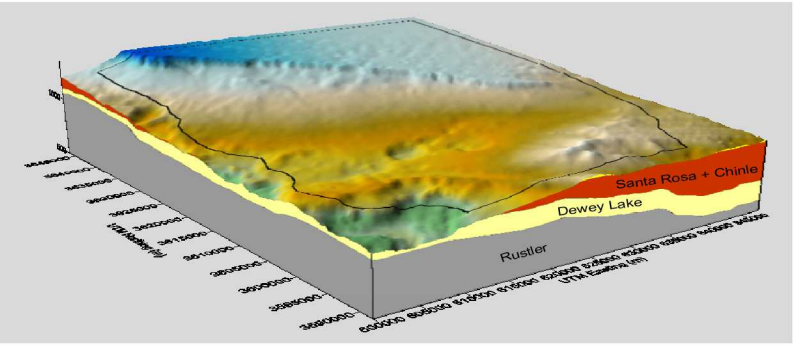
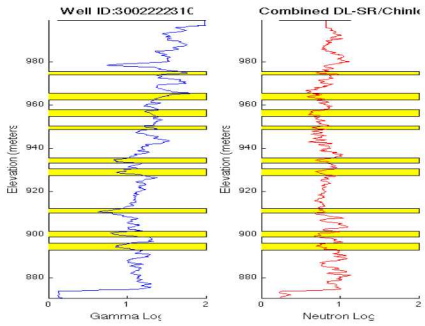
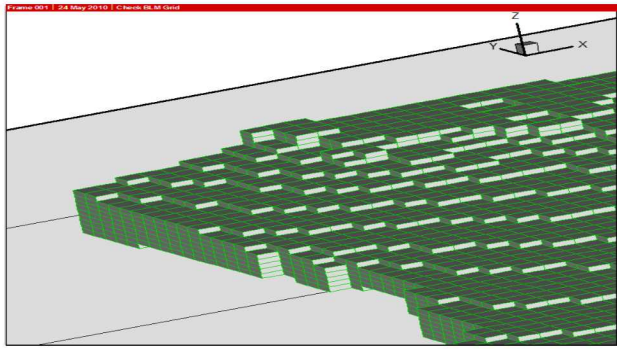
SAND2019-2640C







Modeling Water Sustainability effects on Resource Extraction in the New Mexico Permian Basin

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

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Abstract

Advancements in directional drilling and well completion technologies have resulted in an exponential growth in the use of hydraulic fracturing for oil and gas extraction. Within the New Mexico Permian Basin, water demand to complete each hydraulically fractured well is estimated to average 7.3 acre-feet (2.4 million gallons), resulting in an increase to the regional water demand of over 5000 acre-feet per year. This rising demand is creating concern for the region's ability to meet demand in a manner that fulfills the Bureau of Land Management's (BLM) role of protecting human health and the environment while sustainably meeting the various needs of water users in the region.

This presentation provides a summary of the study that developed the modeling tool, PBWater, to aid the BLM based on the data collection and analysis efforts that established a water-level and chemistry baseline for this region. The modeling tool assists users to understand the regional water supply dynamics under different management, policy, and growth scenarios and to pre-emptively identify risks to water sustainability.

Problem Statement

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With the increase in drilling activity and hydraulic fracturing in particular, there is need to insure the regions ability to meet increasing water demands in a manner that is sustainable while also avoiding unintended, localized impacts.

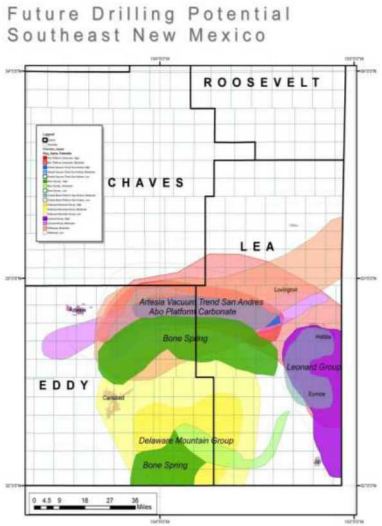
Approach

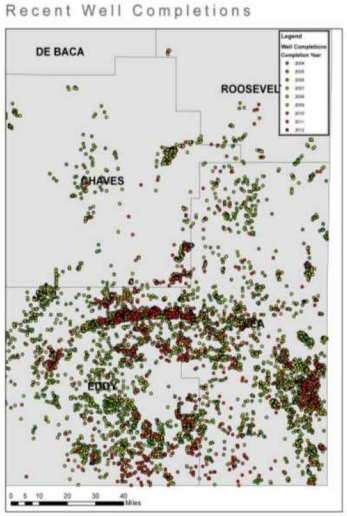
Use a multi-disciplinary approach to identify, assess, and evaluate the cumulative impacts of future water demands. Of key importance is determining the risk to water sustainability and estimating the risk under different future scenarios.

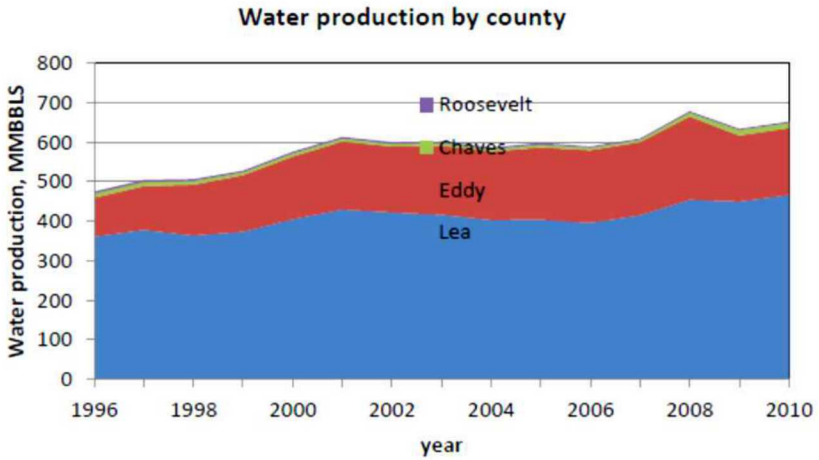
1. Data Collection
2. Field Verification
3. Field Testing and Monitoring
4. System Dynamics Modeling

Reasonable Foreseeable Development (RFD)

- Study by Engler et al. (2012, 2013, 2014) to estimate the development of hydrocarbon production in southeast NM (Chaves, Eddy, Lea, and Roosevelt counties) over the next 20 years
- Identified the major oil (16) and gas (10) plays and categorized them into potential areas of 'low', 'moderate', 'high', or 'very high'
- Oil production ~800 wells / yr, gas production decreasing, water demand increasing (7.3 AF/well ave.)

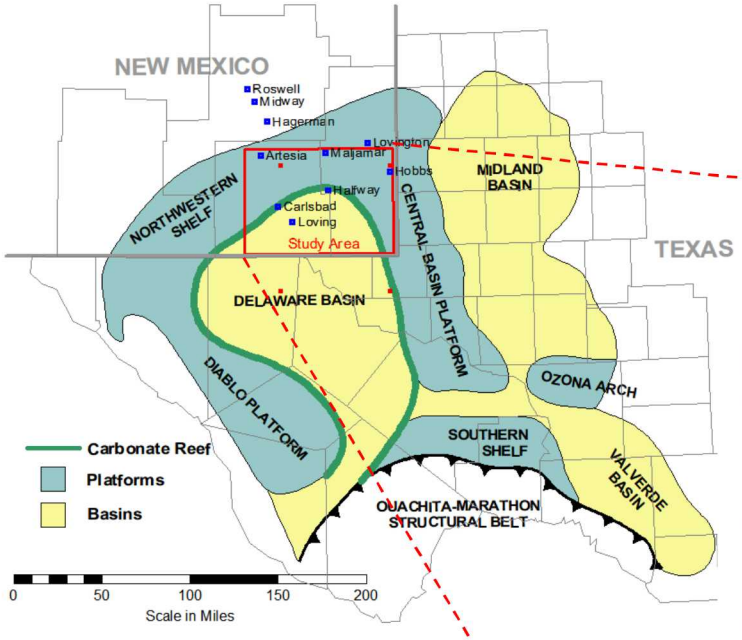


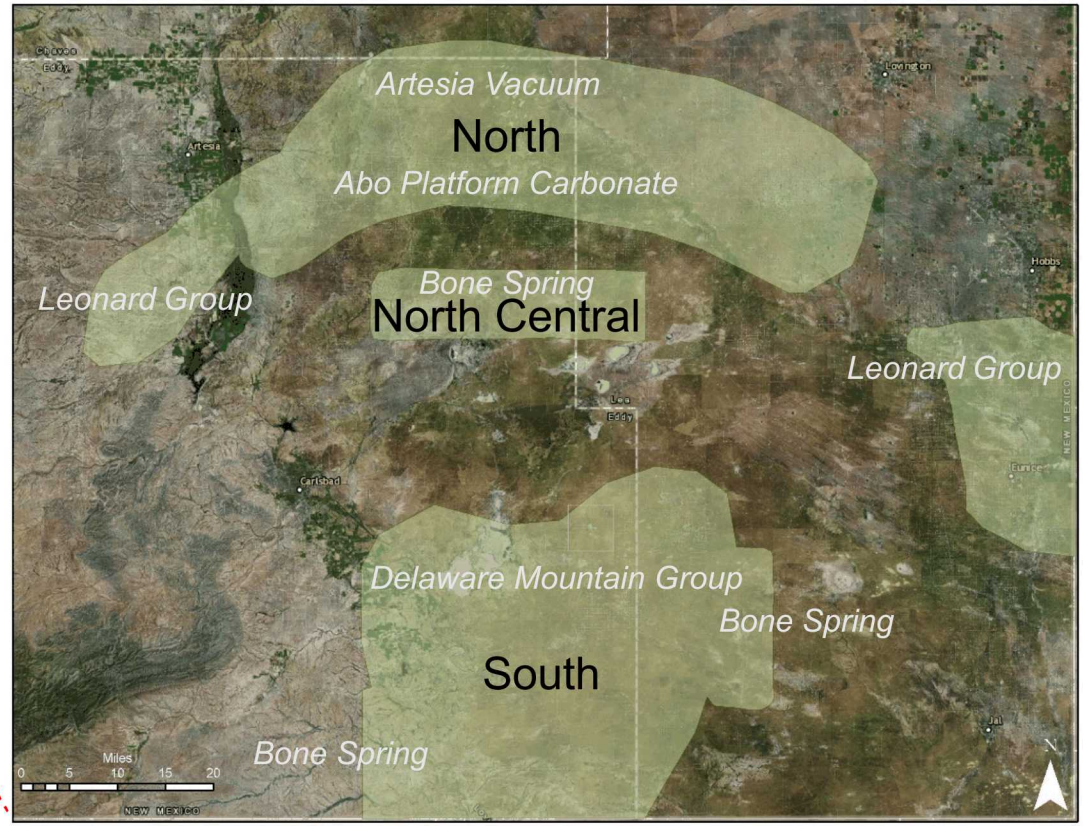




Engler T.W., R. Balch, and M. Cather, 2012, *Reasonable Foreseeable Development (RFD) Scenario for the B.L.M New Mexico Pecos District*, Final Report submitted to Jim Stovall, Project Manager Carlsbad Field Office, 55p

