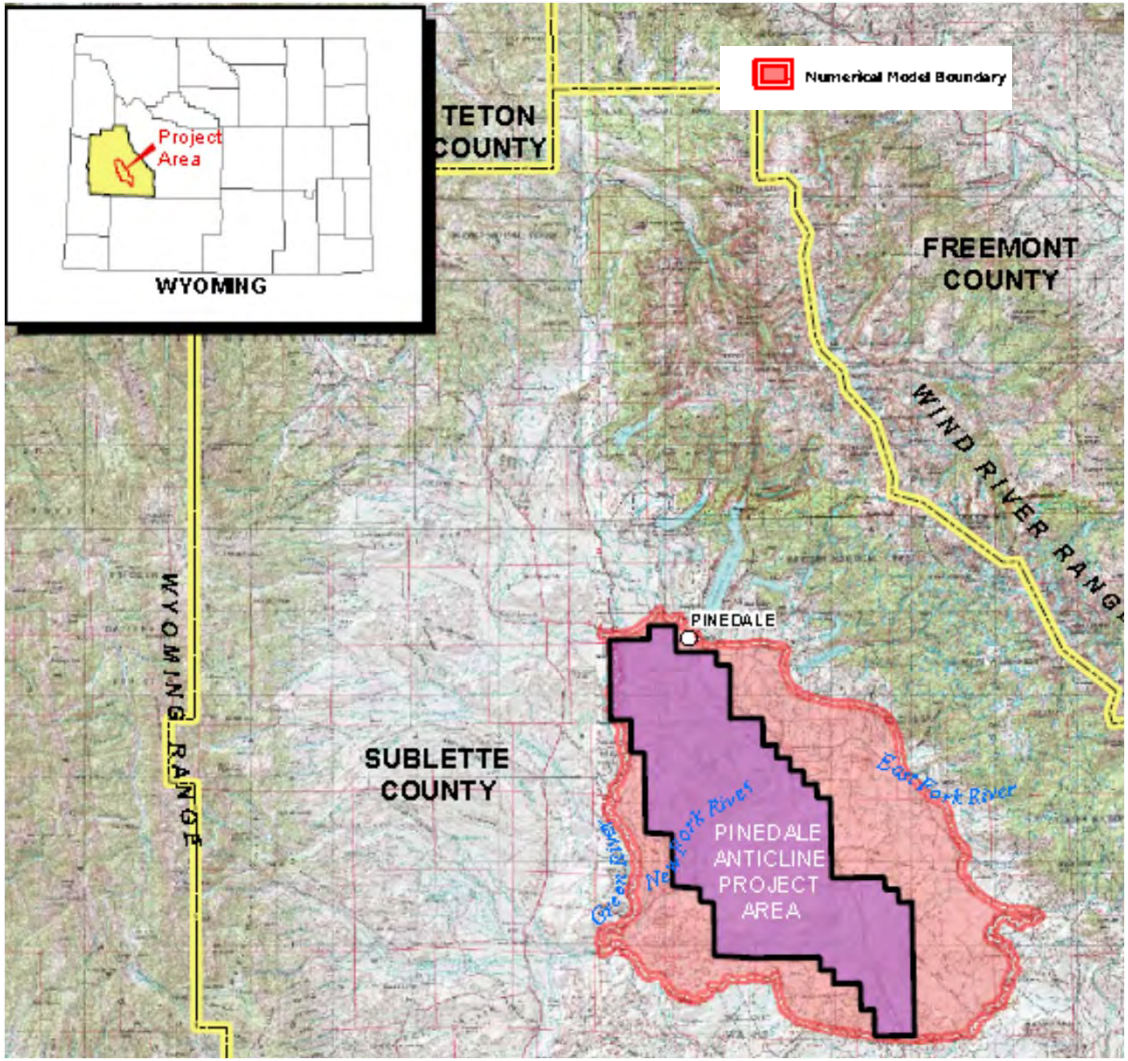
NewFields

NUMERICAL GROUNDWATER MODELING

PINEDALE ANTICLINE OIL AND GAS

EXPLORATION AND DEVELOPMENT PROJECT

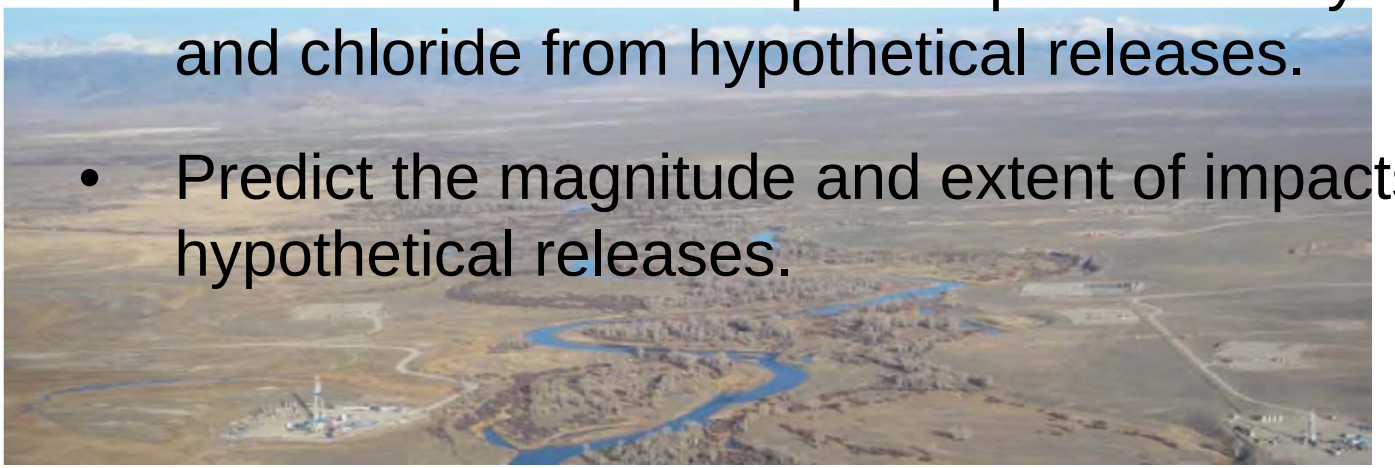
Project Location



Objectives

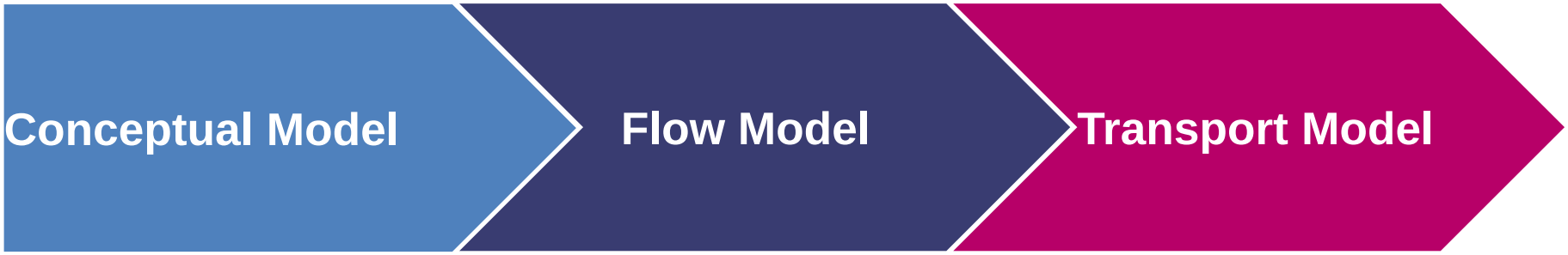
Model intended to serve as a tool to support decision-making regarding protection of groundwater resources in the PAPA.

- Construct a model capable of simulating regional groundwater flow.
- Identify areas and receptors in the PAPA that are potentially vulnerable to contamination.
- Assess fate and transport of petroleum hydrocarbons and chloride from hypothetical releases.
- Predict the magnitude and extent of impacts and from hypothetical releases.

