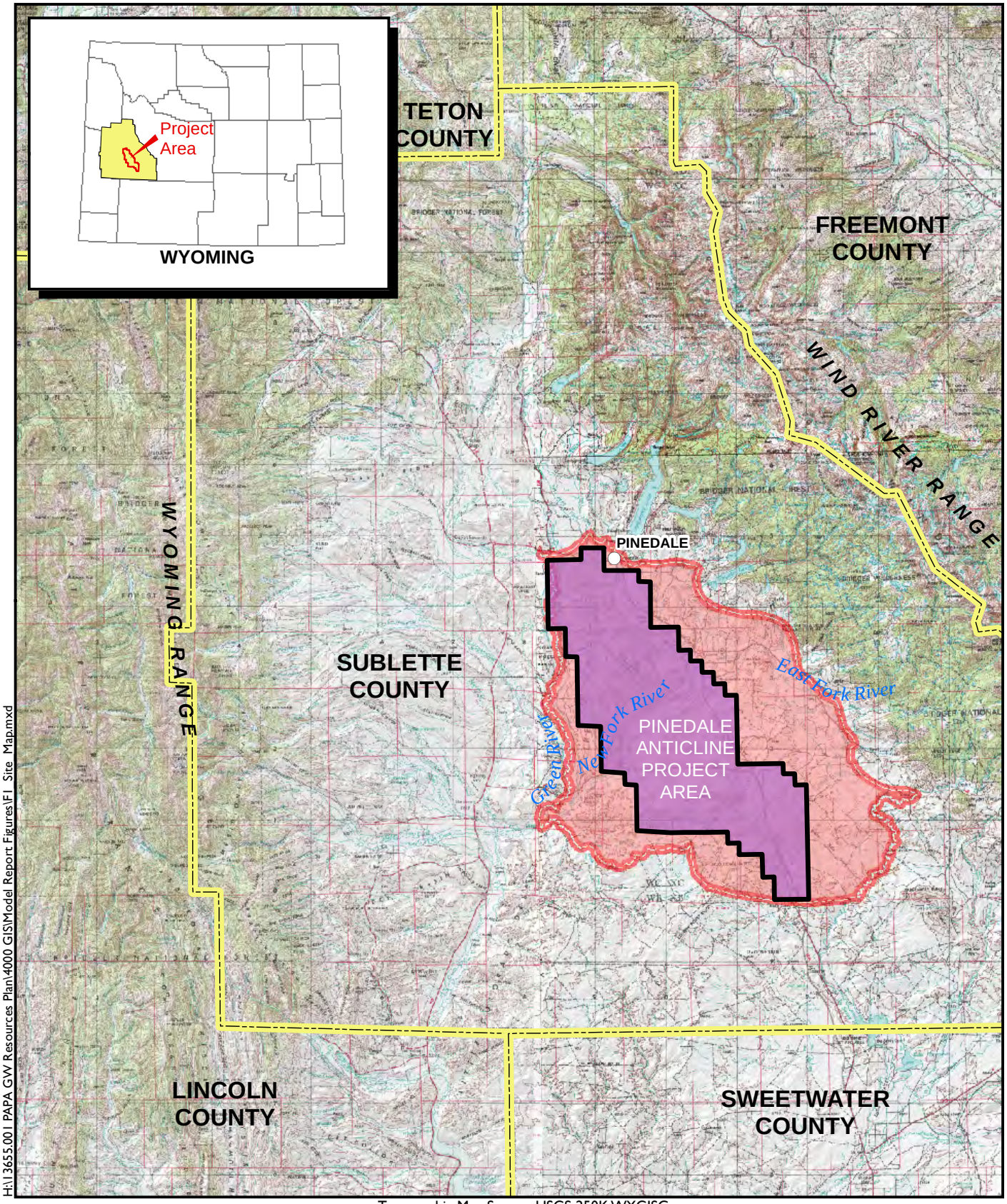
FIGURES



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F1 Site Map.mxd

Topographic Map Source: USGS 250K WYGISC

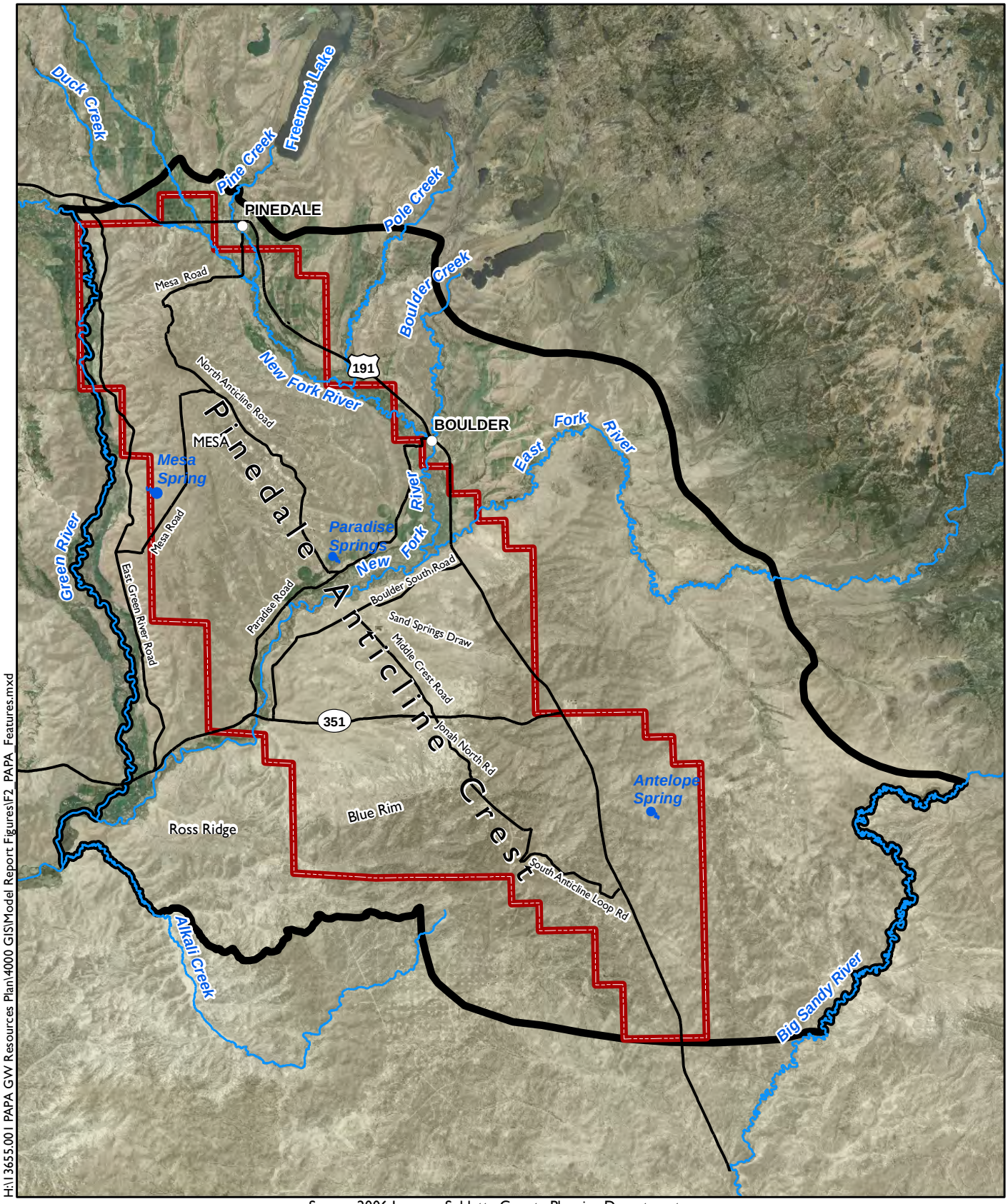
N

0 Miles 12

Numerical Model Boundary

amec

Project Location Map
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 1



Source: 2006 Imagery Sublette County Planning Department

H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F2_PAPA_Features.mxd

N

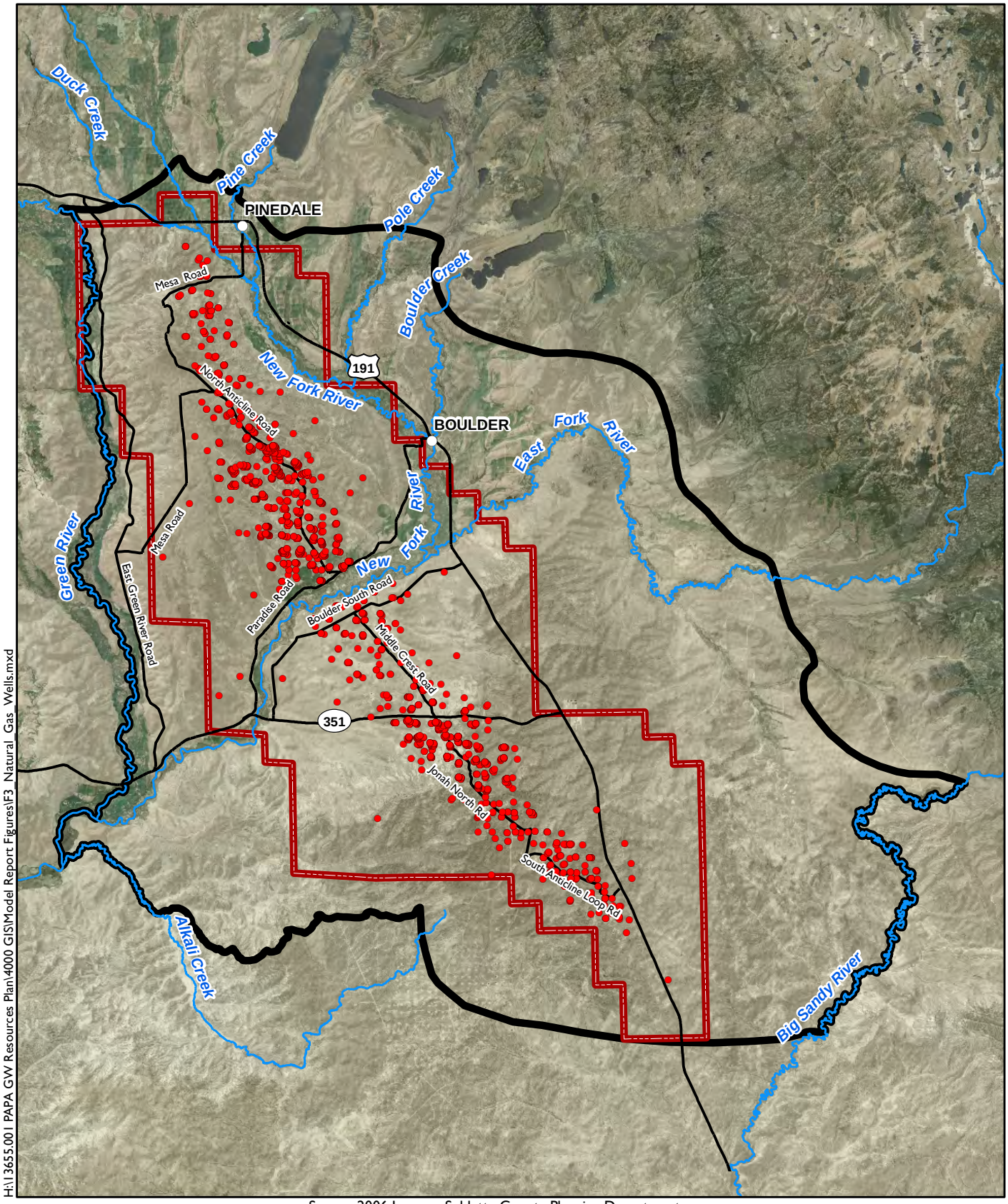
0 Miles 5

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

amec

Geographic Features
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 2



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F3 Natural Gas Wells.mxd

Source: 2006 Imagery Sublette County Planning Department

N

0 Miles 5

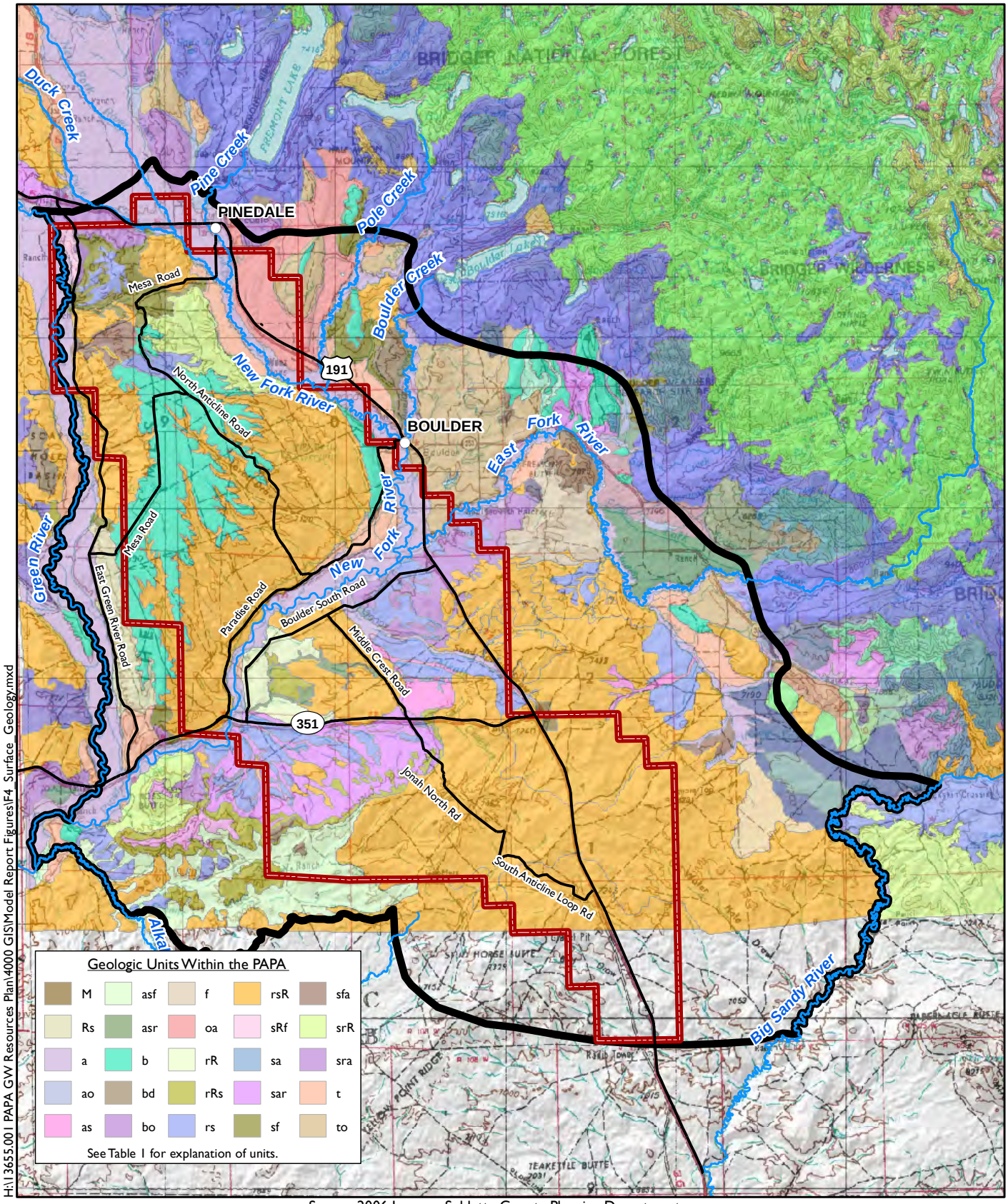
Natural Gas Well

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

amec

Natural Gas Wells in PAPA
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 3



