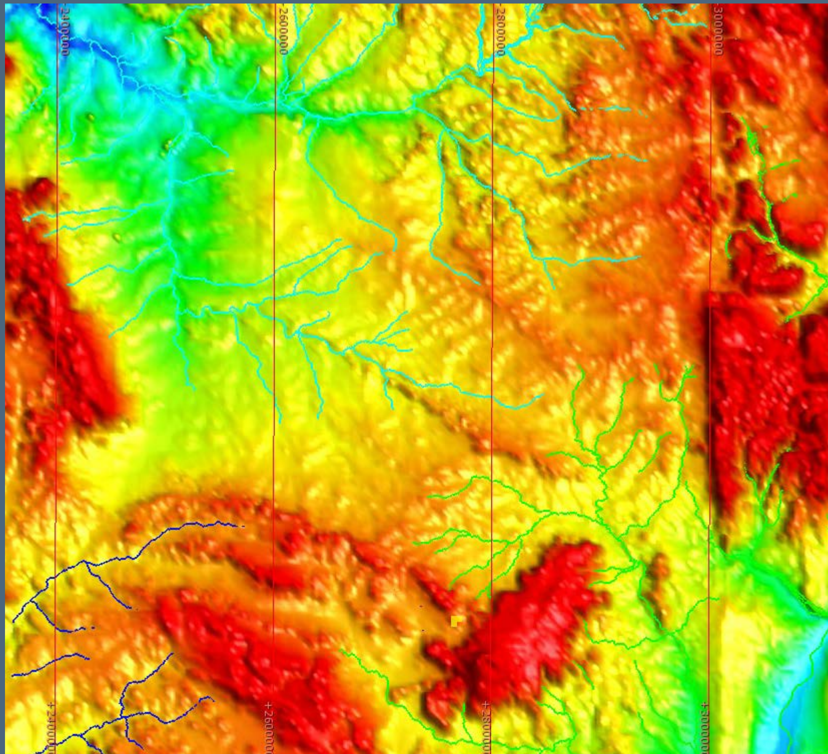

Assessing Potential Impacts from Underground Mine Dewatering in the Gallup, Dakota, and Westwater Canyon Aquifers with a Basin-Wide Groundwater Flow Model

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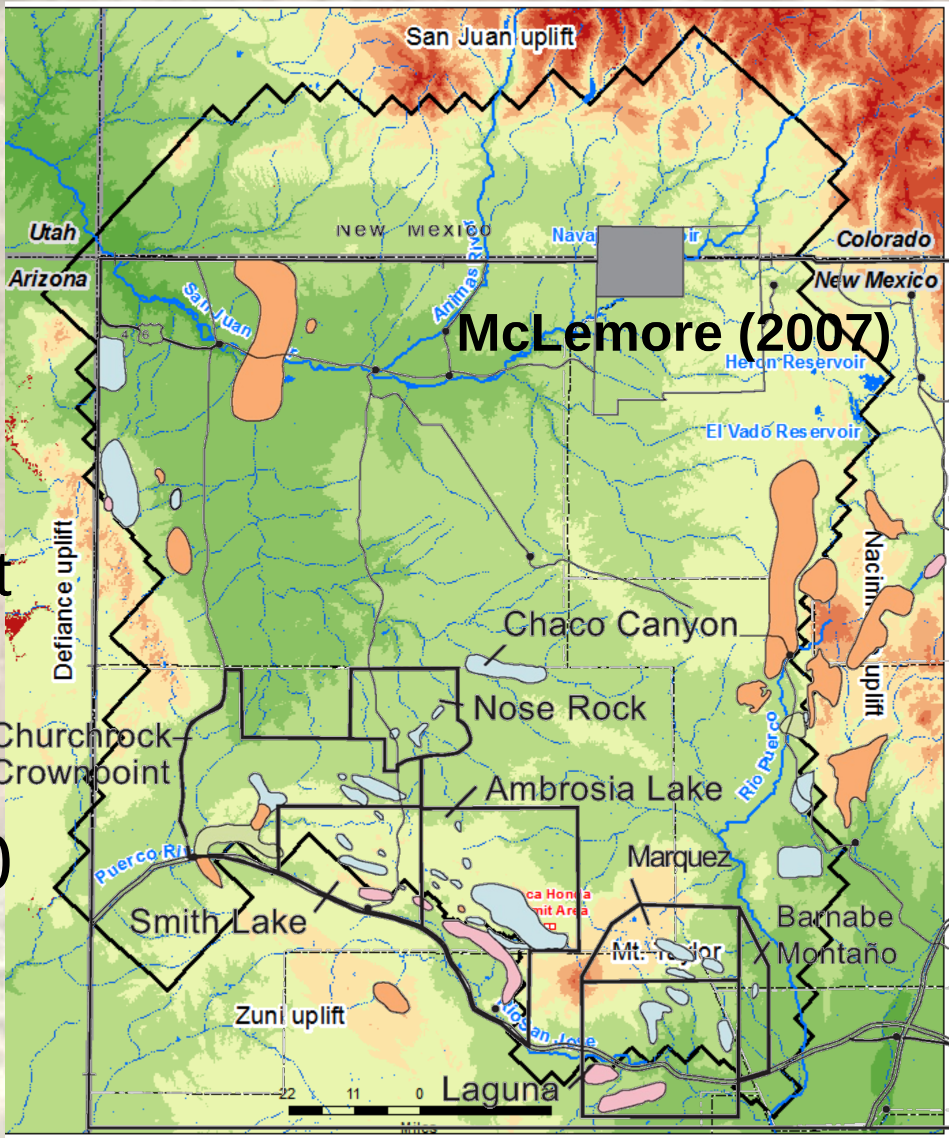
- EIS hydrology technical group

Problem Statement

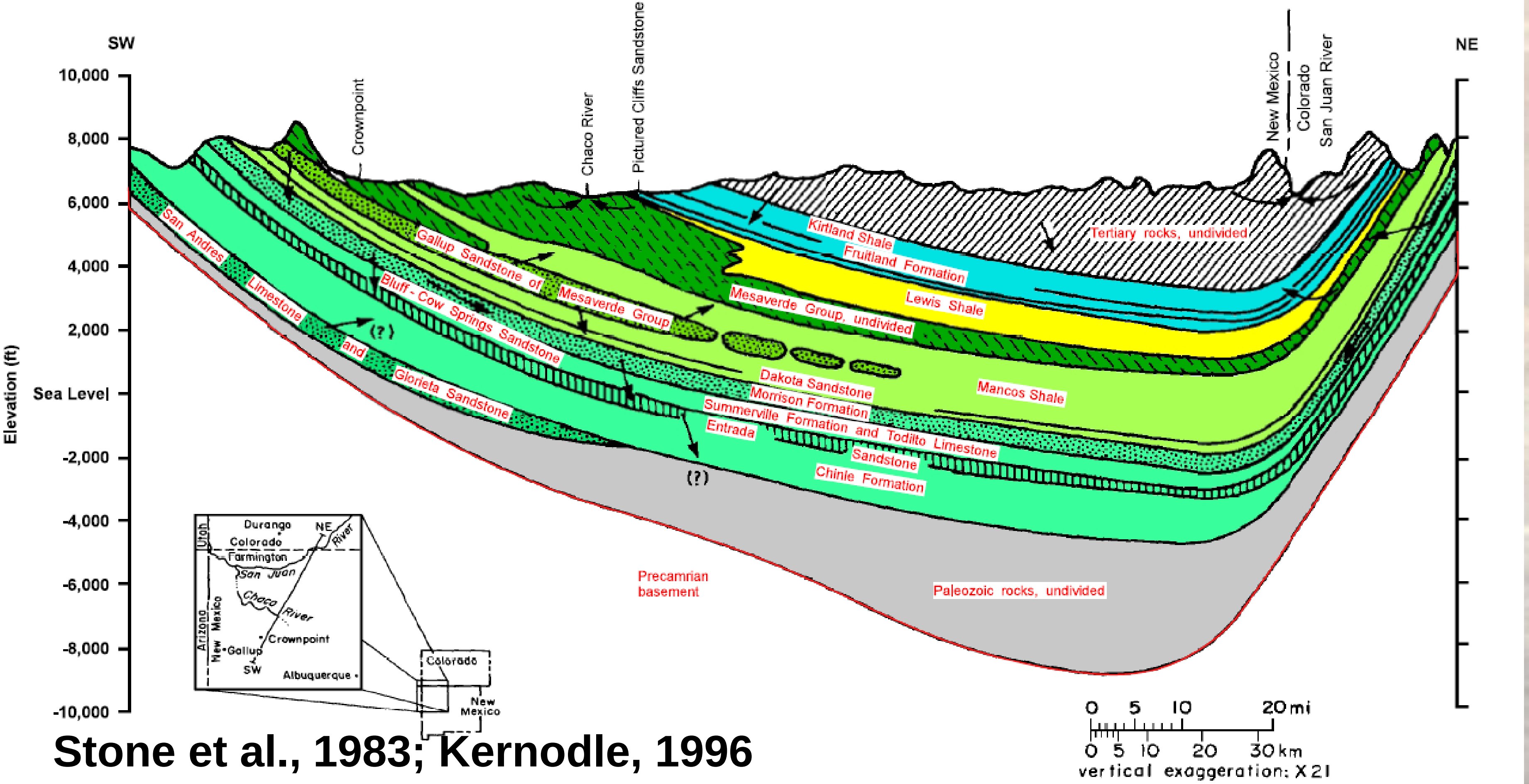
- Proposed Roca Honda uranium mine required modeling tools to assess dewatering impacts on operations, costs, and scarce water resources
  – Can the Westwater be mined safely and cost-effectively?
  – How much water must be removed?
  – How will proposed dewatering affect rivers, springs, and wells?

