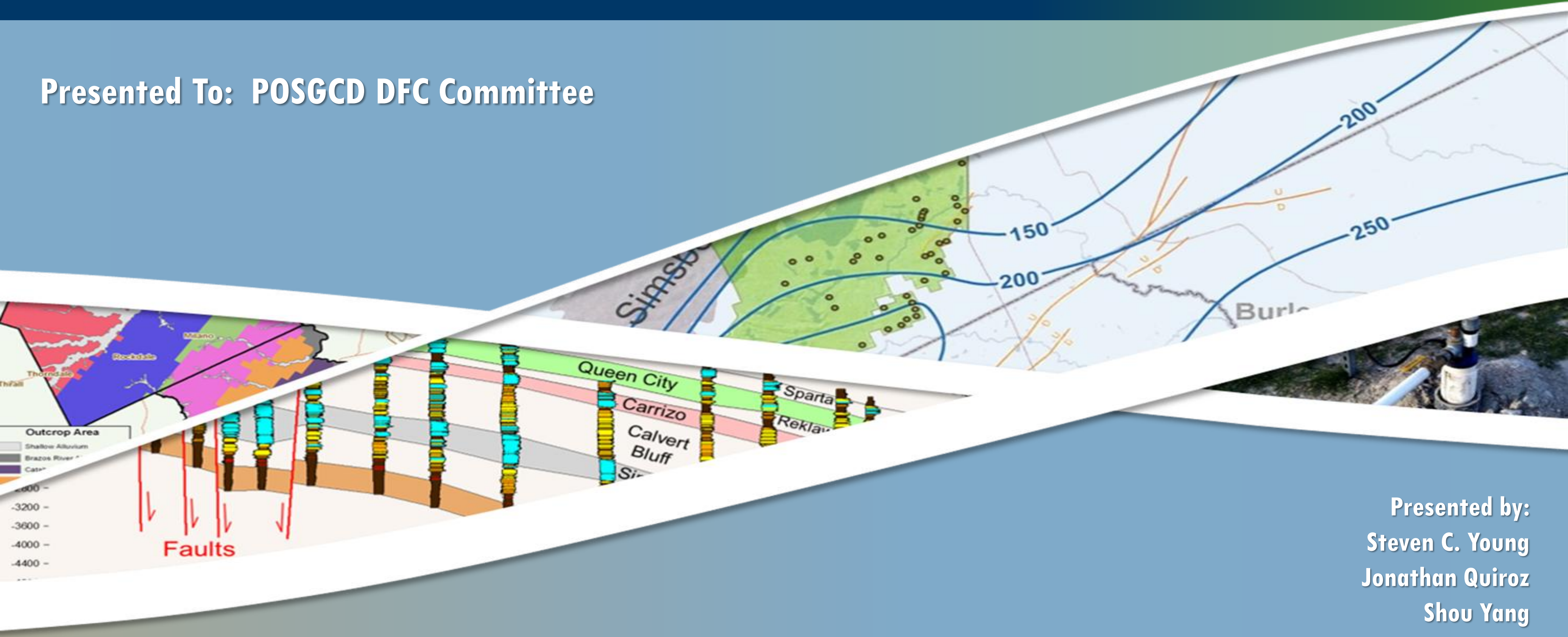
Development and Application of POSGCD Operational Groundwater Model

Presented To: POSGCD DFC Committee



Presented by:
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Jonathan Quiroz
Shou Yang

March 11, 2025

INTERA
GEOSCIENCE & ENGINEERING SOLUTIONS

Outline

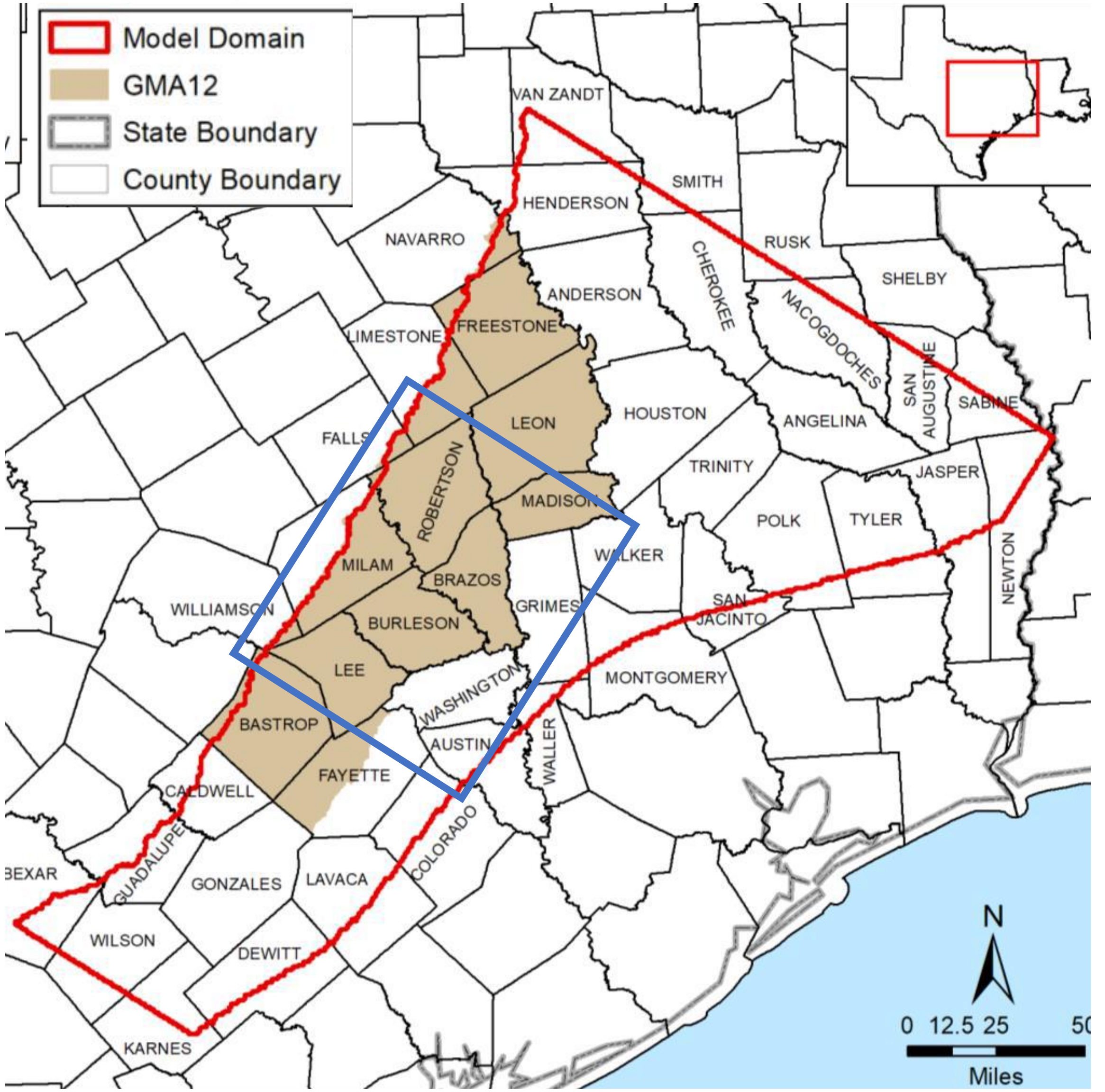
- Reasons for Improving the Model
  - Science
  - Policy
- OPMAN Calibration
  - Historical Water Levels
  - Vista Ridge Production
  - Aquifer Pumping Tests
- OPMAN Application
  - Desired Future Conditions (DFCs)
  - Total Estimated Recoverable Storage (TERS)
  - Sustainable Pumping

Reasons for Improving the Model

Reclamation Study

- Objective
  - Enhance GAM to develop an **OP**erations and **MAN**agement Model (**OPMAN**)
  - Apply OPMAN to help guide management decisions
  - Apply OPMAN to investigate long-term sustainability

- OPMAN (Blue Box)
  - Extend historical calibration (1930 to 2021)
  - Simulate aquifer pumping tests
  - Incorporate predictive uncertainty



Reasons for Improving the Model: Science

- Hydrogeologic Data: Significant New Information Since 2011
  - Geology
  - Water Levels
  - Aquifer Pumping Tests
  - 2012-2023 Gap in Modeling Simulation

- Modeling Approach: Significant Advancement in Modeling Software since 2011
  - Grid Refinement
  - Focused on POSGCD and Adjacent District
  - Advanced Calibration
  - Parameter/Prediction Uncertainty

Reasons for Improving the Model: Policy

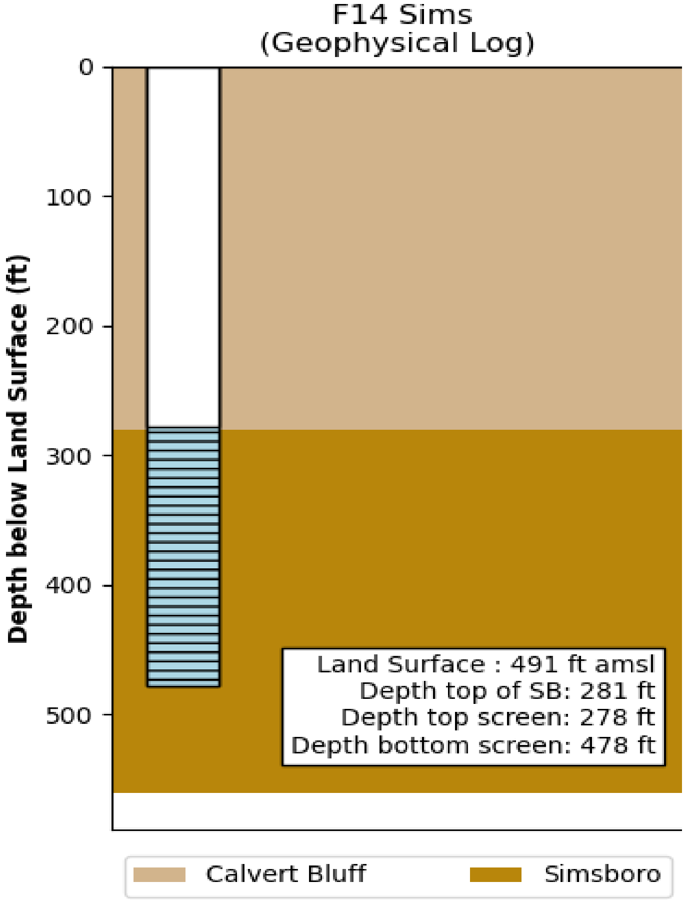
- Management & Evaluations
  - Evaluation of DFCs & PDLs Compliance
  - GWAP Annual Needs Assessment (GANA)
  - Sustainable Pumping
  - Climate/Drought Resiliency
  - Multi-year Average for Production Permits
  - Unreasonable Impacts

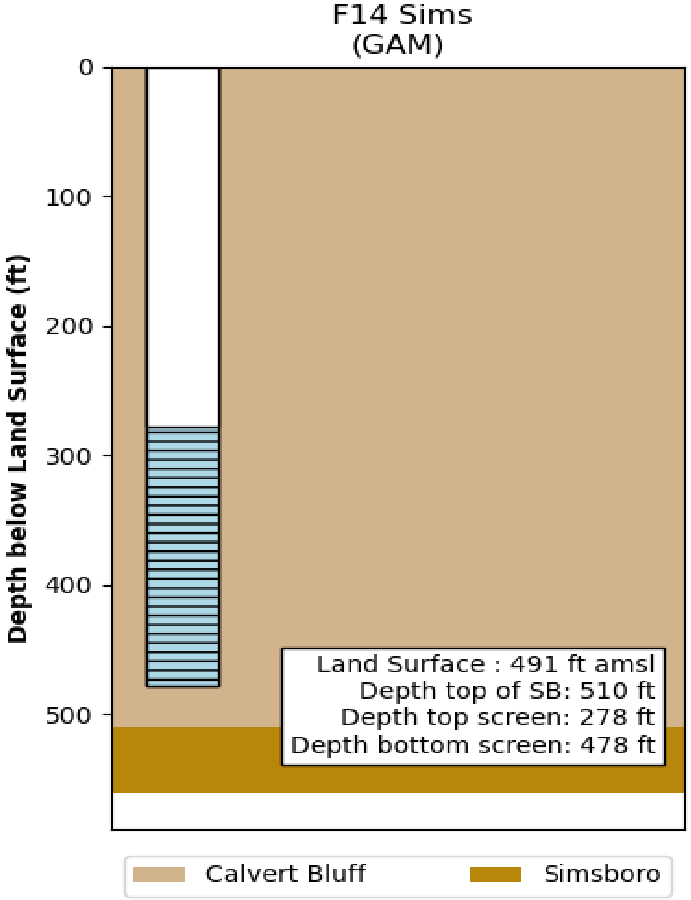
- Curtailment
  - Plan, Implement, and Monitor
  - Maximum Allotment per Acre
  - Litigation Support

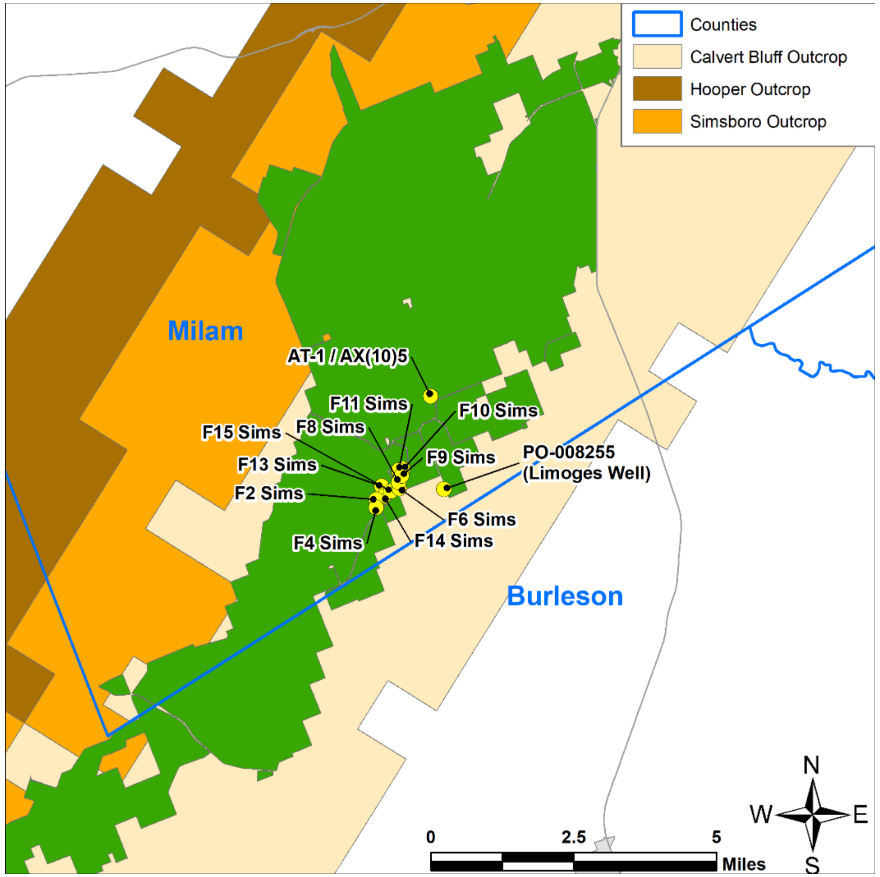
Geology

Summary of INTERA Analysis of 32 Historical Wells As Part of AlCOA's Amendment to 0148 Permit

- INTERA Classified 55 out of the 56 production wells as Simsboro wells
  - 11 of the 32 existing wells mapped into the Calvert Bluff based on GAM data were assigned to Simsboro based on analysis of geophysical logs

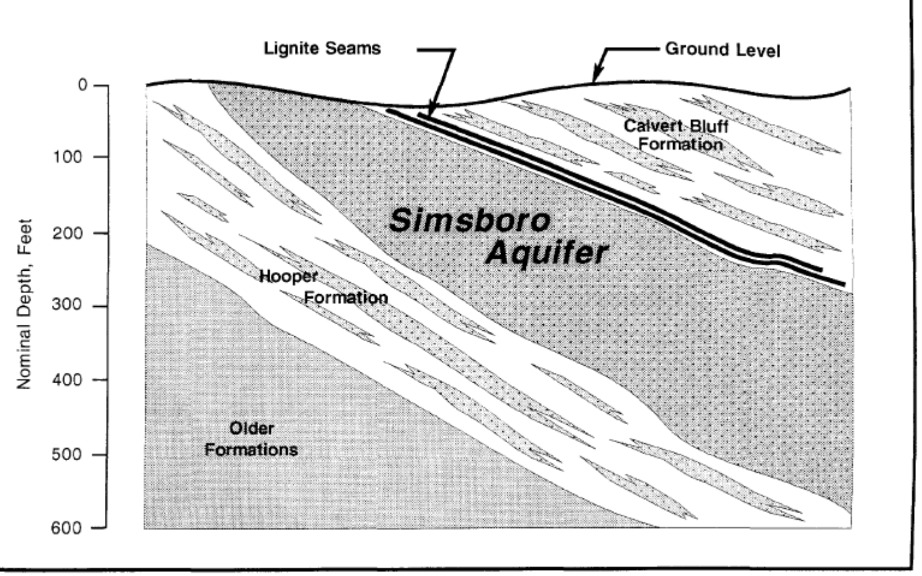






Geology: Lignite Layers in Calvert Bluff

FIGURE 1. Generalized cross section showing geologic units



The morphology of the lignite seams at the site is varied. The main seam is widespread, being traceable for at least ten miles along strike and 2 miles along dip (limits determined by limits of exploration), and is between 5 and 16 ft thick. The seam is absent in several places due

Hydrogeology at the site is variable due to the complex stratigraphy. The hydraulic conductivity of the channel sands has been measured at 5×10^{-3} cm/sec while the clays have hydraulic conductivities of 5×10^{-9} cm/sec or less (Henry, 1976). Regionally the ground water table is

14 ft/dy

1.4e-5

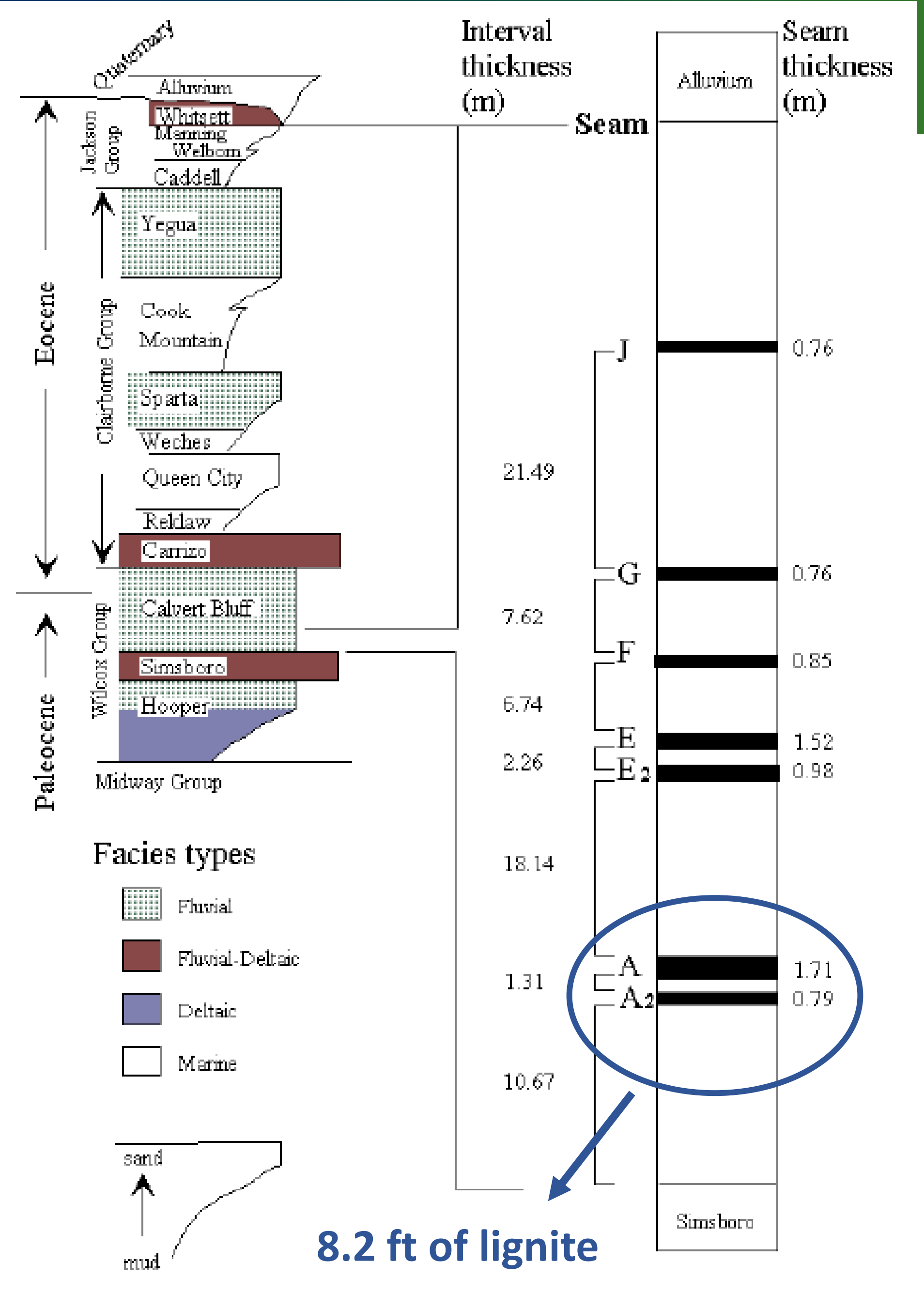
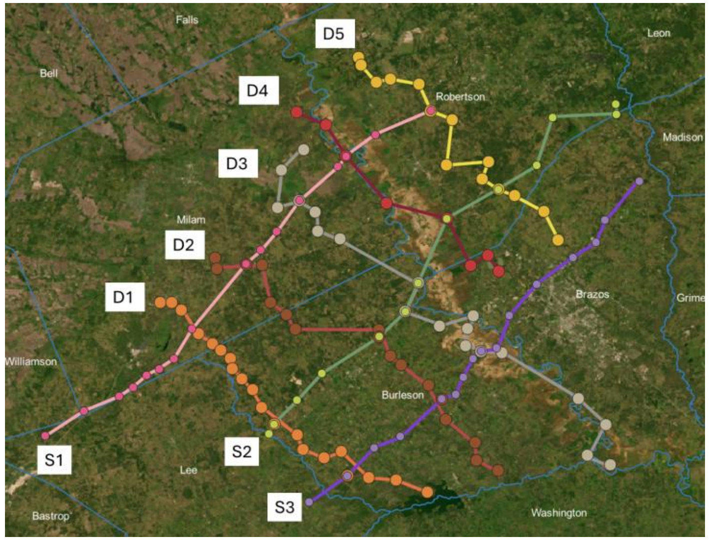
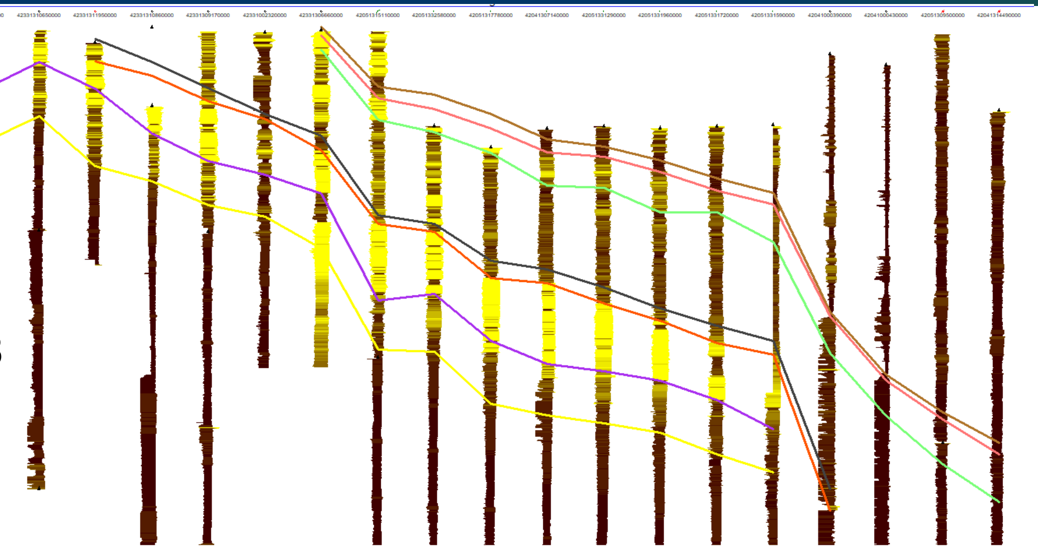


Figure 2. Generalized stratigraphic section of the Calvert mine area. Modified after Kaiser and ot