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F4_Surface_Geology.mxd

Source: 2006 Imagery Sublette County Planning Department

N

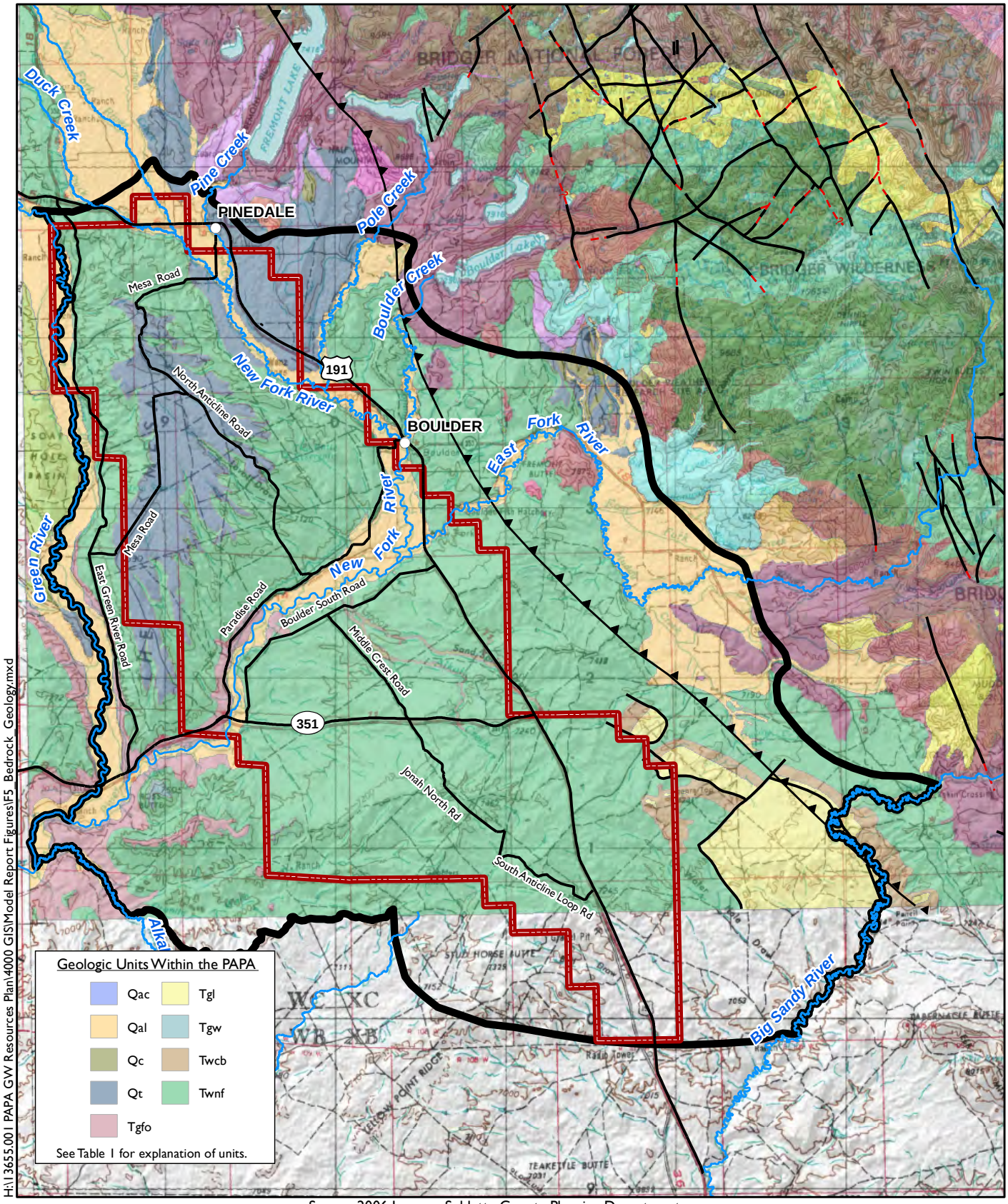
0 Miles 5

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

amec

Surface Geology
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 4



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F5_Bedrock_Geology.mxd

Source: 2006 Imagery Sublette County Planning Department

N

0 Miles 5

Faults

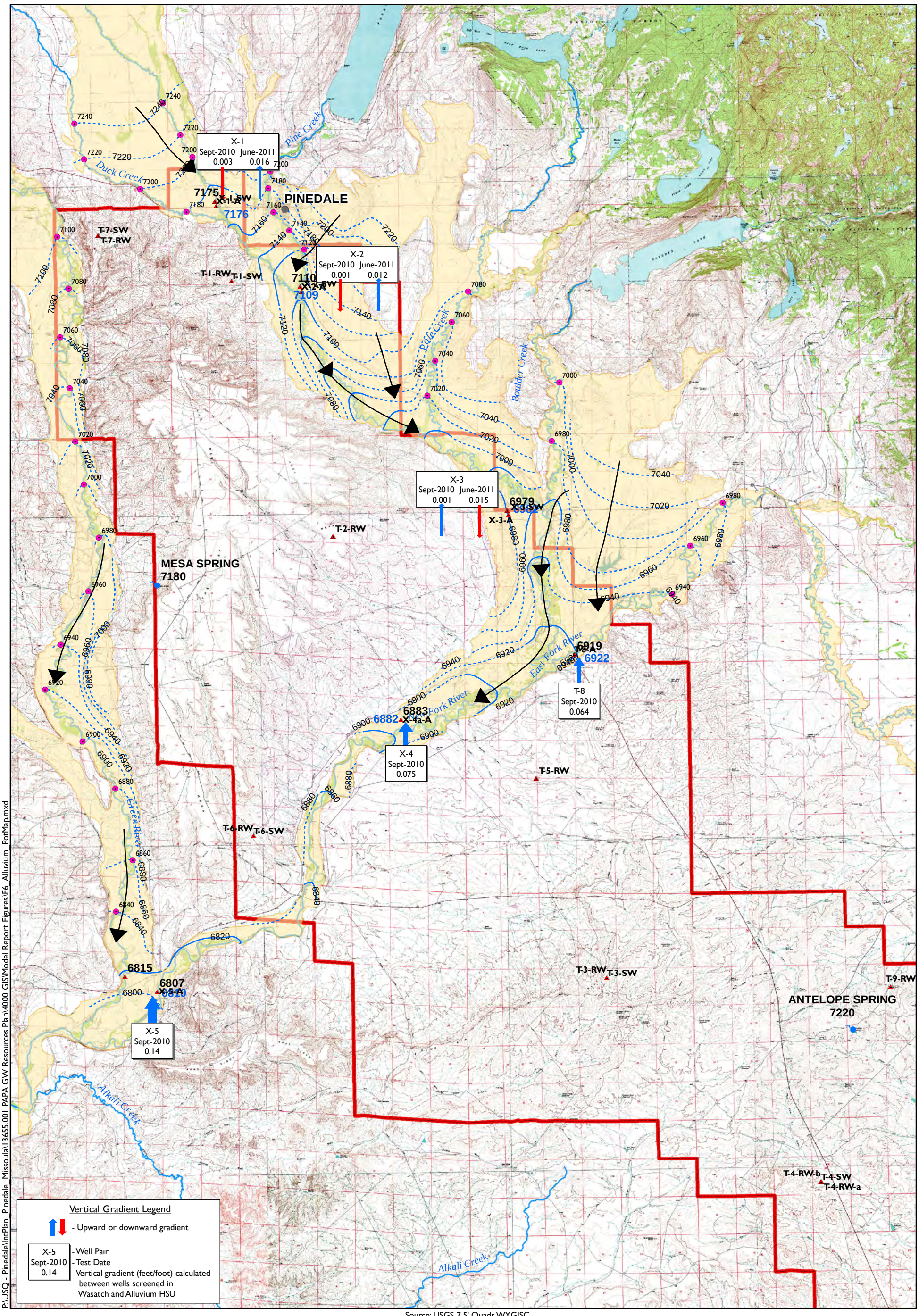
- Inferred
- Normal
- Thrust

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

amec

Bedrock Geology
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 5



Source: USGS 7.5' Quads WYGISC

N

0 Feet 12,000

amec

Alluvial Study Well/Piezometer

7020 Inferred Grounwater Elevation (USGS 7.5' Quads WYGISC)

6958 June 2011 Groundwater Elevation

6958 September 2010 Groundwater Elevation

20 ft Contour (feet above mean sea level, Datum: NAVD88)

Inferred 20 ft Contour

Spring

Generalized Direction of Groundwater Flow

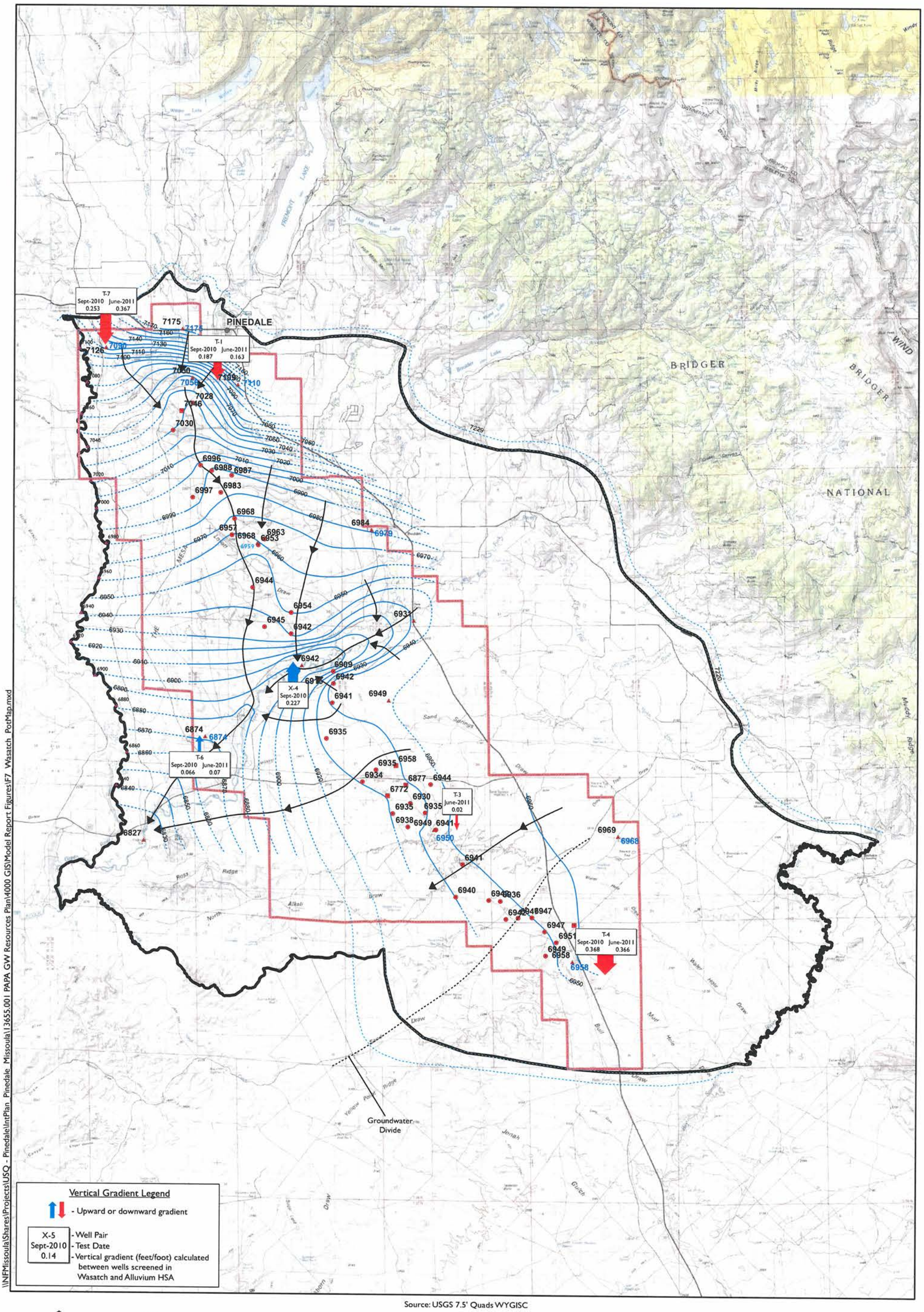
Alluvial Material (Source: WSGS, 2009b)

Pinedale Anticline Project Area (PAPA)

Note: Contours are hand-drawn;
HSU = Hydrostratigraphic Unit;
Water levels for artesian wells X-5-SW, X-4-RW, X-4-SW and T-8-SW were estimated.

Potentiometric Map of the Alluvial HSU September 2010
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 6

P:\USQ - Pinedale\IntPlan_Pinedale_Missoula\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F6_Alluvium_PotMap.mxd



Source: USGS 7.5' Quads WYGISC

N

0 Feet 20,000

amec

6958 June 2011 Groundwater Elevation

6958 September 2010 Groundwater Elevation

Generalized Direction of Groundwater Flow

10 ft Contour (feet above mean sea level, Datum: NAVD88)

Inferred 10 foot Contour

Inferred Contour (Based on USGS topographic map and groundwater elevations from USGS (2011) National Water Information System

7020 Inferred Grounwater Elevation (USGS 7.5' Quads WYGISC)

Pinedale Anticline Project Area (PAPA)

Spring

Study Wells

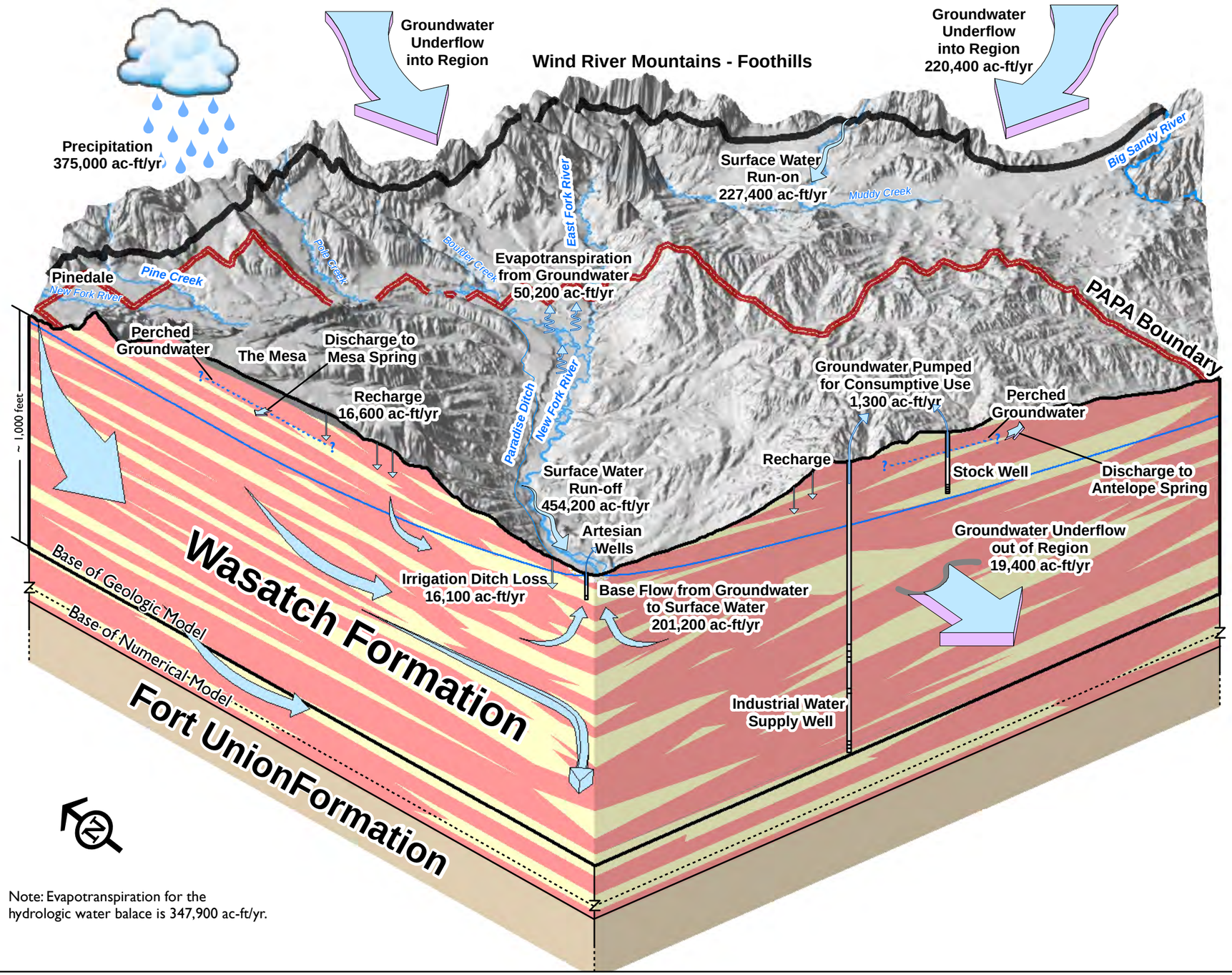
Industrial Supply Wells

Outliers

Note:
Contours are hand-drawn;
HSU = Hydrostratigraphic Unit;
Water levels for artesian wells X-5-SW, X-4-RW, X-4-SW and T-8-SW were estimated.

Potentiometric Map of the Wasatch HSU September 2010
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 7

\\NFMissoula\Shares\Projects\USQ - Pinedale\IntPlan_Pinedale_Missoula\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F7_Wasatch_PotMap.mxd

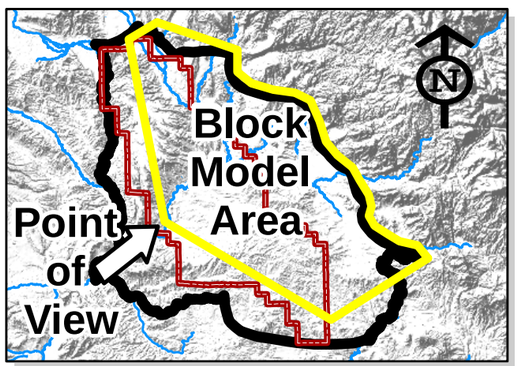


Note: Evapotranspiration for the hydrologic water balace is 347,900 ac-ft/yr.

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)



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F8 Block Model.mxd

Note: Horizontal not to scale; Vertical Exaggeration 70X.