Background

- Regional basin
  - 21,000 square miles
  - Spans 4 states
- Intensive historical uranium mining
  - Grants Uranium Mineral Belt
  - 340 million pounds produced 1948-2002
- Dewatering removed 100 billion gallons

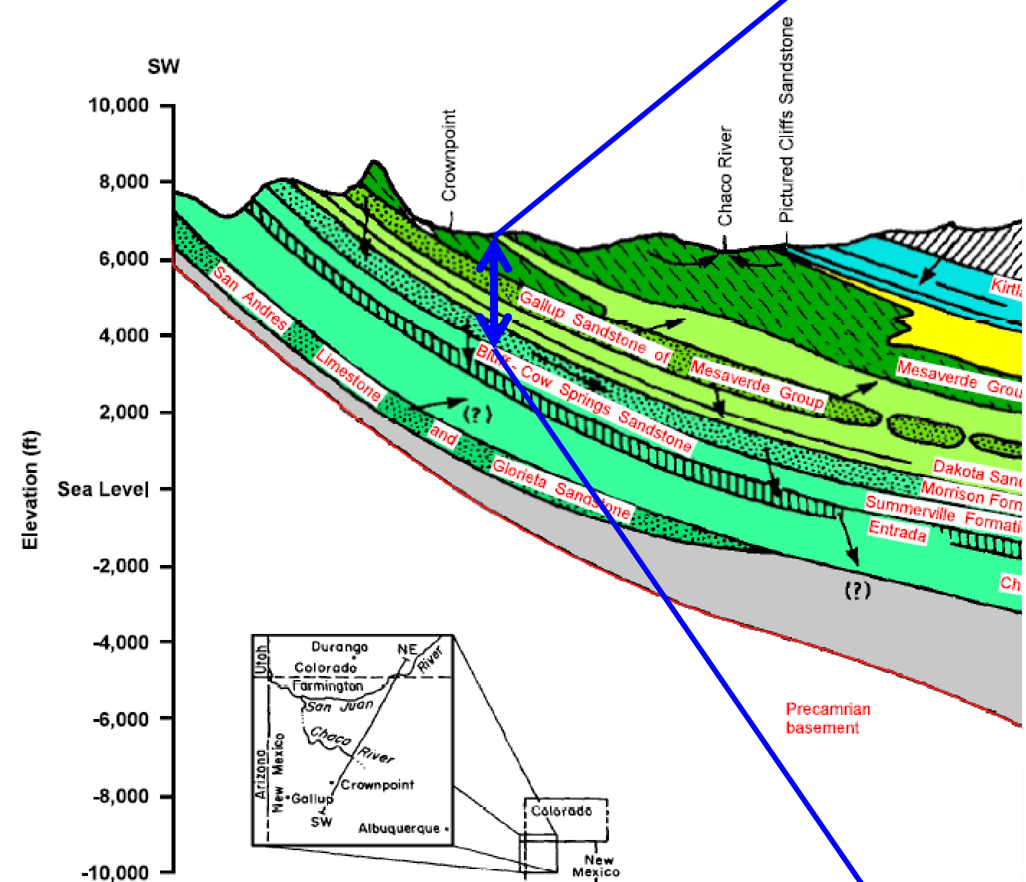


San Juan Basin Stratigraphy
SW-NE Cross-Section

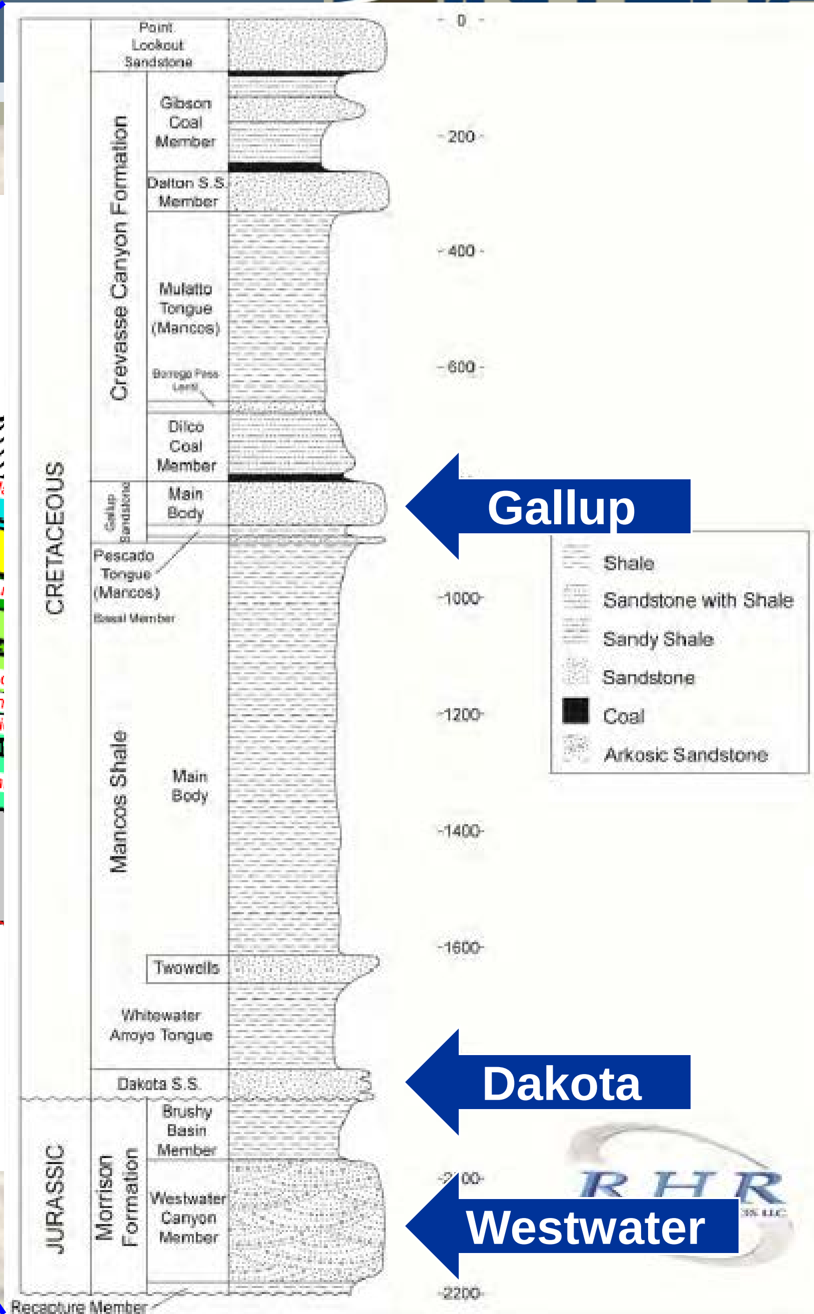


Stone et al., 1983; Kernodle, 1996

San Juan Basin Stratigraphy
SW-NE Cross-Section



Stone et al., 1983; Kernodle, 1996



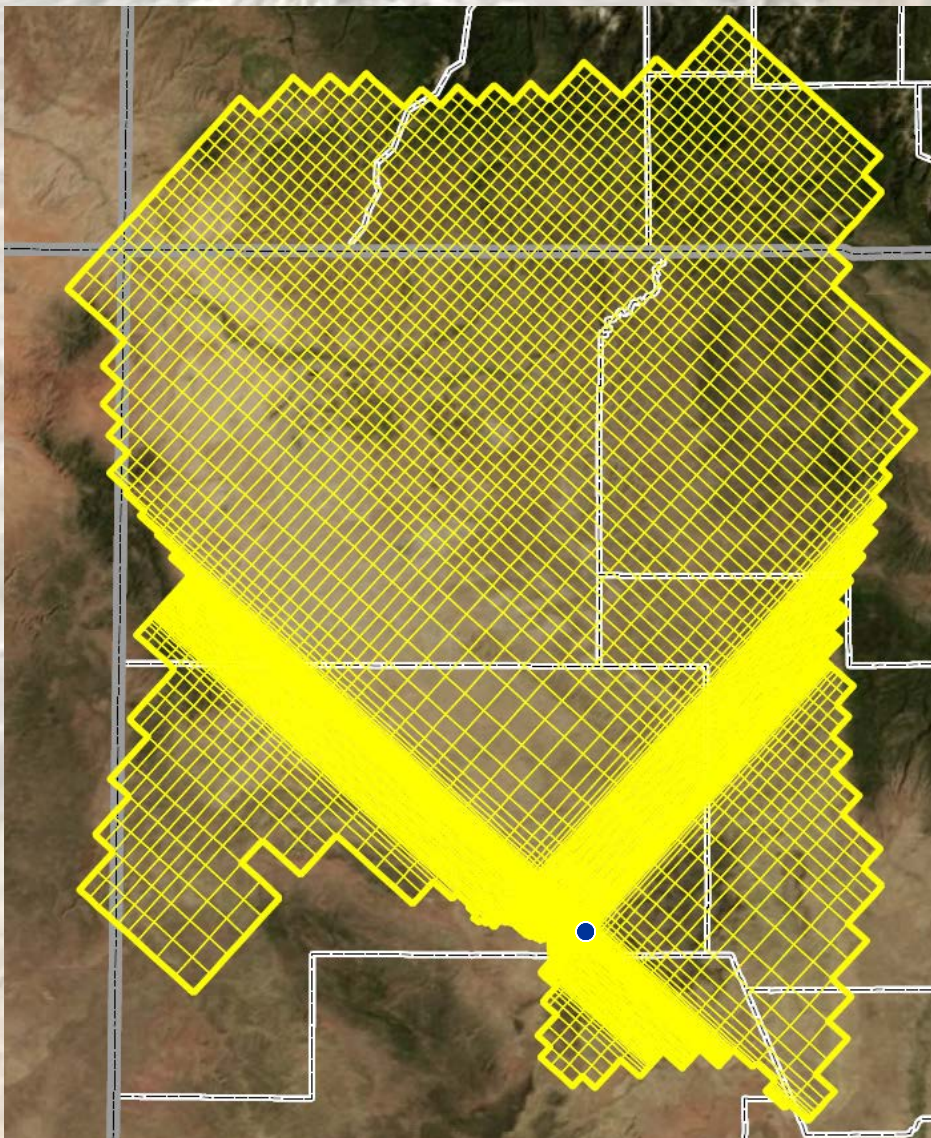
Approach

1. Estimate mine inflows analytically
2. Construct and calibrate 3D numerical groundwater flow modeling tool
3. Confirm mine inflow estimates