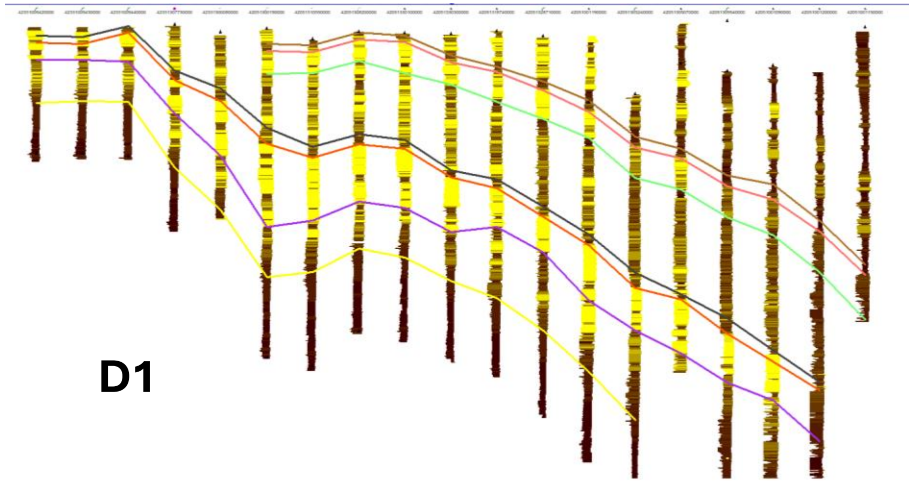
Mapping Lignite Layer



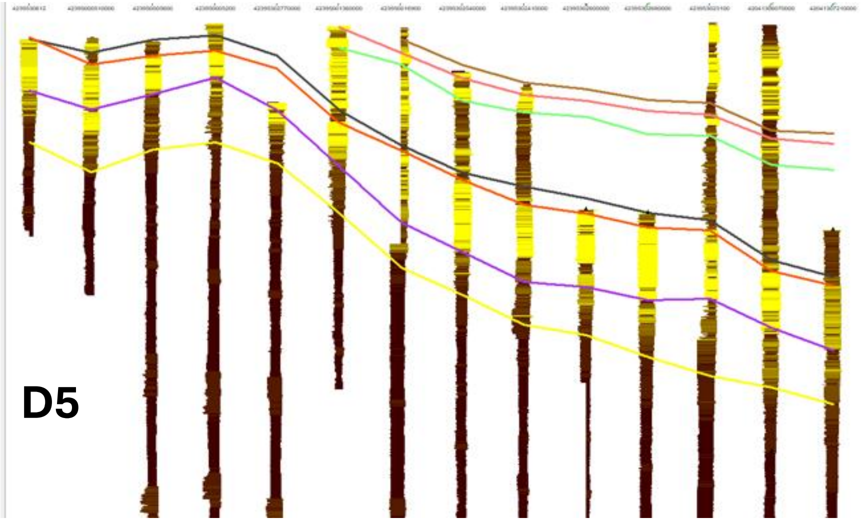


D3

Reklaw
Carrizo
Calvert Bluff
Coal Seam
Simsboro
Hooper
Midway



D1

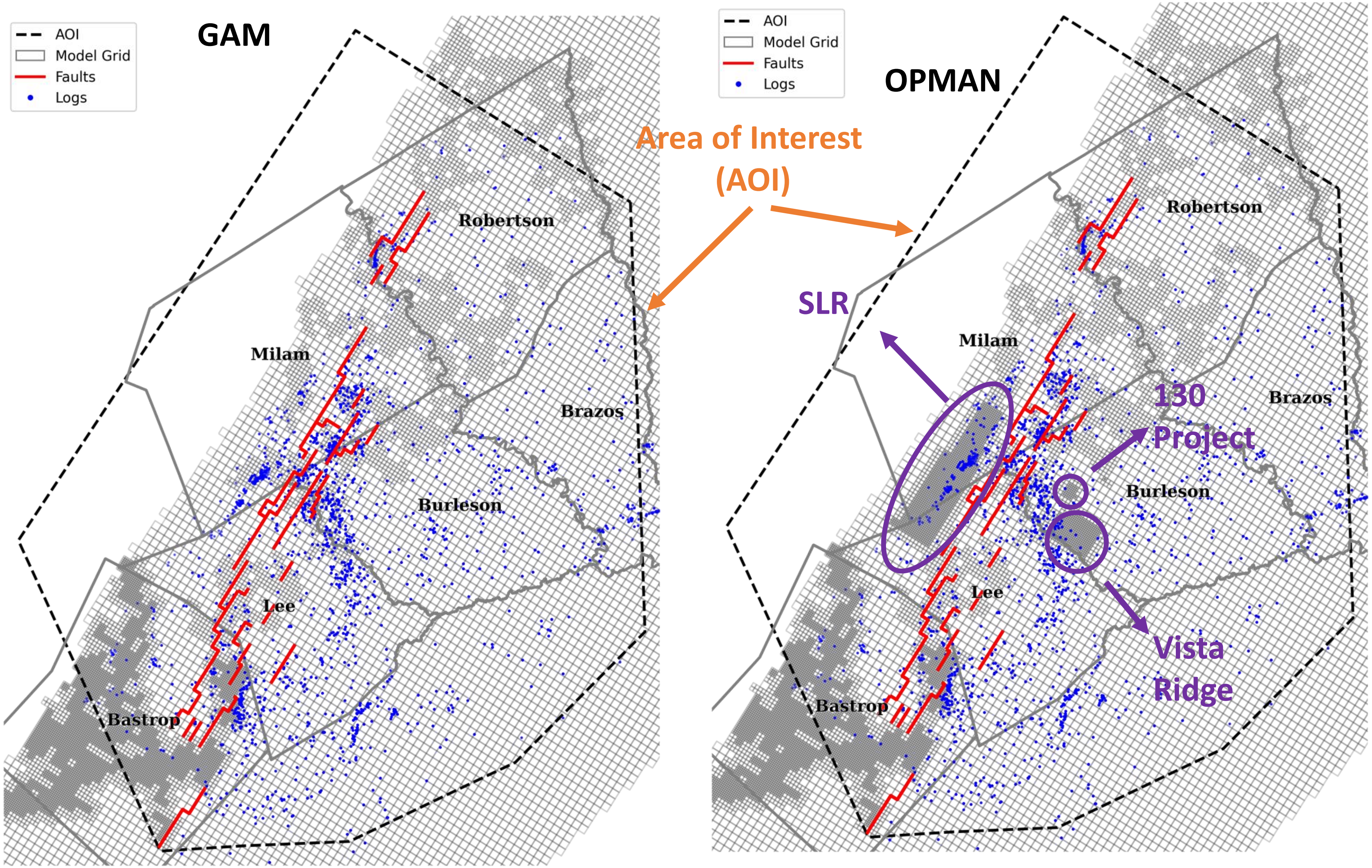


D5

Low permeability lignite layer was added to the bottom of the Calvert Bluff to restrict vertical flow to and from the Simsboro Layer

Changes to Model Grids and Layers

- Grid cells
  - Refine near major pumping centers
- Refined Geology and Model Layers
  - 1600 logs
  - measured water levels
  - fault locations
  - measured water quality

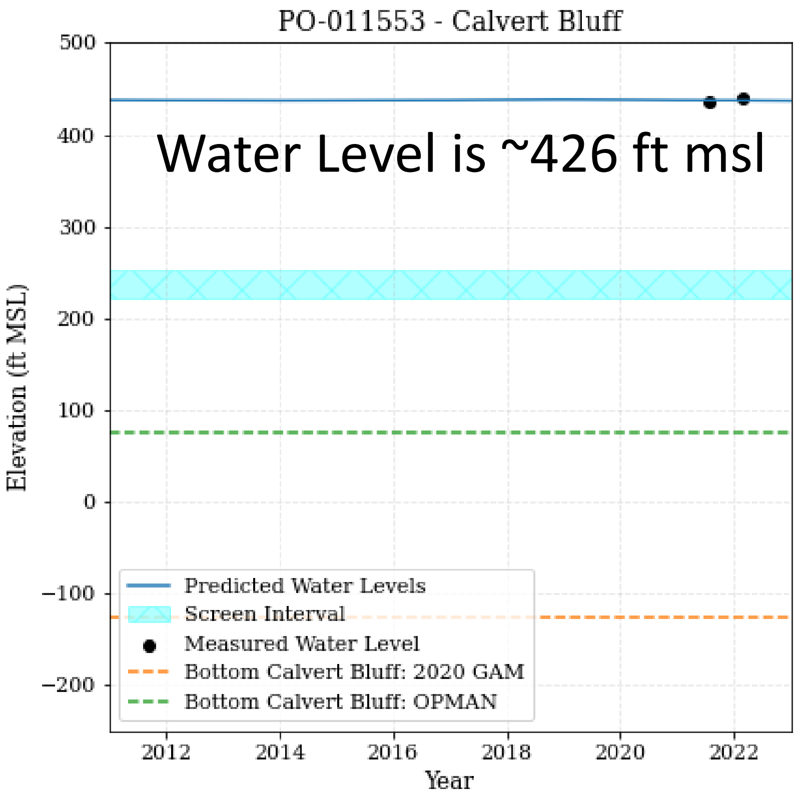


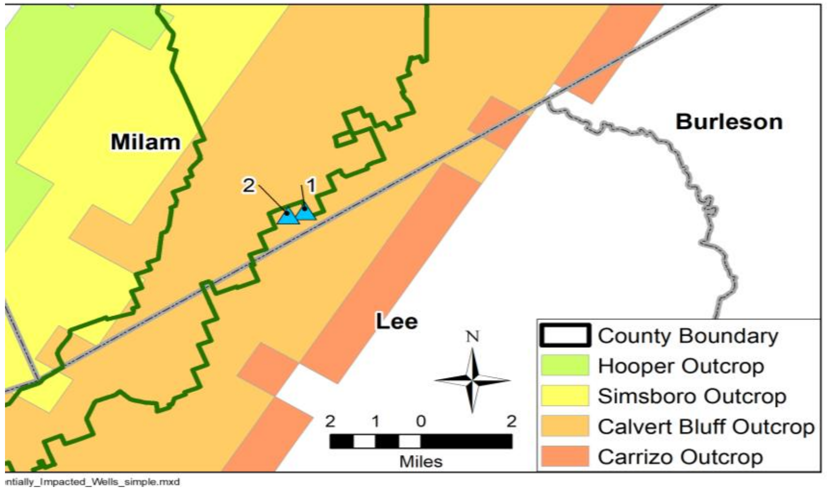
Evidence for Making Changes to Model Layers: Water Levels

GAM
- Well #1 is Calvert Bluff
- Well #2 is Calvert Bluff

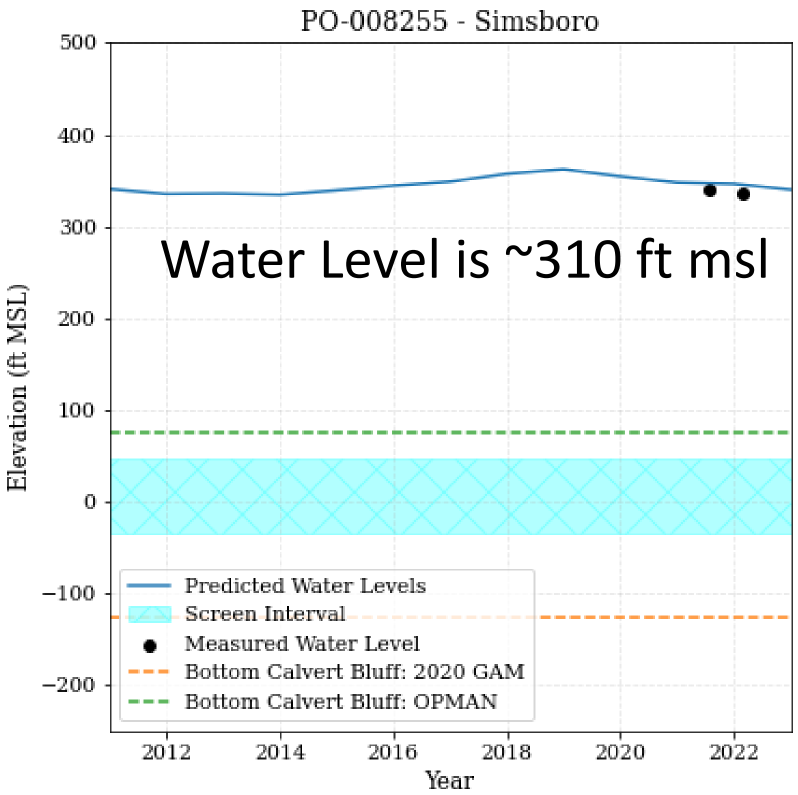
OPMAN
- Well #1 is Simsboro
- Well #2 is Calvert Bluff

#2 Well

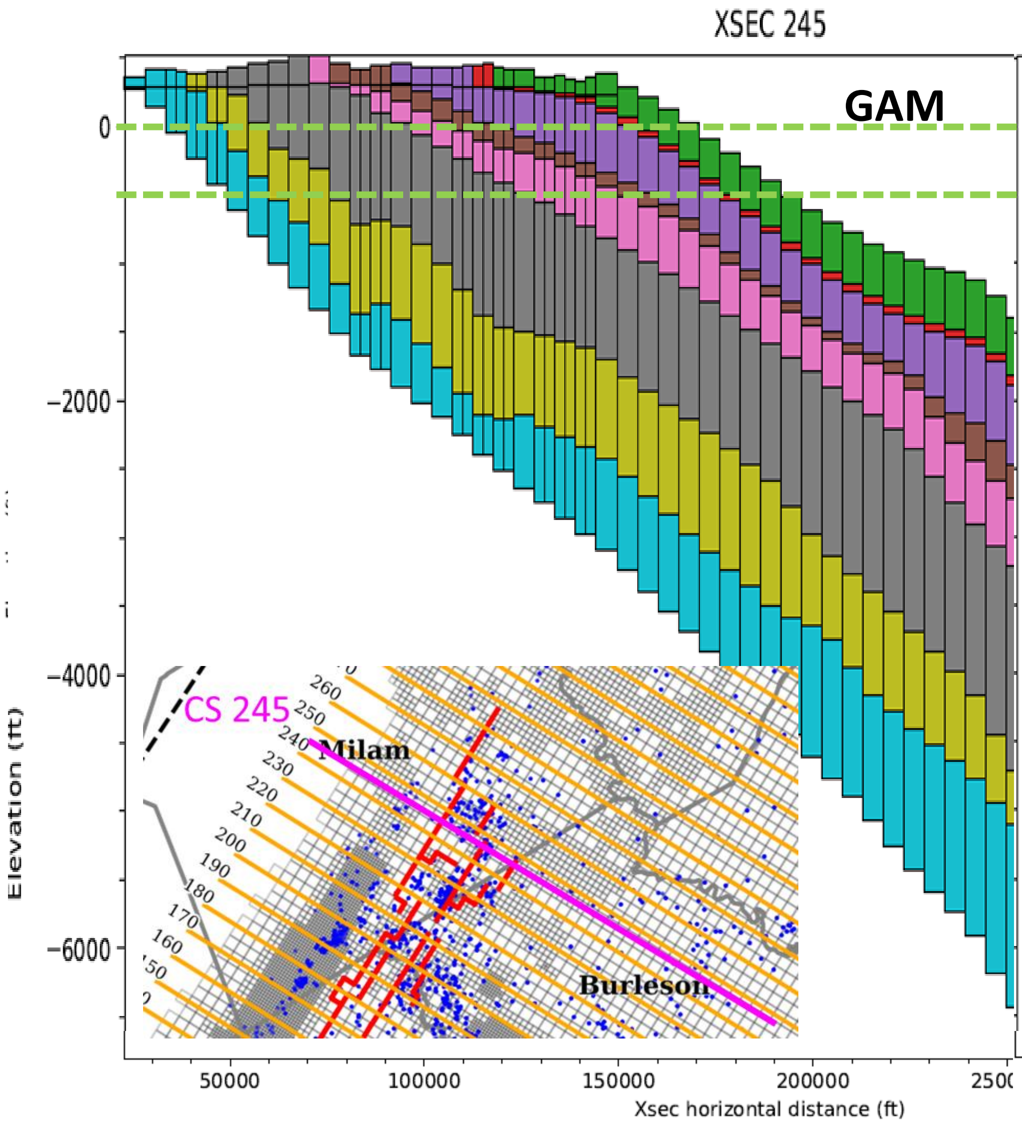


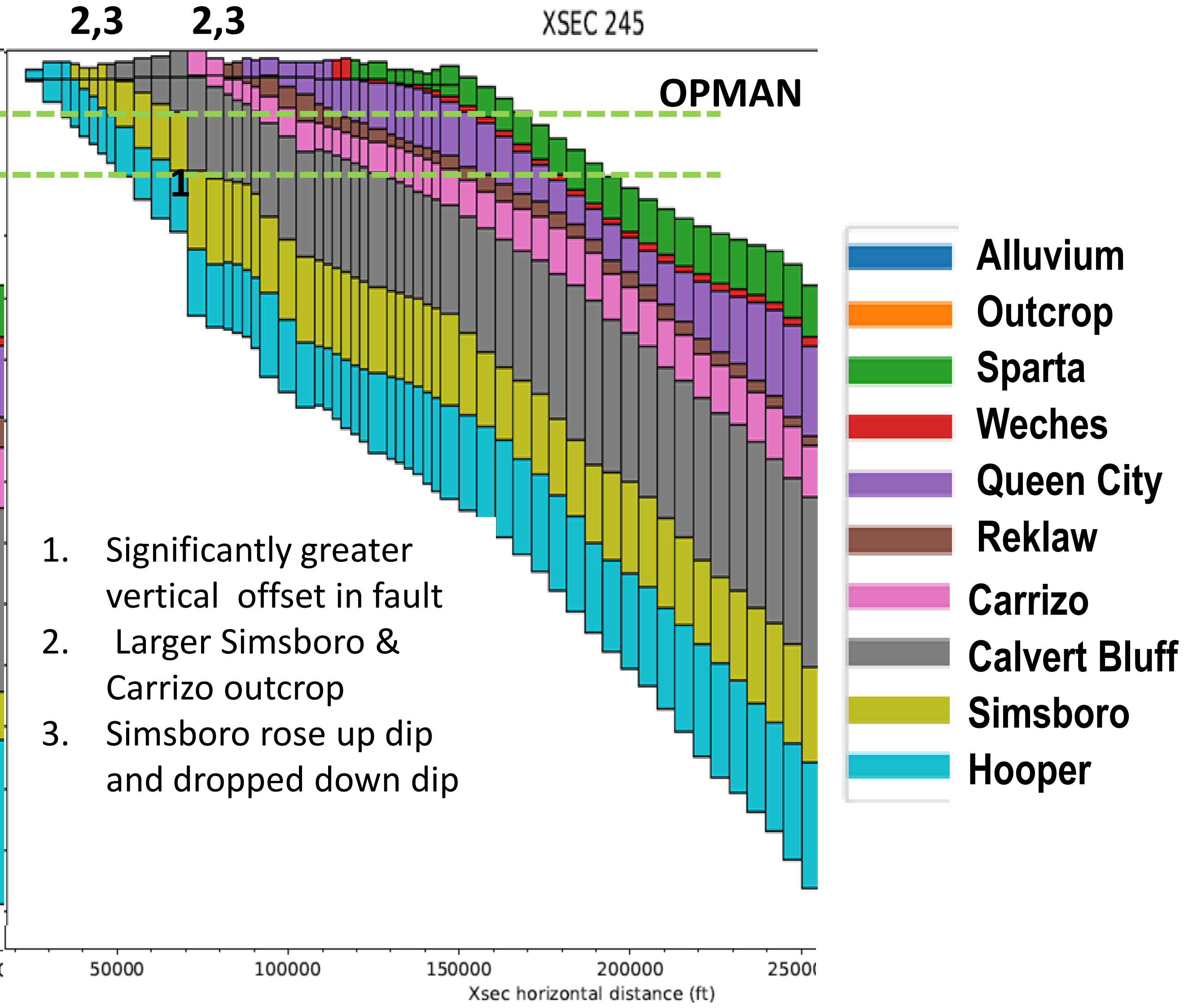


#1 Well



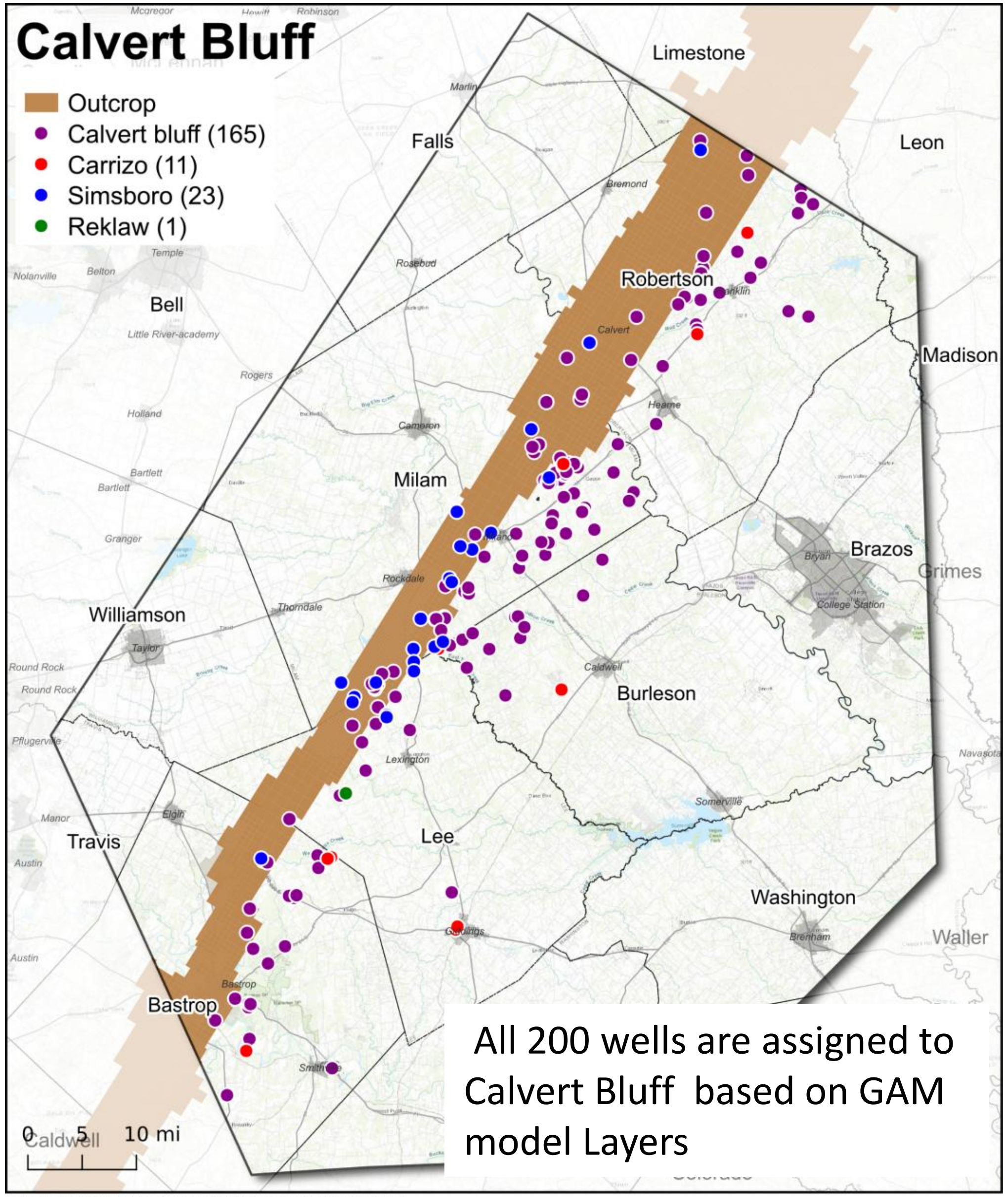
Section 245



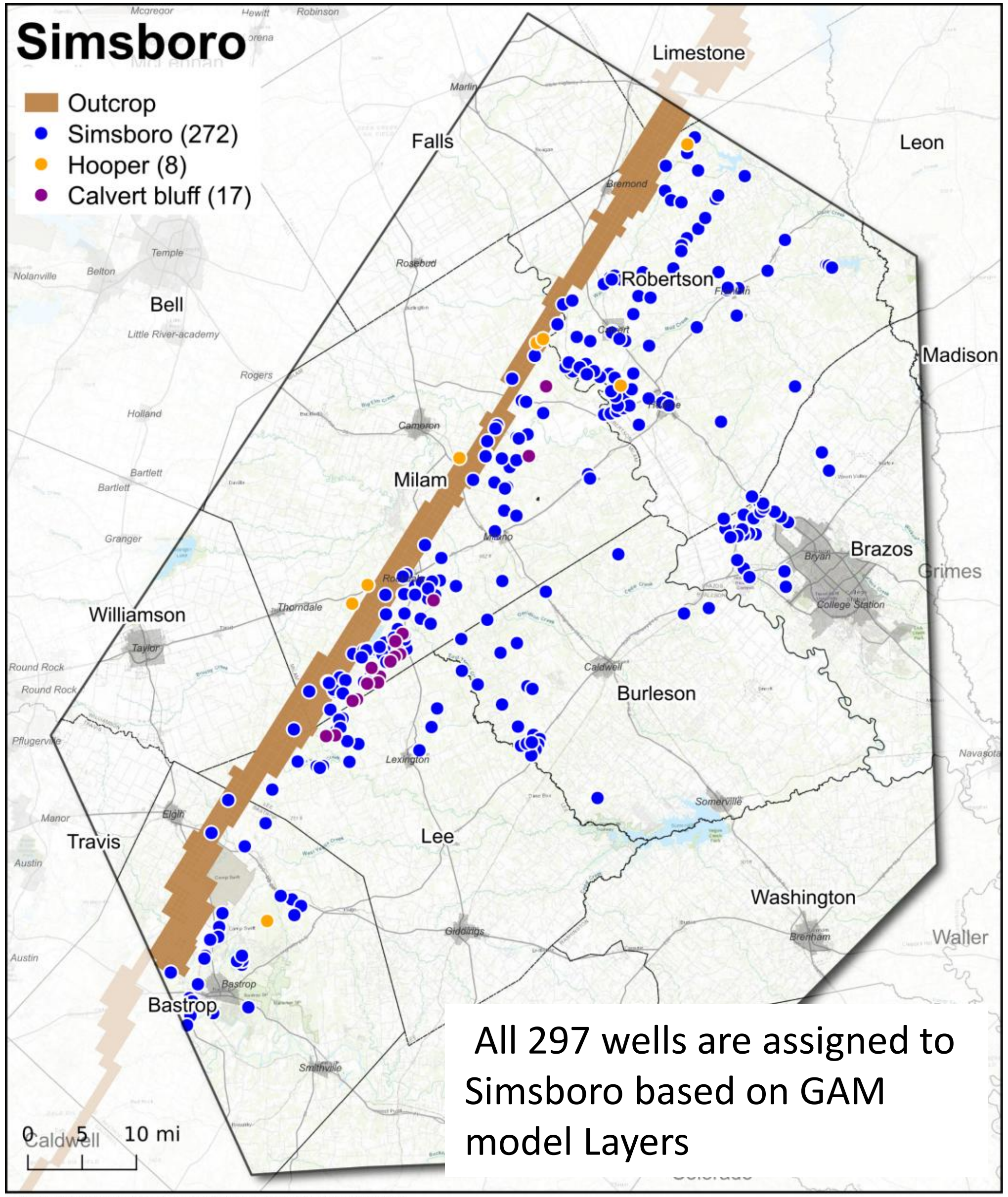


1. Significantly greater vertical offset in fault
2. Larger Simsboro & Carrizo outcrop
3. Simsboro rose up dip and dropped down dip

Aquifer Assignment Change Between GAM and OPMAN



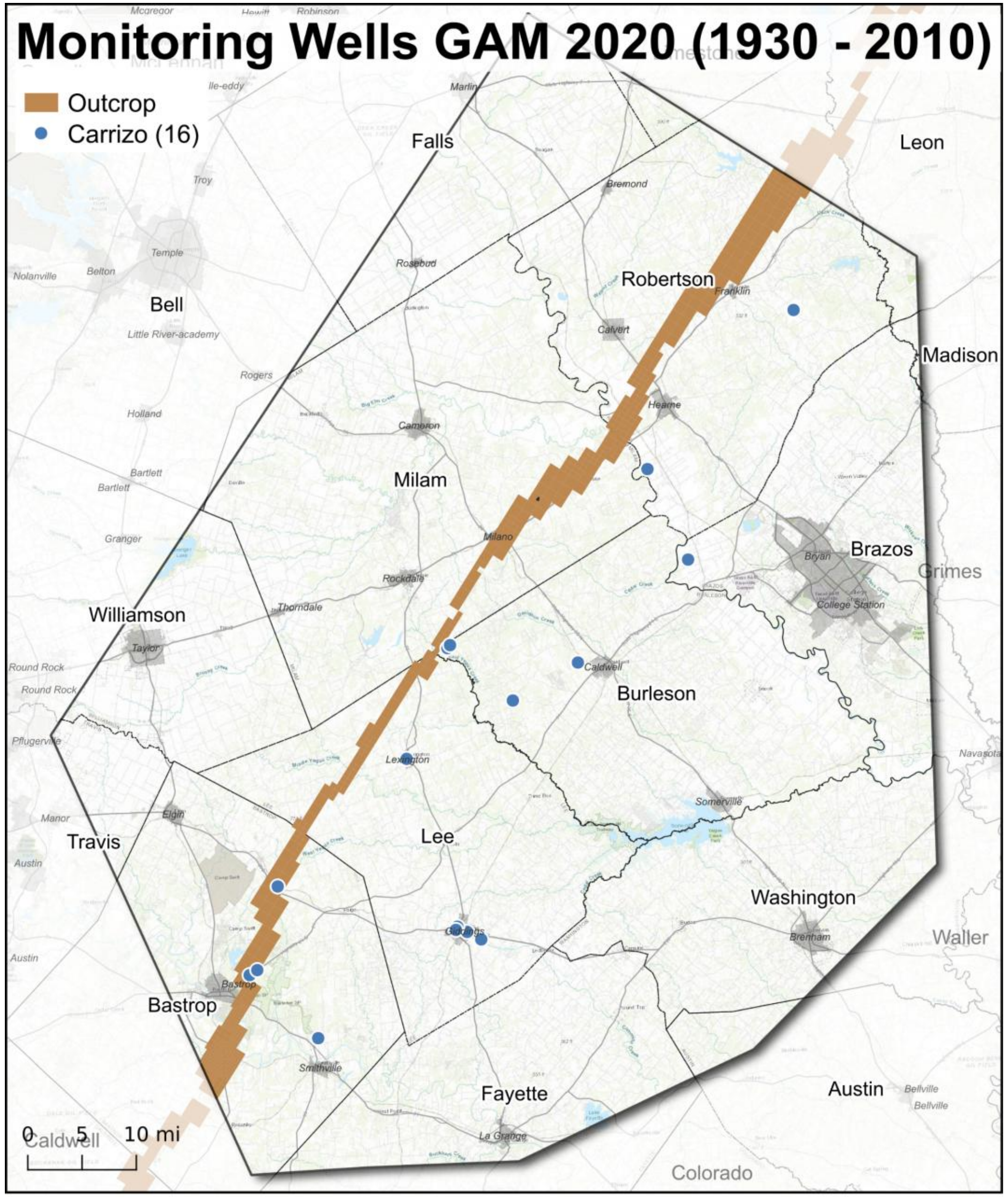
All 200 wells are assigned to Calvert Bluff based on GAM model Layers