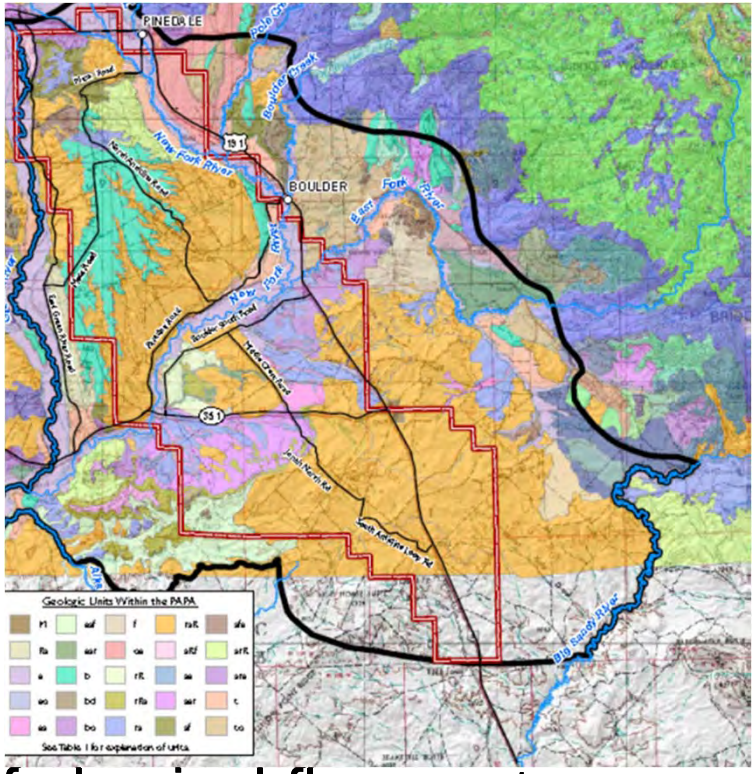


Modeling Process

- Developed in cooperation with Technical Team
  - Agencies, Operators, Contractors
- Web meetings, conference calls and face to face meetings



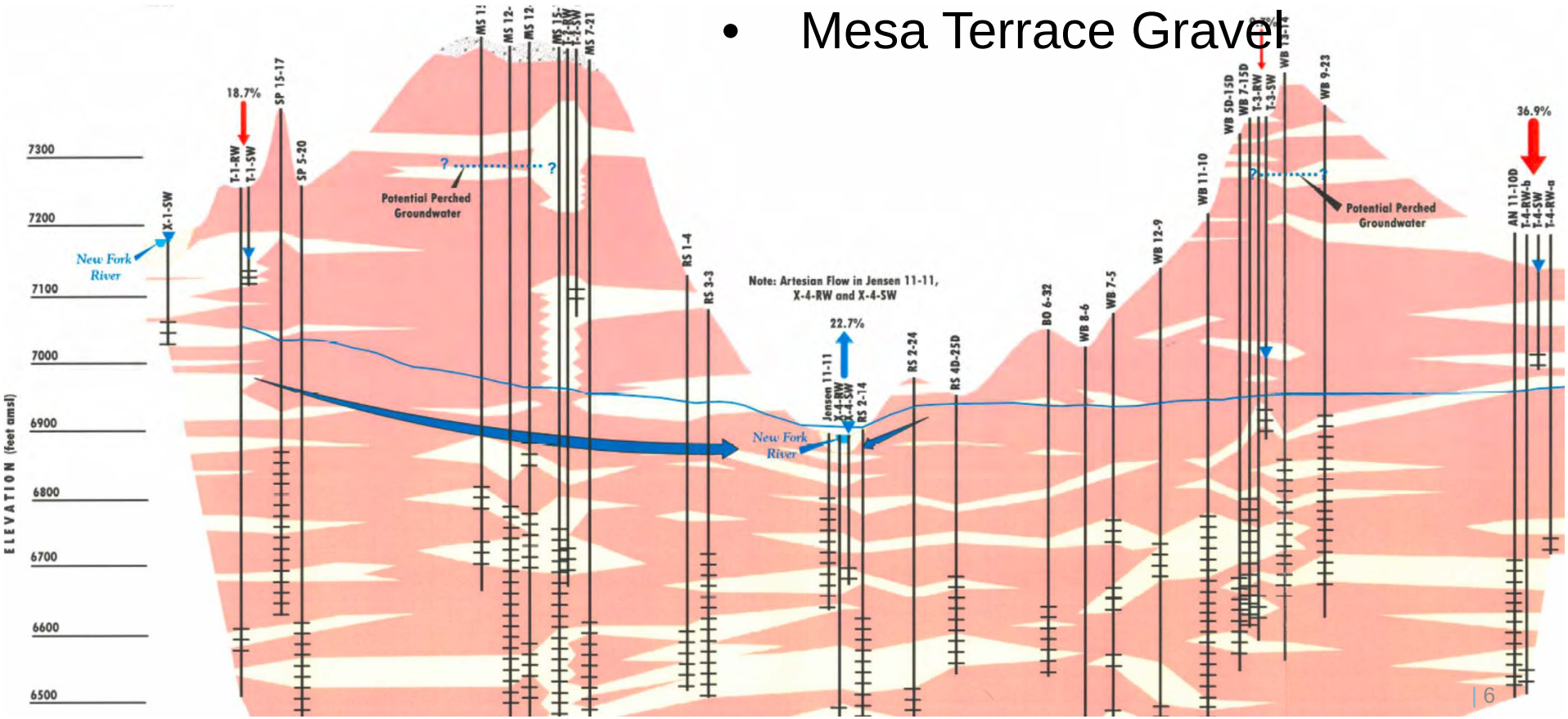
Conceptual Model



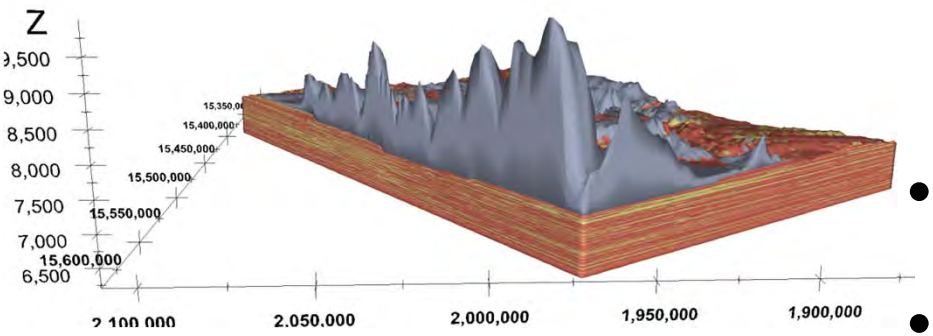
- Synthesize existing information
  - Geology
  - Hydrostratigraphy
  - Flow Directions and Gradients
  - Groundwater Sources and Sinks
  - Aquifer Properties
  - Geochemistry
  - Chemical Properties
- Explains current understanding of physical flow system
- Includes Graphic Representation
- Provides framework for numerical models

Hydrostratigraphy

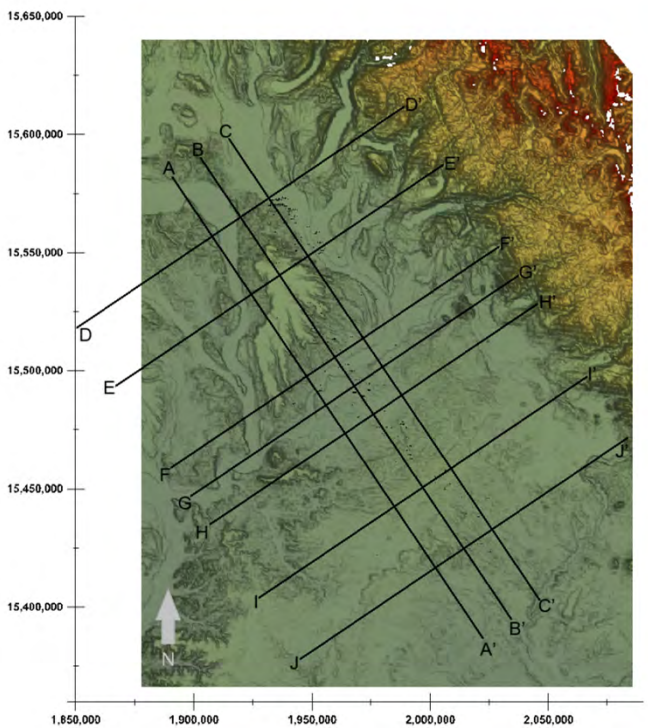
- Tertiary-aged Wasatch Fm
  - Layered sandstone and shale/siltstone
- Alluvial sand and gravel deposits
- Mesa Terrace Gravel