PA's and Study Area





Data Collection, Verification, Testing

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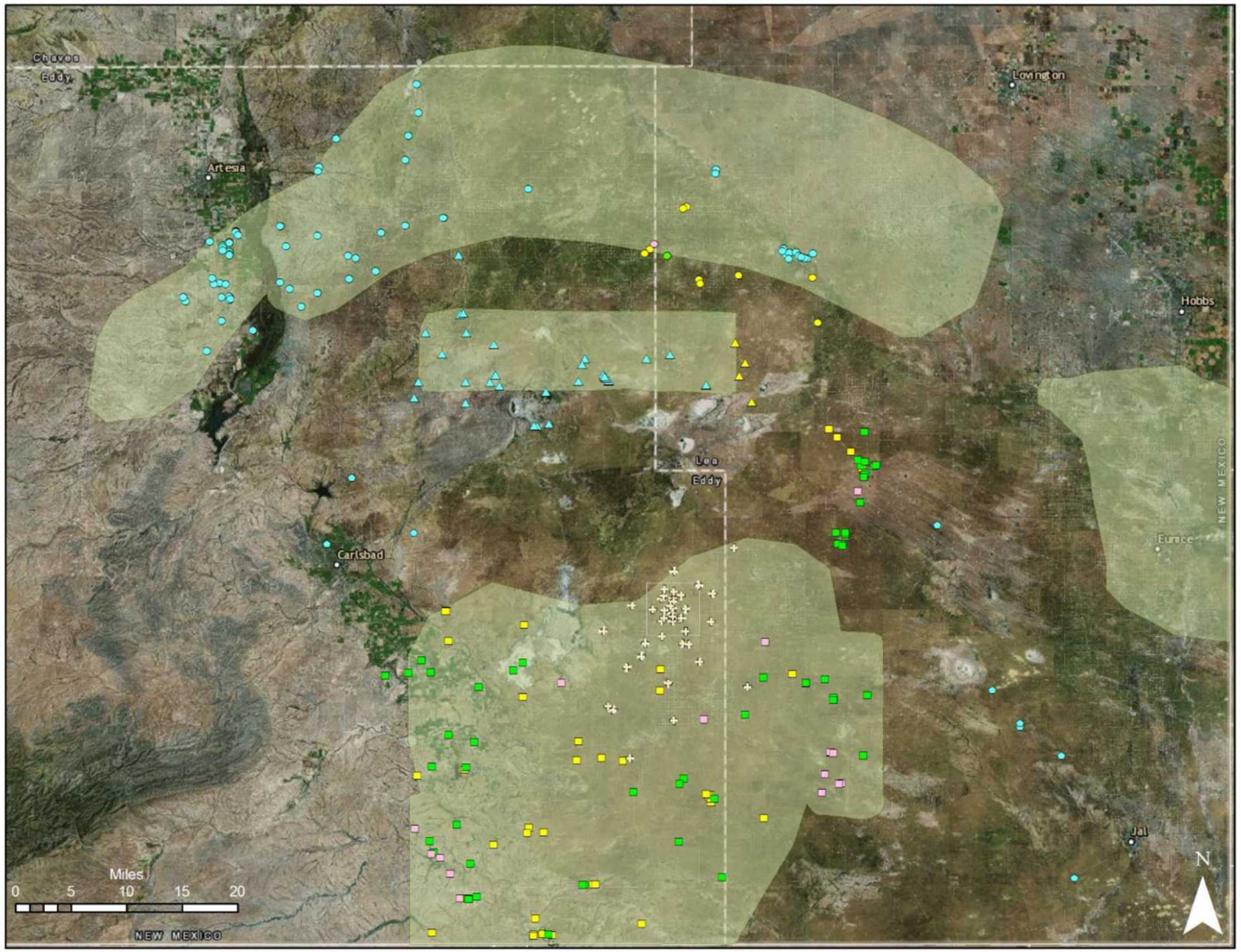
- Inventory of the water users and water sources: Areas of high and very high potential
- Identify past studies and/or tests that may pertain to conditions at each site.
- Verify the data
  - Contact and work with each water user to access their well(s)
- Field Testing and Sampling
  - Measured and Verified: GPS coordinates, surface elevation, well diameter, distance to top of casing depth to water, total depth
  - Sampled: Cations/anions, pH, conductivity, trace metals

Established current baseline from which future changes can be compared to and provide hydrogeologic parameters to the model.

Data Collection, Verification, Testing

Sandia National Laboratories



Ownership

Location	State	Private	BLM	Unknown
North	○	●	●	●
N. Central			△	△
South	□	■	■	
Capitan				⬠

✚ WIPP Wells – DOE Owned

Working with Private Well Owners

Sandia National Laboratories

Figure 42 Wallen Fed. No. 9 East

Dear XXXXXXX, May 24, 2016

On behalf of the Bureau of Land Management (BLM), Sandia National Laboratories (Sandia) is conducting a study to assess the sustainability of water resources in Eddy, Lea, and Chavez Counties. The demand for water is increasing proportionally with the recent increase in hydraulic fracturing and the BLM would like to better understand the sustainability of these practices on federal land given the limitations on water in our arid region.

As part of this study Sandia will be collecting field data on water wells in your area that includes depth to water, overall depth, water quality, and the primary purpose of the well. This information will be compiled into a database and utilized to develop a model that can predict impacts on the regional water supply in correlation with changes in oil and gas production.

You are receiving this letter because one or more wells on your property have been identified as candidates for field data collection. We are asking landowners to participate in our study by granting Sandia access to their wells for the purposes of gathering the various measurements. In return for allowing access, participating landowners will receive a comprehensive report documenting the current status and state of each of their wells. To preserve your anonymity the information will be assigned a generic identification number that will be used in documents released to the public.

The value of this study is greatly dependent on the quality and quantity of information gathered in the field so we hope you will support us as we attempt to find a balance between development and preserving our water resources.

By signing this letter, the Landowner agrees to allow Sandia access to their well(s) for the purposes of measuring water level and total well depth and to collect water samples that will be analyzed for general geochemistry and metals profiling. A copy of the water quality report and the water level data will be supplied to the landowner.

Figure 38 Windmill No. 2 West

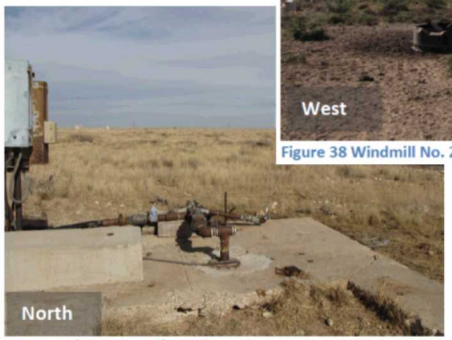


Figure 56 (House Well) North

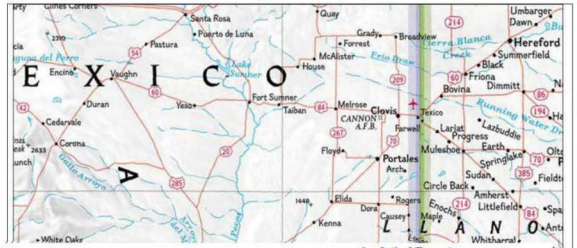
Sandia National Laboratories

Results of Well Survey and Water Quality Analysis
BLM Dewey Lake Study
XXXXXXX Geographic Area Wells
Lea County, New Mexico

dual report is tiered from a former
ıcted by Sandia National Laboratories
was an effort to assist the Bureau of
ıagement (BLM)
sing ground water
ı BLM, State and
ıds, targeting the
ːe and Santa Rosa
aring formations
model boundary
the agency. The
tent of that work
was to better define the
Dewey Lake and Santa Rosa
aquifers to aid the BLM with
on-going and
gas permitting
informing
environmental
to *BLM Lea*
Study for the
Santa Rosa Fo
Report - SANI
more informa
study).

Before field
conducted,
generated usi
query of the
Office of the

geographic area names were selected based on the landowner or grazing permittee's name. This specific report is confined to the



Analytical Report
Lab Order 1412226
Date Reported: 12/19/2014

Hall Environmental Analysis Laboratory, Inc.

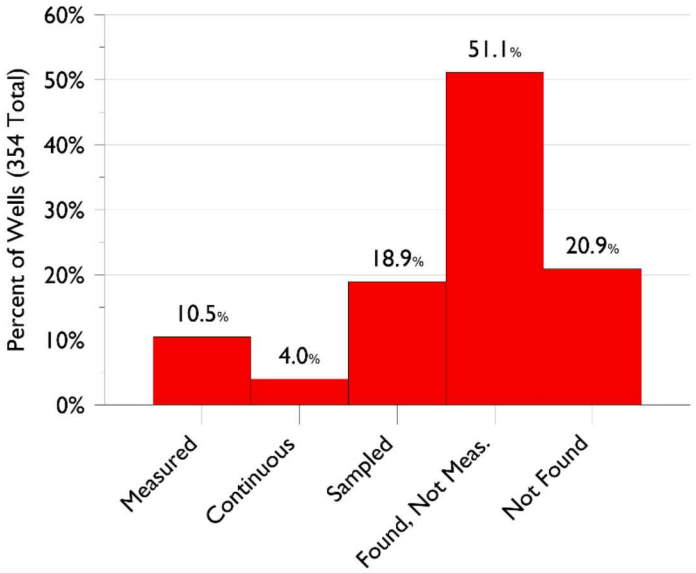
CLIENT: Sandia National Labs — **Client Sample ID:** CP-1330-20141202
Project: BLM-DL — **Collection Date:** 12/2/2014 9:50:00 AM
Lab ID: 1412226-001 — **Matrix:** AQUEOUS — **Received Date:** 12/4/2014 9:00:00 AM

Analyses	Result	RL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 300.0: ANIONS						Analyst:	lgp
Fluoride	1.4	0.10		mg/L	1	12/4/2014 7:17:21 PM	R22950
Chloride	32	10		mg/L	20	12/4/2014 7:29:46 PM	R22950
Bromide	0.18	0.10		mg/L	1	12/4/2014 7:17:21 PM	R22950
Phosphorus, Orthophosphate (As P	ND	0.50	H	mg/L	1	12/4/2014 7:17:21 PM	R22950
Sulfate	190	10		mg/L	20	12/4/2014 7:29:46 PM	R22950
Nitrate+Nitrite as N	ND	1.0		mg/L	5	12/4/2014 10:11:08 PM	R22950
EPA METHOD 6010B: DISSOLVED METALS						Analyst:	ELS
Calcium	8.0	1.0		mg/L	1	12/9/2014 9:26:37 AM	R23012
Magnesium	4.9	1.0		mg/L	1	12/9/2014 9:26:37 AM	R23012
Potassium	1.6	1.0		mg/L	1	12/9/2014 9:26:37 AM	R23012
Sodium	210	5.0		mg/L	5	12/9/2014 9:28:34 AM	R23012
SM2510B: SPECIFIC CONDUCTANCE						Analyst:	JRR
Conductivity	1000	0.010		µmhos/cm	1	12/5/2014 9:49:06 AM	R22984
SM4500-H+B: PH						Analyst:	JRR
pH	8.43	1.68	H	pH units	1	12/5/2014 9:49:06 AM	R22984
SM2320B: ALKALINITY						Analyst:	JRR
Bicarbonate (As CaCO3)	240	20		mg/L CaCO3	1	12/5/2014 9:49:06 AM	R22984
Carbonate (As CaCO3)	4.9	2.0		mg/L CaCO3	1	12/5/2014 9:49:06 AM	R22984
Total Alkalinity (as CaCO3)	240	20		mg/L CaCO3	1	12/5/2014 9:49:06 AM	R22984
SM2540C MOD: TOTAL DISSOLVED SOLIDS						Analyst:	KS
Total Dissolved Solids	636	20.0	*	mg/L	1	12/7/2014 4:12:00 PM	16683