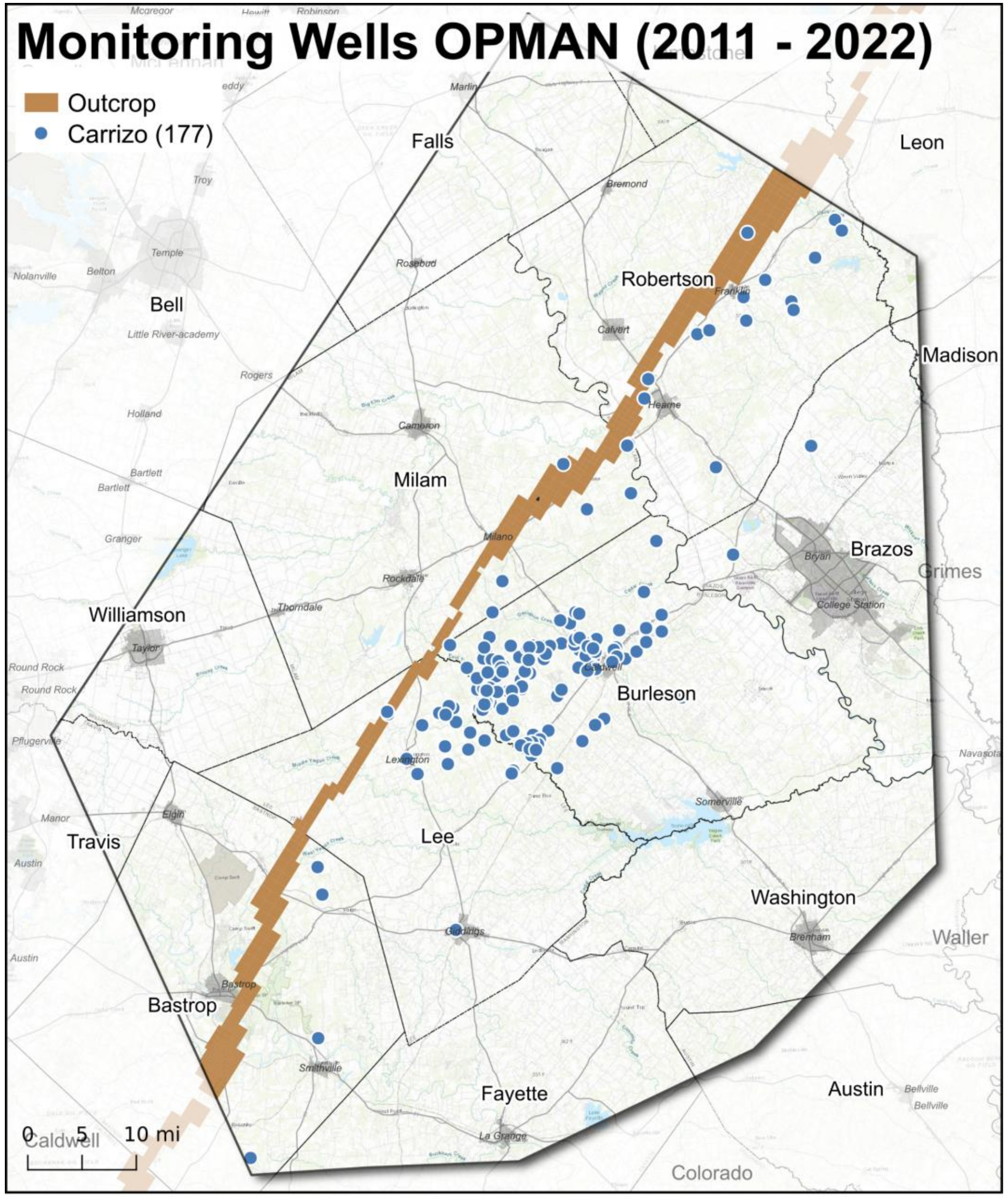


All 297 wells are assigned to Simsboro based on GAM model Layers

Location of Measured Water Levels

Measured Water Levels: Carrizo





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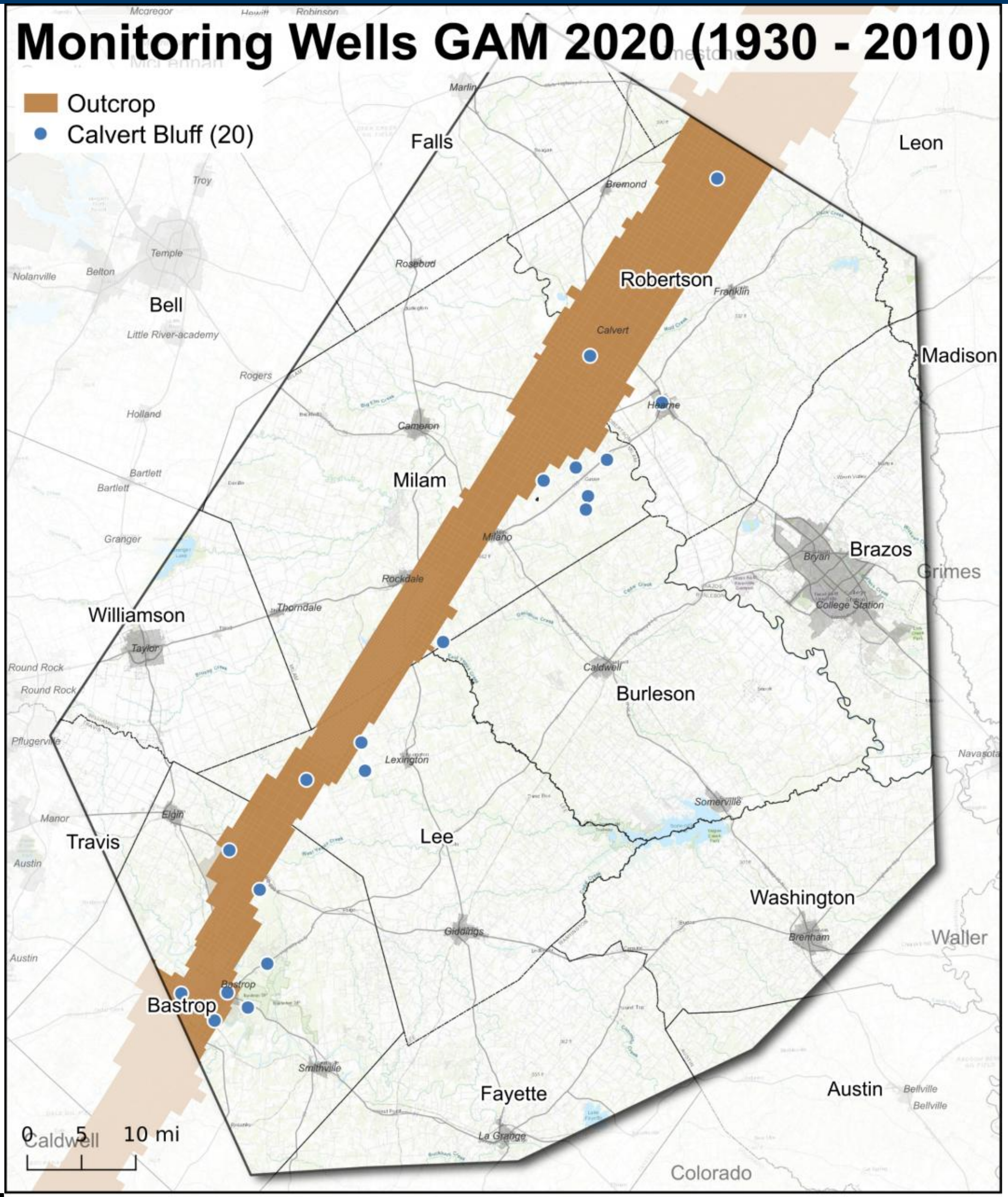
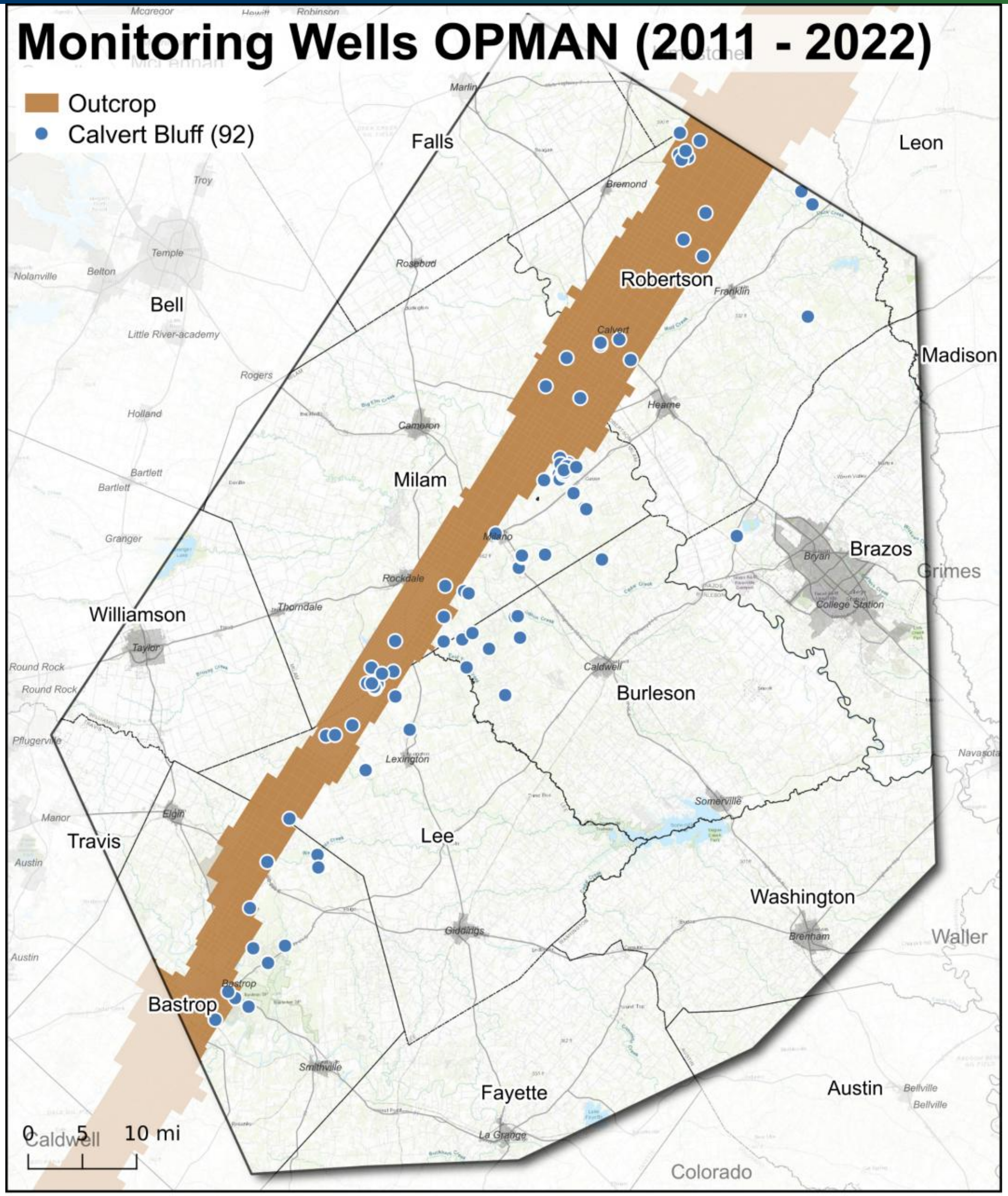
Measured Water Levels: Calvert Bluff





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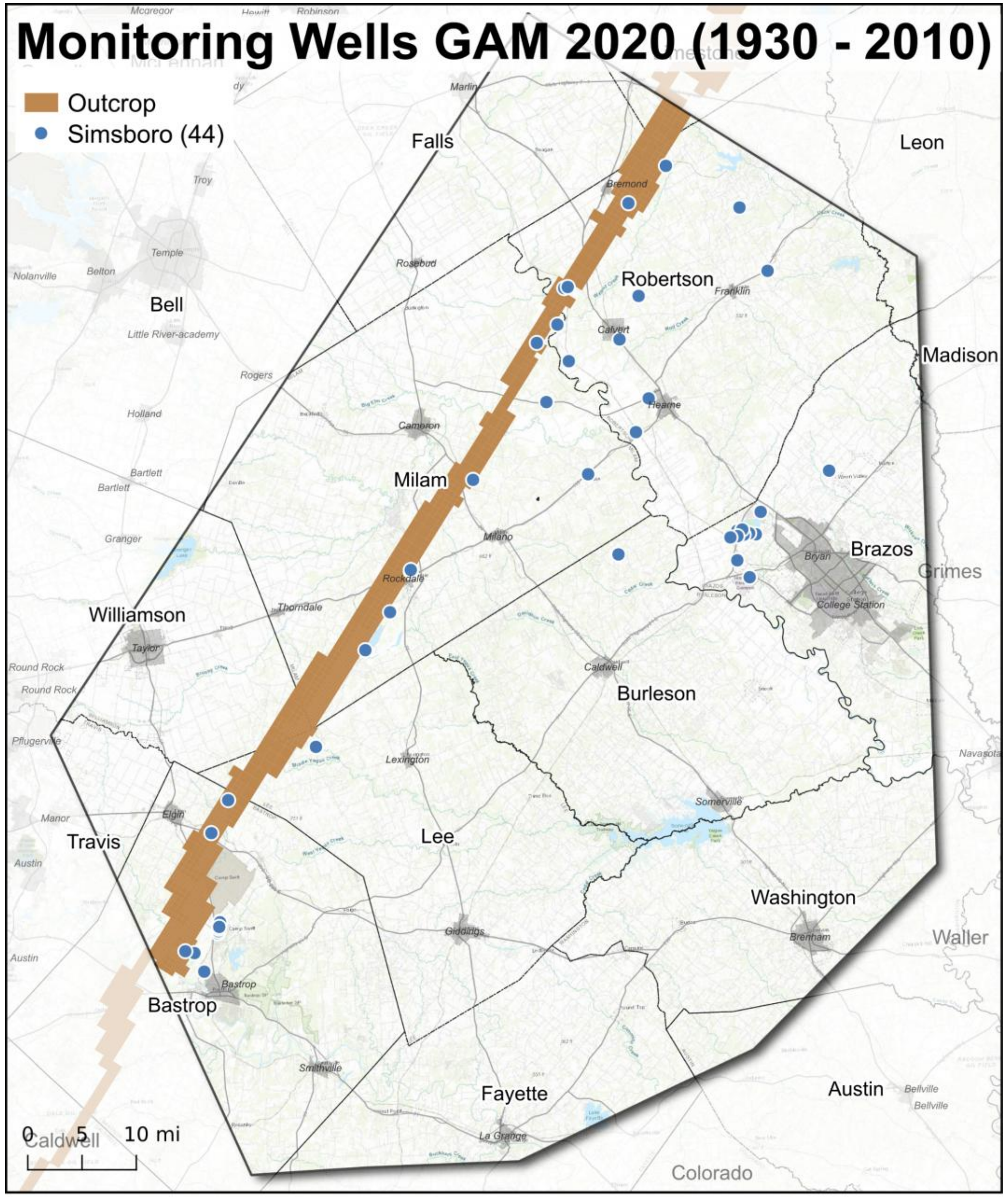
Measured Water Levels: Simsboro



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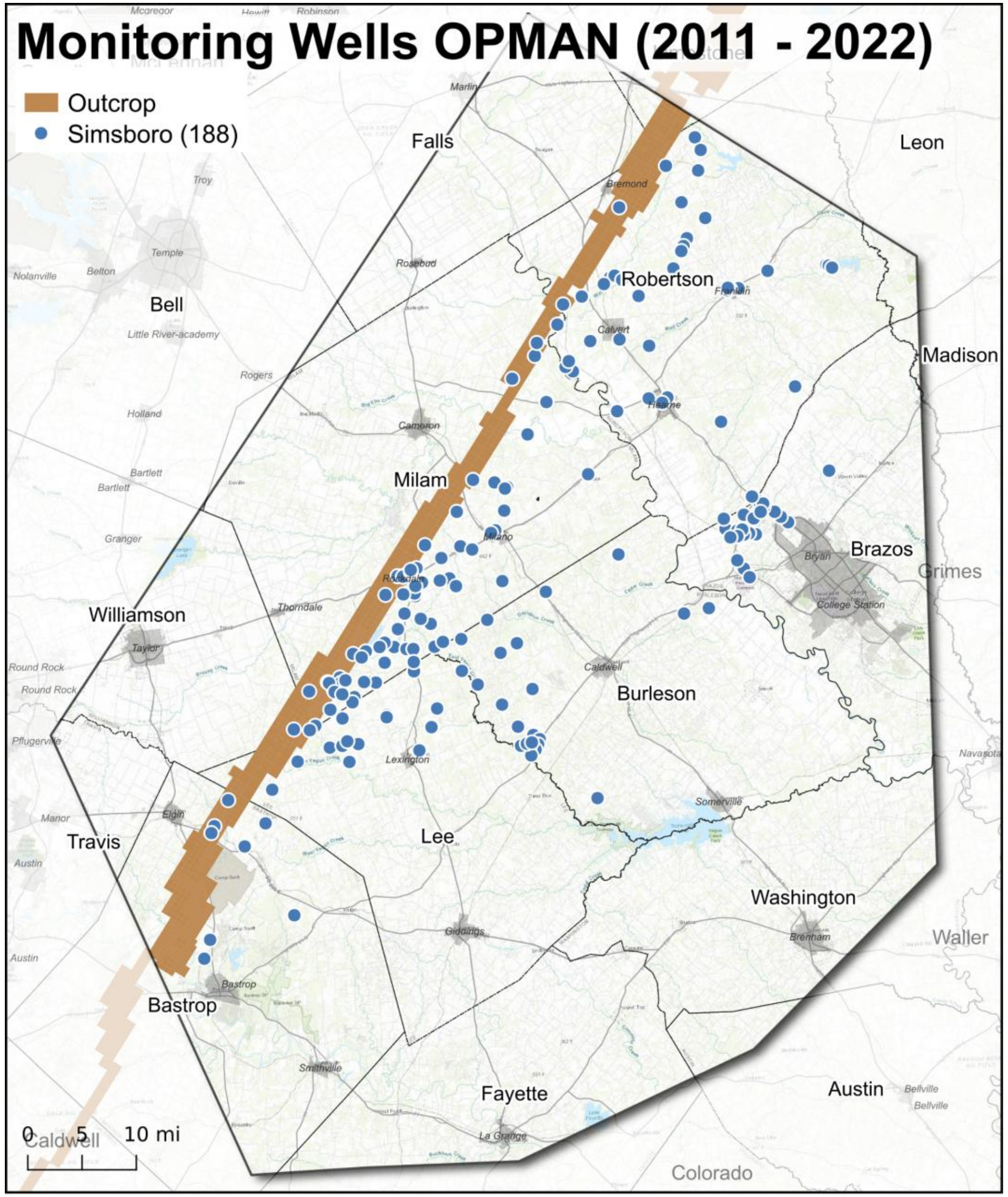

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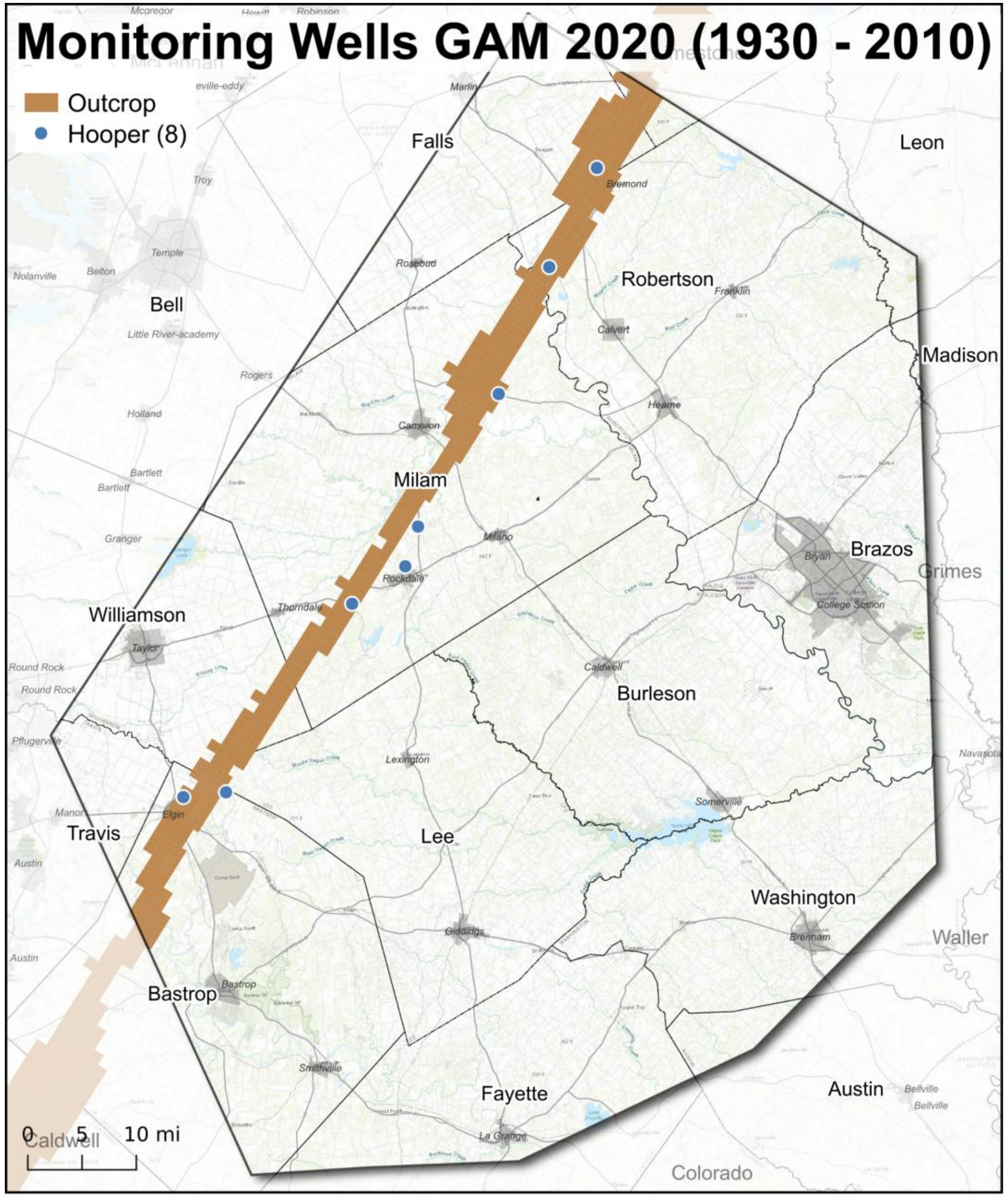
Measured Water Levels: Hooper



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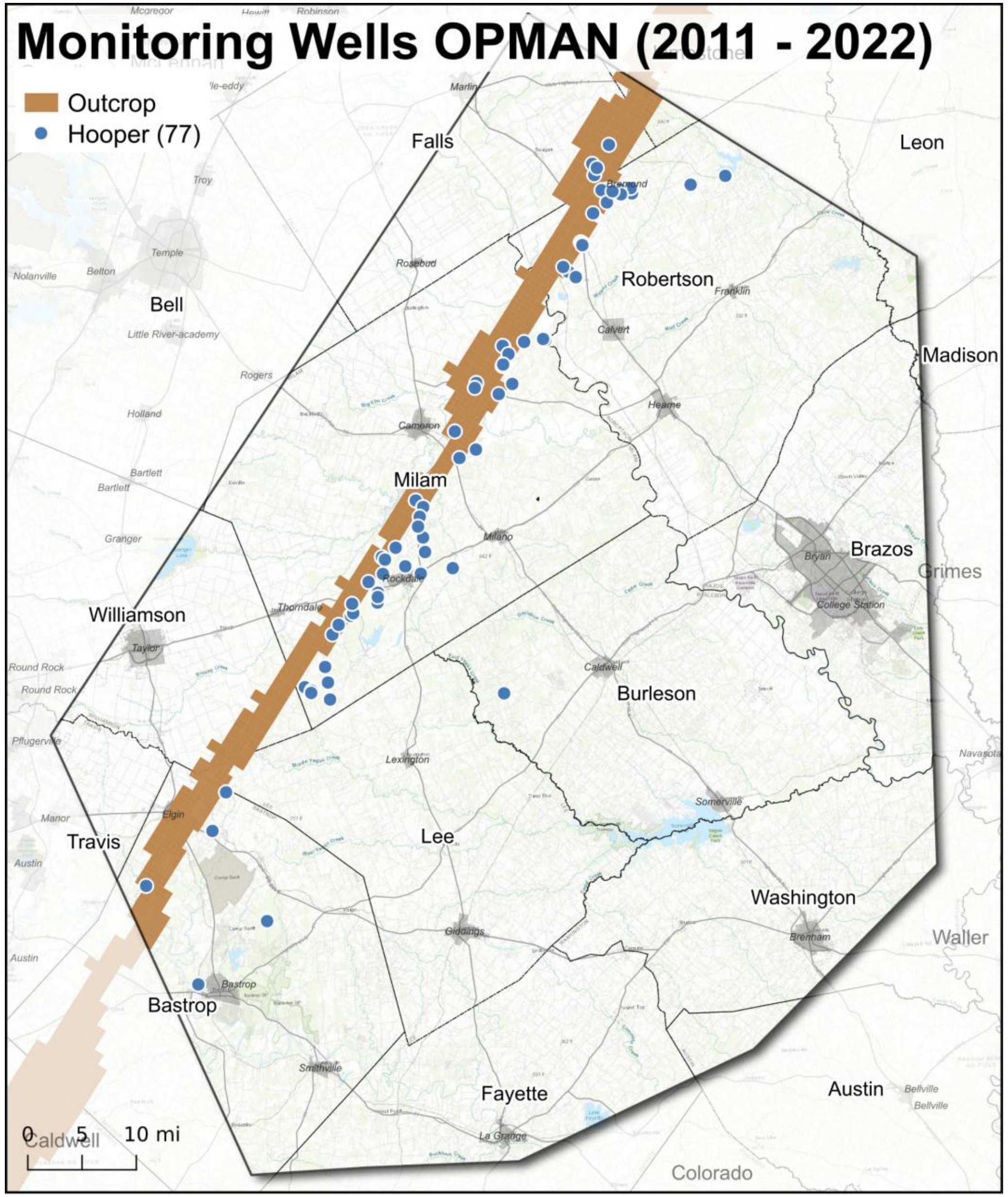

