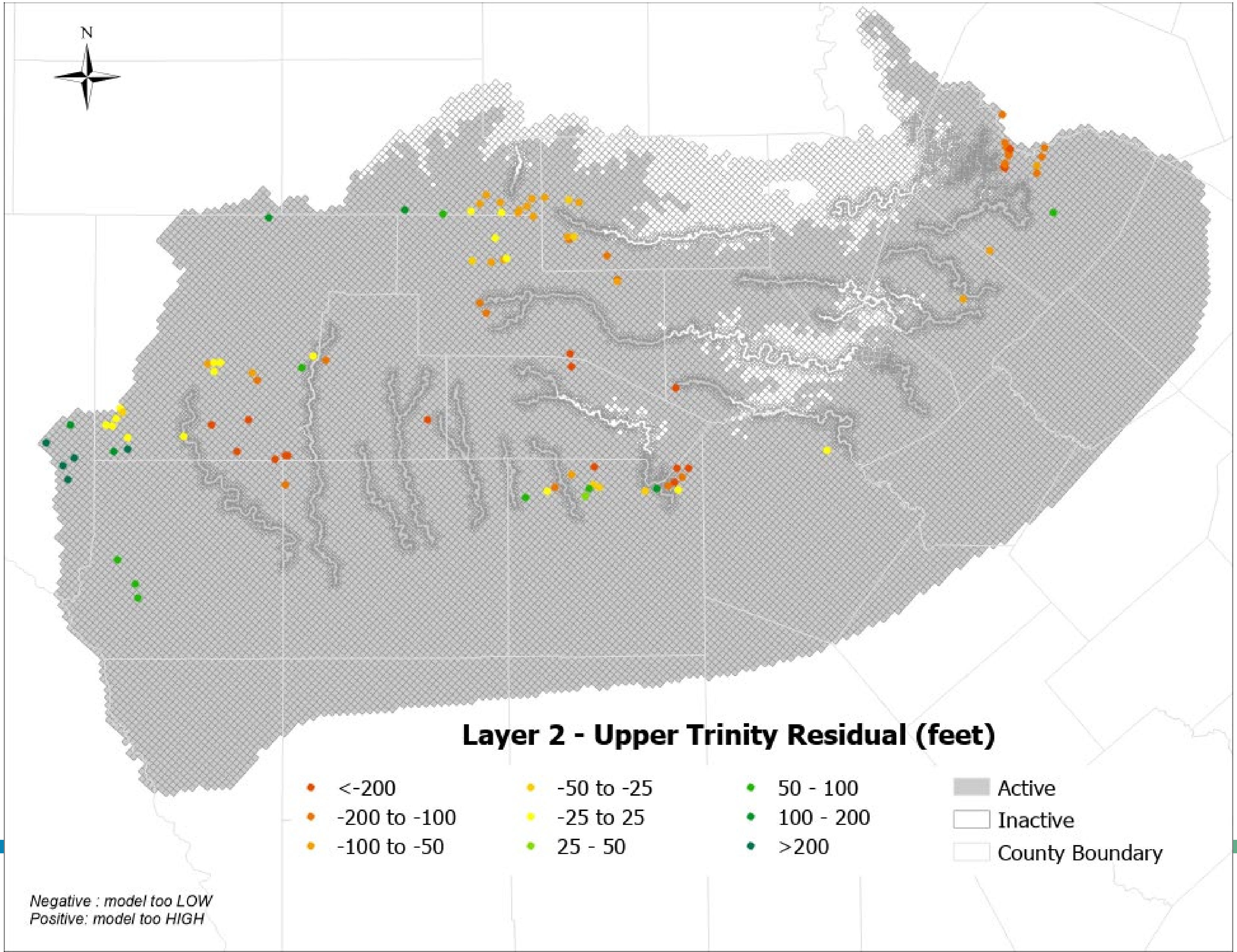


Model Results

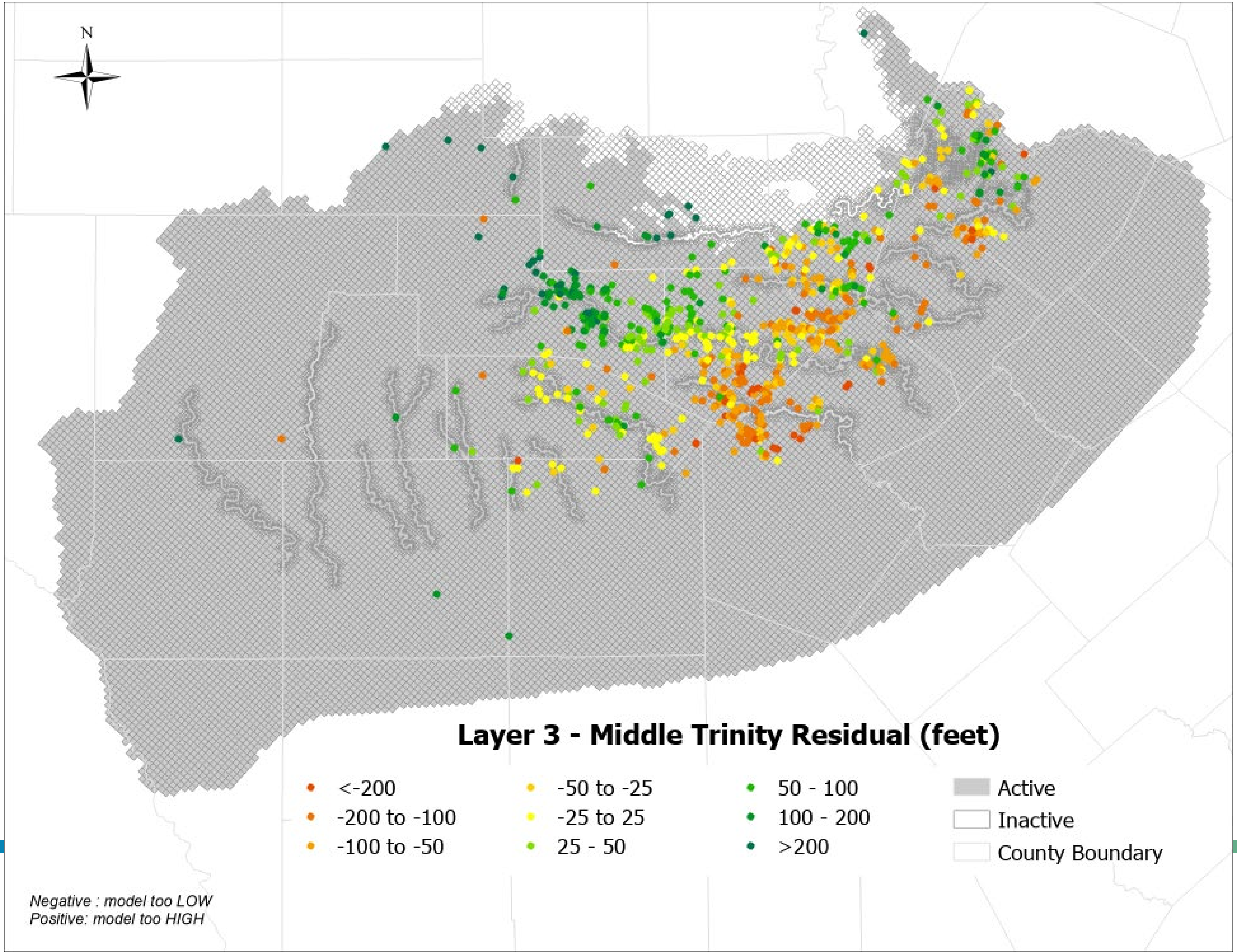


TEXAS WATER DEVELOPMENT BOARD

Model Results

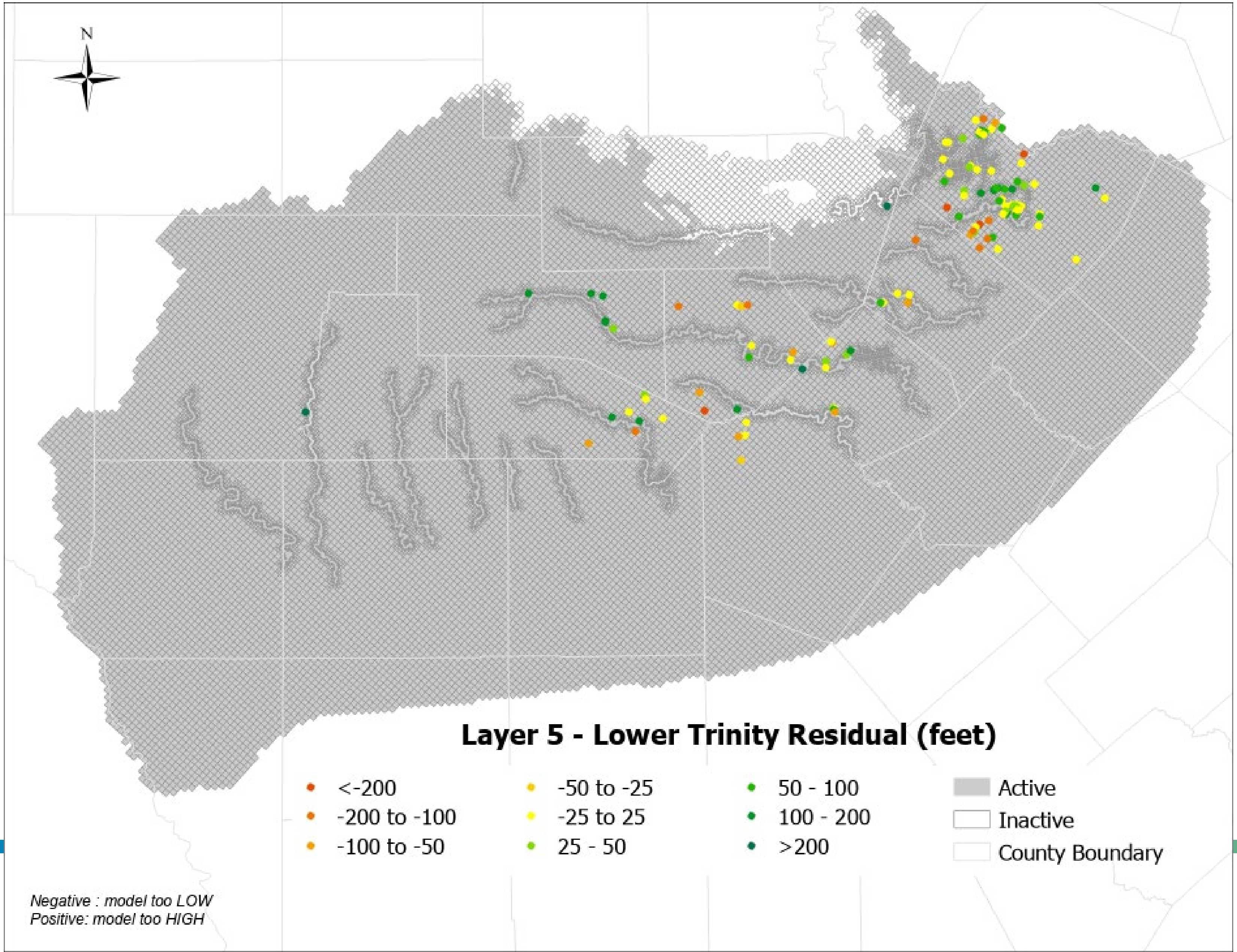


Model Results



TEXAS WATER DEVELOPMENT BOARD

Model Results



TEXAS WATER DEVELOPMENT BOARD

Next Steps

Next Steps: Calibration

- Steady-state Calibration parameters:
  - Recharge multiplier *(by zone)*
  - Hydraulic properties *(by zone)*
  - River conductance
  - GHB conductance
  - Drain conductance *(by individual large spring & by spring category)*

