

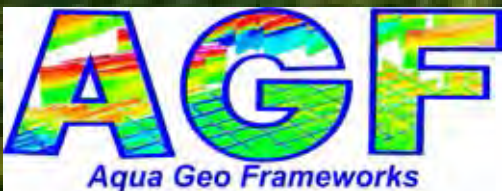
AEM-Based Hydrogeological Frameworks in the Central Valley of California

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Aqua Geo Frameworks, LLC



March 21, 2017



Presentation Outline

- Investigation Objectives
- AEM Data Acquisition
- Processing & Inversion
- Interpretation
 - Recharge Areas
 - New Drilling Targets

Investigation Objectives

- 1) Develop a 3D hydrogeological framework to assist in water resources management.
- 2) Produce maps of aquifer materials including potential Managed Aquifer Recharge (MAR) areas
- 3) Identify optimal drilling locations for production, monitoring, and test wells

AEM Data Acquisition

- 1) Multiple AEM investigations were conducted in the San Joaquin Valley in late 2015 for private land owners.
- 2) 2,255 line-kilometers of airborne time-domain and magnetic Total Field data were acquired with the SkyTEM 508.



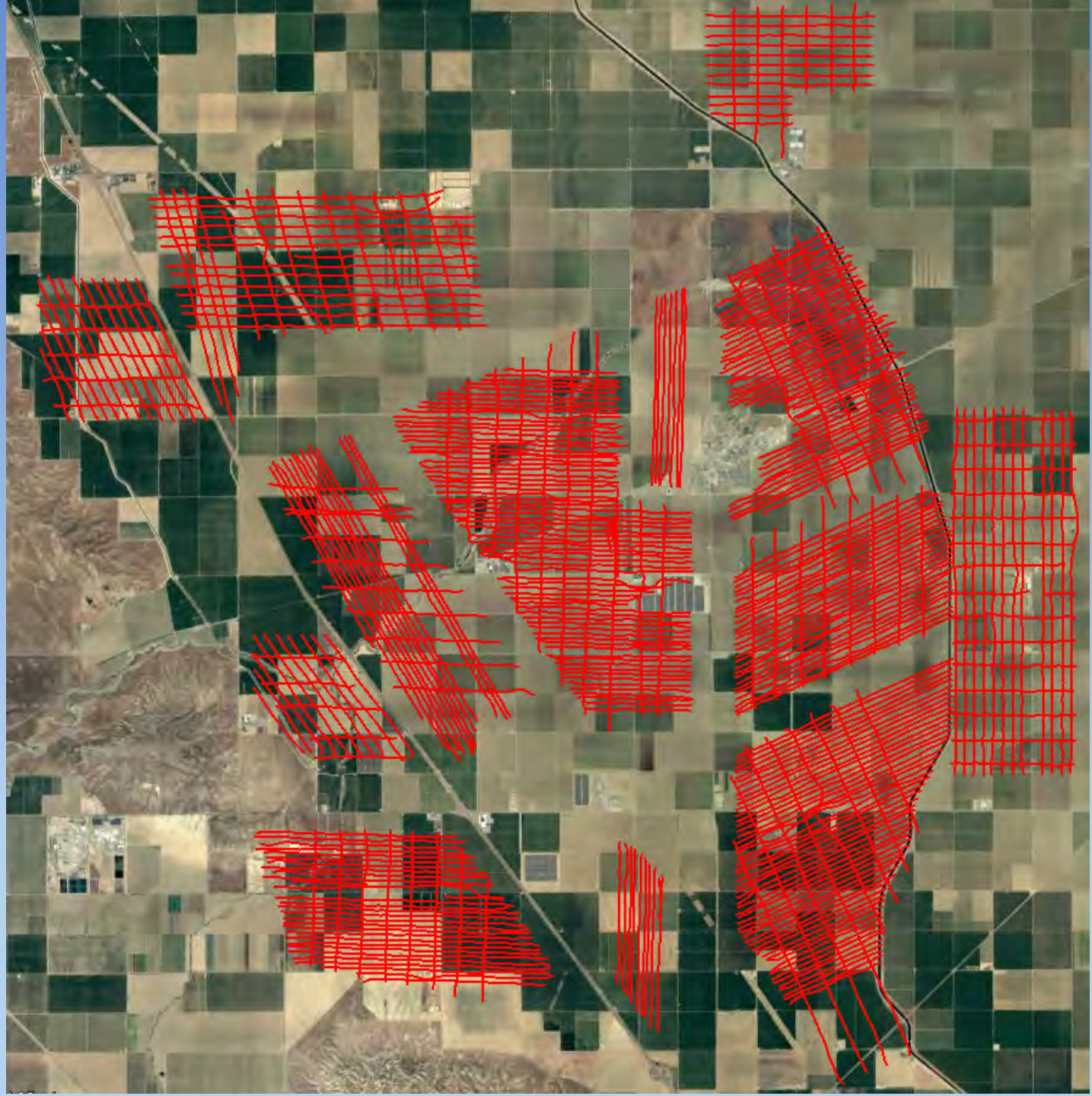
21 March 2017



AEM Data Acquisition

Area 1

1537 line-km
(949 line-miles)

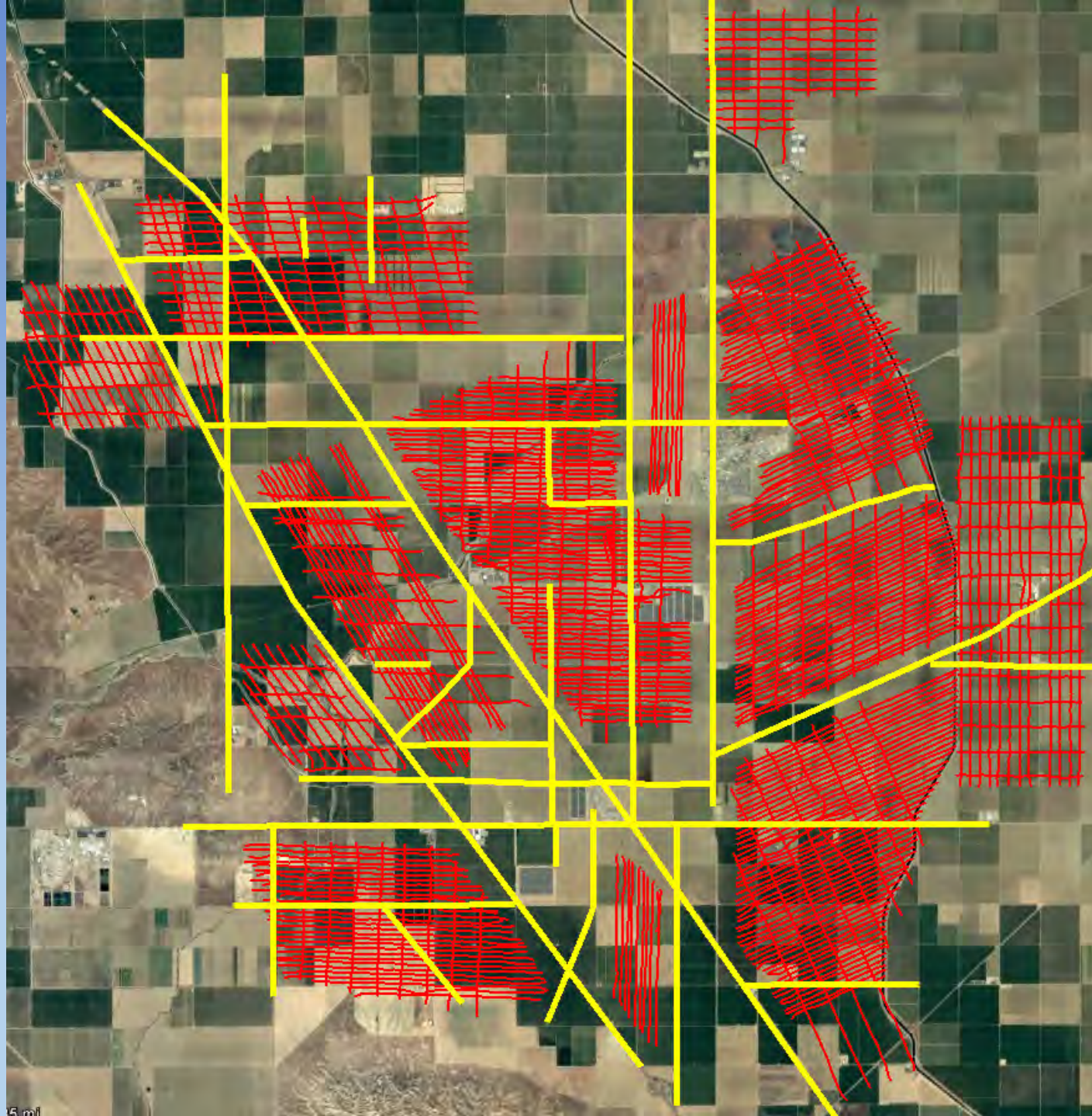


AEM Data Acquisition

Area 1

Power Lines
(Provided by Client)

The survey must be designed to account for power lines, pipelines, and other electromagnetic noise sources.