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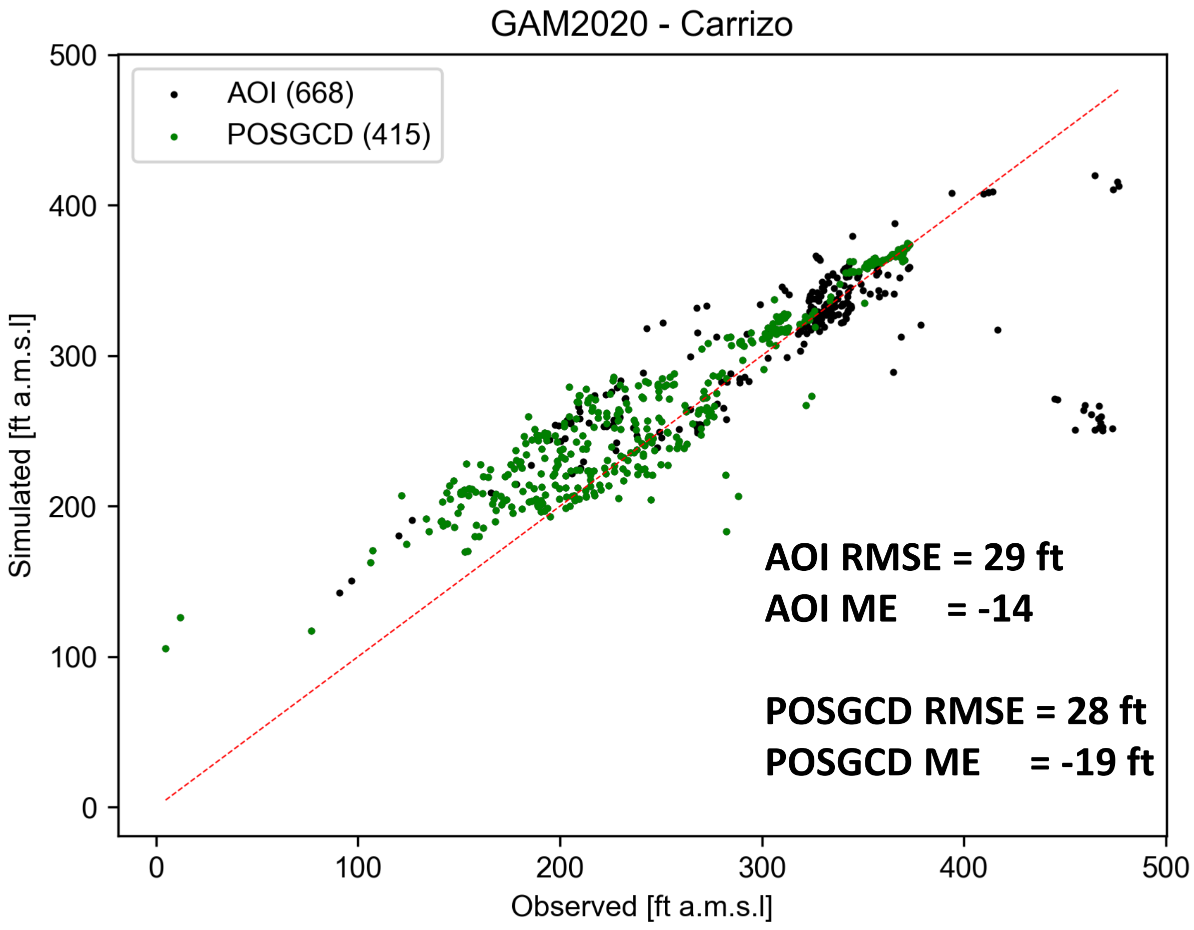
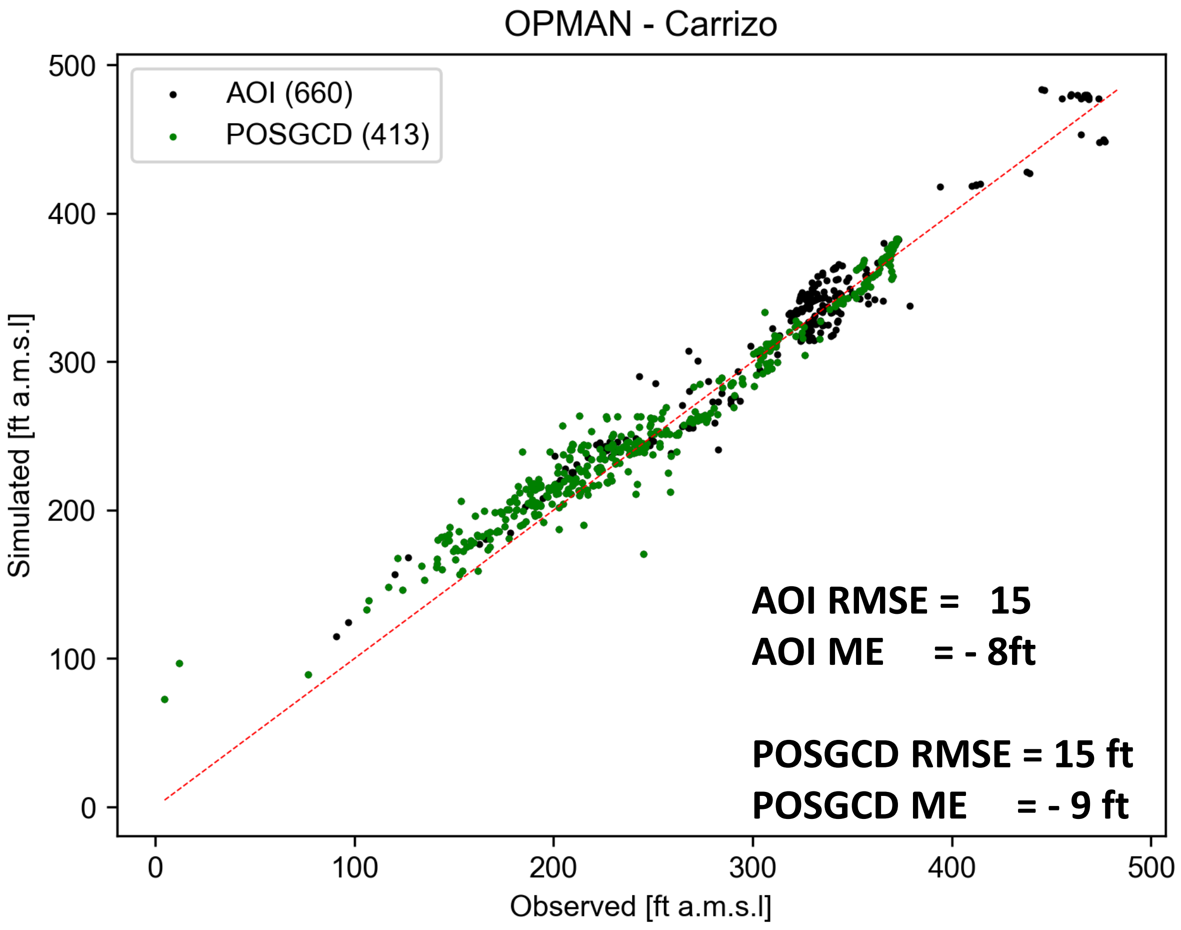
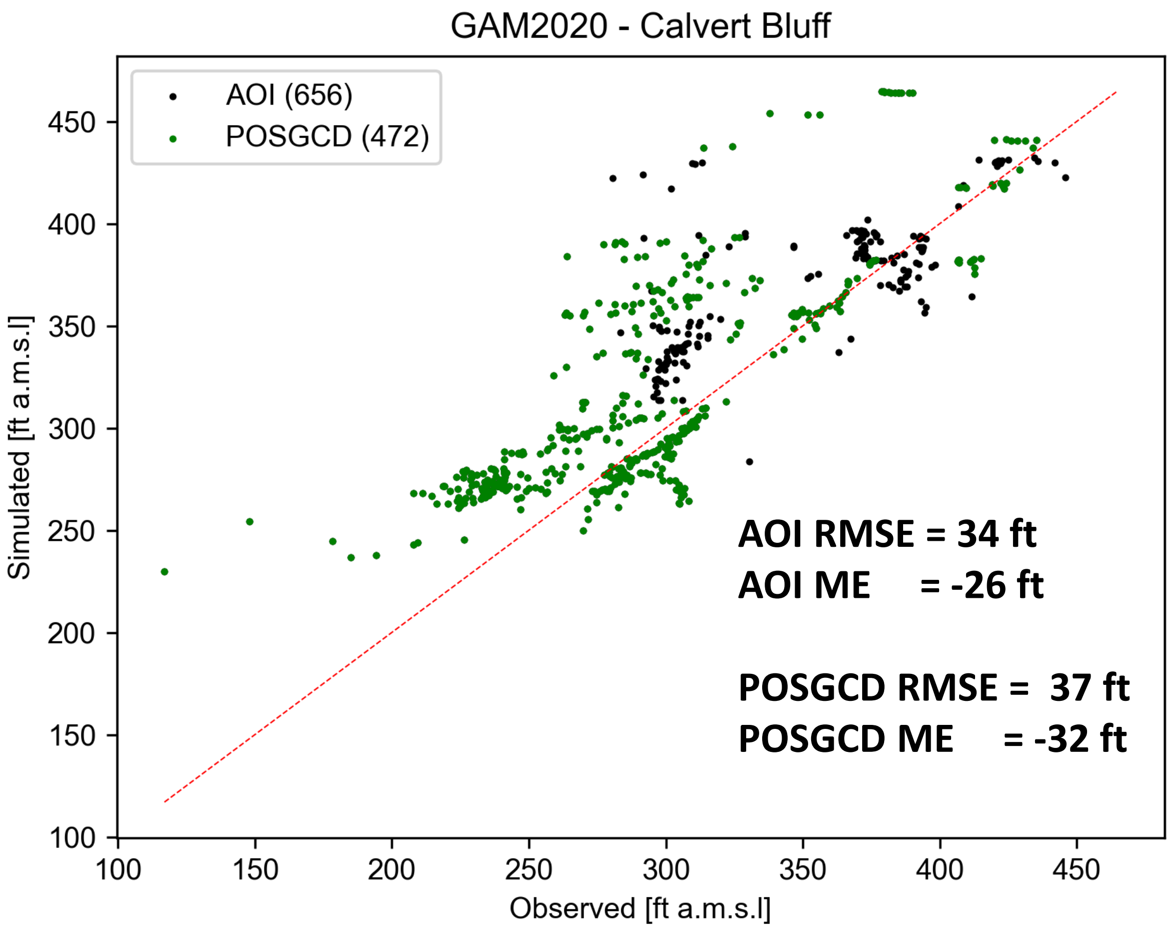
Comparison of Simulated to Measured 1930 – 2022 Water Levels: Carrizo

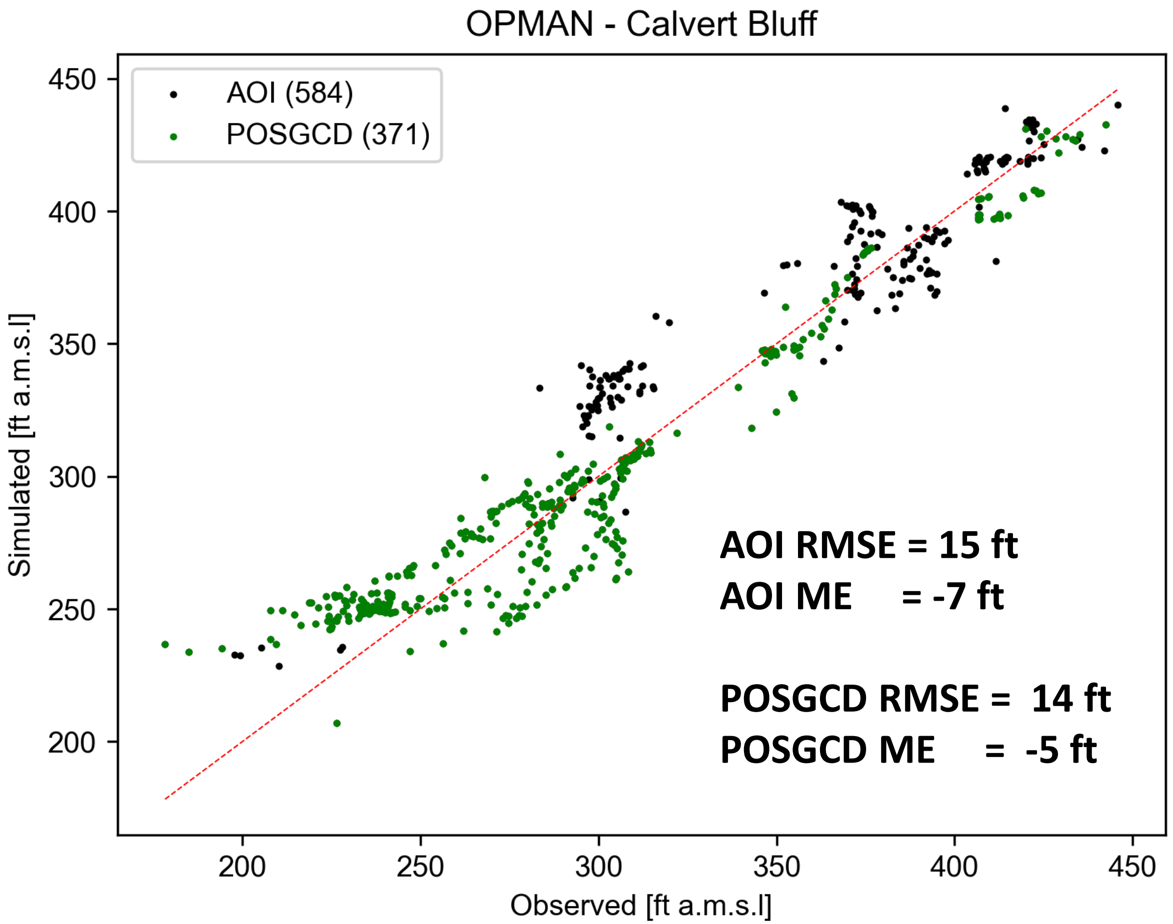




Note: RSME is root-mean square error
ME is mean error (neg. values are overpredictions)

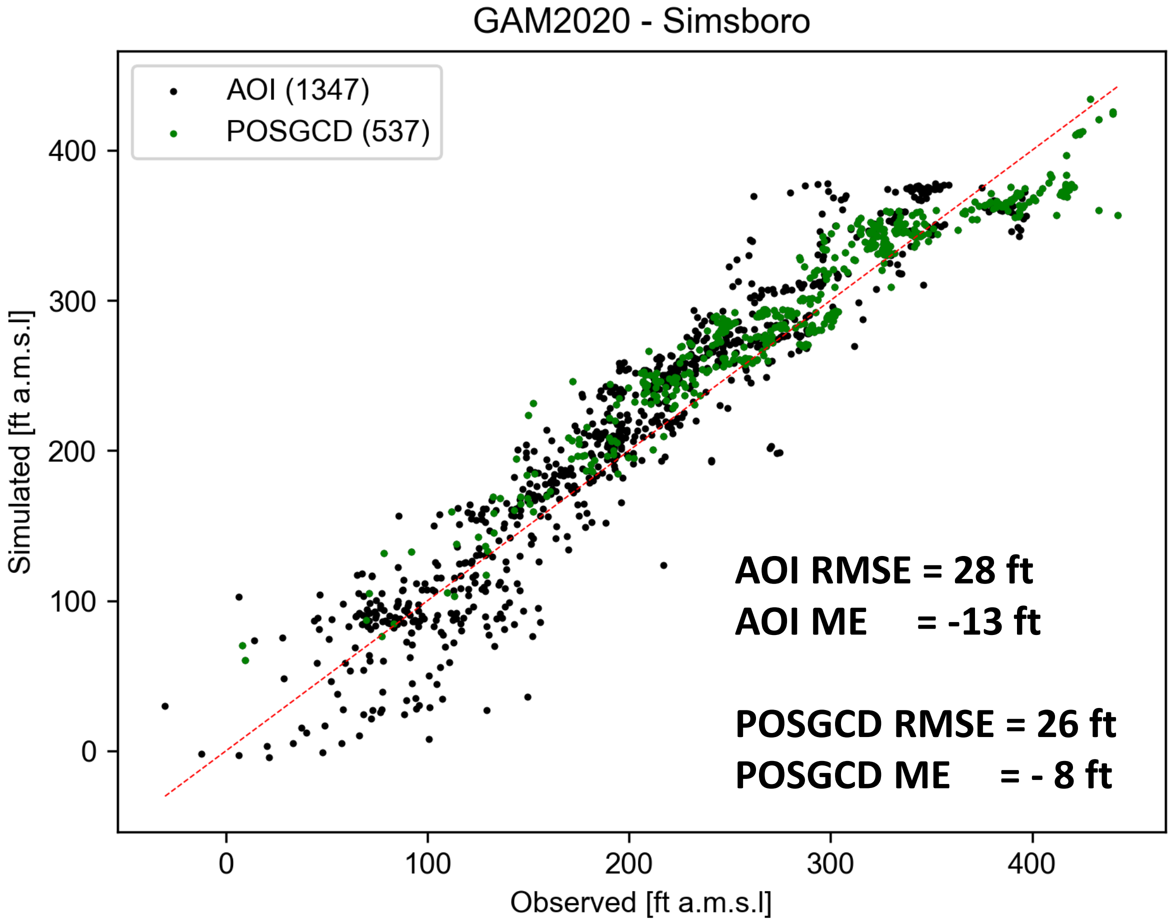
Comparison of Simulated to Measured 1930 – 2022 Water Levels: Calvert Bluff

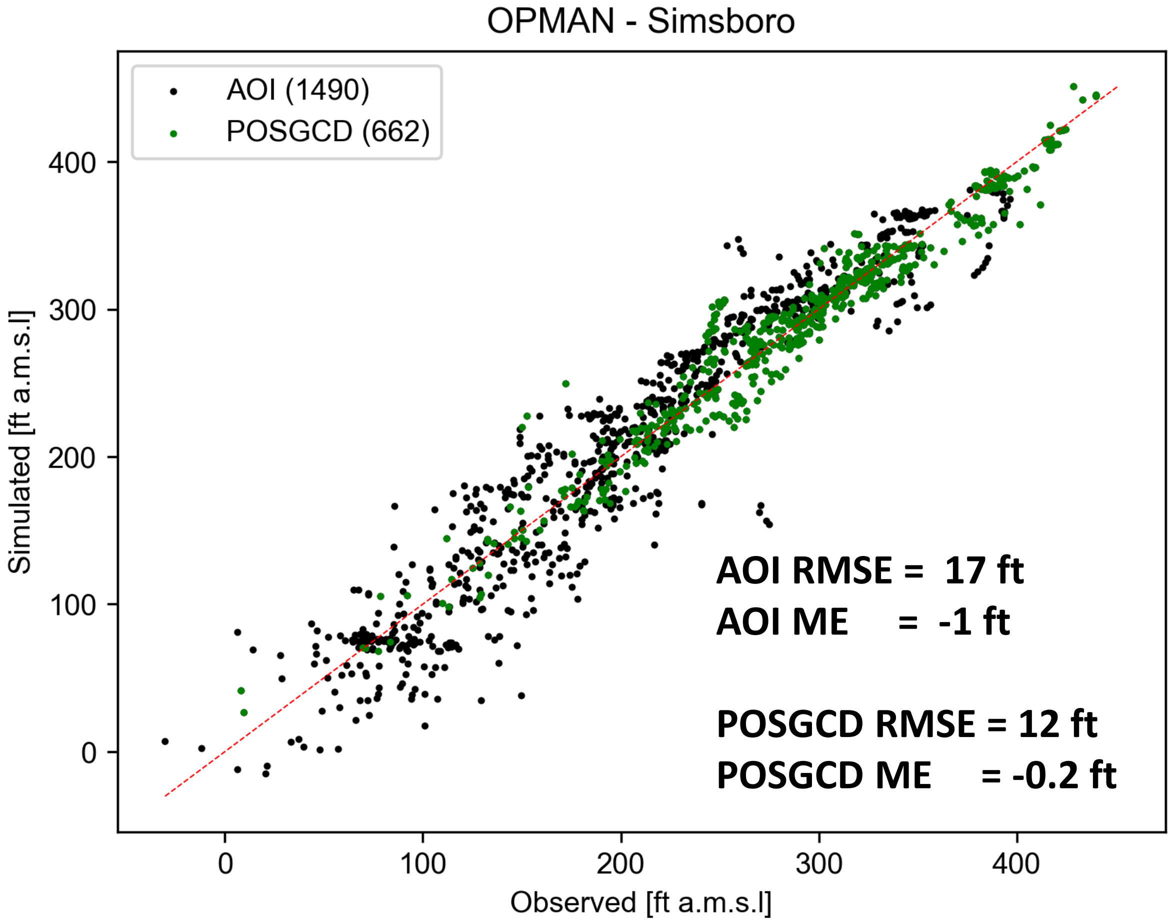




Note: RSME is root-mean square error
ME is mean error (neg. values are overpredictions)

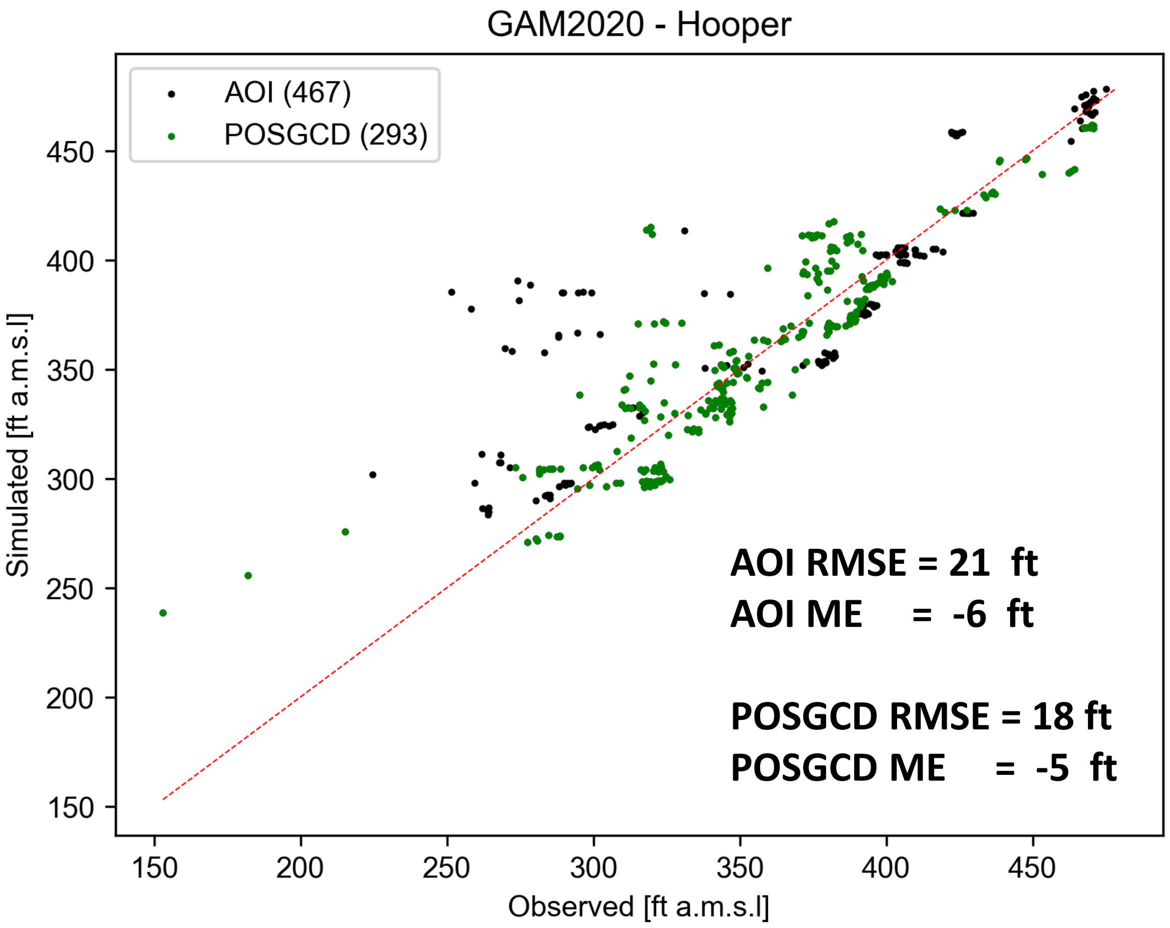
Comparison of Simulated to Measured 1930 – 2022 Water Levels: Simsboro

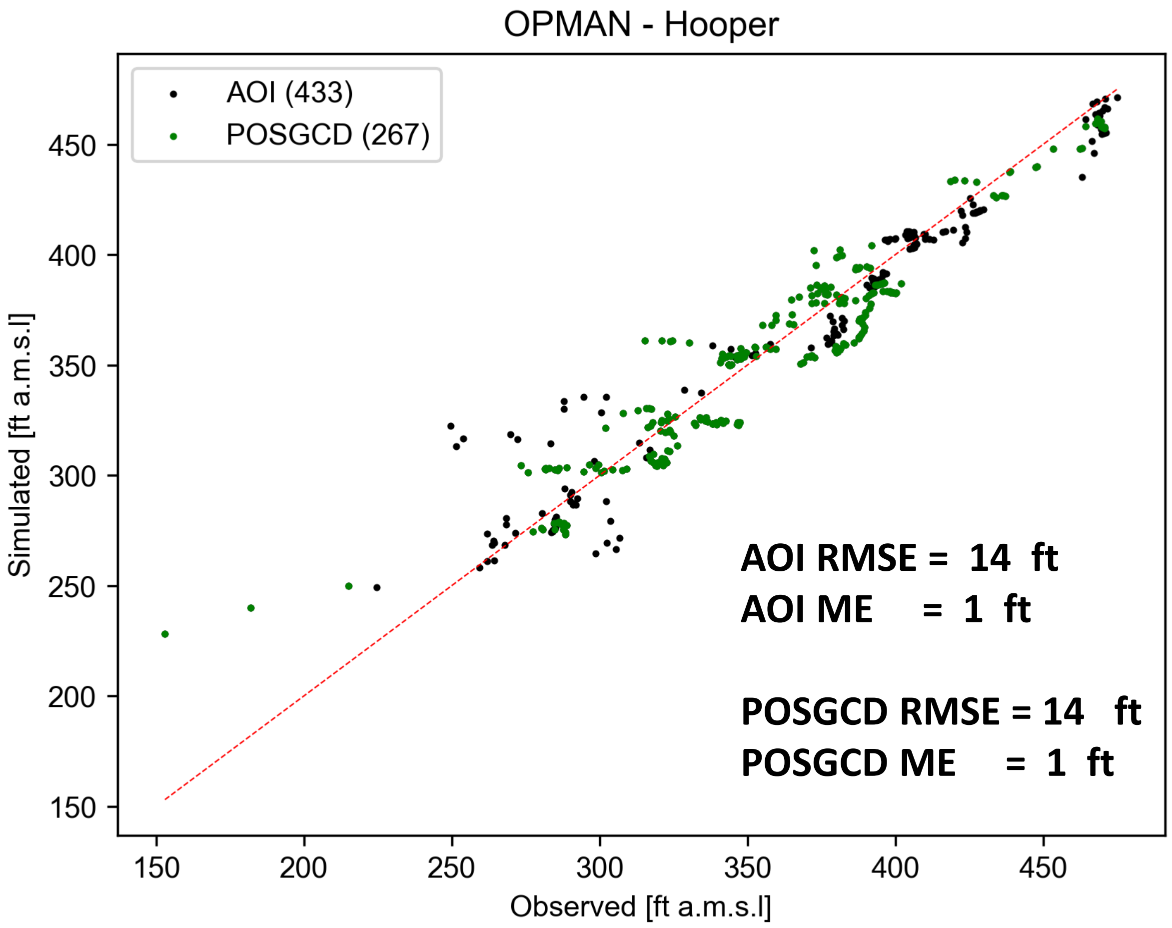




Note: RSME is root-mean square error
ME is mean error (neg. values are overpredictions)

