Airborne Electromagnetic Geophysical (AEM) Study along the I-80 Corridor and Municipal Wellfields within Albany County near Laramie, WY

Year-One Interim Report

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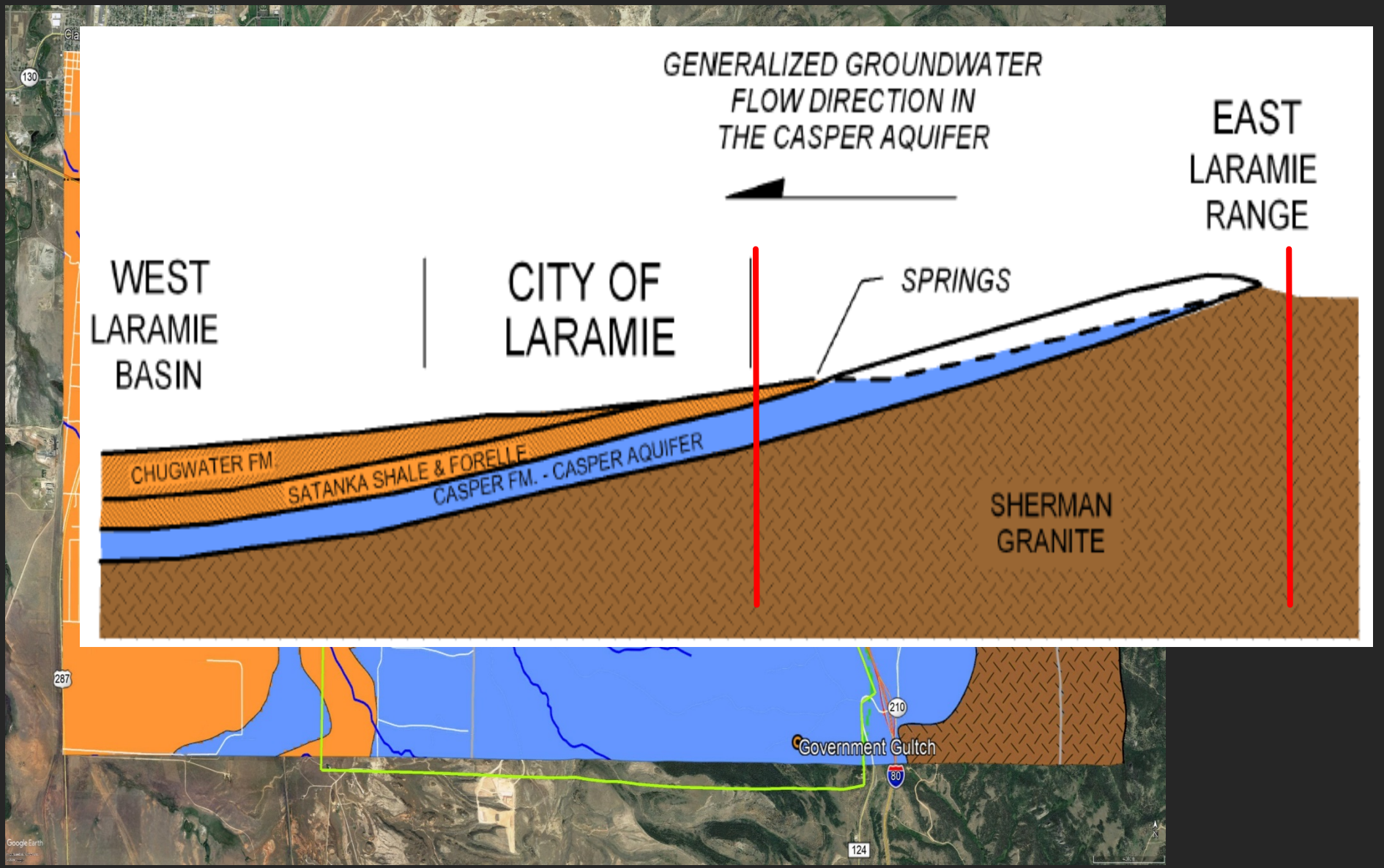
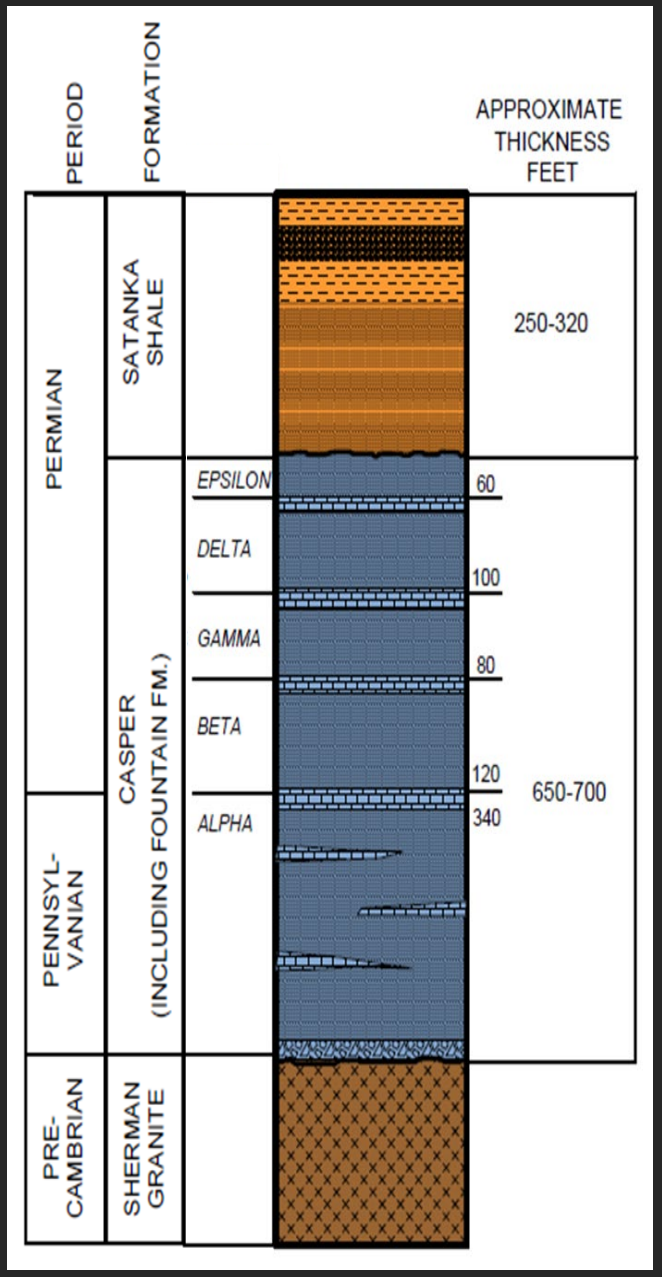
UW Dept. of Geology and Geophysics

Overview of Presentation

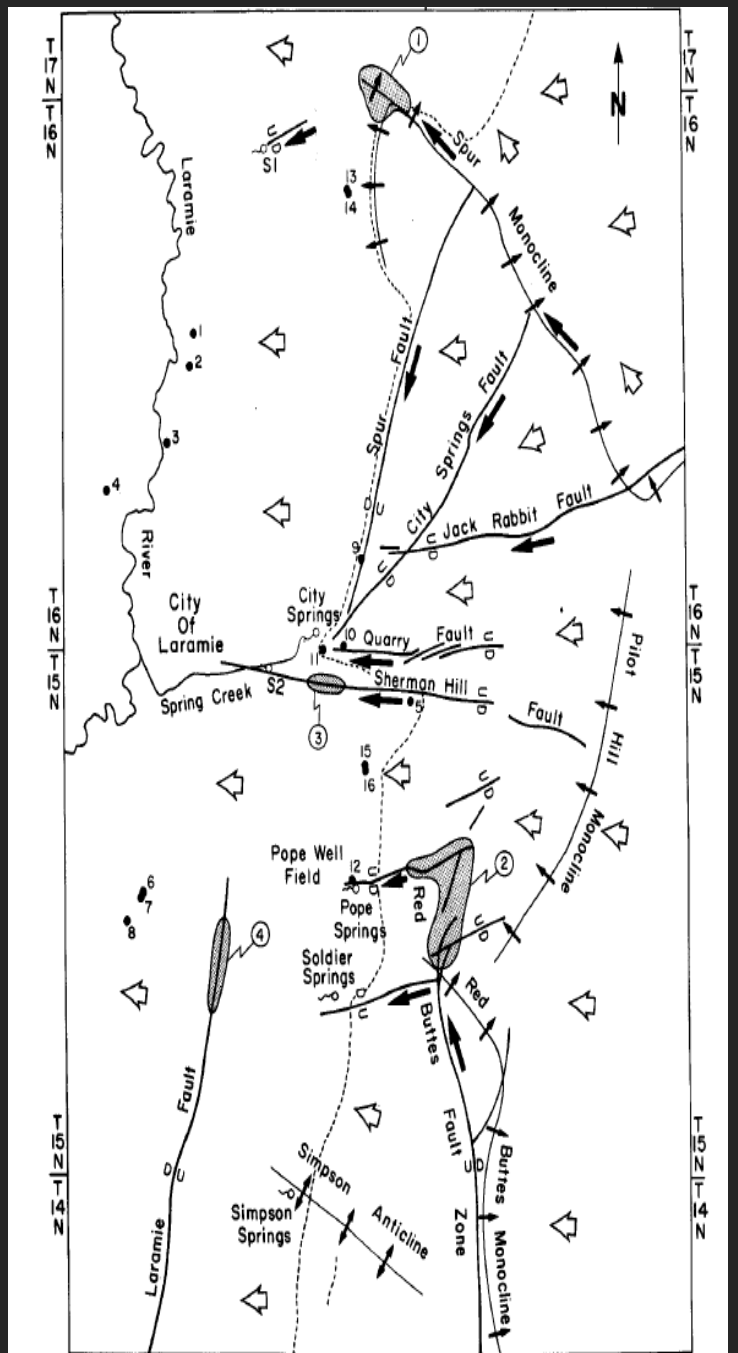
- Project Description
  - Aquifer Geology
  - Survey Location
  - Mountain-Front Recharge
  - Research Questions & Hypotheses
- Addressing the Scientific Questions
  - Analysis Techniques
  - First-year Data Summary
  - Summary and Year-1 Recommendations
- Timeline & Goals for Year 2

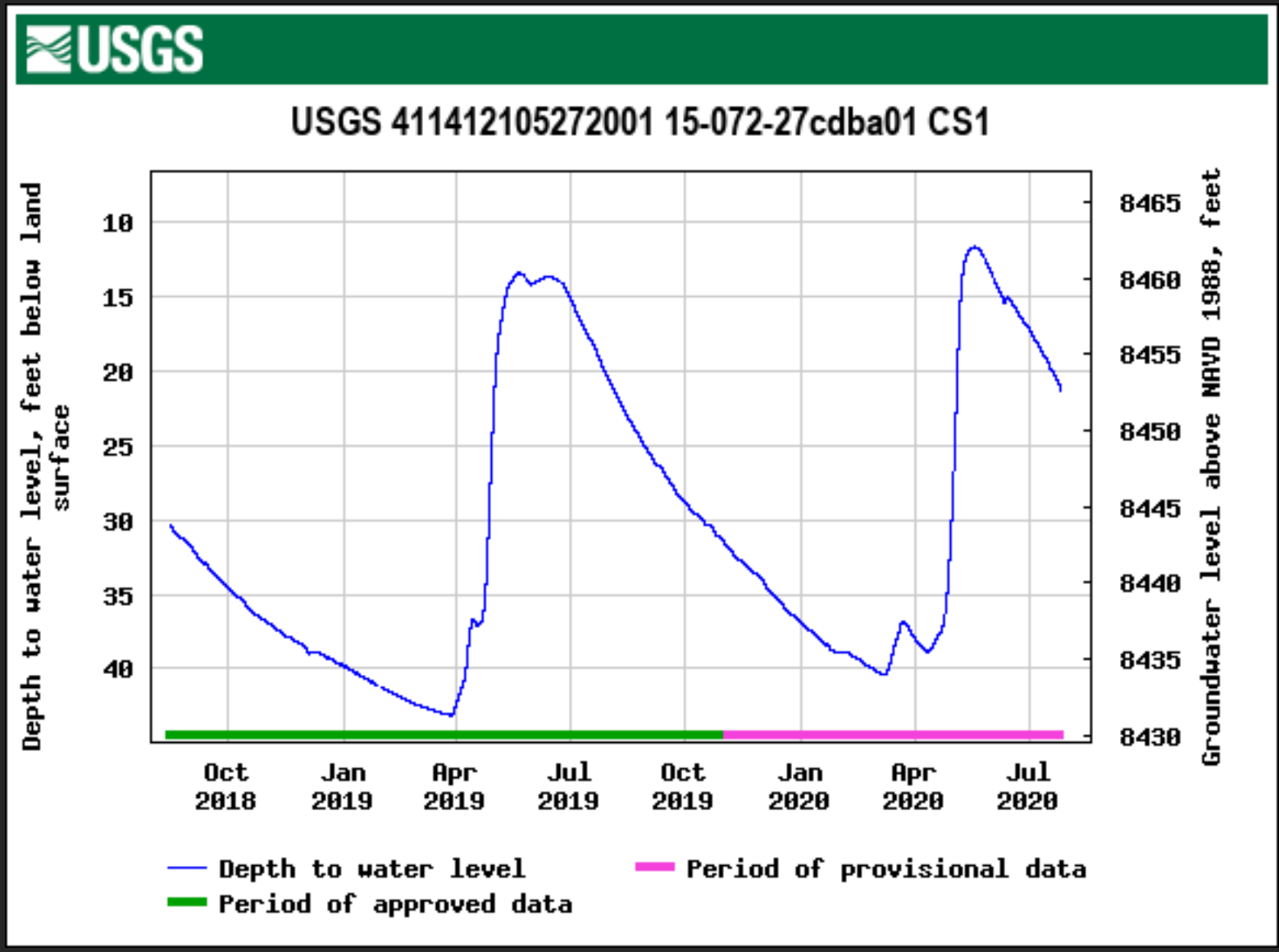


Casper Aquifer Protection Plan, 2015;



Casper Aquifer Protection Plan, 2015; Huntoon et al. 1979



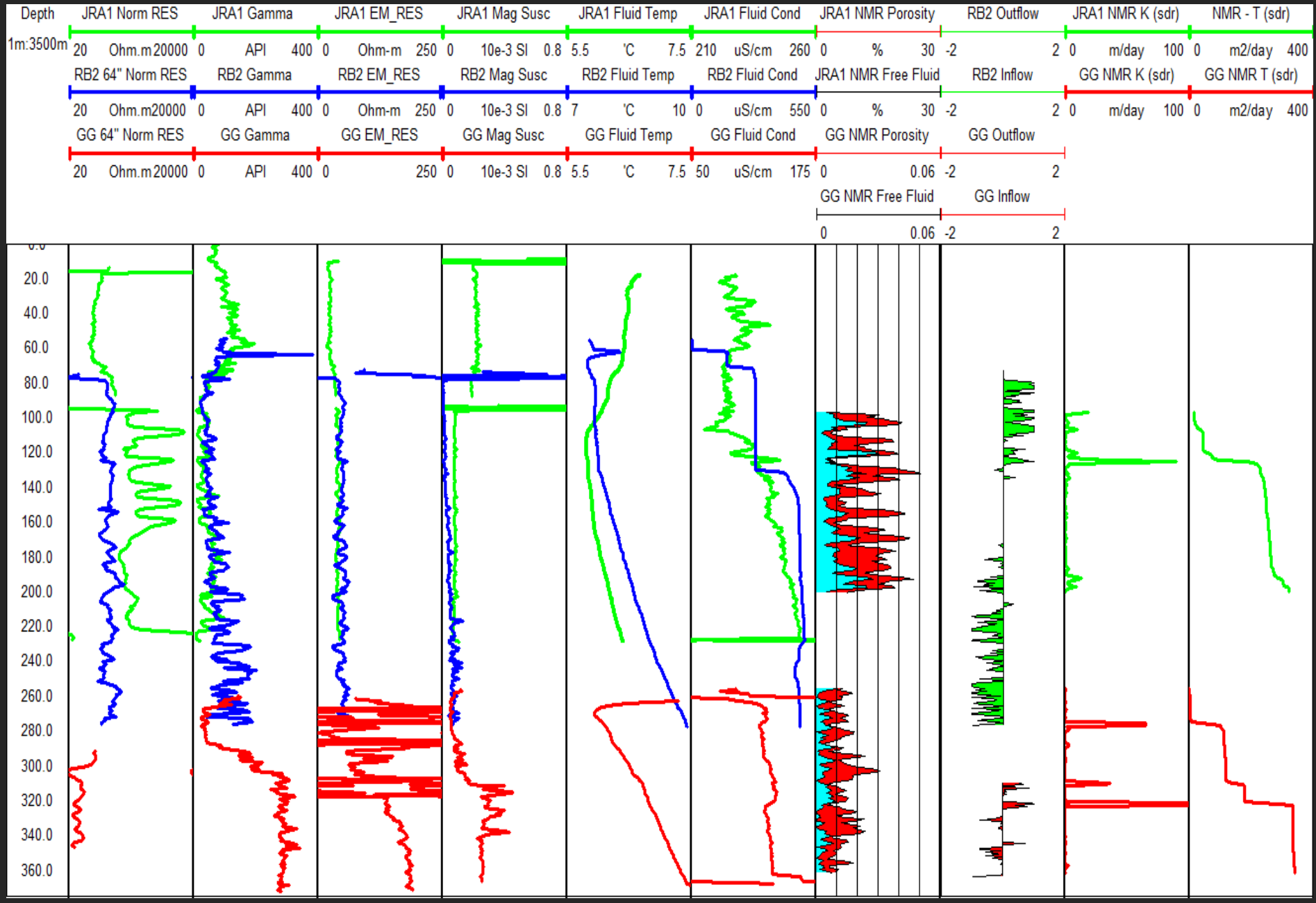


USGS -- National Water Information System: Web Interface --
https://waterdata.usgs.gov/wy/nwis/uv/?site_no=411412105272001&PARAmeter_cd=72019,61055