4. Construct predictive simulations for scenarios without and with mine dewatering
5. Assess impacts by comparing changes in heads and groundwater discharges to surface water bodies

New Modeling Tool

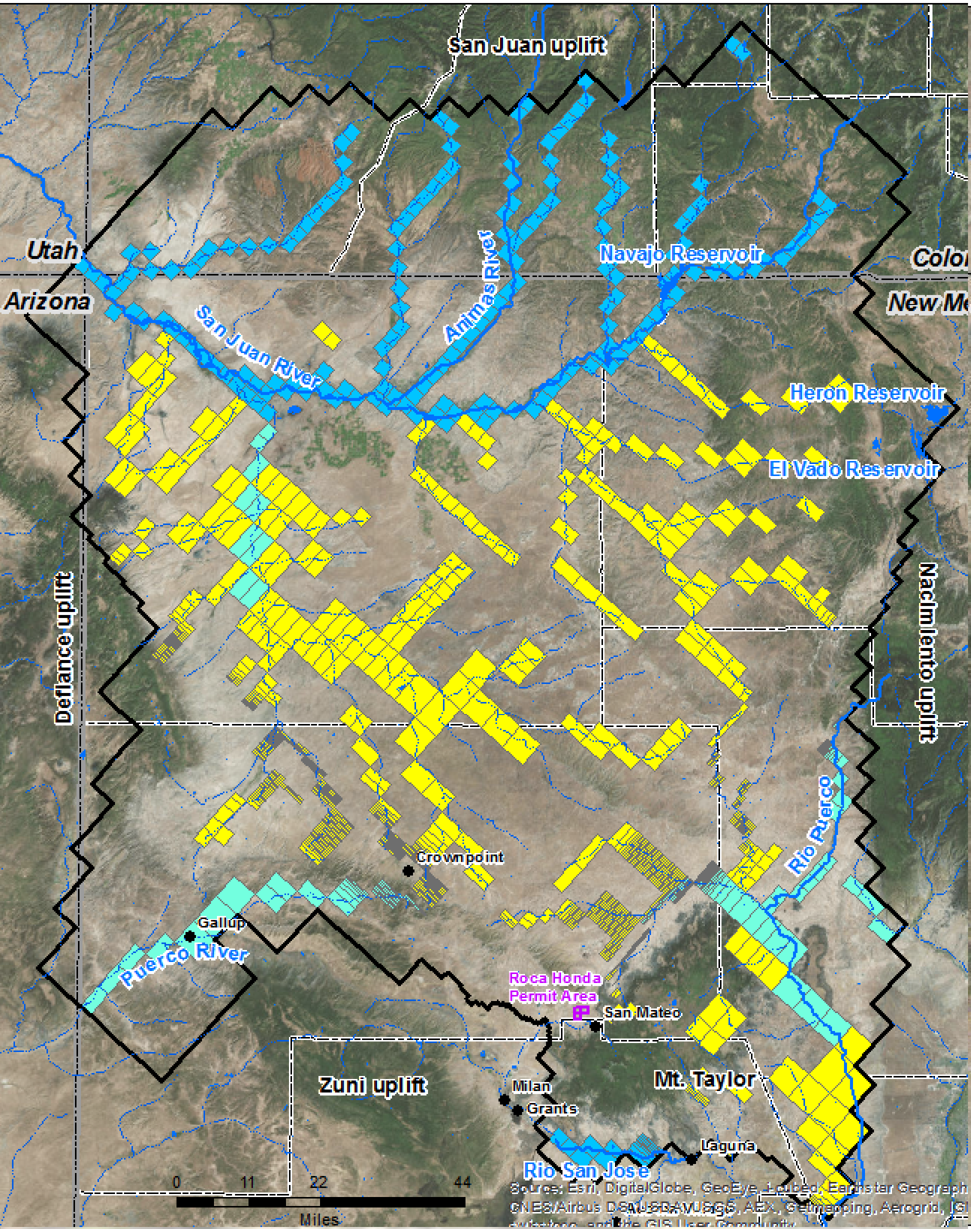
- Refined geologic framework (Leapfrog modeling)
  - Stone et al. (1983) maps, USGS HA 720, bore logs, site data
- Created MODFLOW-SURFACT modeling tool
  - Kernodle (1996), Frenzel and Lyford (1982), Lyford and Stone (1978)
- Calibrated to pre-mining steady state and 1930 to 2012 transient conditions
  - 69 pre-mining targets, 27 transient targets
  - Incorporated 50 years of historical mine dewatering
- Constructed predictive simulations for 13-year mining period and additional 100 years

