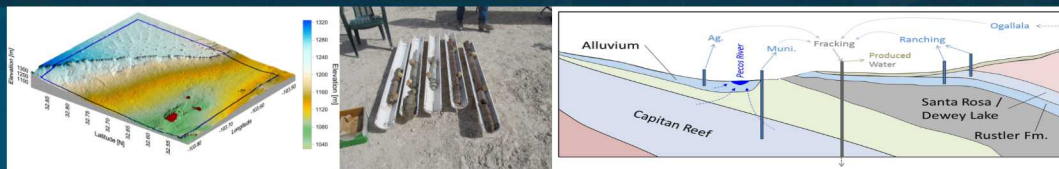


SAND2020-5952C

Assessing Risk to Water Resources from Oil and Gas Activities in the San Juan Basin



Animas and San Juan Watersheds Conference
June 19-20, 2019

PRESENTED BY

Thomas Lowry, Sandia National Laboratories

SAND2019-6771 C

The Project Team

Tom Lowry – Sandia National Laboratories

Owen Lofton – Sandia National Laboratories

Patricia Johnson – Sandia National Laboratories

Dale Bowman – Sandia National Laboratories

Whitney Thomas – BLM Farmington

Dave Herrell – BLM Santa Fe



Introduction

Motivation

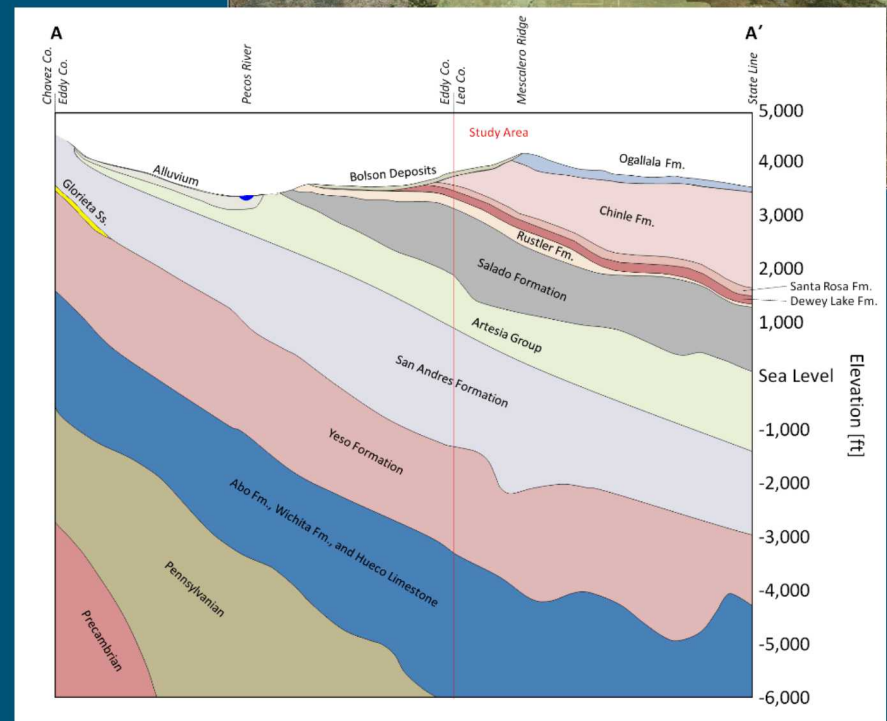
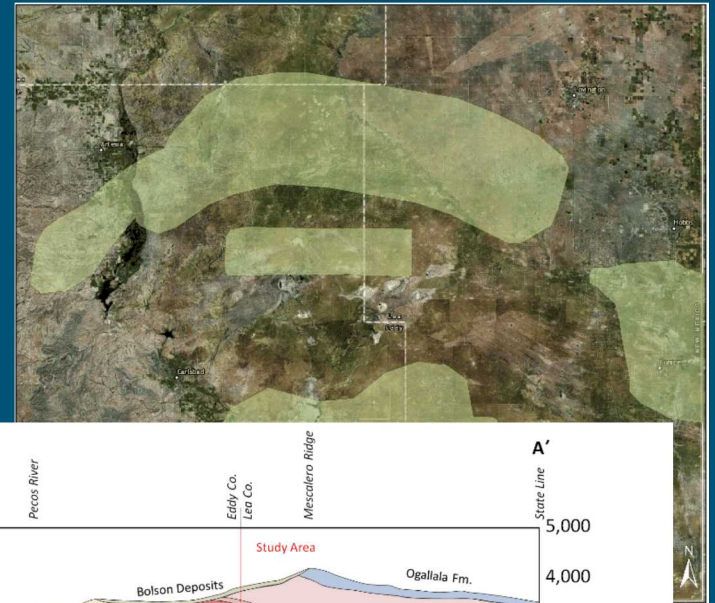
Reasonable Foreseeable
Development

Water Resource Studies

- Dewey Lake / Santa Rosa
- Permian Basin

San Juan Basin

- Groundwork
- Issues
- Schedule
- Shameless call for input



Motivation

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 and rank potential cumulative impacts of future water demands. Of key importance is understanding the current state of the groundwater system (quality and quantity).

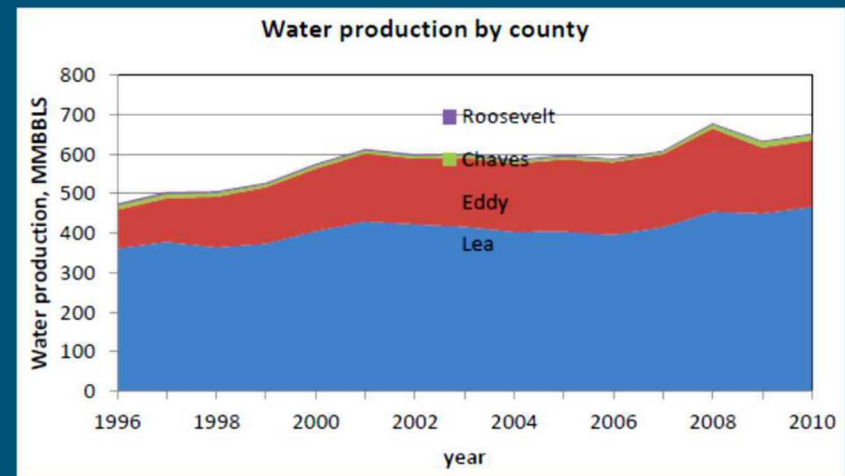
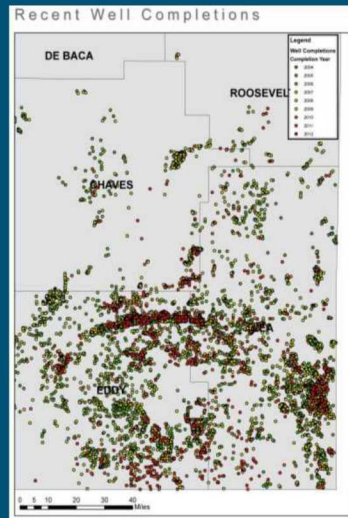
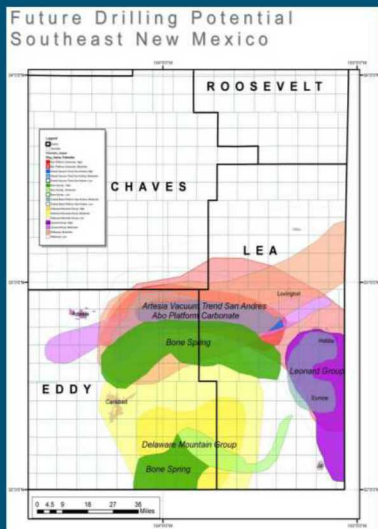
1. Data collection
2. Field verification
3. Field testing and monitoring
4. Modeling??

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

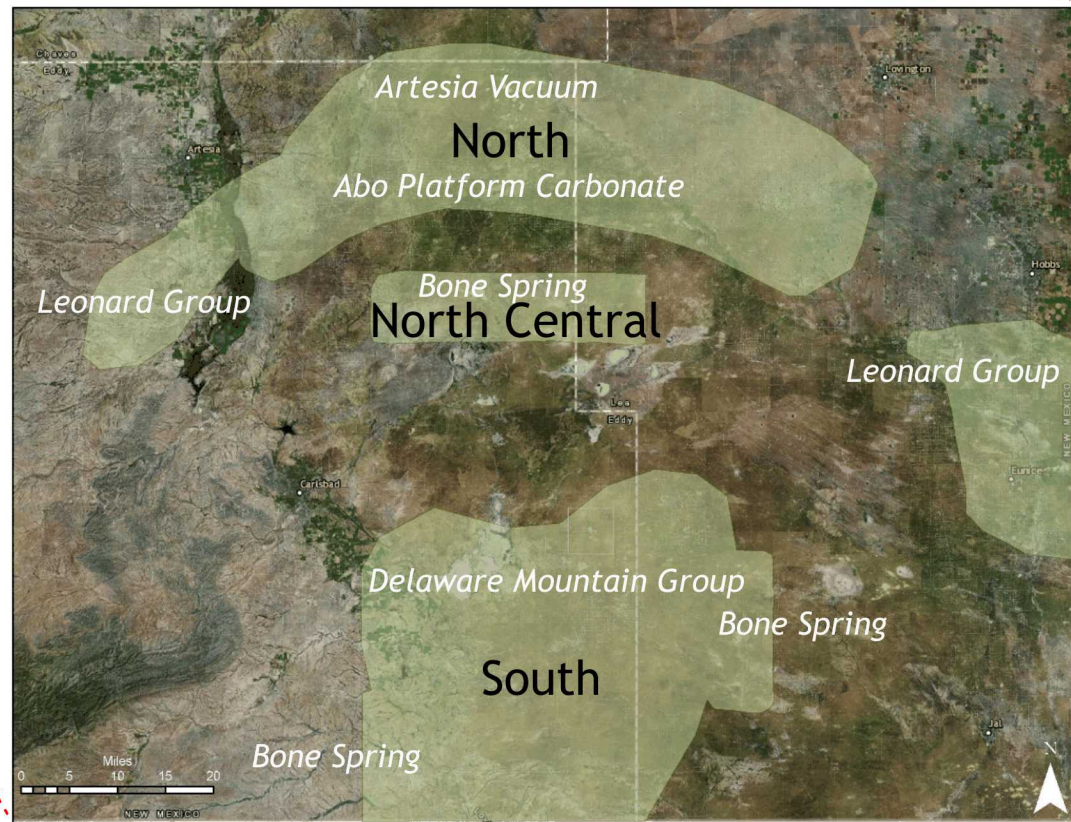
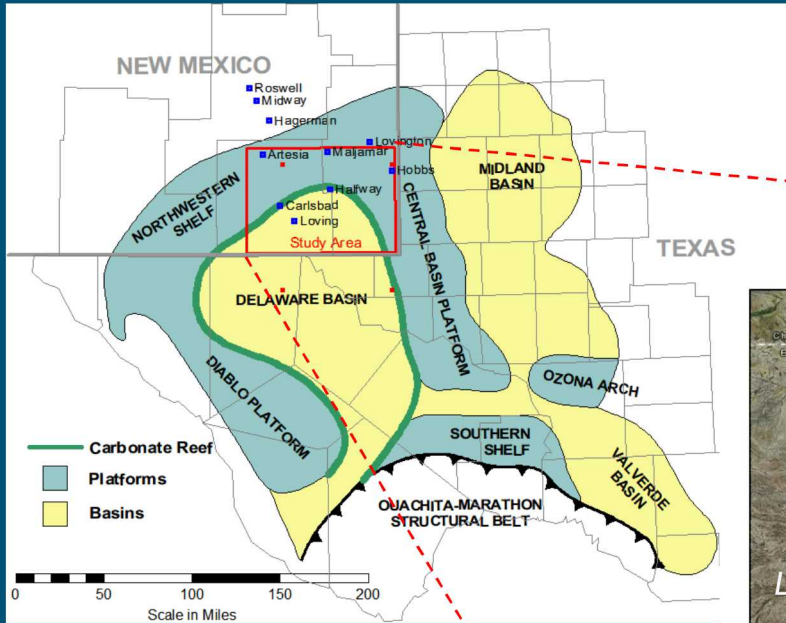
Identified the major oil (16) and gas (10) plays and categorized them into potential areas of 'low', 'moderate', 'high', or 'very high'