TABLE 3-1. HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY OF THE CASPER AQUIFER. ***DATA SOURCE: LUNDY, 1978.***

	HYDRAULIC CONDUCTIVITY (FEET PER DAY)	TRANSMISSIVITY (GALLONS PER DAY PER FOOT)
Epsilon member	1.3 to 2.6	600 to 970
Gamma member	1.5	435
Aggregate members (alpha through epsilon)	0.21 to 0.32	900 to 1,390
Aggregate members (gamma through epsilon)	0.11 to 0.13	315 to 375
Unfractured areas	0.10 to 2.6	135 to 970
Fractured areas	17 to 40	82,300 to 195,000

Casper Aquifer Protection Plan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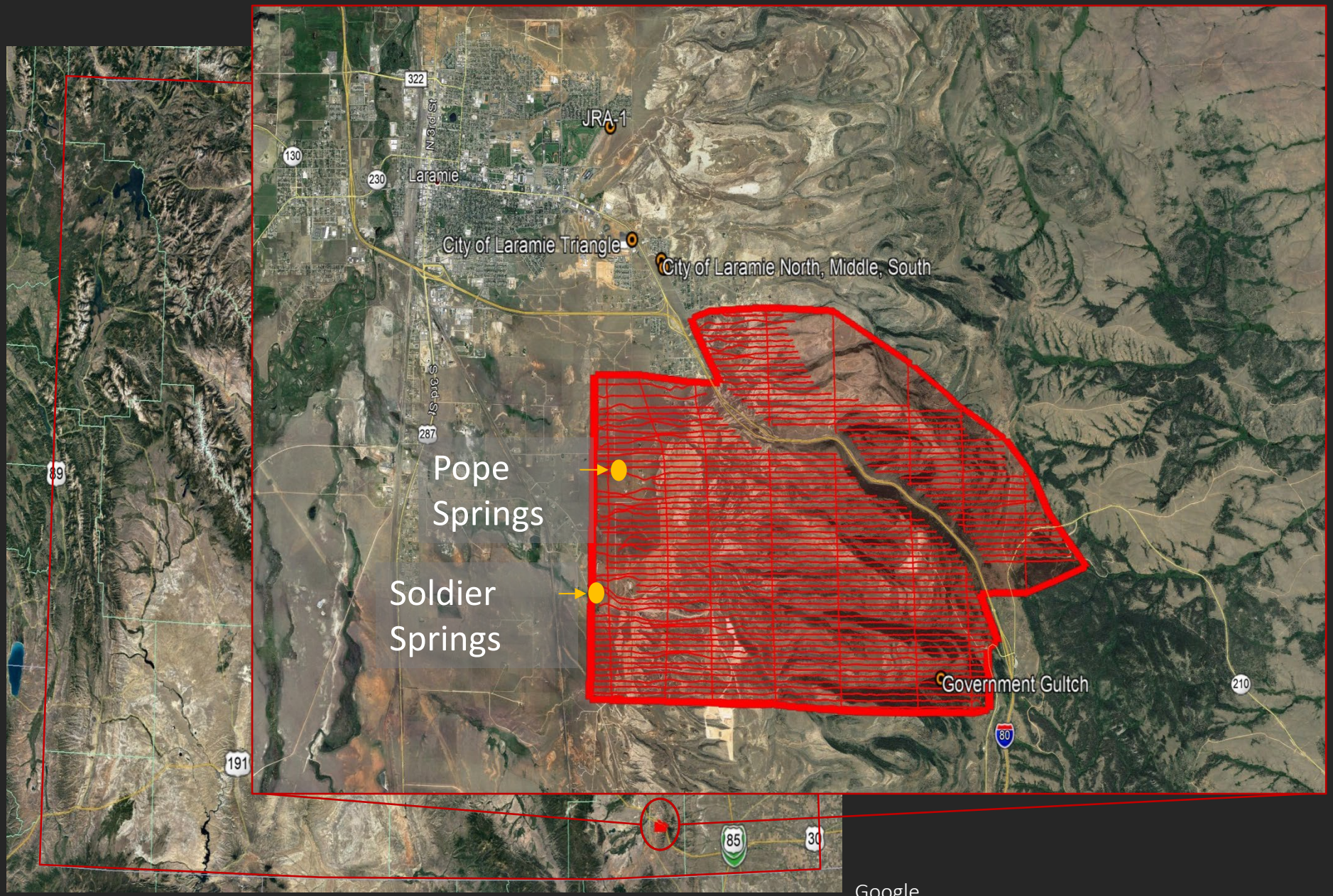
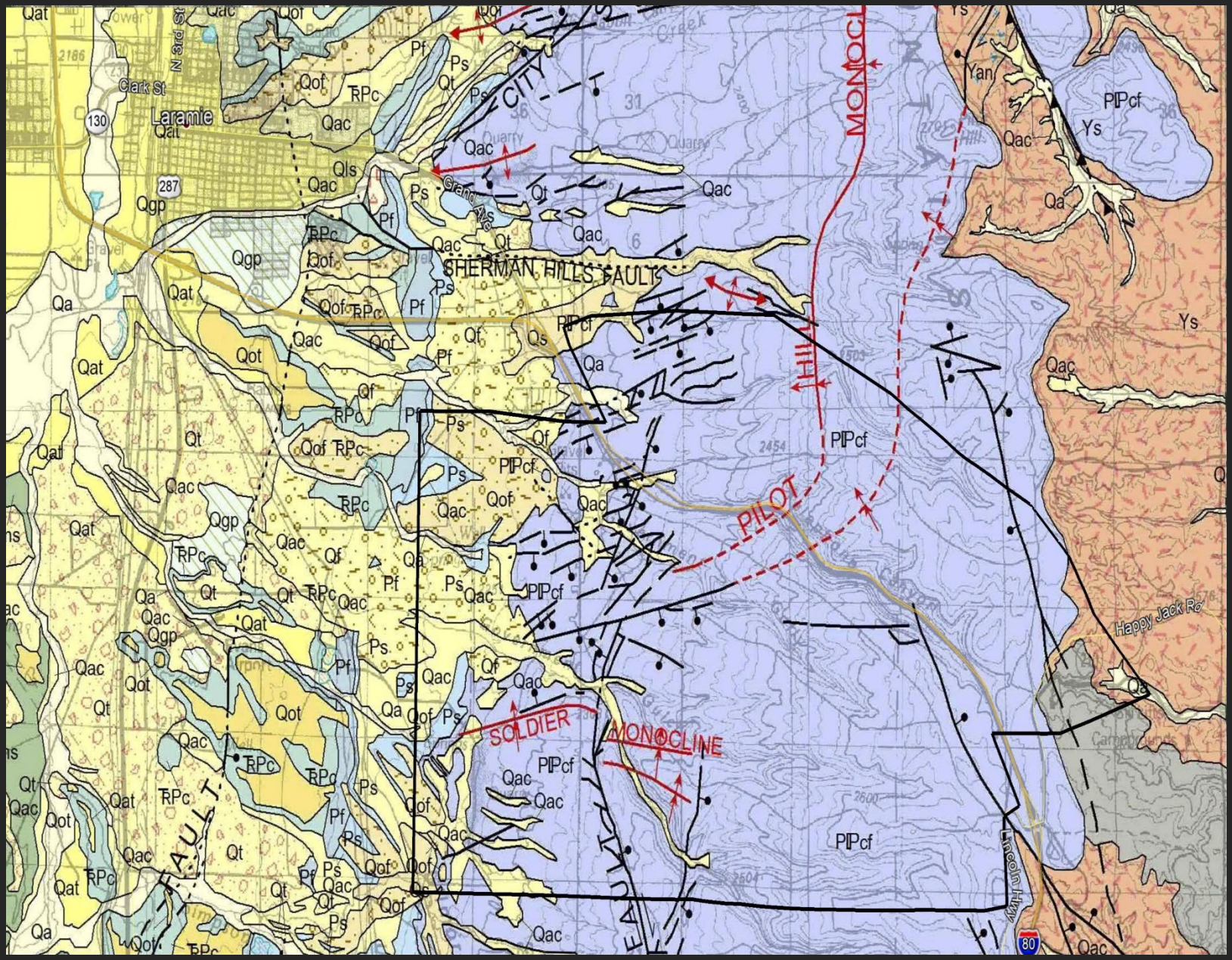
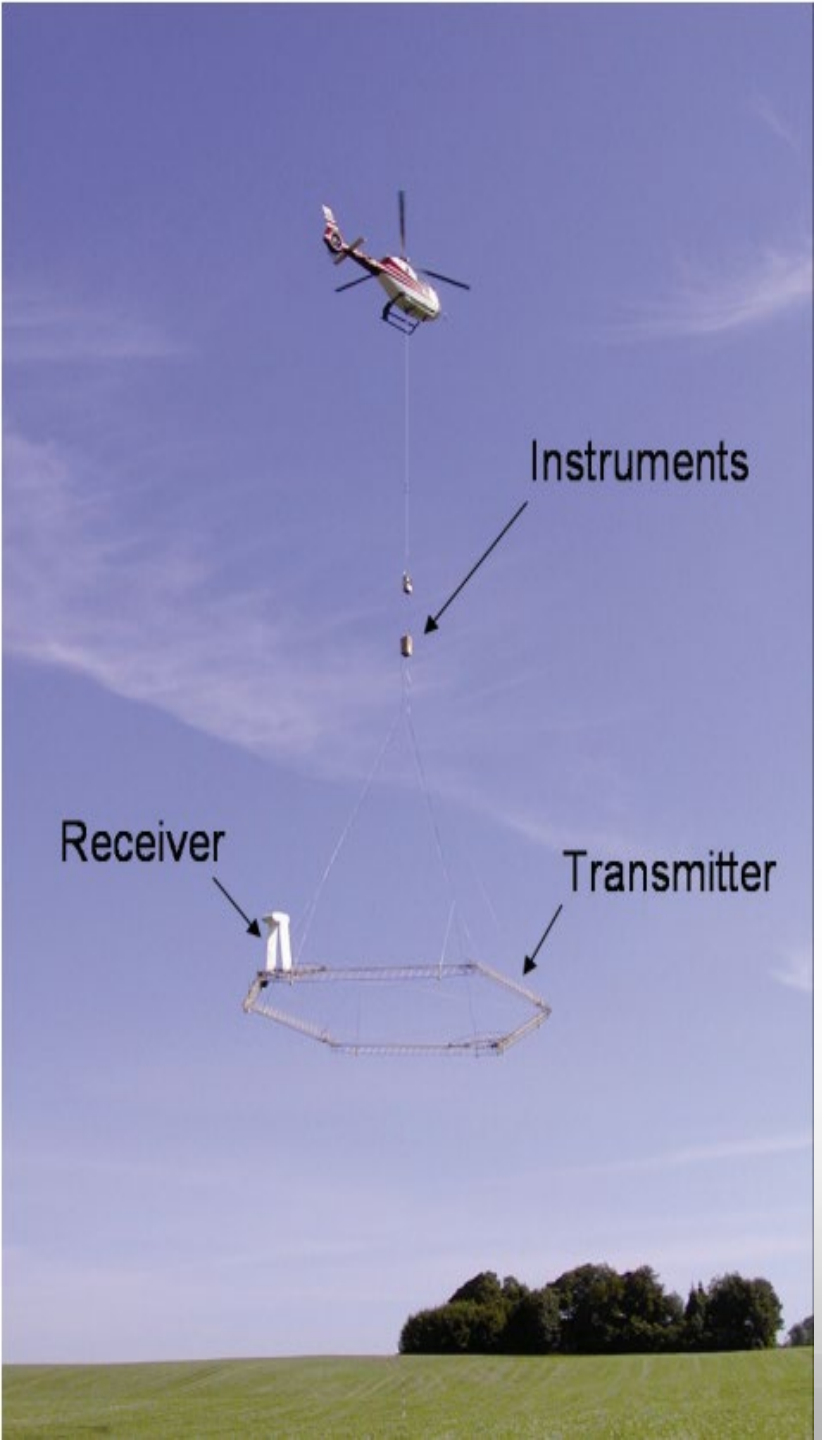
20 Ohm.m 20000
JRA1 Gamma
0 API 400
JRA1 EM_RES
0 Ohm-m 250
JRA1 Mag Susc
0 10e-3 SI 0.8
JRA1 Fluid Temp
5.5 'C 7.5
JRA1 Fluid Cond
210 uS/cm 260
JRA1 NMR Porosity
0 % 30
RB2 Outflow
-2 2
JRA1 NMR K (sdr)
0 m/day 100
NMR - T (sdr)
0 m2/day 400
RB2 64" Norm RES
20 Ohm.m 20000
RB2 Gamma
0 API 400
RB2 EM_RES
0 Ohm-m 250
RB2 Mag Susc
0 10e-3 SI 0.8
RB2 Fluid Temp
7 'C 10
RB2 Fluid Cond
0 uS/cm 550
JRA1 NMR Free Fluid
0 % 30
RB2 Inflow
-2 2
GG NMR K (sdr)
0 m/day 100
GG NMR T (sdr)
0 m2/day 400
GG 64" Norm RES
20 Ohm.m 20000
GG Gamma
0 API 400
GG EM_RES
0 250
GG Mag Susc
0 10e-3 SI 0.8
GG Fluid Temp
5.5 'C 7.5
GG Fluid Cond
50 uS/cm 175
GG NMR Porosity
0 0.06
GG Outflow
-2 2
GG NMR Free Fluid
0 0.06
GG Inflow
-2 2
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
220.0
240.0
260.0
280.0
300.0
320.0
340.0
360.0