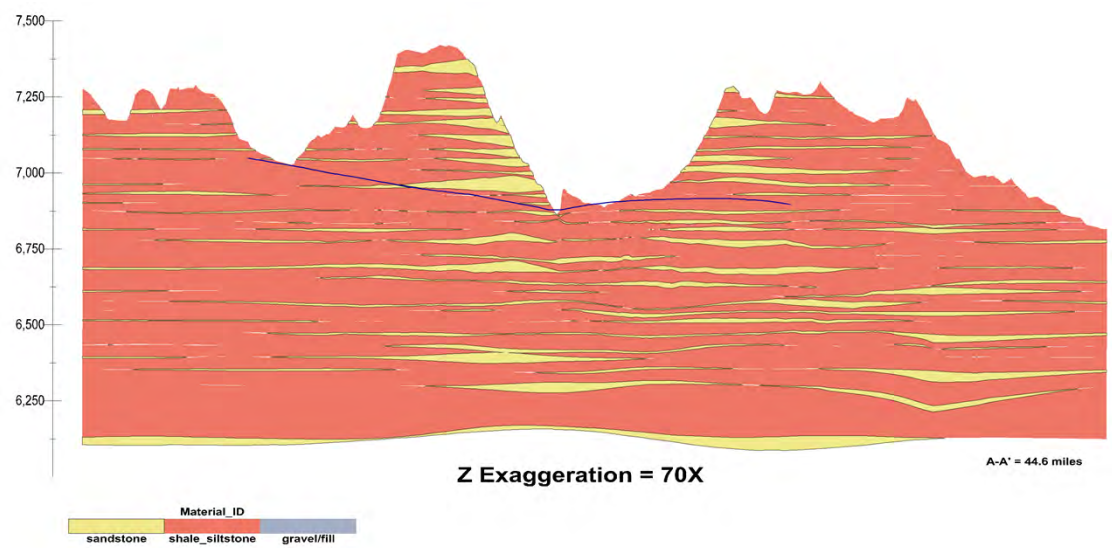


Lithologic Model

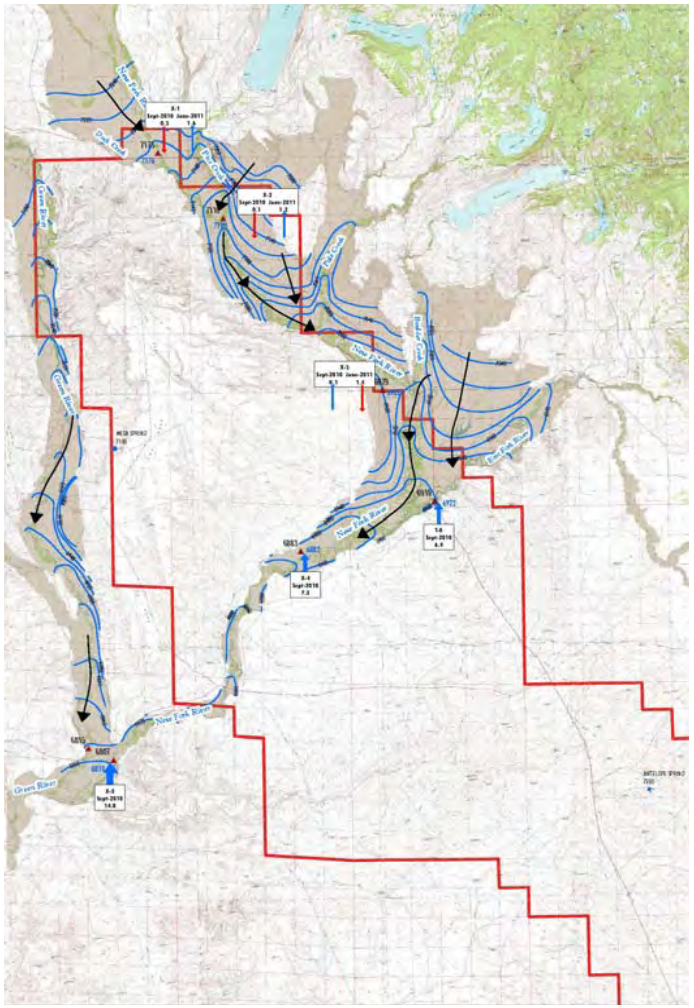


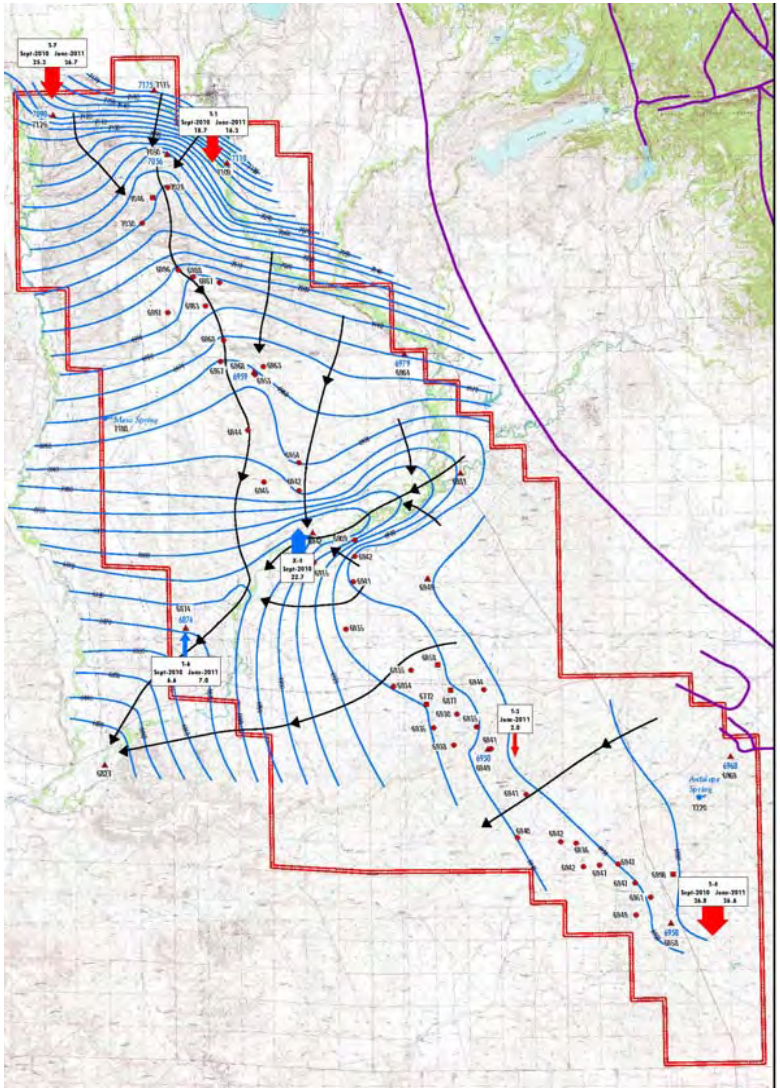
- Lithologic data from > 240 well logs
- MVS software
- Finite difference grid
- Geostatistical interpolation





Groundwater Flow Directions and Gradients



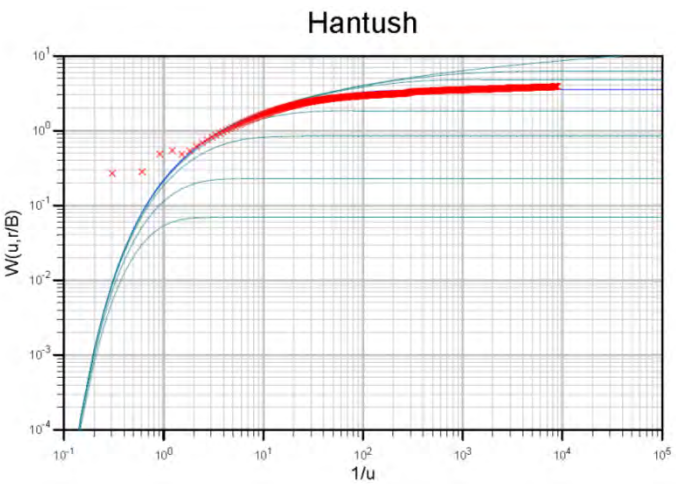


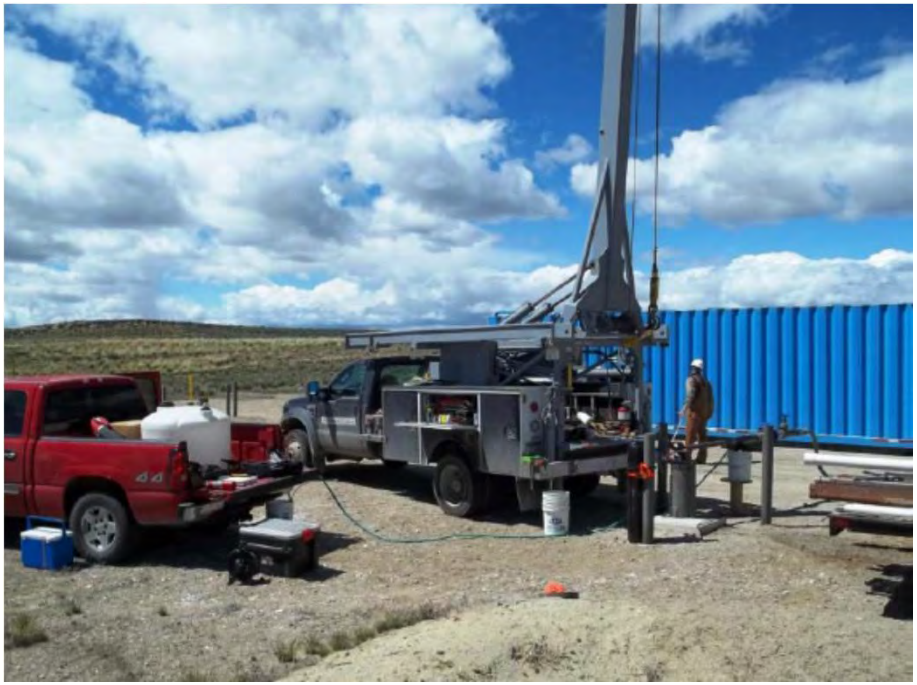
Alluvium

Wasatch Formation

Aquifer Properties

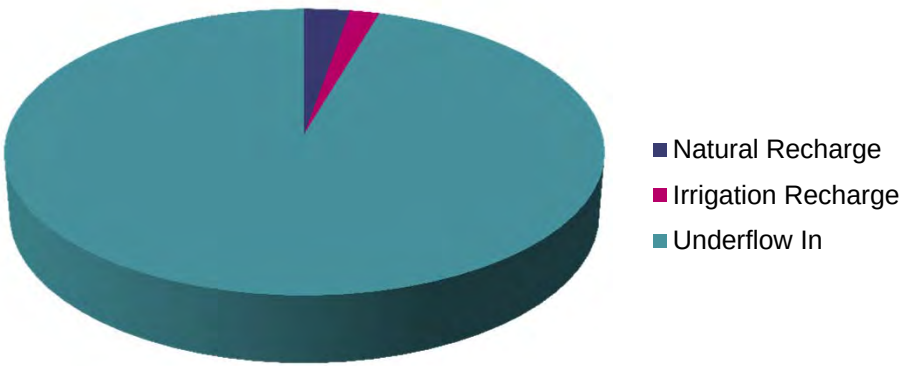
- Aquifer Testing
- Literature Values
- Transmissivity
- Hydraulic Conductivity
- Storativity