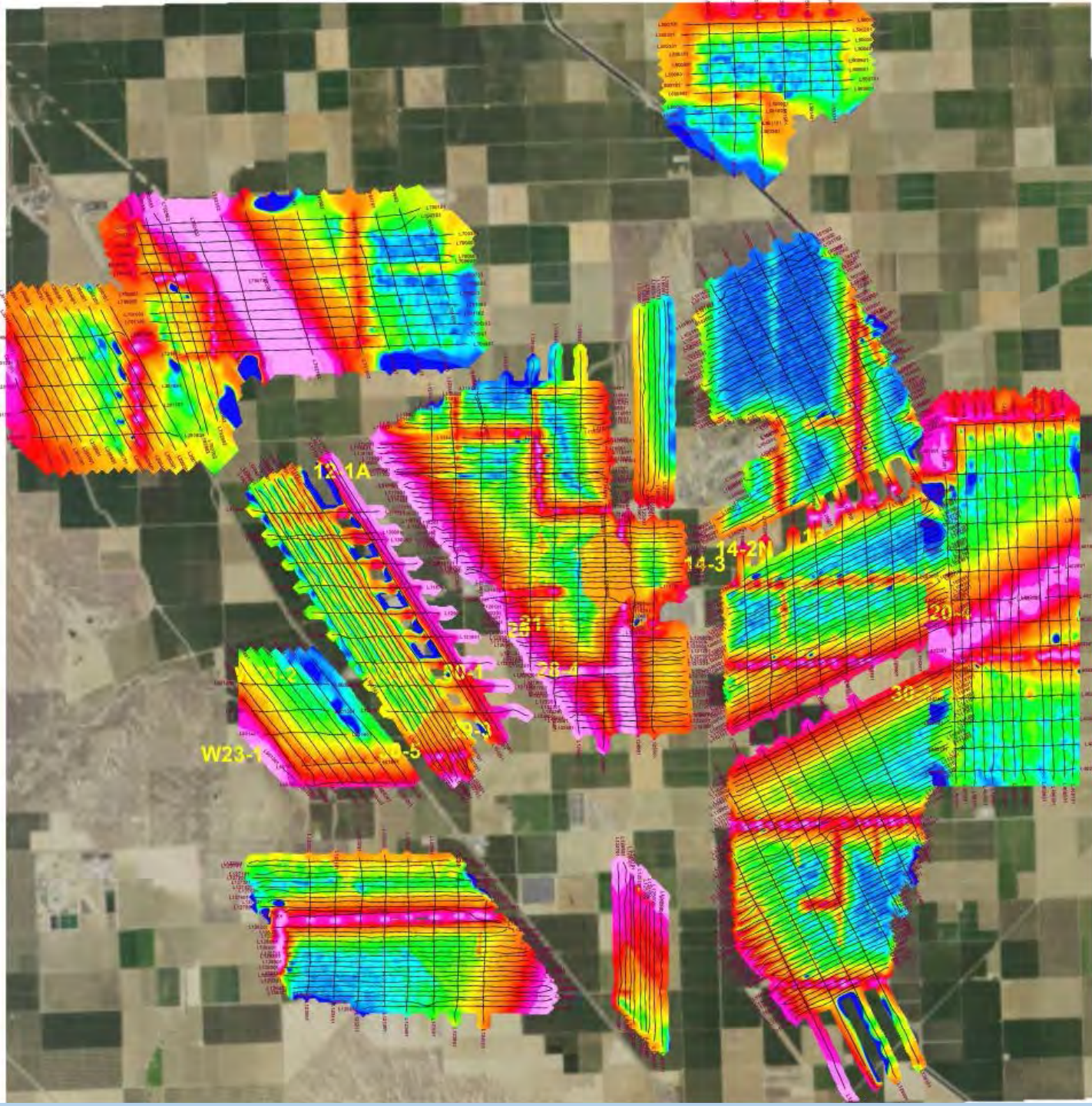


AEM Data Acquisition

Area 1

Power Line Noise Intensity Channel (V/m²)

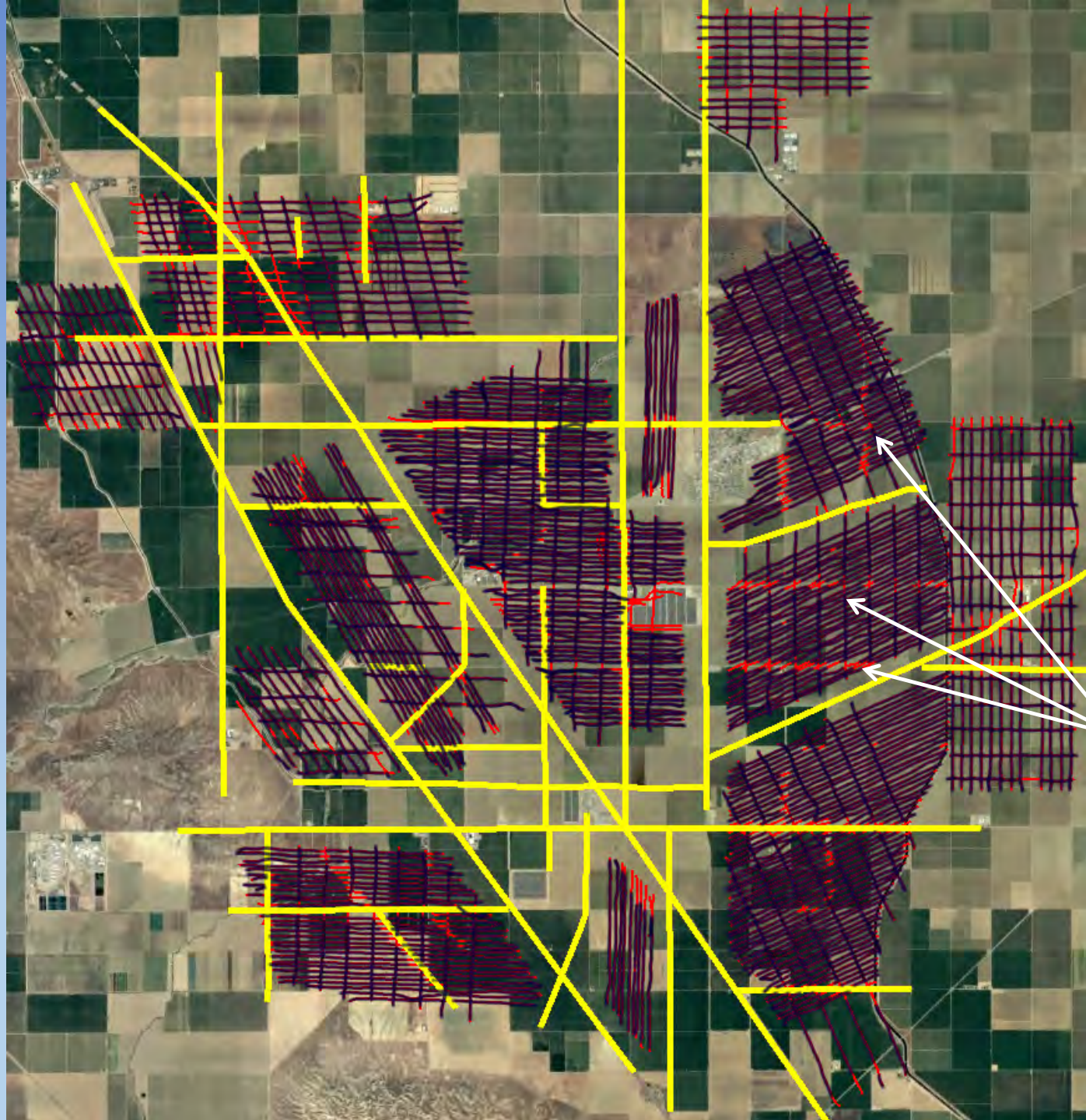
The survey must be designed to account for power lines, pipelines, and other electromagnetic noise sources.



AEM Data Acquisition

Area 1

Blue Lines –
Data Retained
for Inversion
after removal of
coupled em noise.