Project Description – Location

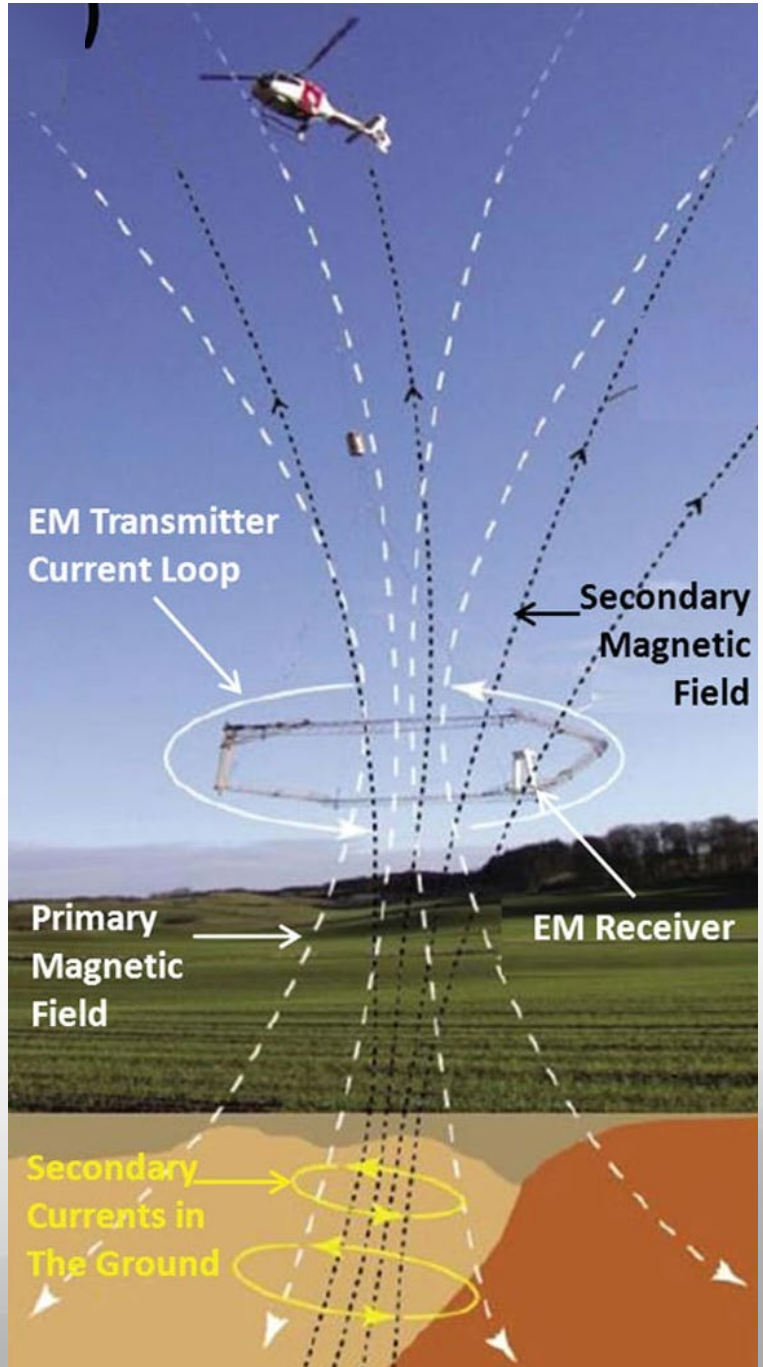


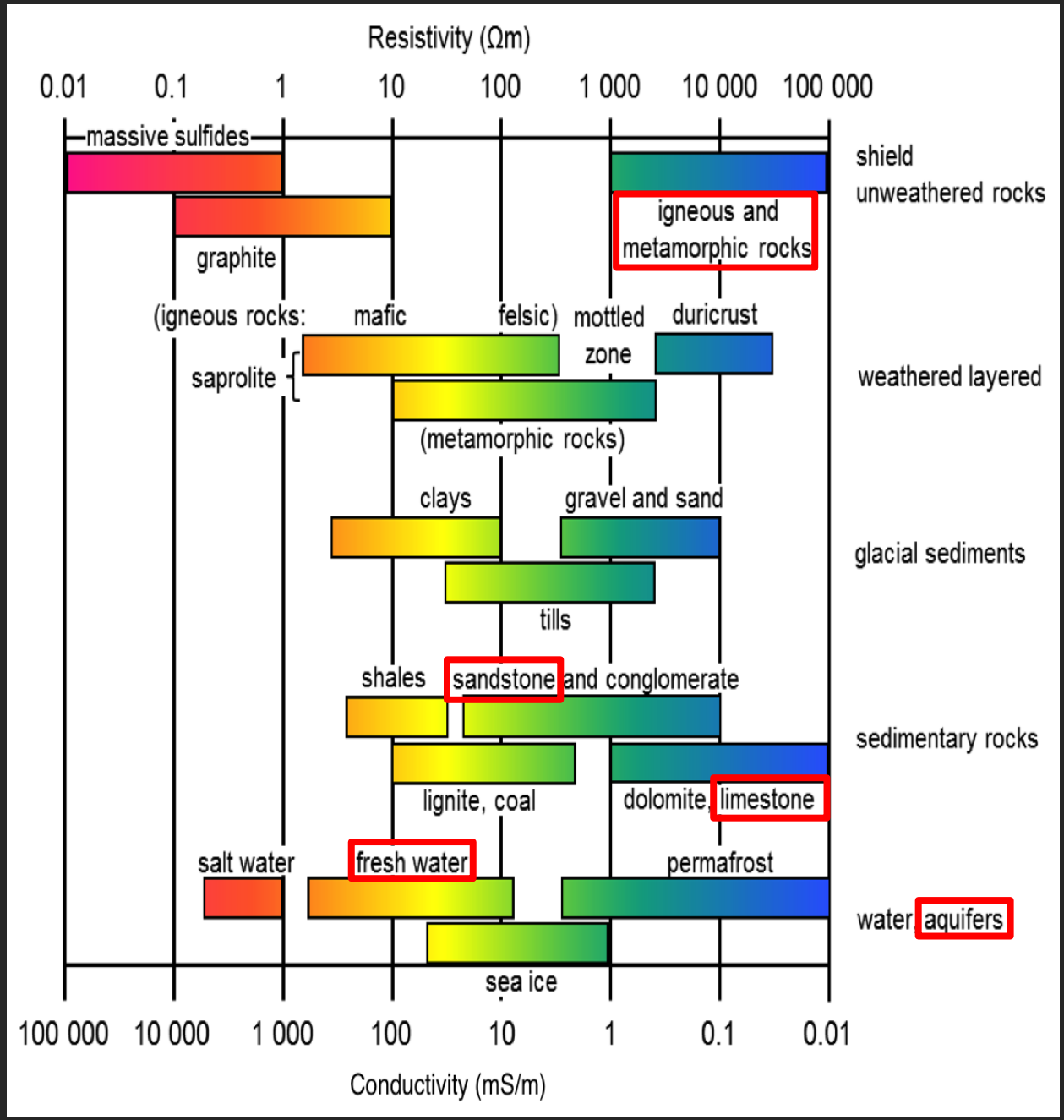


Wyoming State Geological Survey,



How does it work?





Adapted from Palacky, 1987

Research Questions & Working Hypotheses

Q1: What geologic units and structures provide the primary groundwater pathways from the mountains to the basin (a.k.a. Mountain Front Recharge) from surface to bedrock?

Q2: Where is the gravity dominant groundwater interpreted to be moving in the survey area and why?

Q3: Are the municipal wellfields and the I-80 corridor connected hydraulically and if so, at what depths?

H1: Low resistivity areas in the AEM data reflect units with high permeability more than units with just high porosity.

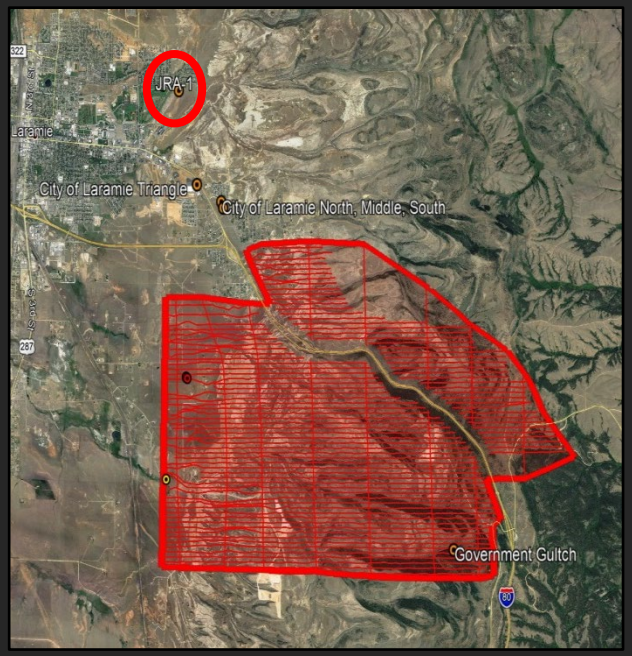
H2: Groundwater flows along existing topographic gradients because gravity dominates flow.

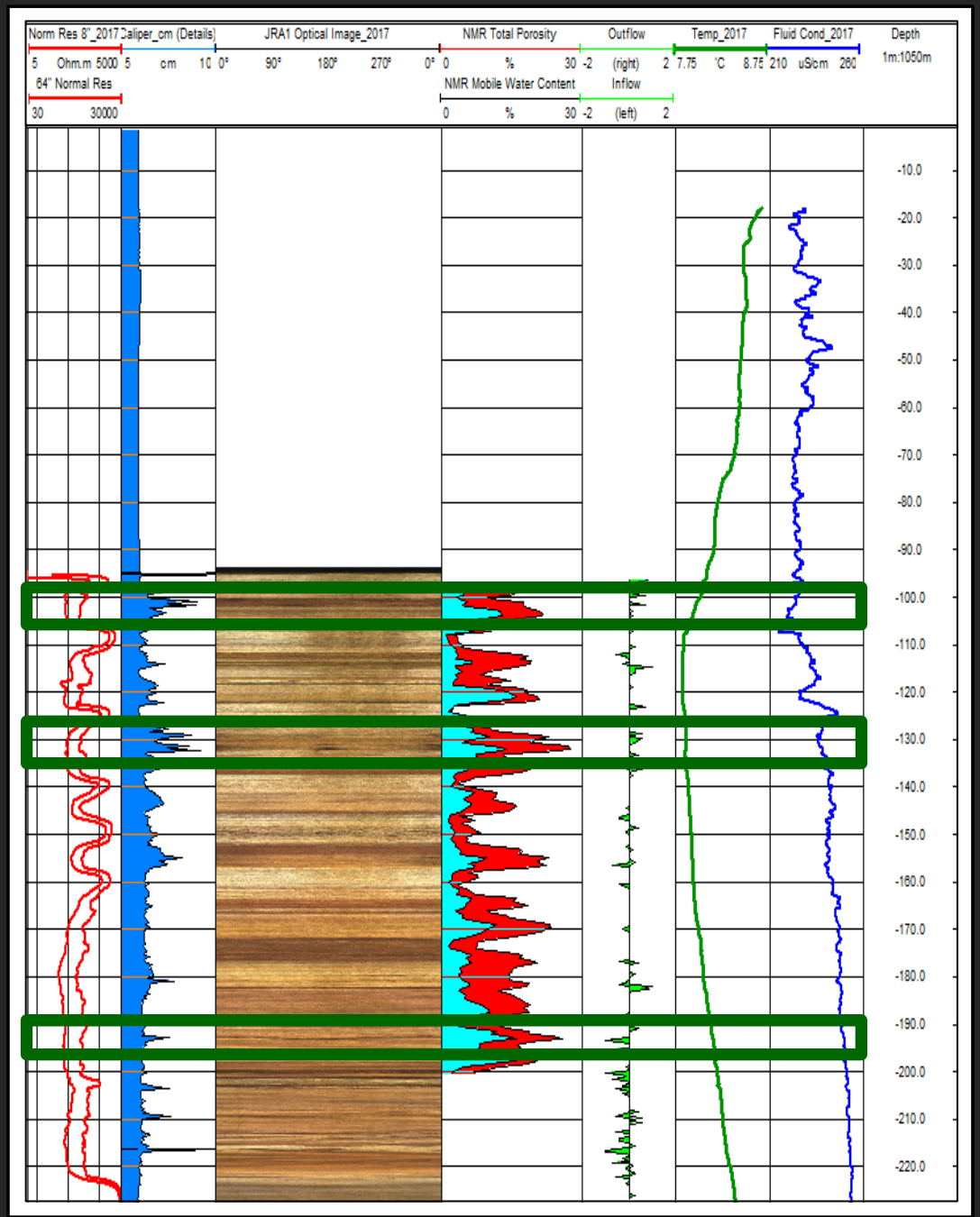
H3: Geophysics data images fractures and folds created by tectonic alteration as low resistivity units that correspond with the main groundwater flow paths within the aquifer.

H4: The underlying basement structure has a major influence on the overlying units and potential permeability pathways.

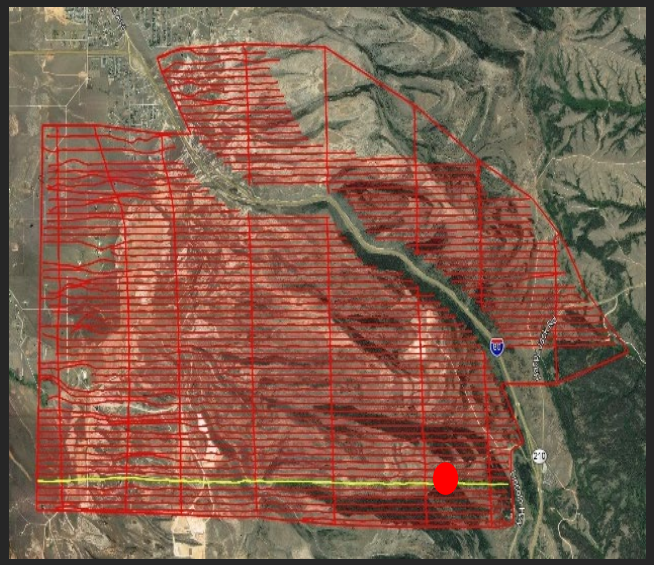
Analysis Techniques

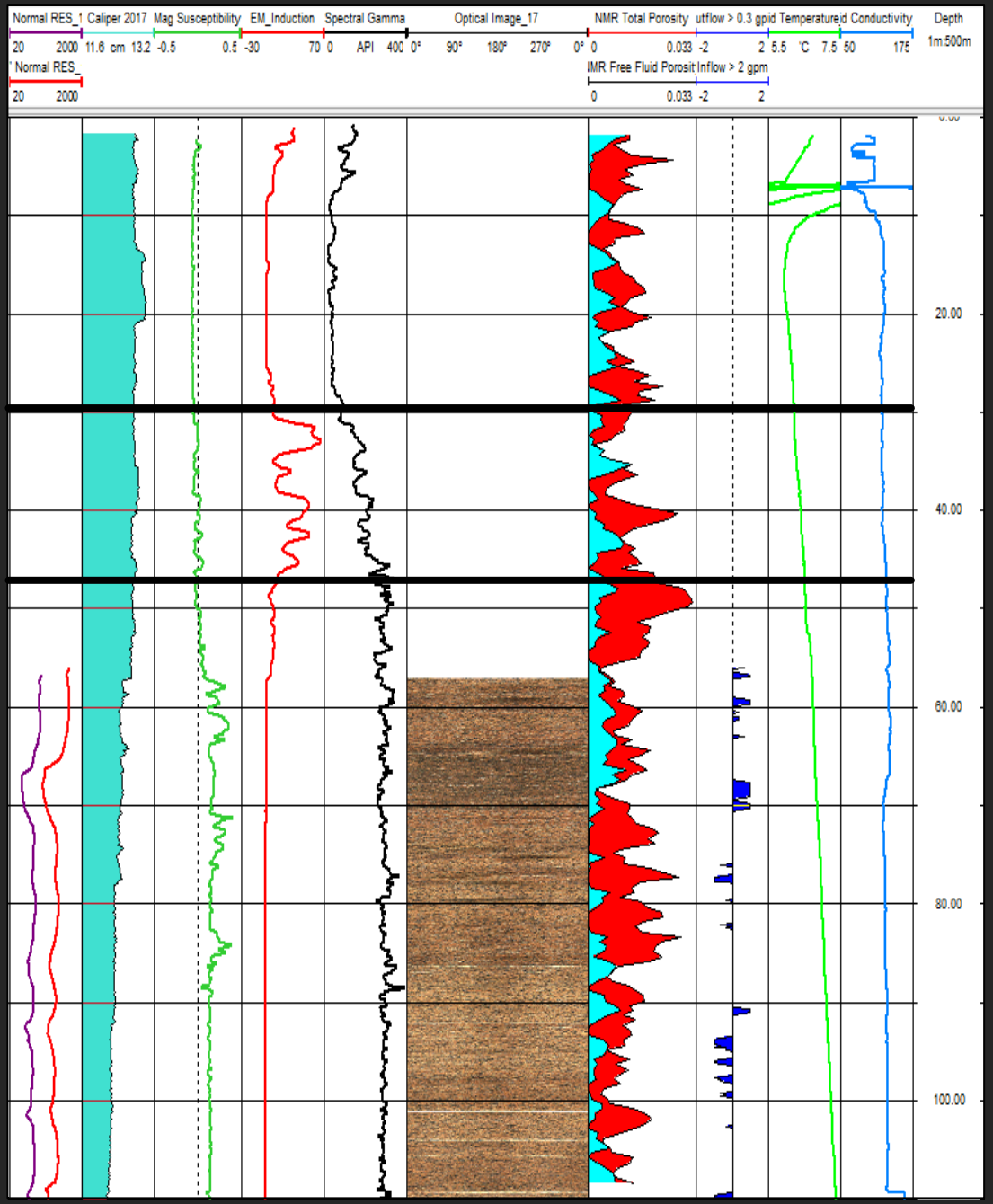
- Aarhus GeoSoftware Workbench
  - Process and invert AEM data
- Geosoft Oasis Montaj
  - Model Aeromag data
  - Create figures of AEM data
- GeoScene3D
  - Create geologic structural model