Data Collection, Verification, Testing

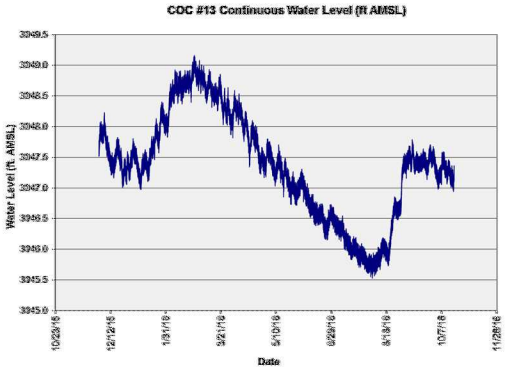
Sandia National Laboratories

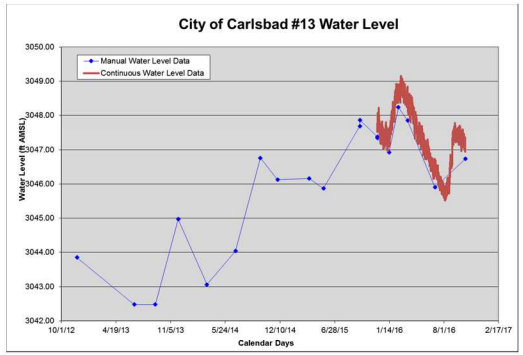
	North	N Central	South	Capitan	Total
Total	127	60	158	9	354
Measured	7	10	16	4	37
Continuous	3	2	5	4	14
Sampled	19	11	30	7	67
Found, Not Measurable	70	24	86	1	181
Not Found	28	17	29	0	74

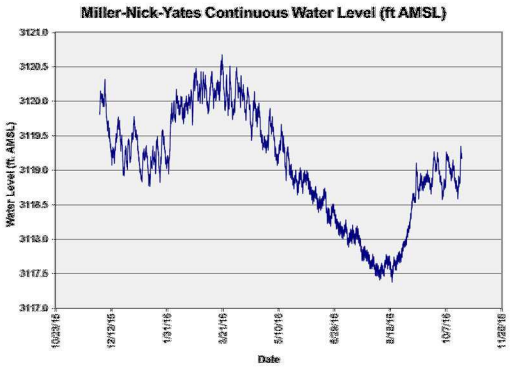


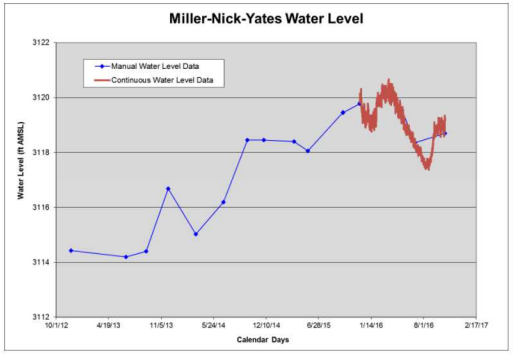
Most of the wells (72%) were either not found or not measurable

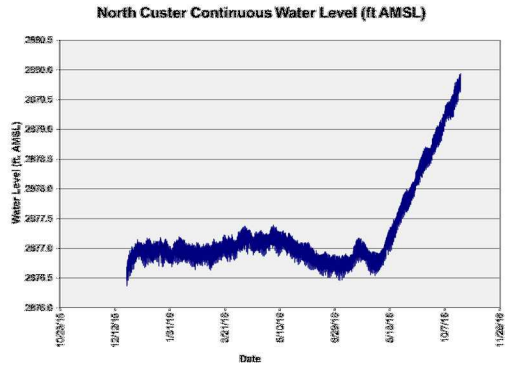
Continuous Measurements

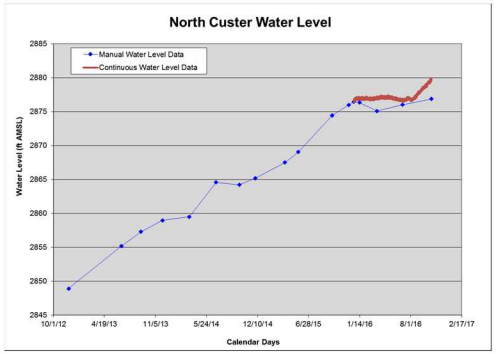






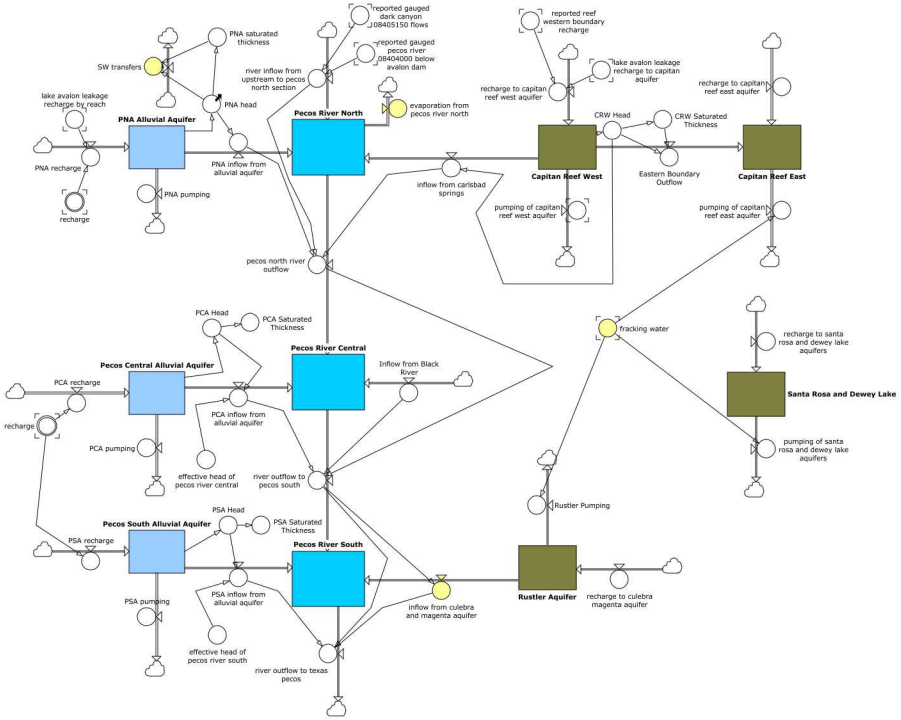




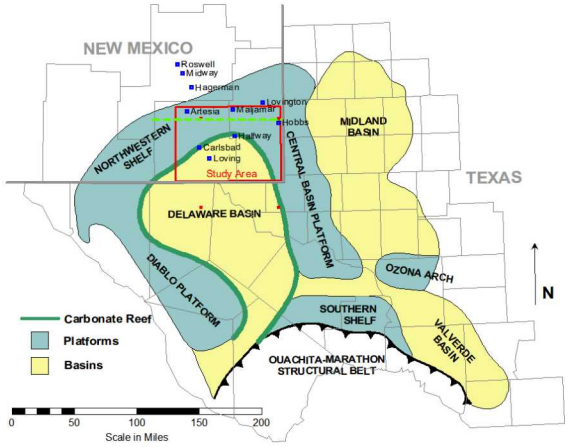


Modeling

- **System Dynamics Modeling** – Develop the Permian Basin Water Availability Model (PBWater), a system dynamics simulation tool to simulate water availability over a range of different future scenarios as identified in the RFD.
  - Table-top player
  - Simulate the increase in drilling activity and water demand relative to each formation and water source to identify the areas/users/formations that are most vulnerable and to estimate the risk to water quantity and quality.
  - Provide decision makers with a tool to assess localized, cumulative impacts.
  - Constructed and calibrated around historical data