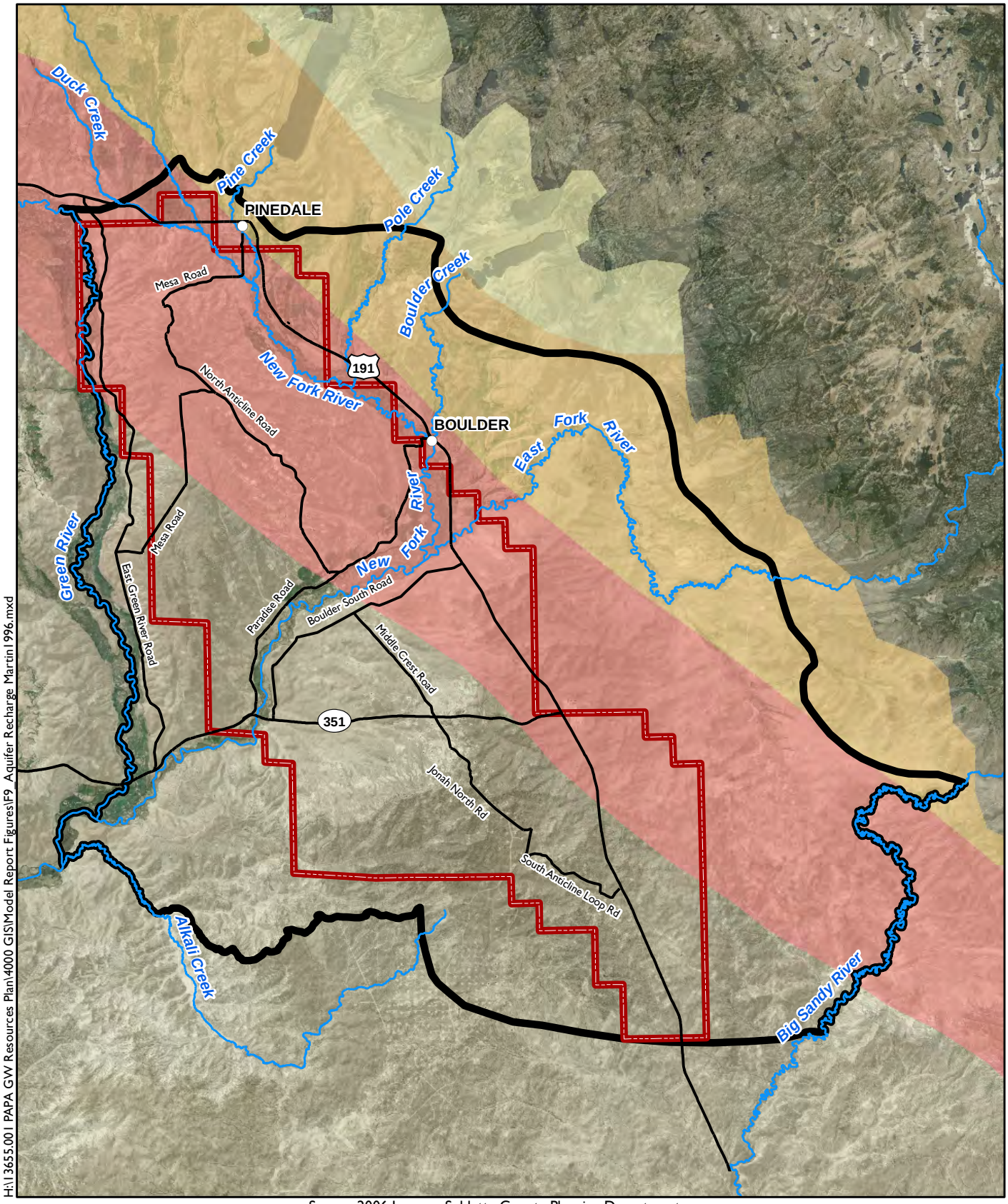
amec

Note: Calculation of the water balance is documented in Section 2.5 and Appendix B. ac-ft/yr = acre-feet/year.

General Water Balance Component
Surface Water Flow Component
Groundwater Flow Component
Approximate Potentiometric Surface in Wasatch Formation
Pinedale Anticline Project Area (PAPA)
Numerical Model Boundary
Well with Screened Sections

Lithology
Alluvium
Gravel
Sandstone
Shale/Siltstone

Conceptual Block Model and Water Balance
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 8



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F9 Aquifer Recharge Martin1996.mxd

Source: 2006 Imagery Sublette County Planning Department

N

0 Miles 5

amec

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

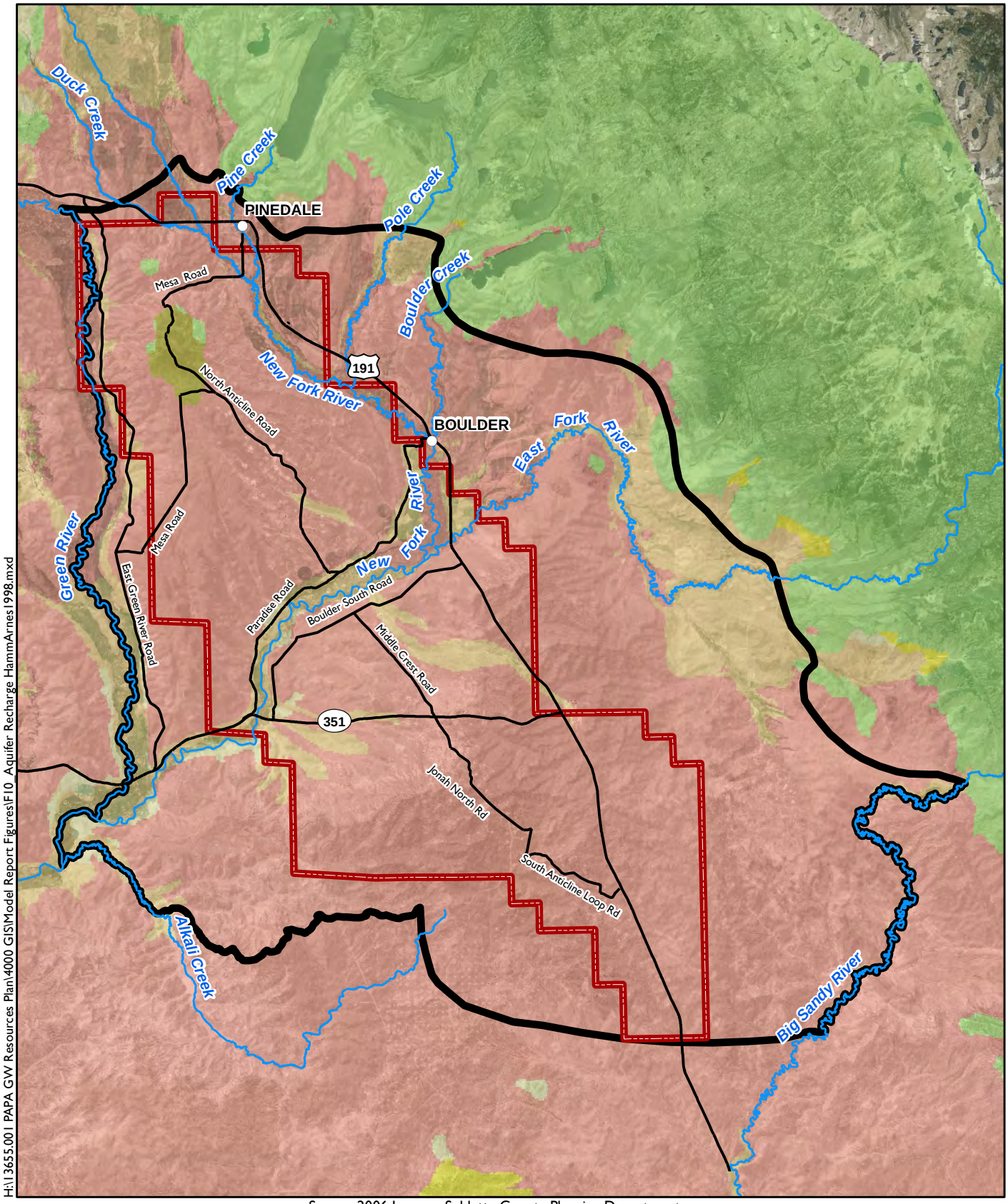
Aquifer Recharge (Martin 1996)

0.25 inches/year

0.75 inches/year

1.25 inches/year

Aquifer Recharge
from Martin (1996)
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 9



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F10_Aquifer Recharge HammArnes1998.mxd

Source: 2006 Imagery Sublette County Planning Department

N

0 Miles 5

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

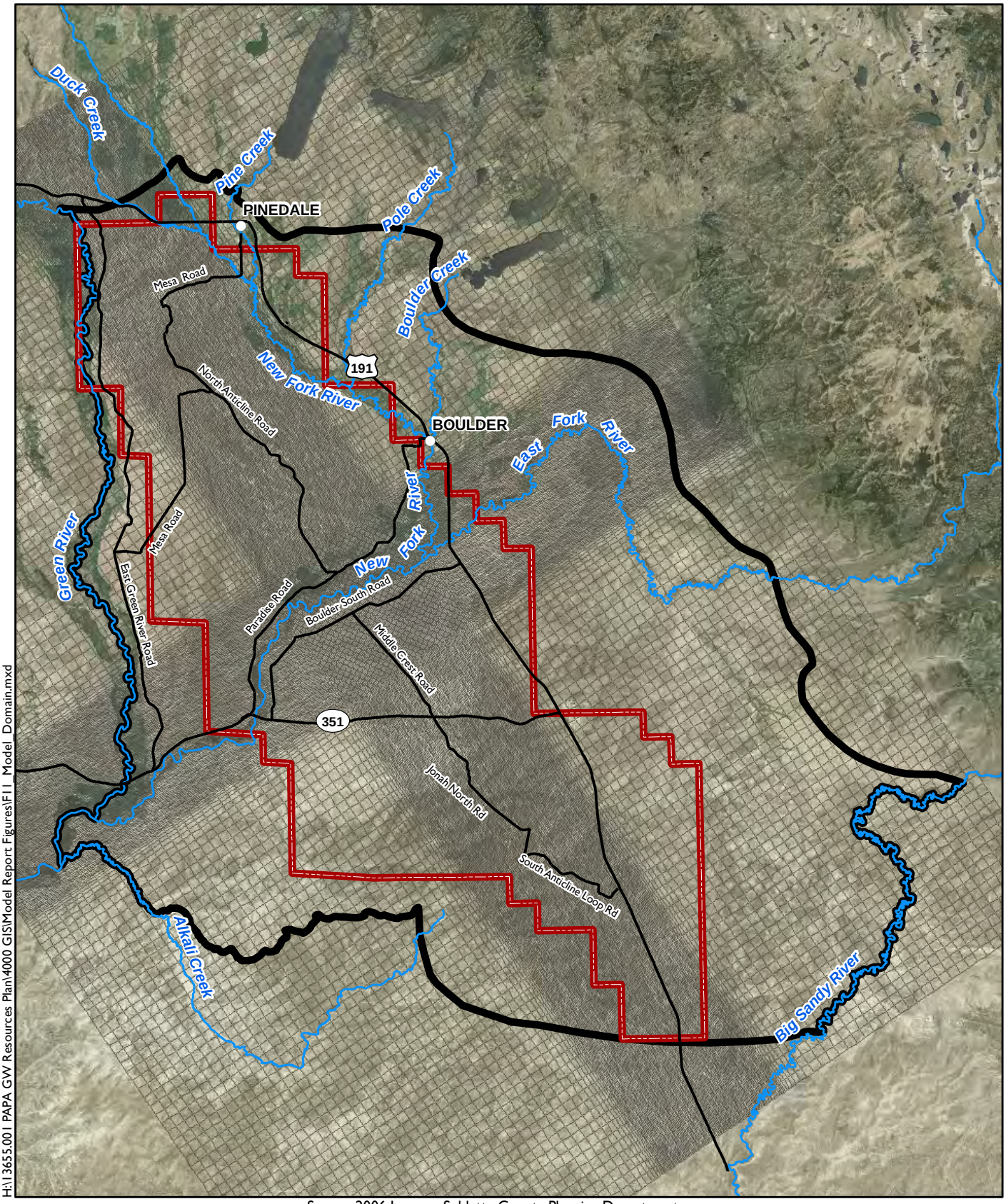
Aquifer Recharge (Hammerlick and Arneson1998) (inches/year)

0	0.51 - 1	2.1 - 2.5
0.01	1.1 - 1.5	2.6 - 3
0.011 - 0.5	1.6 - 2	3.1 - 3.5

amec

Aquifer Recharge from Hammerlick and Arneson (1998) PAPA Numerical Groundwater Model Pinedale Anticline Project Area Sublette County, Wyoming

FIGURE 10



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F11_Model_Domain.mxd

Source: 2006 Imagery Sublette County Planning Department

N

0 Miles 5

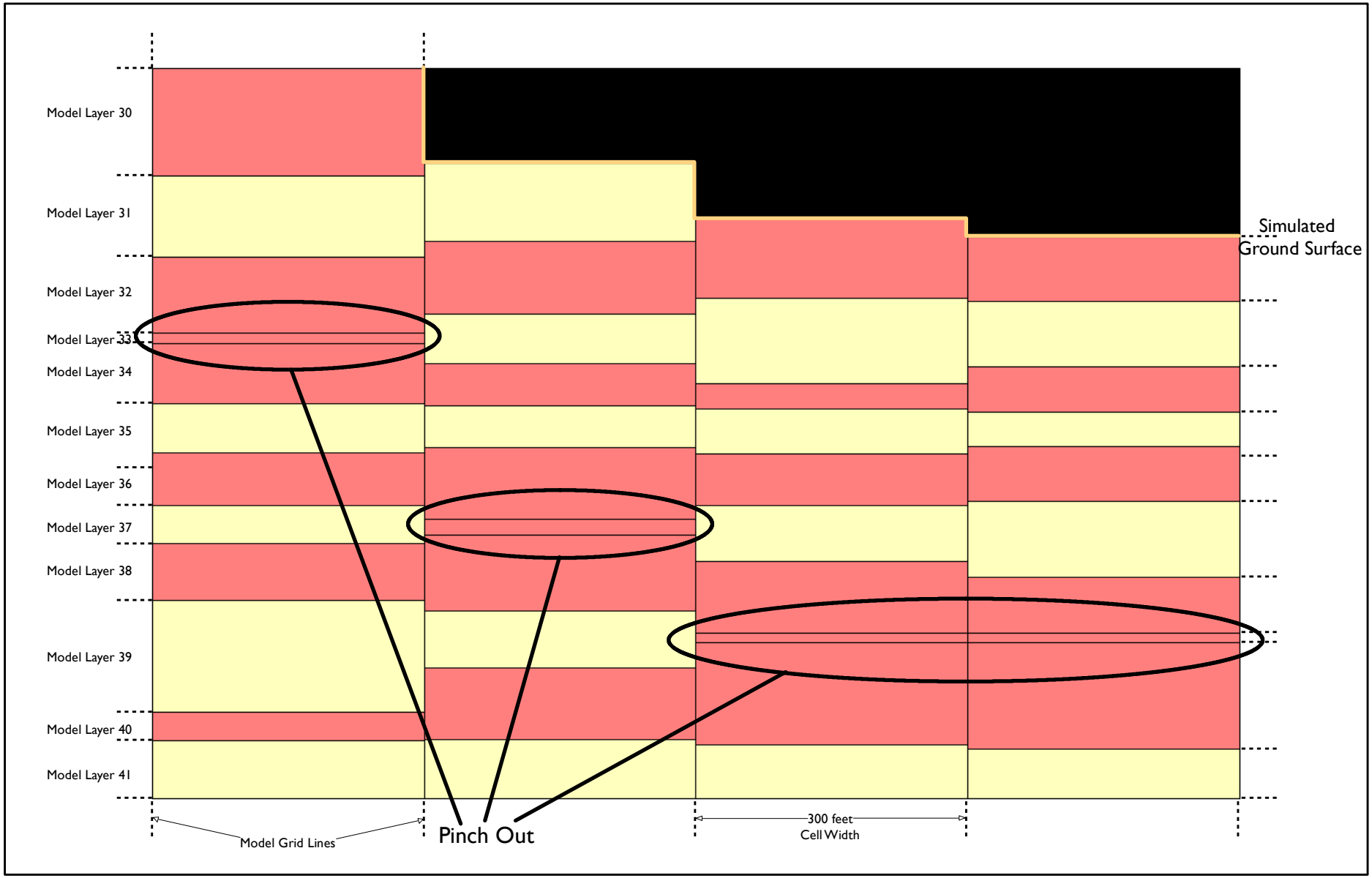
Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