Comparison of Simulated to Measured 1930 – 2022 Water Levels: Hooper

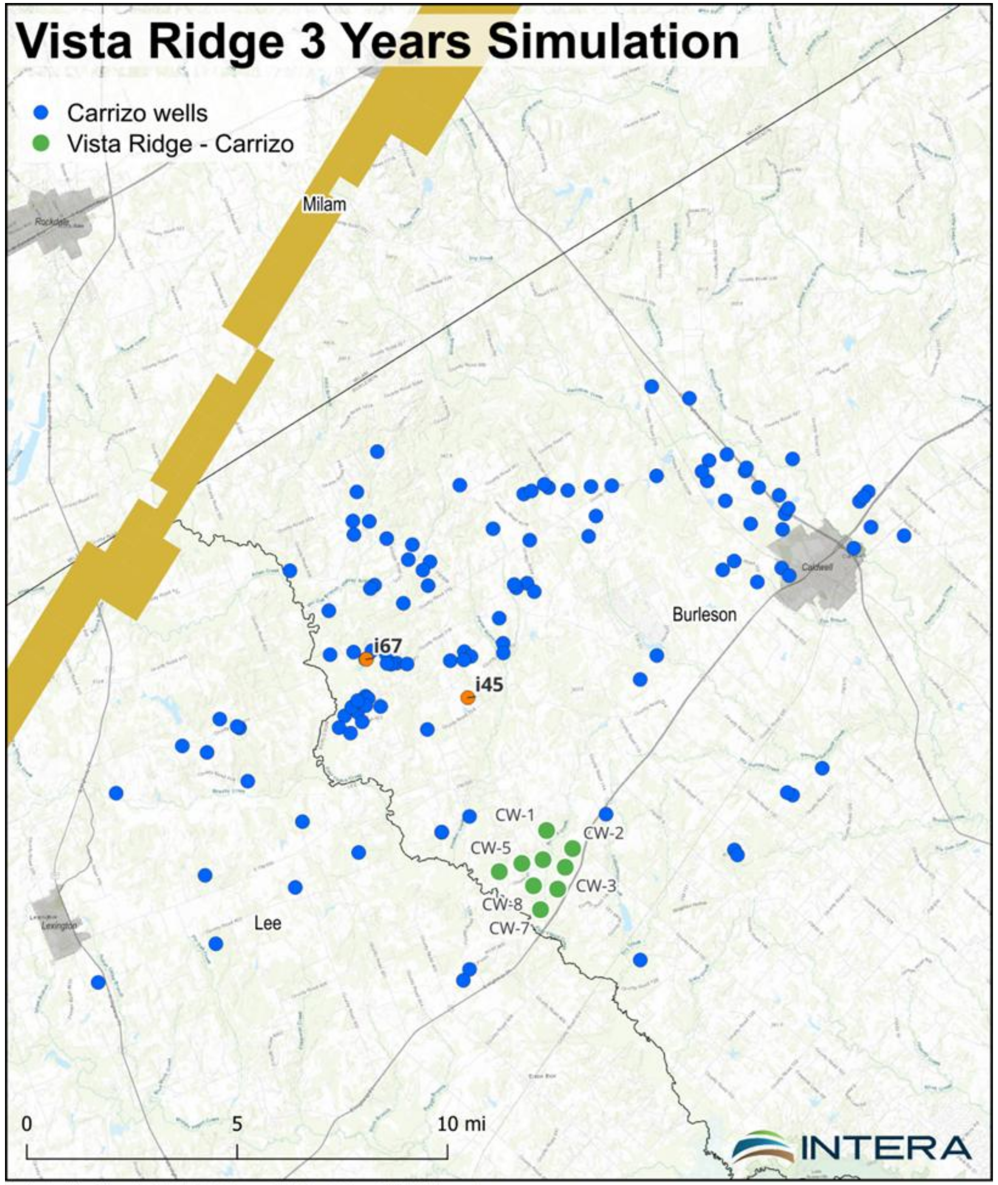




Note: RSME is root-mean square error
ME is mean error (neg. values are overpredictions)

Vista Ridge Drawdowns

Vista Ridge Monitoring Locations: Carrizo & Simsboro



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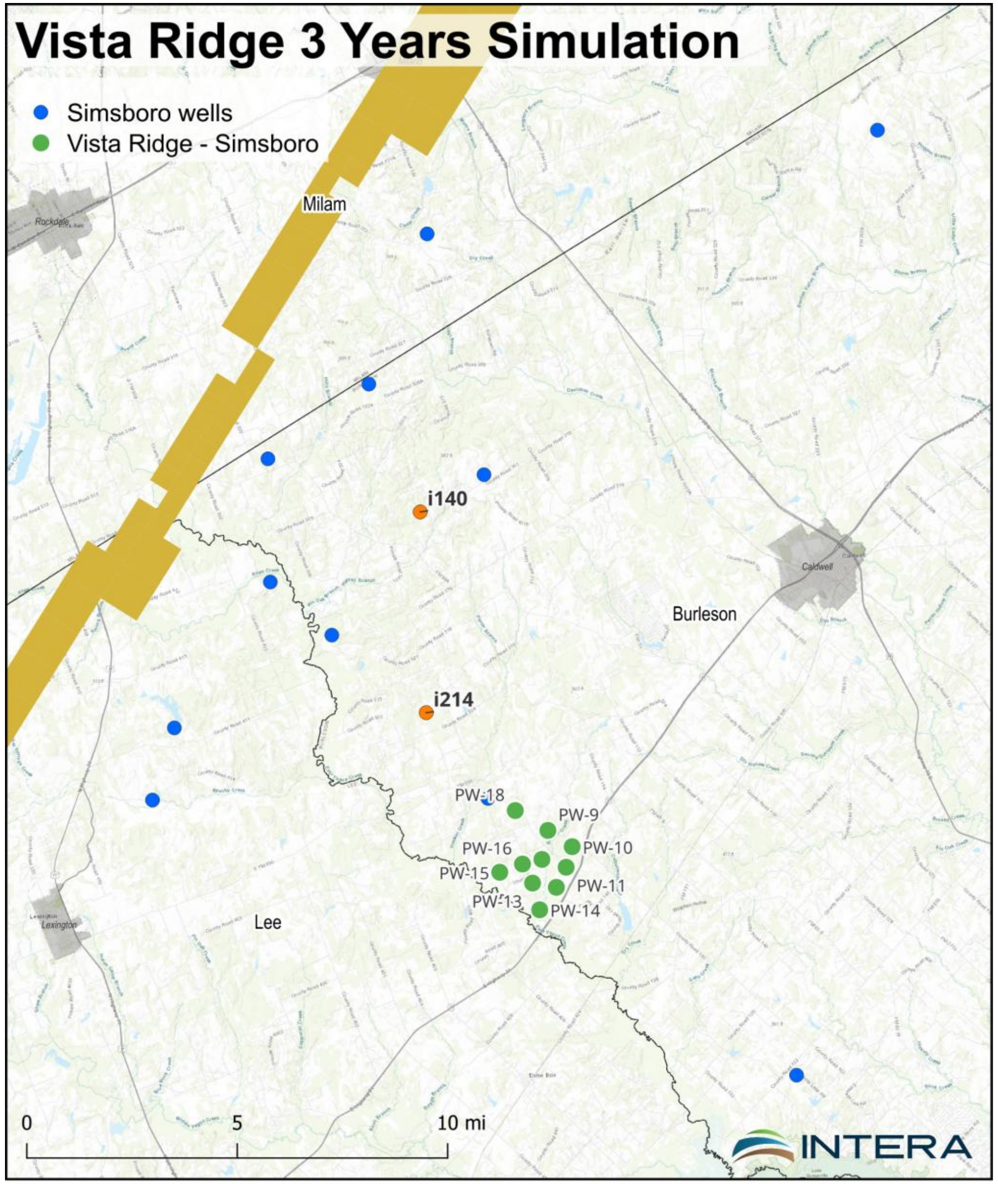

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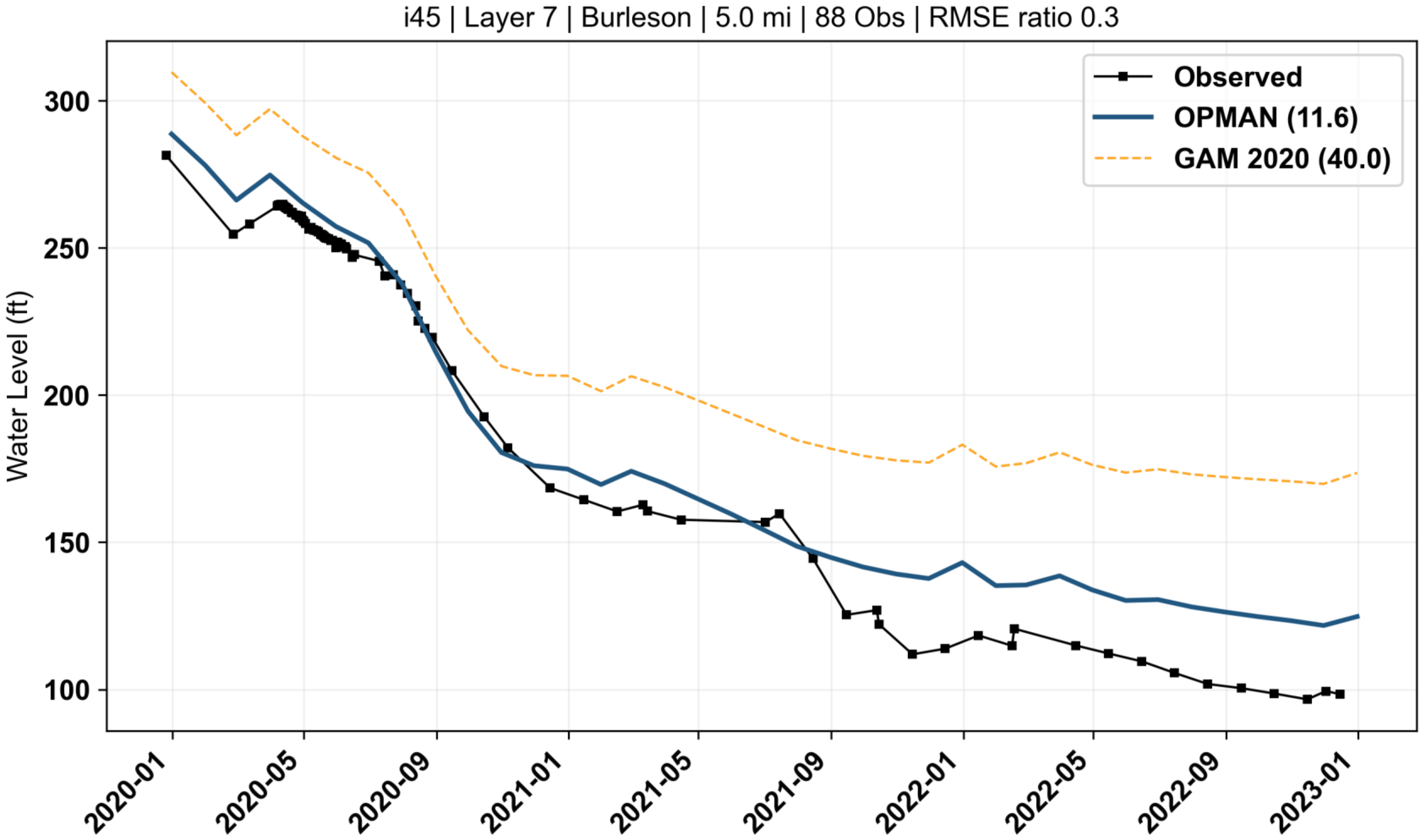
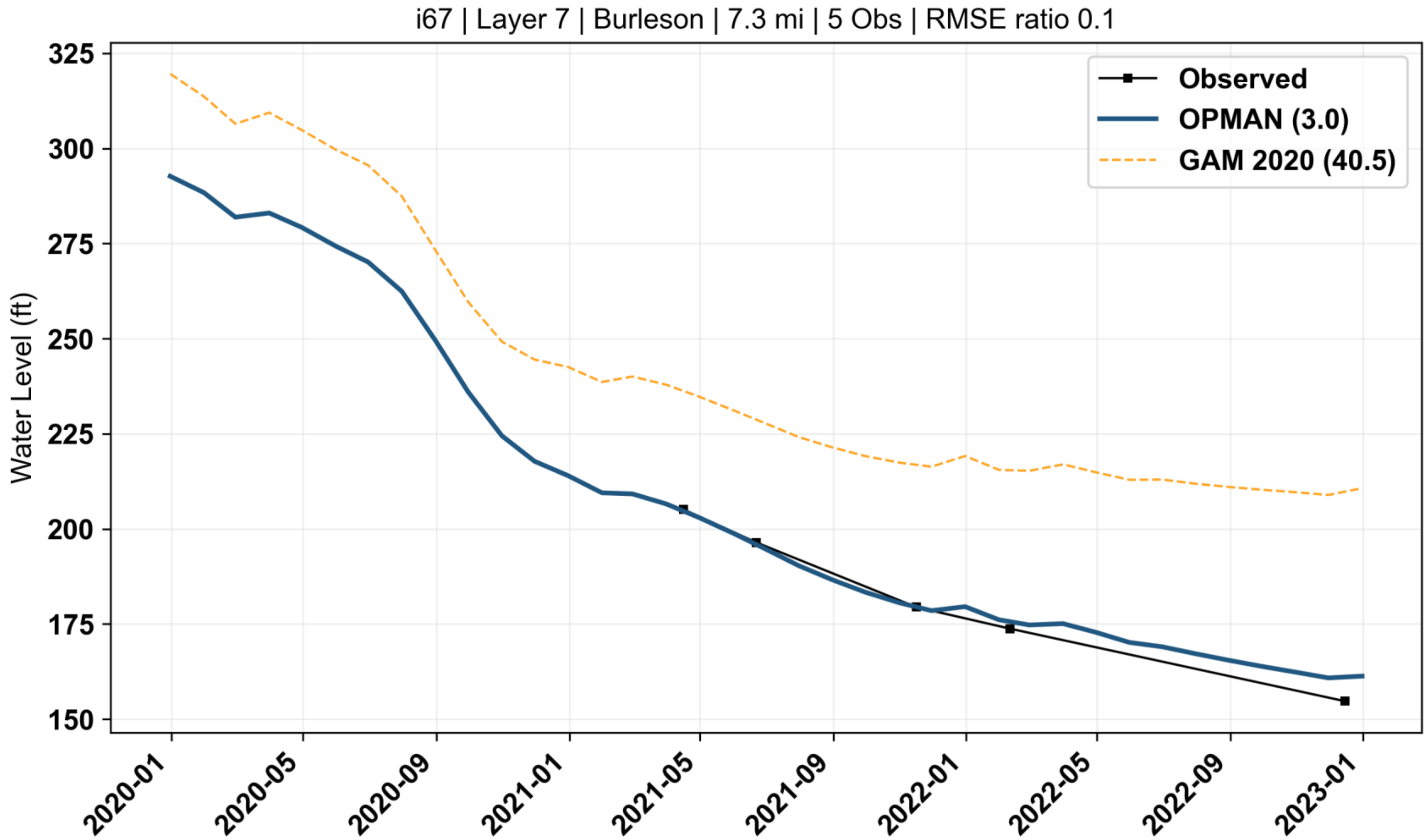
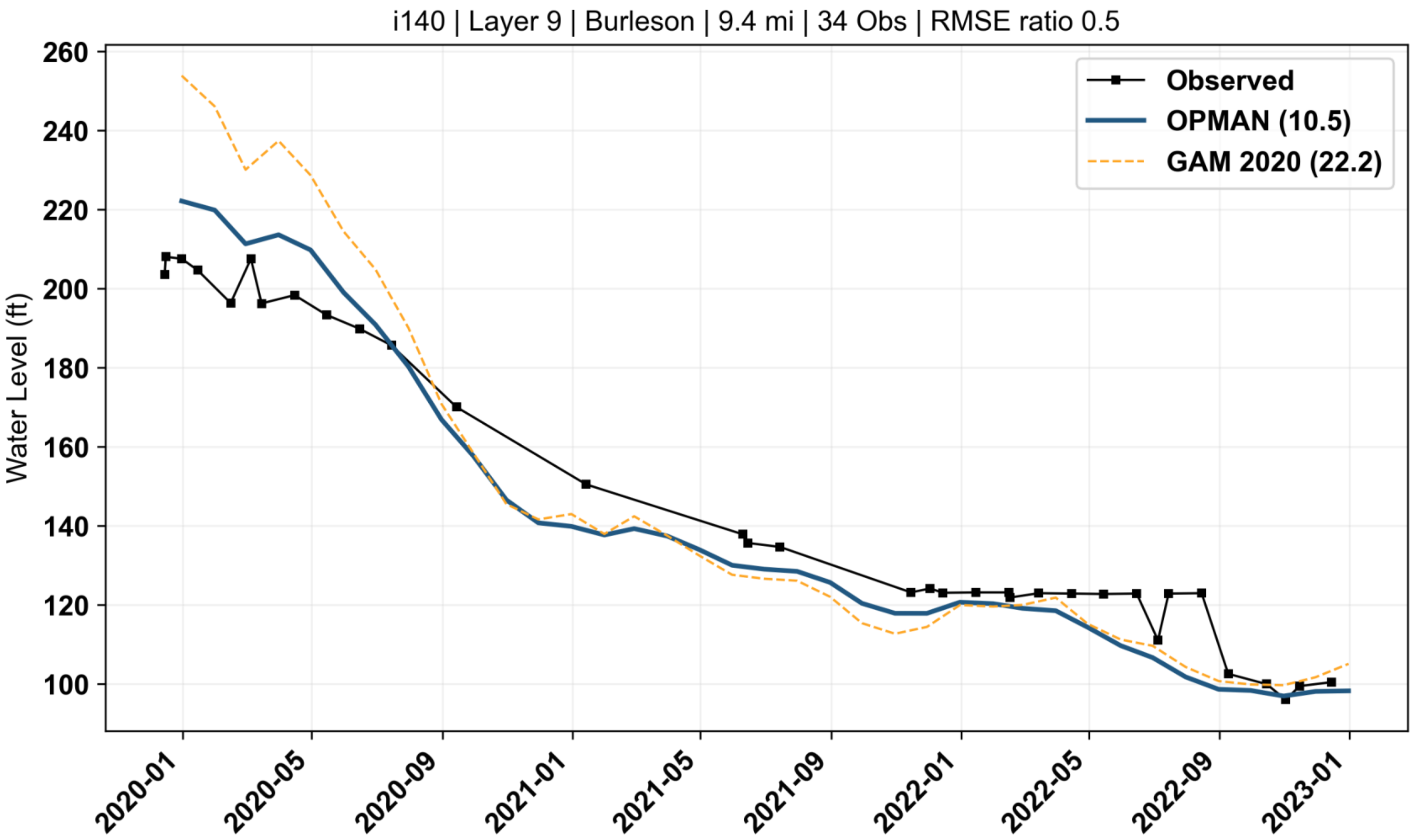
Simulated Drawdown for Vista Ridge Carizzo Monitoring Locations: Well i45



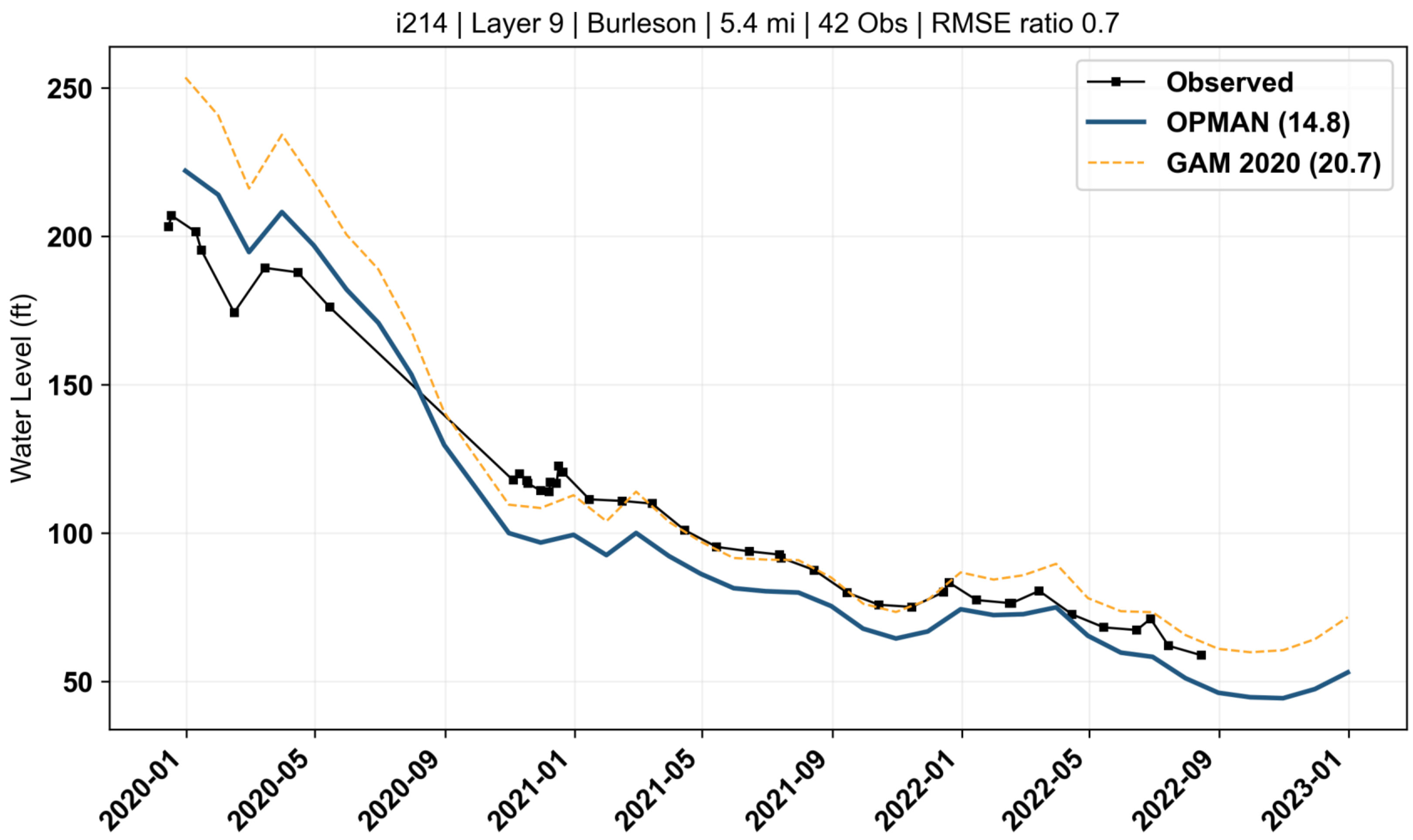
Simulated Drawdown for Vista Ridge Carrizo Monitoring Locations: Well i67



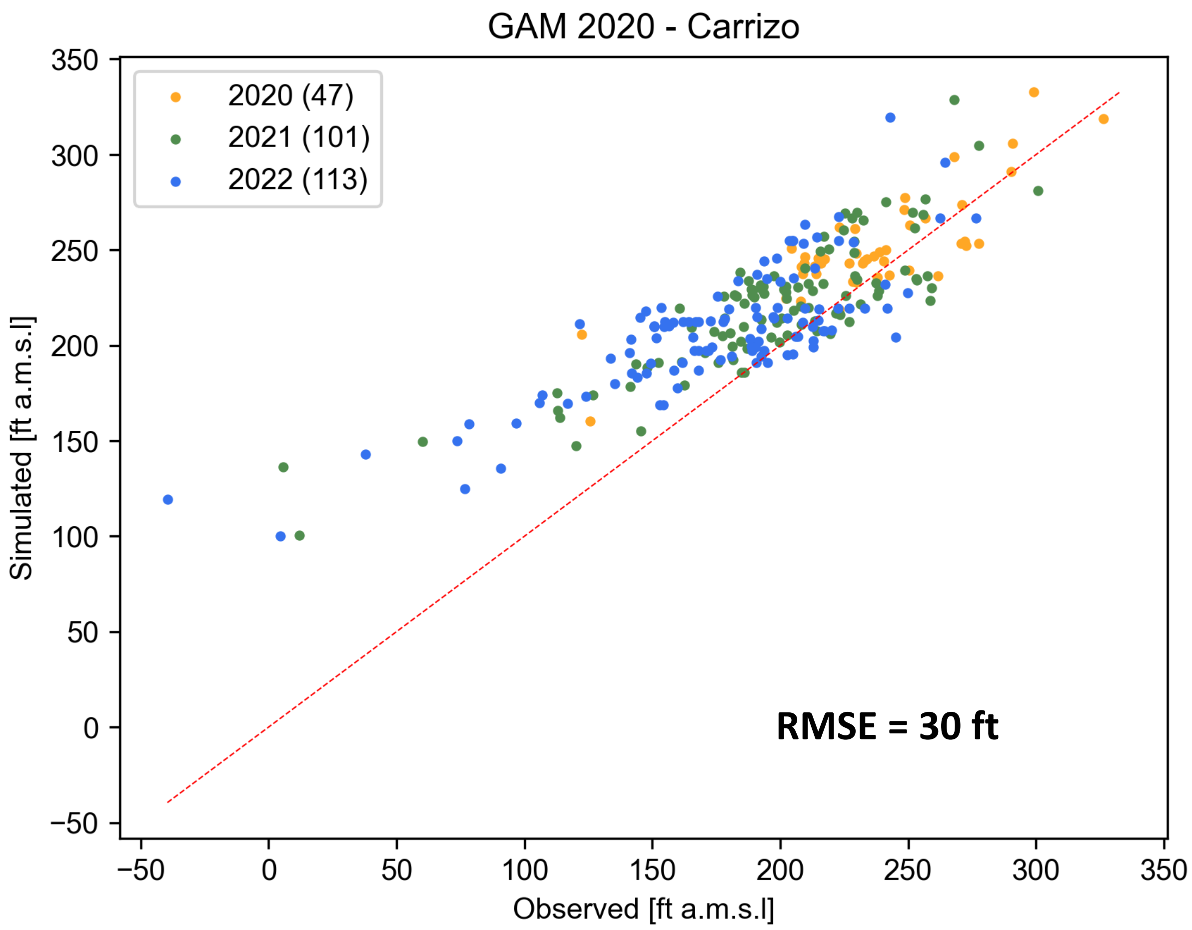
Simulated Drawdown for Vista Ridge Simsboro Monitoring Locations: Well i140