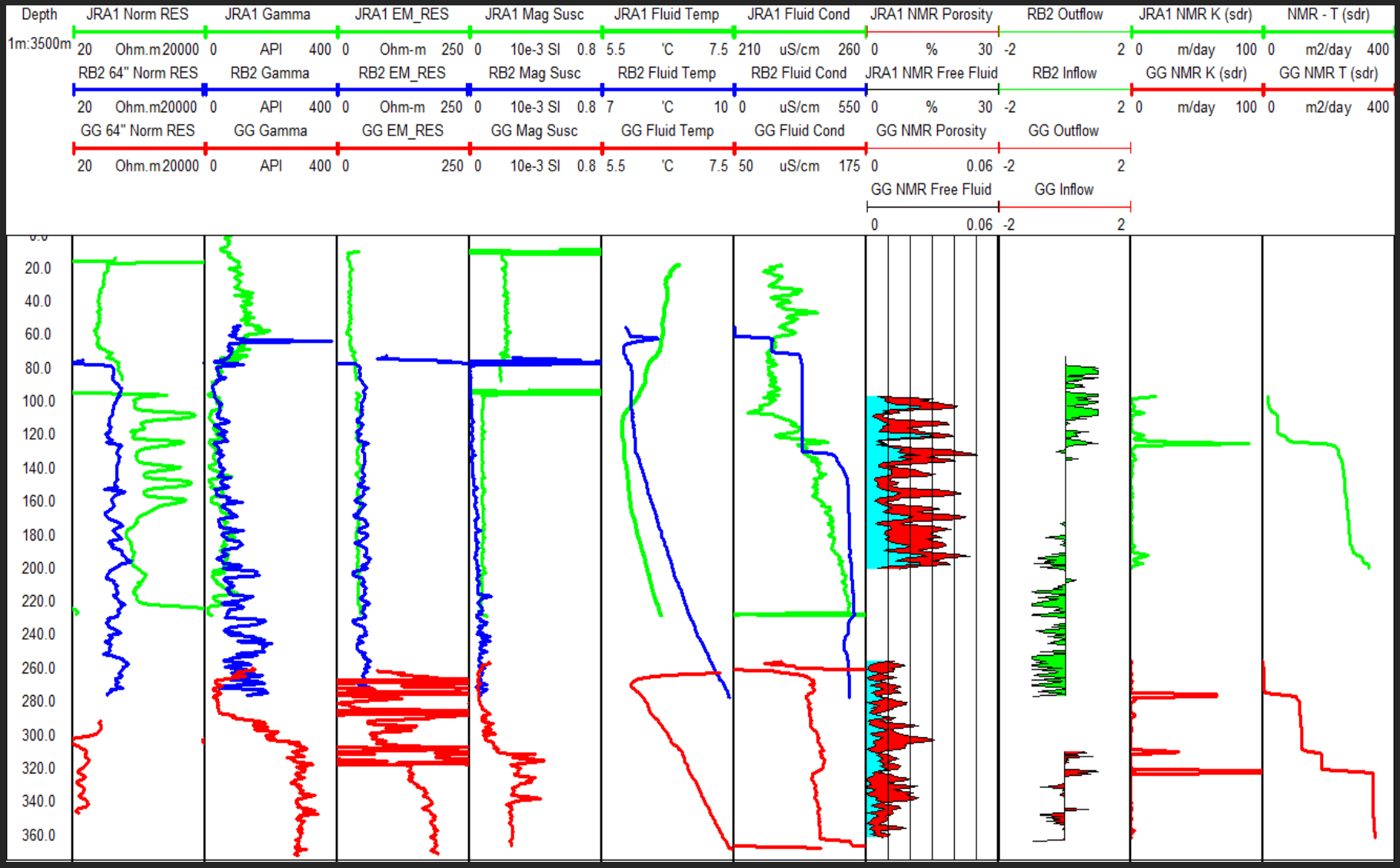




Google Earth; Well JRA1, WellCAD




Normal RES_1
Caliper 2017
Mag Susceptibility
EM_Induction
Spectral Gamma
Optical Image_17
NMR Total Porosity
utflow > 0.3 gpid
Temperature
id Conductivity
Depth
1m:500m
20
2000
11.6 cm 13.2
-0.5
0.5
-30
70
0
API
400
0°
90°
180°
270°
0°
0
0.033
-2
2
5.5
°C
7.5
50
175
Normal RES_
20
2000
IMR Free Fluid Porosit
Inflow > 2 gpm
0
0.033
-2
2
20.00
40.00
60.00
80.00
100.00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1m:3500m
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JRA1 Gamma
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JRA1 EM_RES
0 Ohm-m 250
JRA1 Mag Susc
0 10e-3 SI 0.8
JRA1 Fluid Temp
5.5 'C 7.5
JRA1 Fluid Cond
210 uS/cm 260
JRA1 NMR Porosity
0 % 30
RB2 Outflow
-2 2
JRA1 NMR K (sdr)
0 m/day 100
JRA1 NMR T (sdr)
0 m2/day 400
RB2 64" Norm RES
20 Ohm.m 20000
RB2 Gamma
0 API 400
RB2 EM_RES
0 Ohm-m 250
RB2 Mag Susc
0 10e-3 SI 0.8
RB2 Fluid Temp
7 'C 10
RB2 Fluid Cond
0 uS/cm 550
JRA1 NMR Free Fluid
0 % 30
RB2 Inflow
-2 2
GG NMR K (sdr)
0 m/day 100
GG NMR T (sdr)
0 m2/day 400
GG 64" Norm RES
20 Ohm.m 20000
GG Gamma
0 API 400
GG EM_RES
0 250
GG Mag Susc
0 10e-3 SI 0.8
GG Fluid Temp
5.5 'C 7.5
GG Fluid Cond
50 uS/cm 175
GG NMR Porosity
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GG Outflow
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GG NMR Free Fluid
0 0.06
GG Inflow
-2 2
20.0
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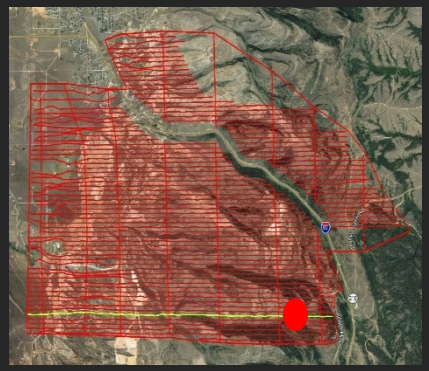
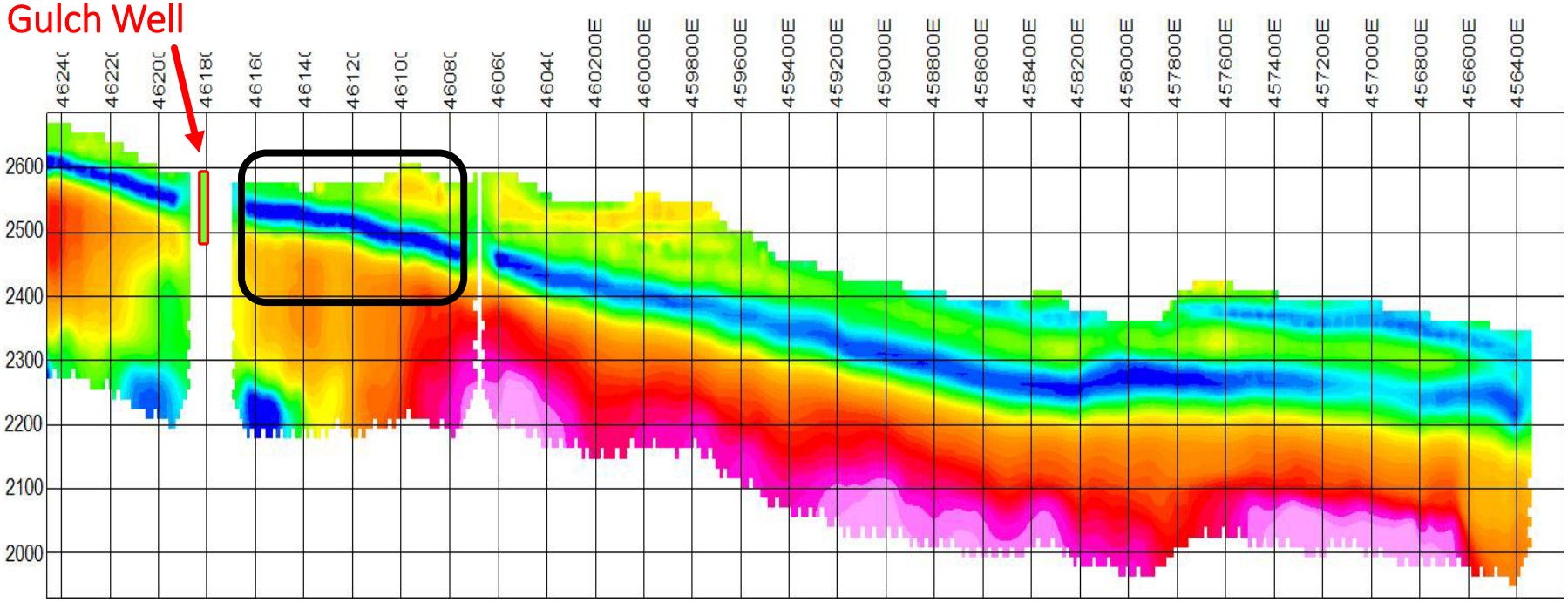


Approximate Location of Gov't Gulch Well

Line 106101 Resistivity

WEST



Scale 1:6000

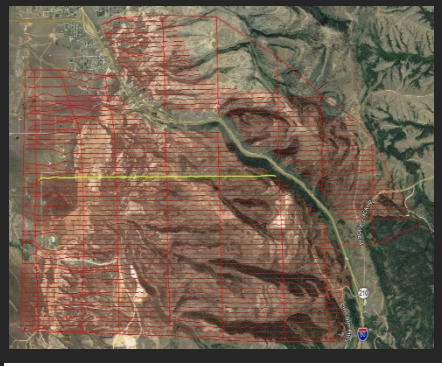
100 0 100

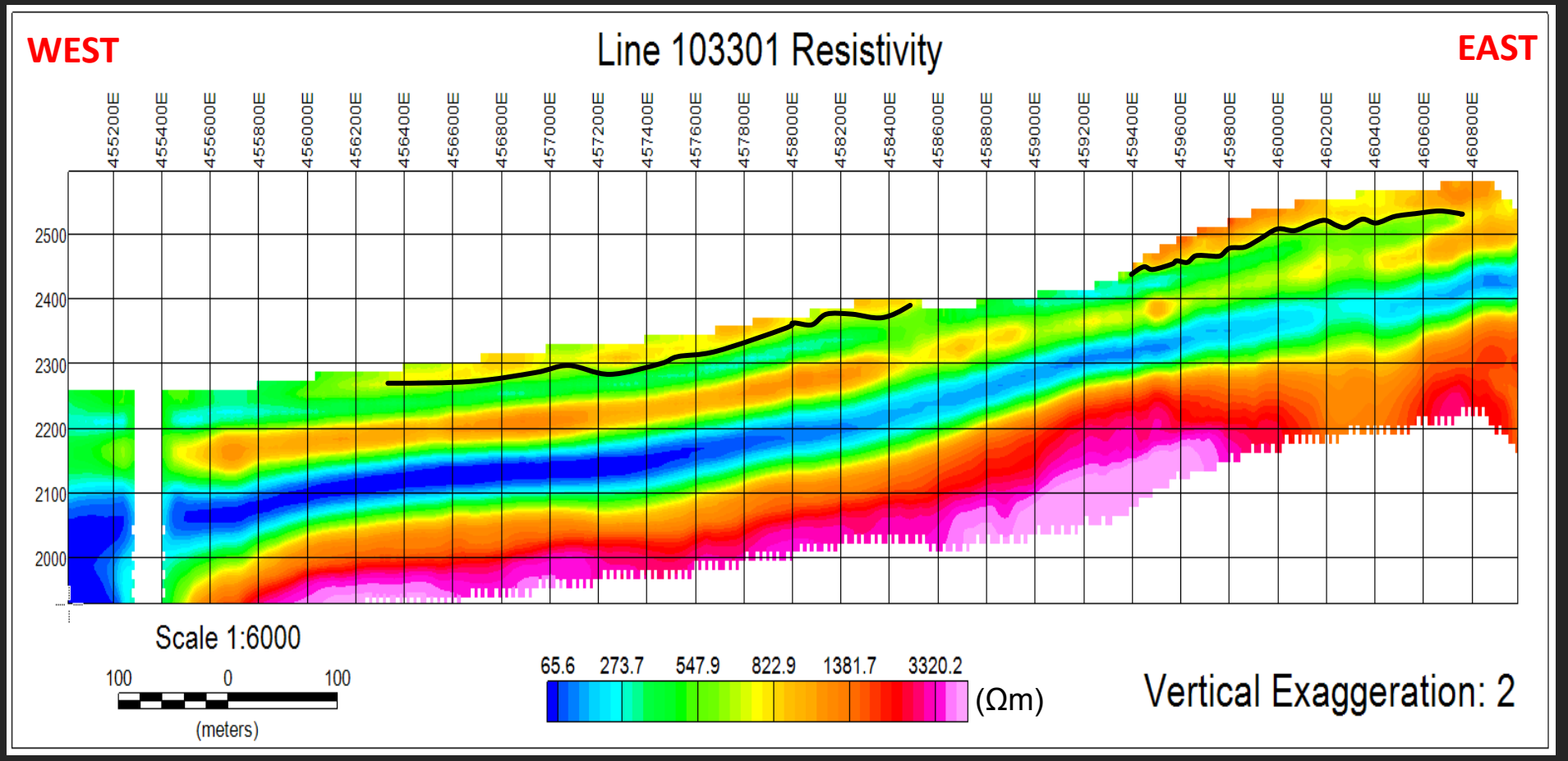
(meters)

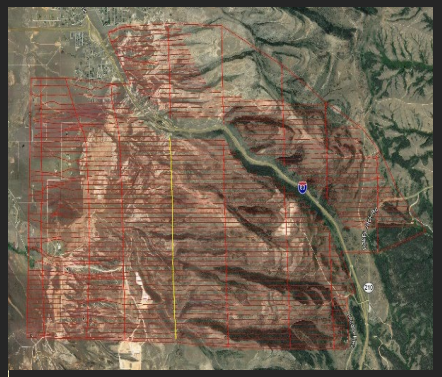
136.4 338.1 603.7 1218.5 2470.0 5015.3

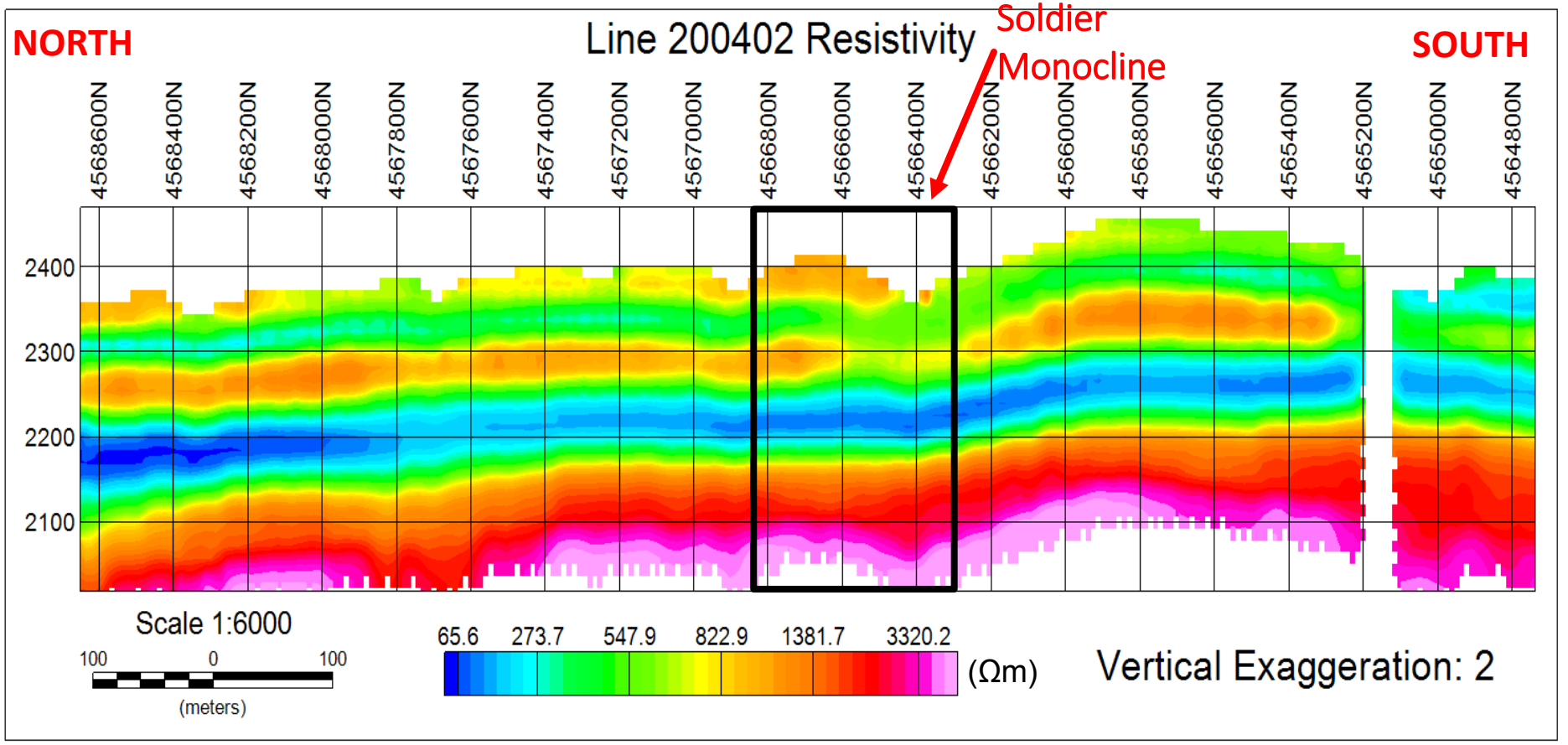
(Ωm)