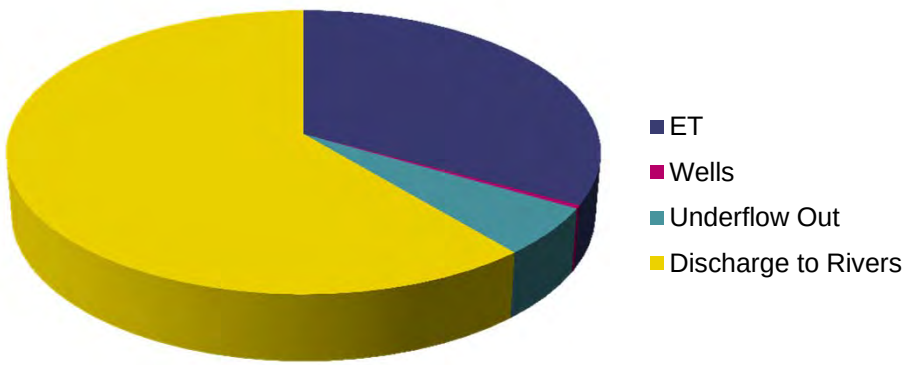


Groundwater Budget

Sources of Water
to Groundwater System



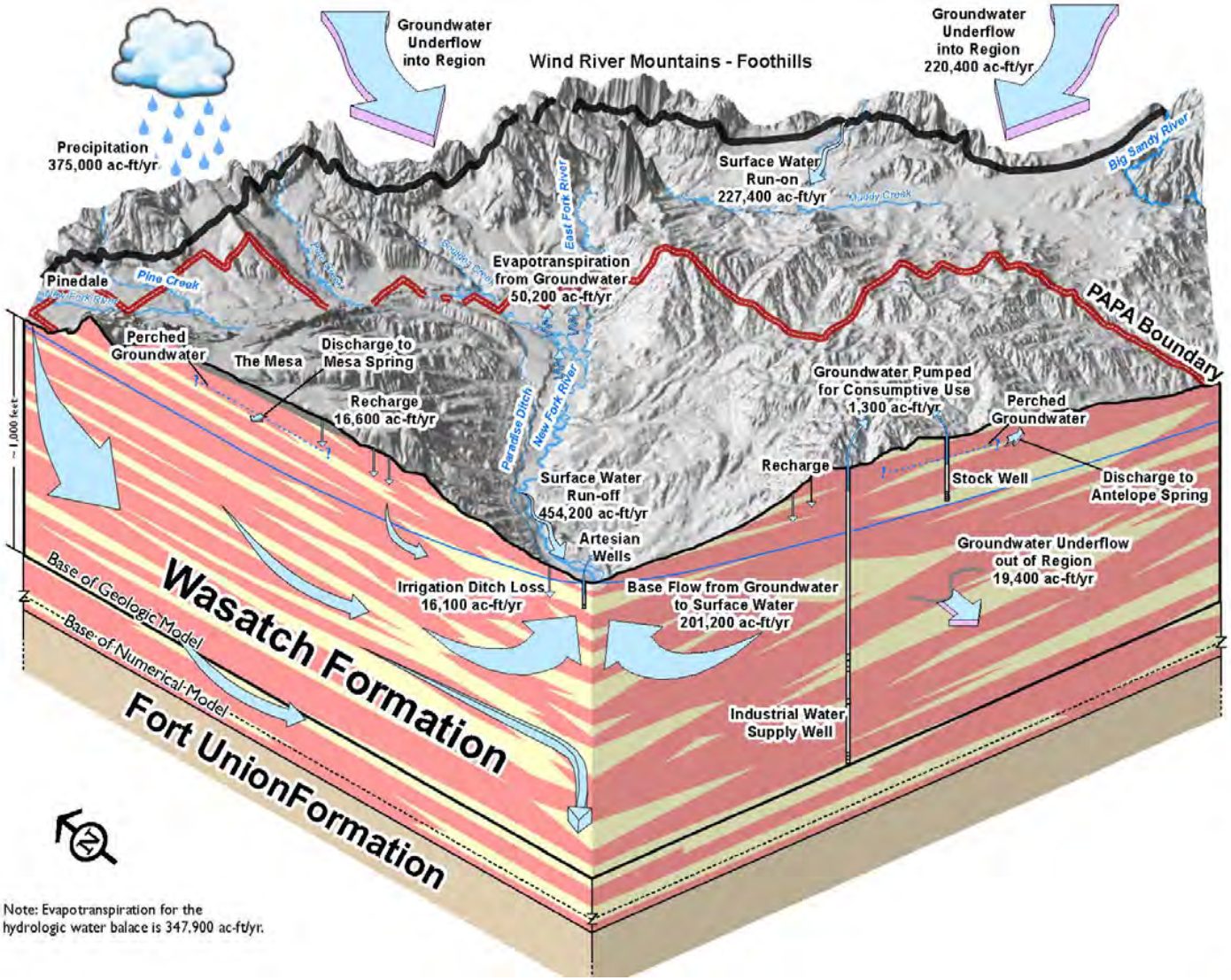
Groundwater System
Discharge



In	Low (acre-ft/yr)	High (acre-ft/yr)	Mid Estimate (acre-ft/yr)
Natural Recharge	7,600	13,000	10,000
Irrigation Recharge	5,900	7,300	6,600
Underflow In	120,000	5710,000	350,000
		Total	366,600
Out	**Low (acre-ft/yr)**	**High (acre-ft/yr)**	**Average (acre-ft/yr)**
ET	83,000	150,000	120,000
Pumped Groundwater *	1,000	1,600	1,300
Underflow Out	4,400	34,000	23,000
Discharge to Rivers*	170,000	26,000	220,000
		Total	364,300

*Minimum and maximum estimates calculated as ± 20 percent of the average estimate.

Conceptual Block Model

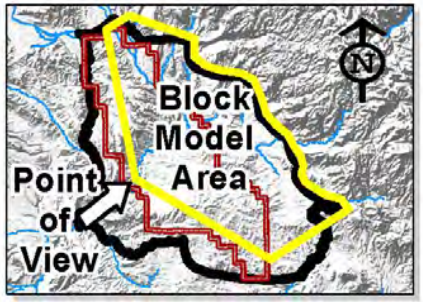


Note: Evapotranspiration for the hydrologic water balace is 347,900 ac-ft/yr.

Hydrologic Water Balance Summary	
Inflow	
Precipitation	375,000
Surface Water Run-on	227,400
Groundwater Underflow into Region	220,400
Outflow	
Surface Water Run-off	454,200
Groundwater Underflow out of Region	19,400
Grounwater Pumped for Consumptive Use	1,300
Evapotranspiration	347,900

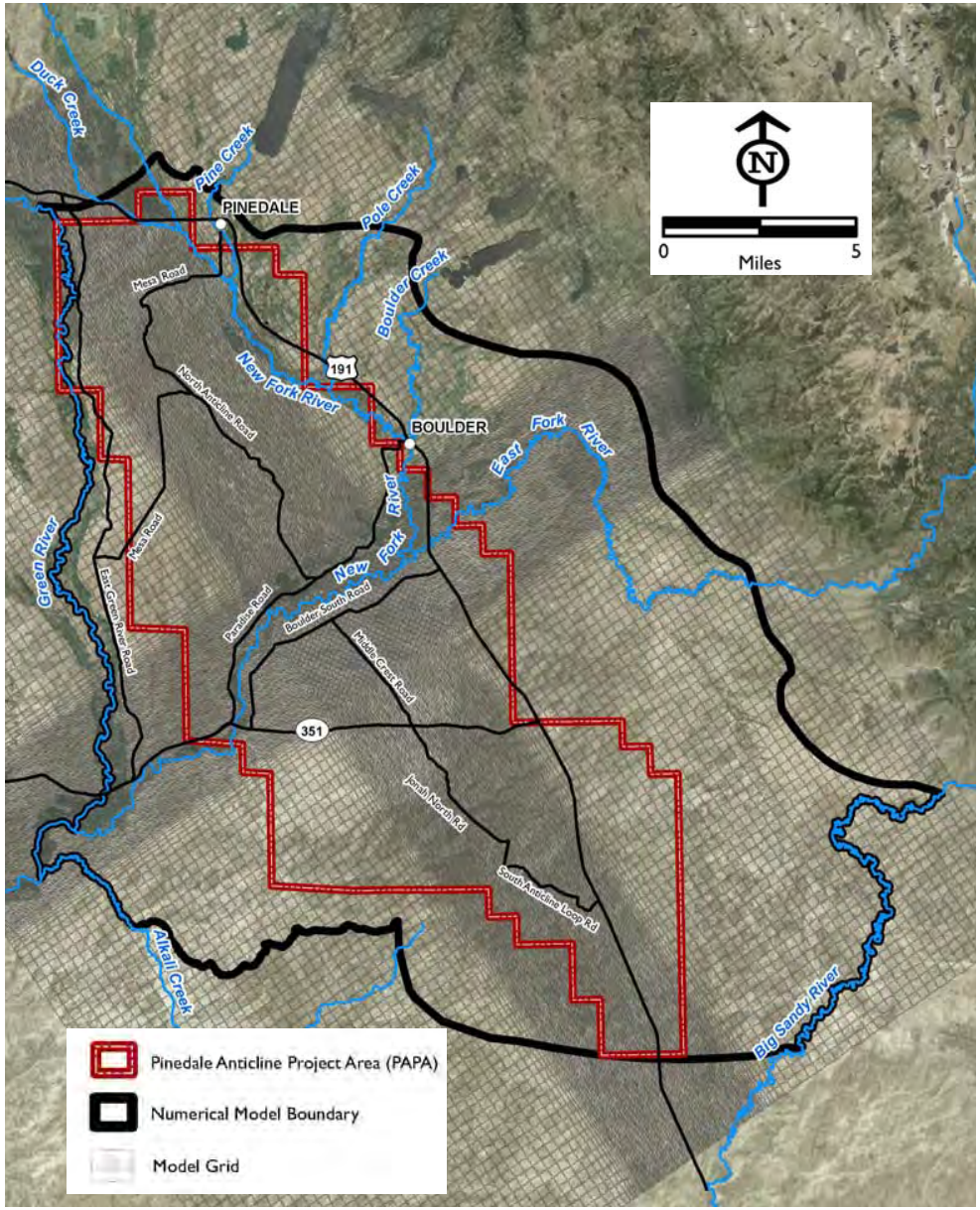
Groundwater Balance Summary	
Inflow	
Natural Recharge	10,100
Irrigation Recharge	6,600
Irrigation Ditch Loss	16,100
Groundwater Underflow into Region	220,400
Outflow	
Groundwater Underflow out of Region	19,400
Grounwater Pumped for Consumptive Use	1,300
Evapotranspiration from Groundwater	50,200
Base Flow from Groundwater to Surface Water	201,200