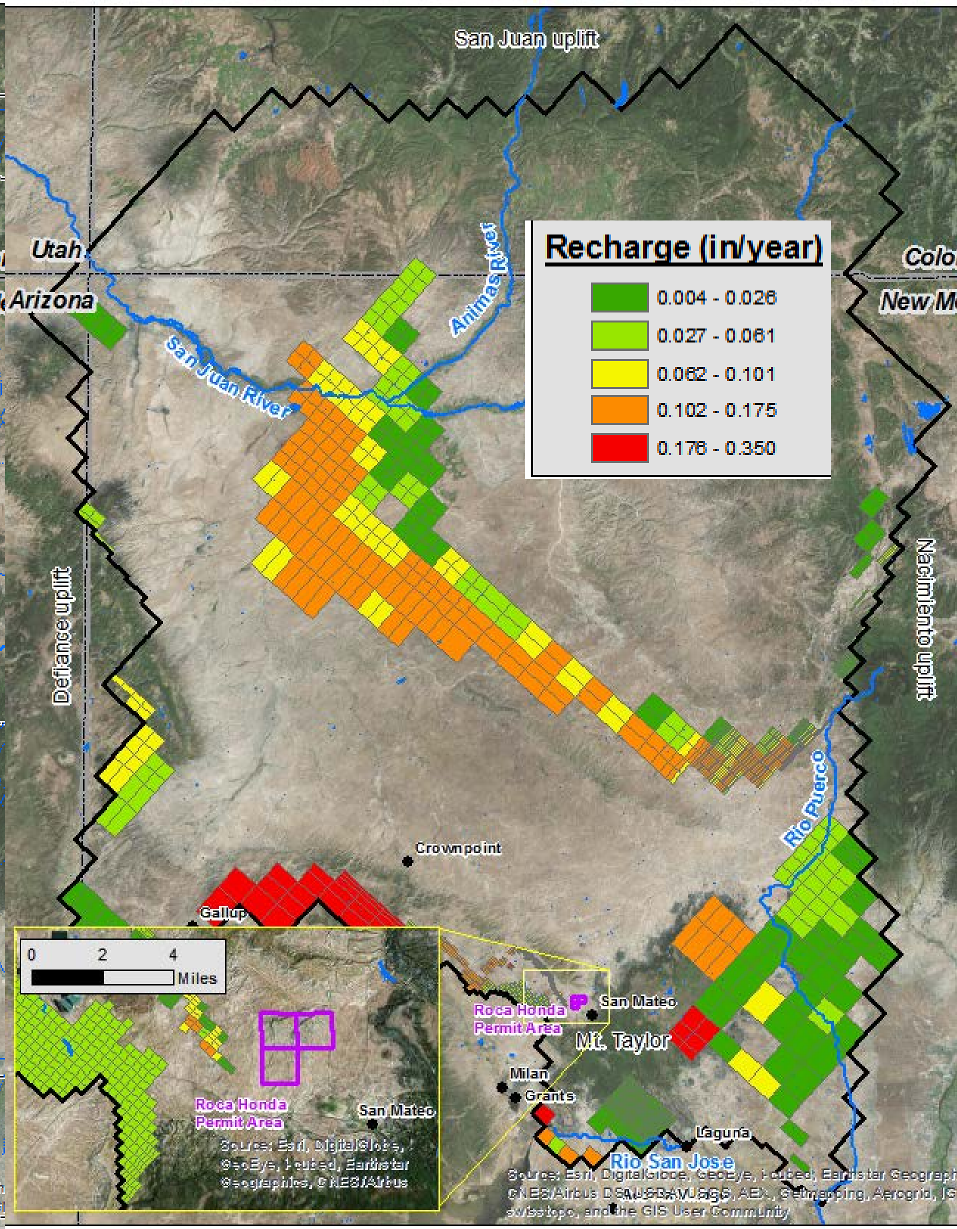
Model Grid and Layers



Model Layer	Hydrostratigraphic Unit	Thickness Range (feet)
1	San Jose Formation	200 – 2,700[a]
2	Animas Fm and Nacimiento Fm	230[d] – 2700[e] 500 – 1,300[f]
	Ojo Alamo Sandstone	20 – 400[e]
3	Kirtland Shale and Fruitland Fm	0 – 1,500[eg] 0 – 500[eg]
	Pictured Cliffs Sandstone	0 – 400[e]
4	Lewis Shale	0 – 2,400
	Cliff House Sandstone	20 – 500
5	Menefee Formation	0 – 2,000[g]
	Point Lookout Sandstone	40 – 415[a]
6	Mancos Shale (NE only)	1,000 – 2,300
	Gallup Sandstone (SW only)	0 – 600[c] 0 - 700[a]
7	Mancos Shale	1,000 – 2,300
8	Dakota Sandstone	50 – 350[a]
9	Brushy Basin Member of Morrison Formation	80 – 250
10	Westwater Canyon Member of Morrison Formation	100 – 300