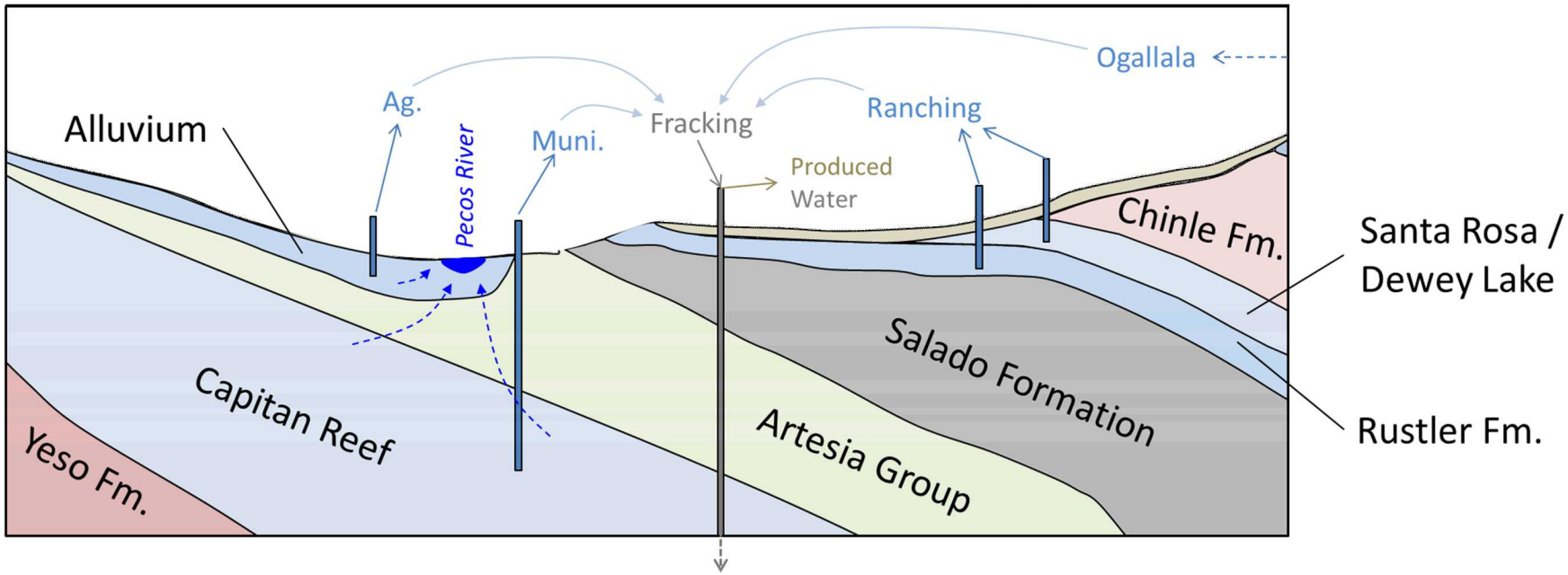


Conceptual Model



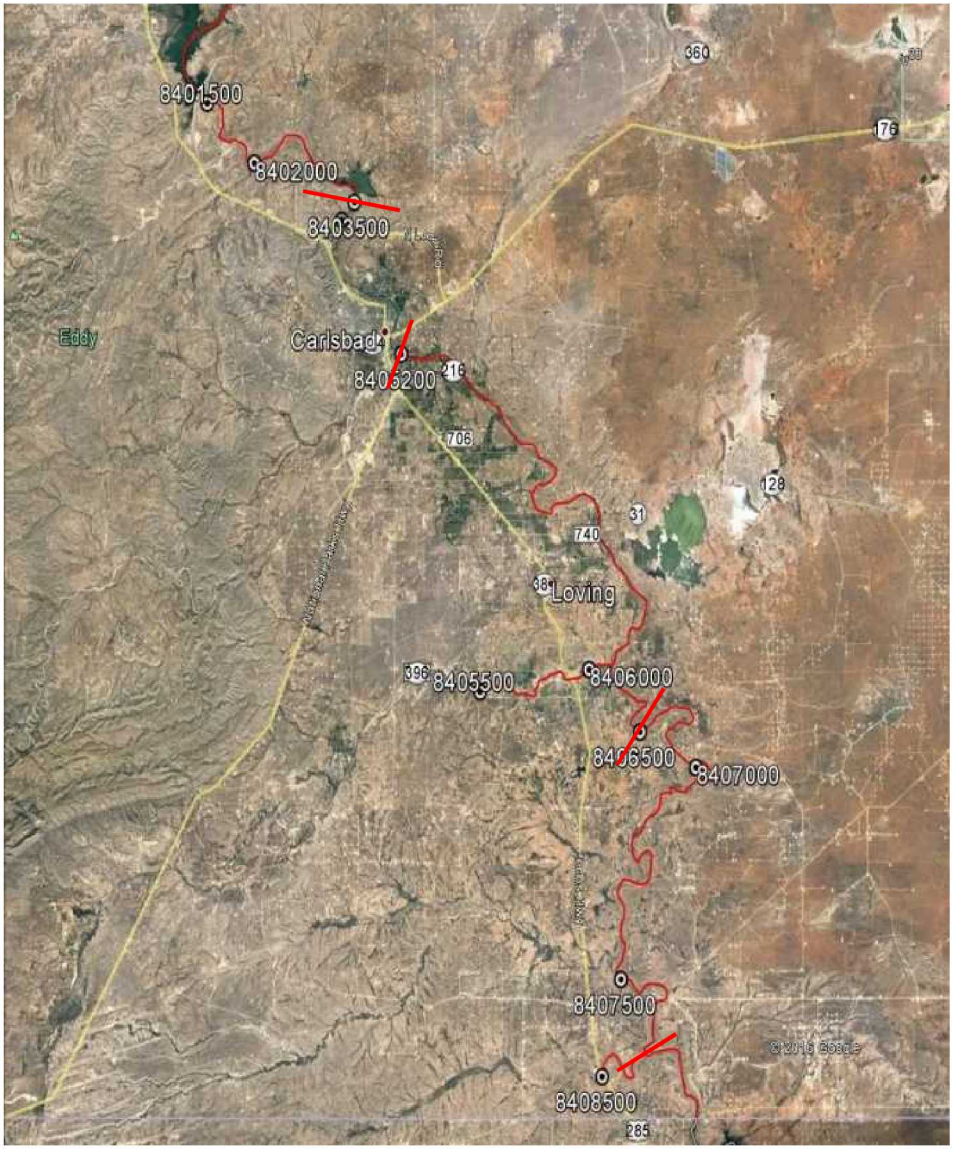
Water Balances simulated in the PBWater Model

Reproduced from Summers, 1972

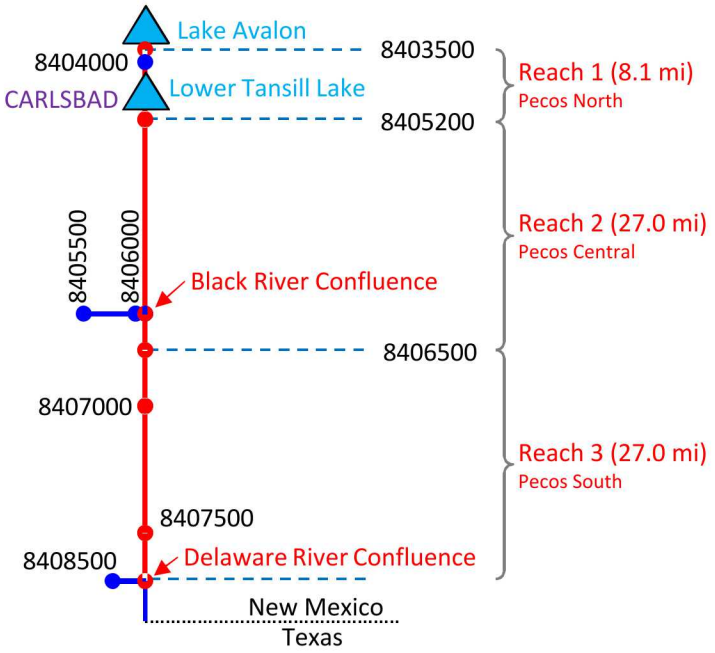


Summers, W.K., 1972, Geology and regional hydrology of the Pecos river basin, New Mexico, Open File Report #37, New Mexico Water Resources Institute, New Mexico State University, Las Cruces, New Mexico, 393 p.

Conceptual Model

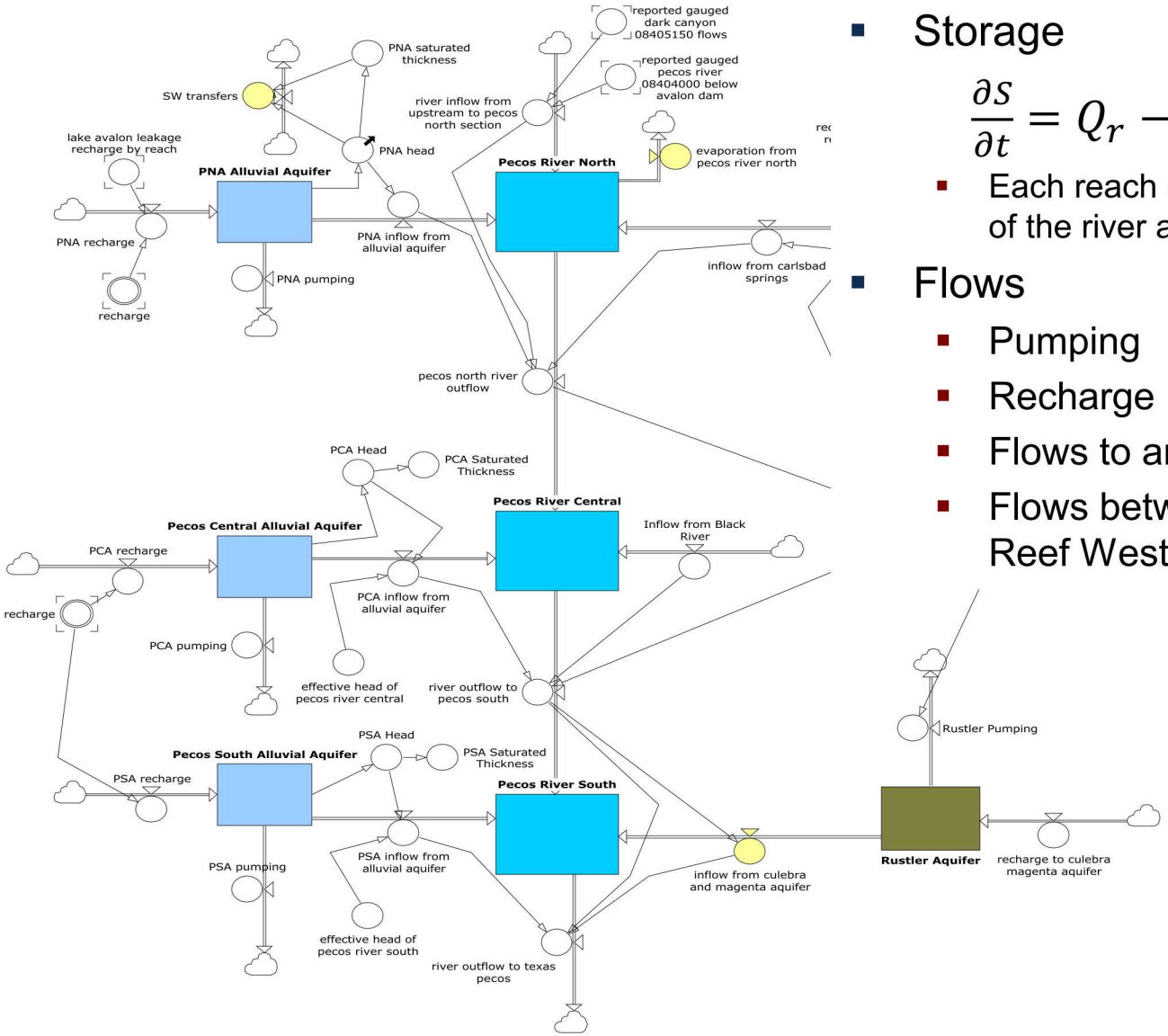


Physical Boundaries



Map view and conceptualization of the model domain. The model simulates 62.1 miles along the Pecos River from just below Lake Avalon (gage #8403500) to the confluence with the Delaware River.

Governing Equations of PBWater

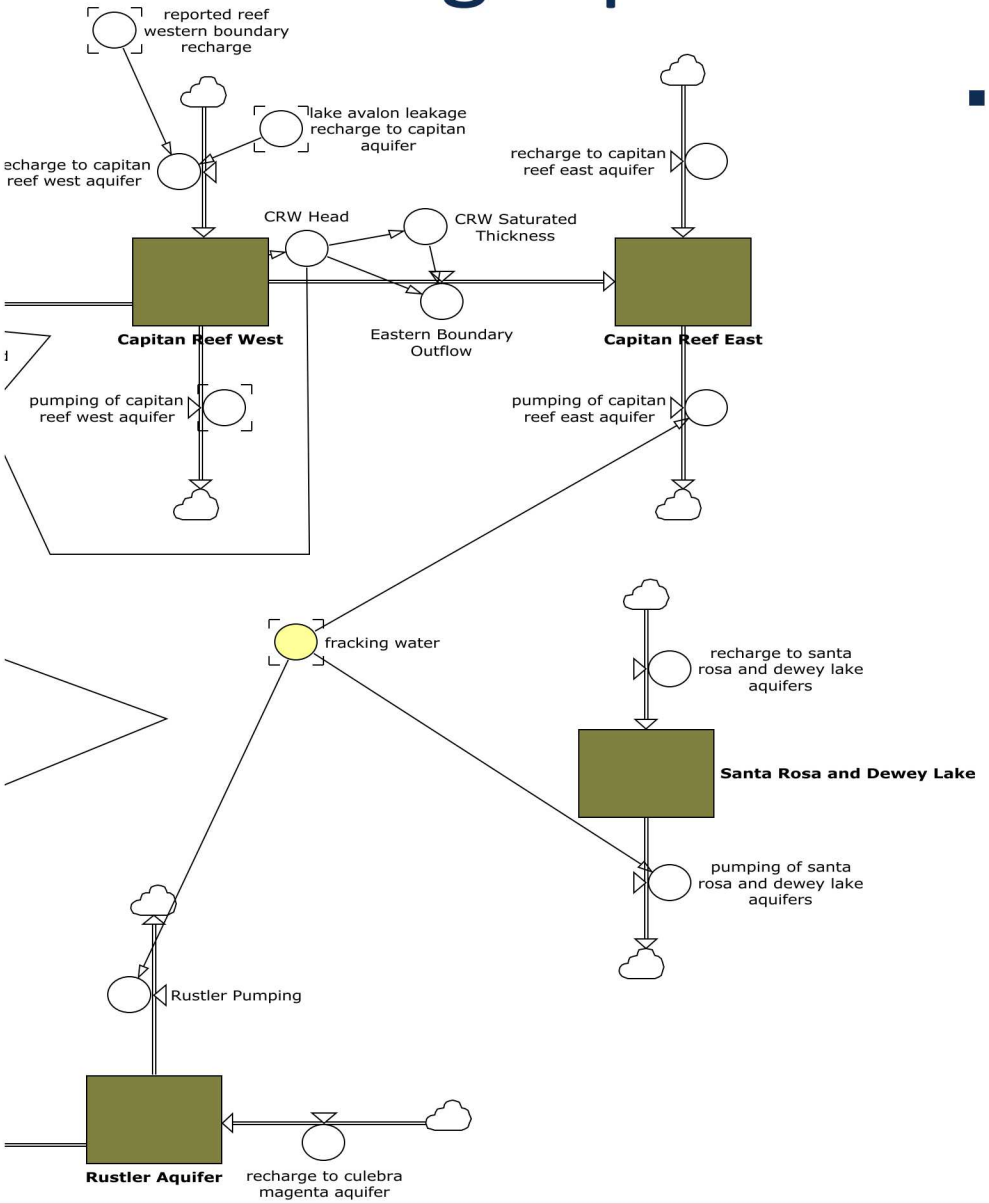


- Storage

$$\frac{\partial S}{\partial t} = Q_r - Q_p + Q_{sw} + Q_{gw}$$

  - Each reach consist of the appropriate length of the river and the adjoining alluvial aquifer
- Flows
  - Pumping
  - Recharge
  - Flows to and from surface water
  - Flows between aquifers of Capitan Reef West and Capitan Reef East