Note: All values in acre-feet per year (ac-ft/yr)



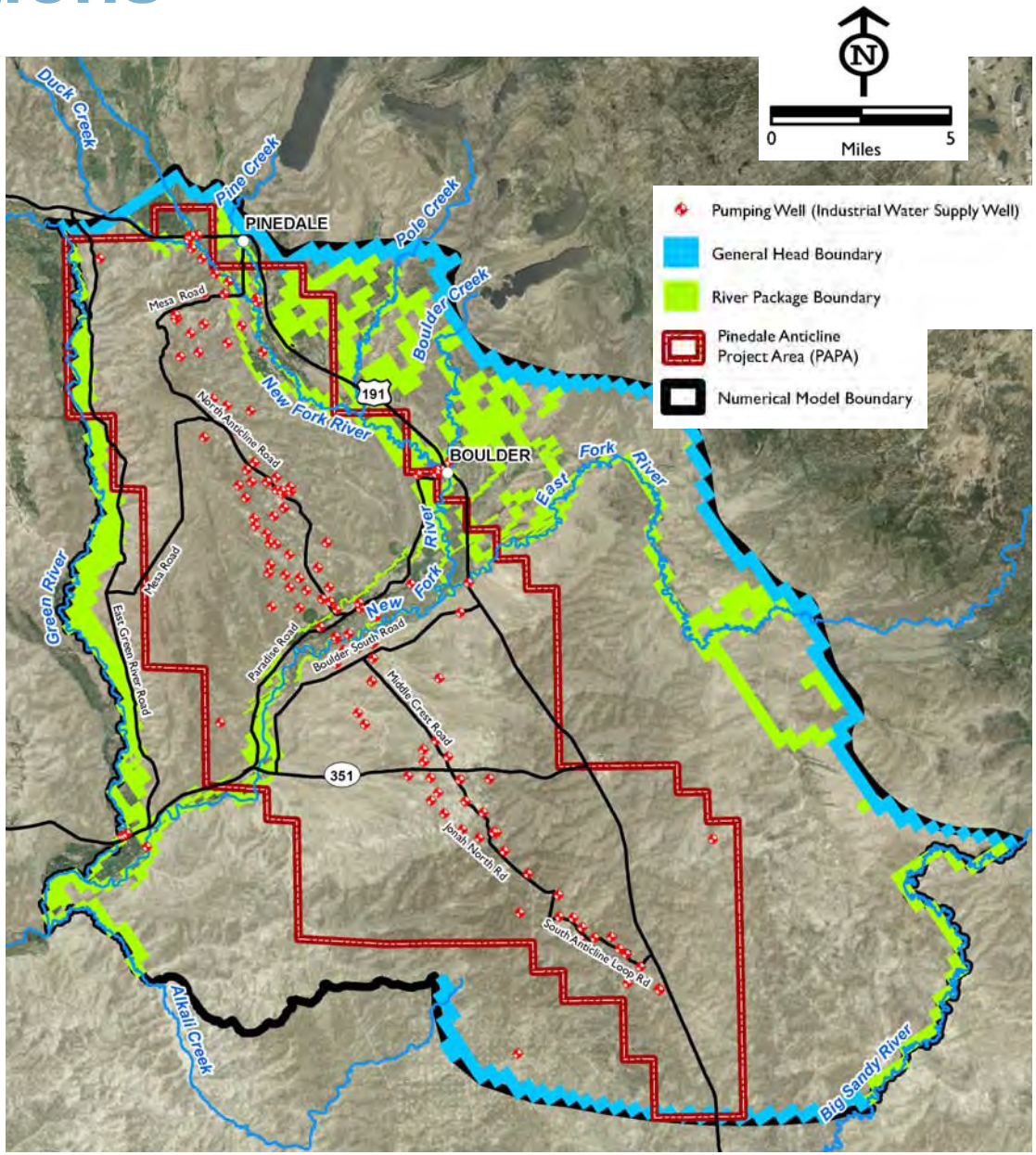
Groundwater Flow Model

- Based on conceptual model
- MODFLOW-SURFACT
- Variable grid spacing (300 - 2,000 feet)
    - Provides greater resolution in area of interest
- 69 Layers
- 2,418,795 model cells

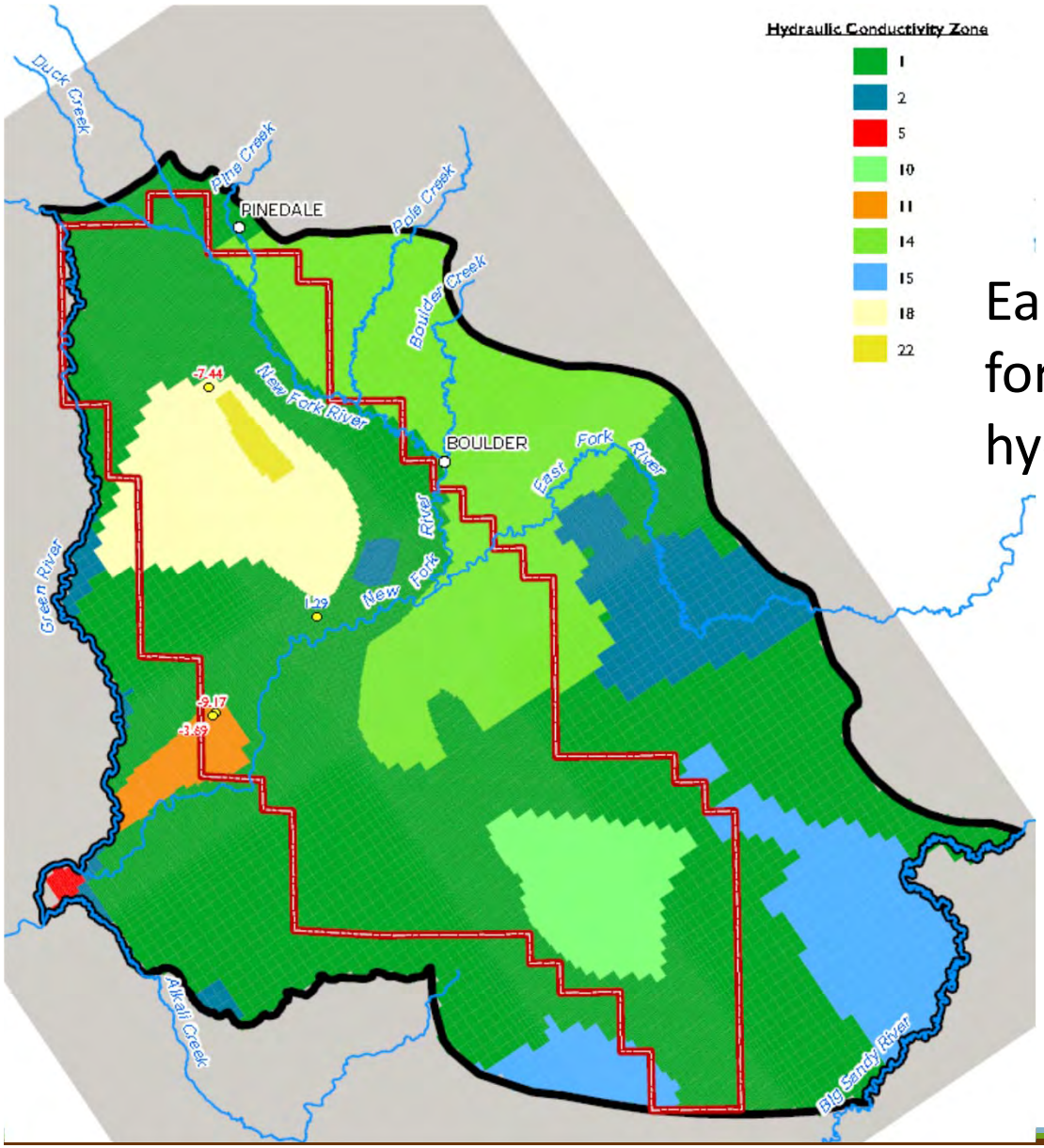


Boundary Conditions

- Sources and Sinks
- Specified Flux
  - Well Package
  - Recharge Package
- Head Dependent
  - River Package
  - GHB Package
  - ET Package