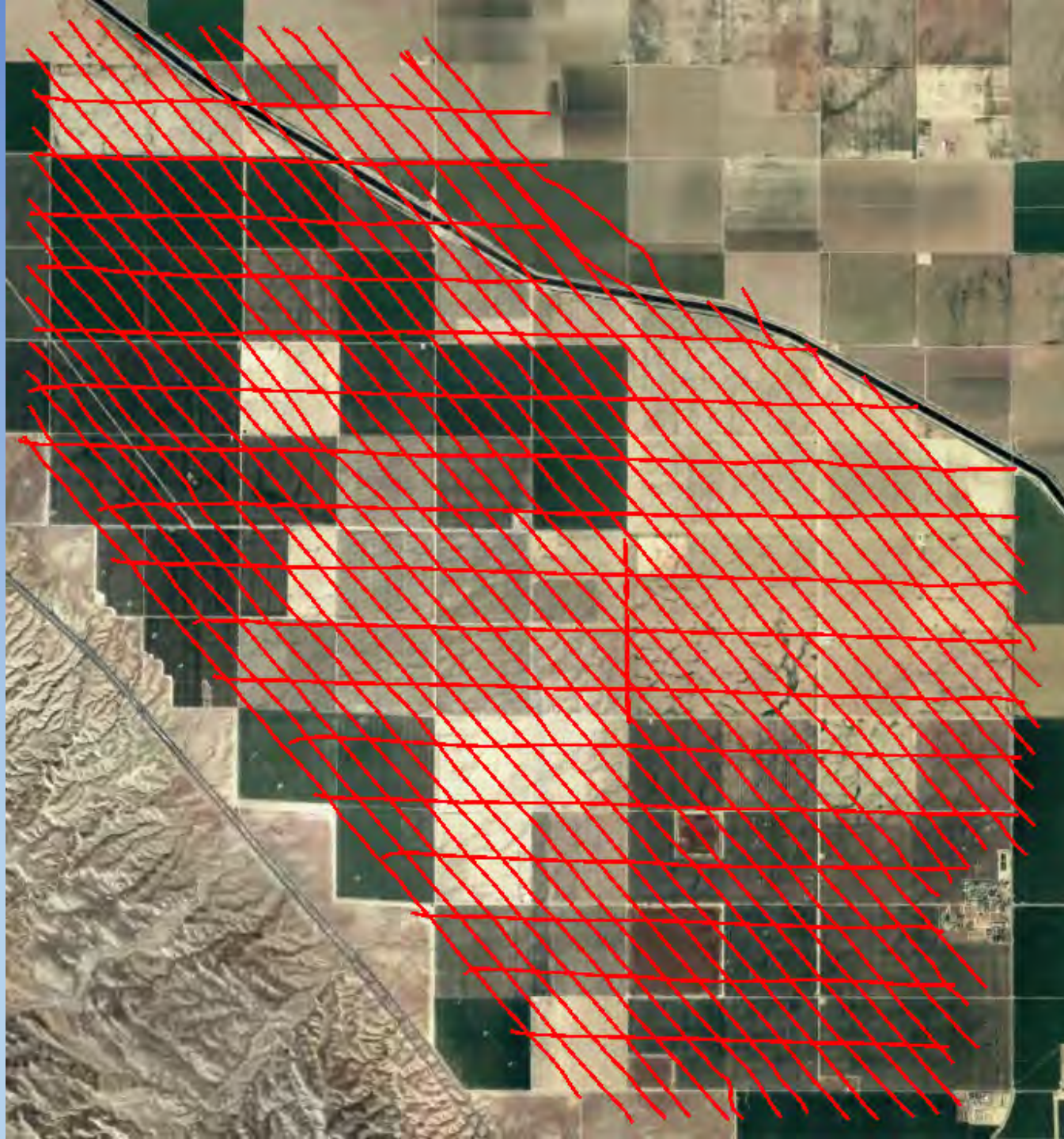


Not all power lines were accounted for

AEM Data Acquisition

Area 2

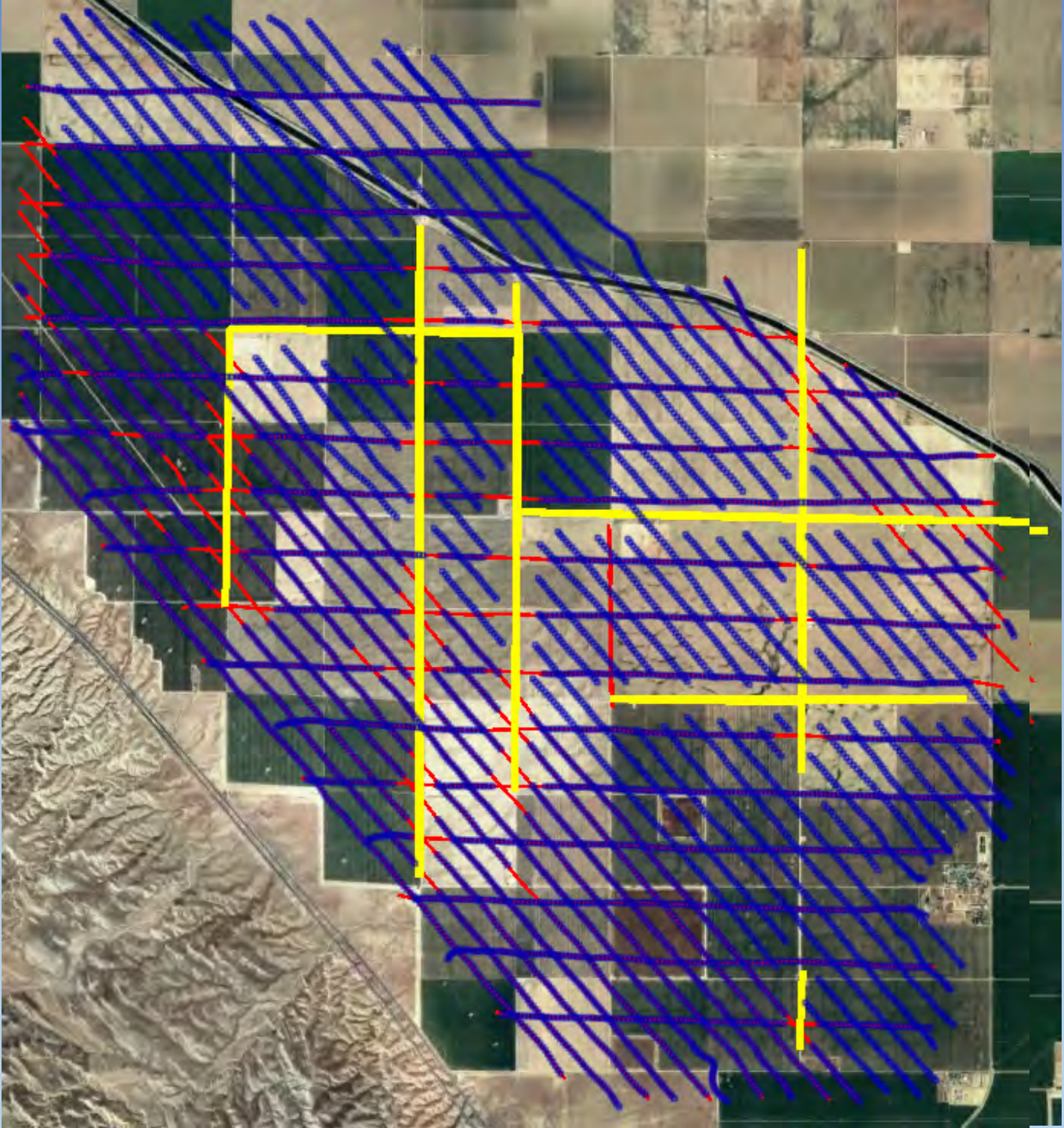
356 line-km
(220 line-miles)



AEM Data Acquisition

Area 2

Blue Lines –
Data Retained
for Inversion
after removal of
coupled em noise.

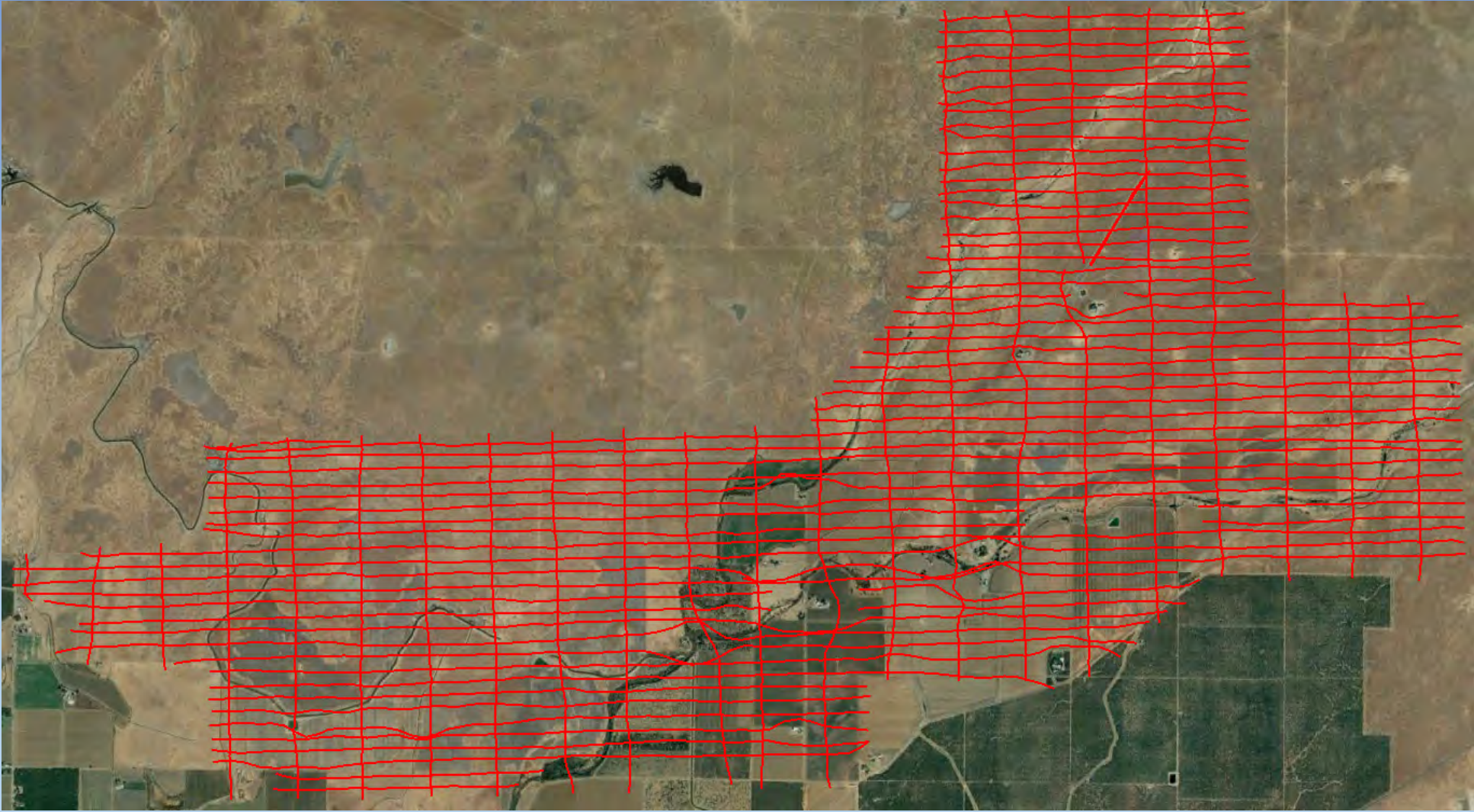


AEM Data Acquisition



Area 3

361 line-km
(223 line-miles)