Governing Equations of PBWater



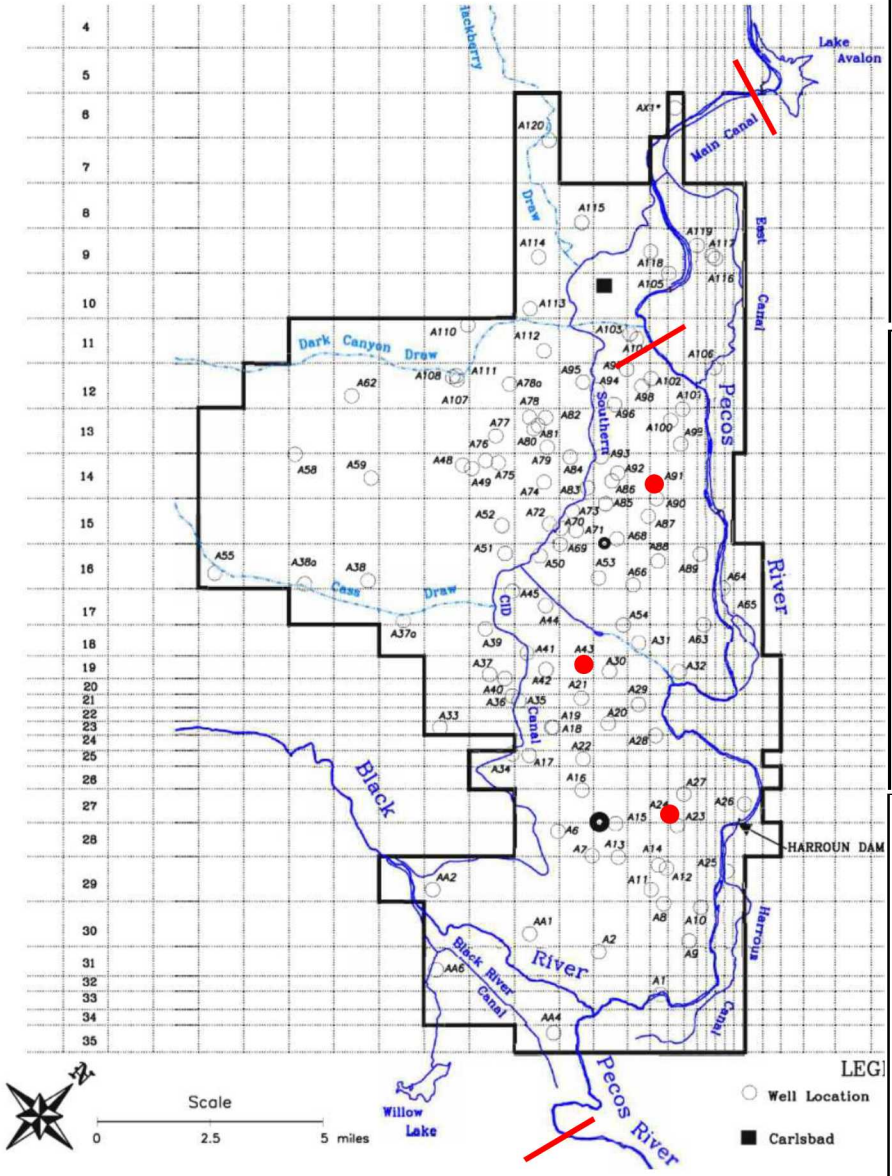
- Darcy Flow equation
  - Interactions between surface and groundwater

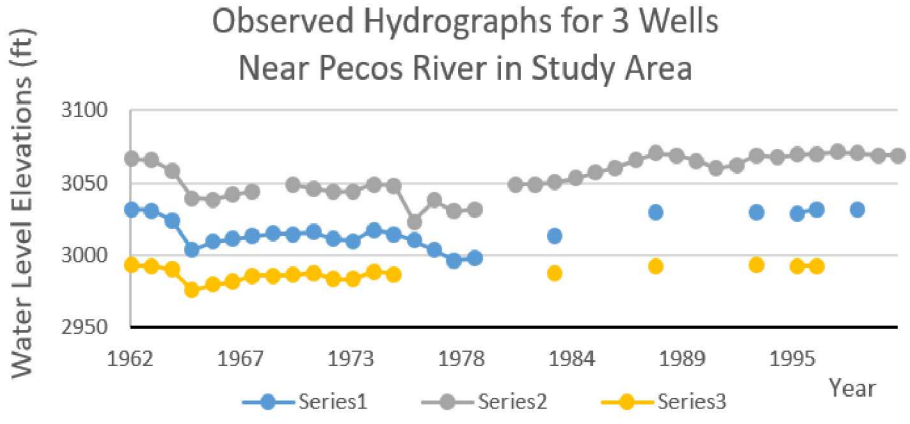
$$Q_{sw} = (H - SWE)C_{sw}$$

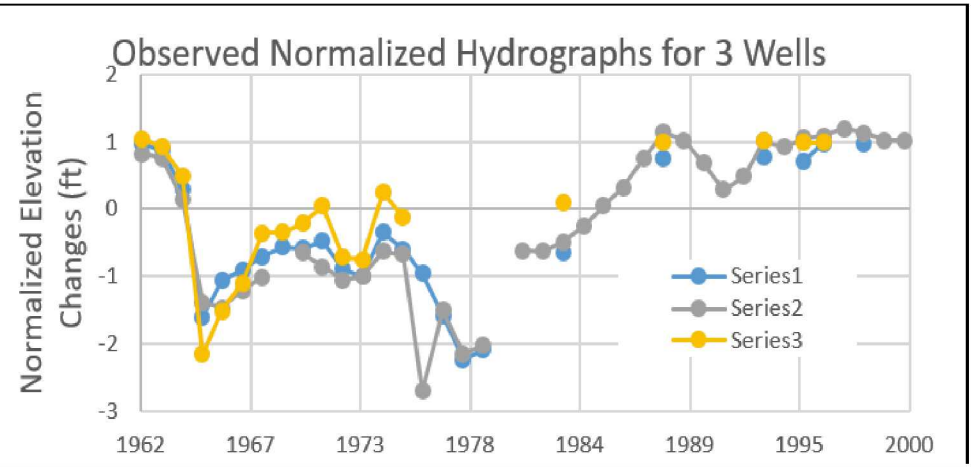
  - Interactions between Capitan Reef aquifer: West and East sides (Darcy Flow equation)

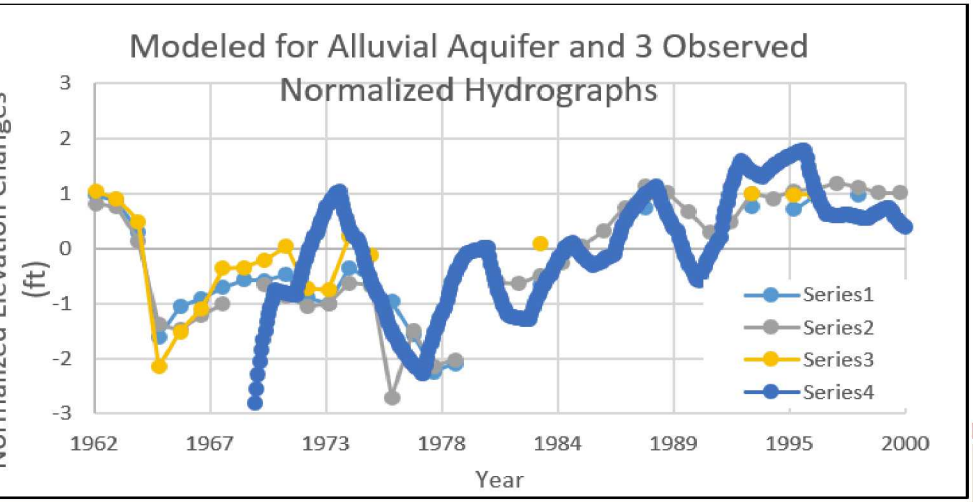
$$Q_{gw} = \frac{(H_{crw} - H_{cre})KbW}{L}$$