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

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)

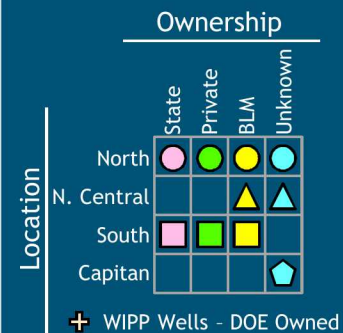
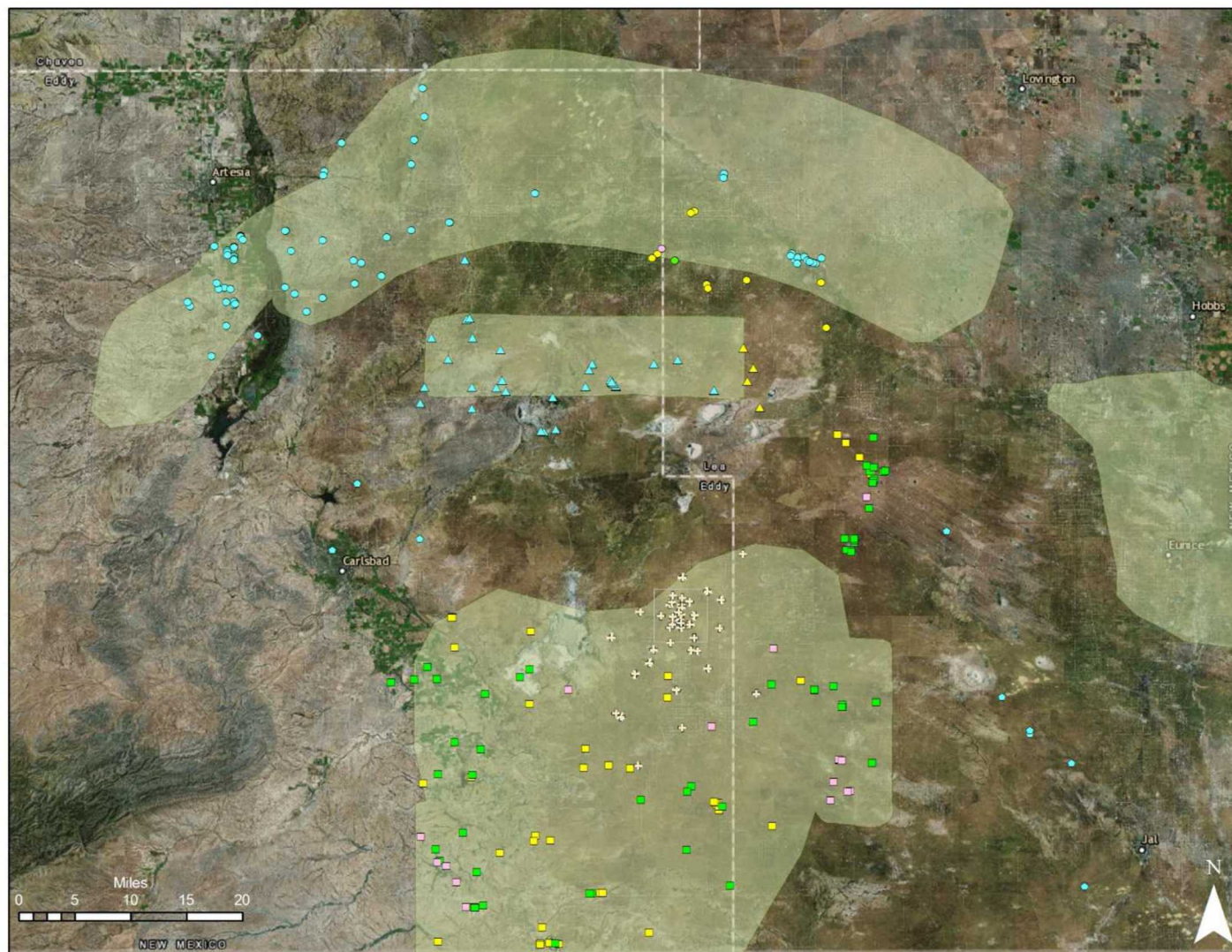
Field Testing and Sampling

- 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



Working with Private Well Owners

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.

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 use query of the Office of the



Figure 42 Wallen Fed. No. 9 East



Figure 38 Windmill No. 2 West



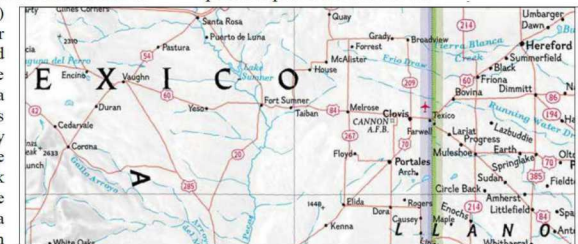
Figure 56 (House Well) North

 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 icted by Sandia National Laboratories was an effort to assist the Bureau of

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



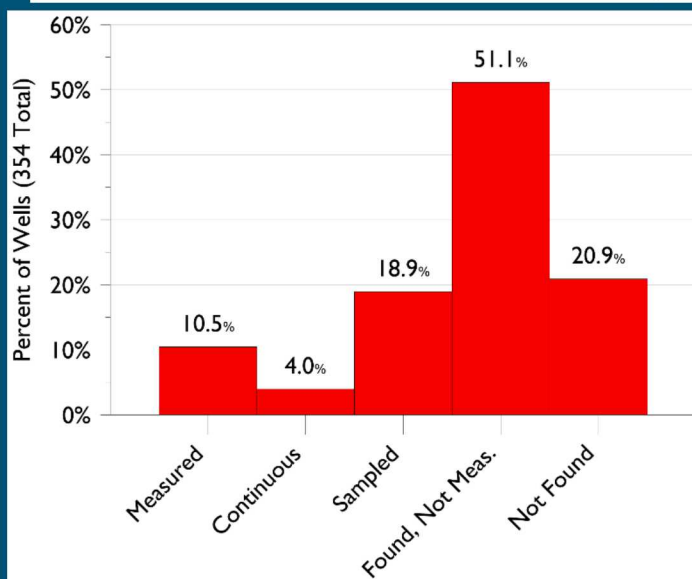
Analytical Report
Lab Order 1412226
Date Reported: 12/19/2014

Hall Environmental Analysis Laboratory, Inc.

CLIENT: Sandia National Labs		Client Sample ID: CP-1336-20141202	
Project: BLM-DL		Collection Date: 12/2/2014 9:50:00 AM	
Lab ID: 1412226-001		Received Date: 12/4/2014 9:00:00 AM	
Matrix: AQUEOUS			
Analyses	Result	RL Qual Units	DF Date Analyzed Batch
EPA METHOD 300.0: ANIONS			
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			
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			
Conductivity	1000	0.010 umhos/cm	1 12/5/2014 9:49:06 AM R22984
SM4500-H+B: PH			
pH	8.43	1.68 H pH units	1 12/5/2014 9:49:06 AM R22984
SM2320B: ALKALINITY			
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 MOO: TOTAL DISSOLVED SOLIDS			
Total Dissolved Solids	636	20.0 mg/L	1 12/7/2014 4:12:00 PM 16683

Data Collection, Verification, Testing

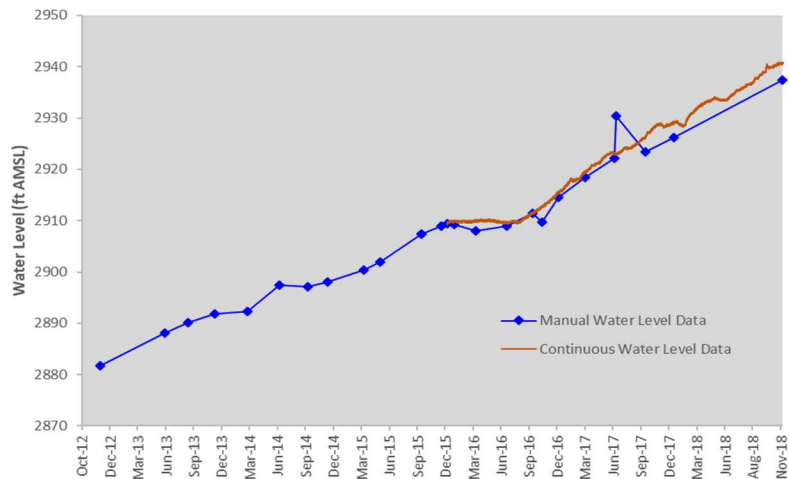
	North	N Central	South	Capitan	Total
Total	127	60	158	9	354
Measured	7	10	16	4	37
Continuous	3	2	5	4	14
Sampled	19	11	30	7	67
Found, Not Measurable	70	24	86	1	181
Not Found	28	17	29	0	74