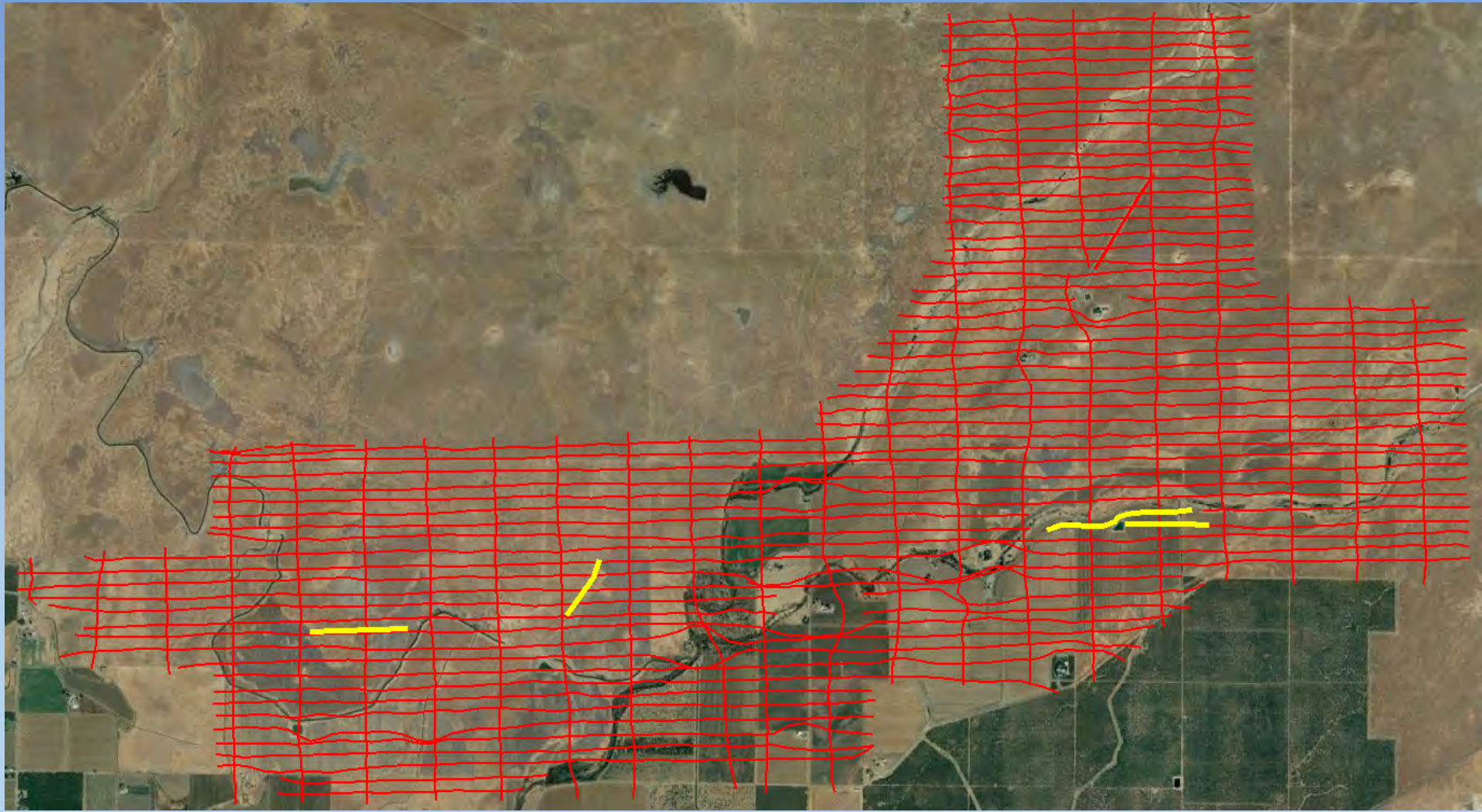
AEM Data Acquisition



Area 3

361 line-km
(223 line-miles)

Power Lines
(Provided by Client)



AEM Data Acquisition

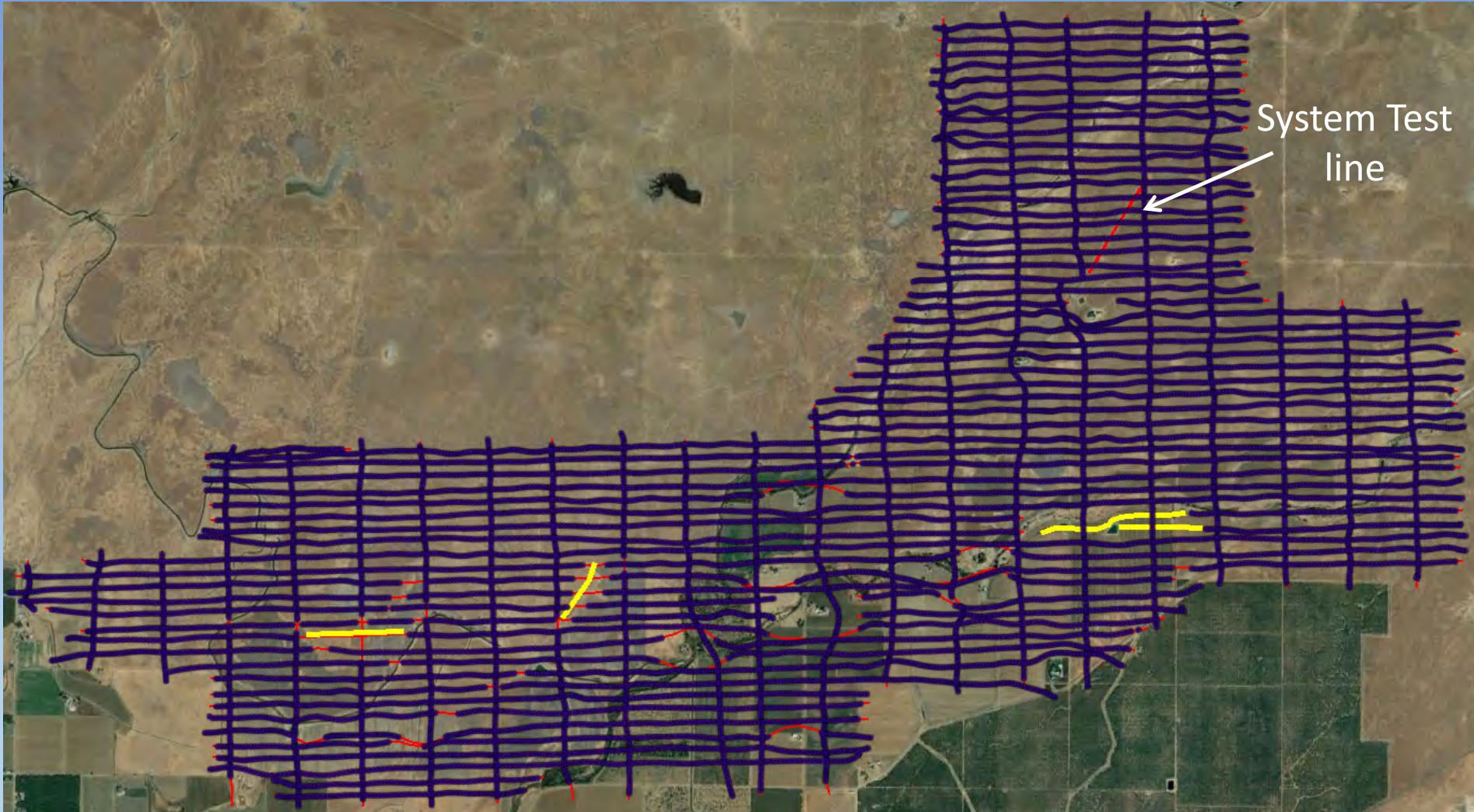


Area 3

361 line-km
(223 line-miles)

Power Lines

Blue Lines –
Data Retained
for Inversion



AEM Data Modeling & Interpretation



- Editing, processing, and inversion were performed within Aarhus Workbench.
- Both Laterally Constrained (LCI) and Spatially Constrained (SCI) Inversions were performed, including borehole logs as *a-priori* data.