Model Grid

amec

Model Domain and Grid
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 11



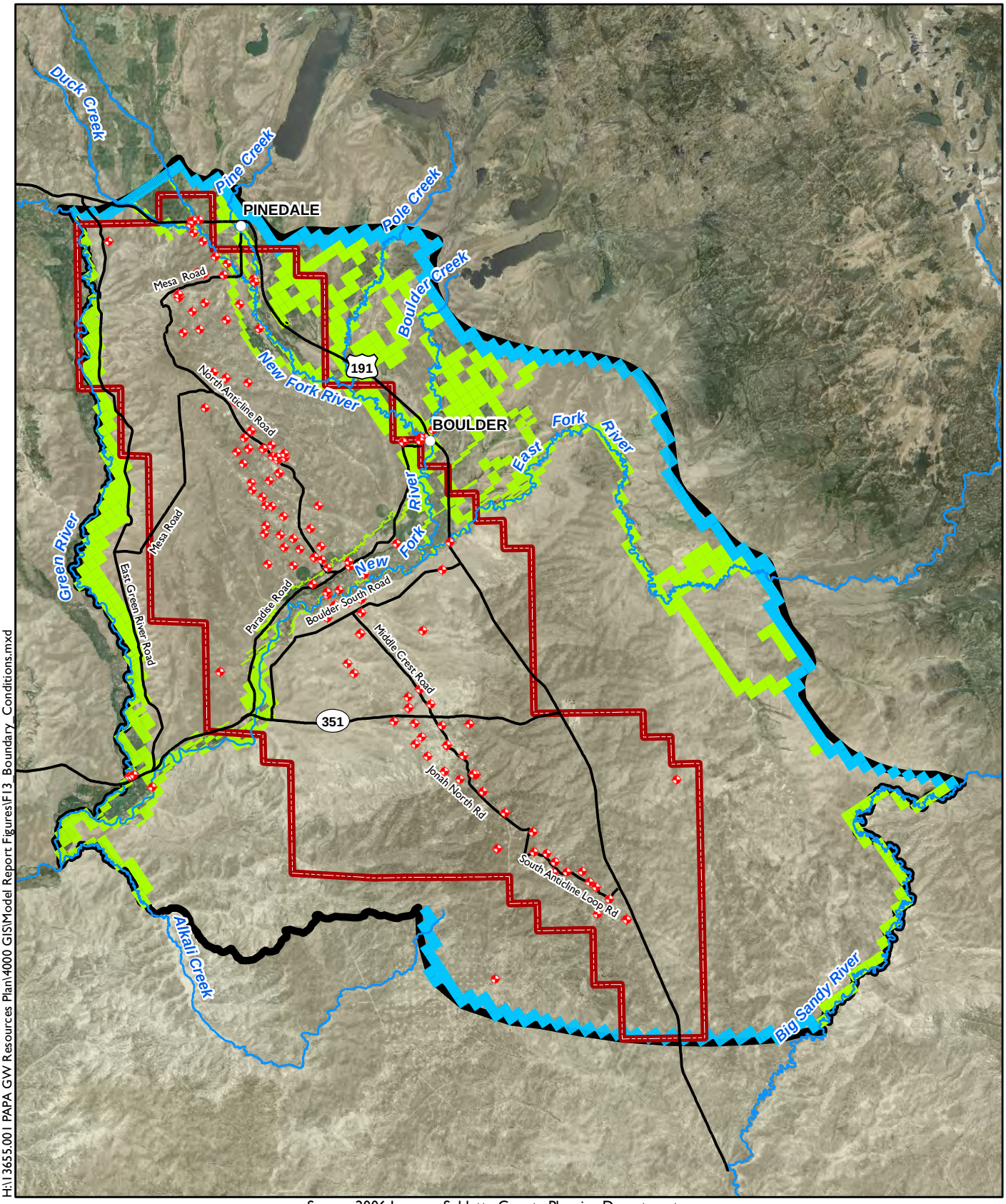
Not To Scale

Note: Pinch outs occur where model layer thickness is less than 0.5 feet.

Lithology/Boundary Condition

- No Flow
- Sandstone
- Shale/Siltstone

Conceptual Model Pinch Out
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 12



Source: 2006 Imagery Sublette County Planning Department

H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F13_Boundary_Conditions.mxd

N

0 Miles 5

Pumping Well (Industrial Water Supply Well)

General Head Boundary

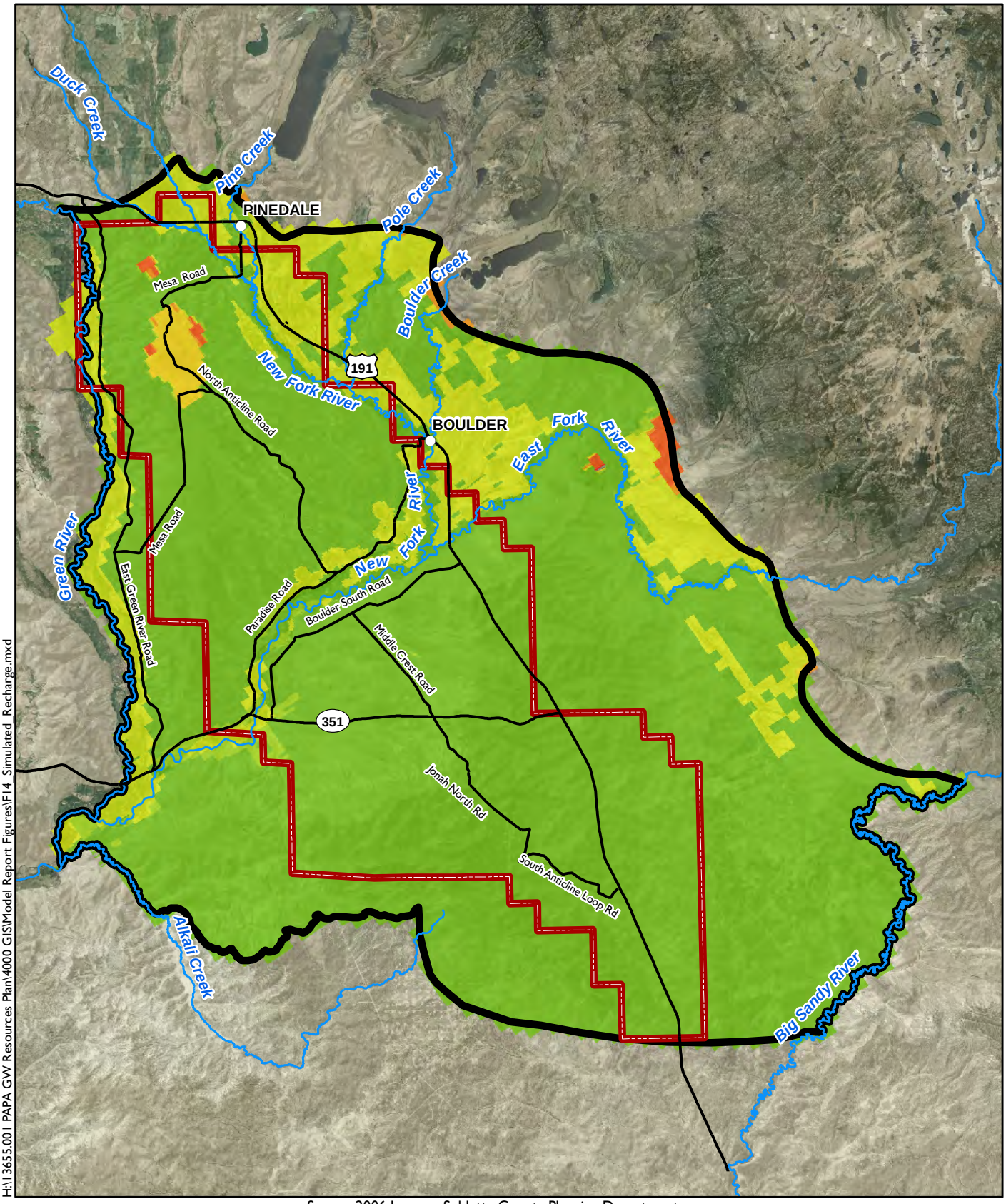
River Package Boundary

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

amec

Model Boundary Conditions
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 13



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F14 Simulated Recharge.mxd

Source: 2006 Imagery Sublette County Planning Department

N

0 Miles 5

amec

Pinedale Anticline Project Area (PAPA)

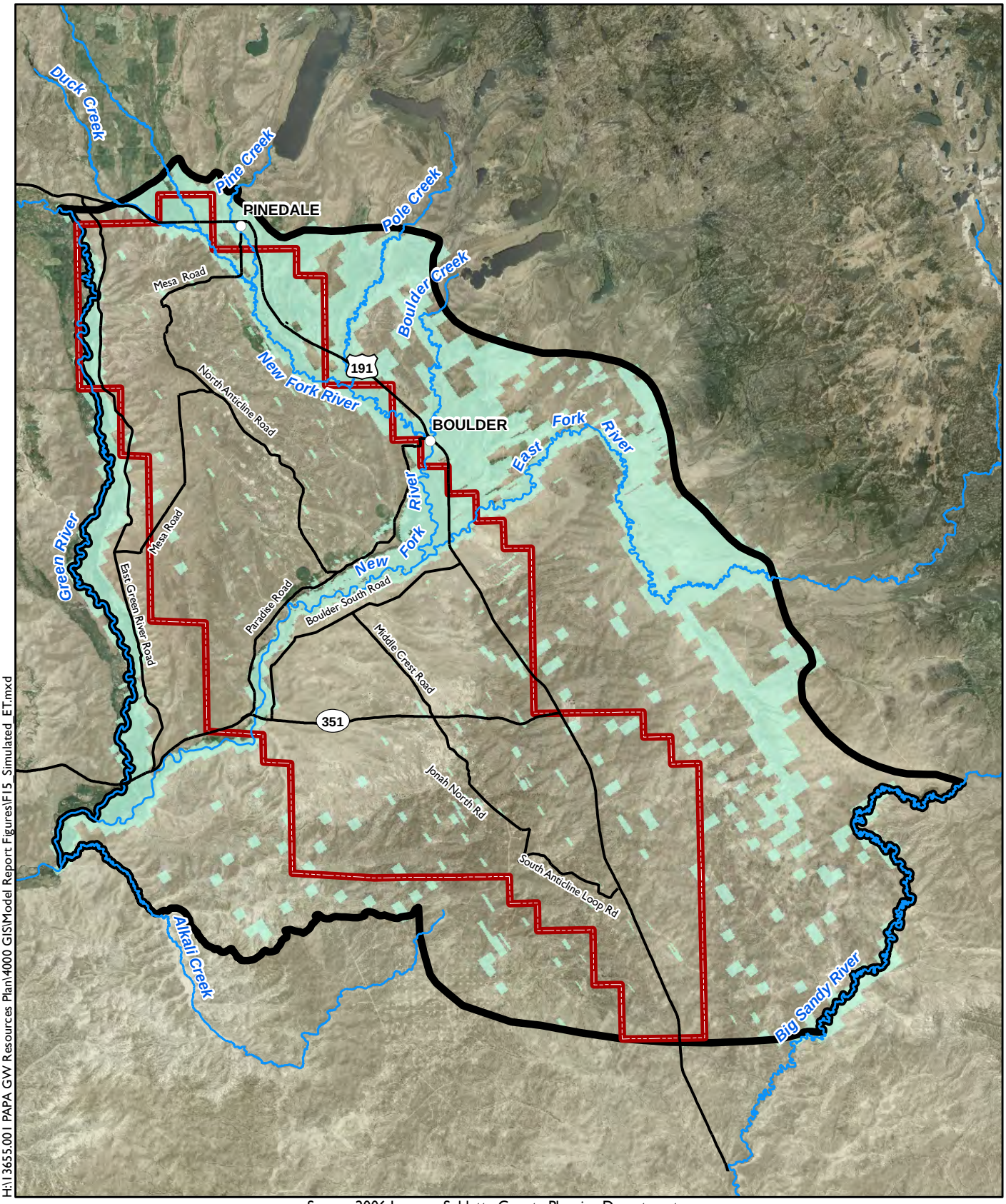
Numerical Model Boundary

Note: Areas around the New Fork and Green rivers include recharge from irrigation.

Recharge (inches/year)

- 0.09 - 0.8
- 0.8 - 1.6
- 1.6 - 2.4
- 2.4 - 3.2
- 3.2 - 4.0
- 4.0- 4.8
- 4.8 - 5.6

Simulated Recharge
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 14



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F15_Simulated_ET.mxd

Source: 2006 Imagery Sublette County Planning Department

N

0 Miles 5

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

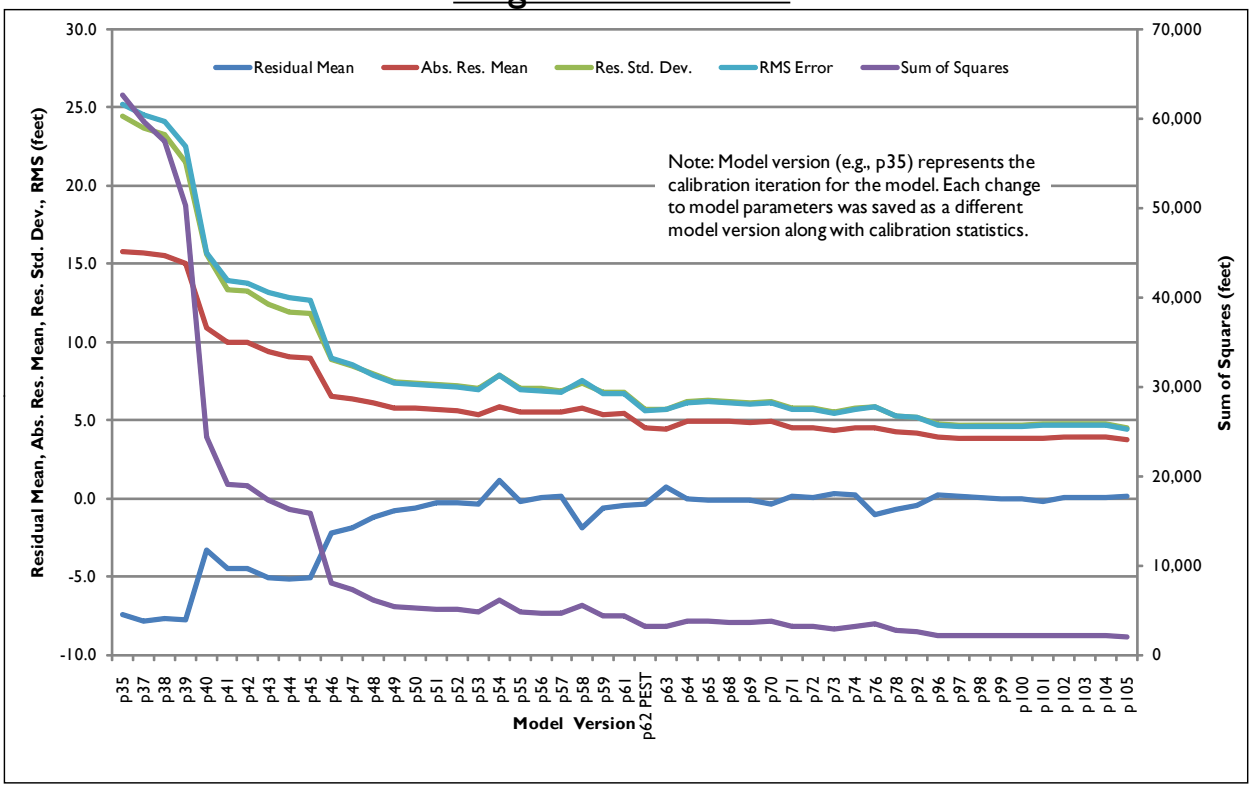
PET Rate (inches/year)

17.5

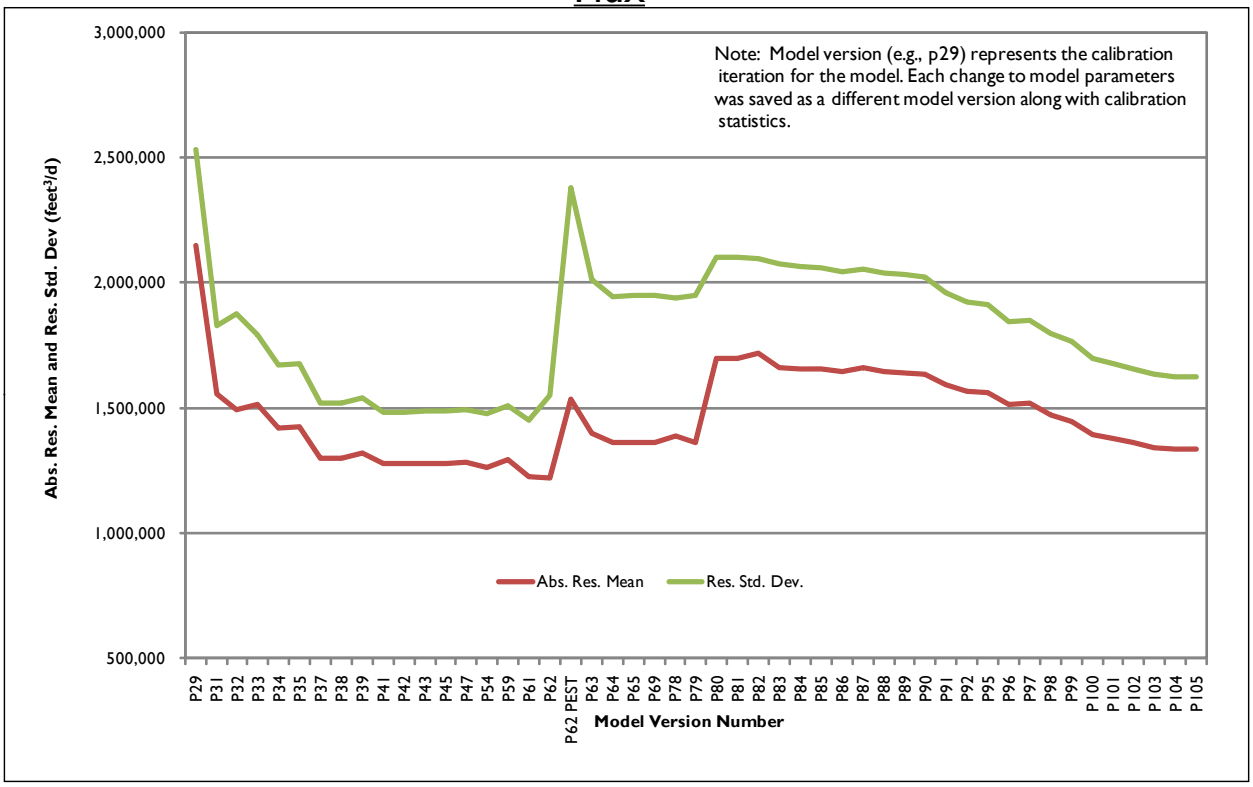
amec

Areas of Potential Evapotranspiration
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 15