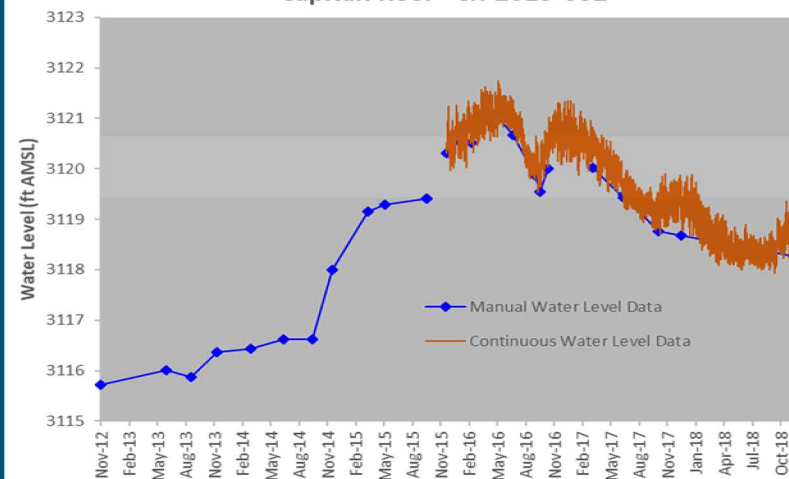
Most of the wells (72%) were either not found or not measurable

Continuous Measurements

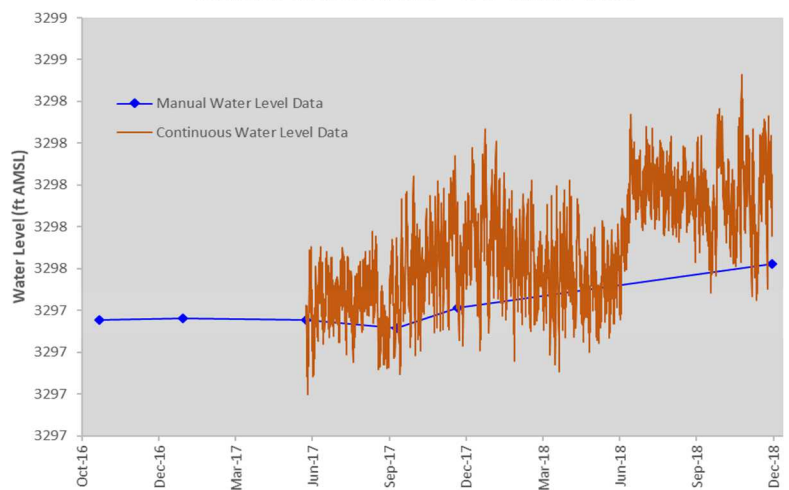
North Custer Water Level - CR-2015-005



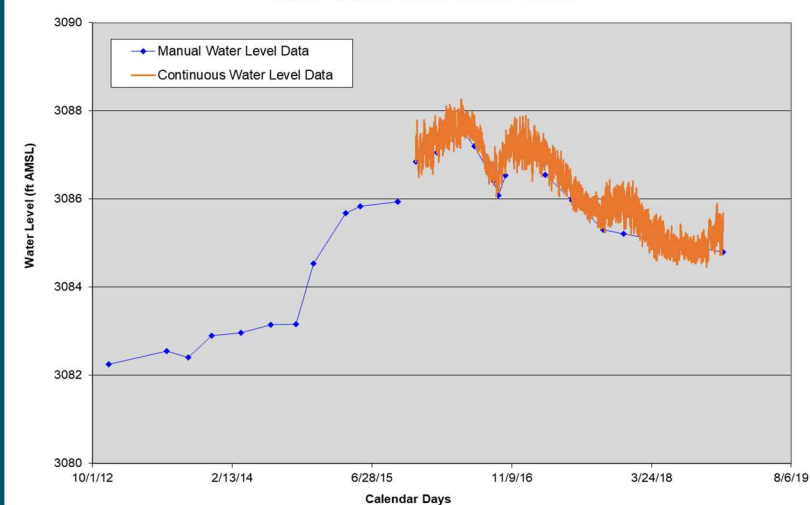
Capitan Reef - CR-2015-002



Center North HPA - CN-2015-013



North Cedar Hills Water Level



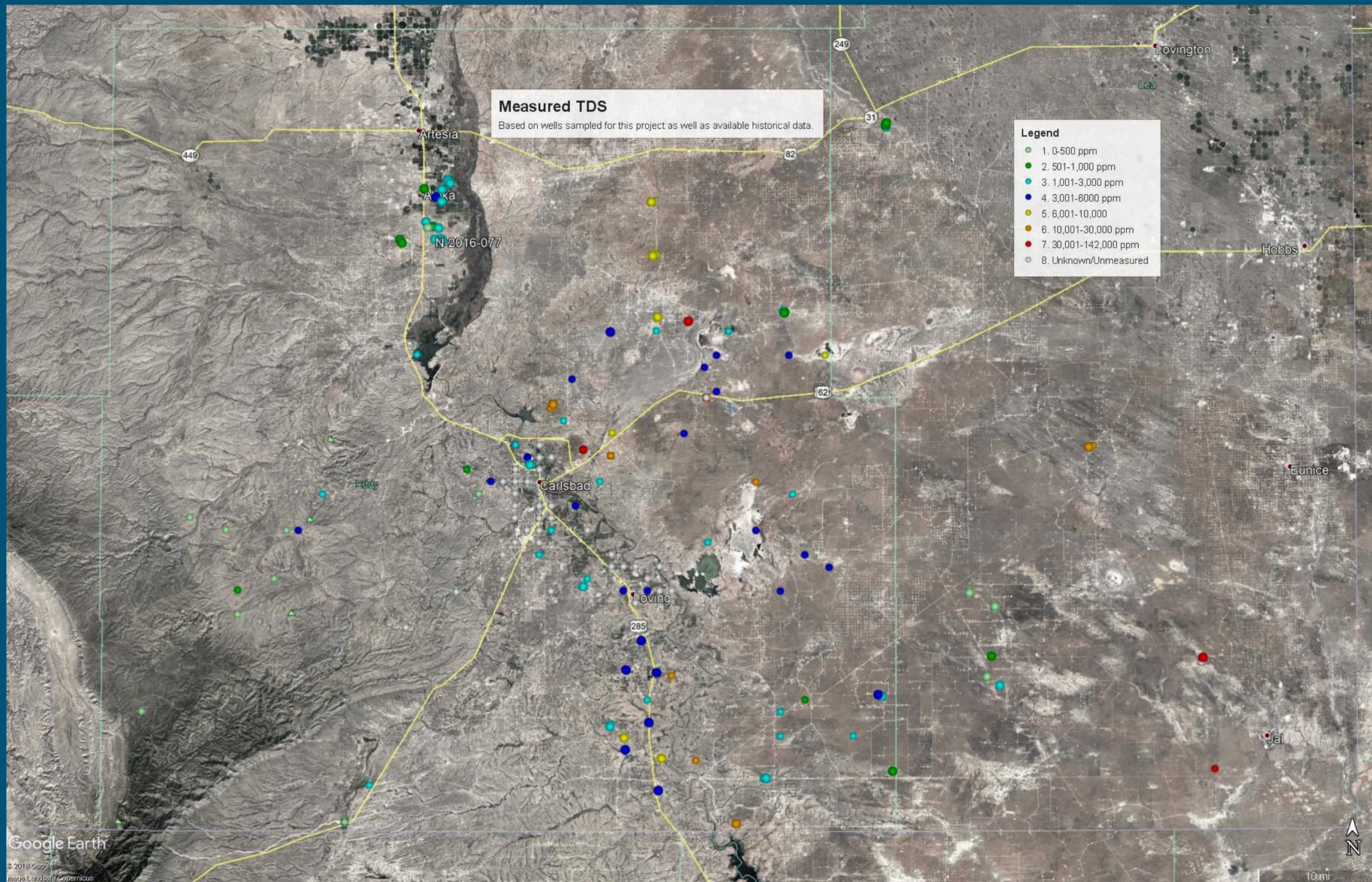
Water Chemistry

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

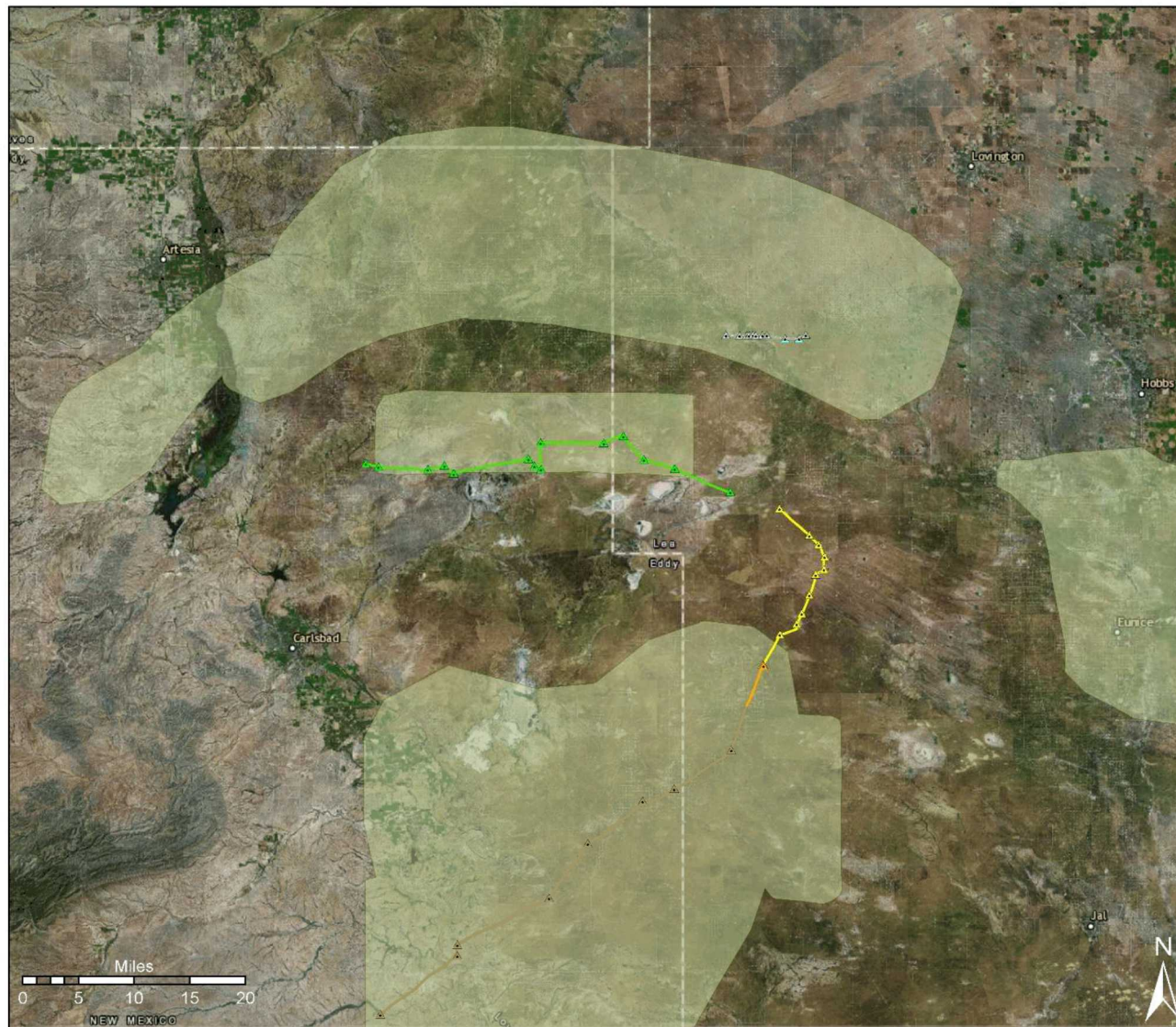
pH	Magnesium (Mg_2^+)	Sulfate (SO_4^{2-})
Specific Conductance	Sodium (Na^+)	Fluoride (F^-)
Total Dissolved Solids (TDS)	Potassium (K^+)	Nitrate (NO_3^-)
Calcium (Ca_2^+)	Bicarbonate (HCO_3^-)	Nitrite (NO_2^-)
Chloride (Cl^-)	Carbonate (CO_3^-)	