Layer	Depth to Bottom (ft)	Thickness (ft)	Layer	Depth to Bottom (ft)	Thickness (ft)
1	9.8	9.8	16	393.3	48.5
2	20.7	10.8	17	447.4	54.1
3	32.8	12.1	18	507.4	60.0
4	46.2	13.4	19	574.3	66.9
5	61.3	15.1	20	648.8	74.5
6	78.1	16.7	21	731.4	82.7
7	96.8	18.7	22	823.6	92.2
8	117.4	20.7	23	925.9	102.3
9	140.4	23.0	24	1040.1	114.1
10	166.0	25.6	25	1167.0	126.9
11	194.5	28.5	26	1308.1	141.0
12	226.3	31.8	27	1464.8	156.8
13	261.7	35.4	28	1639.3	174.5
14	301.1	39.4			
15	344.7	43.6			

Aarhus Workbench Inversions Used 30-Layer Model:

- First Layer – 3 m (10 ft)
- 2nd to Last Layer – 53 m (175 ft)
- Last Layer - Halfspace

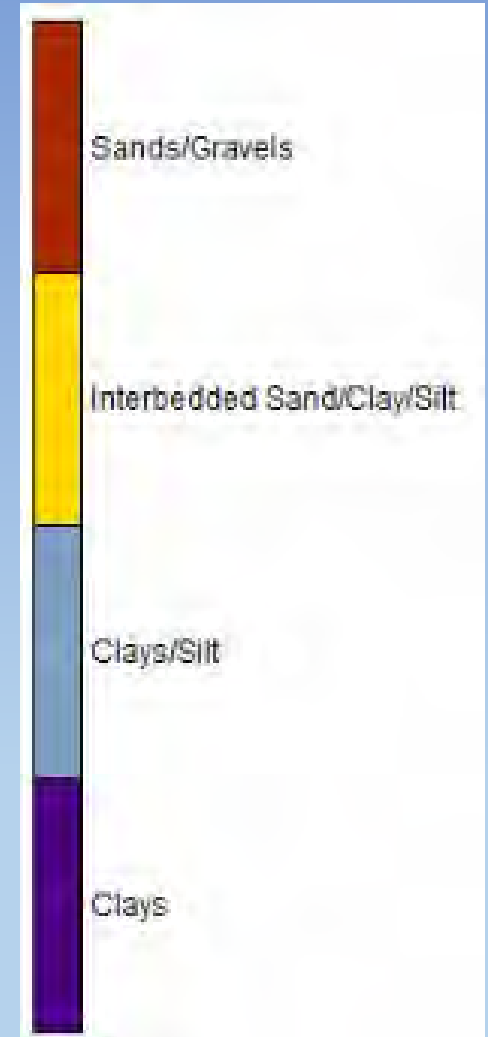
Inversion:

- ‘Spatially Constrained’ – Along the Current Flight Line and on Neighboring Flight Lines, Spatially to a Set Distance
- Data residual mean 0.6 to 0.7

Close examination of local geology maps and borehole logs yielded the following:

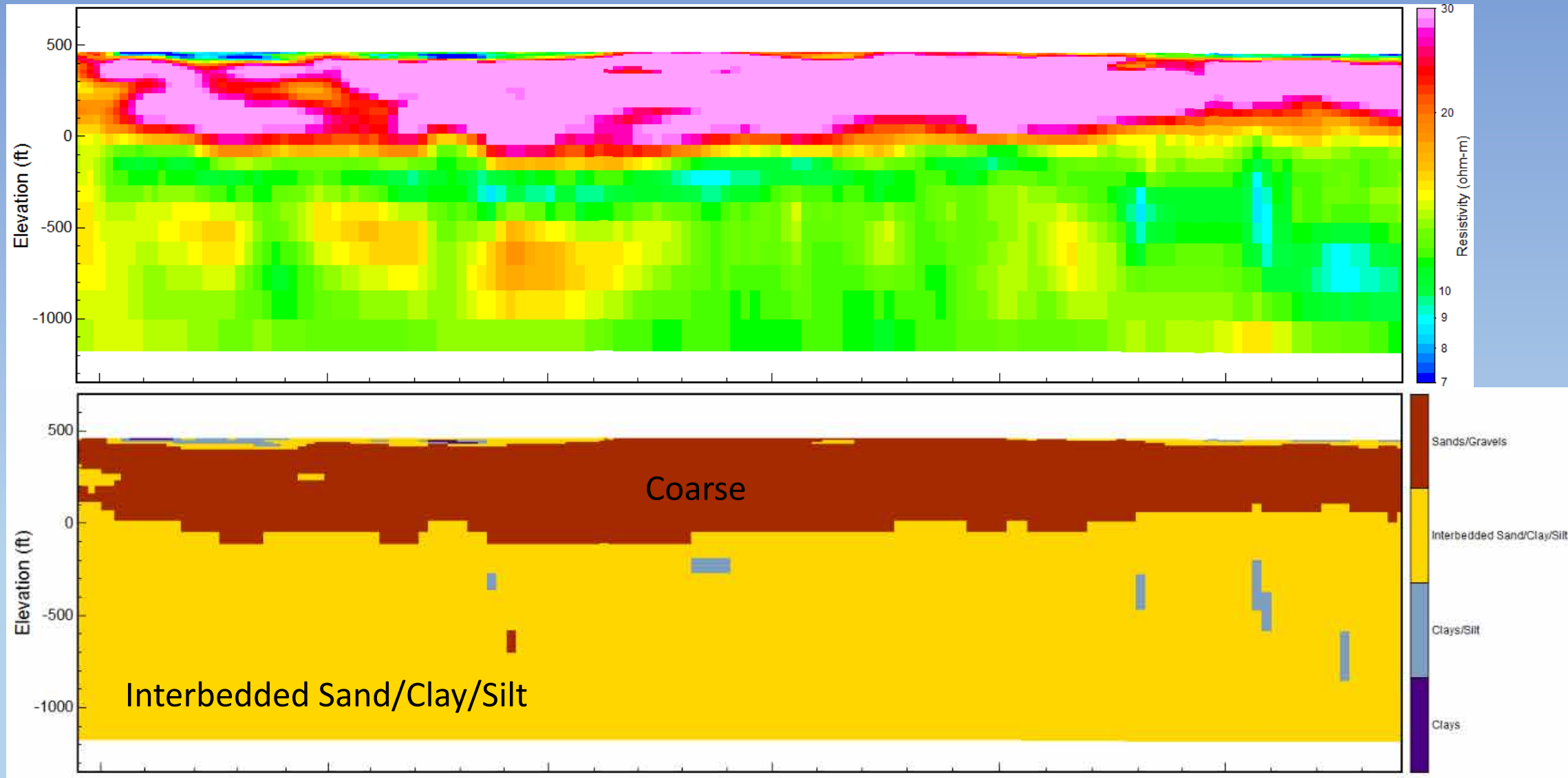
$>18 \text{ ohm-m}$	<i>Sand and Gravel</i>
$9 < x < 18 \text{ ohm-m}$	<i>Interbedded Sand, Silt, and Clay</i>
$6 < x < 9 \text{ ohm-m}$	<i>Clay and Silt</i>
$<6 \text{ ohm-m}$	<i>Clay</i>

Resistivity-Lithology Interpretation



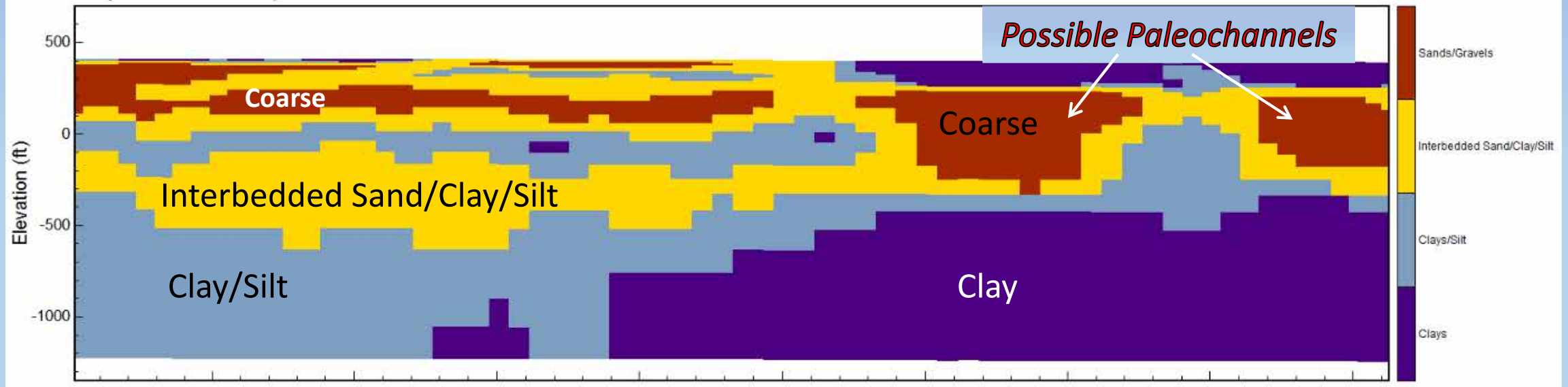
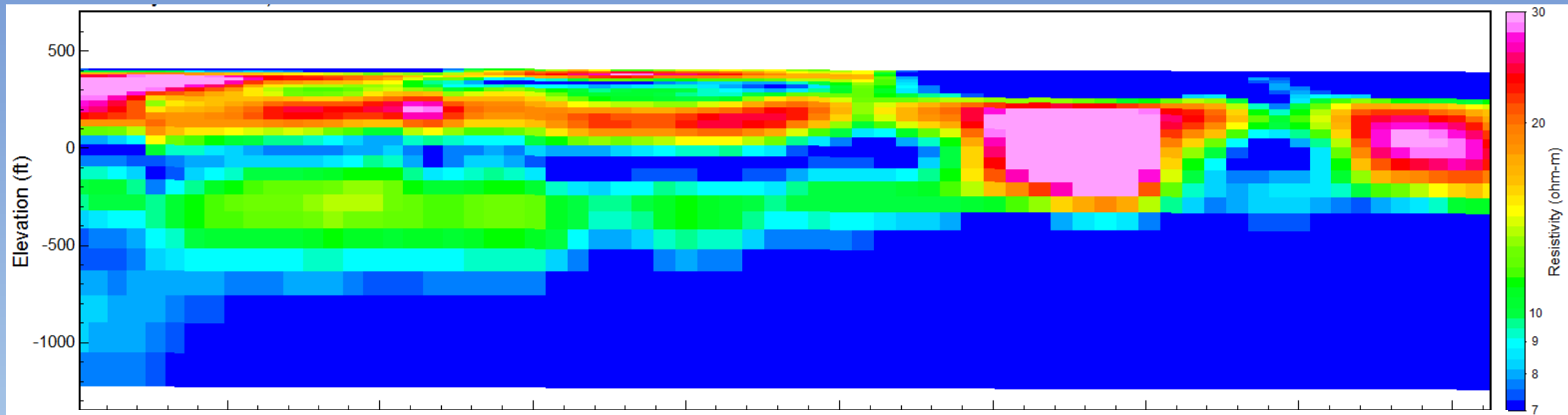
AEM Data Interpretation