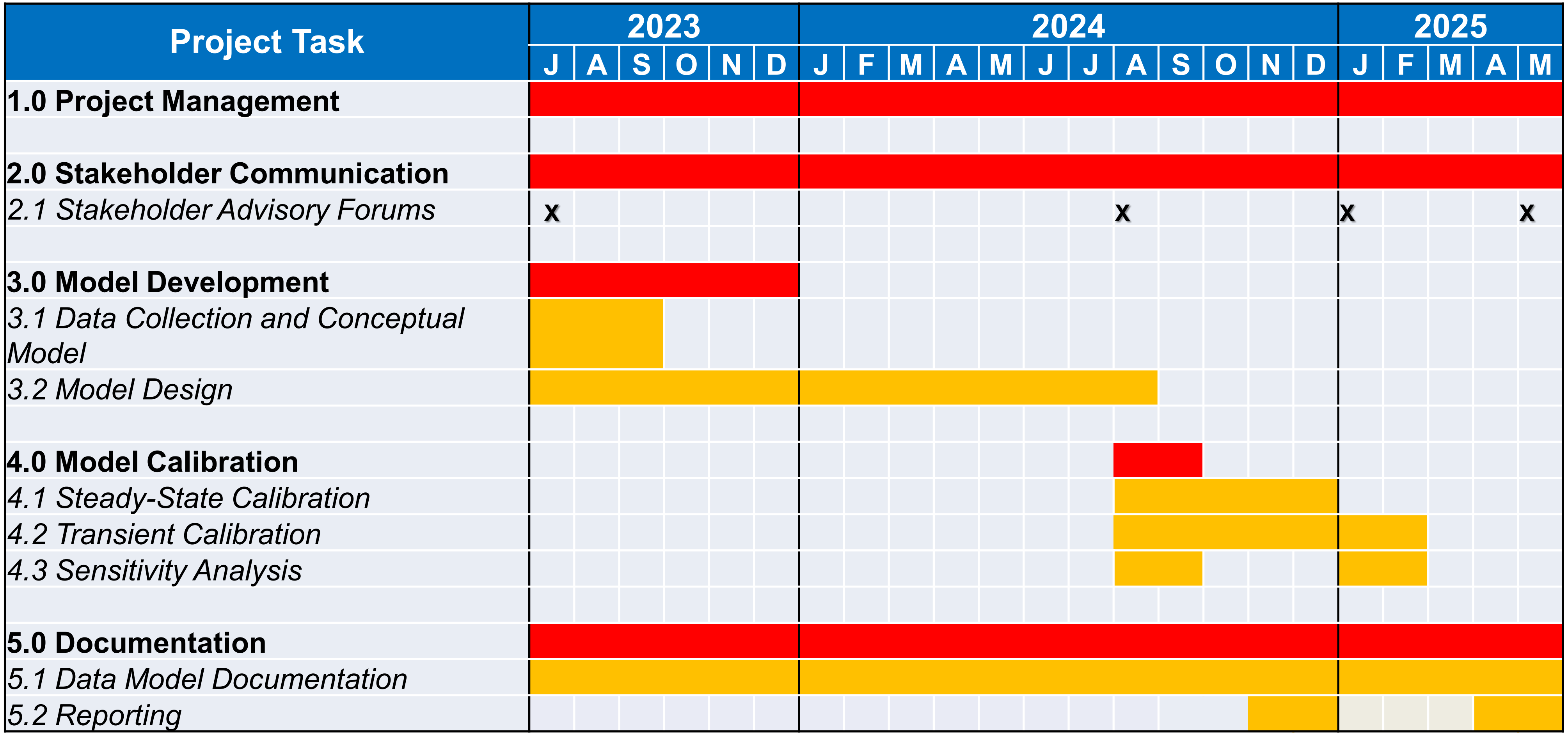
Next Steps: Calibration

- Transient Model:
  - Conditions changing over time
  - Proposed time period : **1980 – 2020**
  - Proposed stress periods: **annual**

- Transient Calibration parameters:
  - Same as steady-state *(all constant through time except recharge multipliers)*
  - Pumping multipliers *(by pumping type zone)*

Schedule

Project Tasks and Schedule



May 2026:
Proposed DFCs

Jan 2027:
Explanatory Report

TEXAS WATER DEVELOPMENT BOARD

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https://www.twdb.texas.gov/groundwater/models/gam/trnt_h/trnt_s.asp