- Some wells also sampled for 17 trace metals

Water Chemistry



Cross-Sections



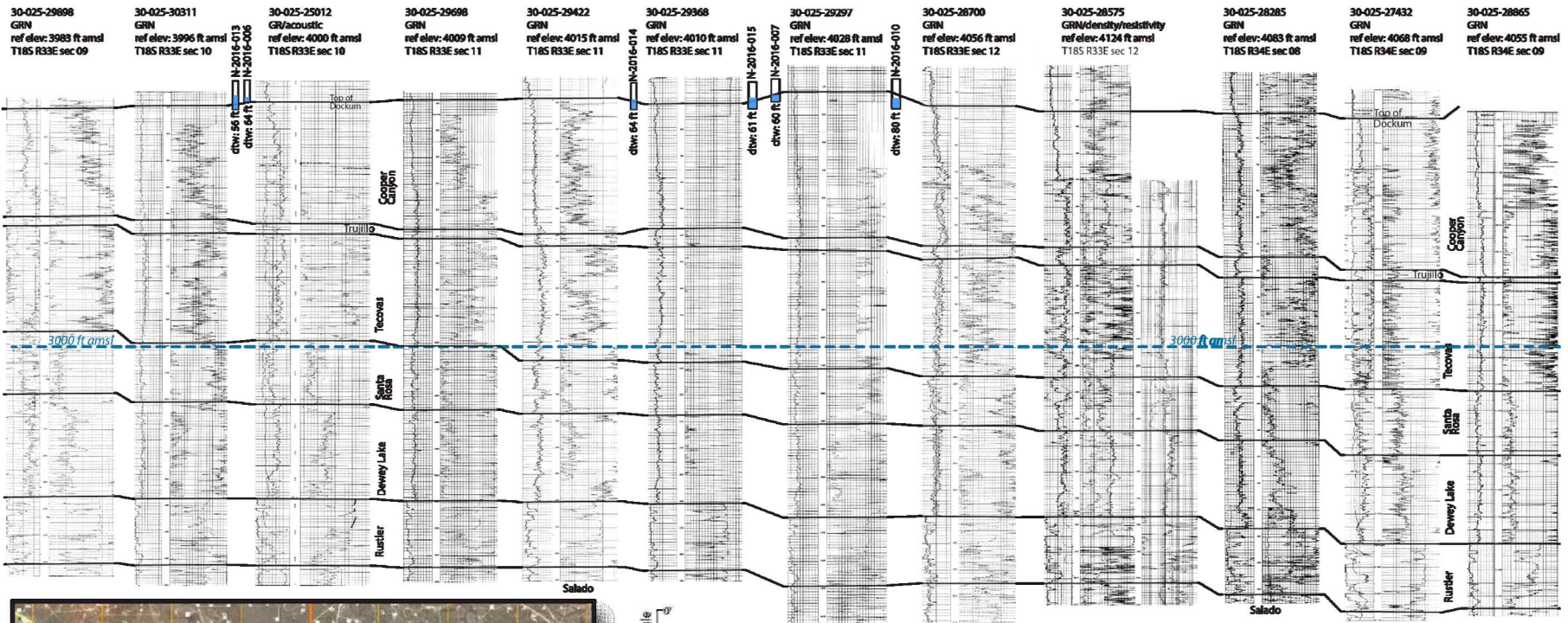
**Cross-Section
Locations**

- 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

North HPA - Mescalero Ridge W to E

West

East



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

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

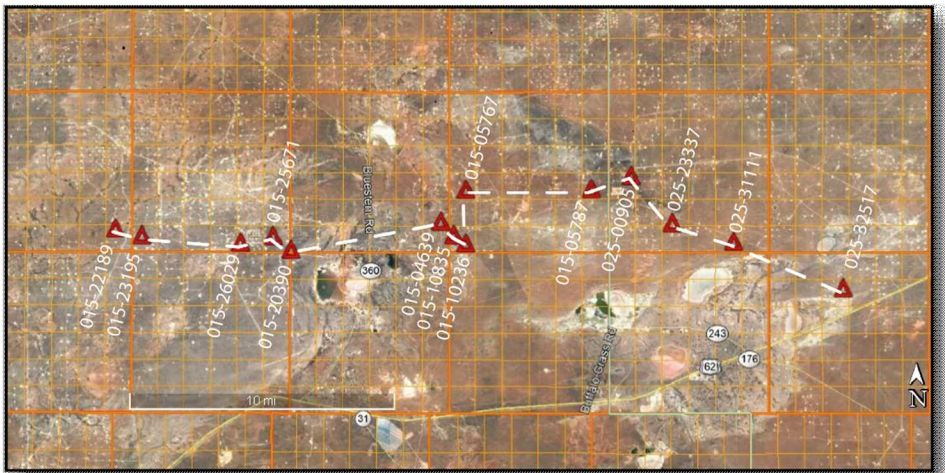
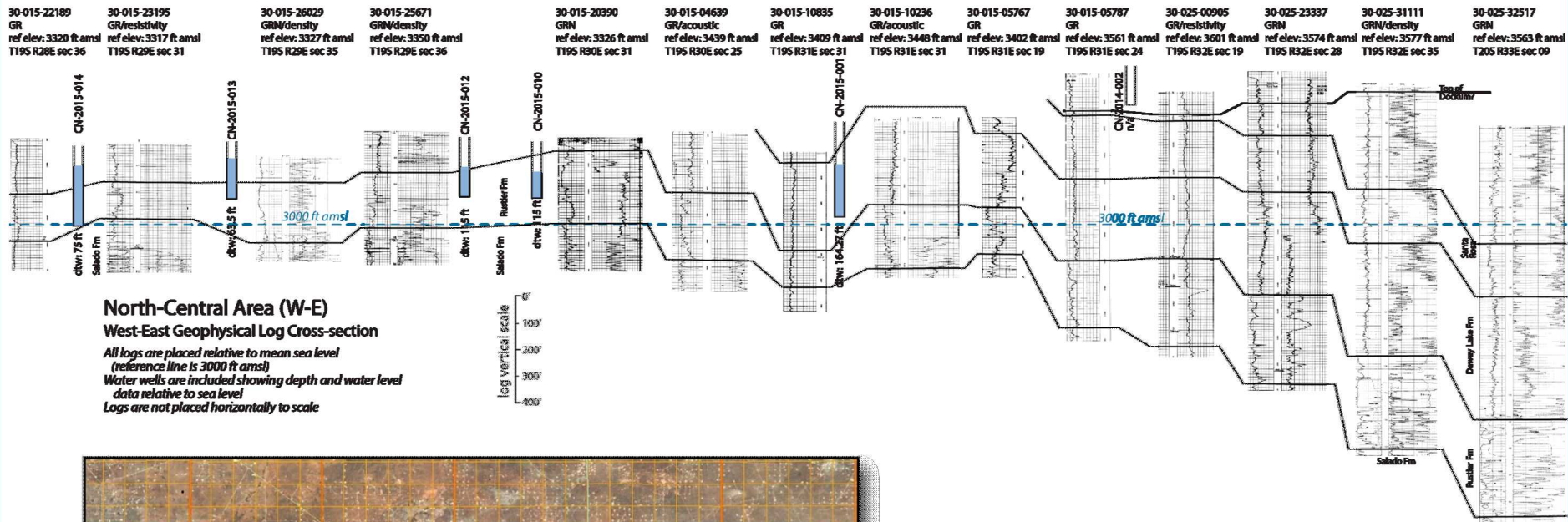
Explanation

GR - gamma ray
GRN - gamma ray/neutron log
formation contact
standard reference elevation
N-2016-xox: 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