Example of Resistivity-Lithology Interpretation: *Area 1, Profile Close to Coast Range, On West Side Of Central Valley*



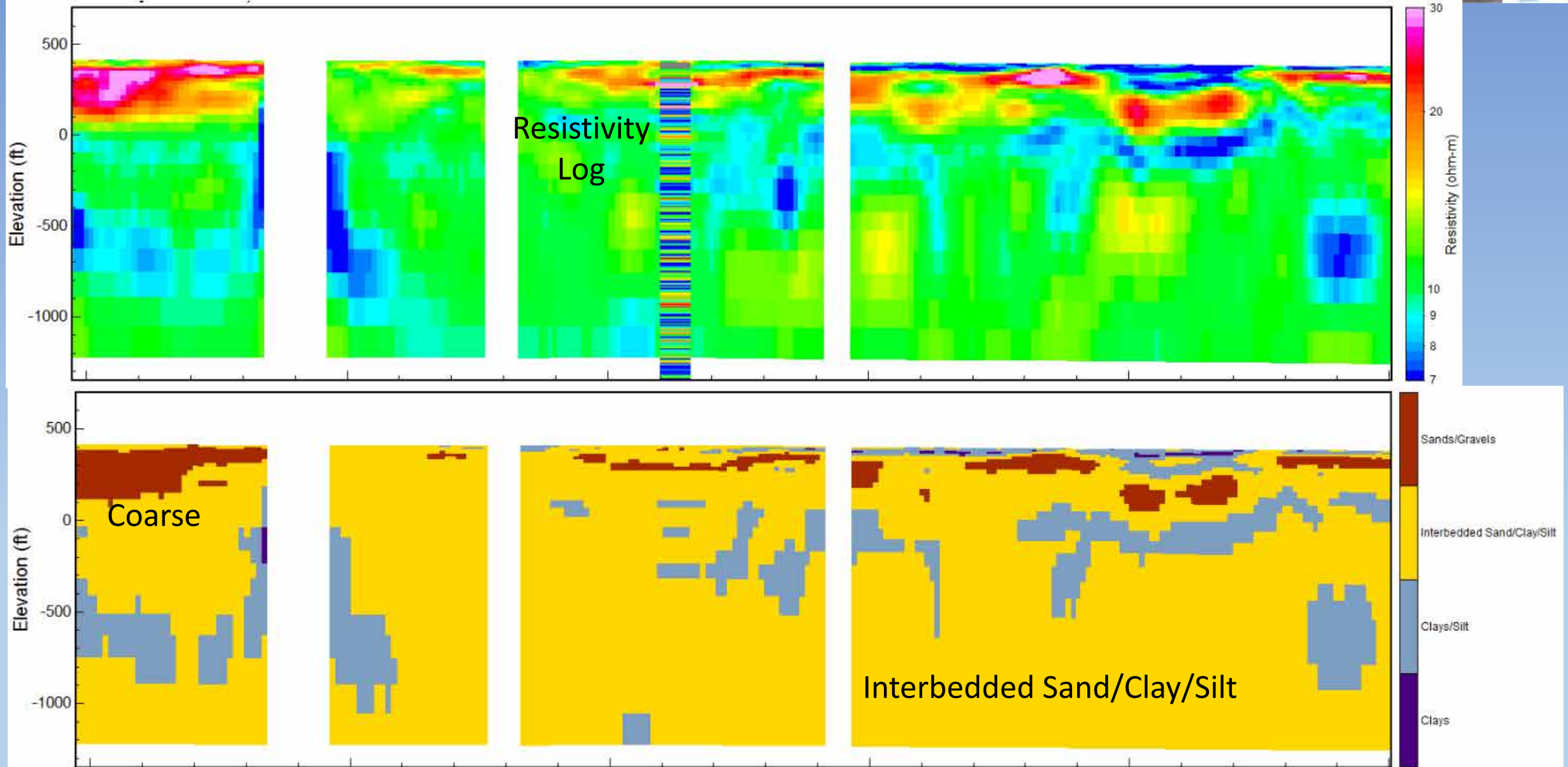
AEM Data Interpretation

Example of Resistivity-Lithology Interpretation: *Area 1, Profile Away From Coast Range Into Central Valley*



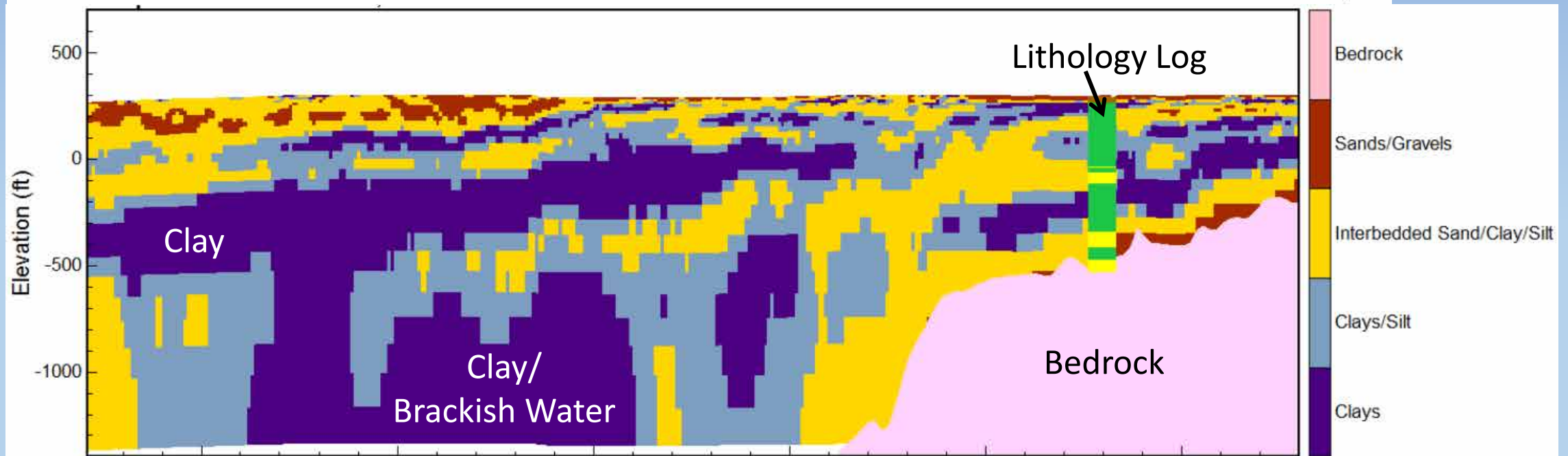
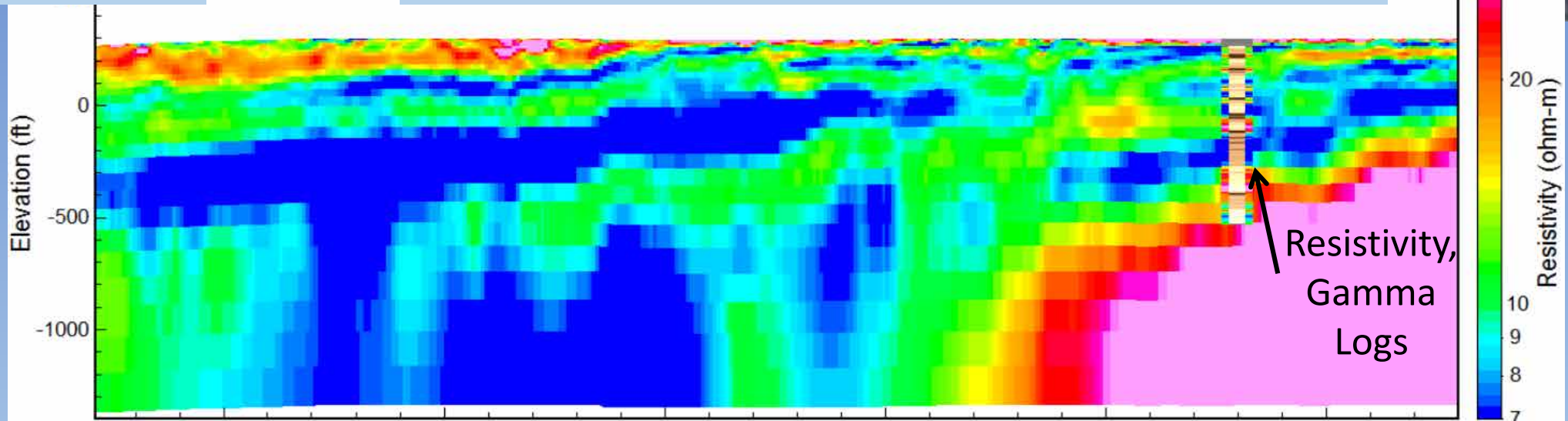
AEM Data Interpretation

Example of Resistivity-Lithology Interpretation: *Area 1, Further Out Into The Central Valley*