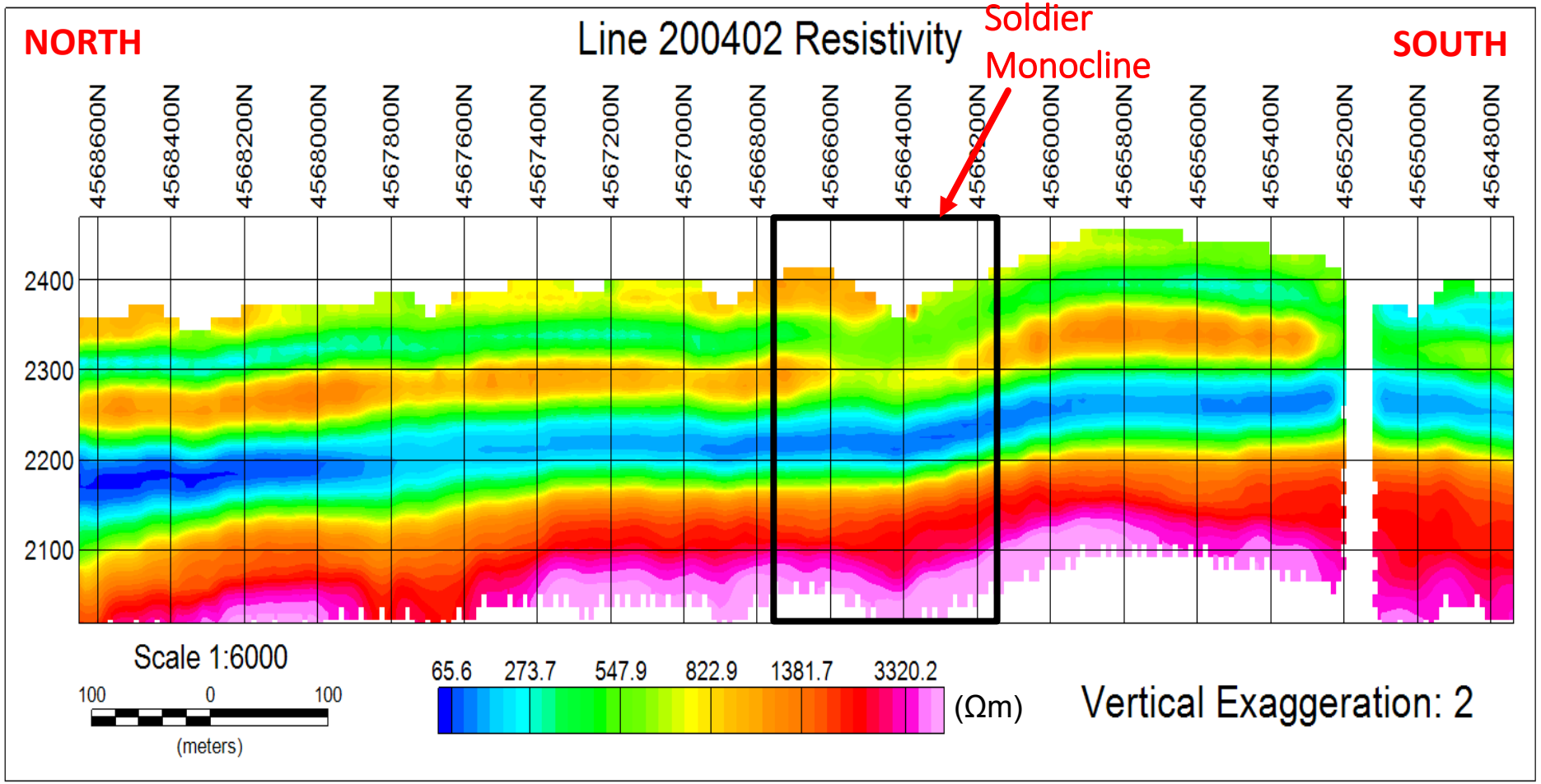
Vertical Exaggeration: 2




WEST
Line 103301 Resistivity
EAST
455200E
455400E
455600E
455800E
456000E
456200E
456400E
456600E
456800E
457000E
457200E
457400E
457600E
457800E
458000E
458200E
458400E
458600E
458800E
459000E
459200E
459400E
459600E
459800E
460000E
460200E
460400E
460600E
460800E
2500
2400
2300
2200
2100
2000
Scale 1:6000
100
0
100
(meters)
65.6
273.7
547.9
822.9
1381.7
3320.2
(Ωm)
Vertical Exaggeration: 2




NORTH
Line 200402 Resistivity
Soldier
Monocline
SOUTH
4568600N
4568400N
4568200N
4568000N
4567800N
4567600N
4567400N
4567200N
4567000N
4566800N
4566600N
4566400N
4566200N
4566000N
4565800N
4565600N
4565400N
4565200N
4565000N
4564800N
2400
2300
2200
2100
Scale 1:6000
100
0
100
(meters)
65.6
273.7
547.9
822.9
1381.7
3320.2
(Ωm)
Vertical Exaggeration: 2


NORTH
Line 200402 Resistivity
Soldier
Monocline
SOUTH
4568600N
4568400N
4568200N
4568000N
4567800N
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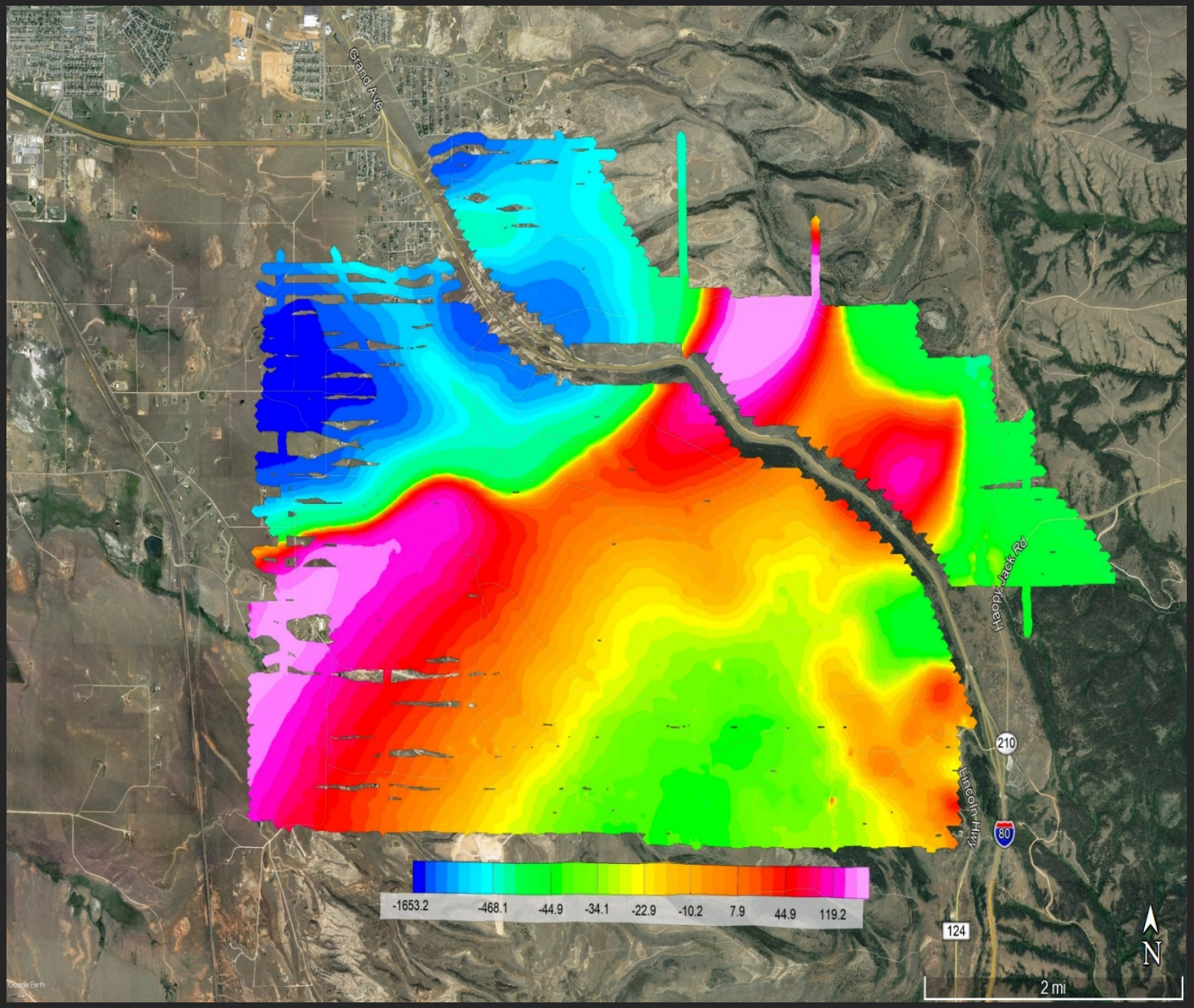
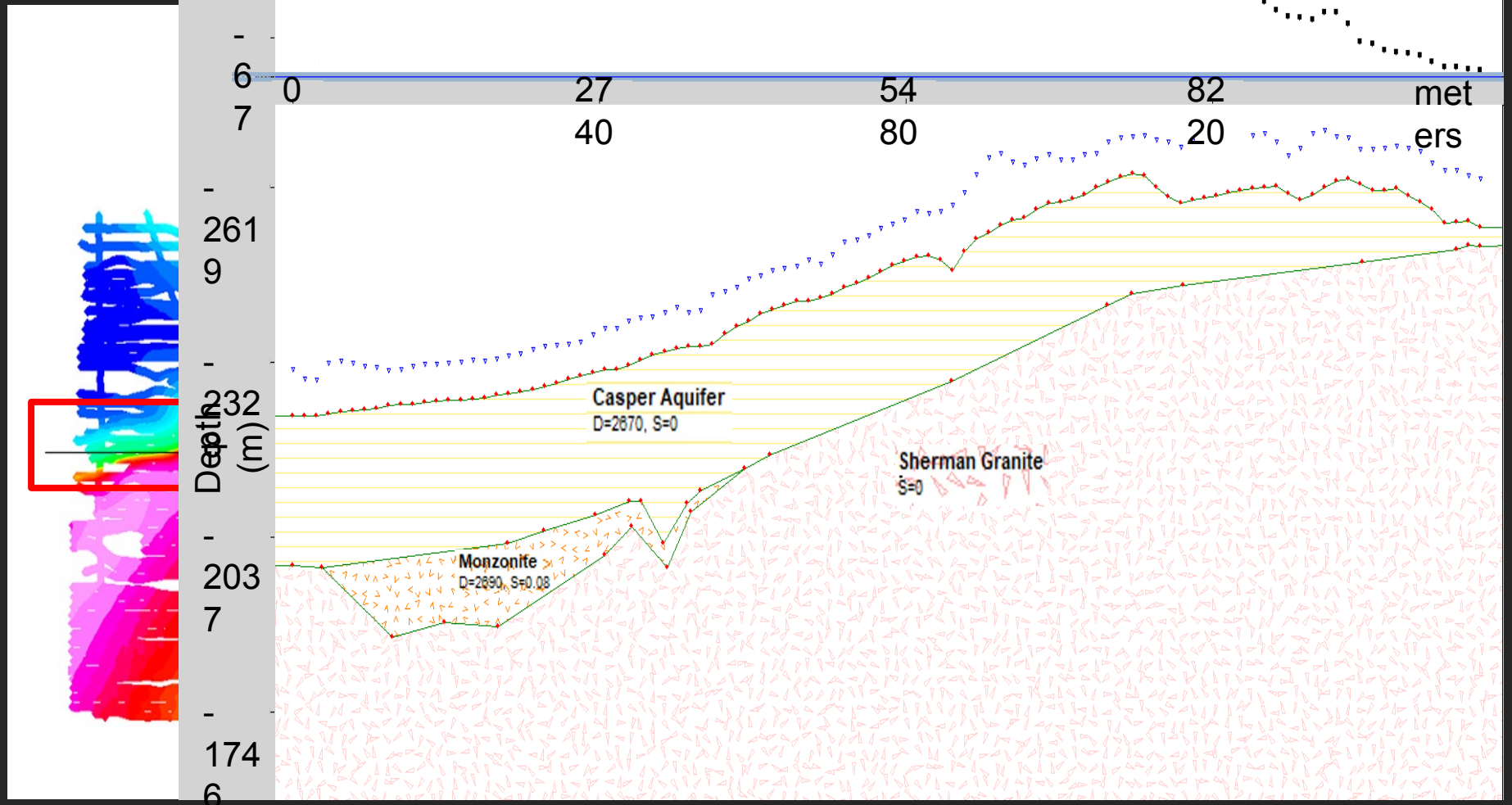
4567400N
4567200N
4567000N
4566800N
4566600N
4566400N
4566200N
4566000N
4565800N
4565600N
4565400N
4565200N
4565000N
4564800N
2400
2300
2200
2100
Scale 1:6000
100
0
100
(meters)
65.6
273.7
547.9
822.9
1381.7
3320.2
(Ωm)
Vertical Exaggeration: 2