West

East



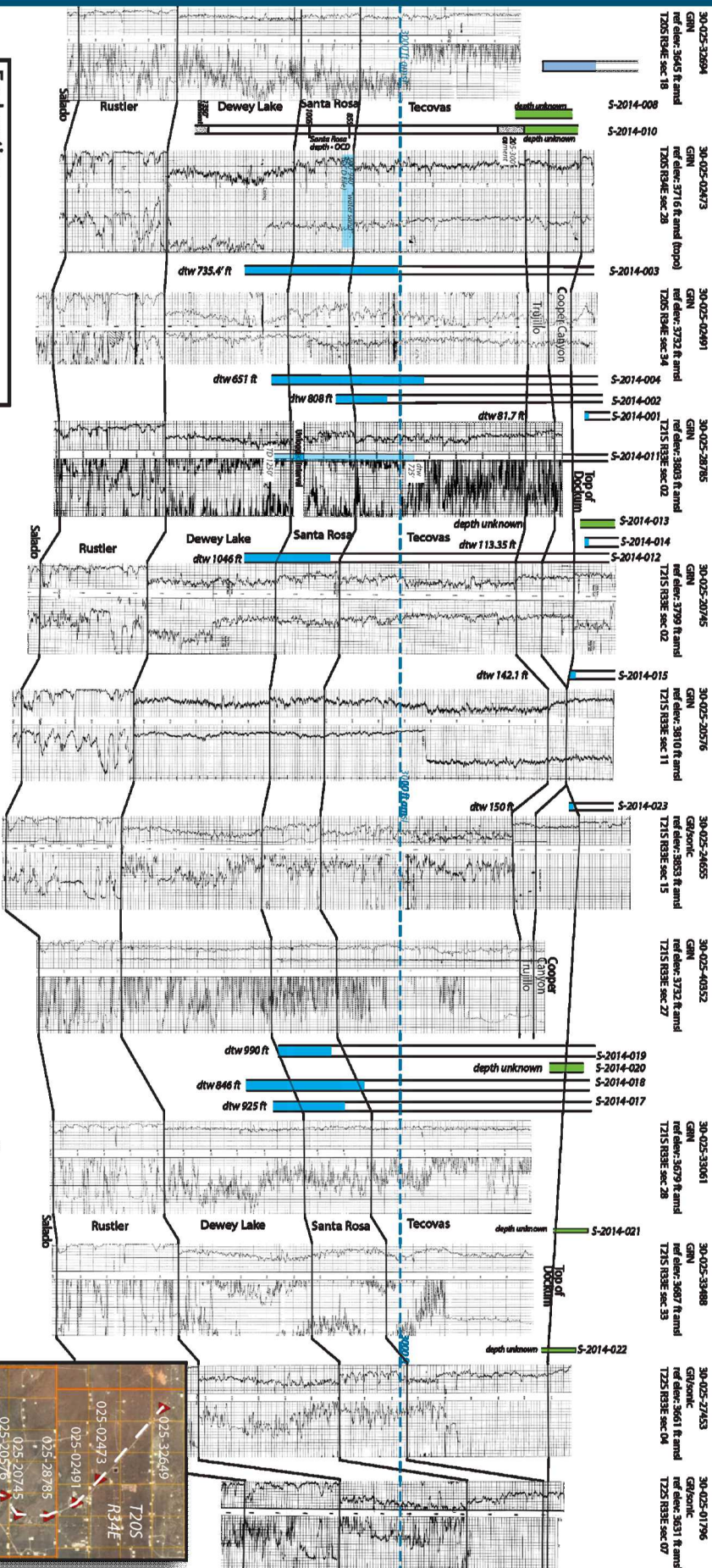
Explanation

- 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

North

South



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 and)
 Water wells are included showing depth and water level
 datum relative to sea level
 Logs are not placed horizontally to scale

log vertical scale
 0
 1000
 2000
 3000
 4000



South HPA – SW to NE

Southwest

30-015-37465
GRN
ref elev: -3016 and
T255 R32E sec. 29

30-015-20156
GRN
ref elev: 2015 and
T255 R29E sec. 31

30-015-20889
GRN
ref elev: 2089 and
T255 R29E sec. 30

30-015-37077
GRN
ref elev: 3707 and
T255 R29E sec. 08

H-8C 10999
GRN
ref elev: 1099 and
T255 R29E sec. 23

30-015-10894
GRN
ref elev: 1089 and
T255 R29E sec. 04

30-025-26822
GRN
ref elev: 2682 and
T255 R31E sec. 36

30-025-68117
GRN
ref elev: 6812 and
T255 R31E sec. 15

30-025-01796
GRN
ref elev: 0179 and
T225 R32E sec. 07

Northeast



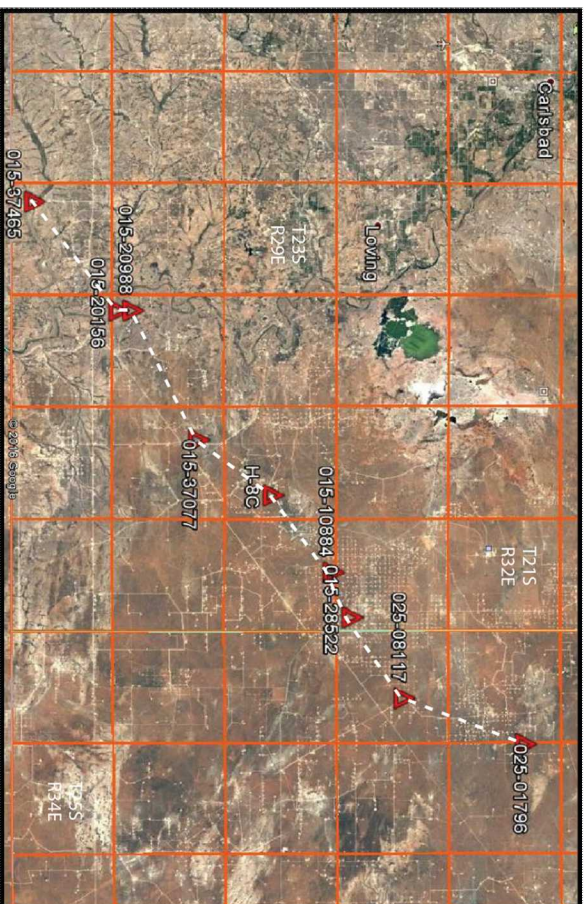
South Area

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



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

Explanation

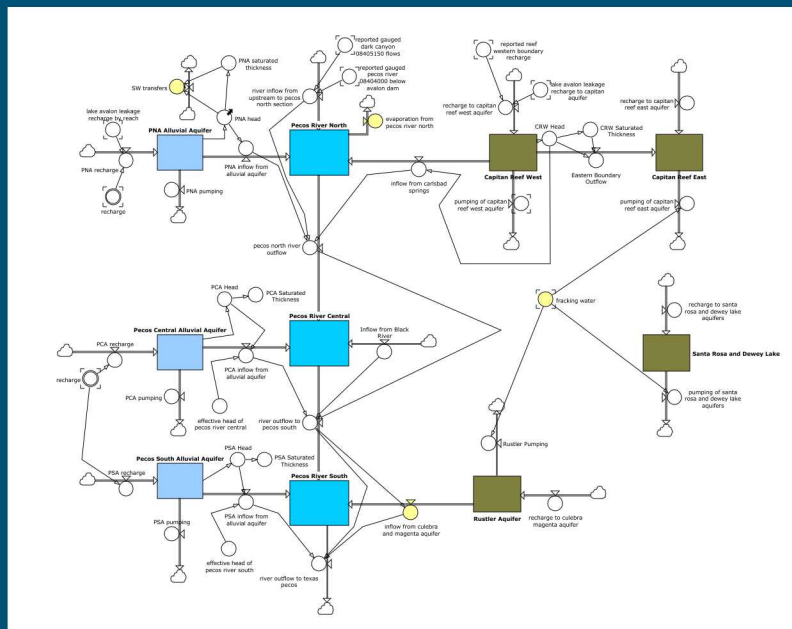
- GR - gamma ray
- GRN - gamma ray/neutron log
- formation contact
- standard reference elevation
- S-2016-xxx: water well identifier
- dtw: depth to water in ft
- well diagram, at reference elevation with scaled dtw in blue



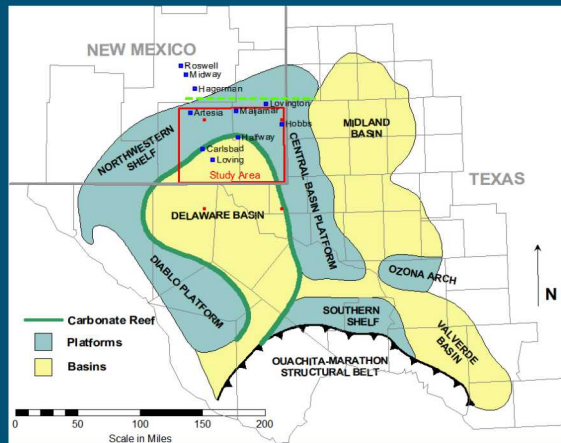
Modeling

System Dynamics Modeling – Develop a system dynamics (SD) simulation tool to simulate water availability over a range of different future scenarios as identified in the RFD.

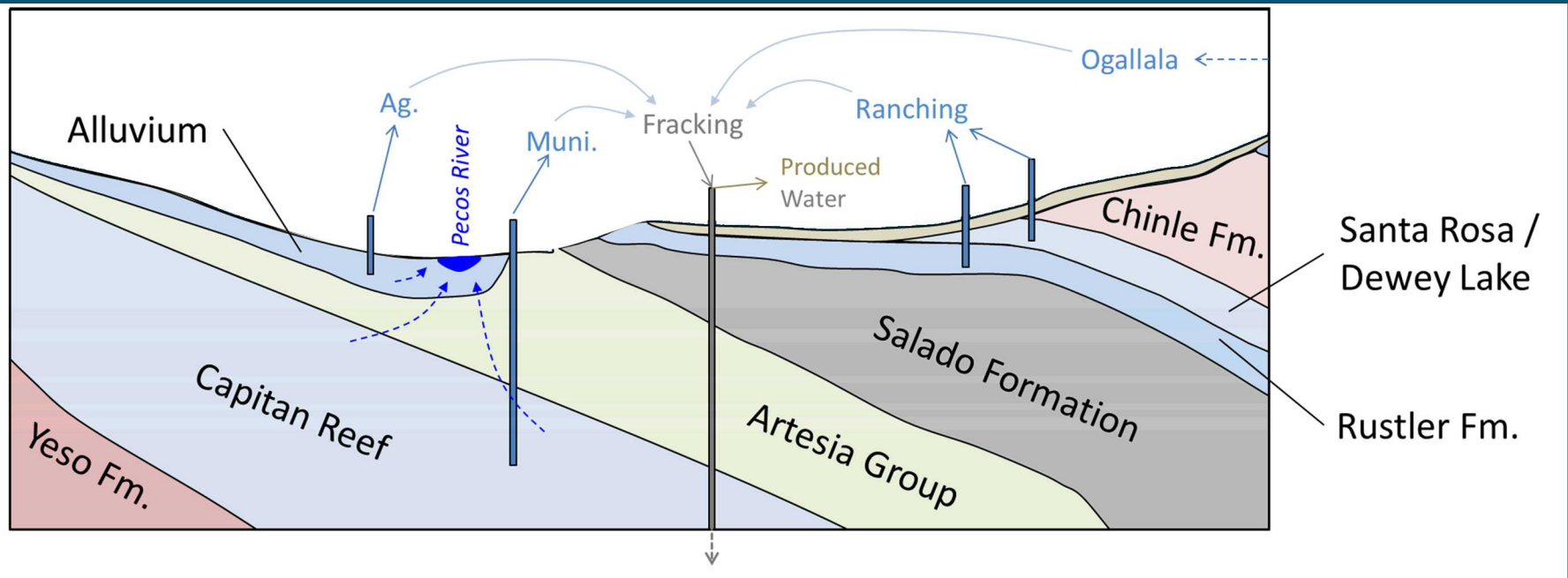
- Table-top player
- Simulate the increase in drilling activity and water demand relative to each formation and water source to identify the areas/users/formations that are most vulnerable and to estimate the risk to water quantity and quality.
- Provide decision makers with a tool to assess localized, cumulative impacts.