Hydraulic Conductivity

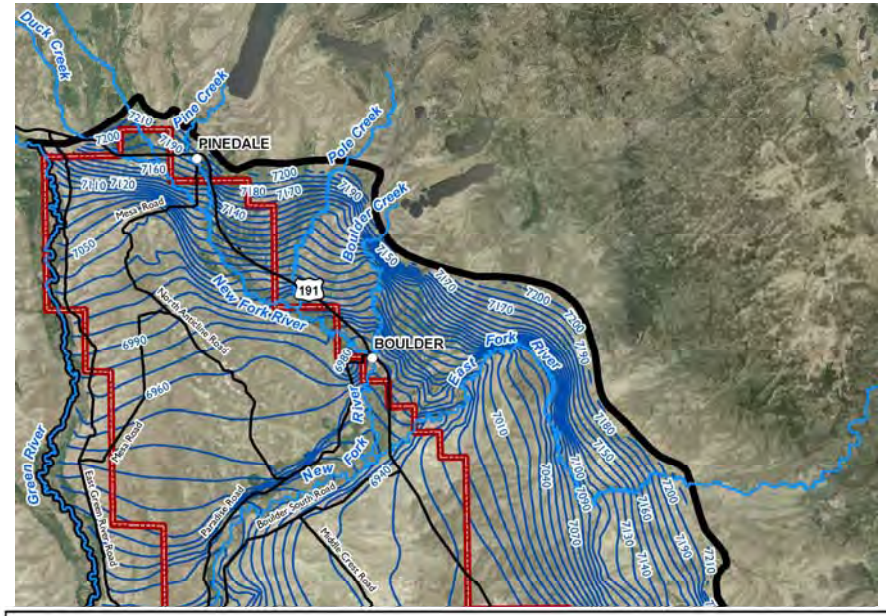


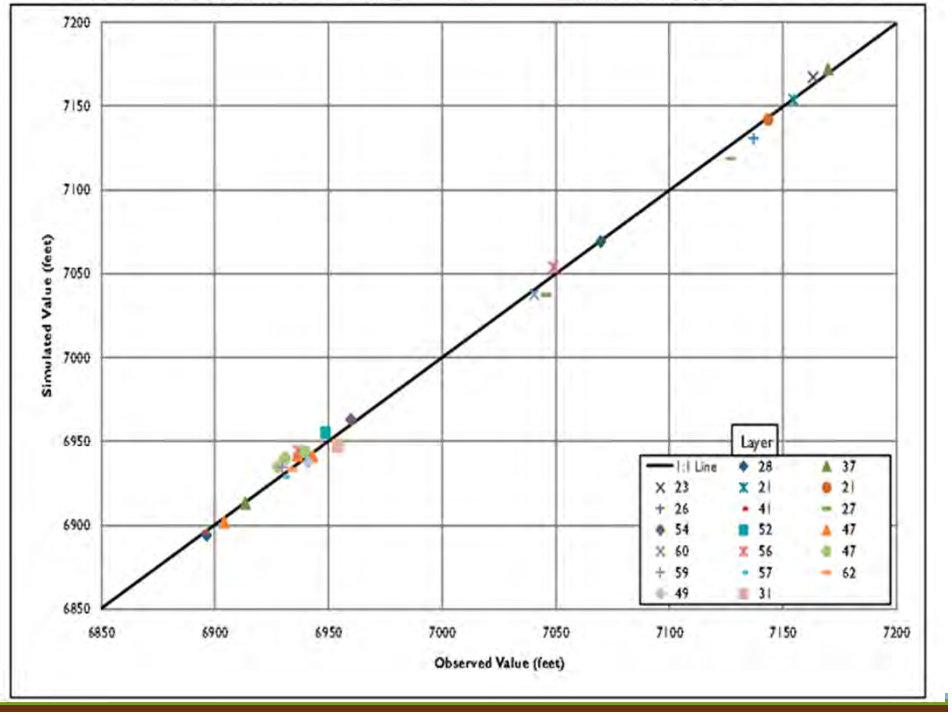
Each model cell applied a values for horizontal and vertical hydraulic conductivity

Calibration

- Match Head and Flux Targets
- Demonstrates model's ability to simulate observed groundwater flow
- Manual and automated techniques employed
- Evaluated Quantitatively and Qualitatively

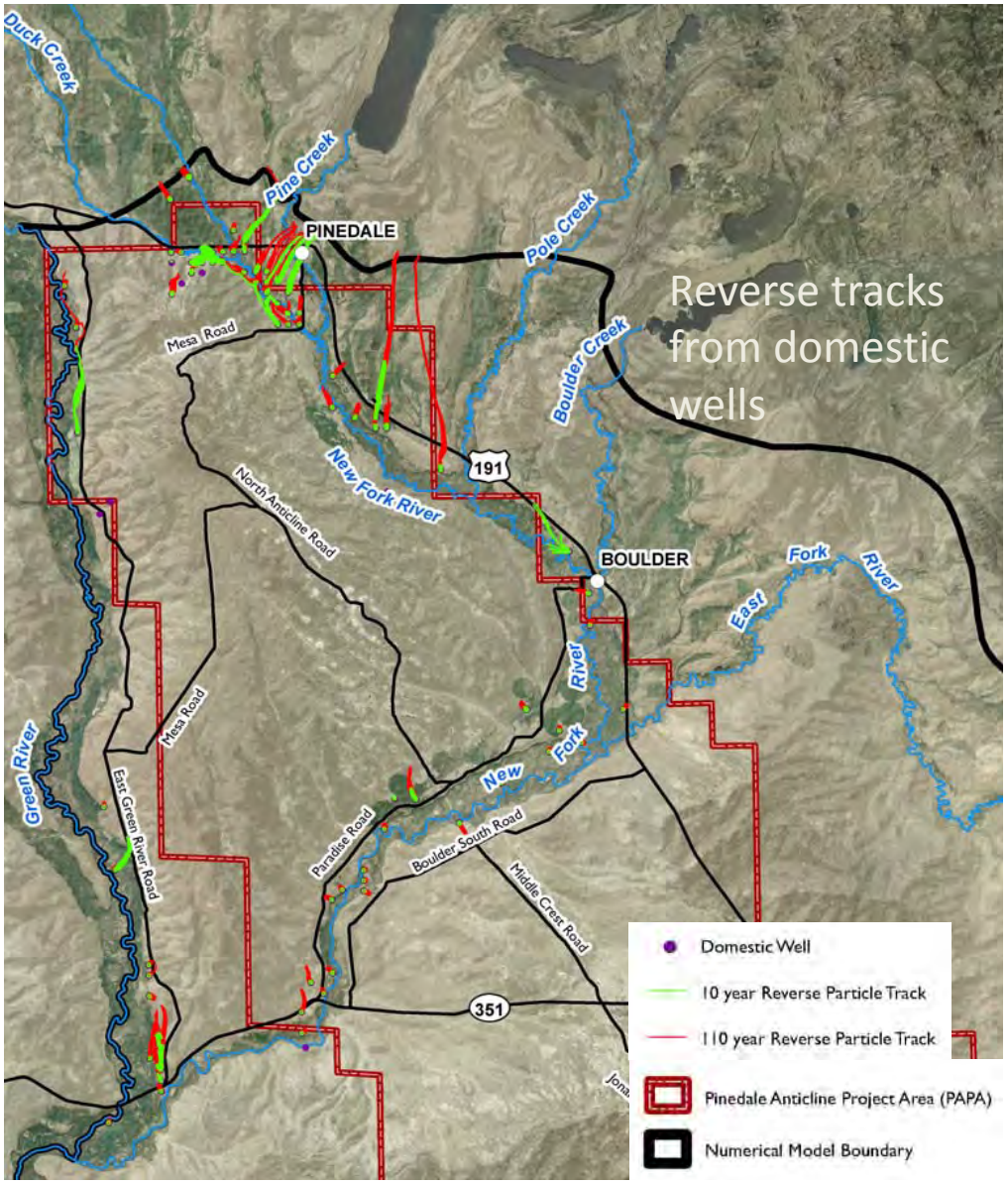
Statistic	Result
Residual Mean	0.16
Absolute Residual Mean	3.77
Residual Standard Deviation	4.53
Sum of Squares	1,976
Root Mean Square Error	4.47
Minimum Residual	-8.6
Maximum Residual	9.4
Scaled Standard Deviation	0.012





Advective Transport

- Forward and Reverse Particle Tracking using MODPATH
- Does not include dispersion, sorption, or biodegradation
- Identified areas potentially susceptible to contamination
- Assessed the susceptibility of receptors in PAPA area.