Numerical Model



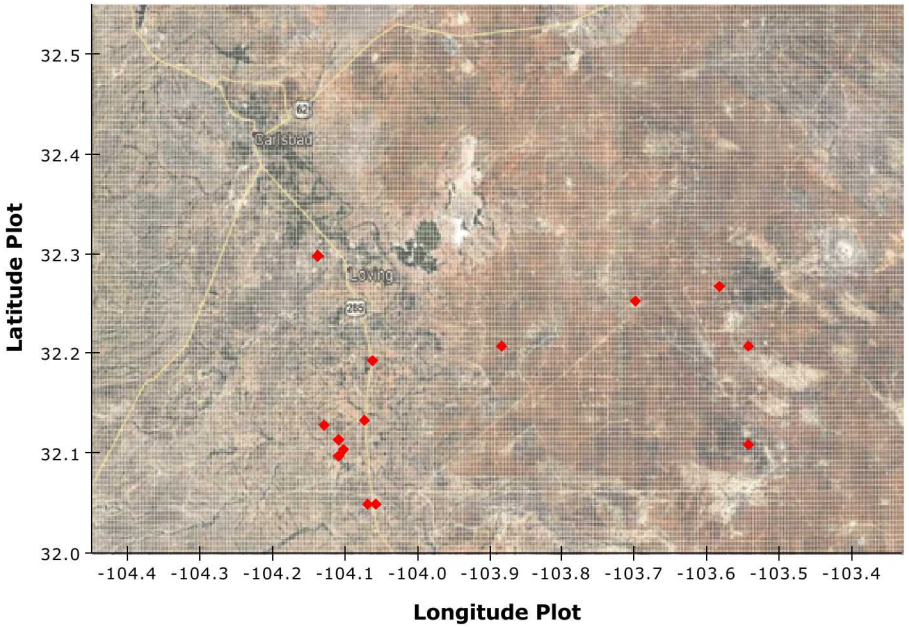


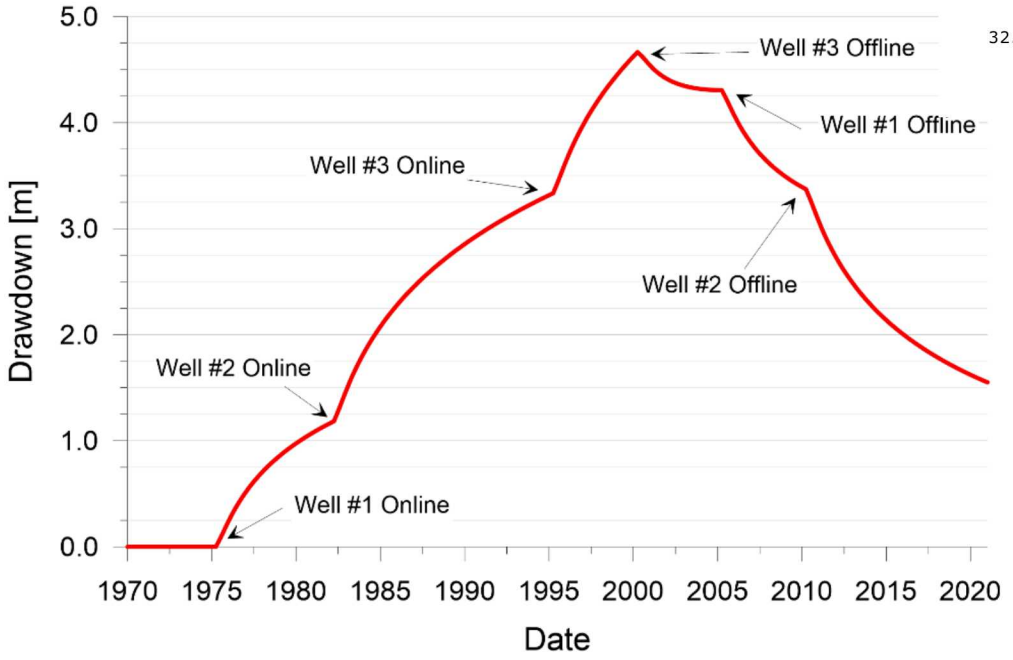




Localized Impacts

- Domain split into 1/200th degree grid (~360 m)
- Mean aquifer dynamics, T, S, pumping rate





Well Drawdown function for confined aquifers (Theis equation)

$$h_o - h = \frac{Q}{4\pi T}\int_u^\infty \frac{e^{-u}}{u}\,du$$

- h_o [L] is the hydraulic head before pumping started,
- h [L] is hydraulic head,
- Q [L^3/t] is the pumping rate, and
- T [L^2/t] is the aquifer transmissivity
- $\int_u^\infty \frac{e^{-u}}{u}\,du$ = well function

Simulated Future

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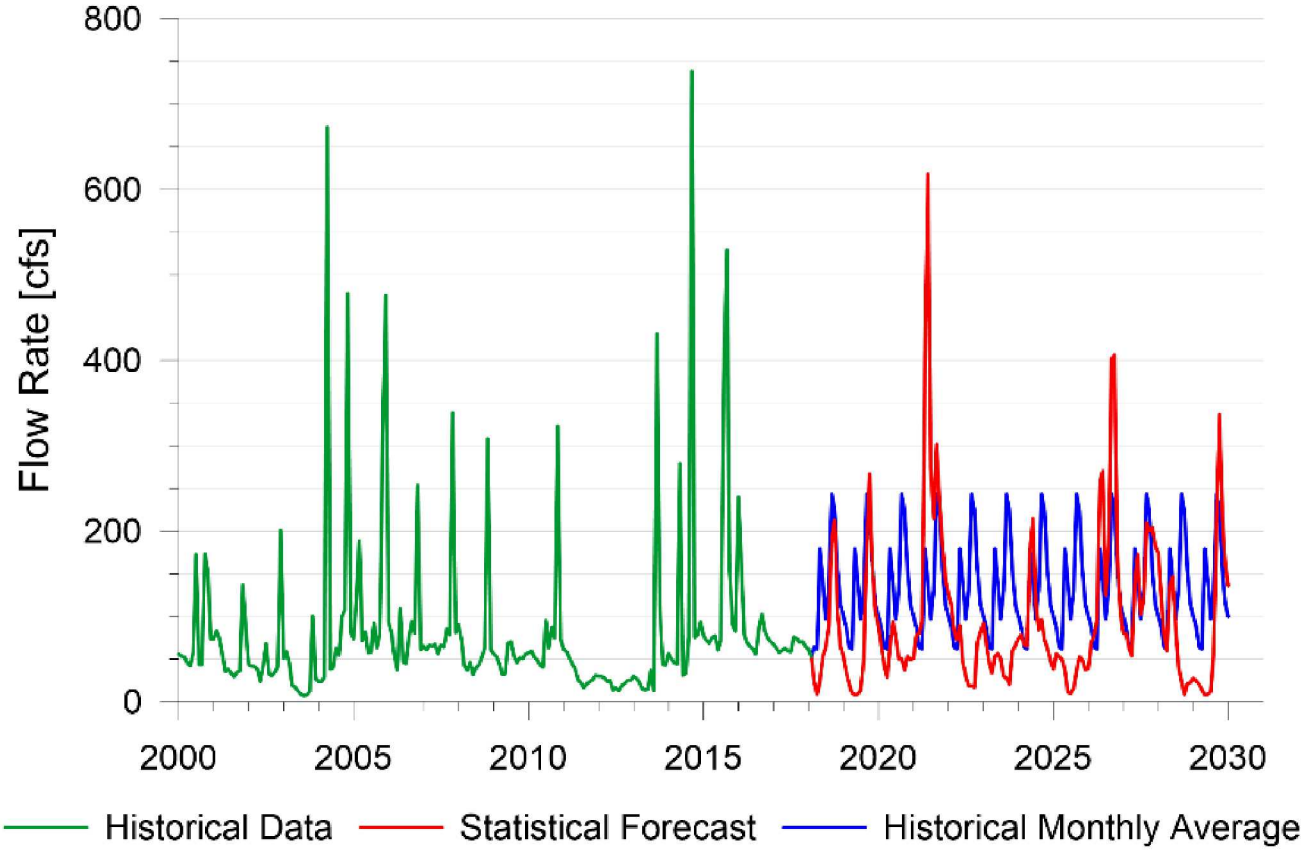
- Requires provisions for providing realistic inputs for streamflow, recharge, and pumping
- Two options offered to simulate future input variables:
  - Historical mean
  - Statistical forecast
- Historical mean option
  - Uses the monthly historical mean
  - Produces a forecast that repeats each year into the future
- Statistical forecast option
  - Based on the cumulative distribution function (CDF) of the historical data for each month
  - Random number generator (0 to 1)
  - Yearly deviation using a normal distribution with a mean of 0.5 and a variance of 0.17

Example of Results



Example using flow data from the 0846500 gage (Pecos near Malaga)

Concluding Remarks

Sandia National Laboratories

- Developed the Permian Basin Water Availability Model (PBWater) as Table-top player
  - Simulate the increase water demand relative to each formation and water source to identify the areas/users/formations that are most vulnerable and to estimate the risk to water quantity and quality
  - Provide decision makers with a tool to assess localized, cumulative impacts
  - Allows BLM to screen future water extraction that may be unsustainable
- Report is complete and to the customer
- Version 1 of the model in beta-testing
- Data to go through review process and be made available to the public
- Continuous monitoring (13 wells) is ongoing and will be added to the database as it is collected

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Backup Slides

Cross-Sections

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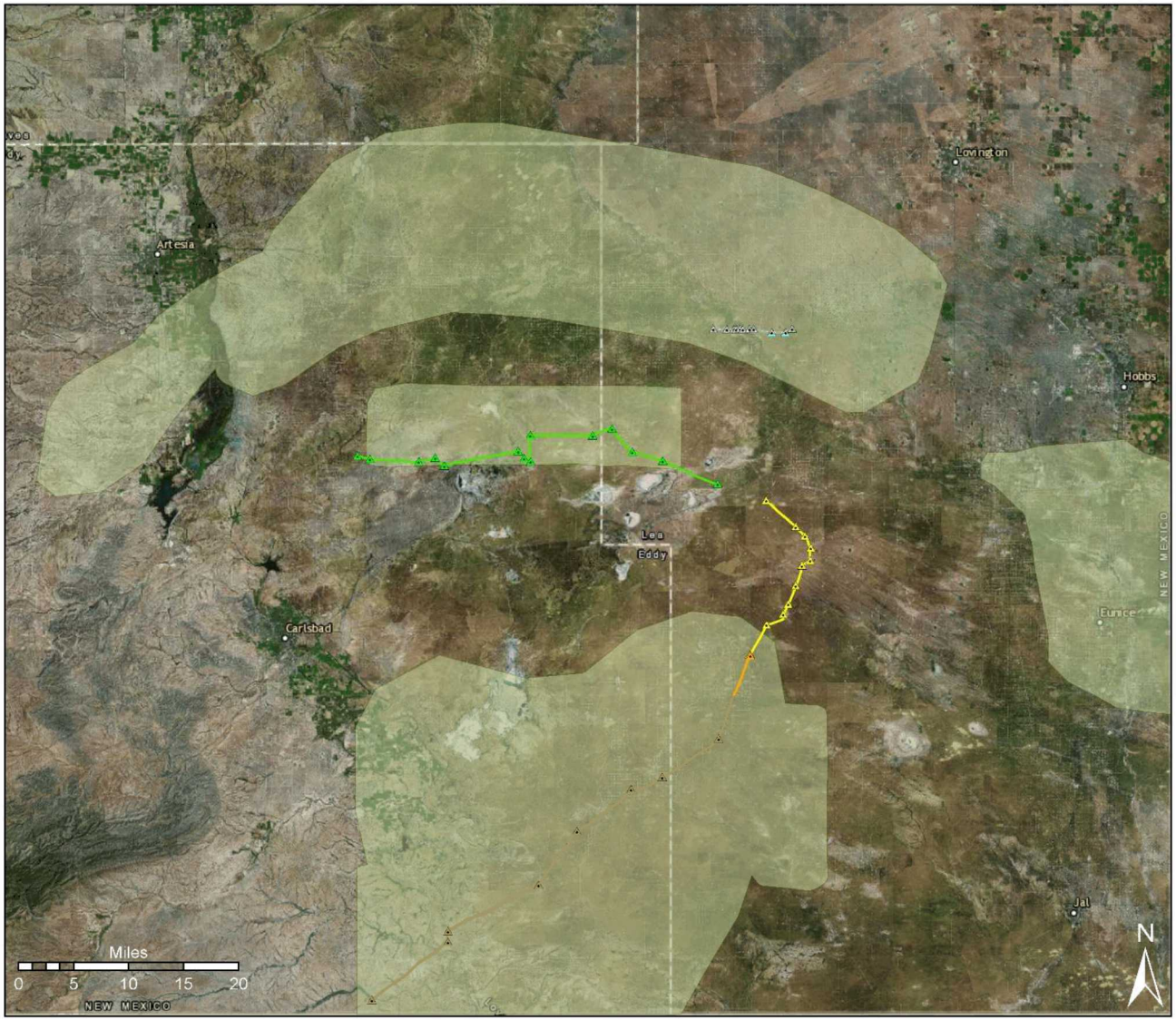

Cross-Section Locations

- South Area X-Section
- North-Central Area (N-S) X-Section
- Mescalero Ridge South X-Section
- North-Central Area (W-E) X-Section
- BLM High Potential Areas