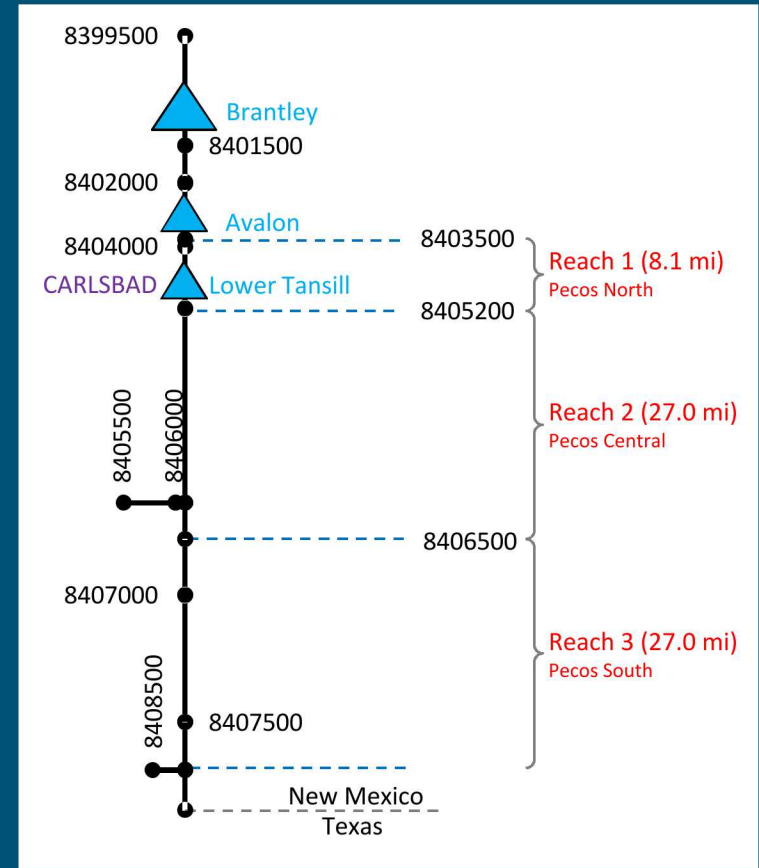
Conceptual Model



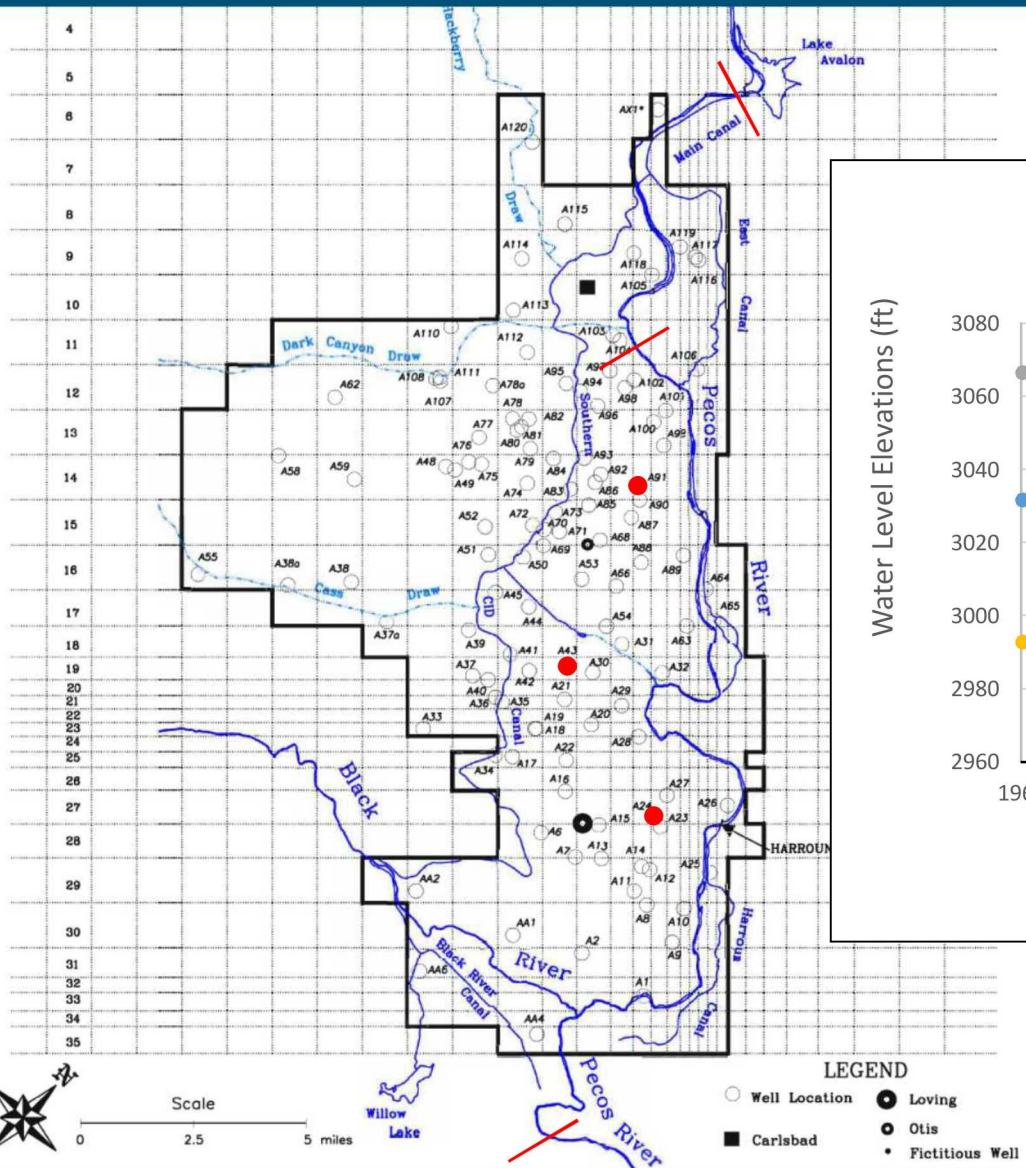
Reproduced from Summers, 1972



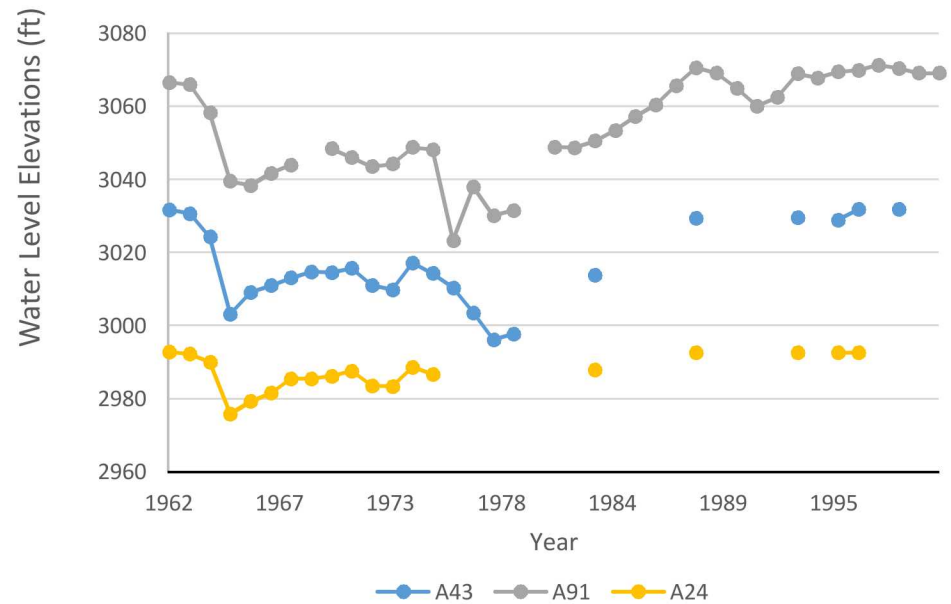
Conceptual Model



Numerical Model



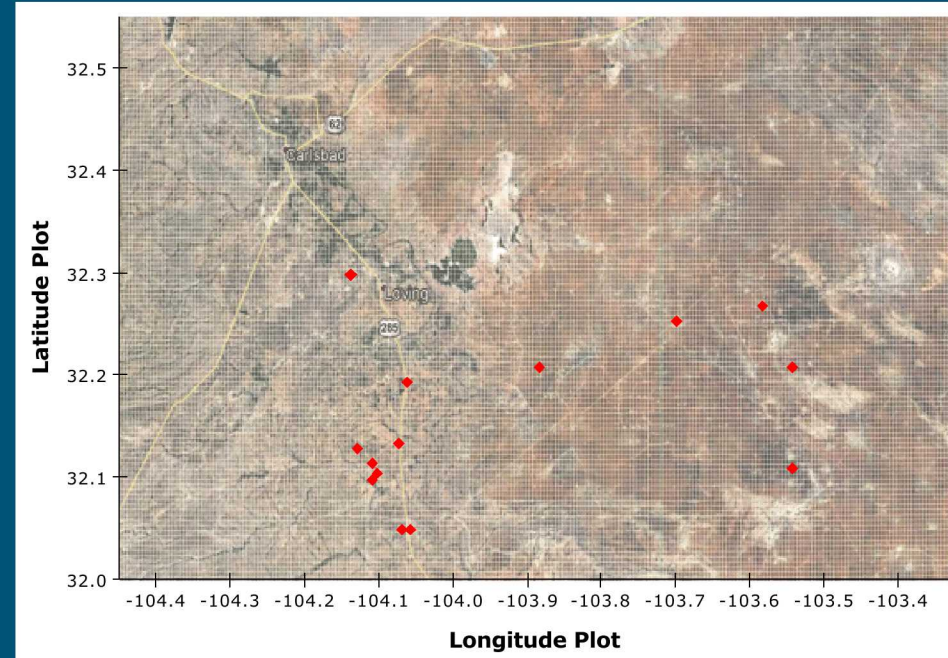
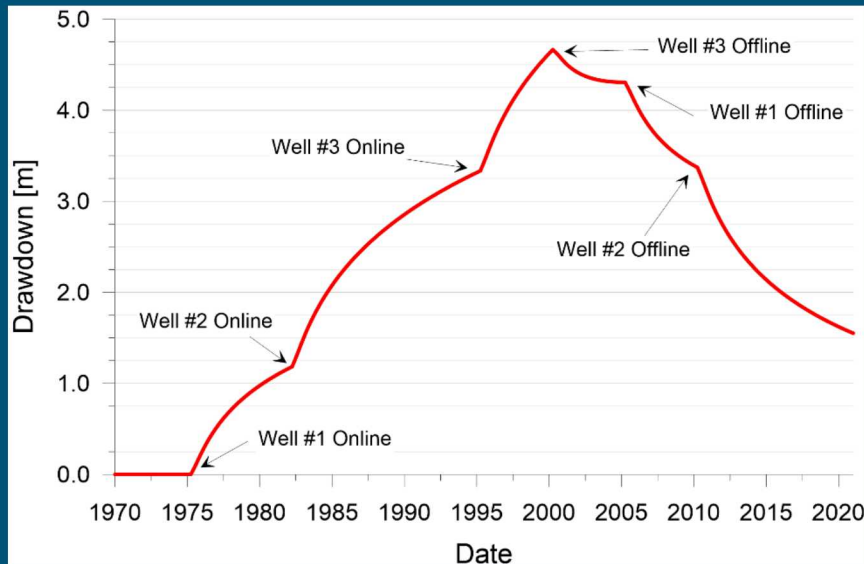
Observed Hydrographs for 3 Wells
Near Pecos River in Study Area