RHR Model Boundary Conditions





Public Water Supply Wells

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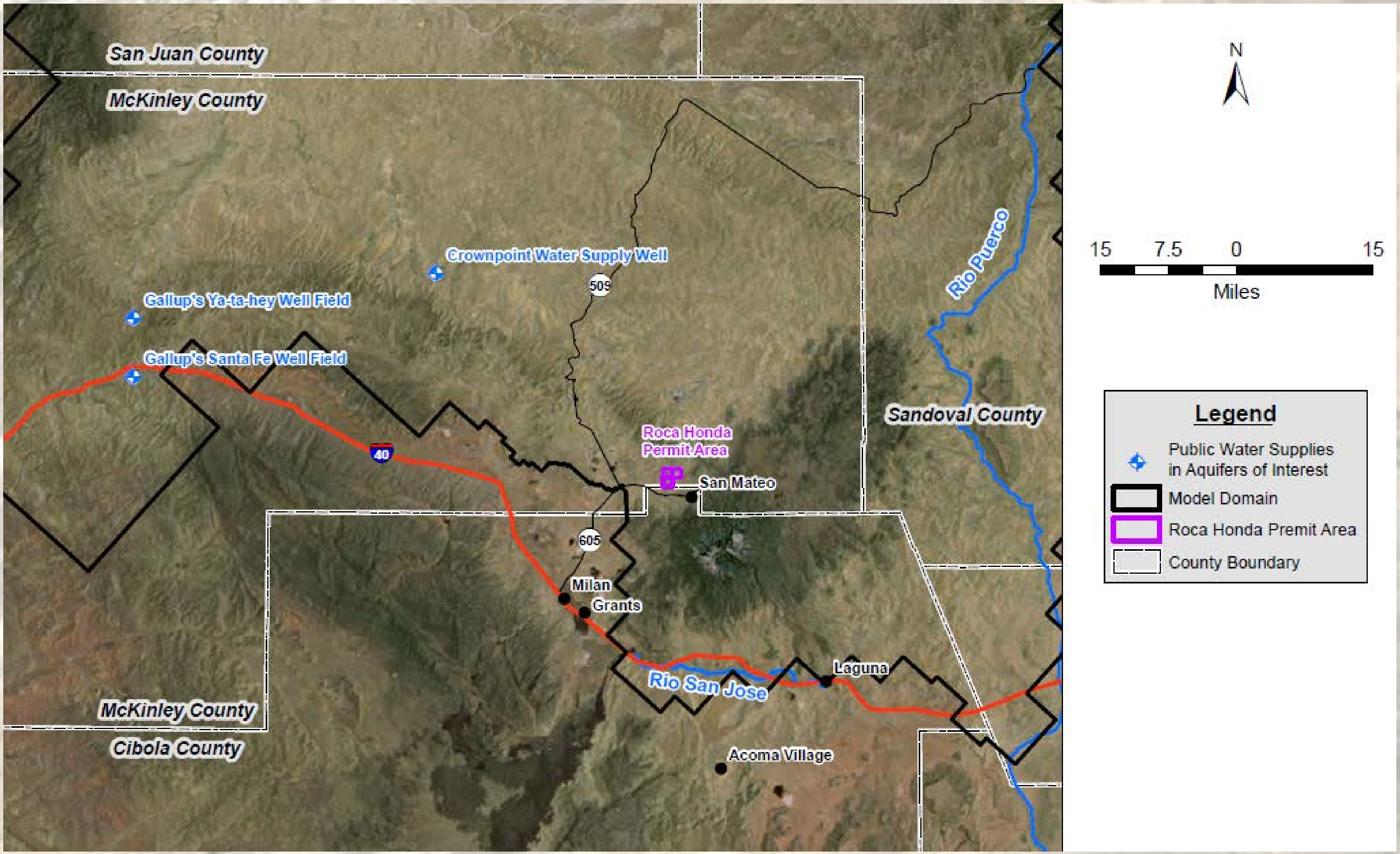
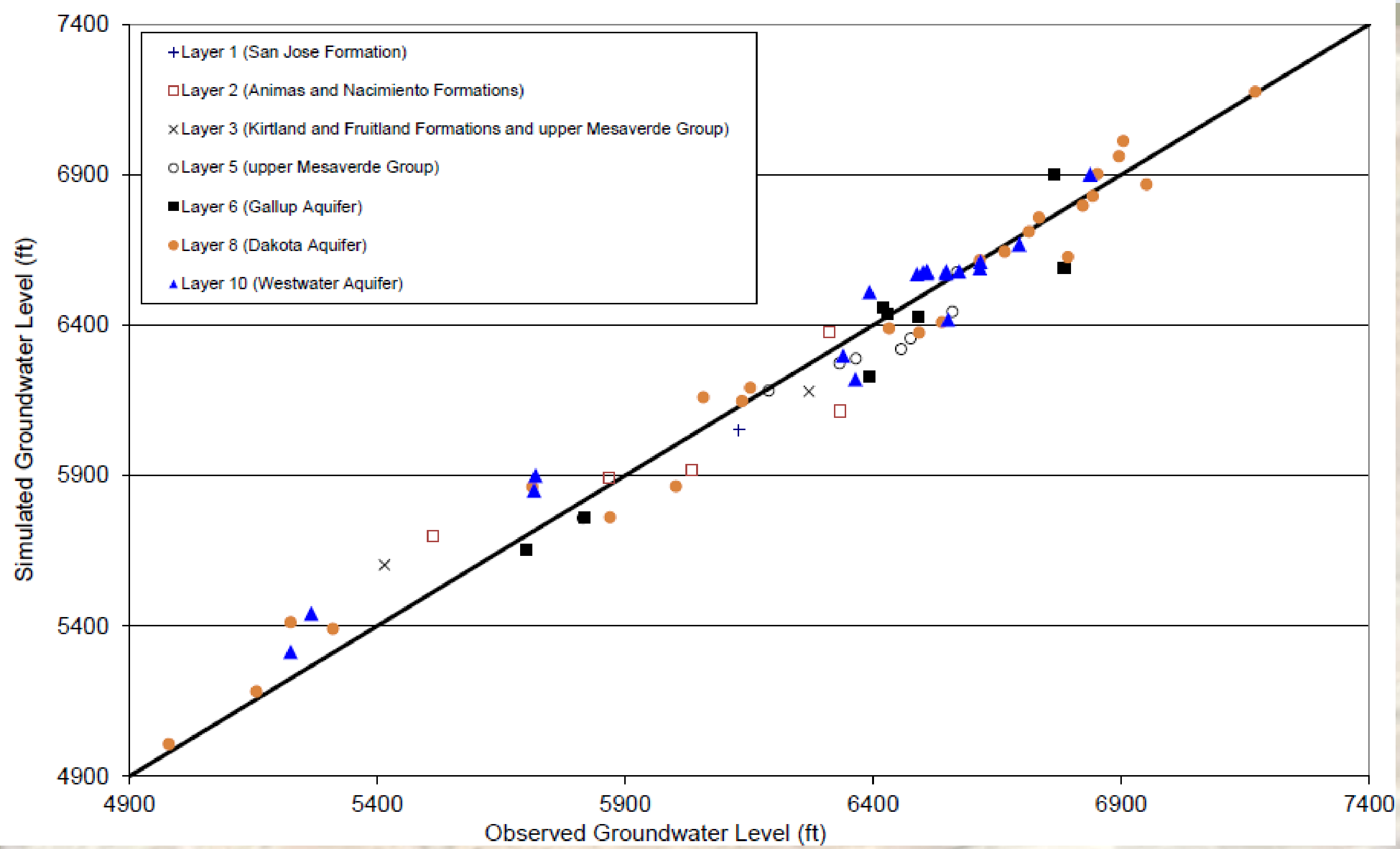


Steady-State Calibration



69 residuals
Mean residual = 1.8 ft
NRMSE = 0.045

- Total inflow for RHR model: 58 ft^3/s
- Falls within the range of 30 and 195 ft^3/s from Frenzel and Lyford (1982) and Kernodle (1996), respectively
- Matches 60 ft^3/s estimated by Lyford and Stone (1978)