South HPA – SW to NE

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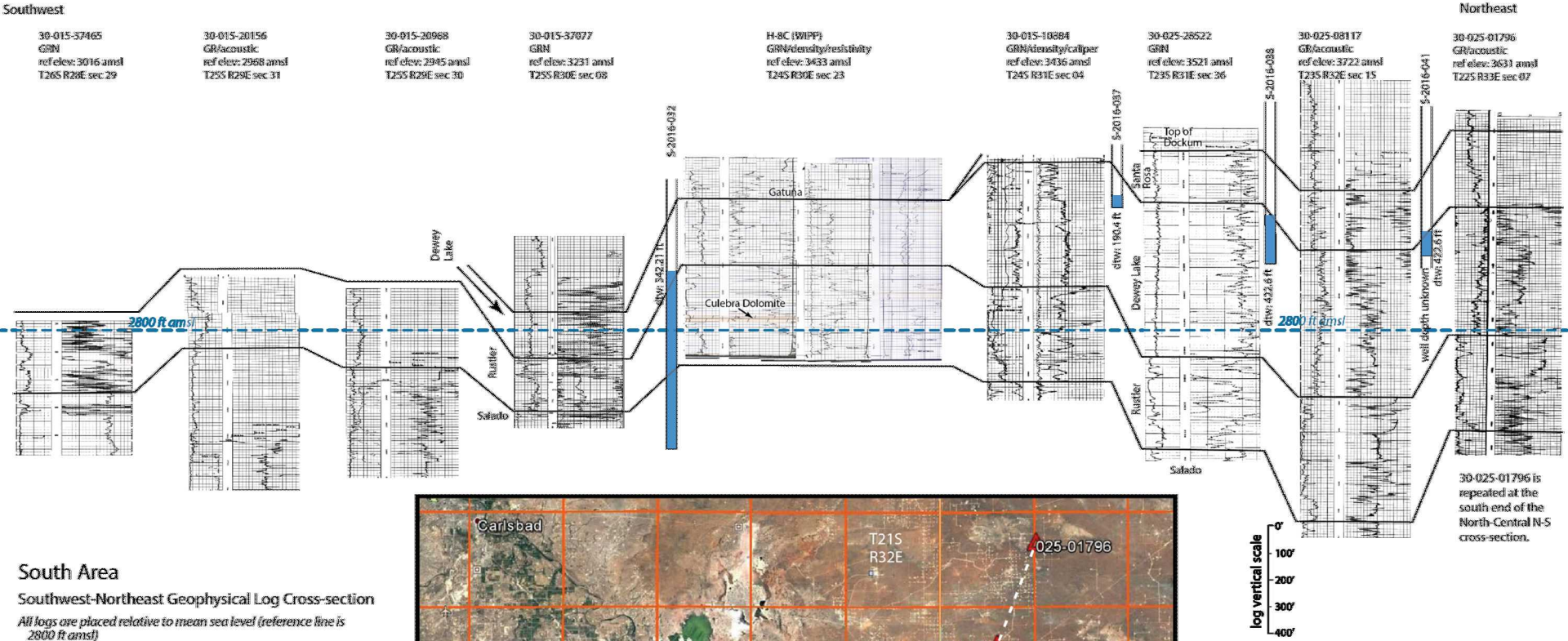

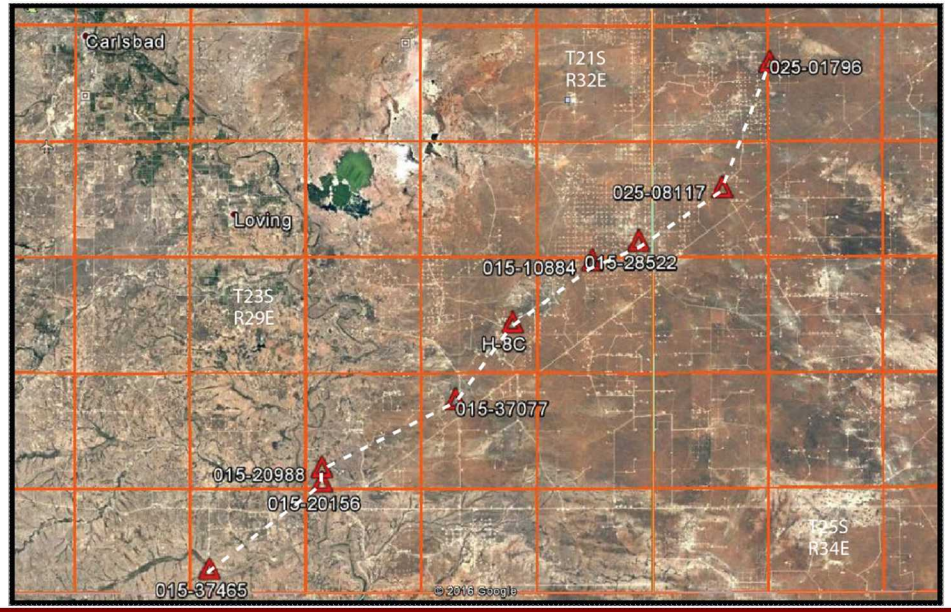

South Area

Southwest-Northeast Geophysical Log Cross-section

All logs are placed relative to mean sea level (reference line is 2800 ft amsl)

Water wells are not included due to lack of depth and water level data along trend

Logs are not placed horizontally to scale

Explanation

- GR - gamma ray
- GRN - gamma ray/neutron log
- formation contact
- standard reference elevation
- S-2016-xxx: water well identifier
- dtw: depth to water in ft
- well diagram, at reference elevation with scaled dtw in blue

North HPA - Mescalero Ridge W to E

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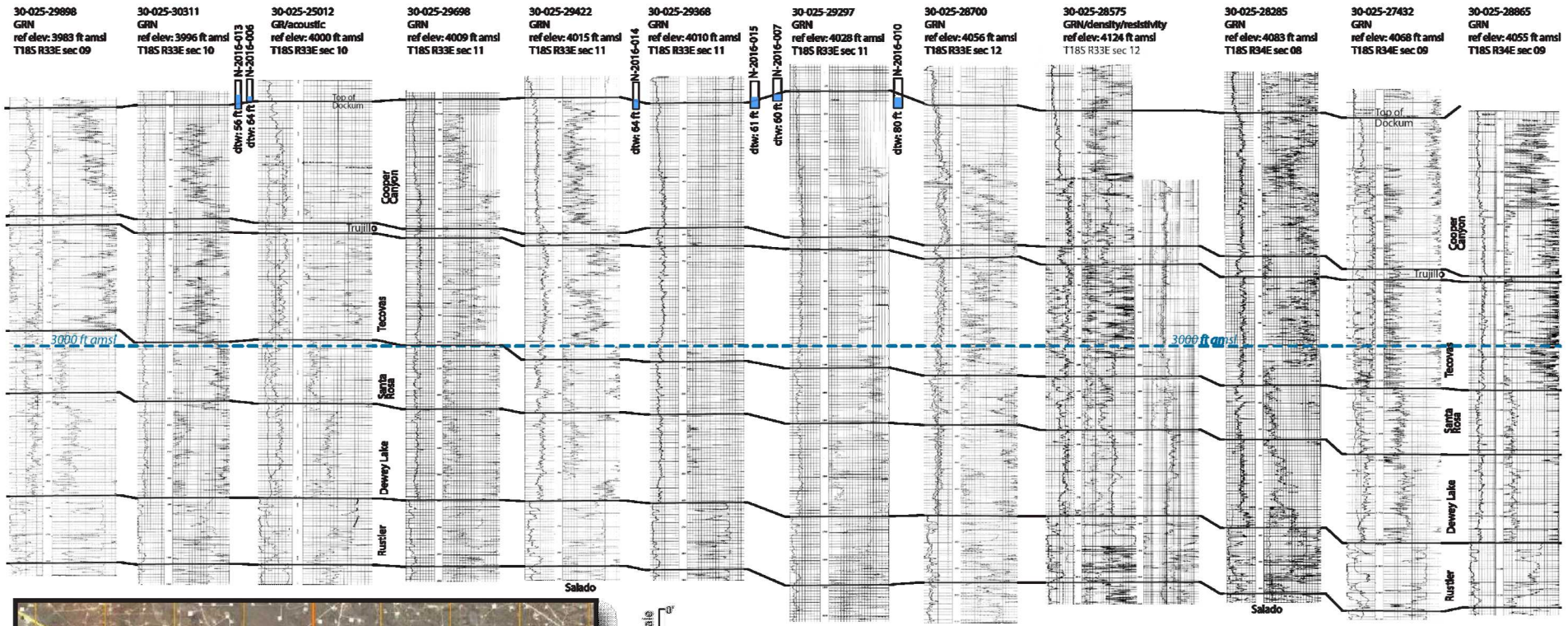
West

East



Mescalero Ridge South

West-East Geophysical Log Cross-section

All logs are placed relative to mean sea level (reference line is 3000 ft amsl)
Nearby water wells are projected into the log cross-section where depth and water level data are available
Logs are not placed horizontally to scale

Explanation

- GR - gamma ray
- GRN - gamma ray/neutron log
- formation contact
- standard reference elevation
- N-2016-xxxc: water well identifier
- dtw: depth to water in ft
- well diagram, at reference elevation with scaled dtw in blue

North-Central HPA - W to E

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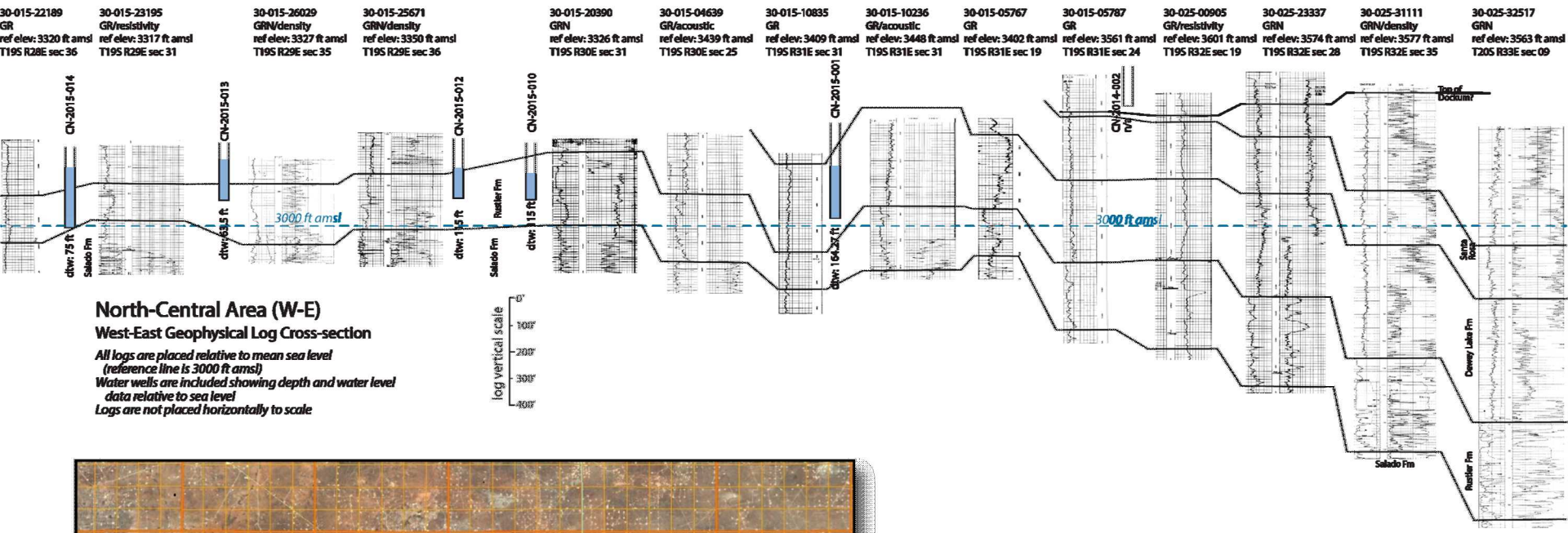
West