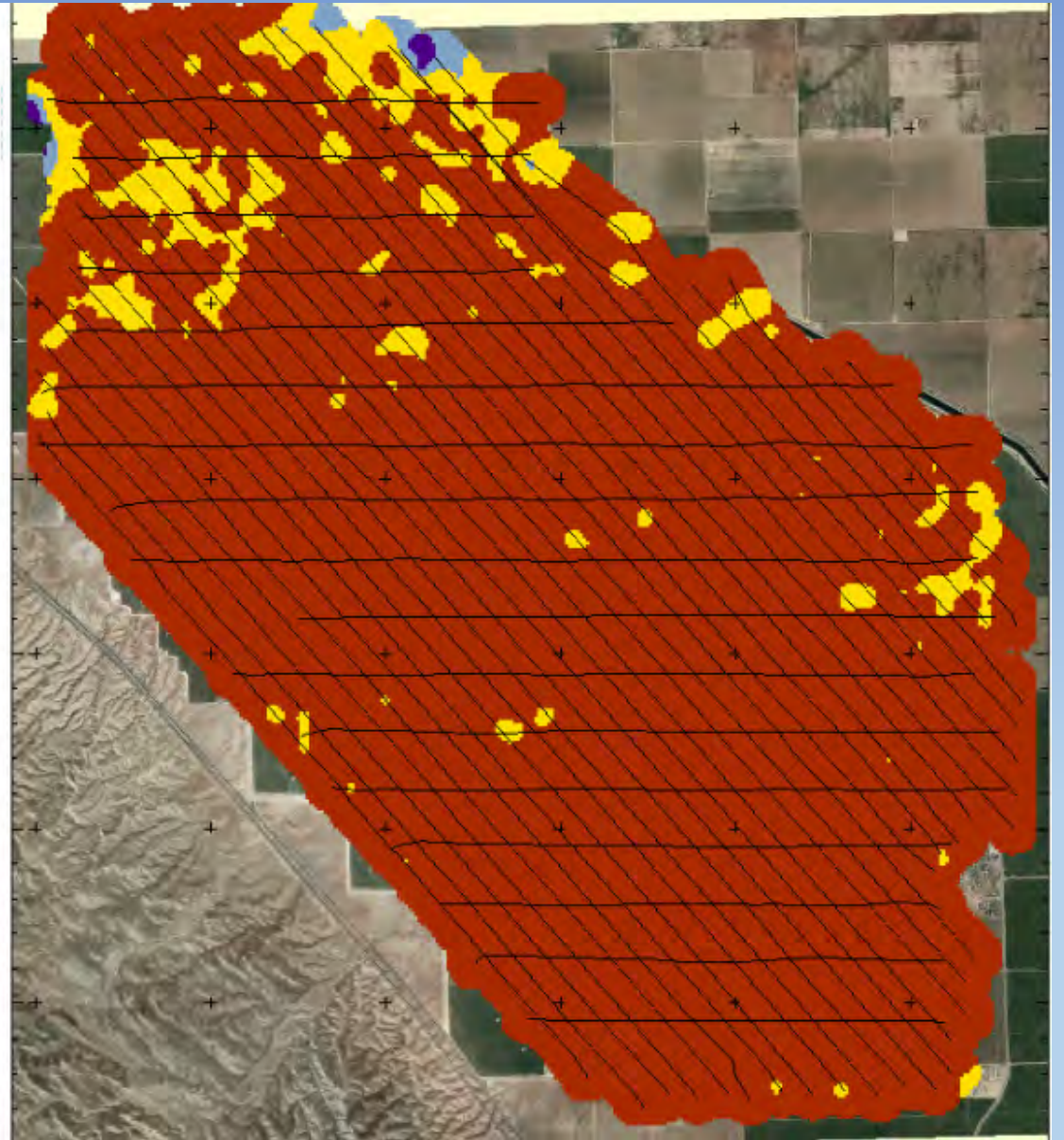
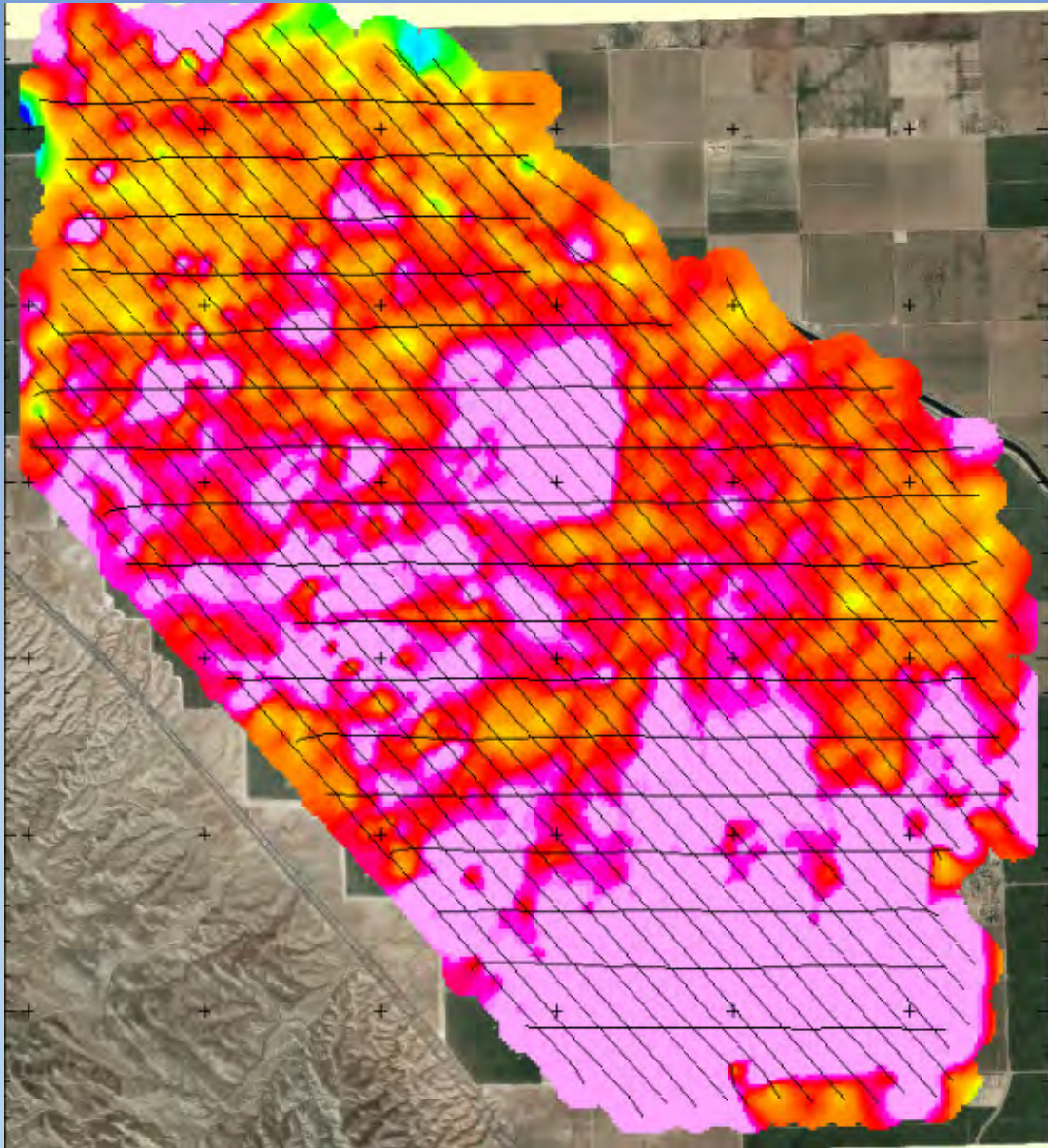
AEM Data Interpretation

Example of Resistivity-Lithology Interpretation: *Area 3 on East Side Of The Central Valley*