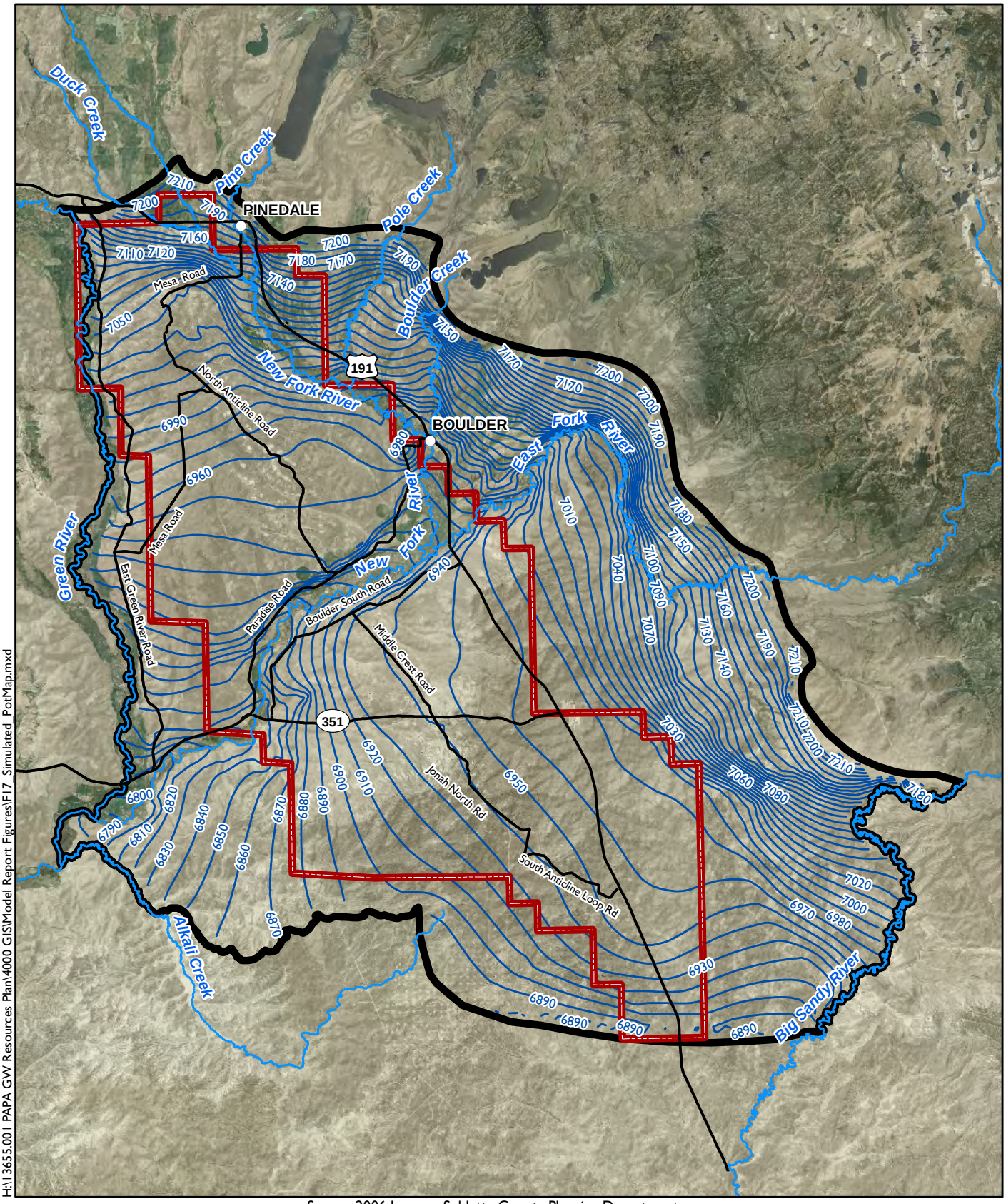
Target Head Values



Flux



Calibration Statistics Based on Target Head Values and Flux During the Calibration Process
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 16



Source: 2006 Imagery Sublette County Planning Department

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

Simulated Potentiometric Contour (feet amsl)

NOTES:
Potentiomentric contours from layer 40 of the model;
Contour interval 10 feet.

N

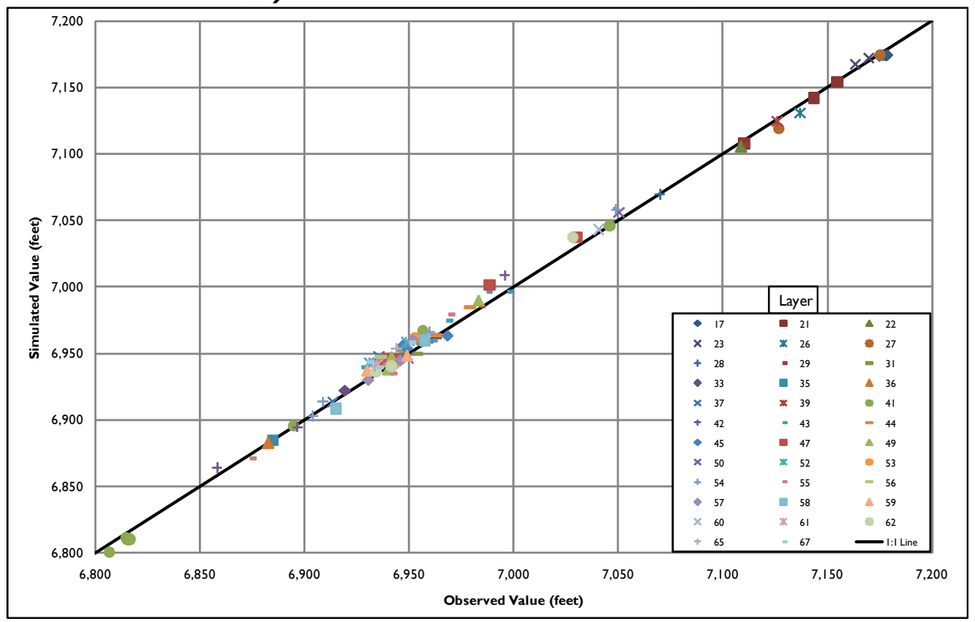
0 Miles 5

amec

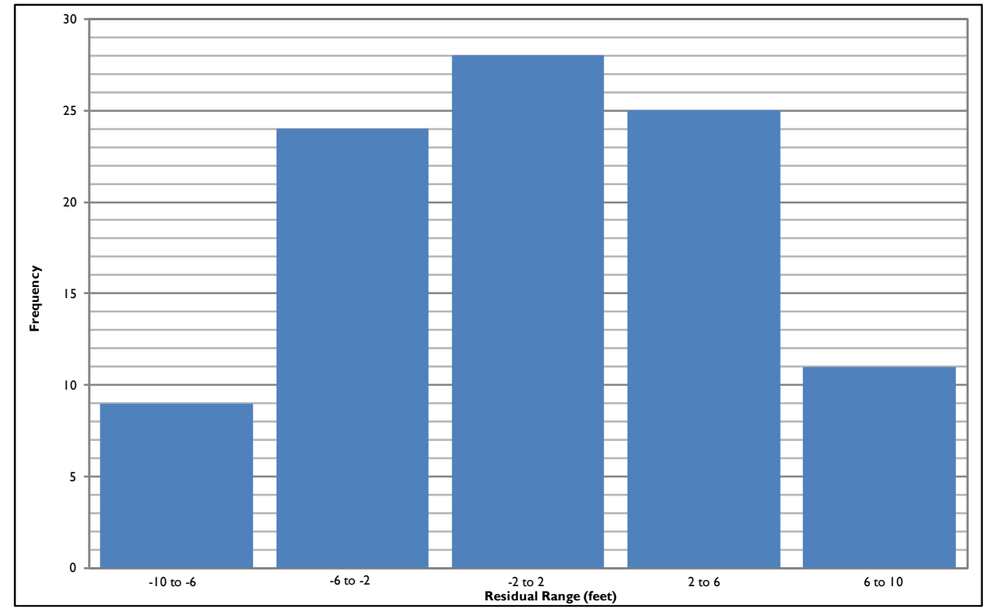
Simulated Potentiometric Surface
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 17

H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F17_Simulated_PotMap.mxd

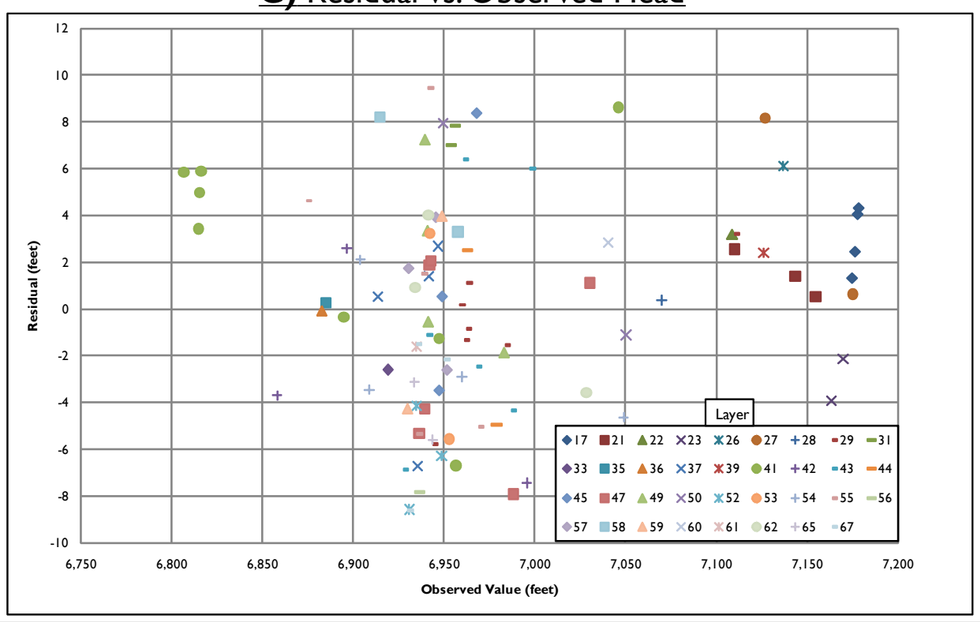
A) Observed vs. Simulated Head



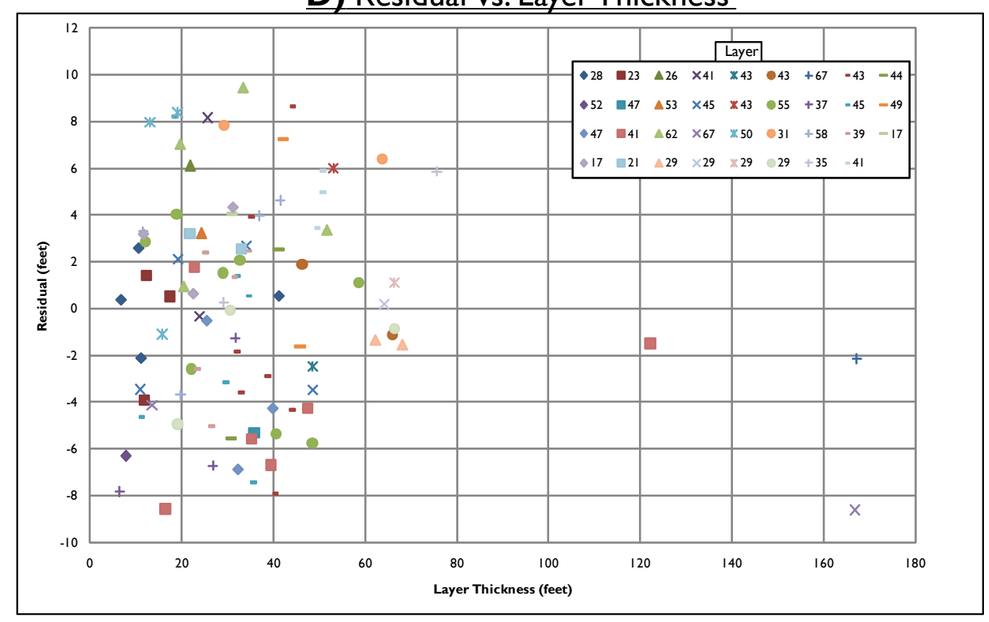
B) Statistical Distribution of Residuals