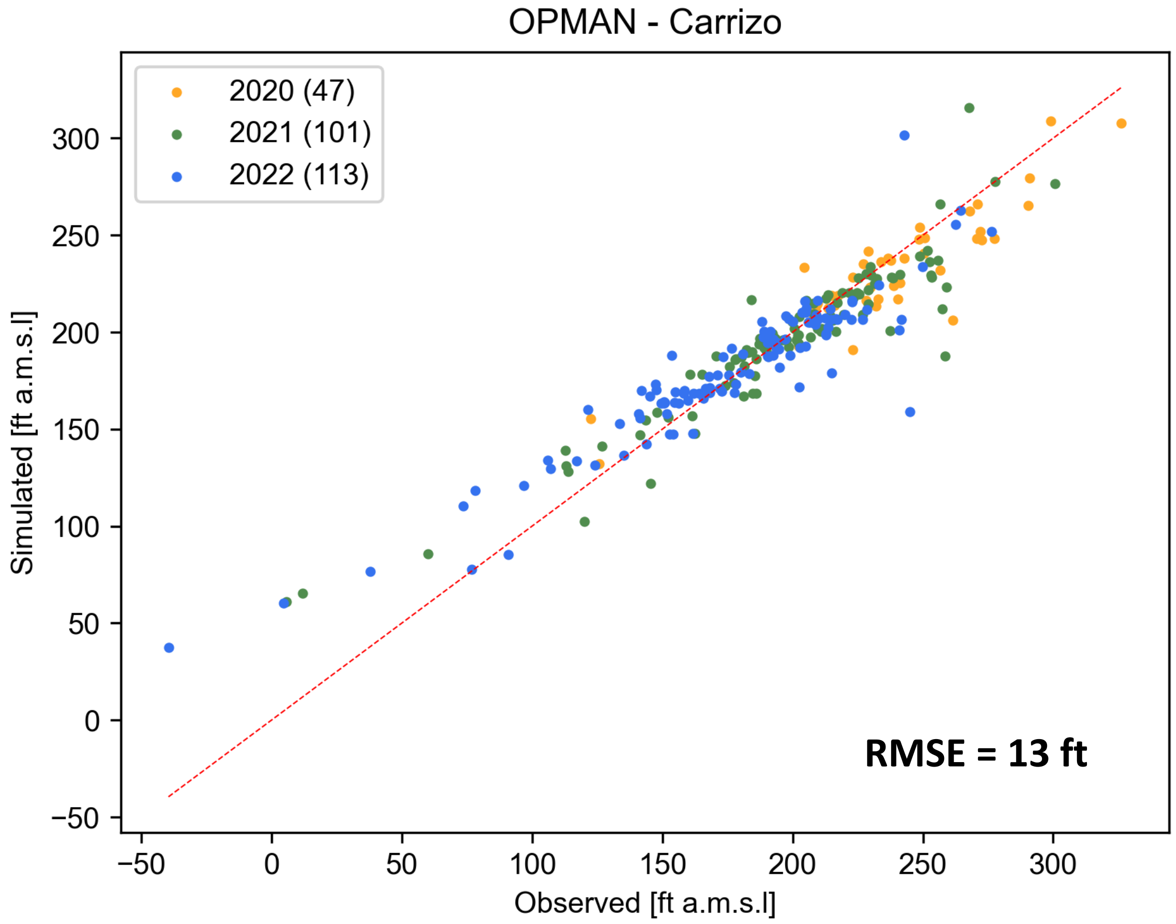


Simulated Drawdown for Vista Ridge Simsboro Monitoring Locations: Well i214

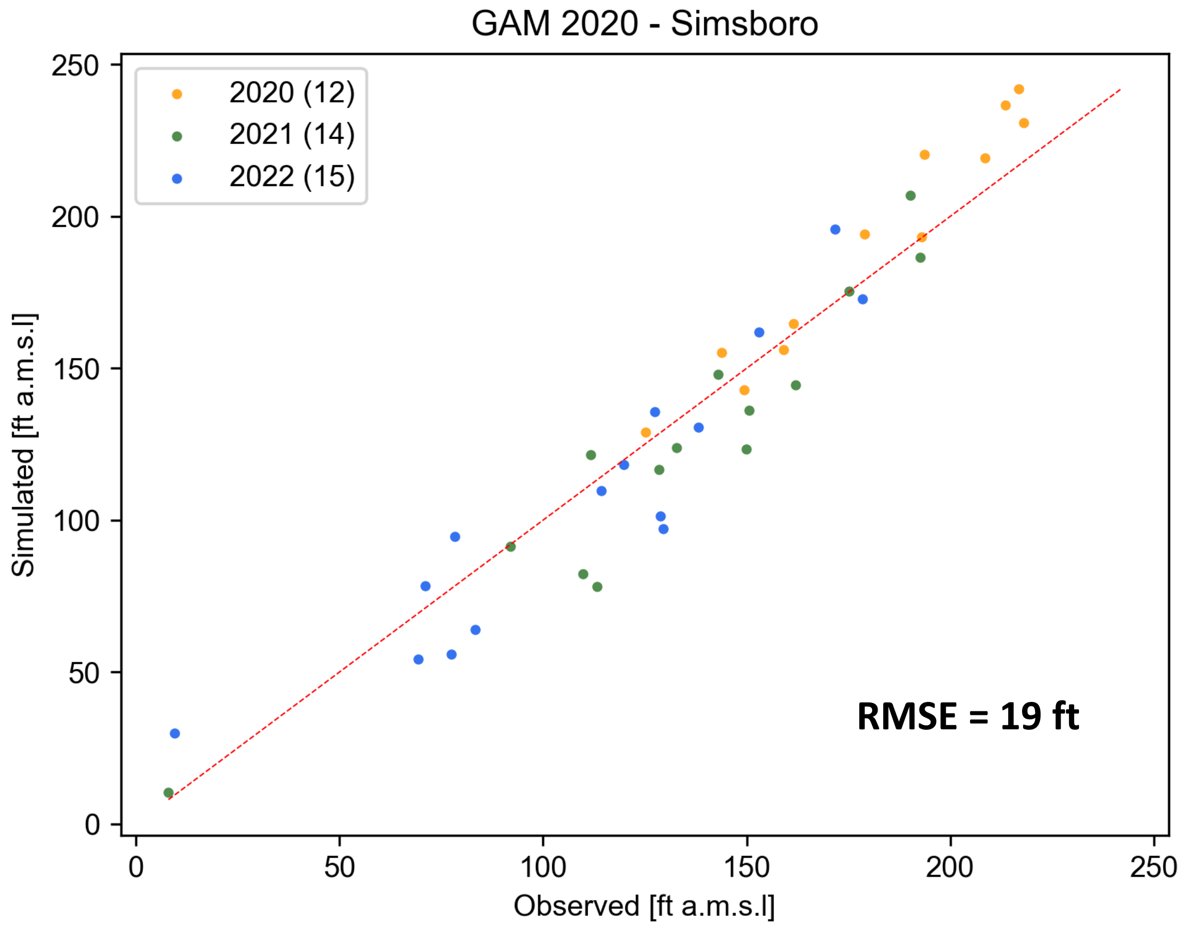


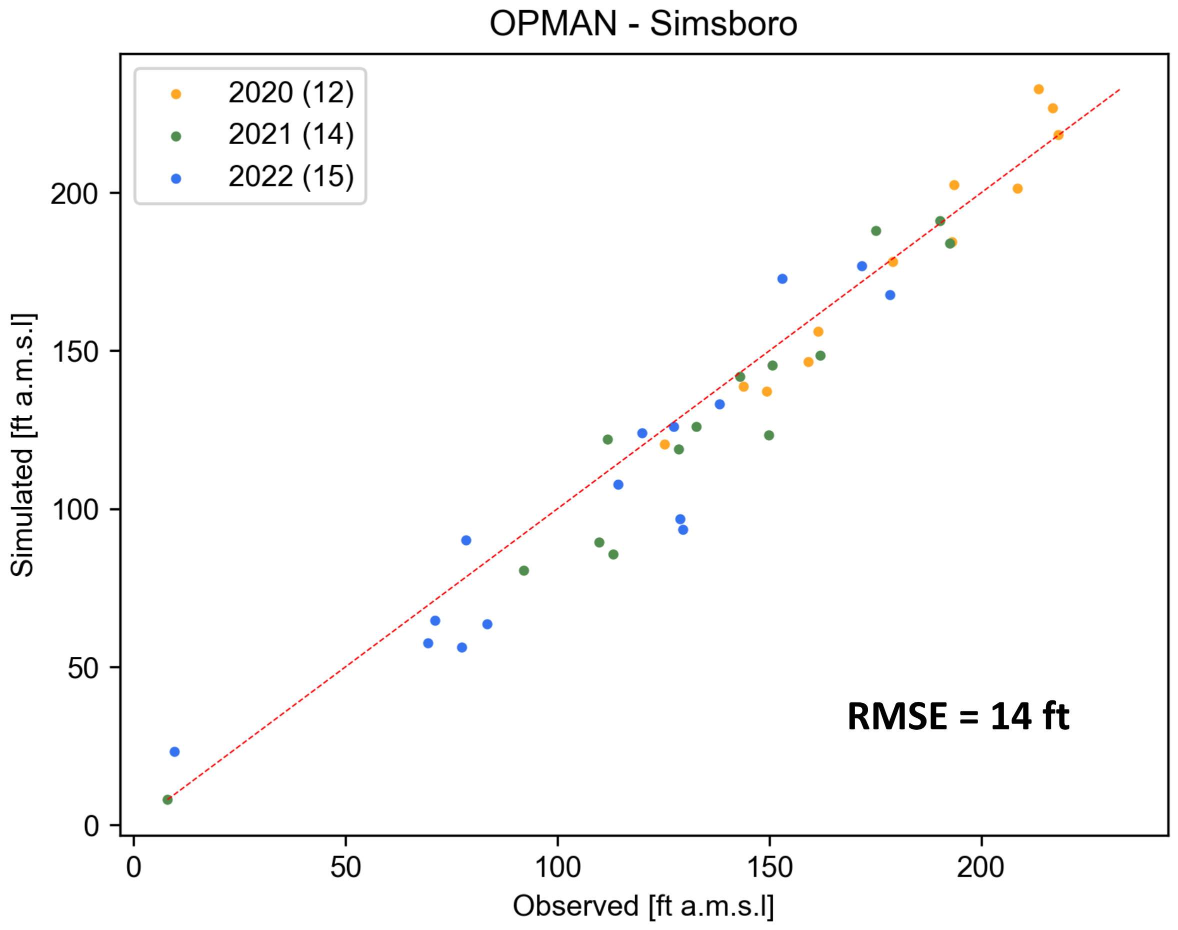
Comparison of Measured versus Modeled Drawdowns: Monthly Intervals from 2020 to 2030: Carrizo





Comparison of Measured versus Modeled Drawdowns: Monthly Intervals from 2020 to 2030: Simsboro



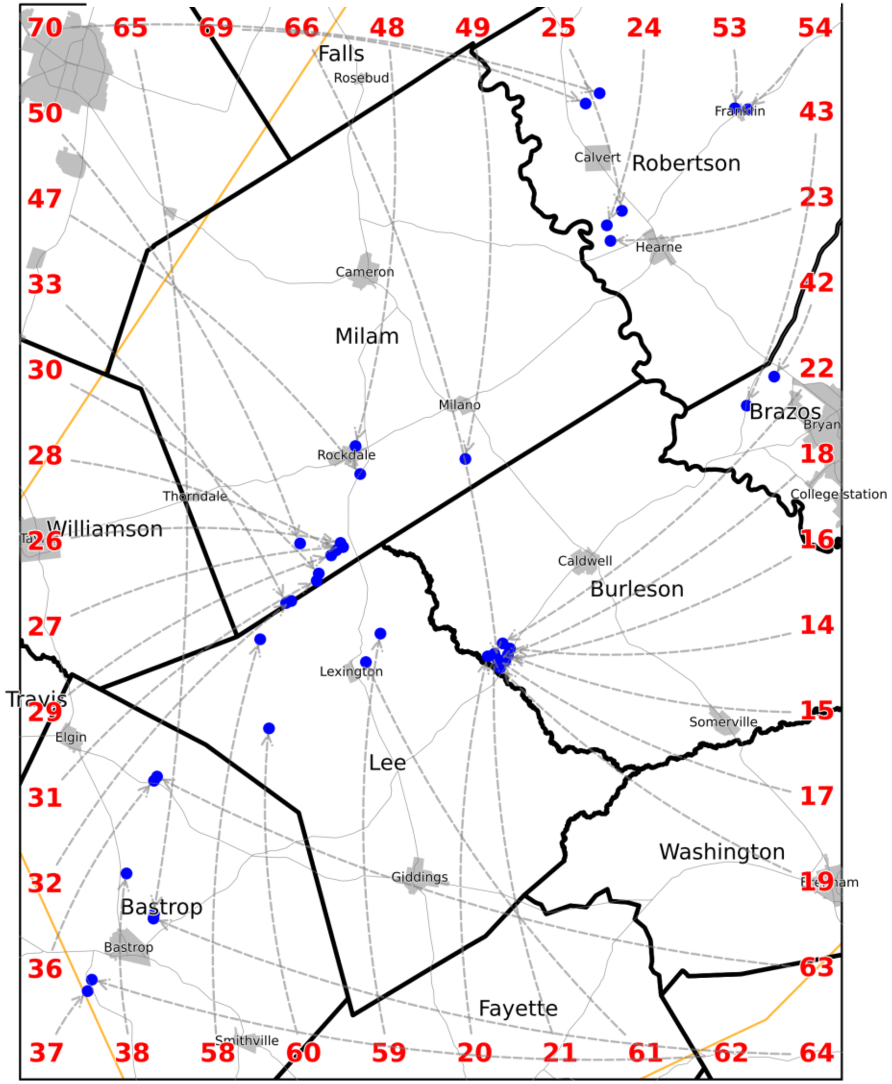


Aquifer Pumping Tests

Aquifer Pumping Tests: Locations

- GAM Model Calibration - 2018
  - Historical Simulation 1930 – 2010 to match water levels
- GAM Model Calibration - 2020
  - Adjust Simboro properties at Vista Ridge to match transmissivity of aquifer pumping test results
- OPMAN – Calibration
  - Historical Simulation 1930 – 2022 to match water levels
  - 71 simulations of aquifer pumping test
  - 3-year simulation of Vista Ridge production (2020-2022)

Simsboro (42 aquifer pumping tests)

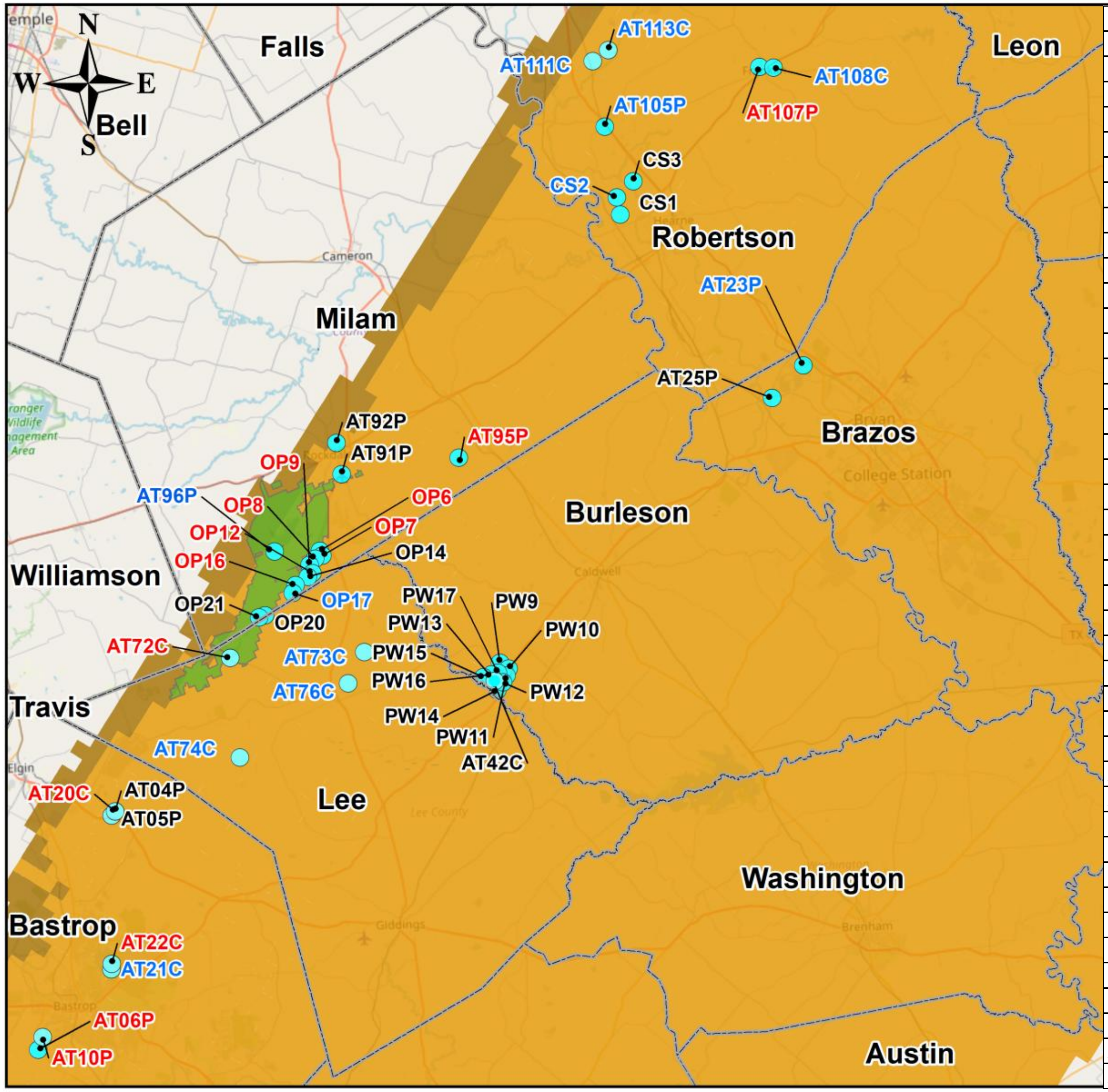


Aquifer Properties: Simsboro Transmissivity Values

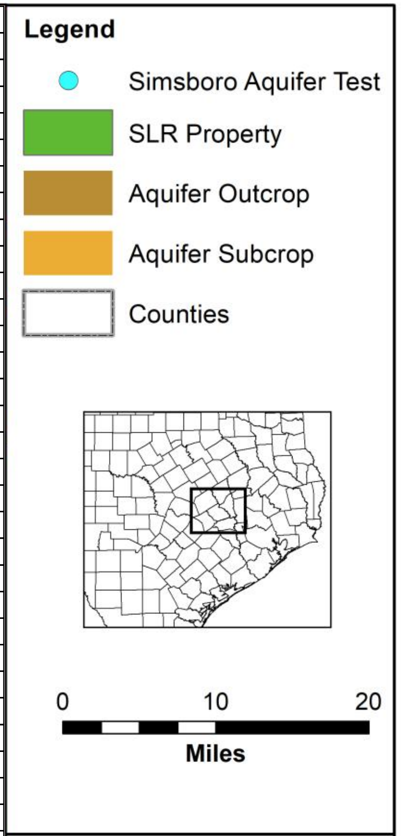
Red
GAM Transmissivity is Higher than Measured

Blue
GAM Transmissivity is Lower than Measured

Black
GAM Transmissivity is within 15% of Measured



LABEL	Observed	Simulated
PW10	13,906	15,772
PW11	17,335	15,772
PW12	19,785	16,385
PW13	14,559	15,038
PW13	15,871	14,110
PW14	14,664	15,954
PW15	15,215	12,603
PW16	10,736	13,412
PW9	10,928	11,843
CS1	7,600	6,364
CS2	8,877	5,671
CS3	8,836	7,555
OP6	4,997	7,931
OP7	4,693	7,931
OP8	2,520	7,931
OP9	4,306	7,179
OP16	4,273	5,919
OP17	7,430	5,117
OP20	5,232	5,045
OP21	5,330	5,531
AT05P	2,608	2,940
AT06P	3,193	4,581
AT14P	8,185	6,760
AT23P	17,768	11,476
AT25P	13,668	11,640
AT91P	4,226	4,854
AT92P	3,468	2,874
AT95P	5,076	8,969
AT96P	6,089	3,950
AT107P	4,722	6,570
AT108C	7,804	5,148
AT72C	3,122	5,869
AT73C	11,478	6,144
AT74C	8,706	3,690
AT76C	12,946	6,949
AT10P	3,175	5,966
AT20C	1,773	2,815
AT21C	11,183	6,432
AT22C	2,631	7,281
AT42C	16,964	15,780
AT111C	8,948	2,917
AT113C	10,241	3,909



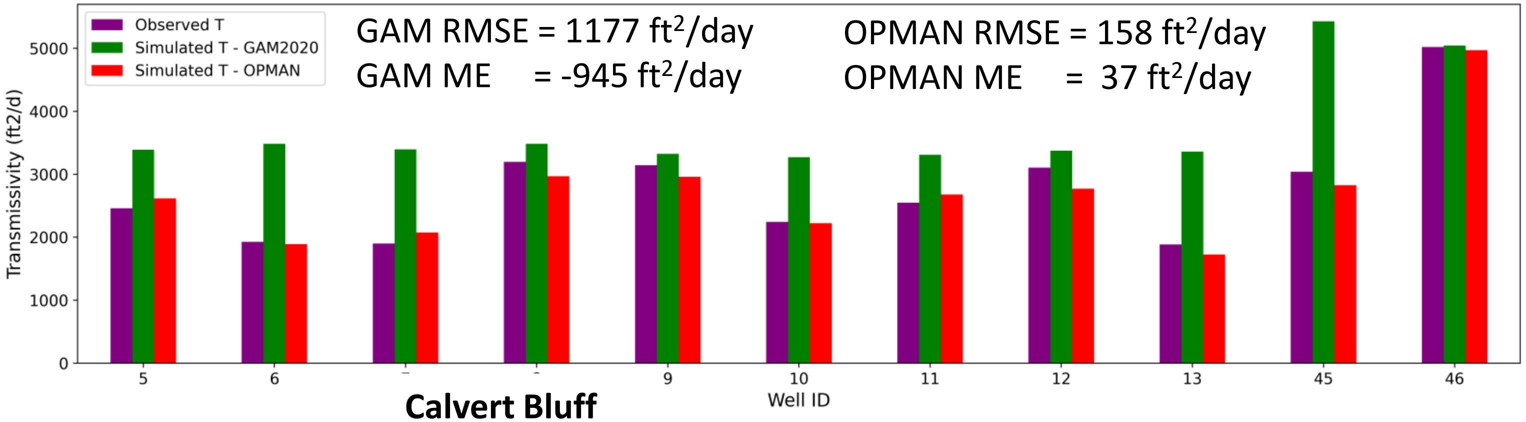
Simsboro Aquifer

Pump Test Locations

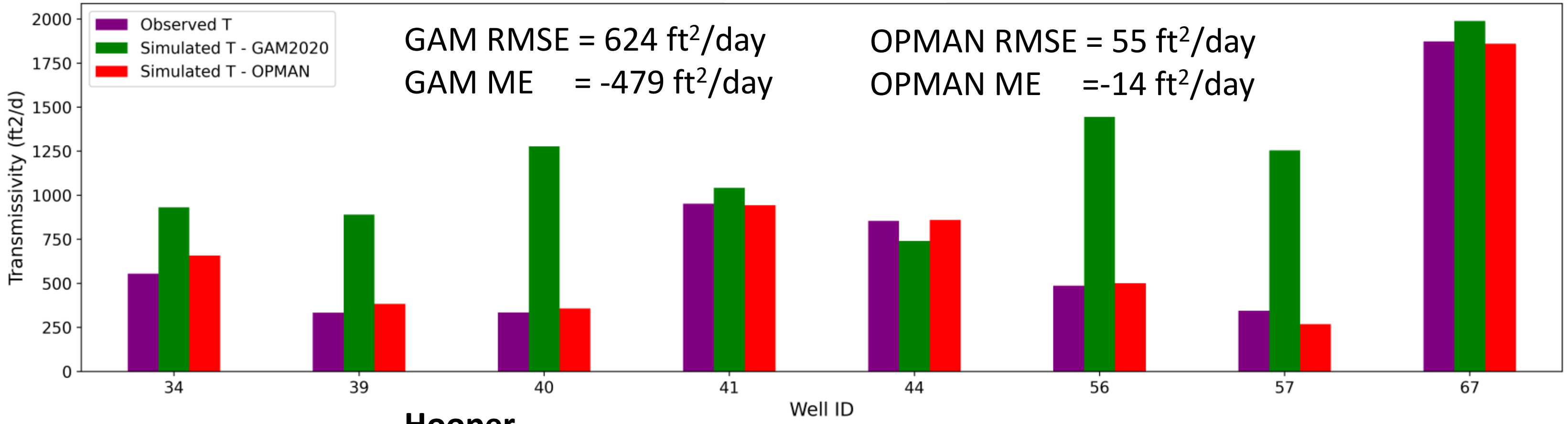
INTERA

Aquifer Transmissivity: Measured versus Modeled

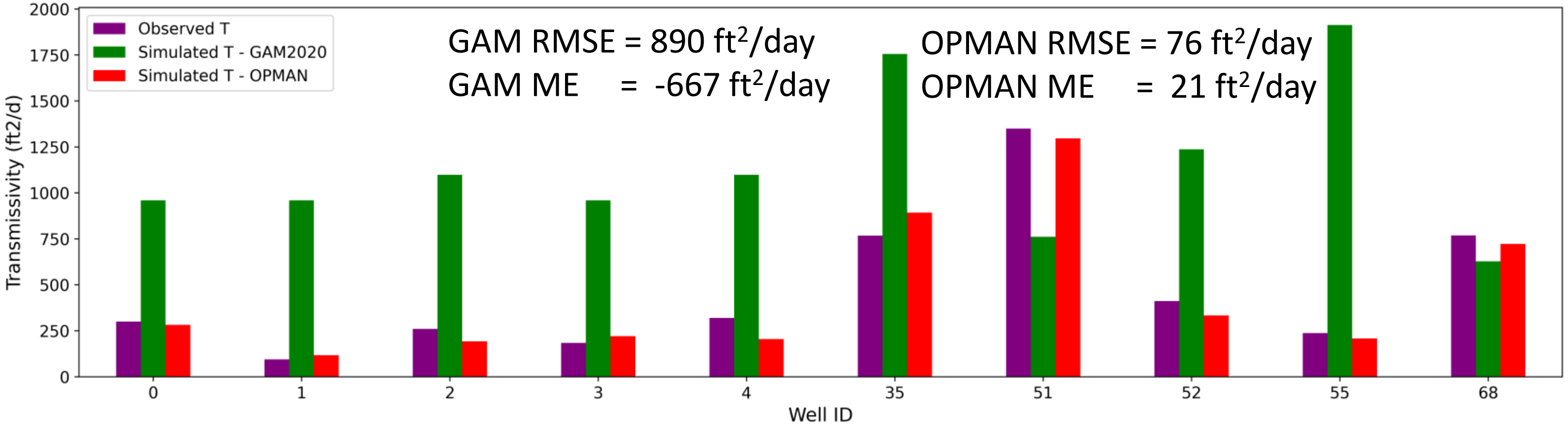
Carrizo



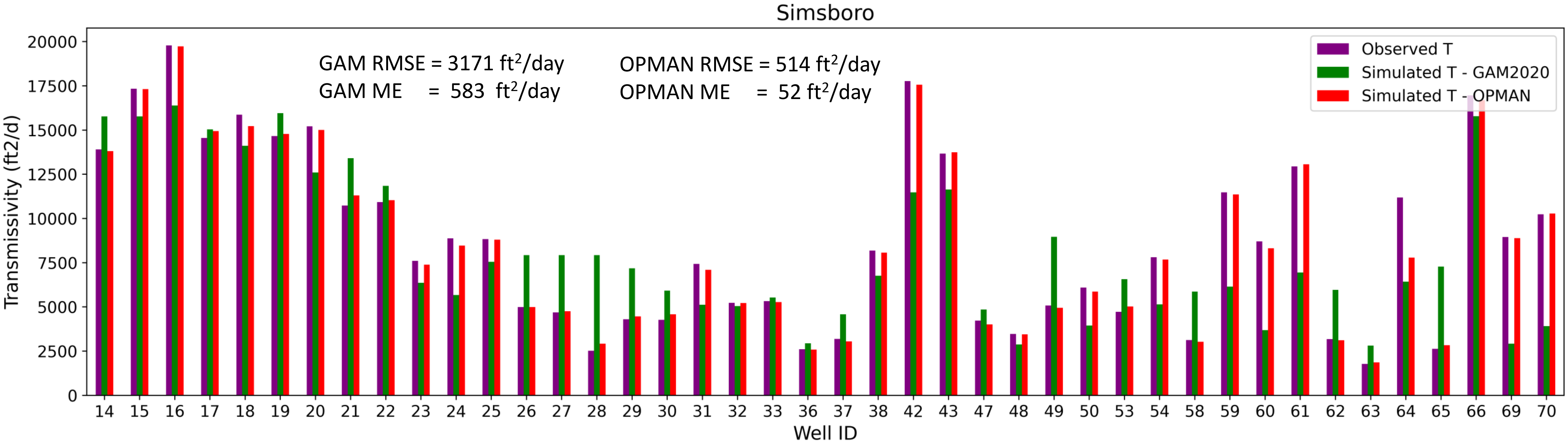
Calvert Bluff



Hooper



Aquifer Properties: Simsboro Transmissivity Values



Desired Future Conditions (DFCs)
&
Protective Drawdown Limits (PDLs)