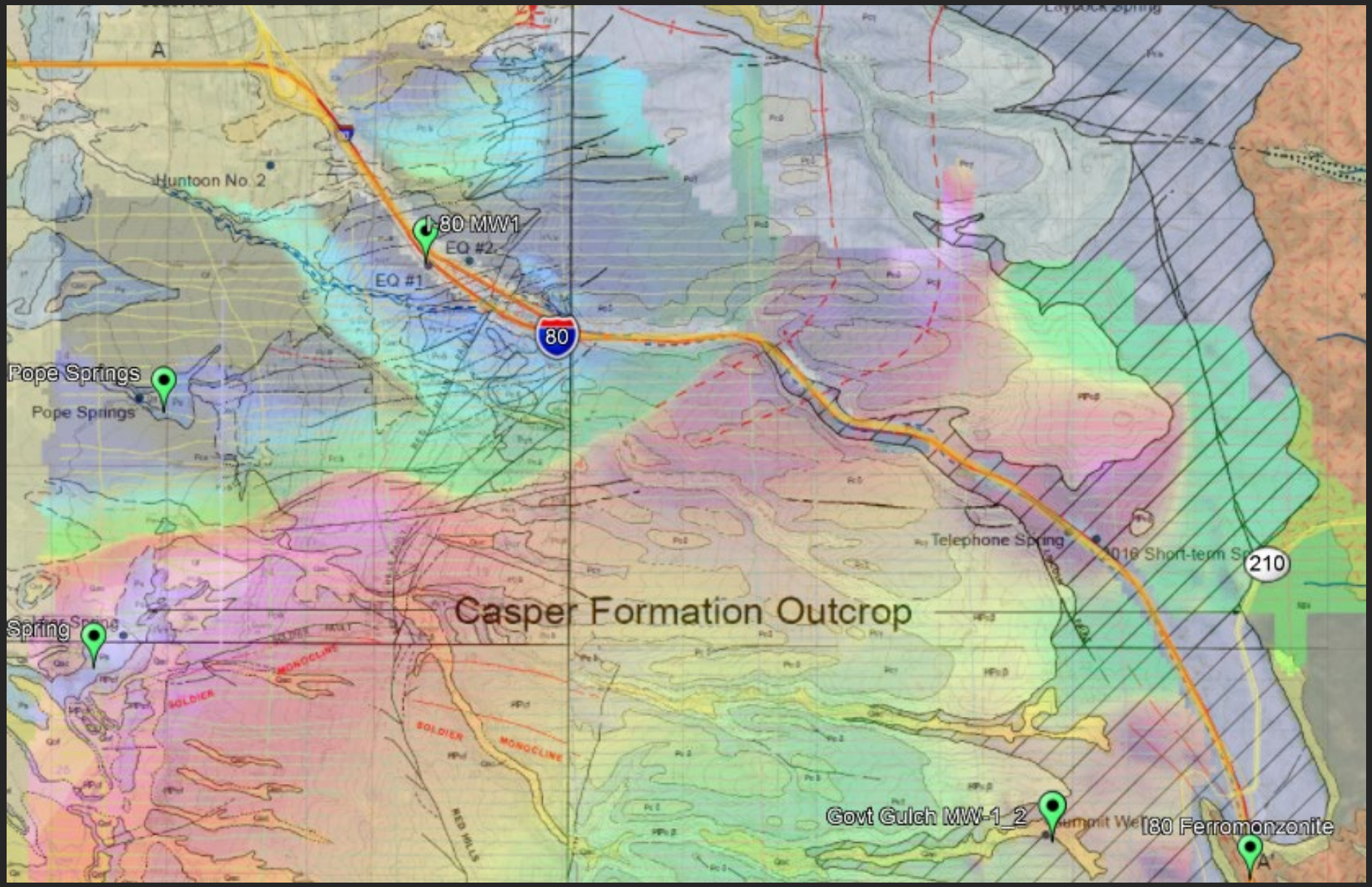
Airborne Magnetics (Aeromag)



Geosoft Oasis Montaj and Google Earth

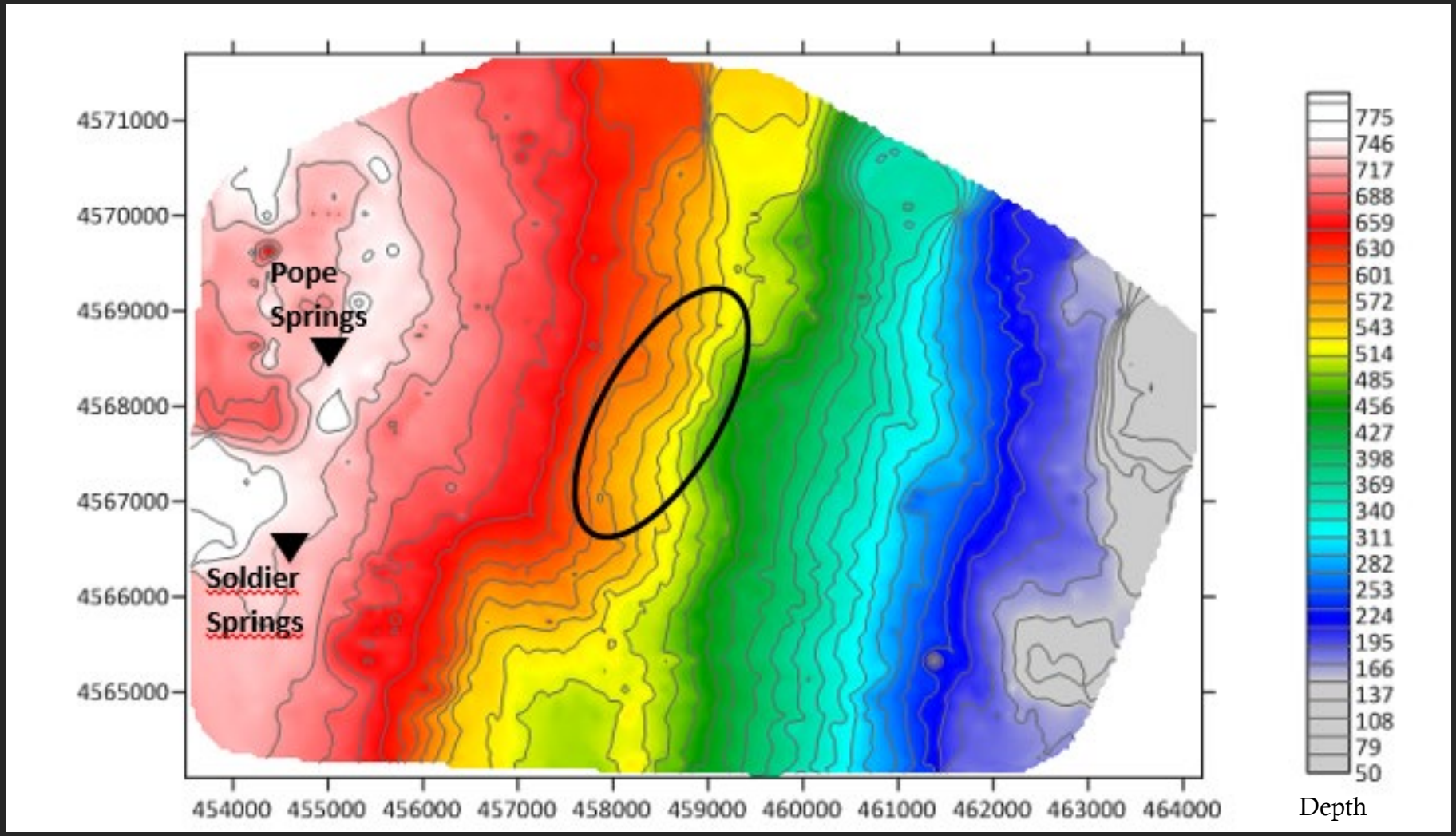

nT
1
3
4
0
7
-
6
7
0
27
40
54
80
82
20
meters
Depth (m)
-
261
9
-
232
4
-
203
7
-
174
6
Casper Aquifer
D=2670, S=0
Sherman Granite
S=0
Monzonite
D=2690, S=0.08