C) Residual vs. Observed Head

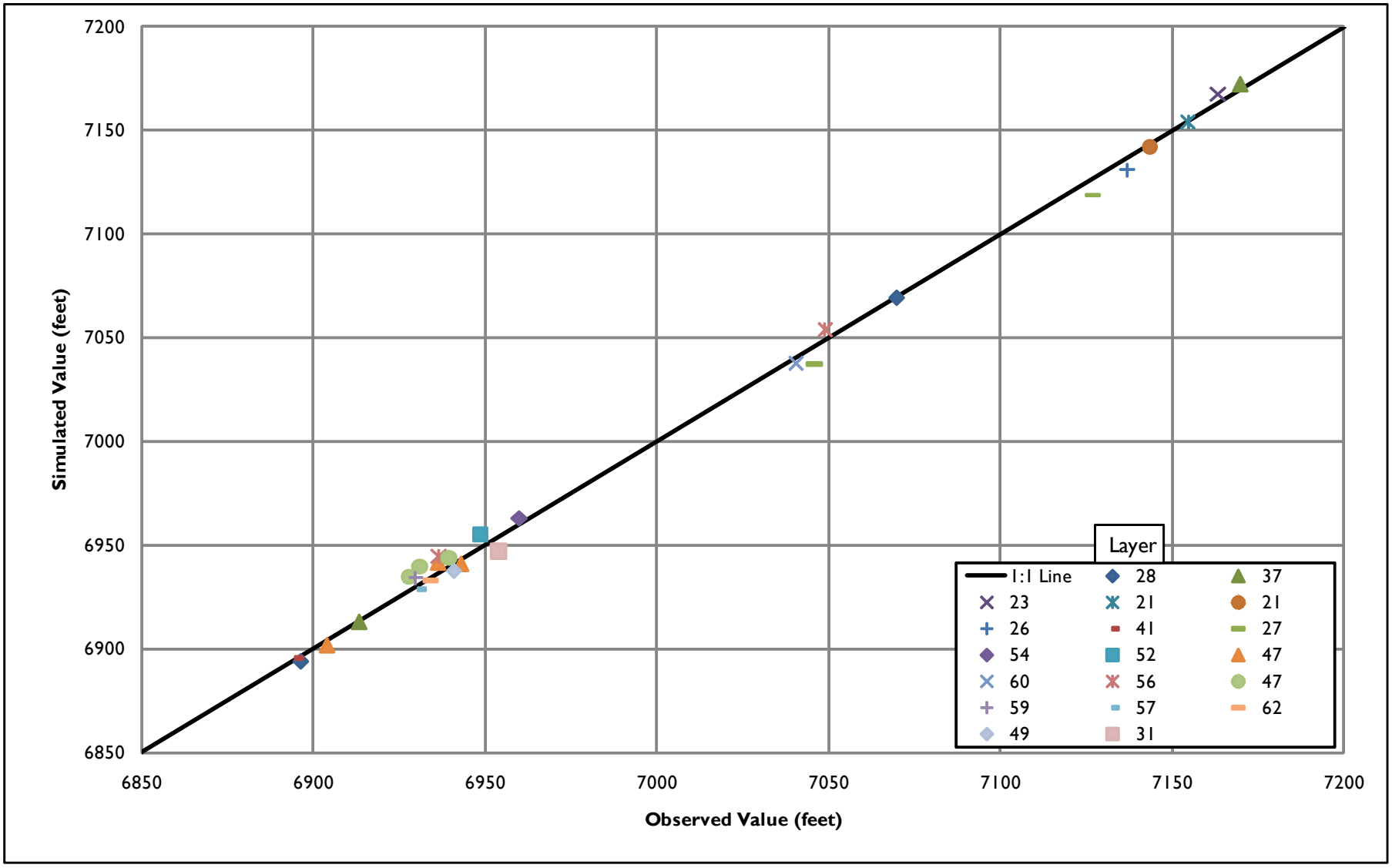


D) Residual vs. Layer Thickness



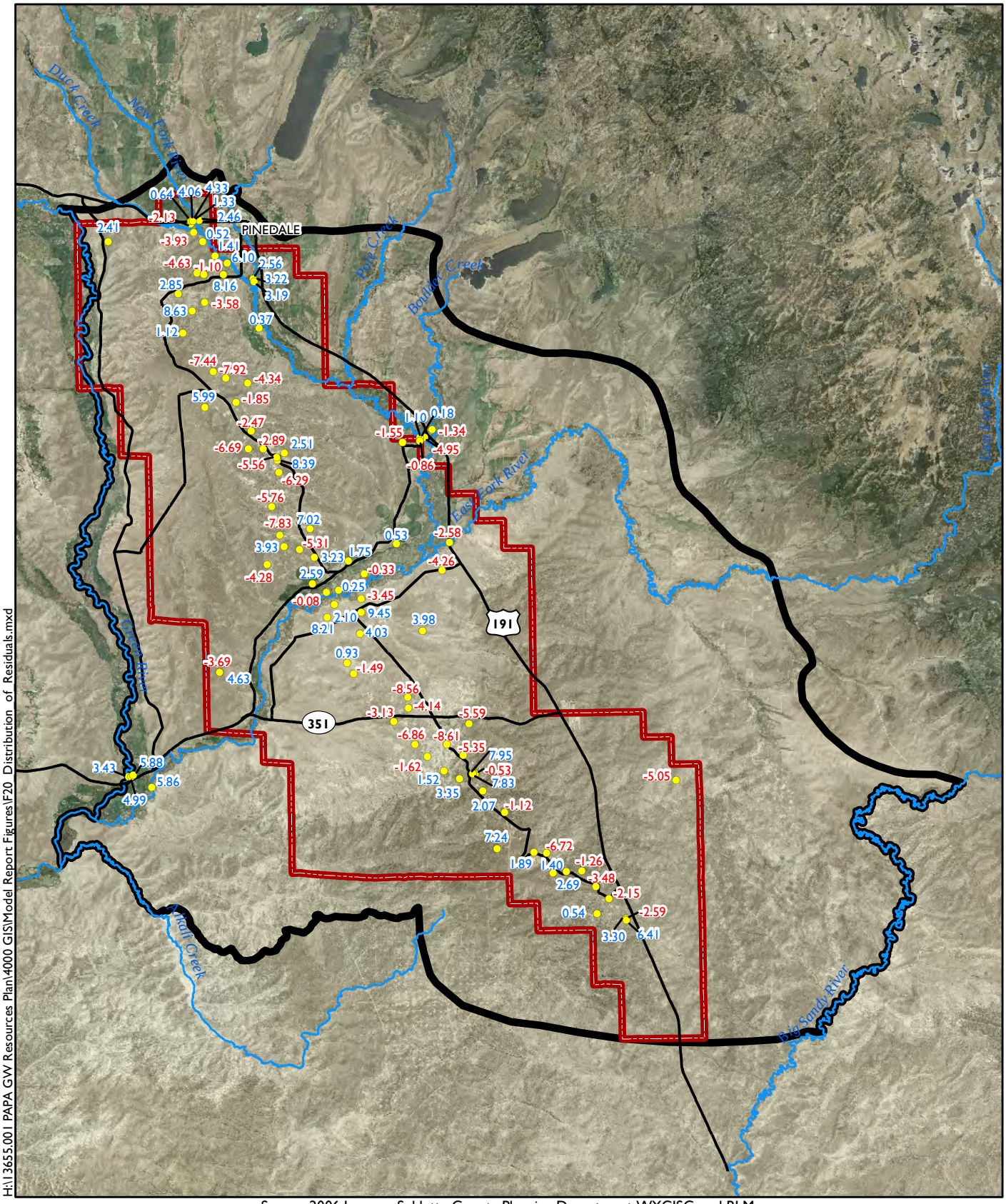
Statistical Distribution and
Relationships of Model Calibration
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 18

amec



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F19_2009_Obs_v_Sim.mxd

2009 Observed vs. Simulated Head
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 19



H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F20 Distribution of Residuals.mxd

Source: 2006 Imagery Sublette County Planning Department, WYGISC, and BLM.

N

0 Miles 5

Groundwater Elevation Target

3.30 Positive Residual (feet under predicted)

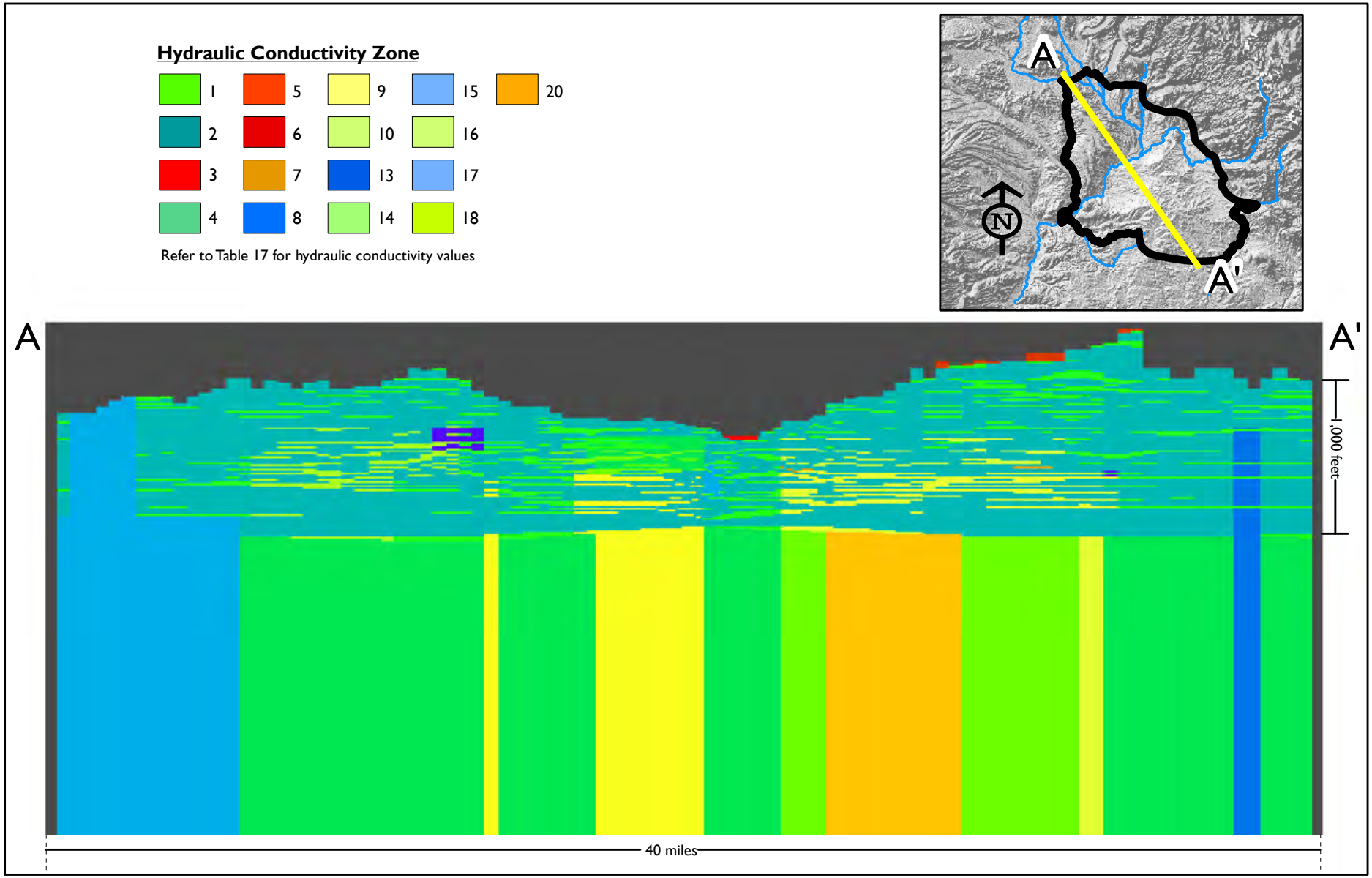
-2.59 Negetive Residual (feet over predicted)

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

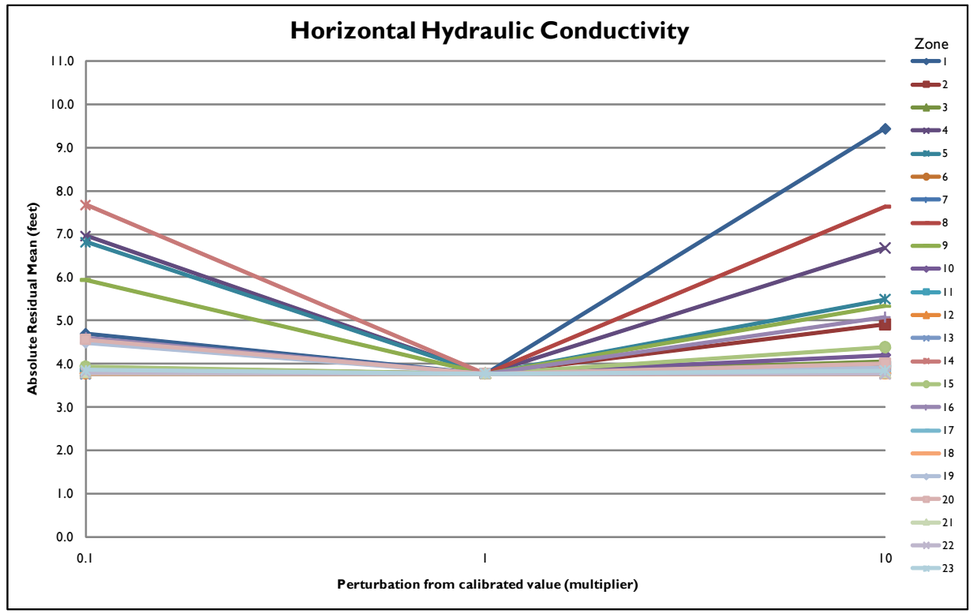
amec

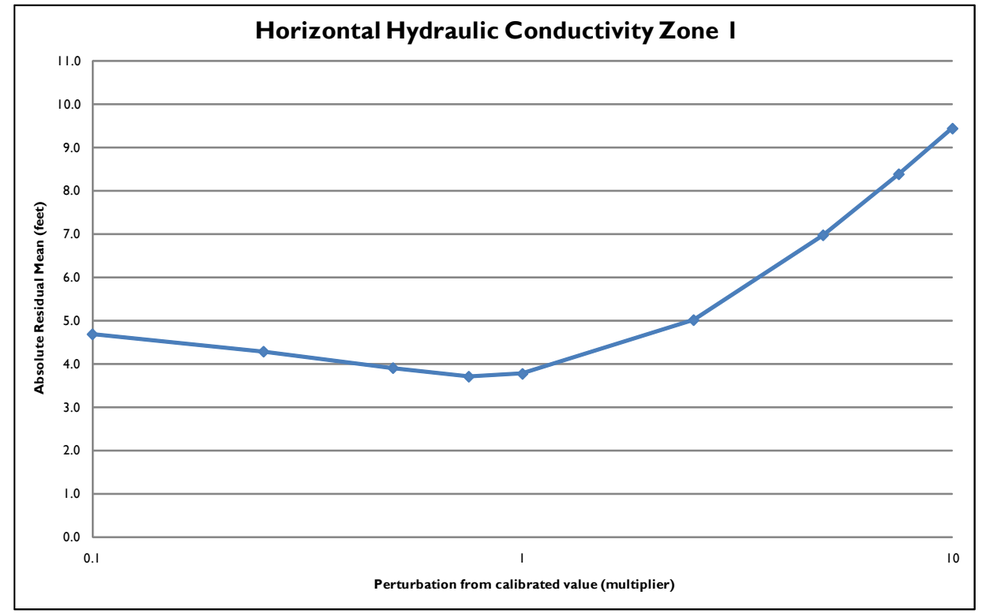
Spatial Distribution of Residuals
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 20

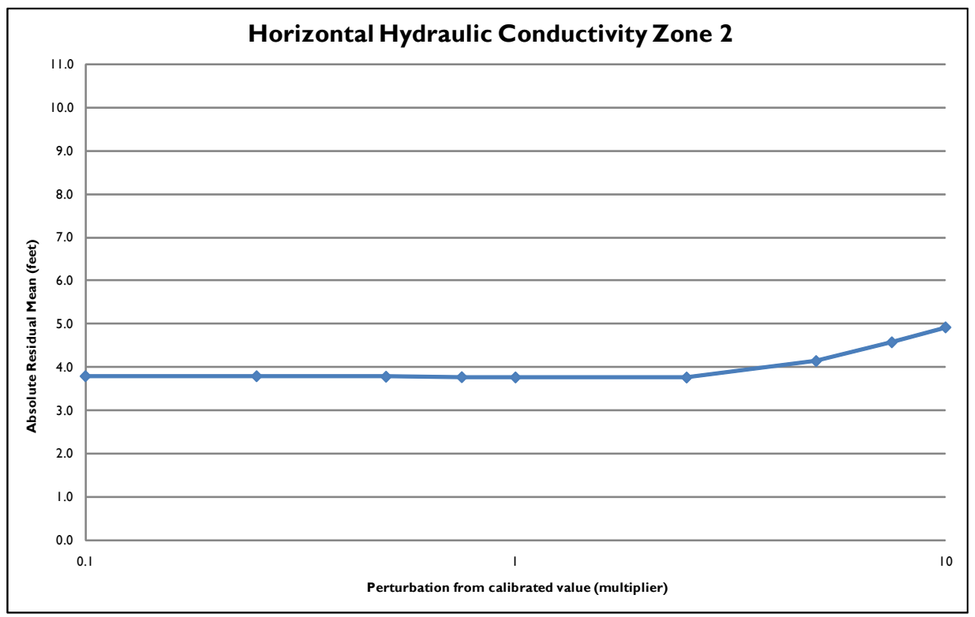


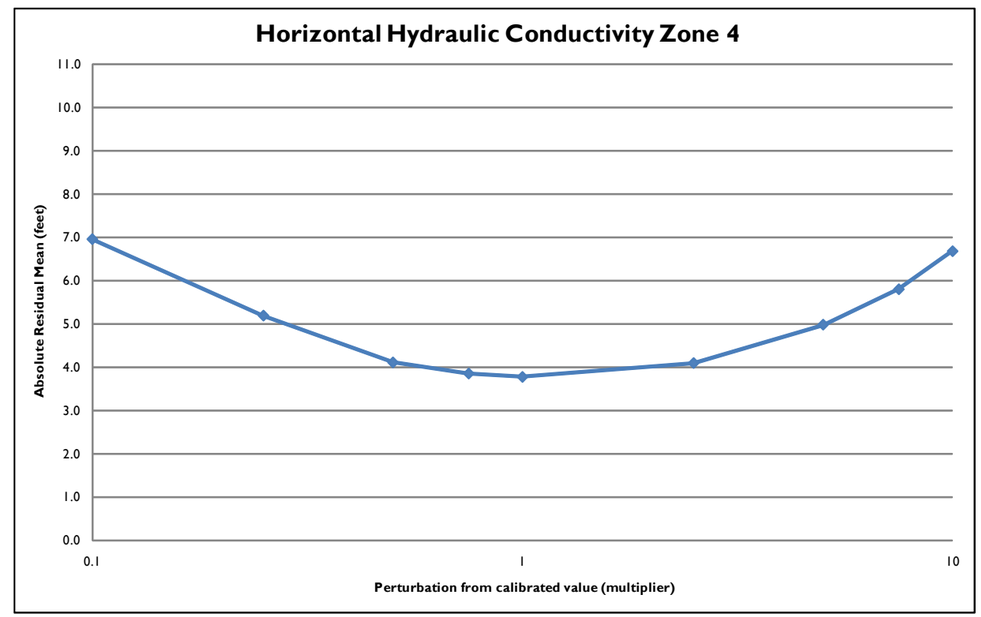
Note: Cross-Section is from
Column 84 of the numerical model.