OPMAN "DFC" Prediction with Uncertainty: Carrizo

2020 GAM

Drawdown (2011 to 2070)

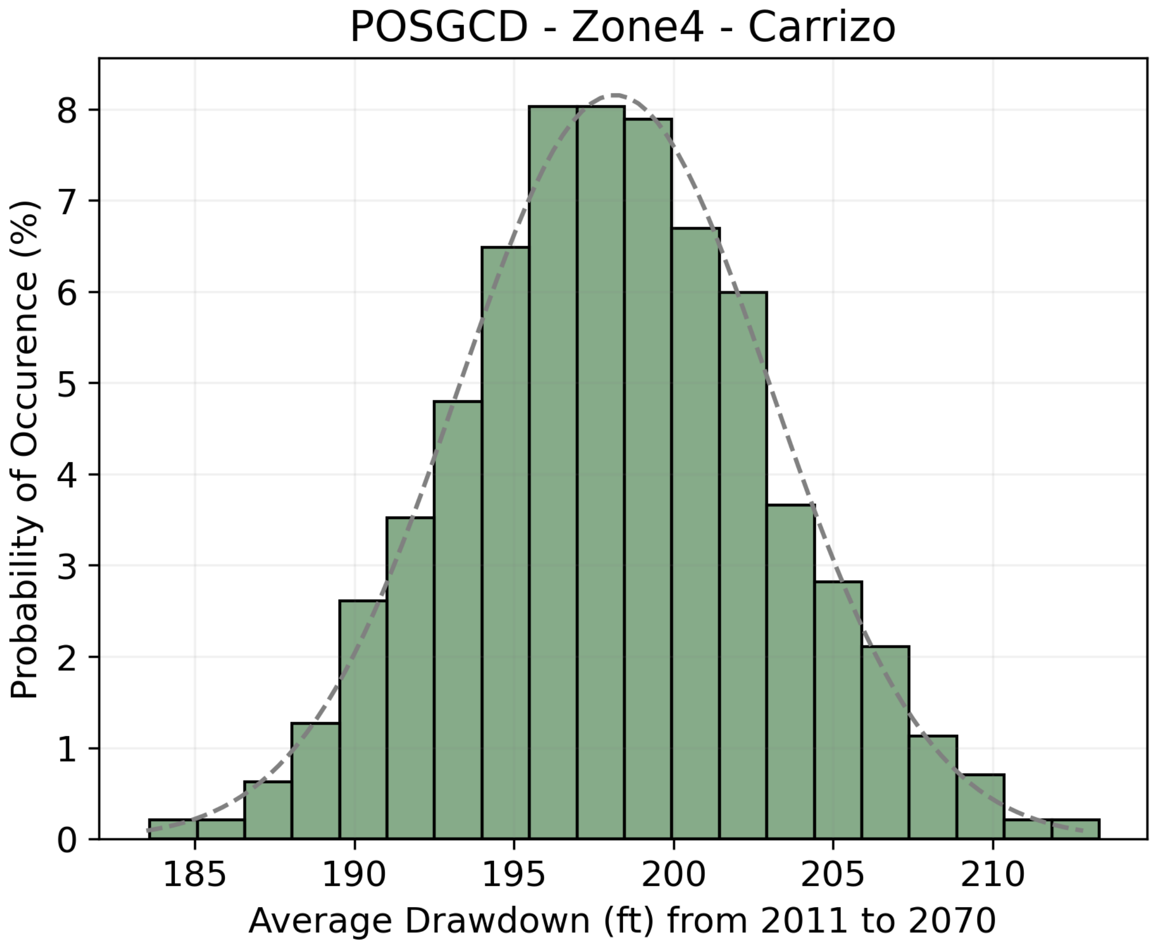
- S-19 prediction: 162 ft
- Adopted DFC: 146 ft*

OPMAN Predictions

Drawdown (2011 to 2070)

- S-19 prediction: 197 ft
- Uncertainty (95%)
- : 198 ft ± 10 ft

OPMAN Prediction approximately 35 ft (22%) greater drawdown than 2020 GAM



1000 different models were calibrated and run to generate the range of DFC predictions

* DFC adopted as 90% of DB Stephens DFC calculations

OPMAN "DFC" Prediction with Uncertainty : Calvert Bluff

2020 GAM

Drawdown (2011 to 2070)

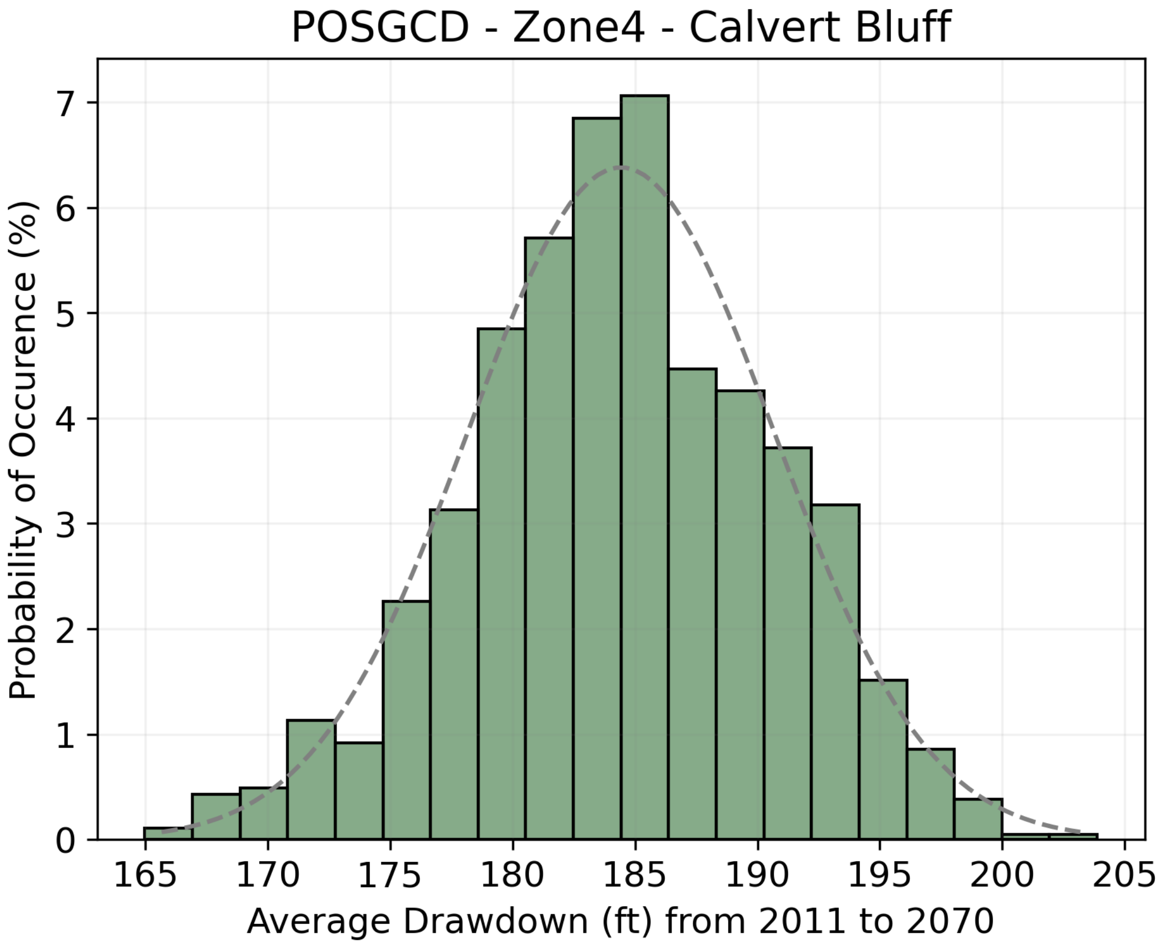
- S-19 prediction: 158 ft
- Adopted DFC: 156 ft *

OPMAN Predictions

Drawdown (2011 to 2070)

- S-19 prediction: 183 ft
- Uncertainty (95%)
- : 184 ft ± 13 ft

OPMAN Prediction approximately 25 ft (16%) greater drawdown than 2020 GAM



1000 different models were calibrated and run to generate the range of DFC predictions

* DFC adopted based on DB Stephens DFC calculations

OPMAN "DFC" Prediction with Uncertainty : Simsboro

2020 GAM

Drawdown (2011 to 2070)

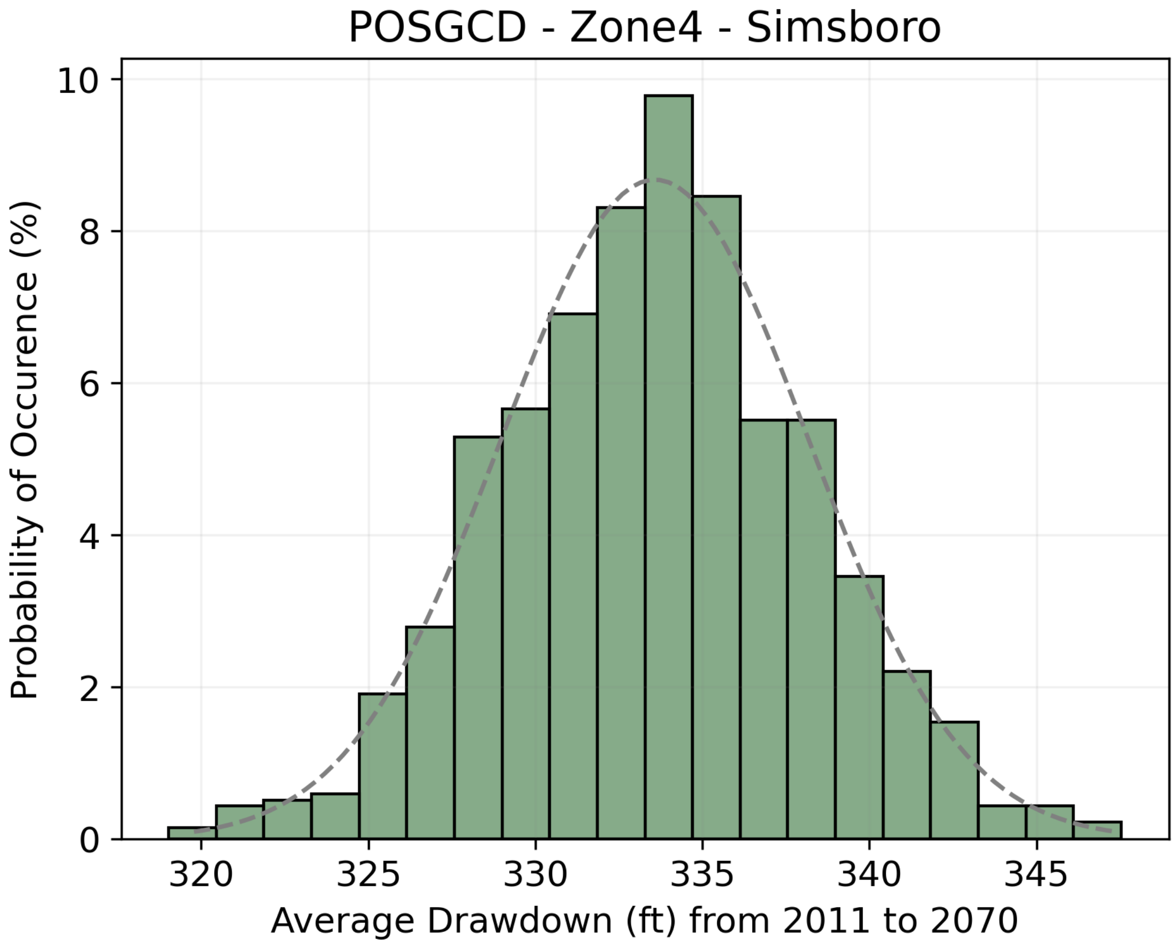
- S-19 prediction: 277 ft
- Adopted DFC: 278 ft *

OPMAN Predictions

Drawdown (2011 to 2070)

- S-19 prediction: 330 ft
- Uncertainty (95%): 334 ft ± 18 ft

OPMAN Prediction approximately 53 ft (19%) greater drawdown than 2020 GAM



1000 different models were calibrated and run to generate the range of DFC predictions

* DFC adopted based on DB Stephens DFC calculations

OPMAN "DFC" Prediction with Uncertainty : Hooper

2020 GAM

Drawdown (2011 to 2070)

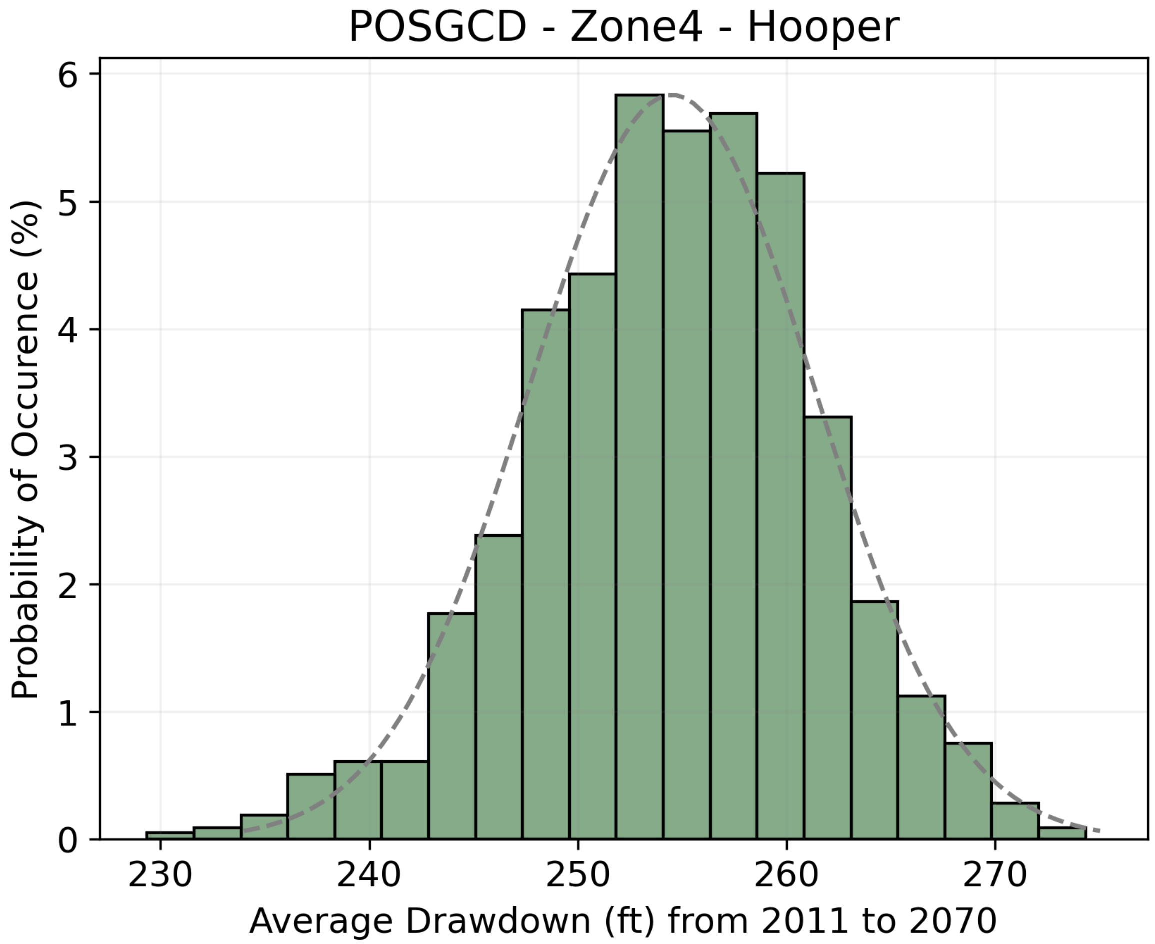
- S-19 prediction: 176 ft
- Adopted DFC: 178 ft *

OPMAN Predictions

Drawdown (2011 to 2070)

- S-19 prediction: 253 ft
- Uncertainty (95%): 255 ft ± 14 ft

OPMAN Prediction approximately 77 ft (44%) greater drawdown than 2020 GAM



1000 different models were calibrated and run to generate the range of DFC predictions

* DFC adopted based on DB Stephens DFC calculations

Sustainable Pumping

Nine Factors Districts Shall Consider When Adopting DFCs

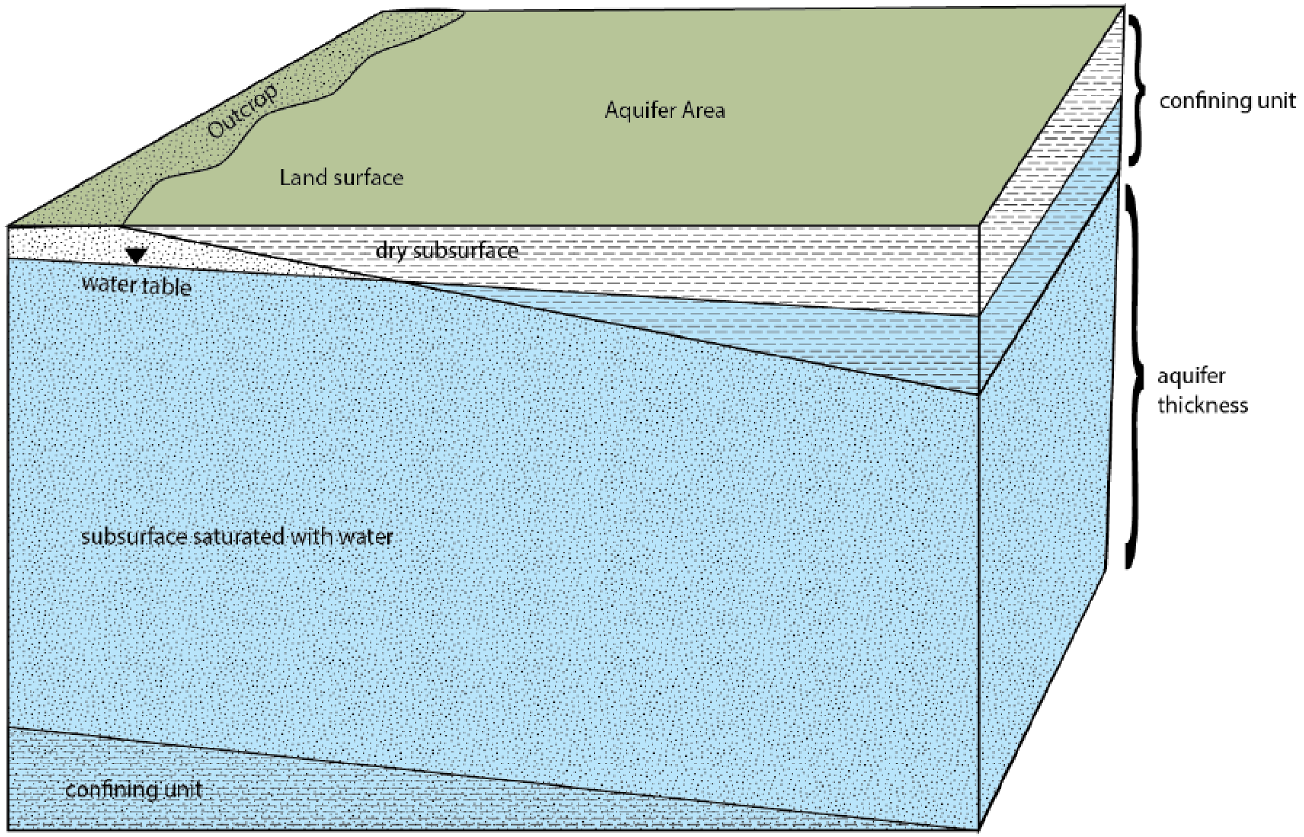
Paraphrased Factors in Texas Water Code Sec. 36.108(d) :

1. Aquifer uses or conditions…
2. Water supply needs and management strategies…
3. Hydrological conditions, **including for each aquifer in the management area the total estimated recoverable storage (TERS) as provided by the executive administrator [of TWDB]**…
4. Other environmental impacts
5. Impact on subsidence
6. Socioeconomic impacts
7. Impact on private property rights
8. Feasibility of achieving the DFC
9. Any other relevant information

TERS Defined

Total Estimated Recoverable Storage—The estimated amount of groundwater within an aquifer that accounts for recovery scenarios that range between 25% and 75% of the porosity-adjusted aquifer volume

Texas Administrative Code Sec. 356.10



Storage volume = area x thickness x specific yield
(Plus some for the confined storage)

TERS: Example of Depletion of a Confined Aquifer

Example Aquifer

Initial Water Level

500 feet of confined pressure head

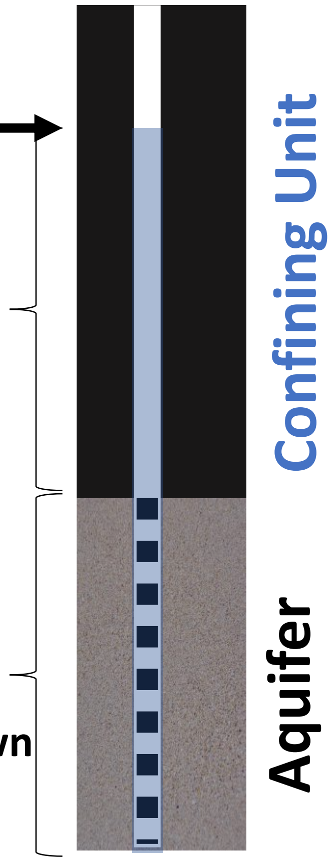
(Specific Storage =

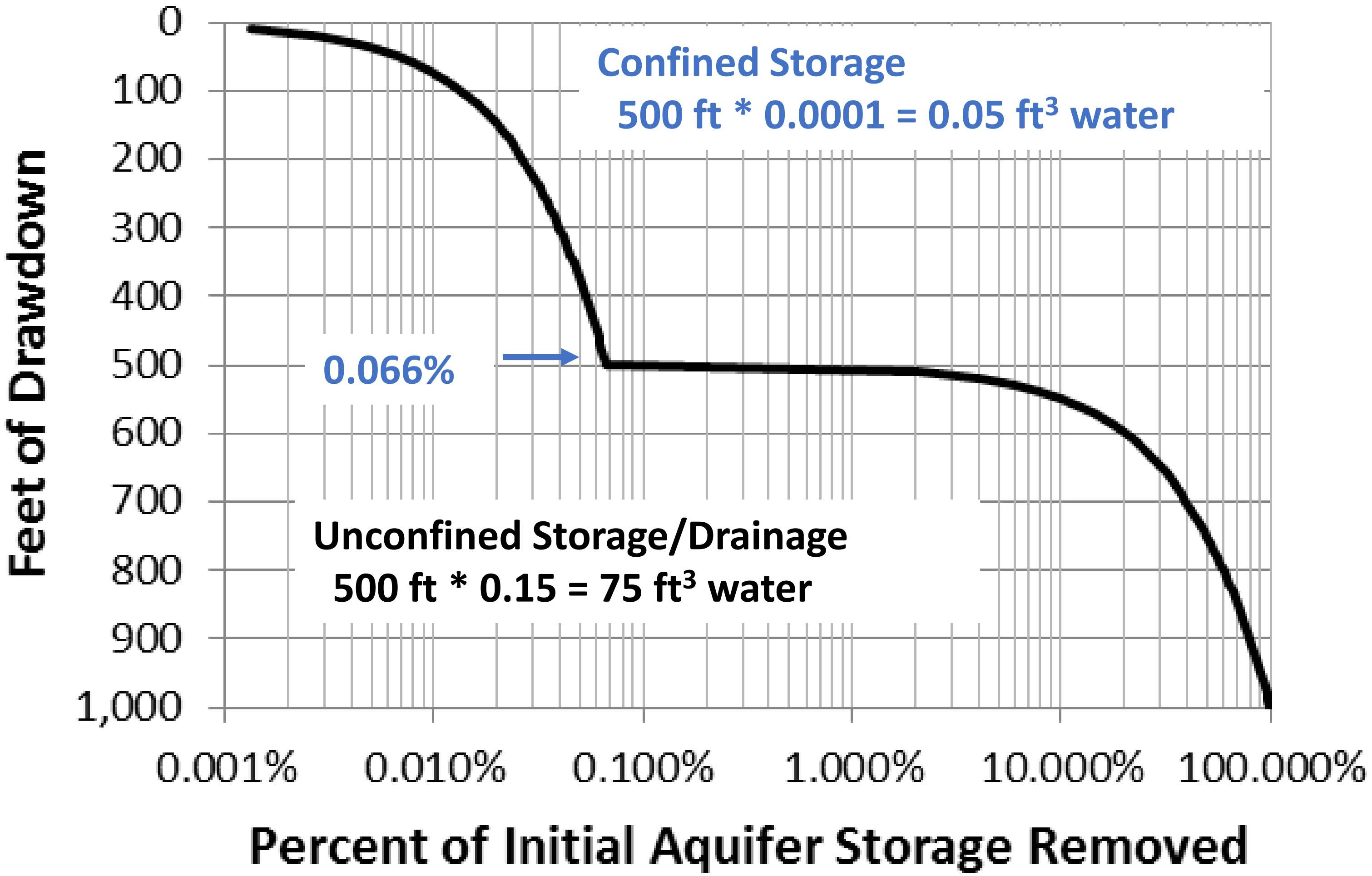
Ss = 0.0001)