Steady State Westwater Heads

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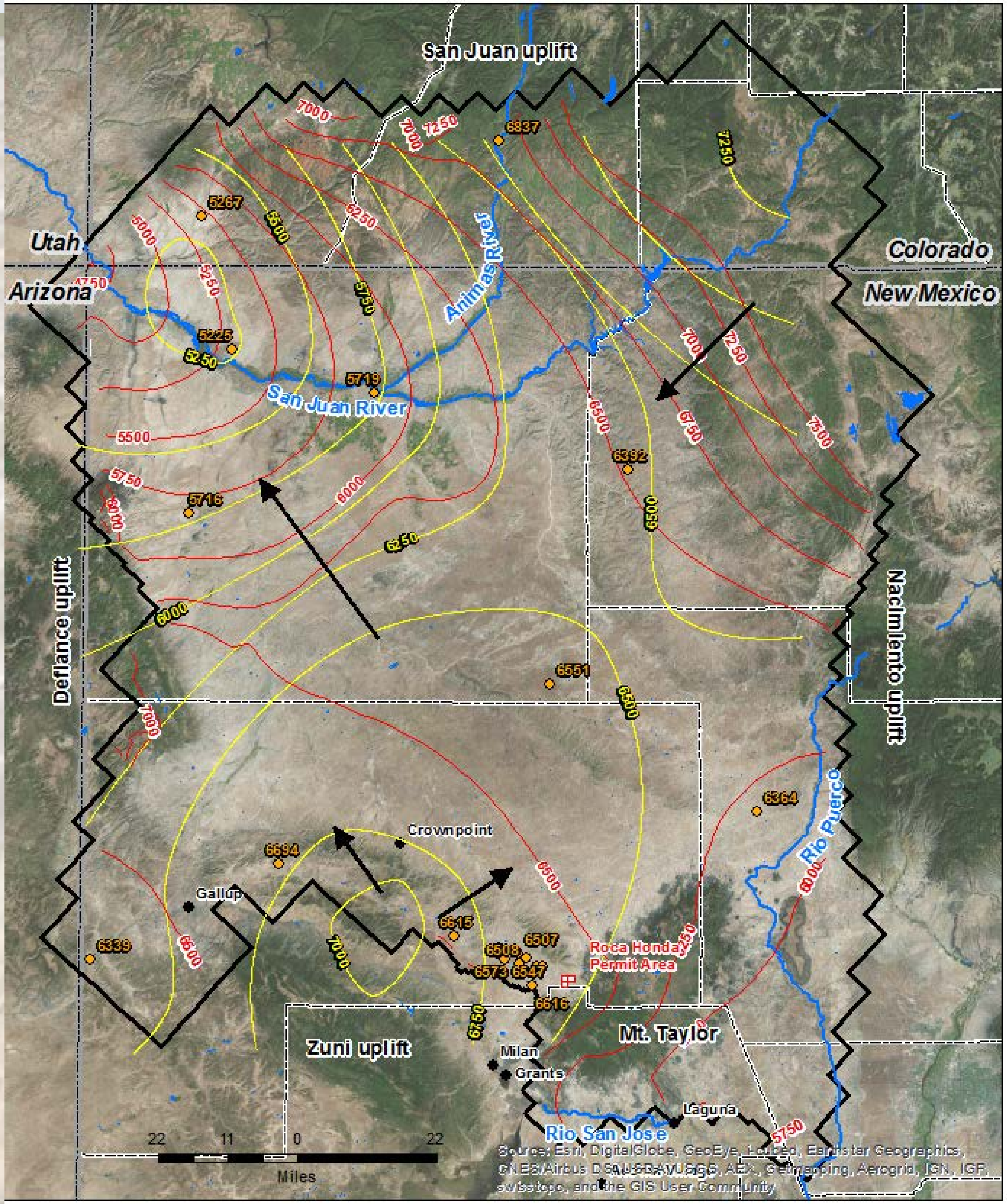
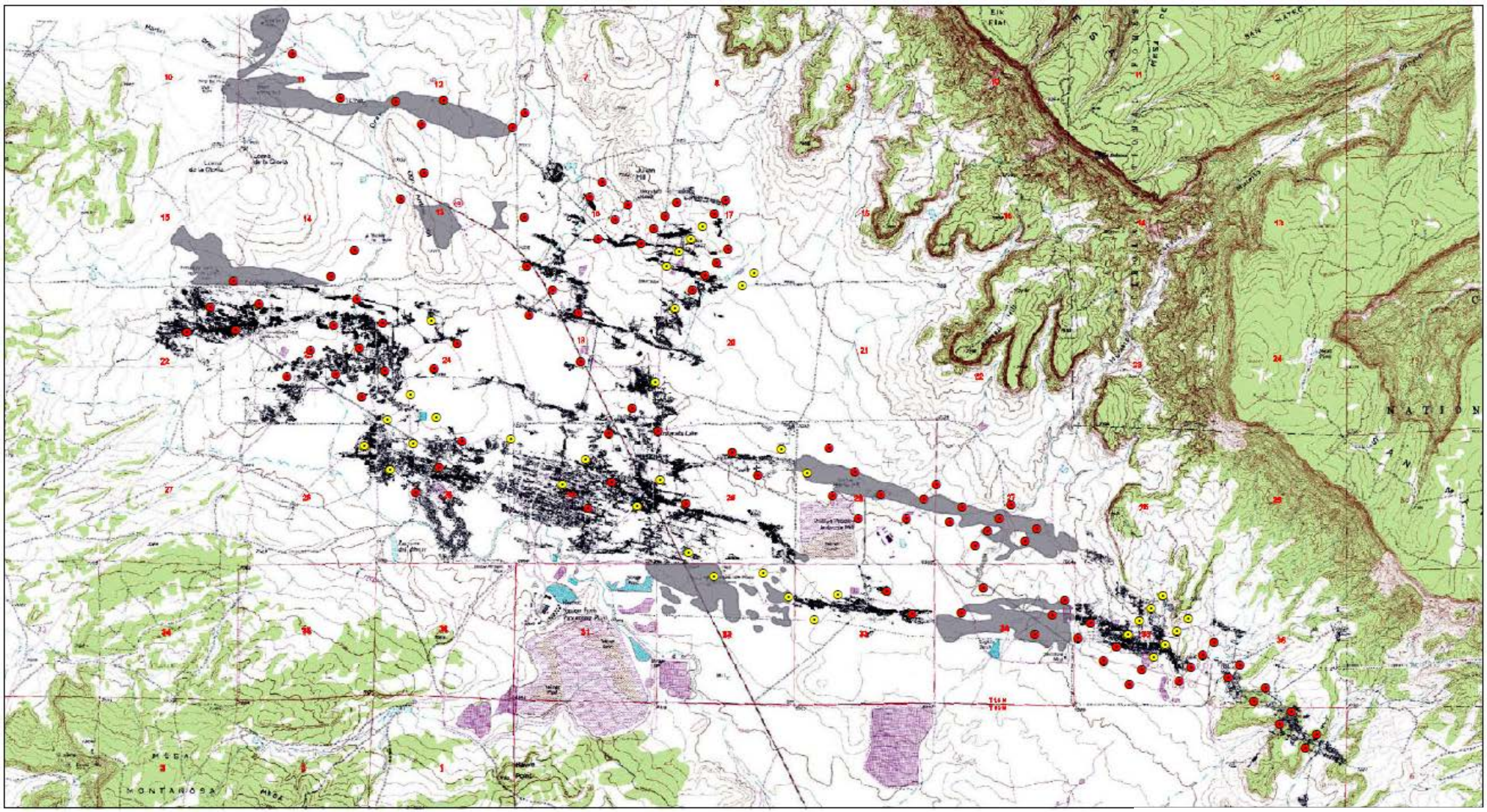


Legend

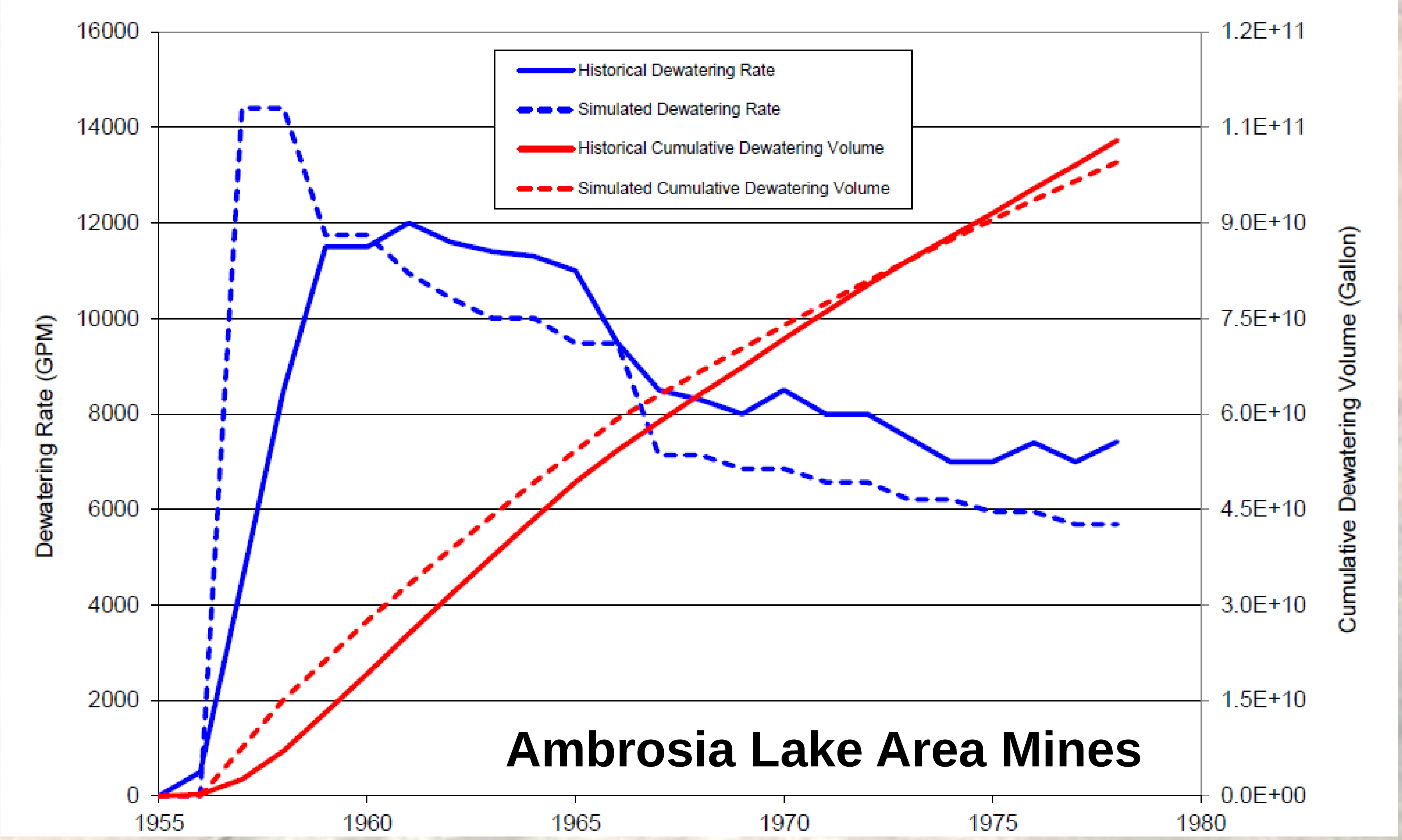
- Groundwater Level from Hydroscience (2009c) (ft amsl)
- Measured Groundwater Levels (ft amsl)
- Direction of Groundwater Flow
- Roca Honda Permit Area
- Model Domain
- State Boundary
- County Boundary