East



North-Central Area (W-E)

West-East Geophysical Log Cross-section

All logs are placed relative to mean sea level (reference line is 3000 ft amsl)
Water wells are included showing depth and water level data relative to sea level
Logs are not placed horizontally to scale

log vertical scale
0'
100'
200'
300'
400'

Explanation

- GR - gamma ray
- GRN - gamma ray/neutron log
- formation contact
- standard reference elevation
- CN-201x-xxx: water well identifier
- dtw: depth to water in ft
- well diagram, at reference elevation with scaled dtw in blue

North-Central HPA - N to S

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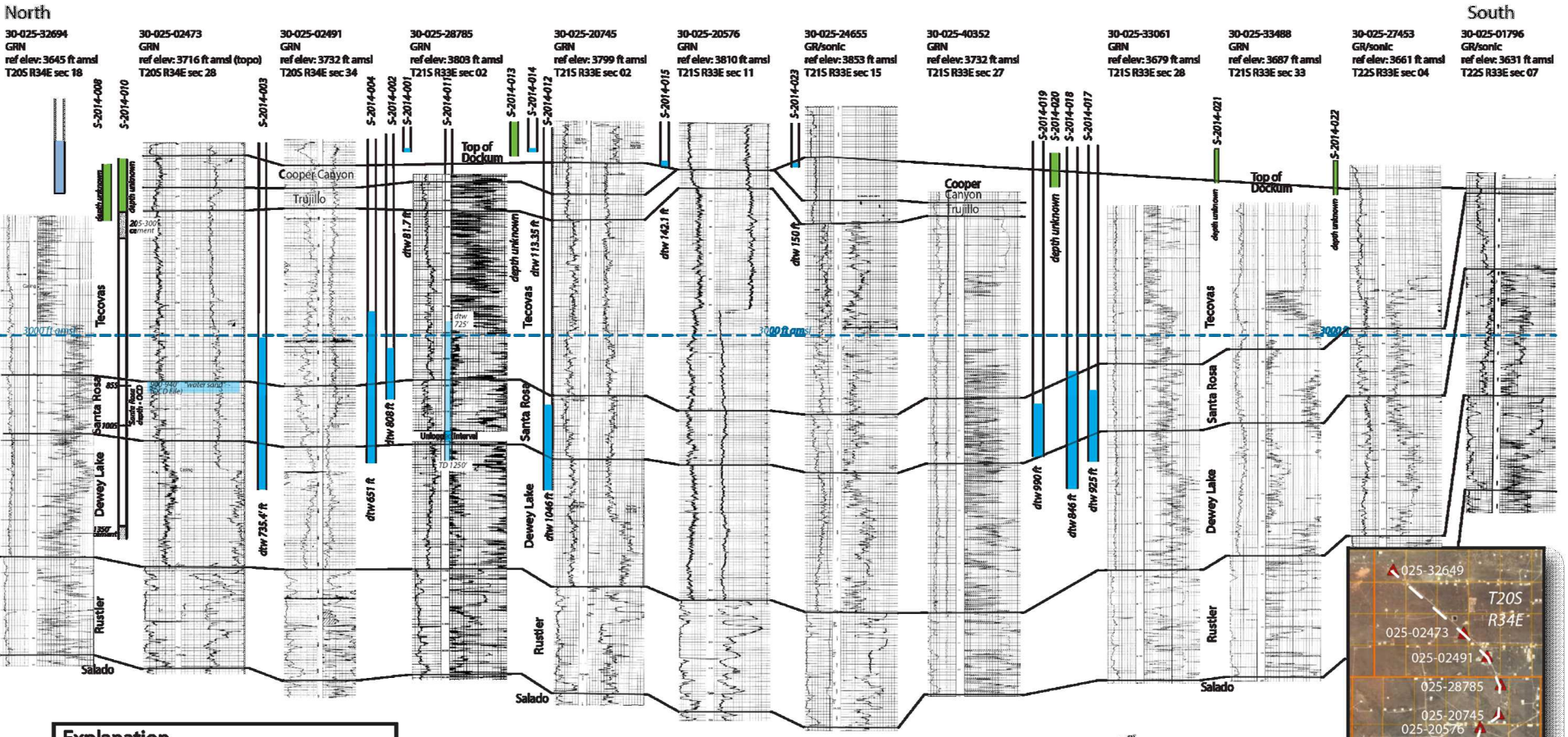


Explanation

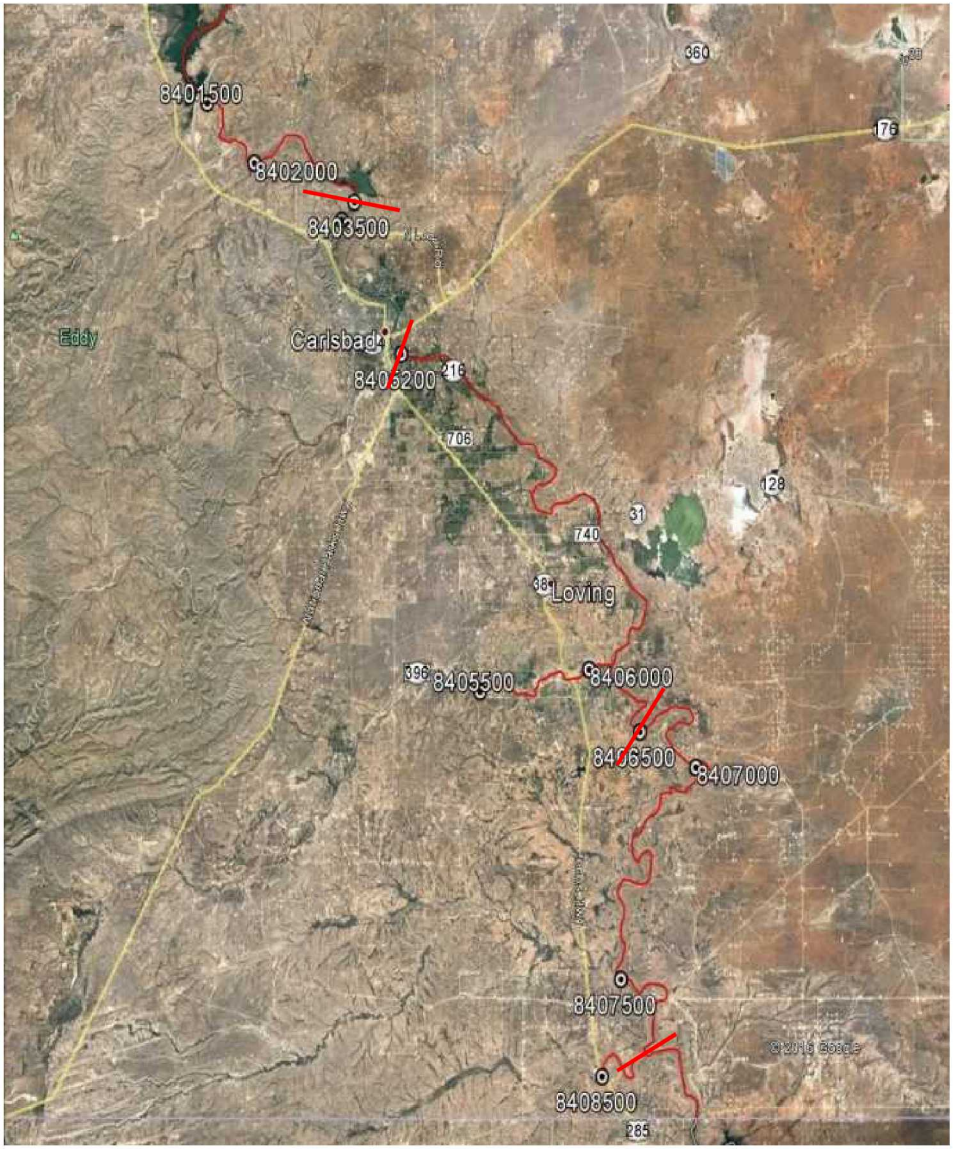
- GR - gamma ray
- GRN - gamma ray/neutron log
- formation contact
- standard reference elevation
- S-2014-xxx: water well identifier
- dtw: depth to water in ft
- well diagram, at reference elevation with scaled dtw in blue

North-Central Area (N-S)

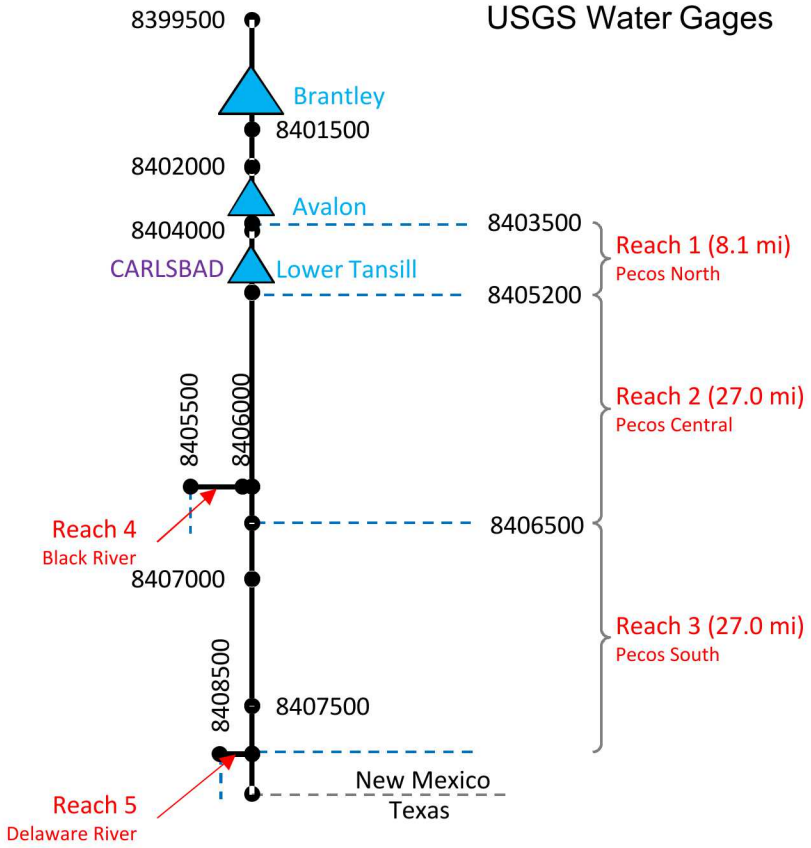
North-South Geophysical Log Cross-section

All logs are placed relative to mean sea level (reference line is 3000 ft amsl)
Water wells are included showing depth and water level data relative to sea level
Logs are not placed horizontally to scale

Conceptual Model



Physical Boundaries



Map view and conceptualization of the model domain. The model simulates 62.1 miles along the Pecos River from just below Lake Avalon (gage #8403500) to the confluence with the Delaware River.

Water Chemistry

- Water samples on ~27% of wells identified/accessed
- Looked at cation/anion balance and other water quality indicators

pH	Magnesium (Mg_2^+)	Sulfate ($S0_4^{2-}$)
Specific Conductance	Sodium (Na^+)	Fluoride (F^-)
Total Dissolved Solids (TDS)	Potassium (K^+)	Nitrate (NO_3^-)
Calcium (Ca_2^+)	Bicarbonate (HCO_3^-)	Nitrite (NO_2^-)
Chloride ($^{Cl-}$)	Carbonate (CO_3^-)	

- Some wells also sampled for 17 trace metals

Water Chemistry