Airborne Magnetics (Aeromag) with surface geologic map overlay

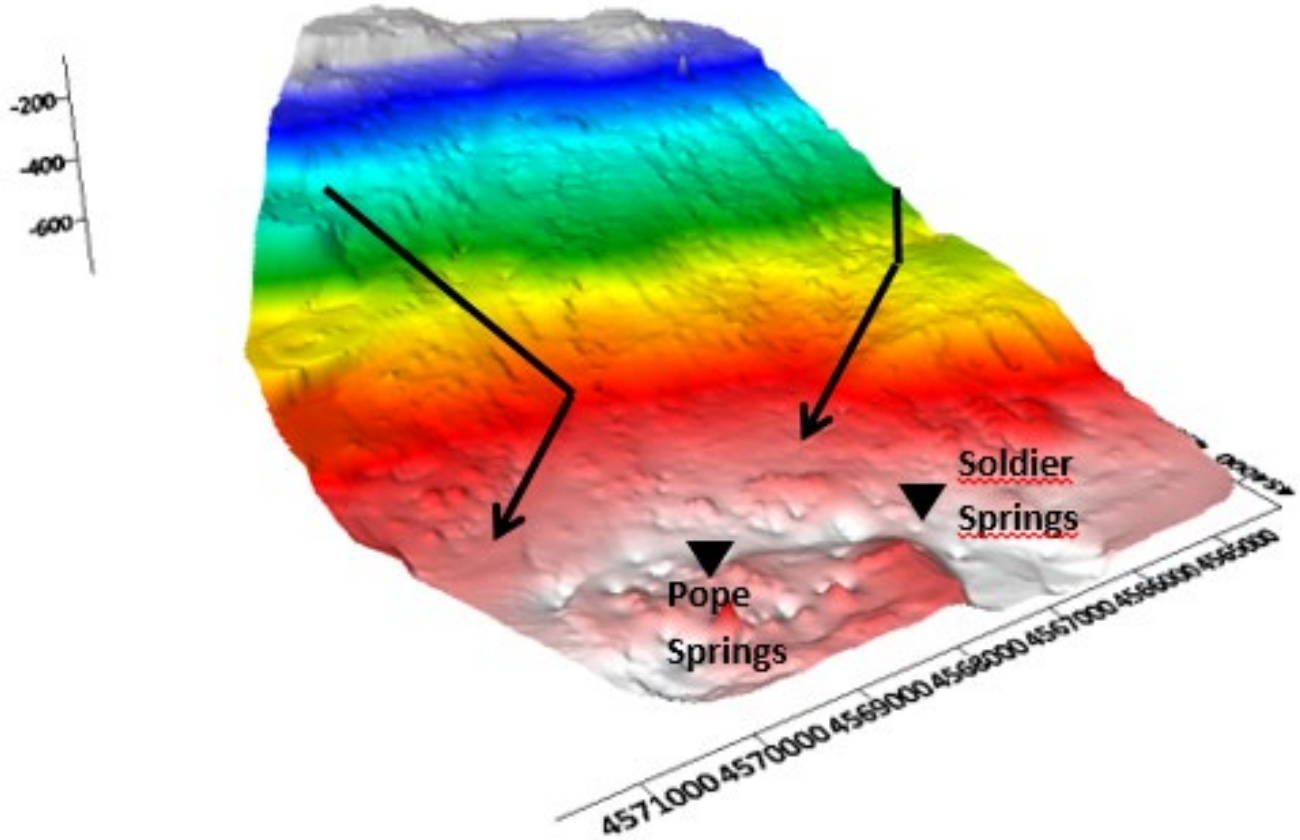


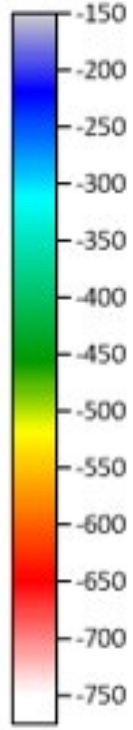
Geosoft Oasis Montaj and
Google Earth

AEM 2019 " Top of Basement" contour map view



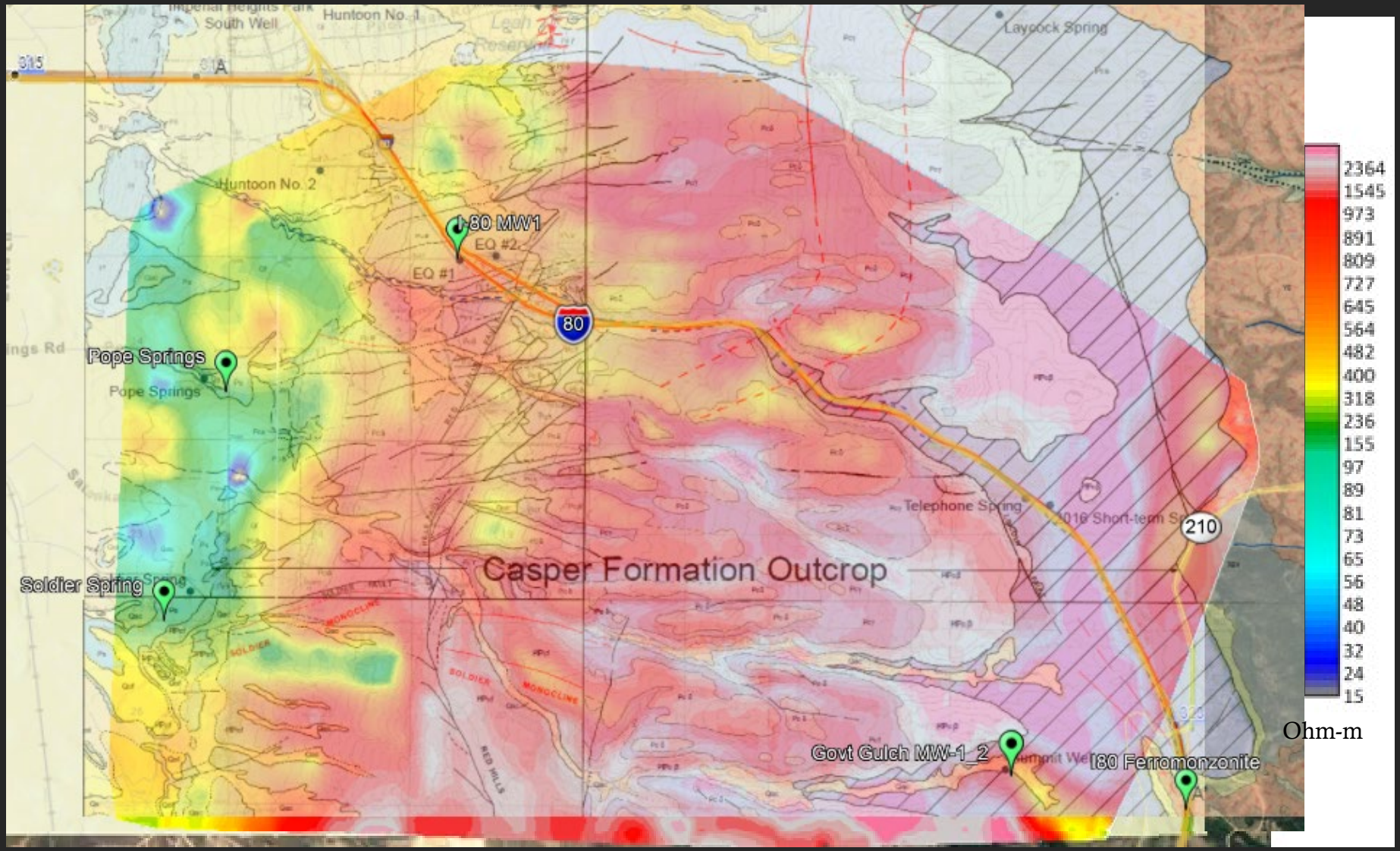
AEM 2019 " Top of Basement" 3D view



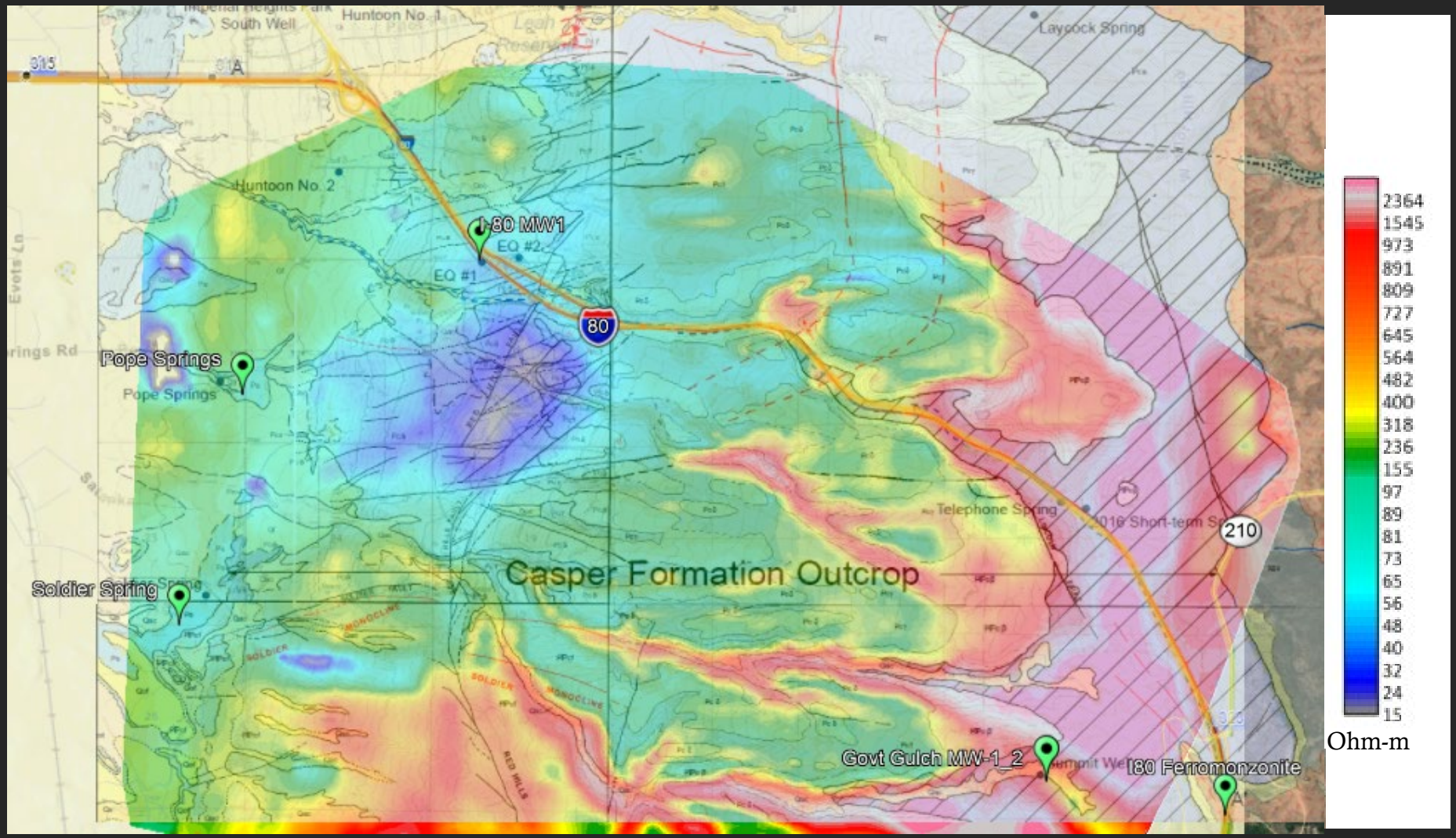


Depth

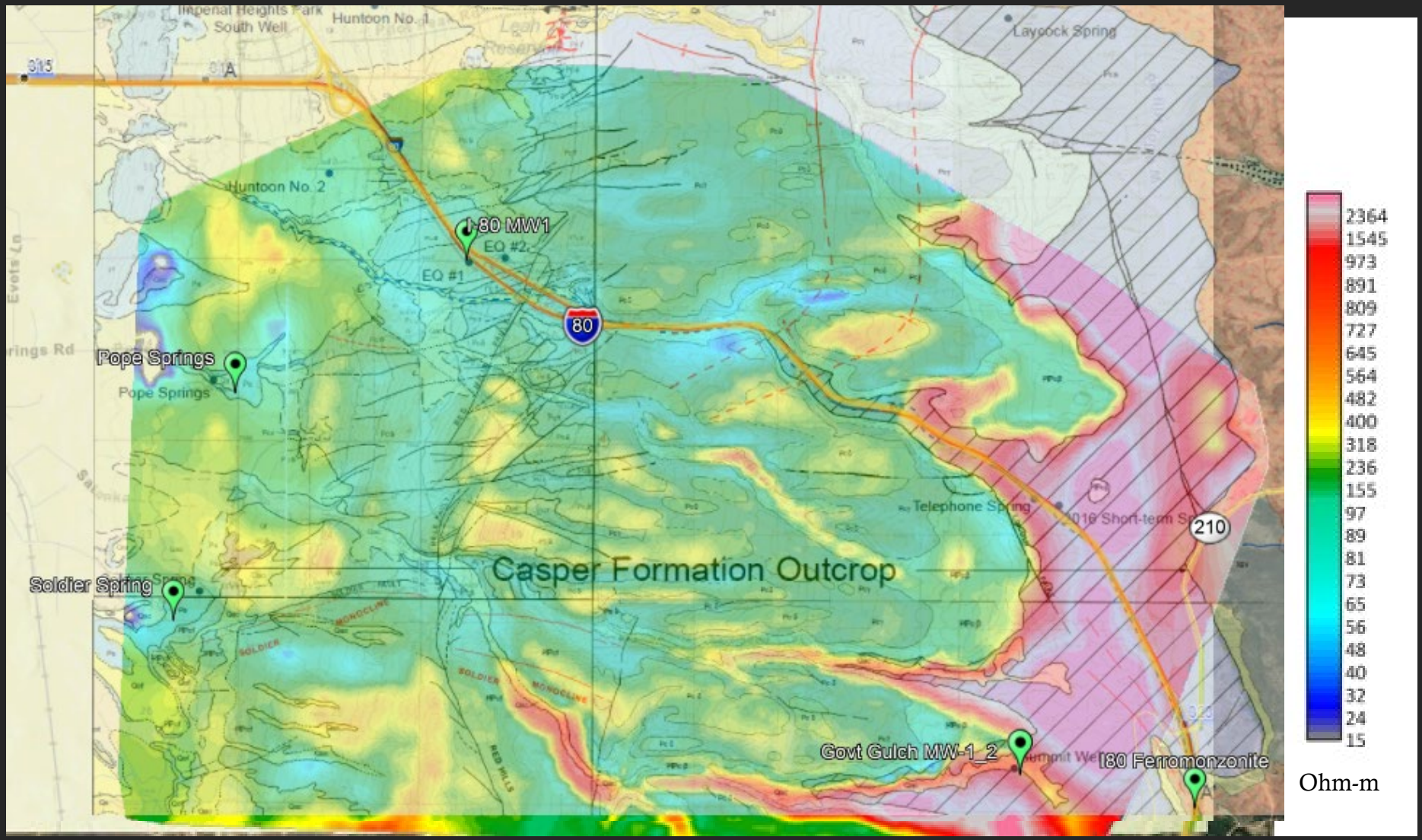
AEM 2019 Resistivity depth slice at 250 m bgs



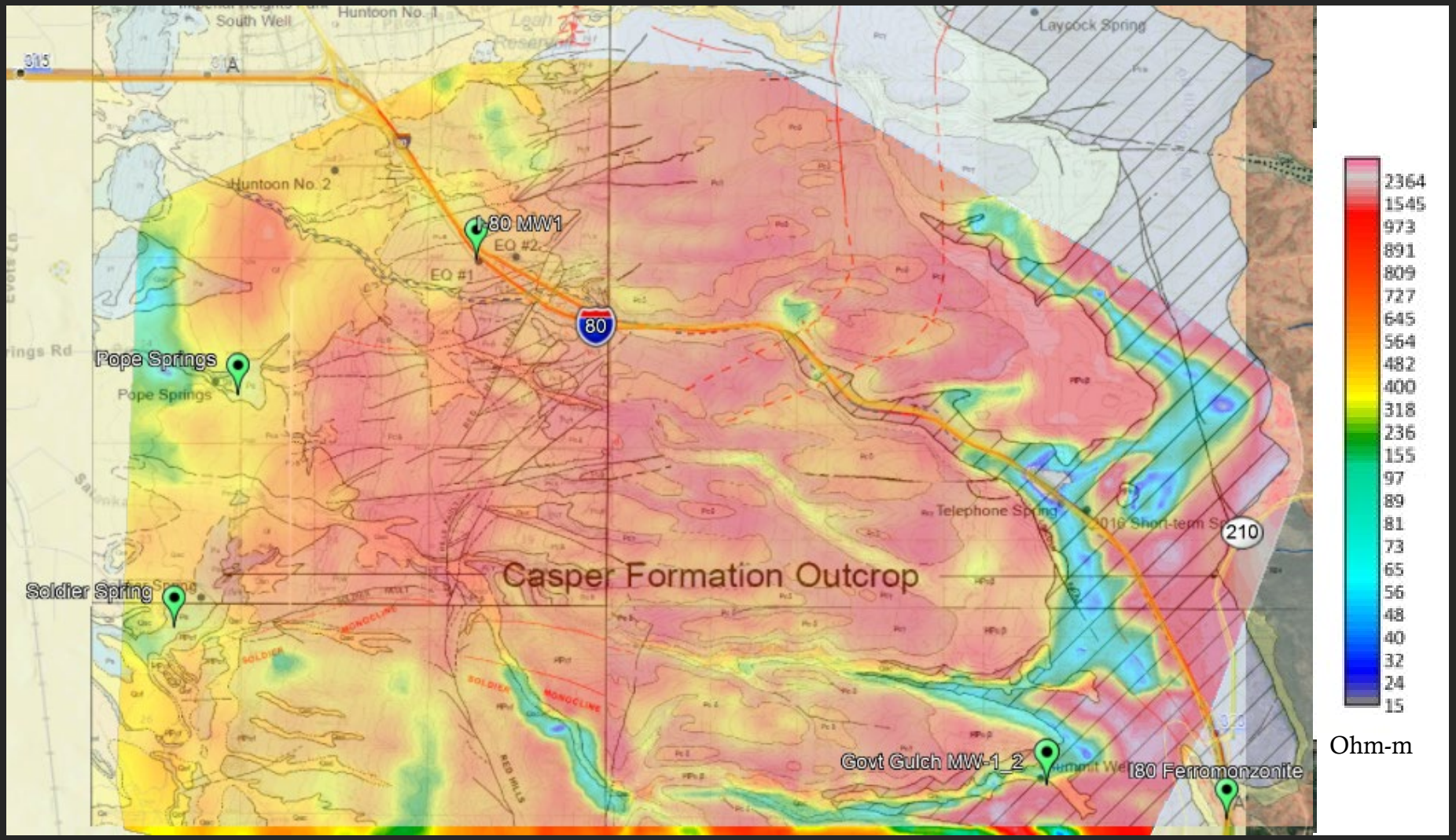
AEM 2019 Resistivity depth slice at 190 m bgs



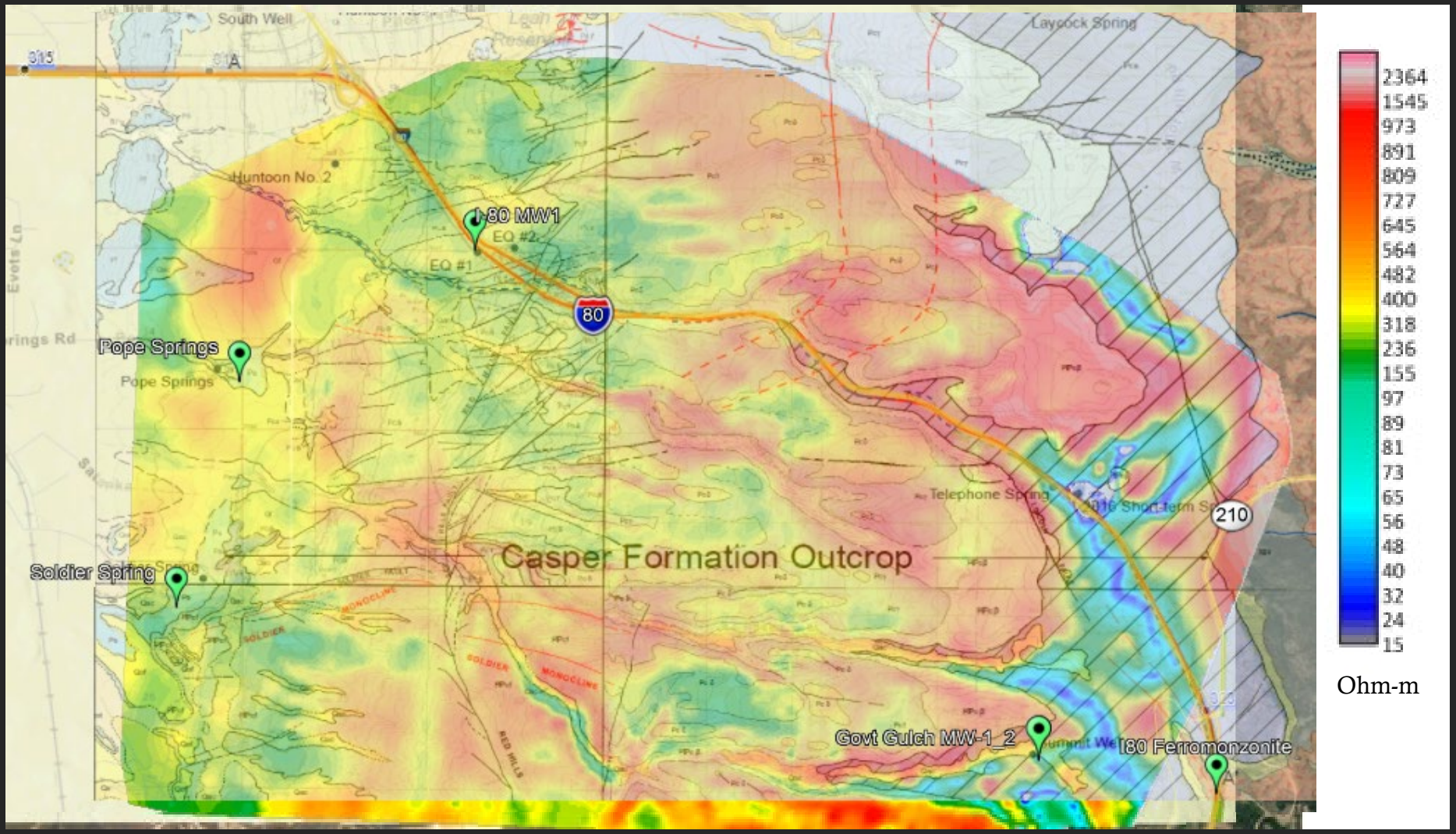
AEM 2019 Resistivity depth slice at 160 m bgs



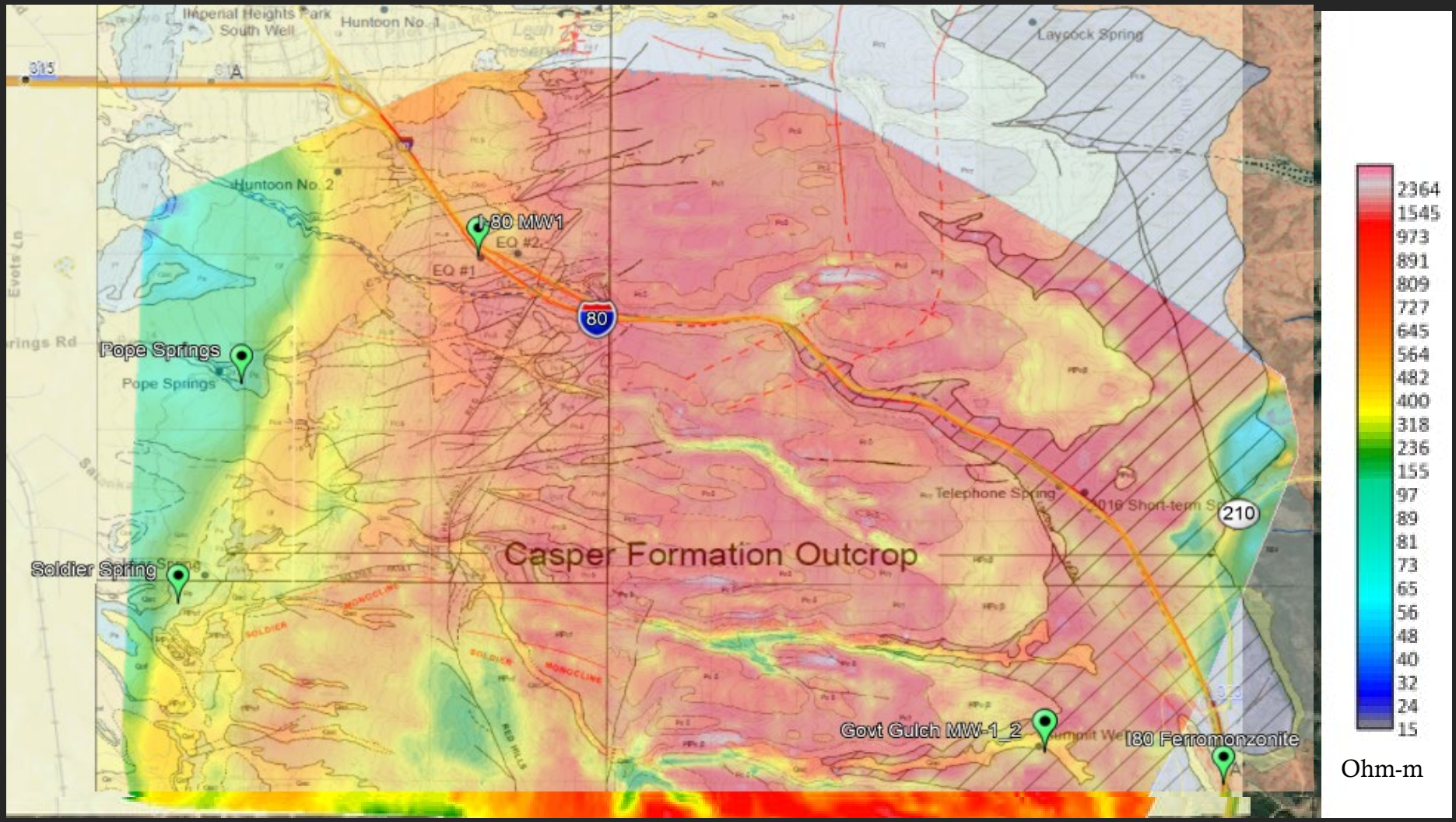
AEM 2019 Resistivity depth slice at 90 m bgs