Transient Calibration: Historical Mine Dewatering

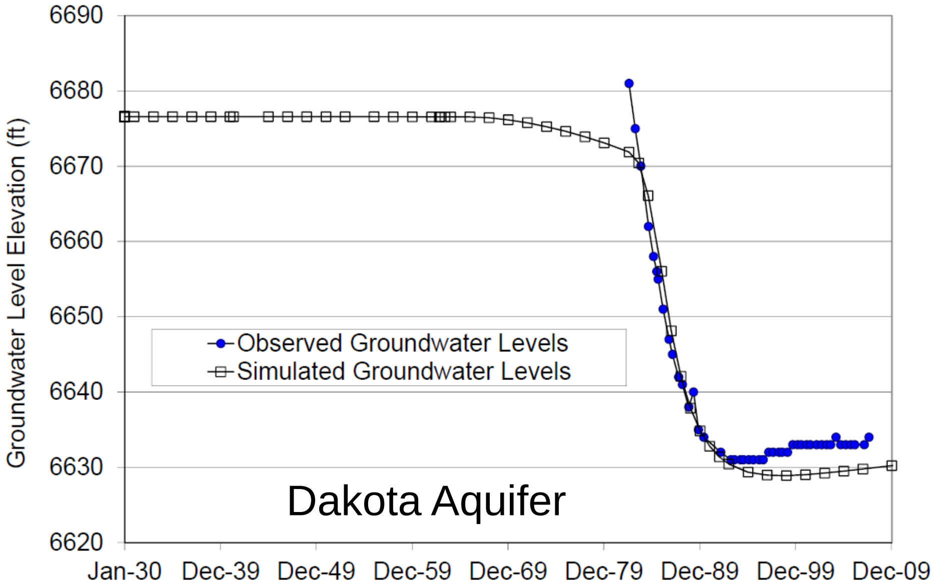


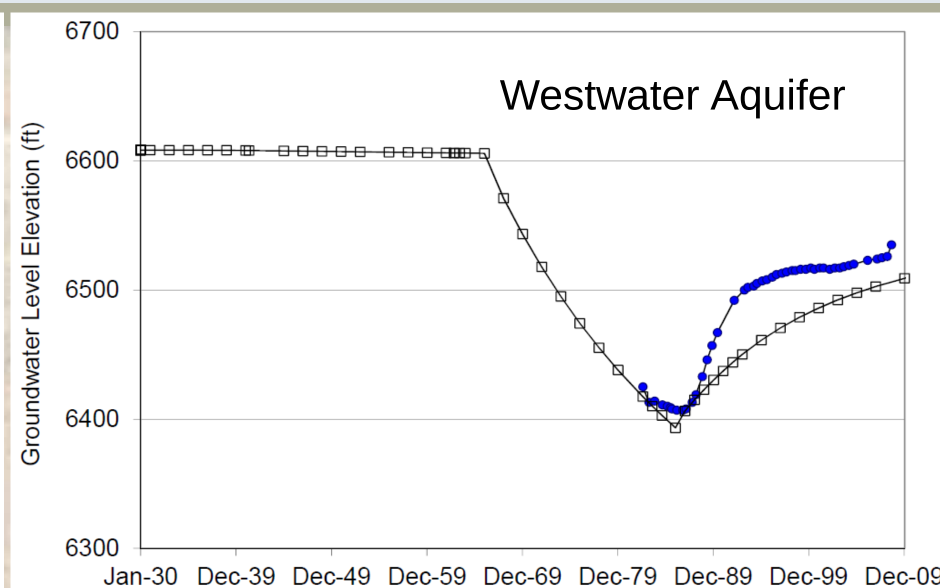
Chenoweth (1989)

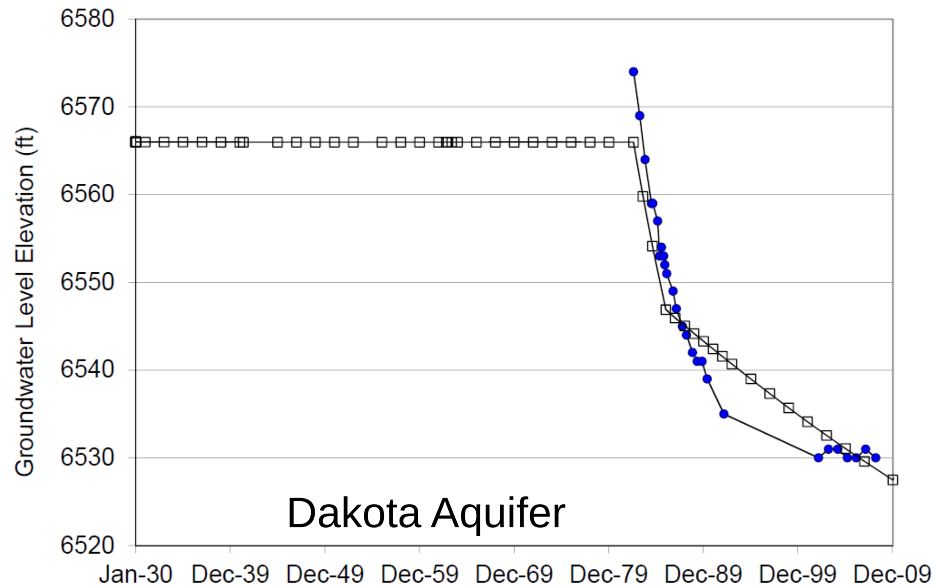
Compare Historical and Simulated Dewatering Stresses

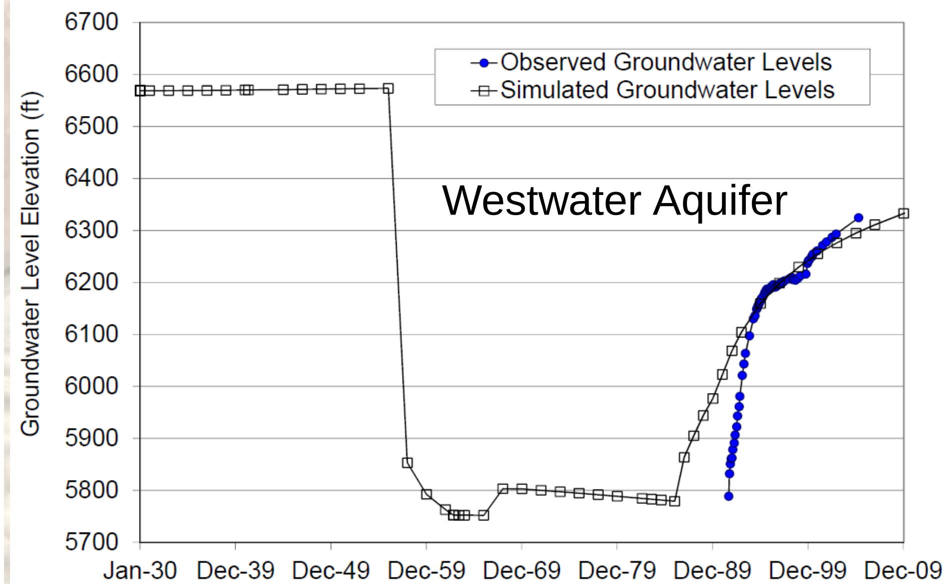


Transient Calibration Plots









Impact Assessment

- Scenario 1: no Roca Honda pumping
- Scenario 2: Roca Honda pumping at maximum rate for entire mining period
- Impacts defined by differences between scenarios
  - Differences in groundwater discharge to surface water bodies for rivers and Horace Spring
  - Drawdown for wells and springs