500 feet of saturated thickness

Specific Yield (Sy) =

0.15 ft^3 water/ 1 ft of drawdown



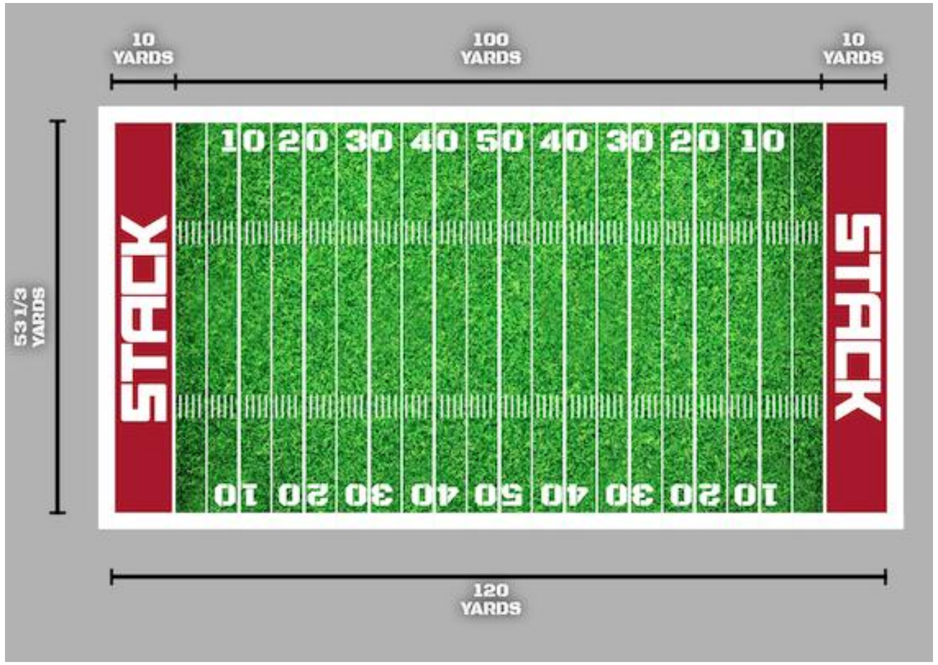


POSGCD Total Estimated Storage: Carrizo & Simsboro

An acre-foot = 325,851 gallons

An acre-foot will cover a foot field with 0.8 ft of water

Aquifer	Confined storage (acre-ft)	Unconfined storage (acre-ft)	Total storage (acre-ft)
Carrizo	132,135 (.5%)	24,897,133 (99.5%)	25,029,268
Simsboro	194,232 (0.3%)	6,1224,718 (99.7%)	61,418,951



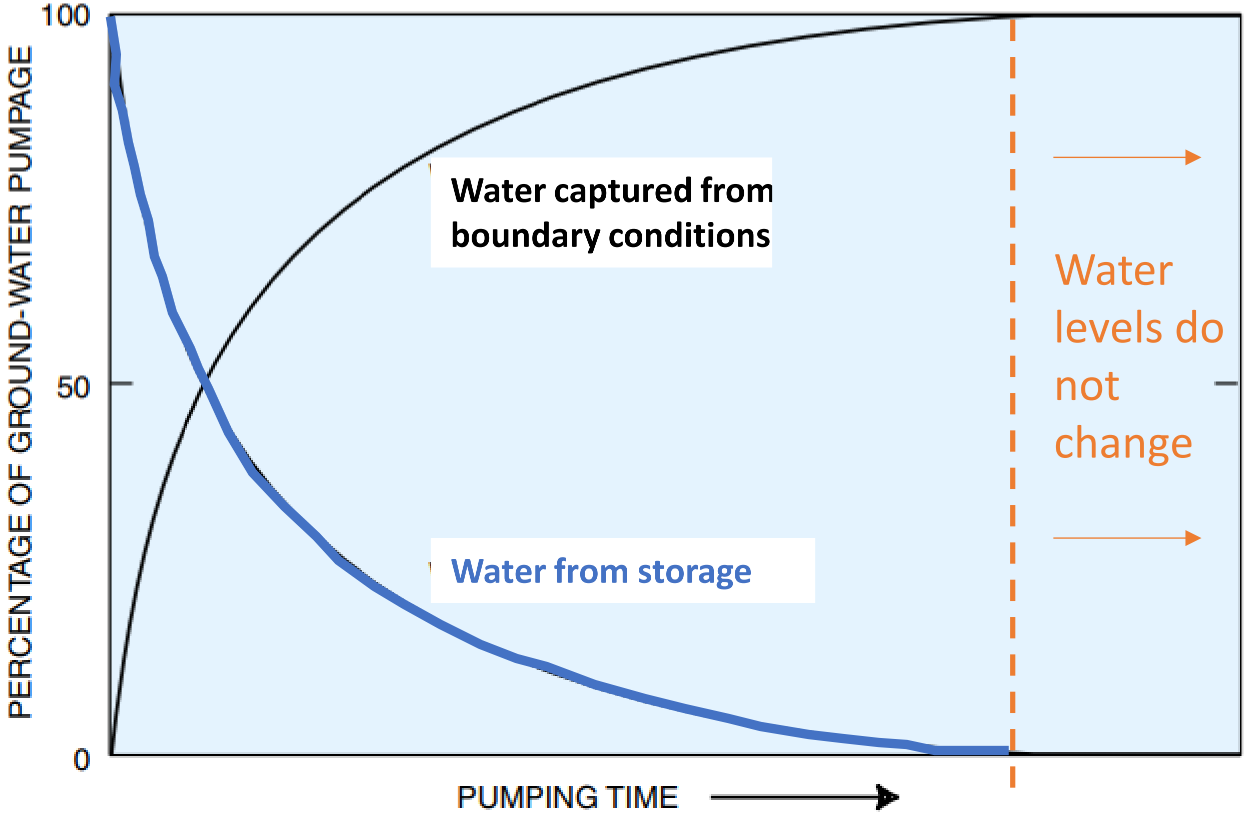
Recoverable Storage: Considerations and Constraints

- TWDB Definition – between 25% and 75% of the porosity-adjusted aquifer volume

- No considerations
  - Unreasonable impacts
    - Groundwater & surface resources
    - Existing wells
  - Aquifer water quality
  - Water levels dropping below pumps
  - Land surface subsidence
  - Degradation of water quality
  - Changes to surface water-groundwater interaction
  - **<u>Practicality/economics of development</u>**
  - **<u>Groundwater physics of removing of removing the</u>**

Aquifer Dynamics for Sustainable Pumping

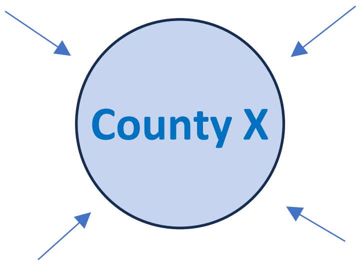
- Sources for Pumped Water
  - Initial water is from aquifer itself (storage)
  - As cone-of-depression spreads outwards, additional sources of water besides storage
  - At very late times, cone-of-depression stops migration and water levels remains constant
  - At very late times, all water is from boundary conditions
- Hydraulic Boundary Conditions
  - Streams, lakes, creeks, springs
  - Recharge from precipitation
  - Adjacent aquifers



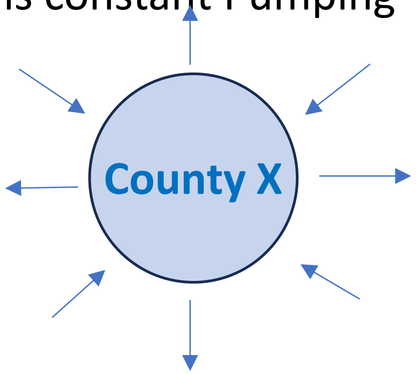
What Hydrogeologic Conditions will Favor Maximum Sustainable Pumping

External Conditions

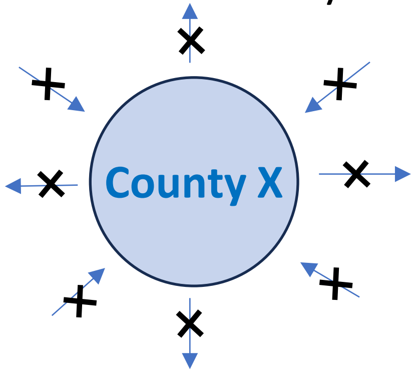
Condition #1
Water Exists Outside of County and there is no Pumping



Condition #2
Water Exists Outside of County and there is constant Pumping



Condition #3
No Water Exists Outside of County.

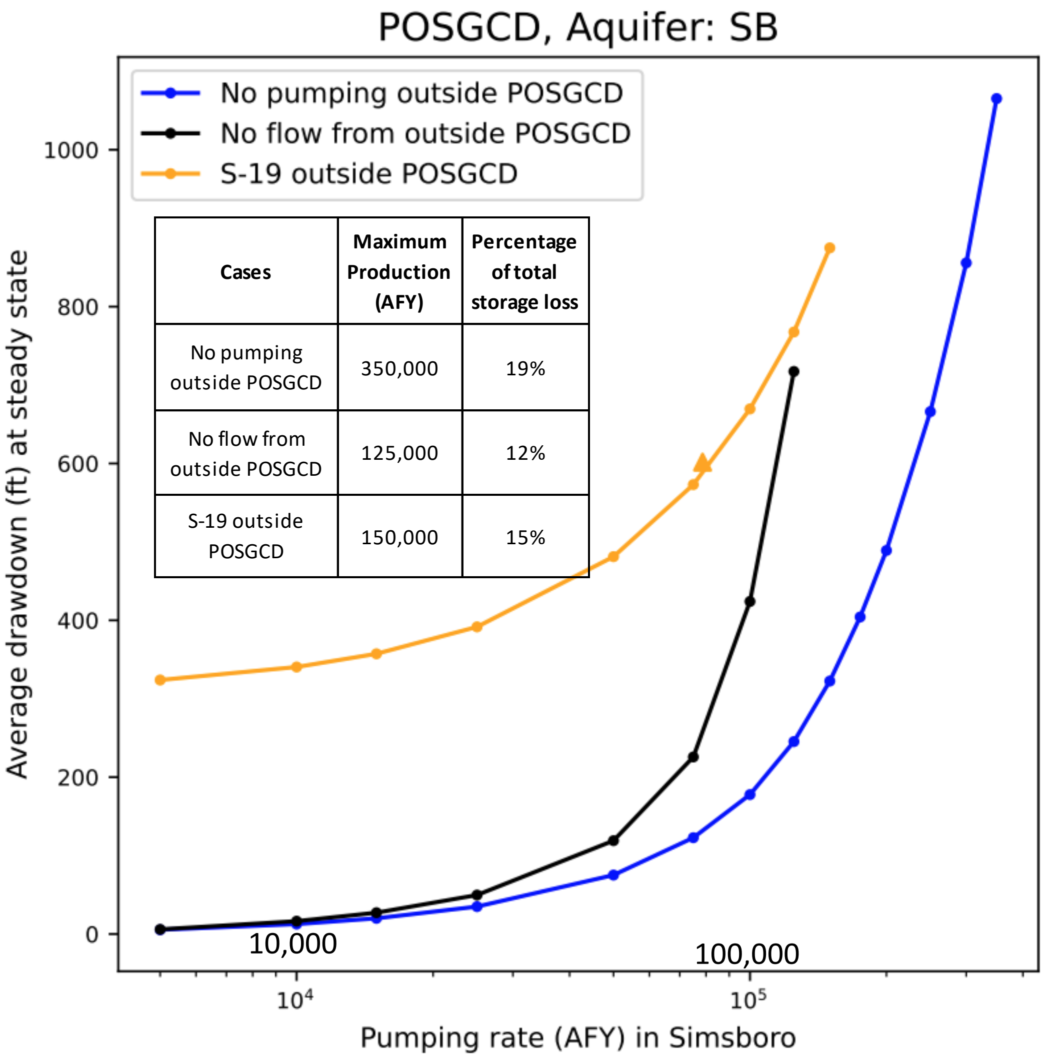


Internal Conditions

Condition #A
Constant pumping at a few selected wellfields

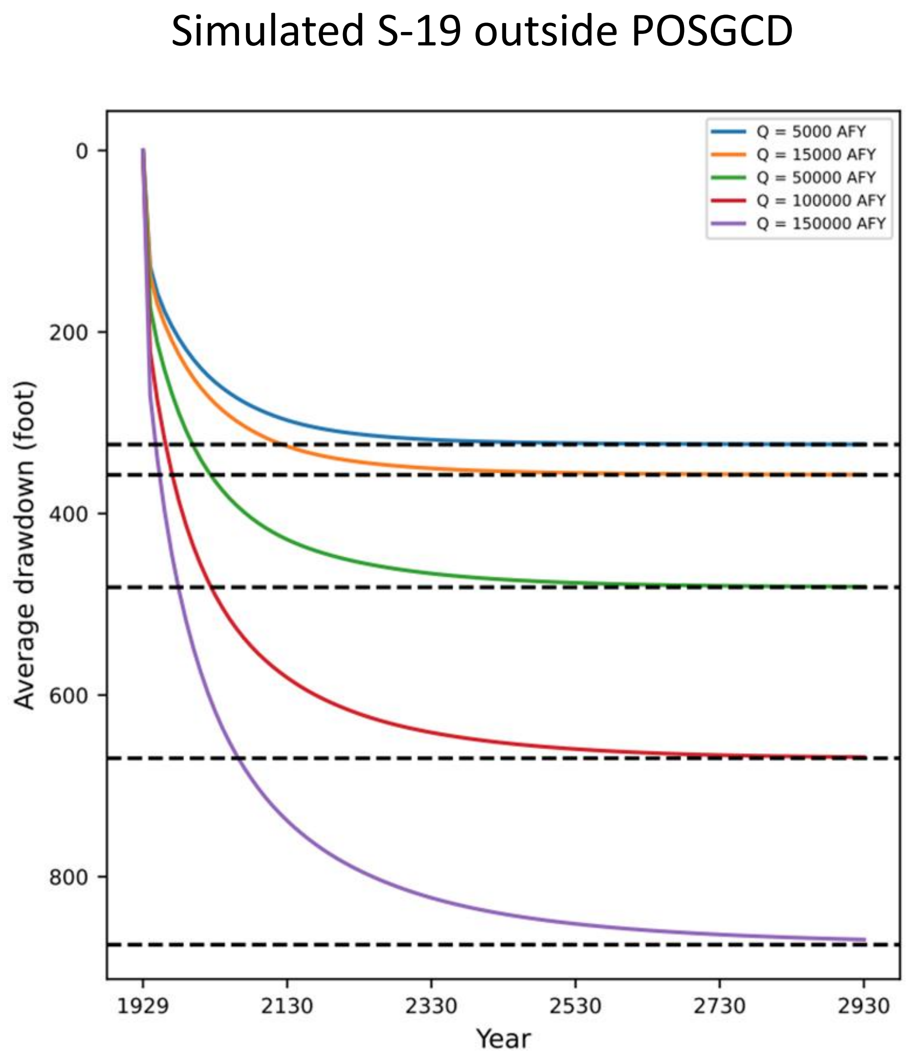
Condition #B
Constant pumping at maximum number of wells spaced as close as possible

Sustainable Production from POSGCD: Simsboro



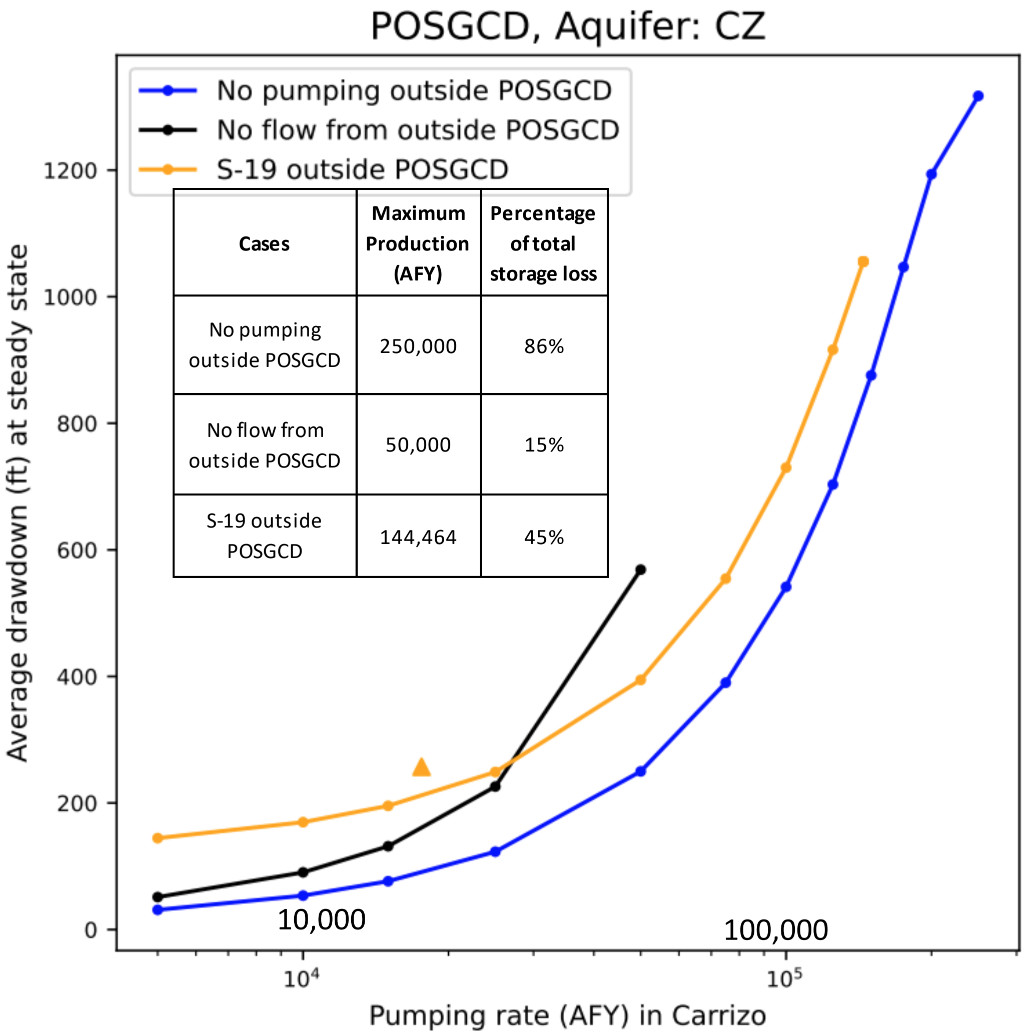
Cases	Maximum Production (AFY)	Percentage of total storage loss
No pumping outside POSGCD	350,000	19%
No flow from outside POSGCD	125,000	12%
S-19 outside POSGCD	150,000	15%

Steady-state drawdown versus pumping in Carrizo in POSGCD.



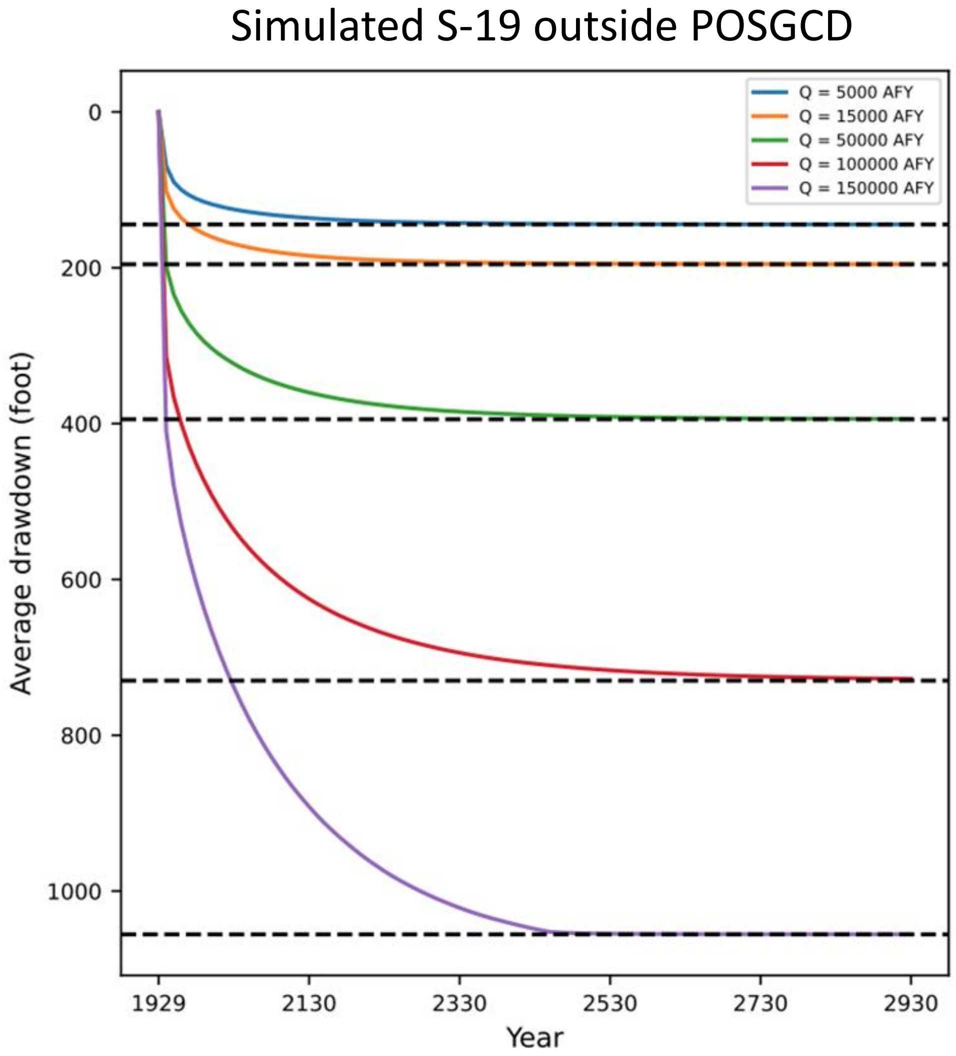
Transient drawdown in Carrizo with S-19 outside POSGCD (time to reach point where all water .

Sustainable Production from POSGCD : Carrizo



Cases	Maximum Production (AFY)	Percentage of total storage loss
No pumping outside POSGCD	250,000	86%
No flow from outside POSGCD	50,000	15%
S-19 outside POSGCD	144,464	45%

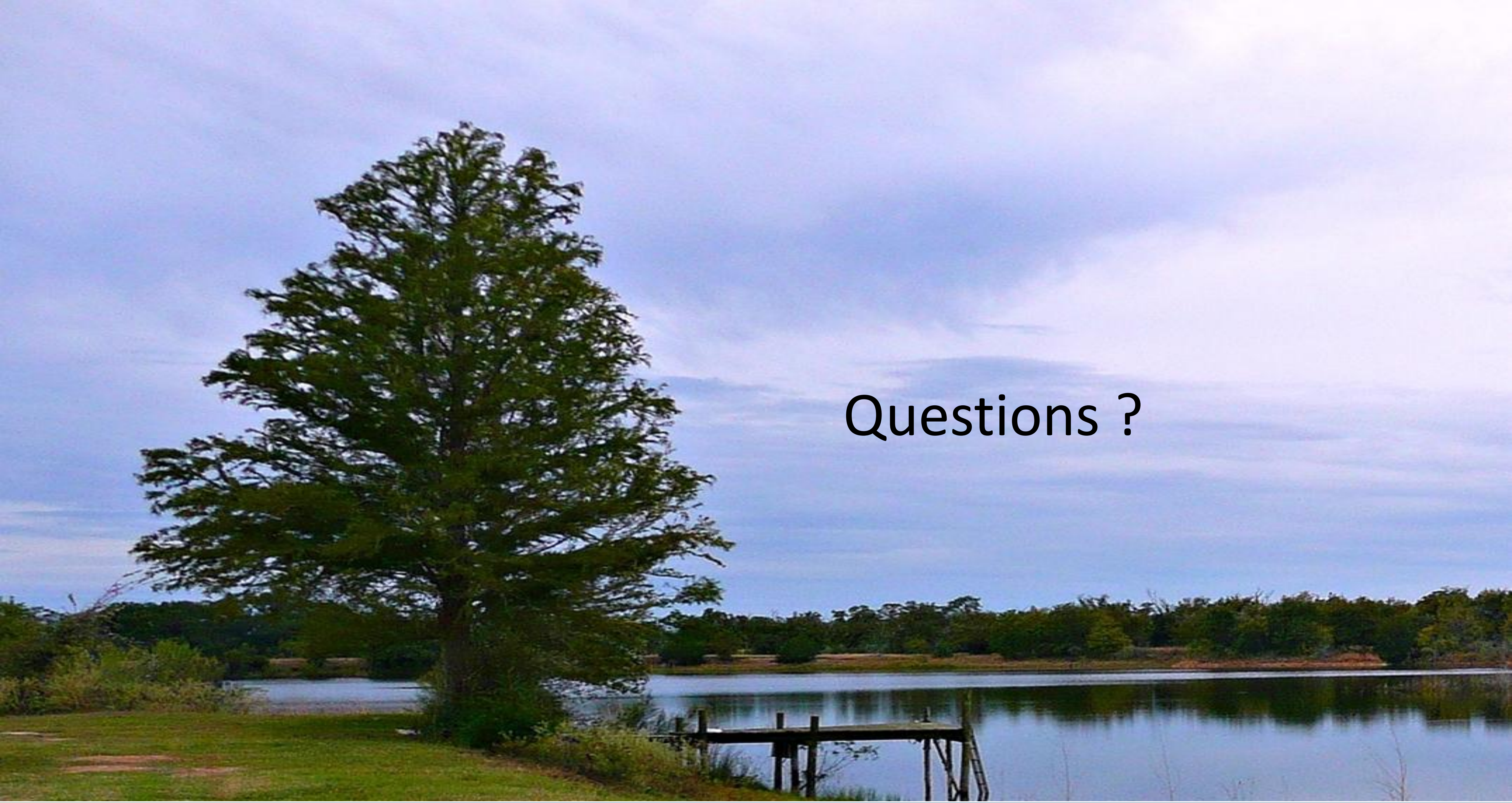
Steady-state drawdown versus pumping in Carrizo in POSGCD.



Transient drawdown in Carrizo with S-19 outside POSGCD.

Sustainable Production With Social-Economic and Environmental Considerations

- Land Subsidence
- Water levels below pump elevations
- Water levels in and below well screens
- Impacts to environmental flows for streams
- Impacts to springs
- Degradation of water quality
- Costs to produce water
- Costs associated with lost of water


Questions ?