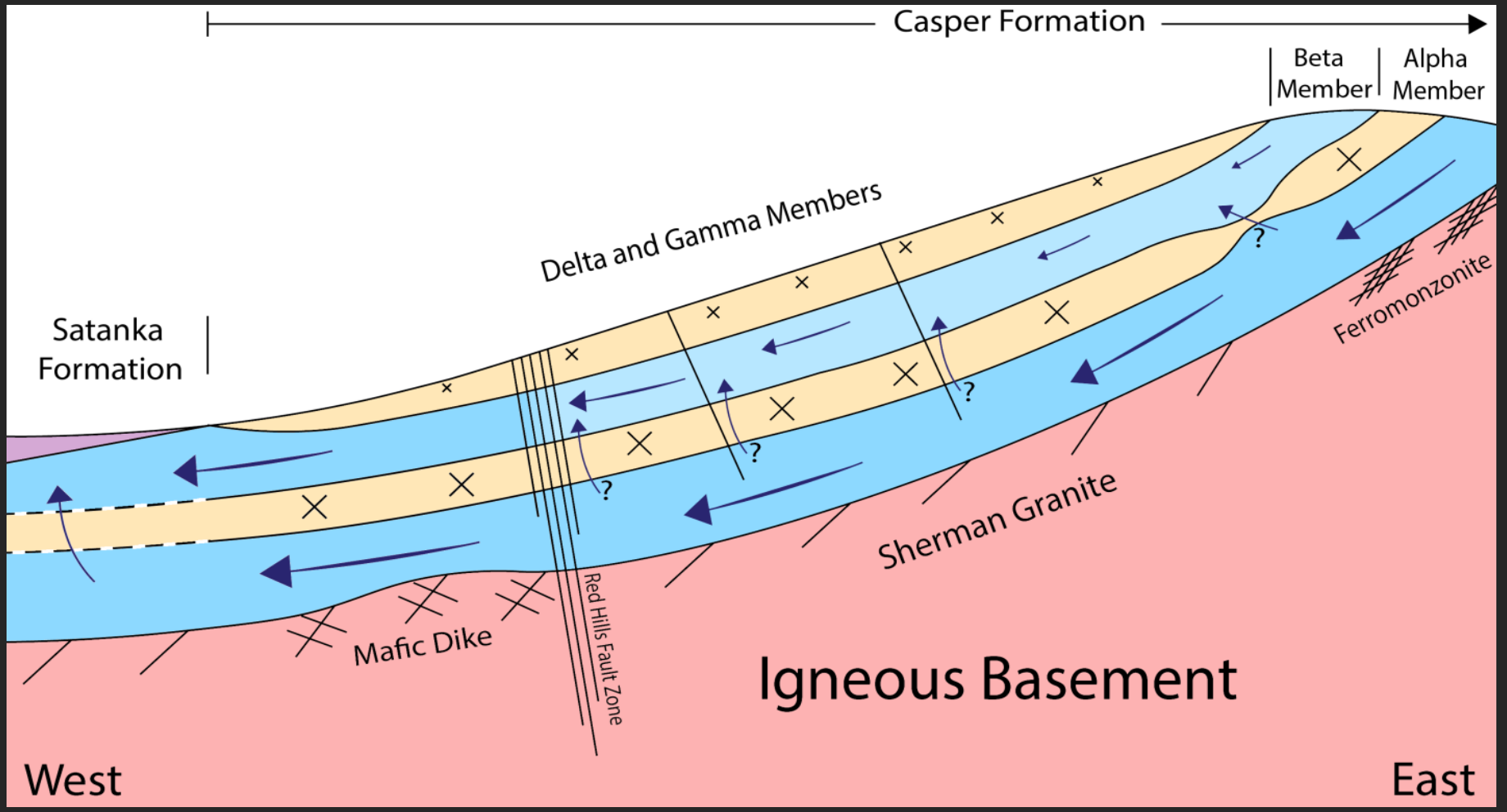
AEM 2019 Resistivity depth slice at 70 m bgs



AEM 2019 Resistivity depth slice at 10 m bgs

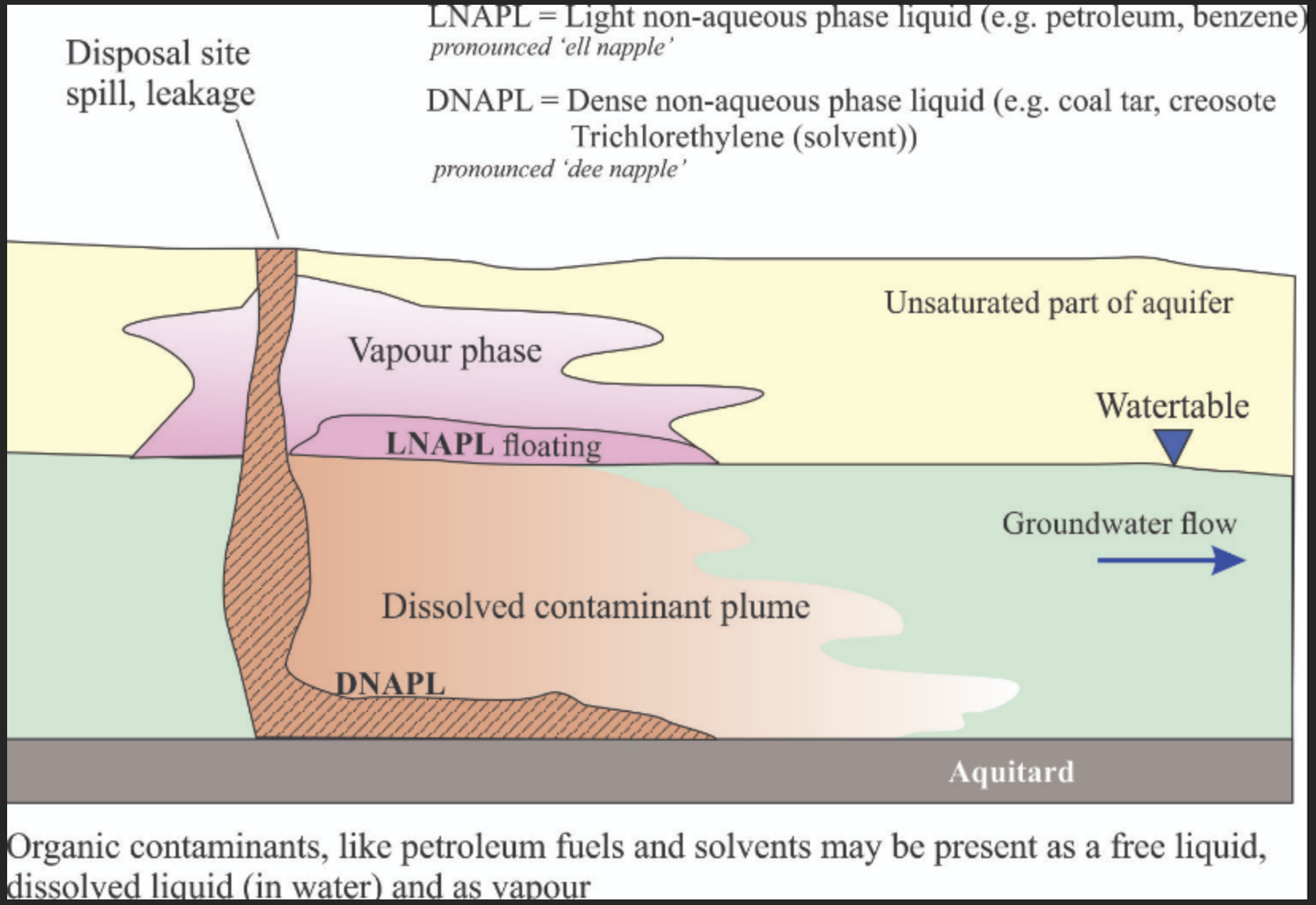


Generalized Conceptual Model



**Not to scale **

Generalized conceptual model of contaminant flow

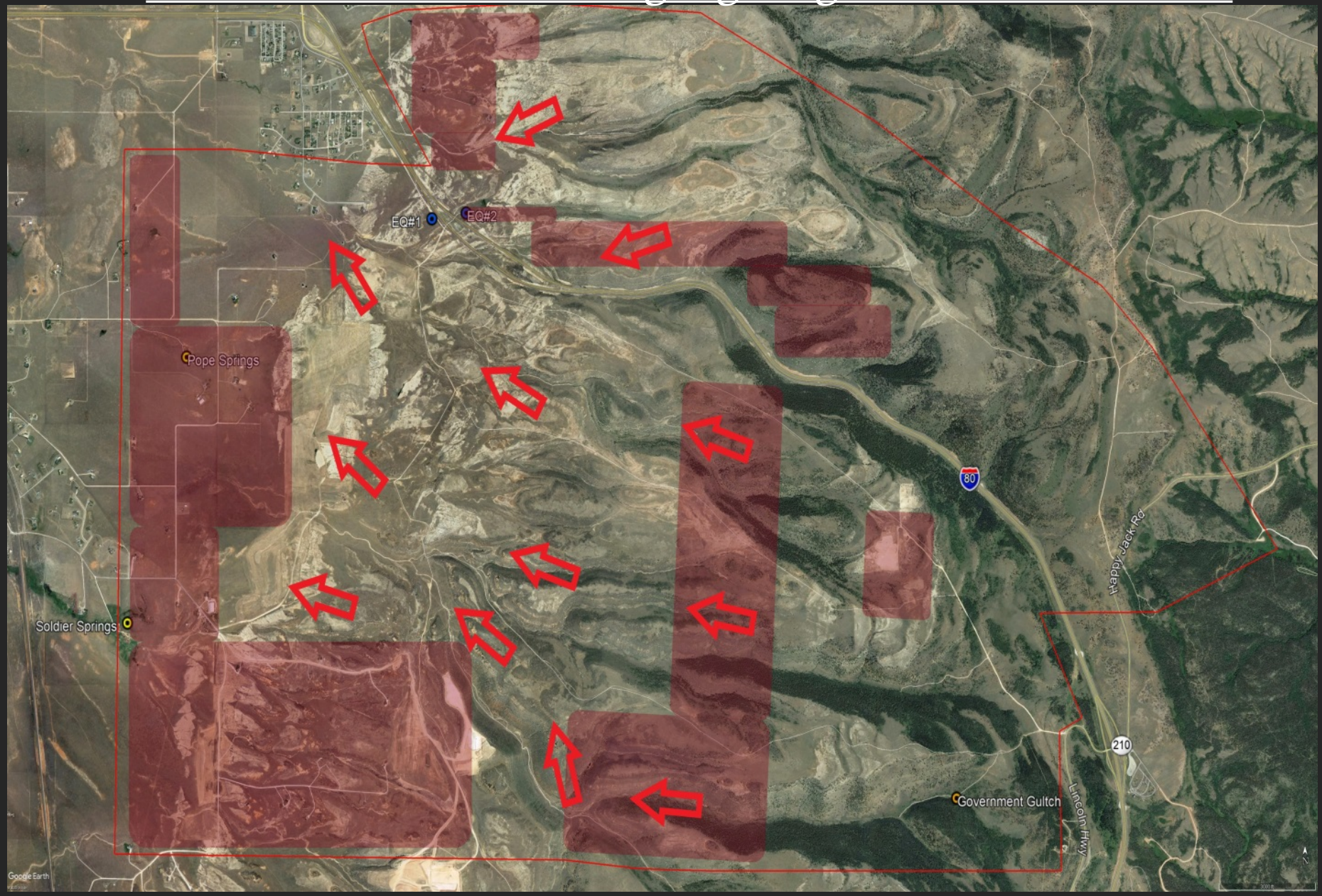


Organic contaminants, like petroleum fuels and solvents may be present as a free liquid, dissolved liquid (in water) and as vapour

Heron Instruments - https://www.heroninstruments.com/news/dnapl-and-lnapl

Interpreted GW Flow in the “deep” hydrostratigraphic unit

Interpreted GW Flow in the "shallow" hydrostratigraphic units with shaded areas highlighting vertical connections



Summary & Year-1 Recommendations

S1: The primary hydrologic unit for Mountain Front Recharge at this site is the lower Casper-Alpha and Fountain formations. Higher stratigraphic members in the Casper Fm. receive “bottom up” GW starting around I-80 mile mark 320 thru faulted zones and geologic structures.

S2: Igneous “basement” (i.e. the Sherman Granite and associated igneous rocks) exhibit a variable surface due again to geologic structures , minerologic changes (i.e. the mafic dike) and faulting which defines a “funnel” like top of basement structure which is interpreted to redirect ambient groundwater in #1 toward Laramie (and specifically City Springs). Further a circular depression in the bedrock surface above the municipal wellfields is interpreted to influence overlying sedimentary units allowing hydraulic connections thru fault zones at shallower depths.

S3: GW connectivity between I-80 and the municipal wellfields occurs best at the Fountain Fm. hydrogeophysical unit compared to mid-upper Casper Fm. units. However, pumping at the municipal wellfields would likely adjust the ambient condition. Year 2 groundwater modeling will provide greater insight into this question.

Summary & Year-1 Recommendations, cont.

R1: At this stage in the analysis, it seems less likely that under "ambient" conditions an I-80 spill will migrate toward the municipal wellfields structurally or by gravity. It would more probably move toward the City of Laramie. However, under a combination of "unfortunate" conditions and/or municipal wellfield pumping, spilled material at I-80 could migrate both toward Laramie and the municipal wellfields. To potentially mitigate either scenario, one recommendation is to modify the I-80 monitoring wells (near mile mark 318) and a portion of the Pope Springs wellfield to not only sampling wells but "pump and treat" wells, if needed. If these specific wells can not be modified properly for this, nearby construction of 2 new wells at each site for this purpose would provide an "early warning" for the shallow, hydraulic units of the Casper Fm.

R2: Drilling and installing wells into the deeper hydrostratigraphic unit (i.e. the lower Casper-Alpha and Fountain for groundwater and casing overlying shallower units minimizes "short distance" contaminate pathways for shallower Casper units. To monitor threats to the "deeper" hydrostratigraphic unit, 2 new monitoring wells (with a "pump and treat" potential) between mile mark 322 and 323 along I-80.

R3: Seek additional funding airborne EM studies along the entire defined Casper Aquifer Protection Area to better define areas for future groundwater development, if needed.

Year 2 Goals & Timeline

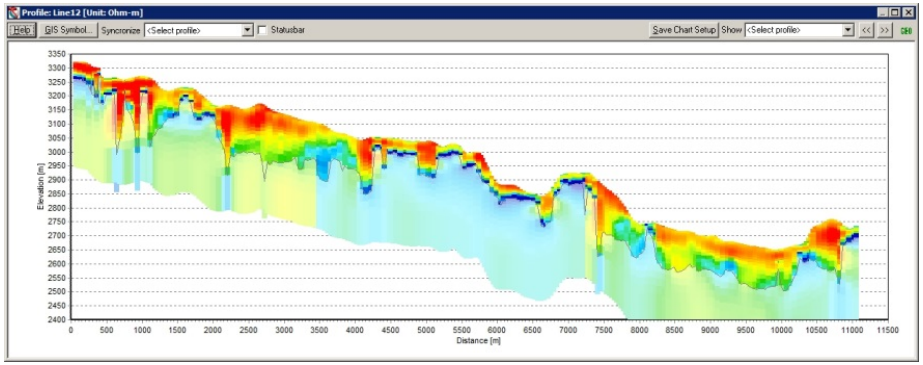
- Groundwater modeling

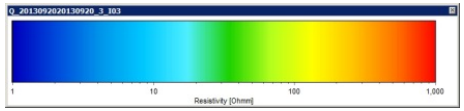
  (Summer 2020 thru Spring 2021)

- Possible use of USGS MODFLOW/MODPATH
  - Groundwater flow and contaminant transport models
- Modeling of both generalized Recharge and I-80 Contaminant scenarios
- July-August 2021 – Year 2 – Final Report and Presentation

Thank you

Questions?





2013 UW AEM Survey of the Snowy Range, WY

-Right: Helicopter taking off near Centennial

-Above: Subsurface resistivity data from the UW 2013 AEM survey.