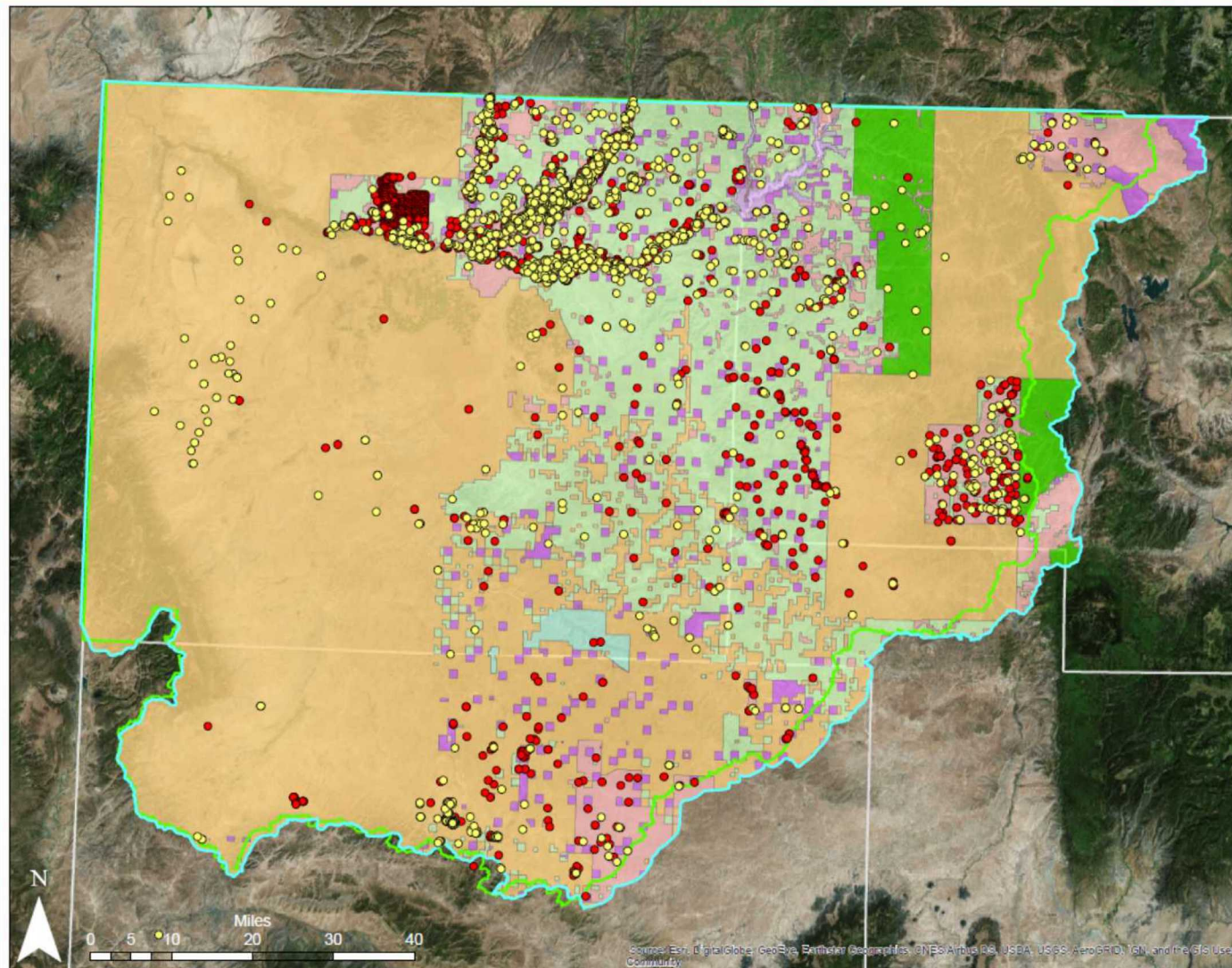
Localized Impacts

Domain split into $1/200^{\text{th}}$ degree grid
(~ 360 m)

Mean aquifer dynamics, T, S, pumping rate



San Juan Basin



NMOSSE Wells Identified in San Juan SW Basin

WATERS Database Results

Well Type

- Meter Attached
- Well Log Not Received
- Well Log Received

San Juan Surface Water Basin

San Juan Groundwater Basin

Land Ownership

- Bureau of Land Mgmt
- Bureau of Rec
- Forest Service
- Pueblo/Tribal
- National Park Service
- Private
- State
- State Game and Fish
- County Boundaries

Past Work

Oil Potential Map

REASONABLE FORESEEABLE DEVELOPMENT (RFD) FOR NORTHERN NEW MEXICO

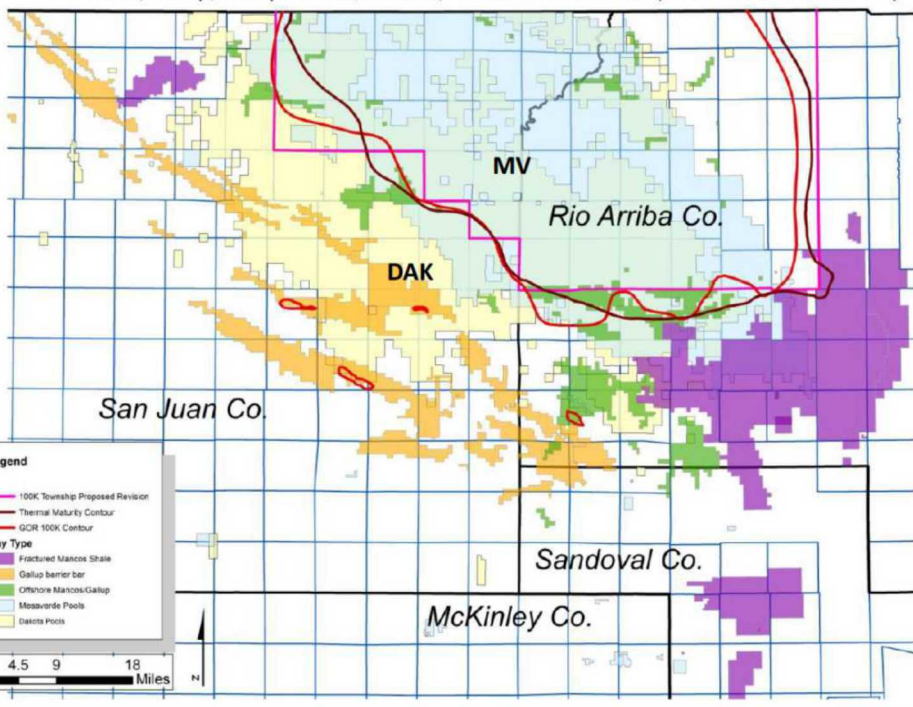
Open-file Report 567

2015

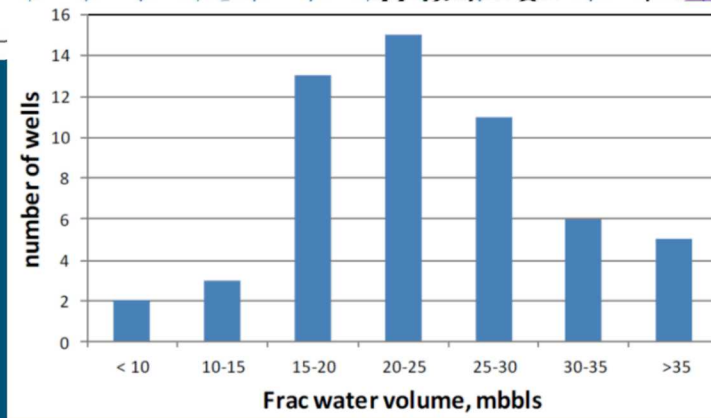
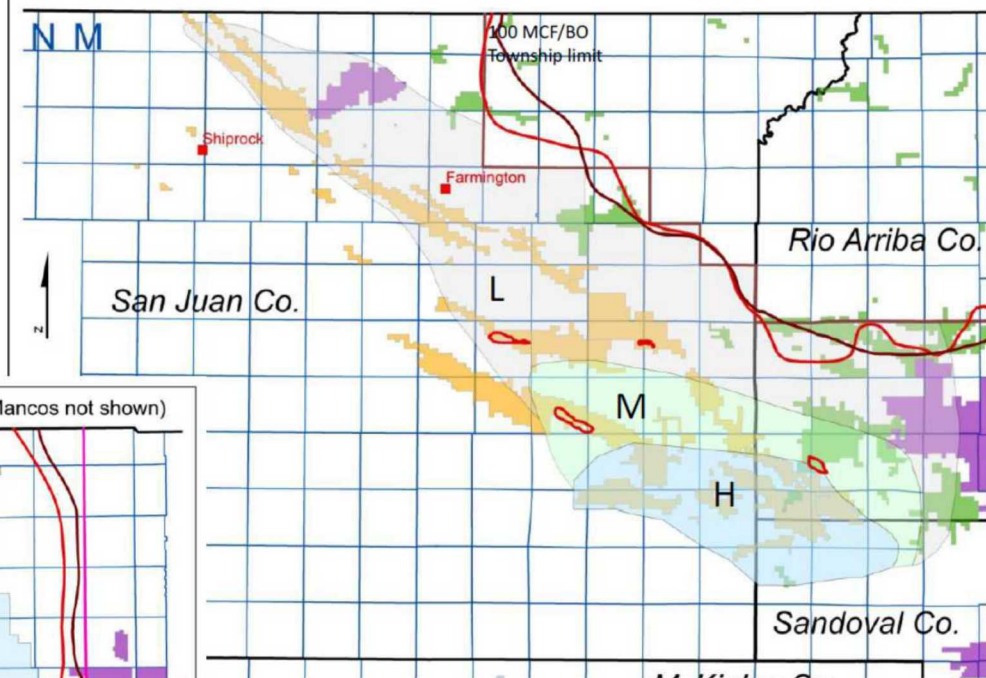
Thomas W. Engler, Shari Kelley, and Martha Cather

New Mexico Bureau of Geology and Mineral Resources
New Mexico Institute of Mining & Technology
Socorro, New Mexico 87801

Dakota, Gallup, Gallup-Dakota, Mancos, and Mesaverde Pools (Basin Mancos not shown)



Mancos Gas Potential



Water Use Distribution (3.13 AF/well ave.)