Reverse Particle Tracking

Indicates sources of water to potential receptors.

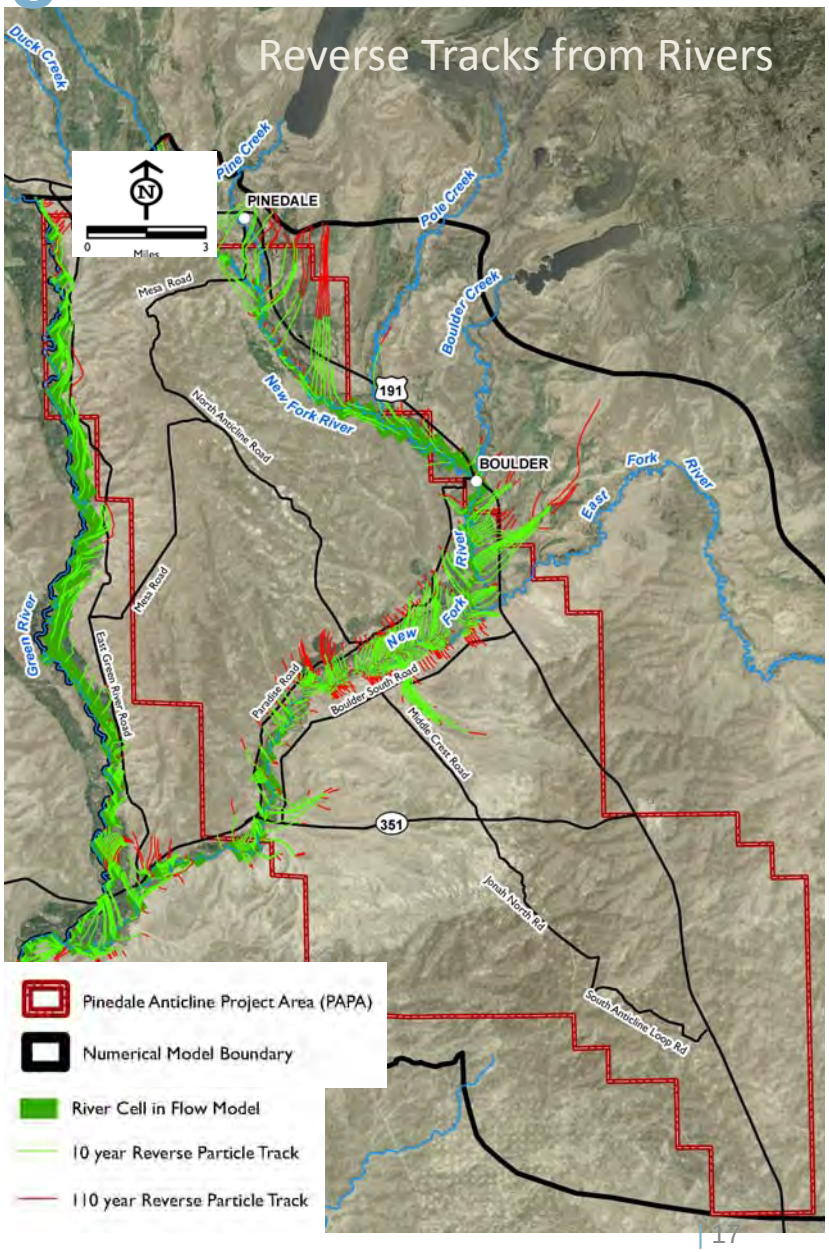
- Rivers
- Stock Wells
- Domestic Wells
- Irrigation Ditches

Ran particles for twice the estimated life of gas field – 110 years.

110-year path lengths are less than 1.5 miles in Wasatch.

Velocities in NFR and GR alluvium 100 to 700 times greater than in Wasatch Formation.

Town of Pinedale area wells not susceptible to releases in groundwater.



Forward Particle Tracking

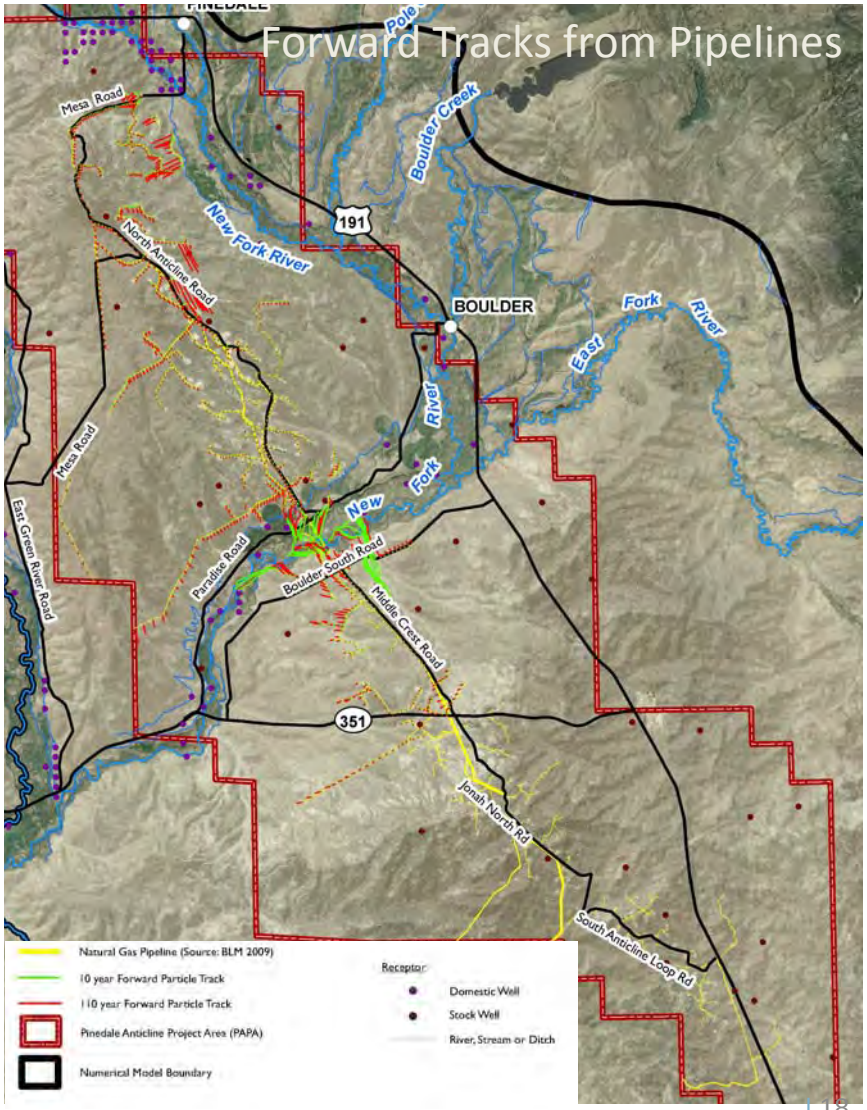
Simulate releases from hypothetical releases

- shut-in pre-1984 gas wells
- liquid-gathering facilities,
- natural gas pads, pipelines,
- roads,
- saltwater disposal facilities

Particles from pre-1984 four gas wells closest to the New Fork River reach river.

Particles from the 10 LGFs reach an identified receptor.

Particles from natural gas pads in or near alluvial material near NFR and Sand Springs Draw reached receptors.