Cross-Section of Calibrated
Hydraulic Conductivity Zones
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 21

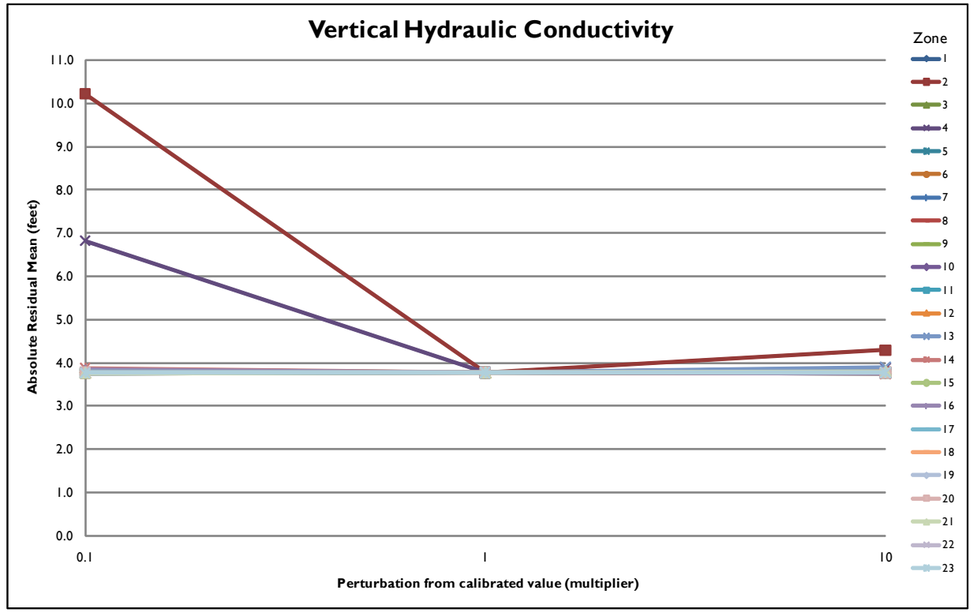


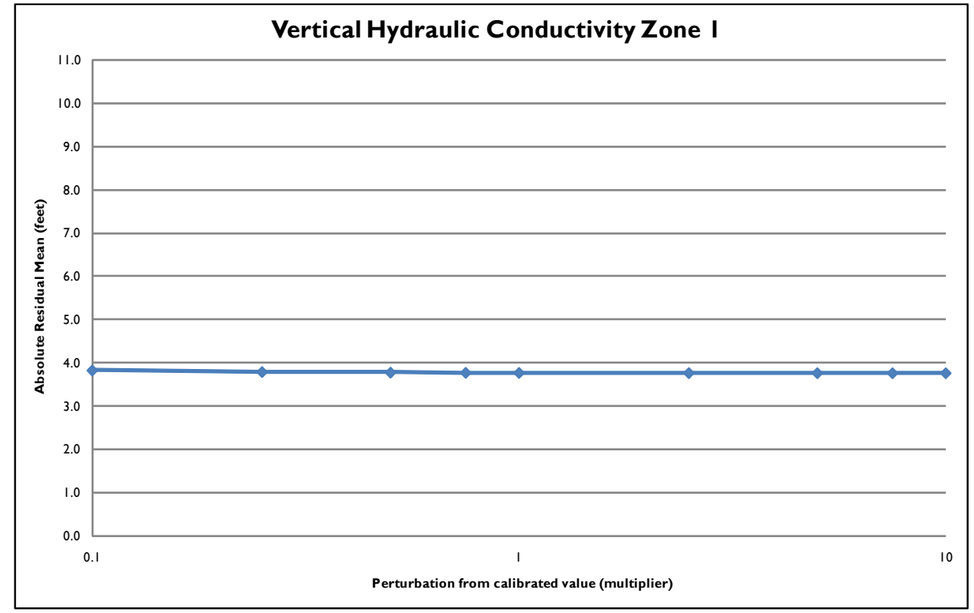


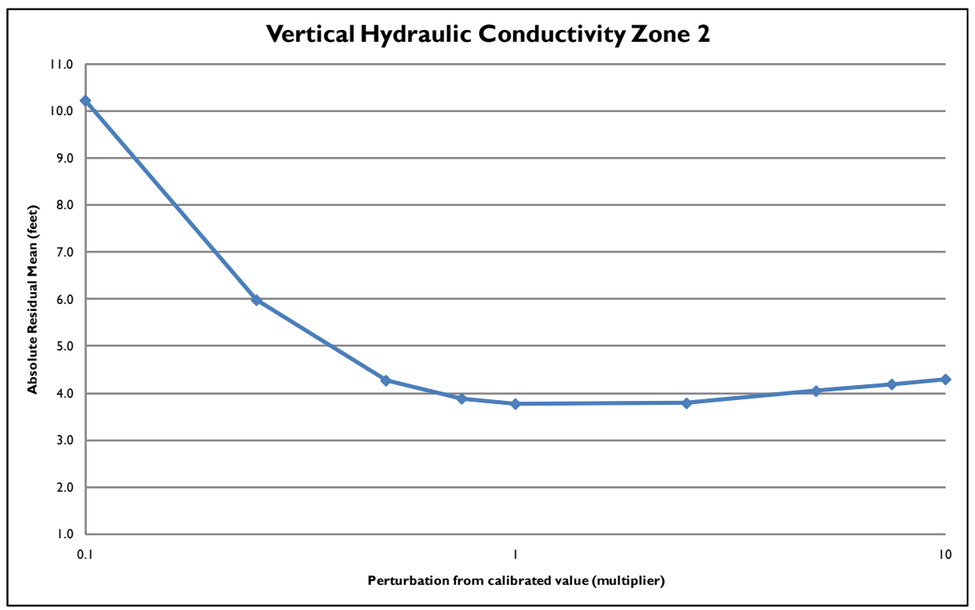


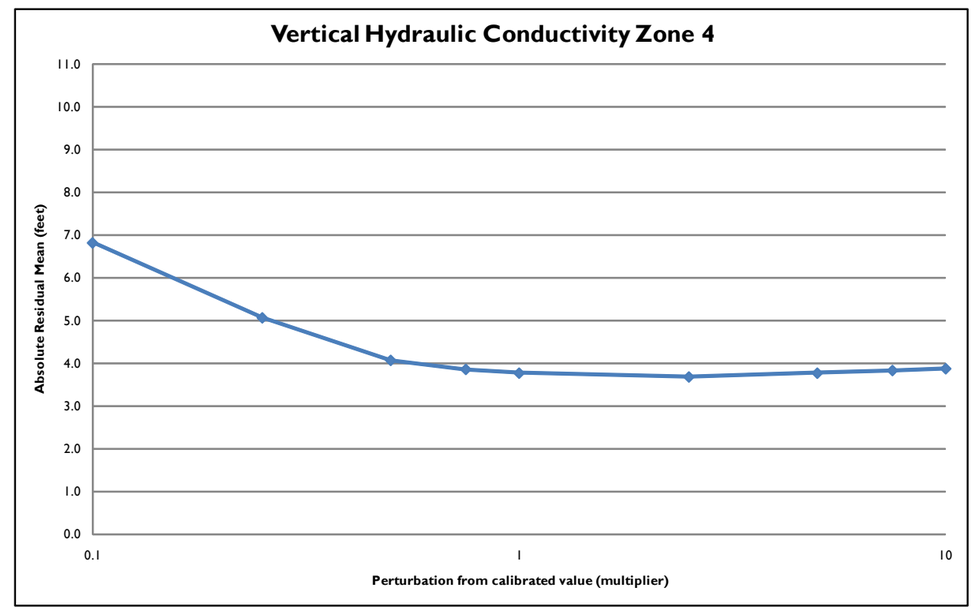


Horizontal Hydraulic Conductivity
Sensitivity Analysis
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 22

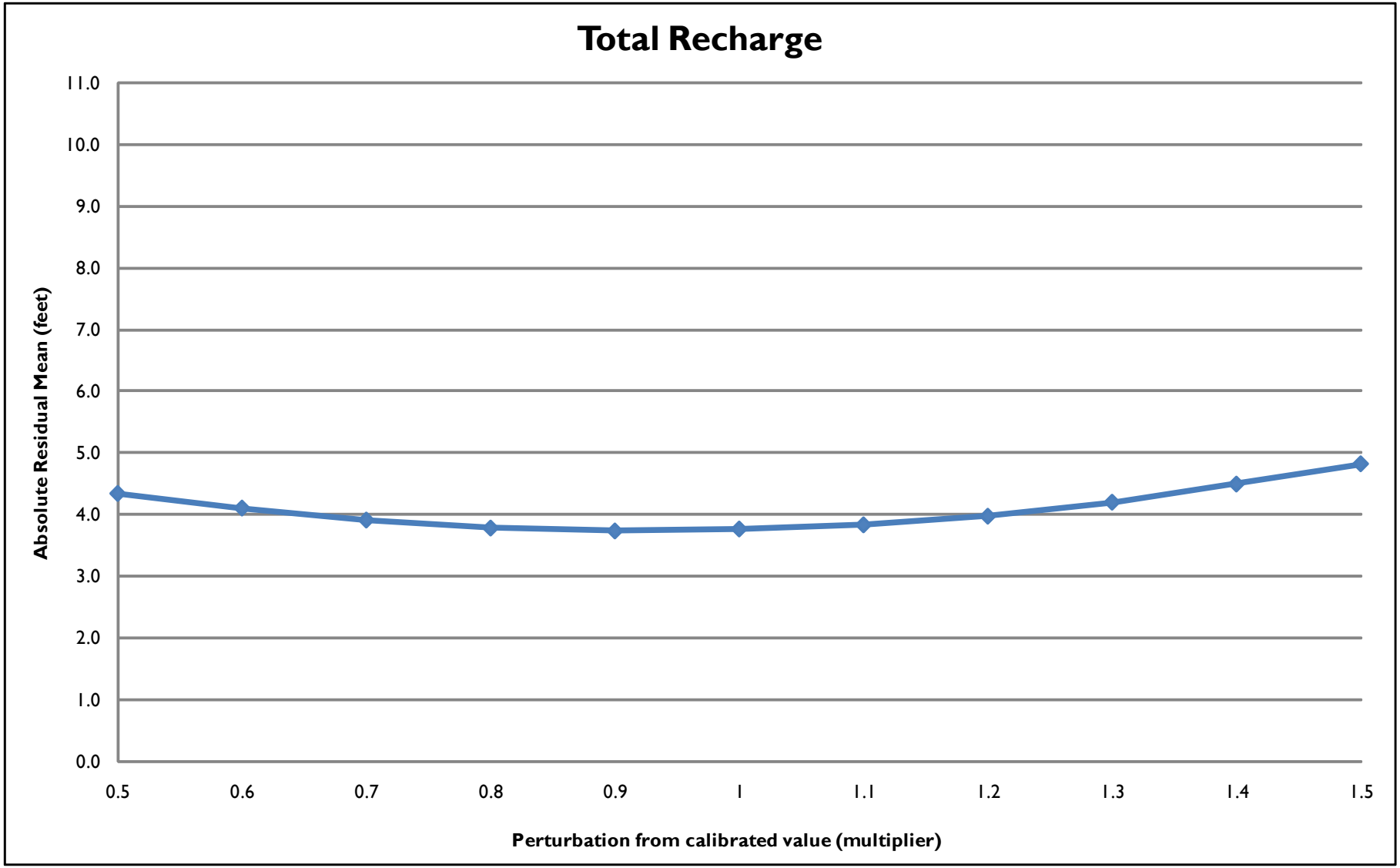








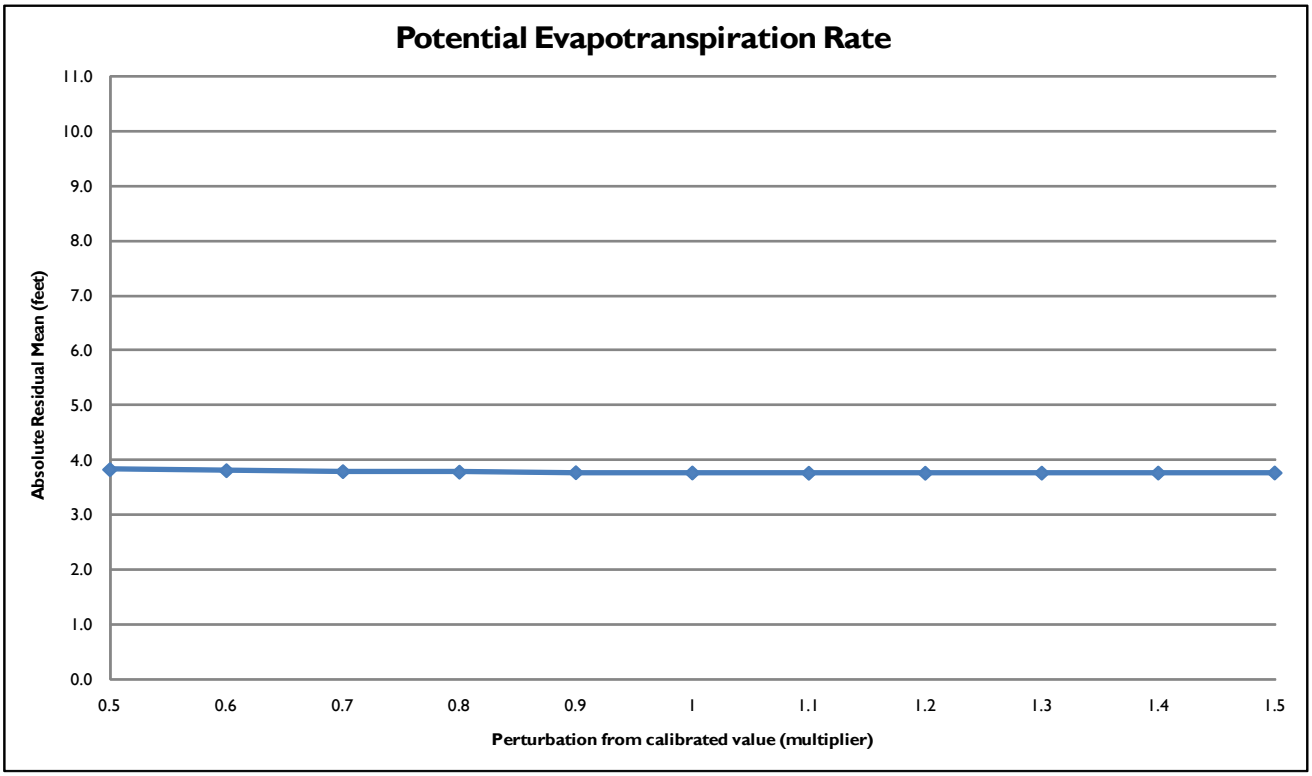
Vertical Hydraulic Conductivity
Sensitivity Analysis
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 23

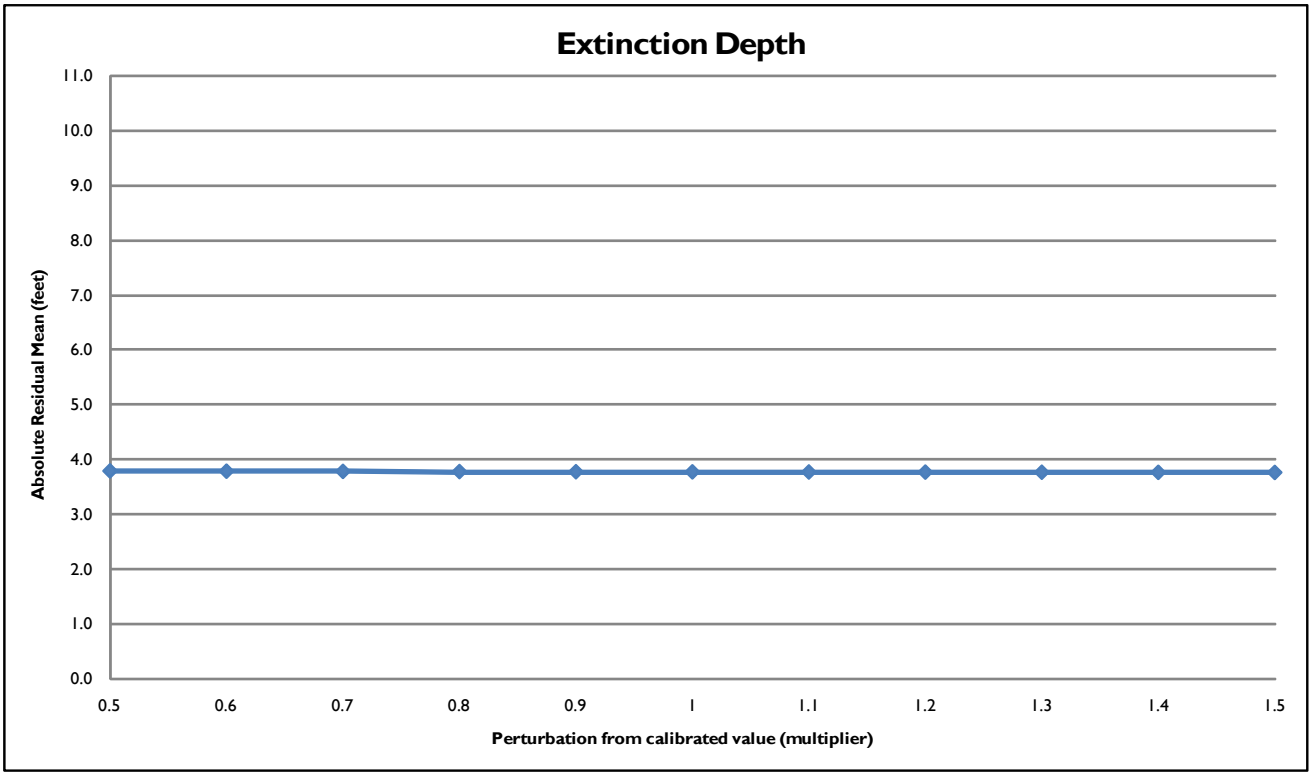


H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F24 Sensitivity Analysis RCH.mxd