Springs

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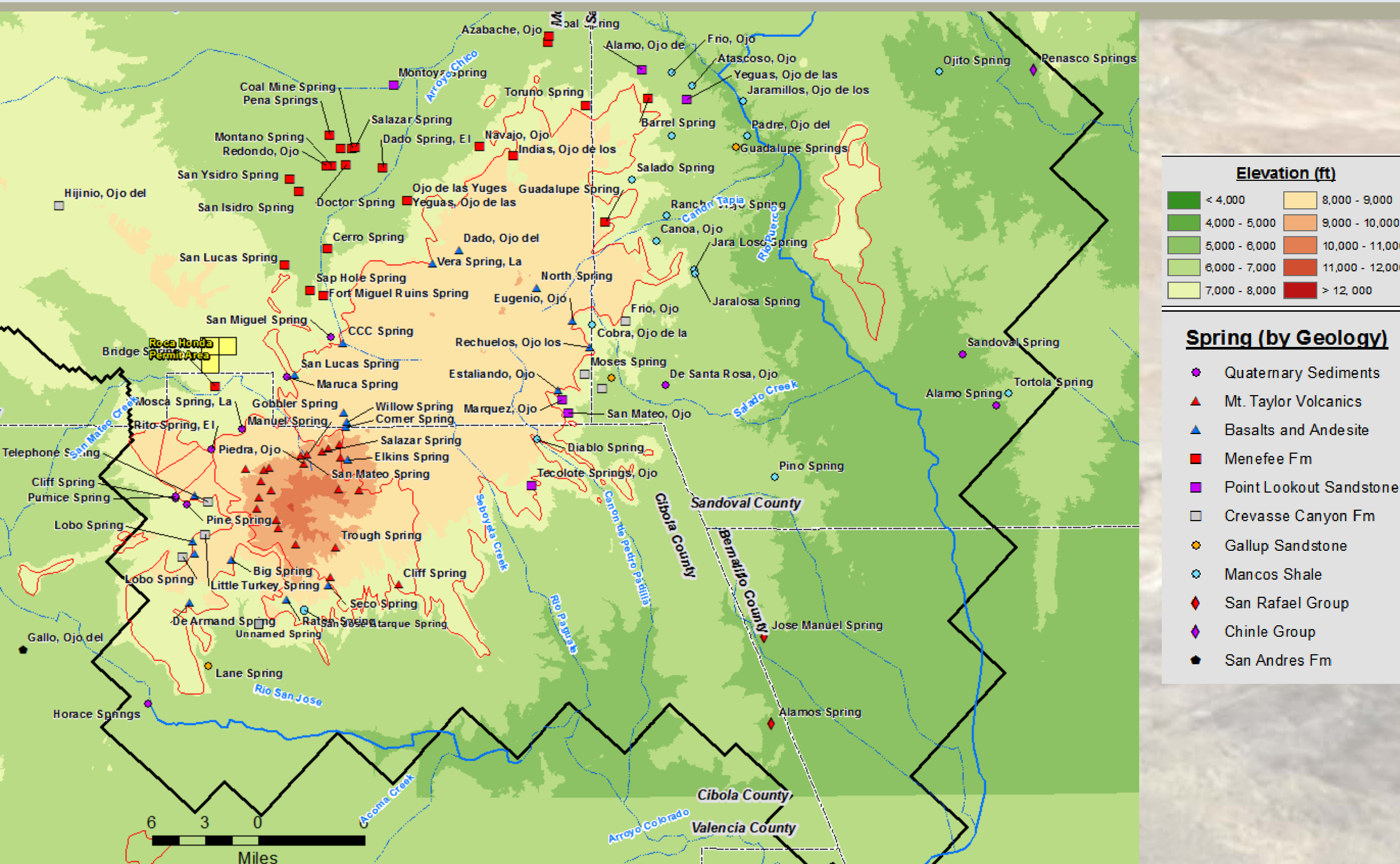
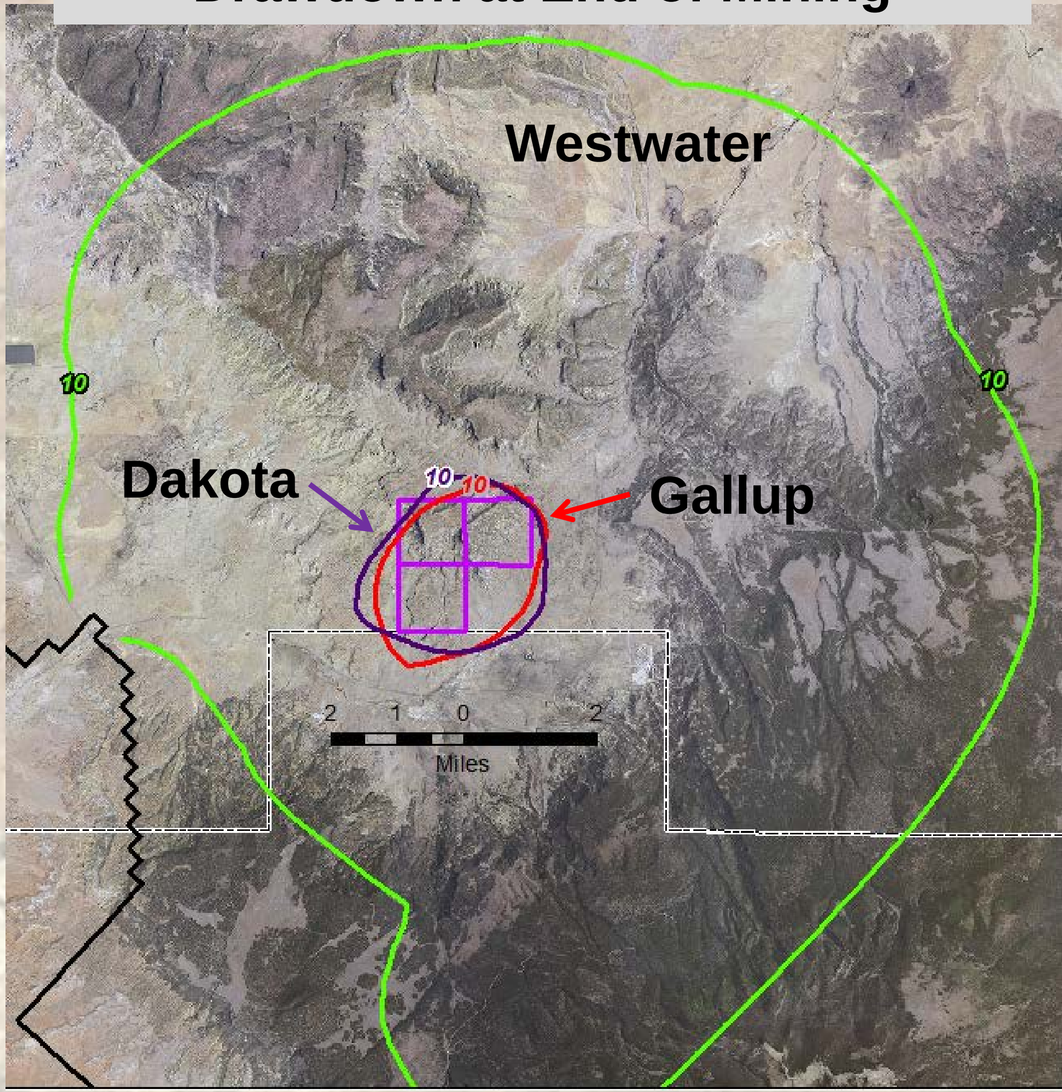


Results

- Negligible impacts at springs
  - 0.7 ft max drawdown
- 1 Westwater well affected
- Westwater head recovers to 97% within 100 years after end of mining
- Negligible changes in groundwater discharges
  - << 1% for San Juan, Rio San Jose, and Rio Puerco Rivers and Horace Springs
  - < 2% for Puerco River

Drawdown at End of Mining



Conclusions

- Constructed and calibrated a new groundwater flow modeling tool for the San Juan Basin
  - First to incorporate historical mine dewatering
- Predictive model used to evaluate potential impacts to water resources from mine dewatering
  - No impacts to rivers, springs, and all but 1 well
- US Forest Service accepted model for EIS analysis
- NM State Engineer awarded Roca Honda the first mine dewatering permit since NM's Mine Dewatering Act was passed in 1980