Past Work

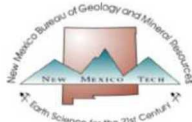
HYDROLOGIC ASSESSMENT OF OIL AND GAS RESOURCE DEVELOPMENT OF THE MANCOS SHALE IN THE SAN JUAN BASIN, NEW MEXICO

Open-file Report 566

By

Shari Kelley, Thomas Engler, Martha Cather,
Cathryn Pokorny, Cheng-Heng Yang, Ethan Mamer,
Gretchen Hoffman, Joe Wilch, Peggy Johnson,
and Kate Zeigler

New Mexico Bureau of Geology & Mineral Resources
New Mexico Institute of Mining & Technology
Socorro, New Mexico 87801



November 2014

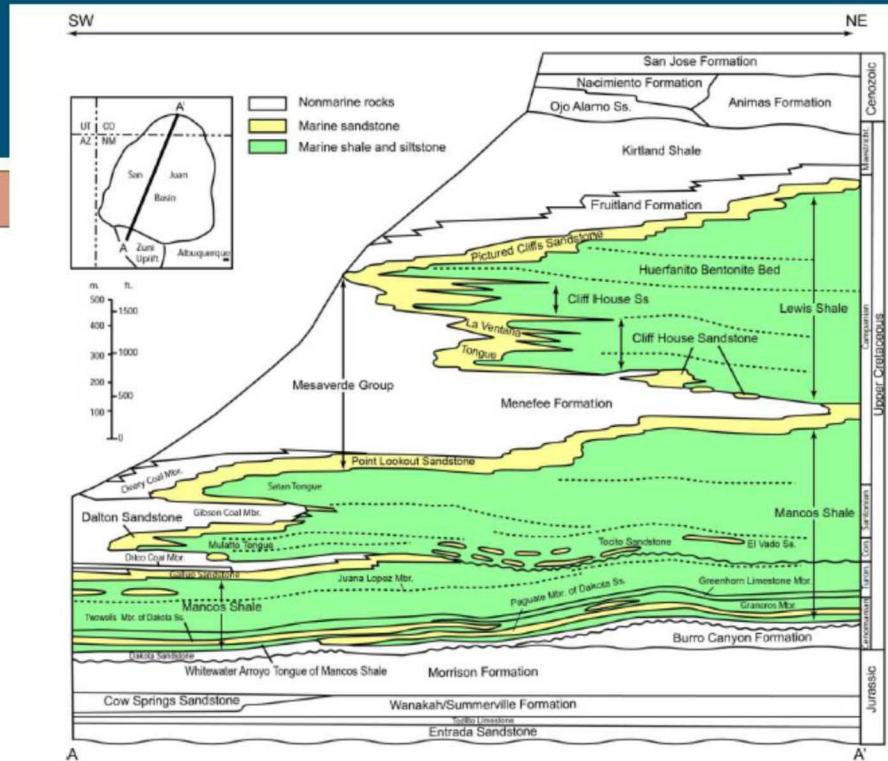
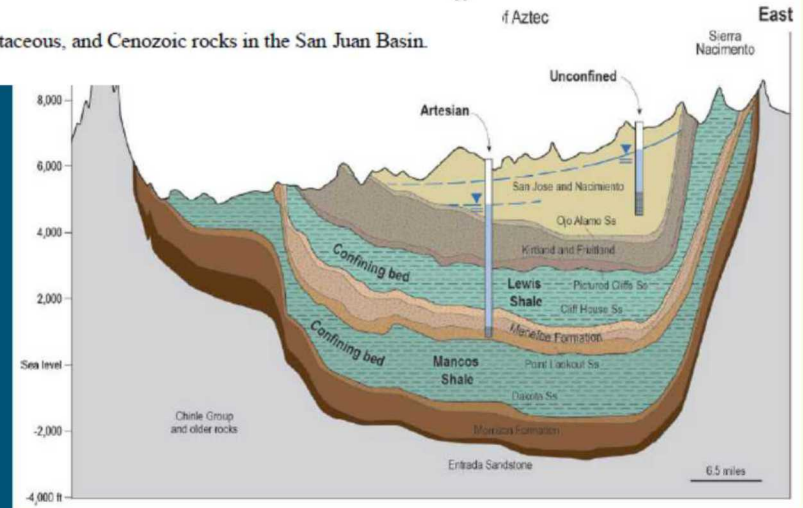
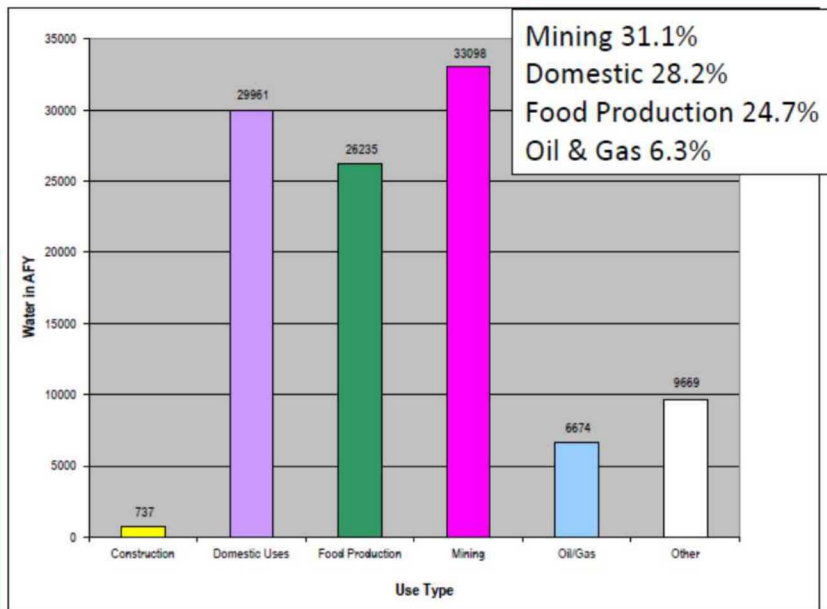


Figure 3—Stratigraphy of the Jurassic, Cretaceous, and Cenozoic rocks in the San Juan Basin.
Modified from Molenaar (1977, 1989).

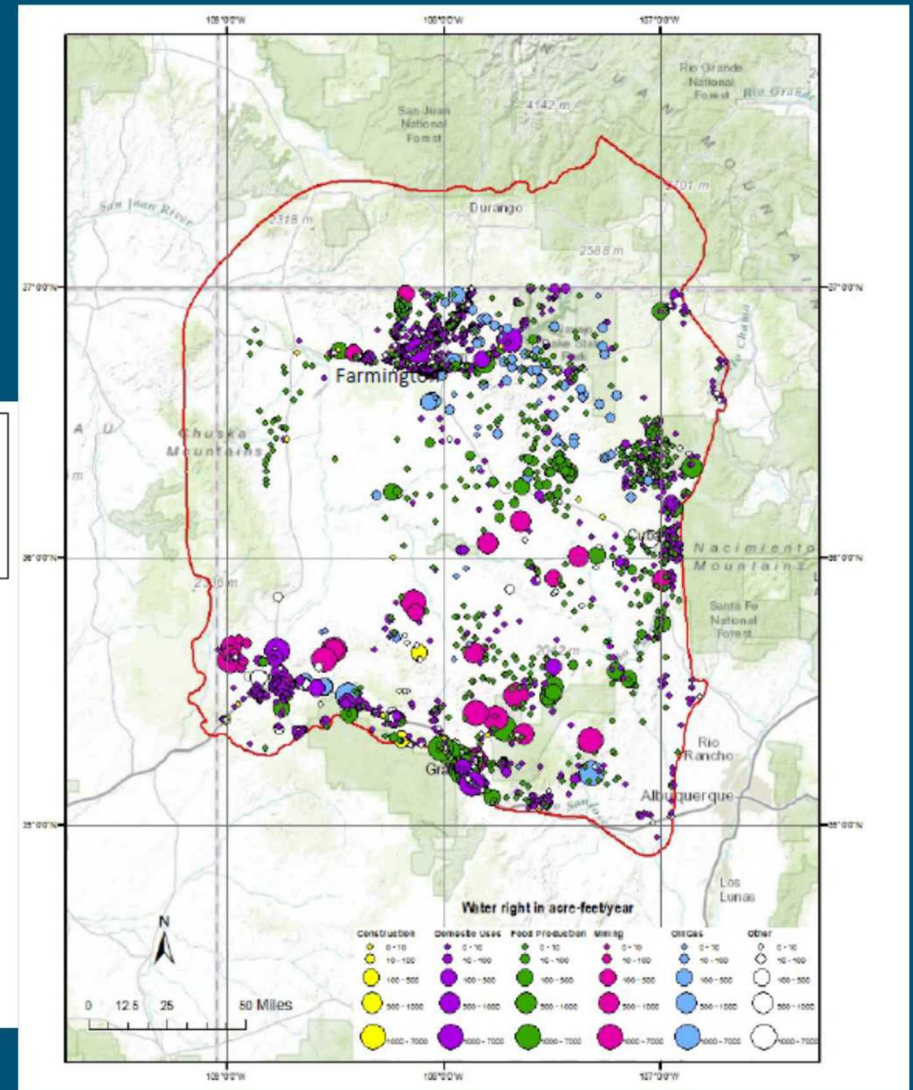


New Mexico Bureau Geology & Mineral Resources
New Mexico Institute of Mining & Technology
Socorro, New Mexico 87801



GW Water Right Usage

Spatial Distribution of GW Water Rights



Questions for This Project

Field Work

- Where, what, how often?

Modeling

- Systems model? (Decision support?)
- Basin-scale flow model?
- Other?

Monitoring

- Periodic vs continuous
- Locations
- Who manages it?

Data Repository

How to not be redundant? Collaboration with other agencies (USGS, OSE, etc.)

Benefits to BLM / Farmington Office / Nation



Thank You