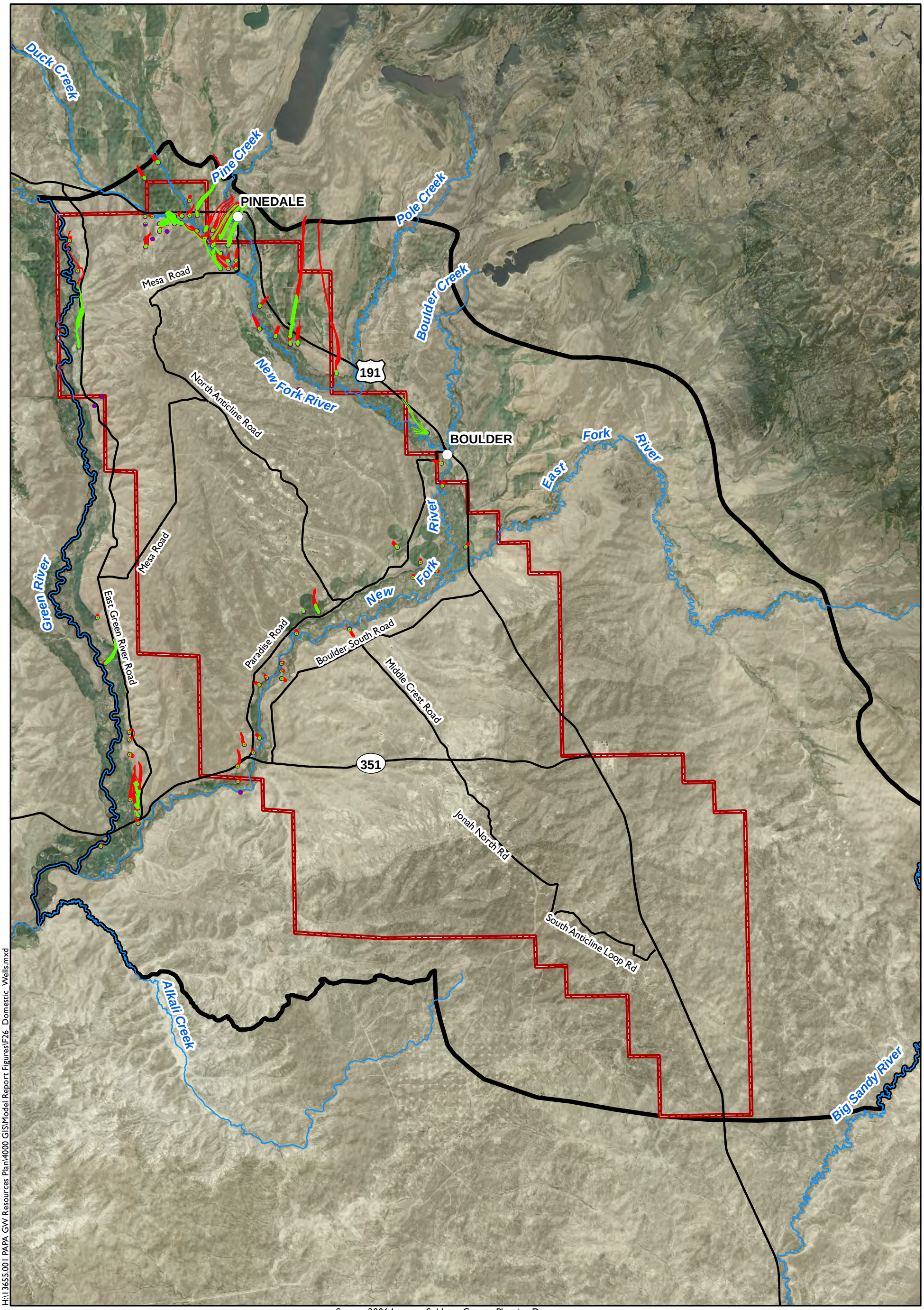
Absolute Residual Mean for Total
Recharge Sensitivity Analysis
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 24

amec





Potential Evapotranspiration Rate and
Extinction Depth Sensitivity Analysis
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 25



Source: 2006 Imagery Sublette County Planning Department

H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F26 Domestic Wells.mxd

N

0 Miles 3

amec

Domestic Well

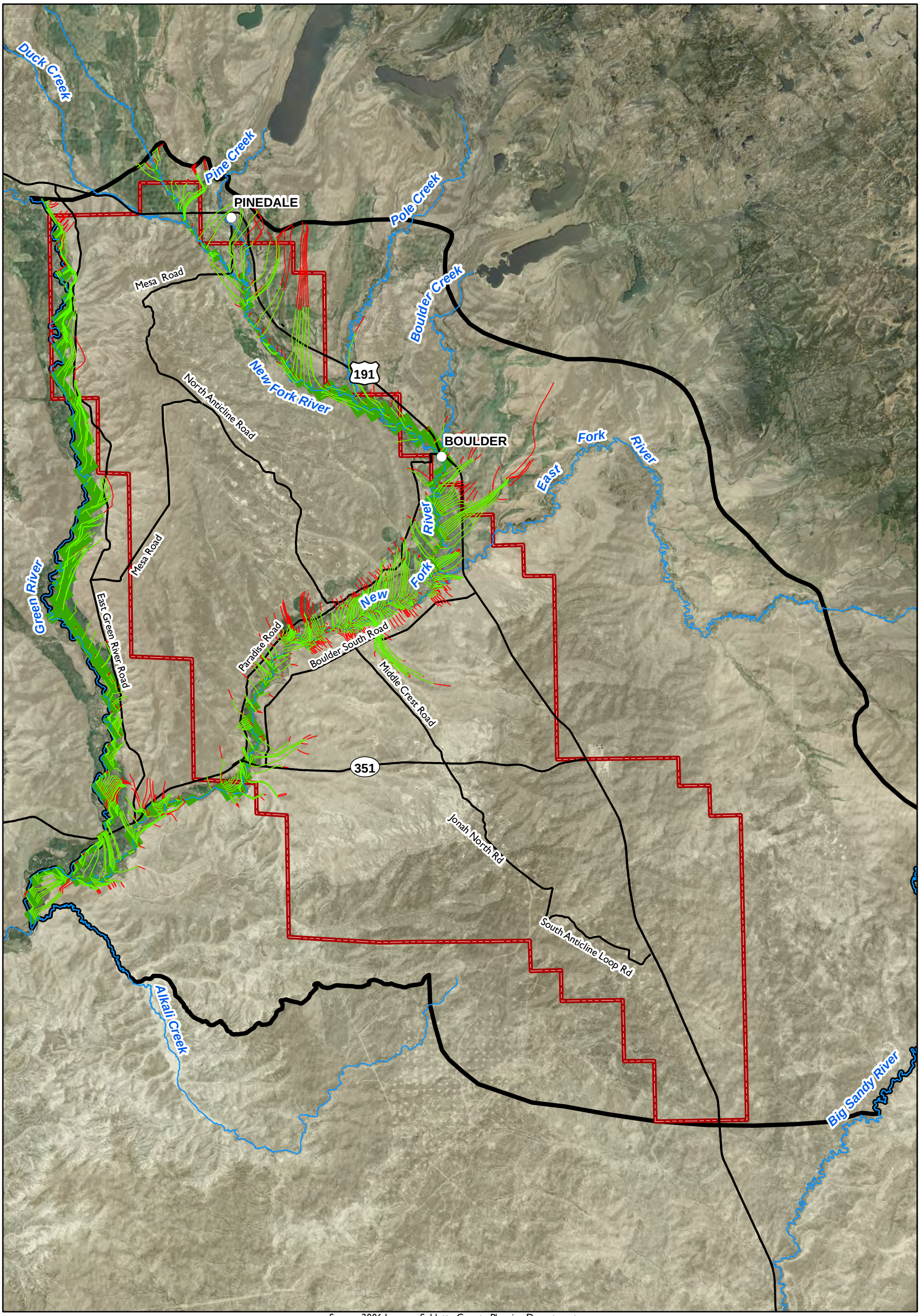
10 year Reverse Particle Track

110 year Reverse Particle Track

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

Reverse Particle Track - Domestic Wells in River Corridor
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 26



Source: 2006 Imagery Sublette County Planning Department

N

0 Miles 3

amec

River Cell in Flow Model

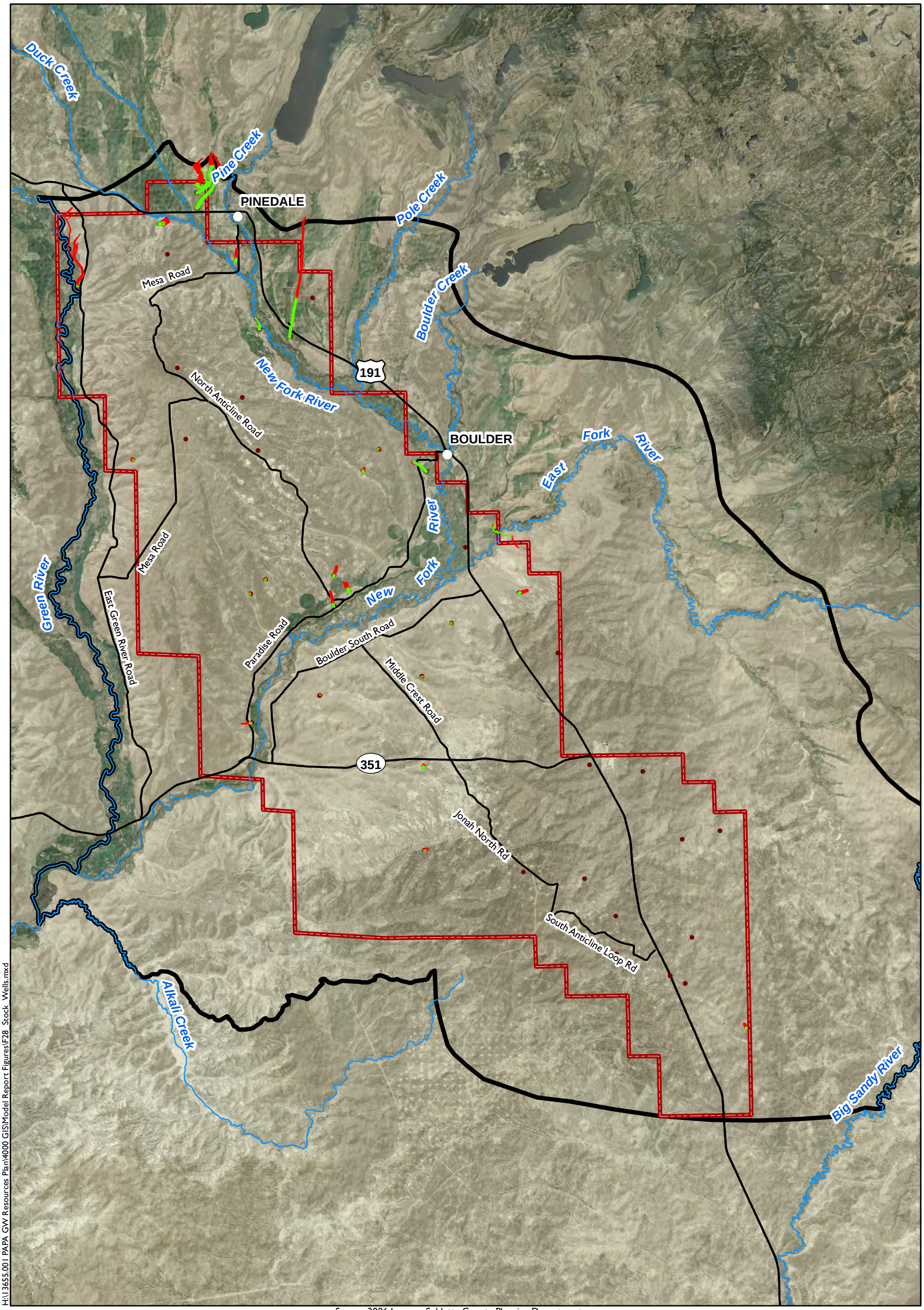
10 year Reverse Particle Track

110 year Reverse Particle Track

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

Reverse Particle Track -
New Fork River and Green River
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 27



Source: 2006 Imagery Sublette County Planning Department

H:\13655.001 PAPA GW Resources Plan\4000 GIS\Model Report Figures\F28 Stock Wells.mxd

N

0 Miles 3

amec

Stock Well

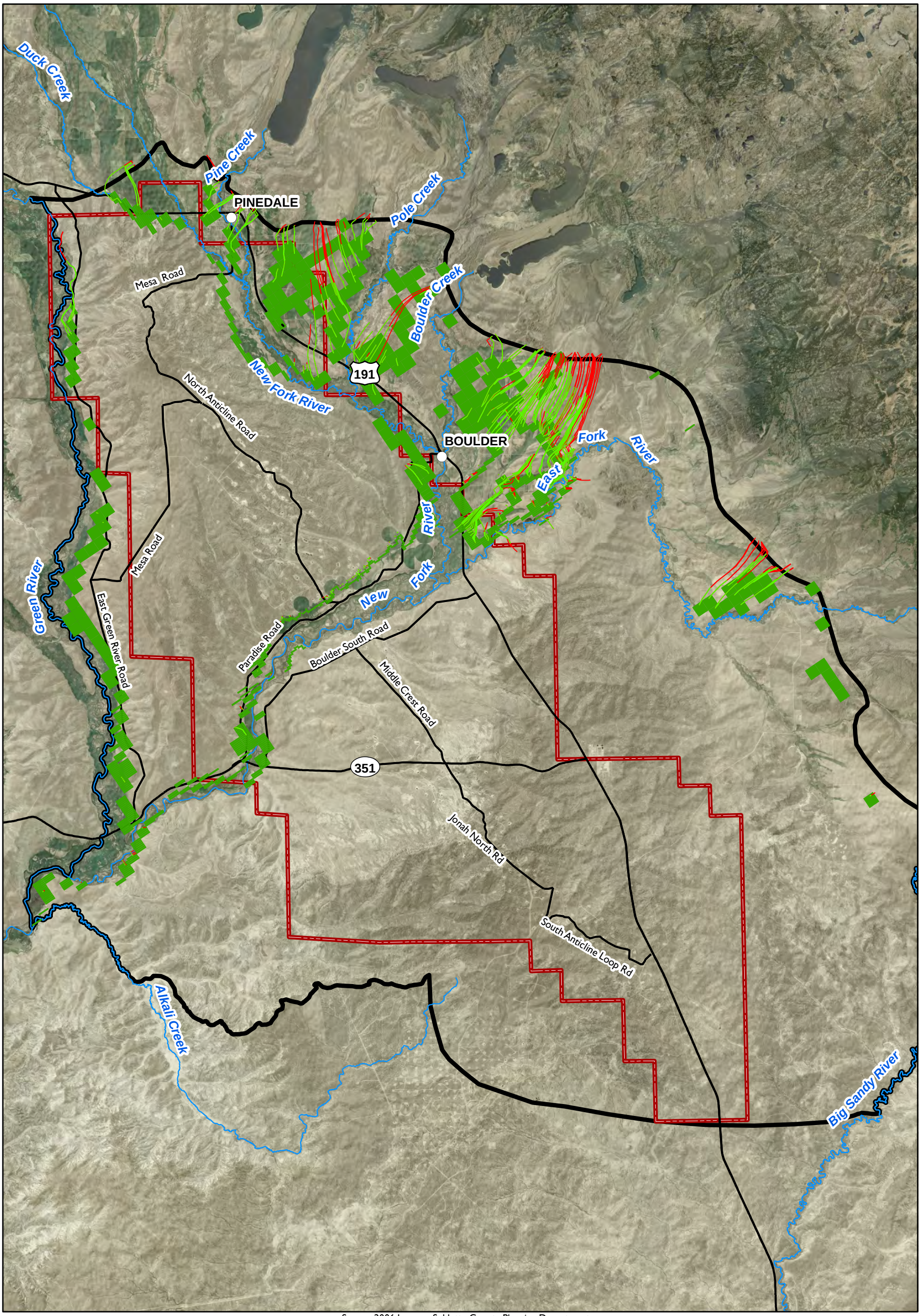
10 year Reverse Particle Track

110 year Reverse Particle Track

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

Reverse Particle Track - Stock Wells
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 28



Source: 2006 Imagery Sublette County Planning Department

N

0 Miles 3

amec

Irrigation Ditch Cell in Flow Model

10 year Reverse Particle Track

110 year Reverse Particle Track

Pinedale Anticline Project Area (PAPA)

Numerical Model Boundary

Reverse Particle Track - Irrigation Ditches
PAPA Numerical Groundwater Model
Pinedale Anticline Project Area
Sublette County, Wyoming
FIGURE 29