Vulnerable Areas

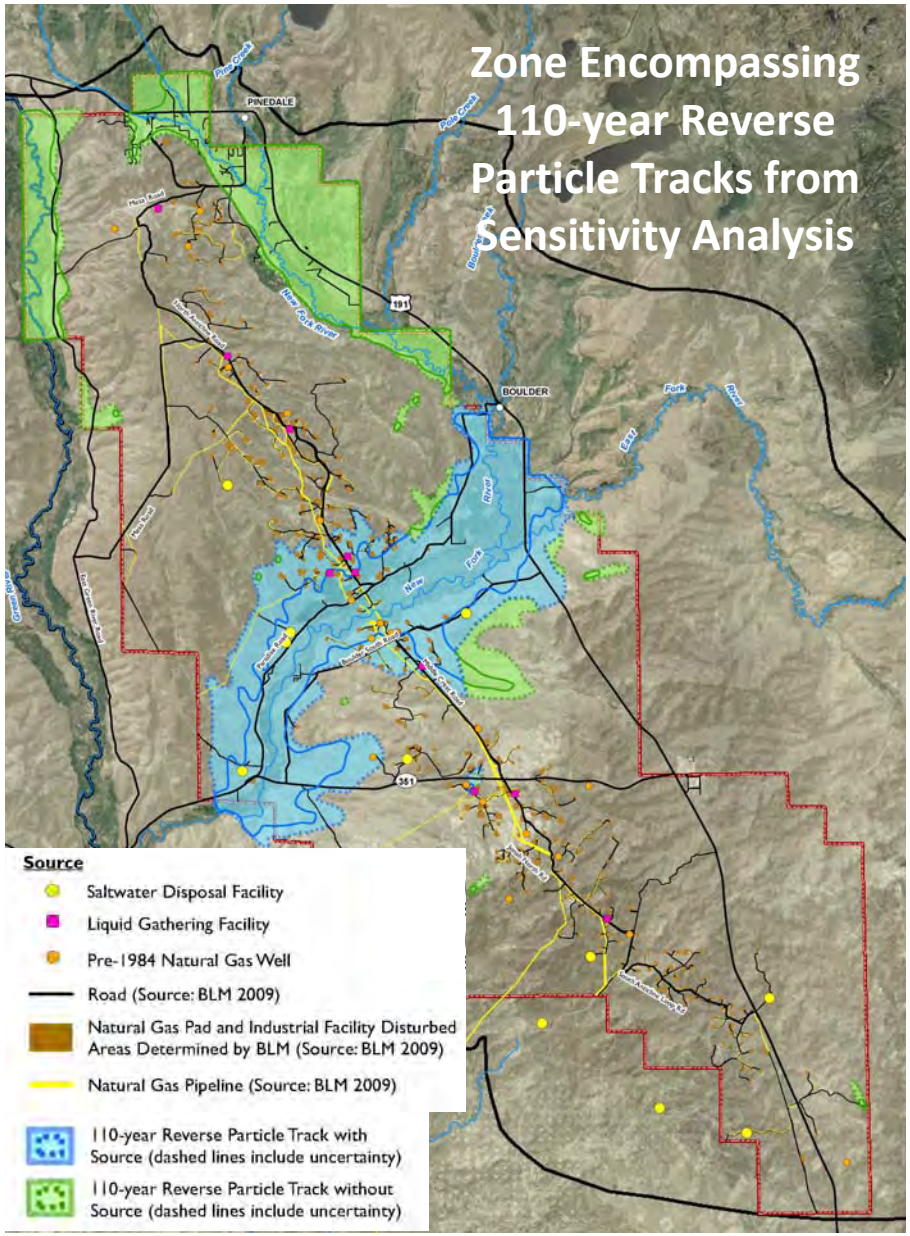
Sensitivity analysis - identified worst case

Blue zone shows potential receptors with natural gas activities with 110-year travel time

Green potential receptors without upgradient source

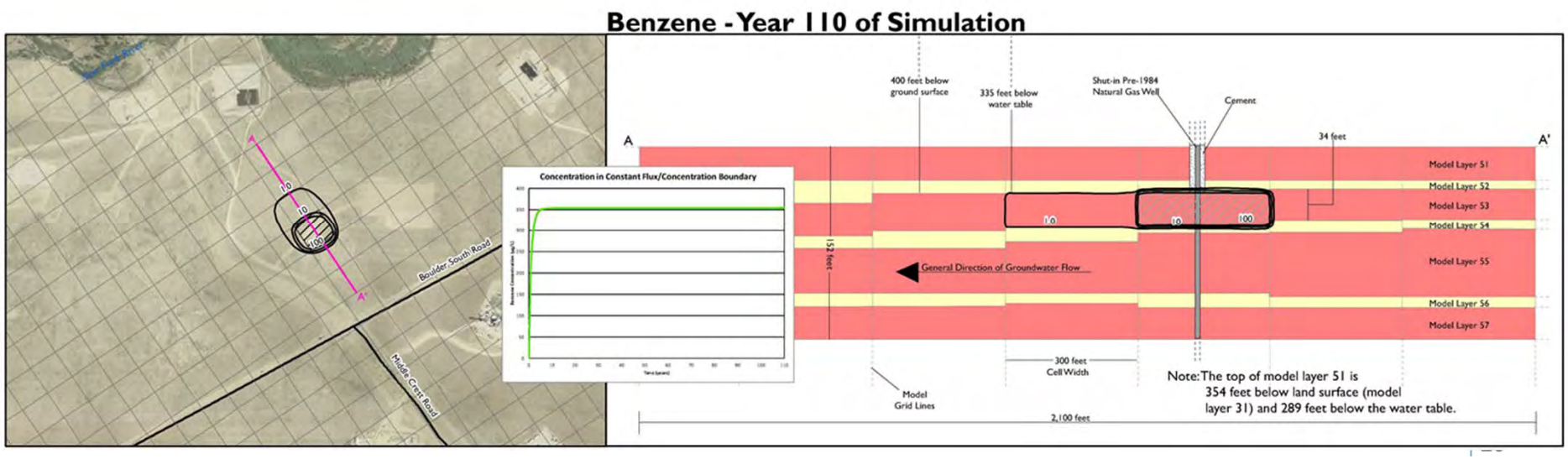
Conservative Estimates:

- Velocity.
- Does not include natural attenuation.
- Twice the age of field



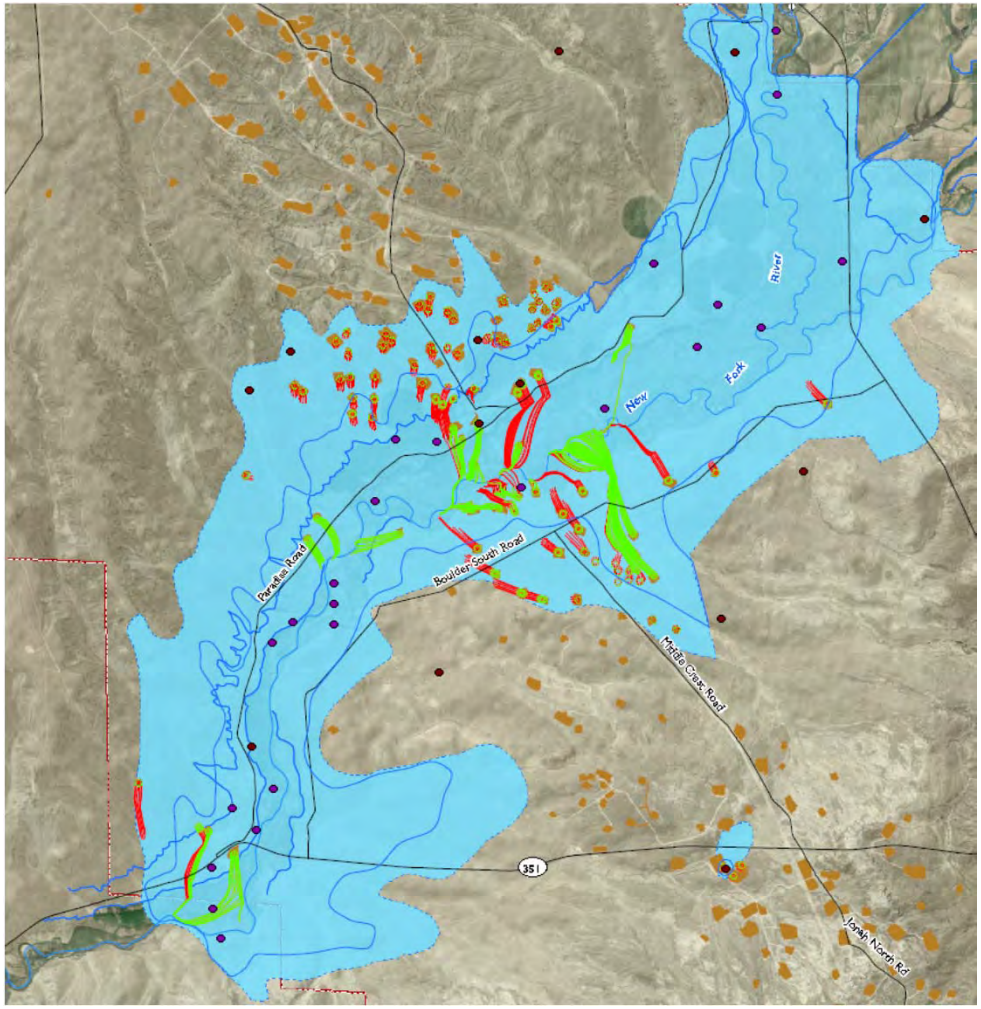
Solute Transport Modeling

- Hypothetical releases of benzene, toluene, and chloride from hypothetical releases.
  - Attenuated vs. Conservative
- Accounts for dispersion, sorption and biodegradation.
- Hypothetical releases: Roads, pipelines, LGF, tank, shut-in gas well (pre 1984).
- Simulated the maximum lateral and vertical extent.
- Predicted maximum concentrations expected in groundwater.
  - Benzene and toluene < 150 feet
  - Chloride < 1500 feet



Model Limitations

- Scarcity of data outside of the axis
- Transport models have not been calibrated
- Model cells are larger than hypothetical release areas
- Limited information regarding fractures and faults



Conclusions

- Natural gas activities in the PAPA will not affect groundwater in or around the town of Pinedale.
- Particles outside of the river corridors travel less than 1.5 miles in 110 years.
- Except for a few stock wells, identified potential receptors farther than 1.5 miles from the New Fork River are not at risk of contamination.
- The most susceptible area is the New Fork River valley between Boulder Creek and the downstream PAPA boundary.
- Predicted benzene and toluene concentrations do not exceed standards >150 feet from simulated sources .
- An individual release is unlikely to impact large portions of the Wasatch or Alluvial aquifers.
- Model results are helpful in identifying regions within system that are most susceptible to groundwater quality impacts, and identifying appropriate locations for long-term water quality monitoring.