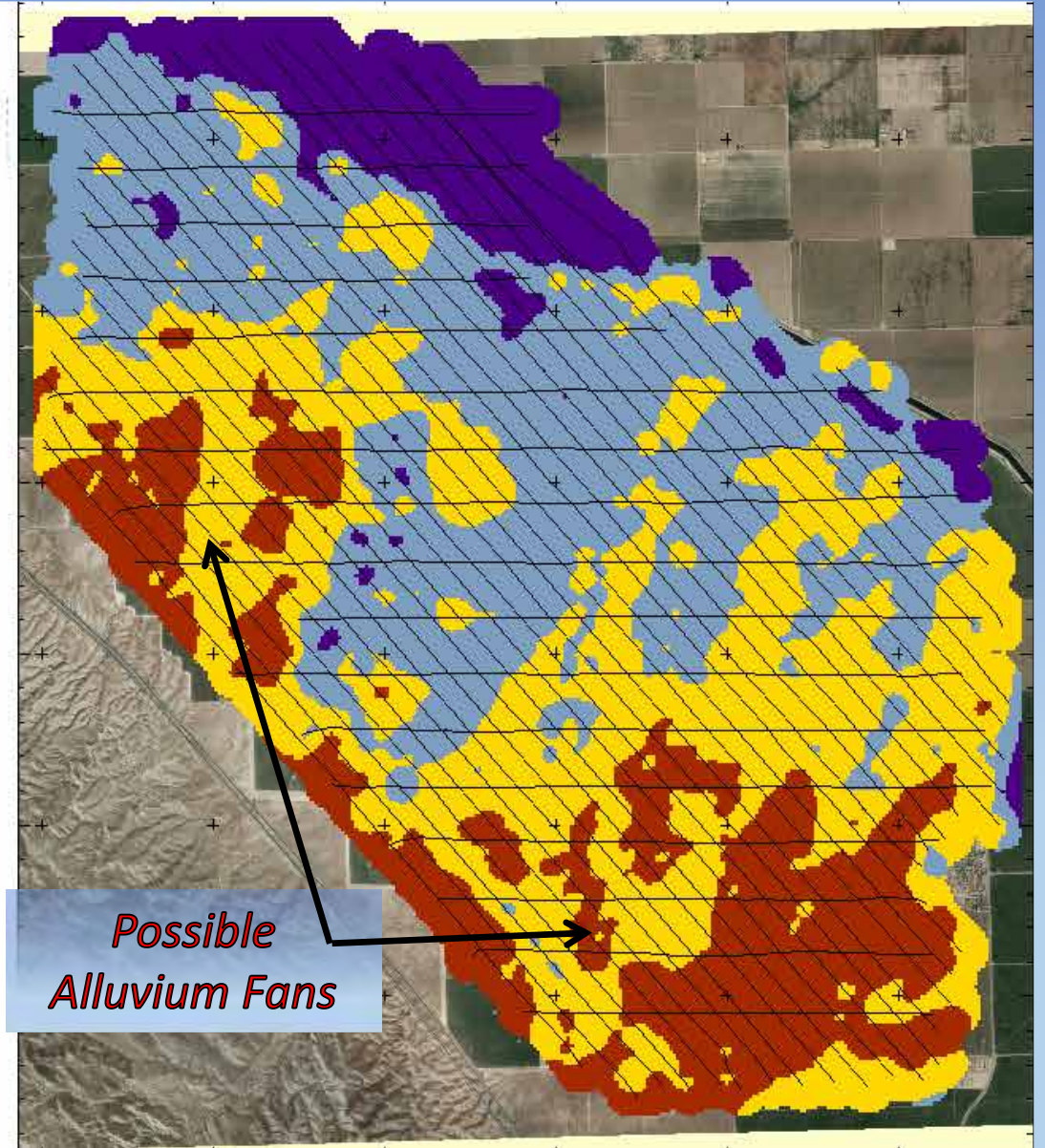
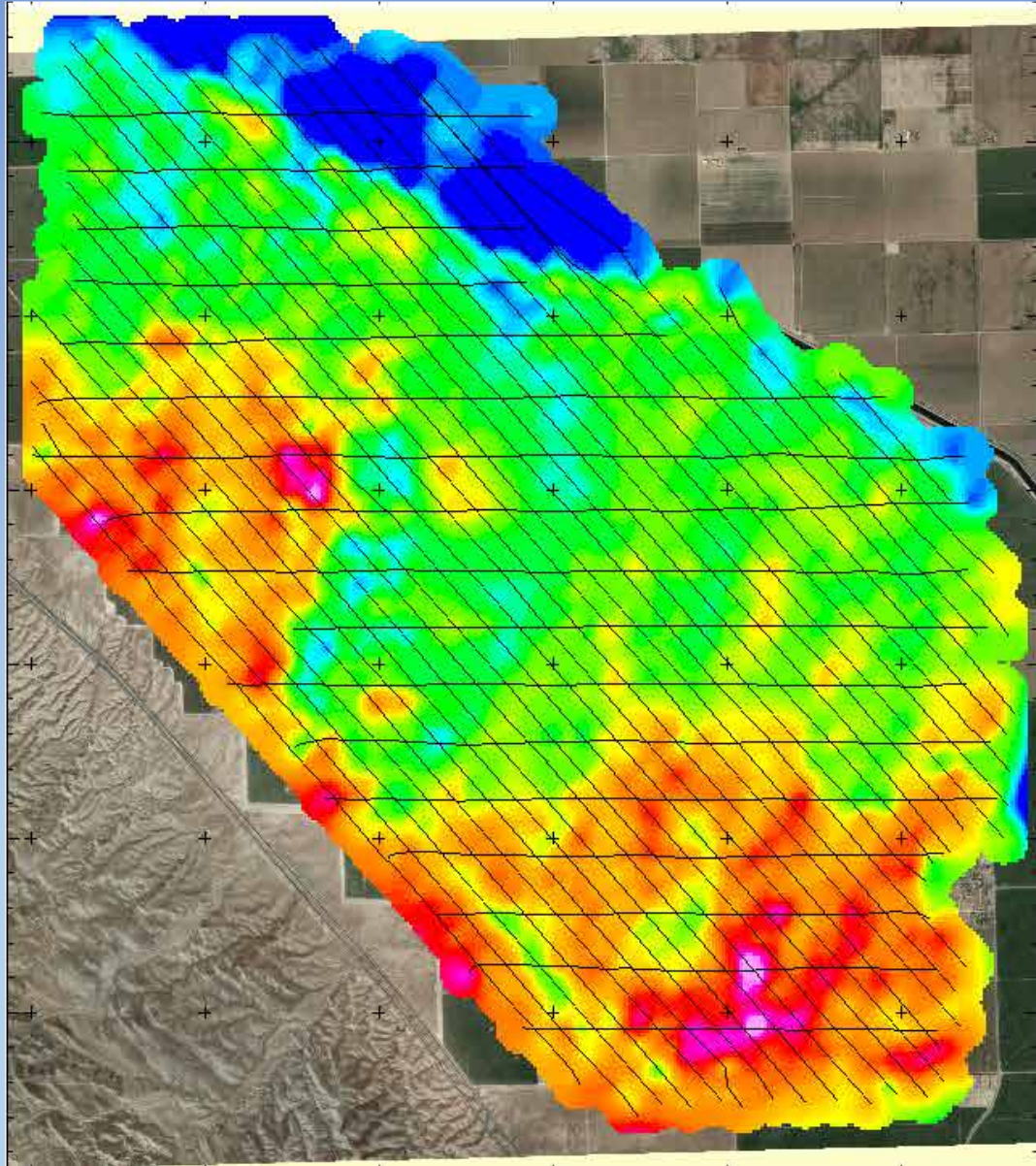
AEM Data Interpretation

Example of Resistivity-Lithology Interpretation: *Area 2, Depth Slice, 0-10 feet*



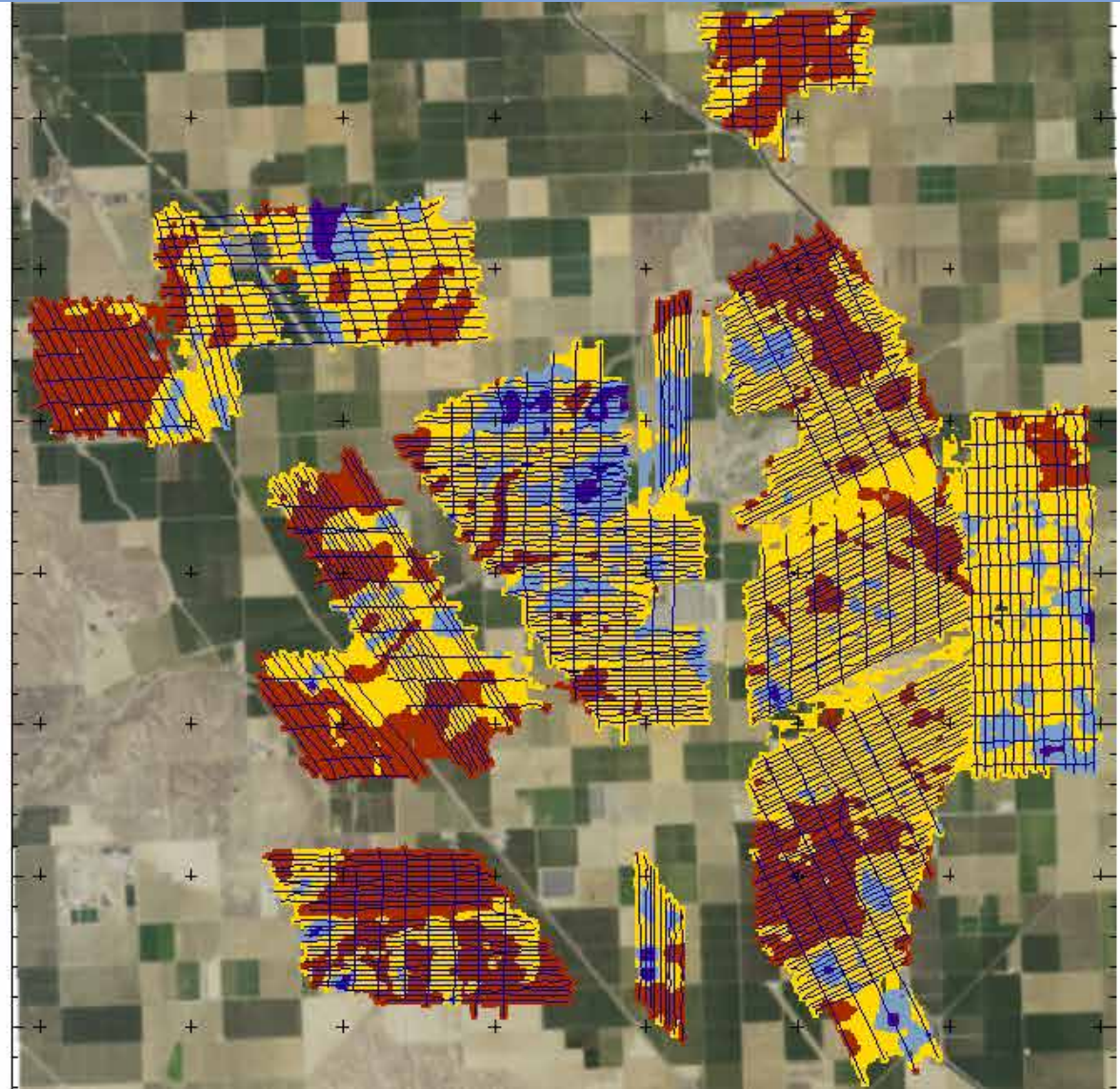
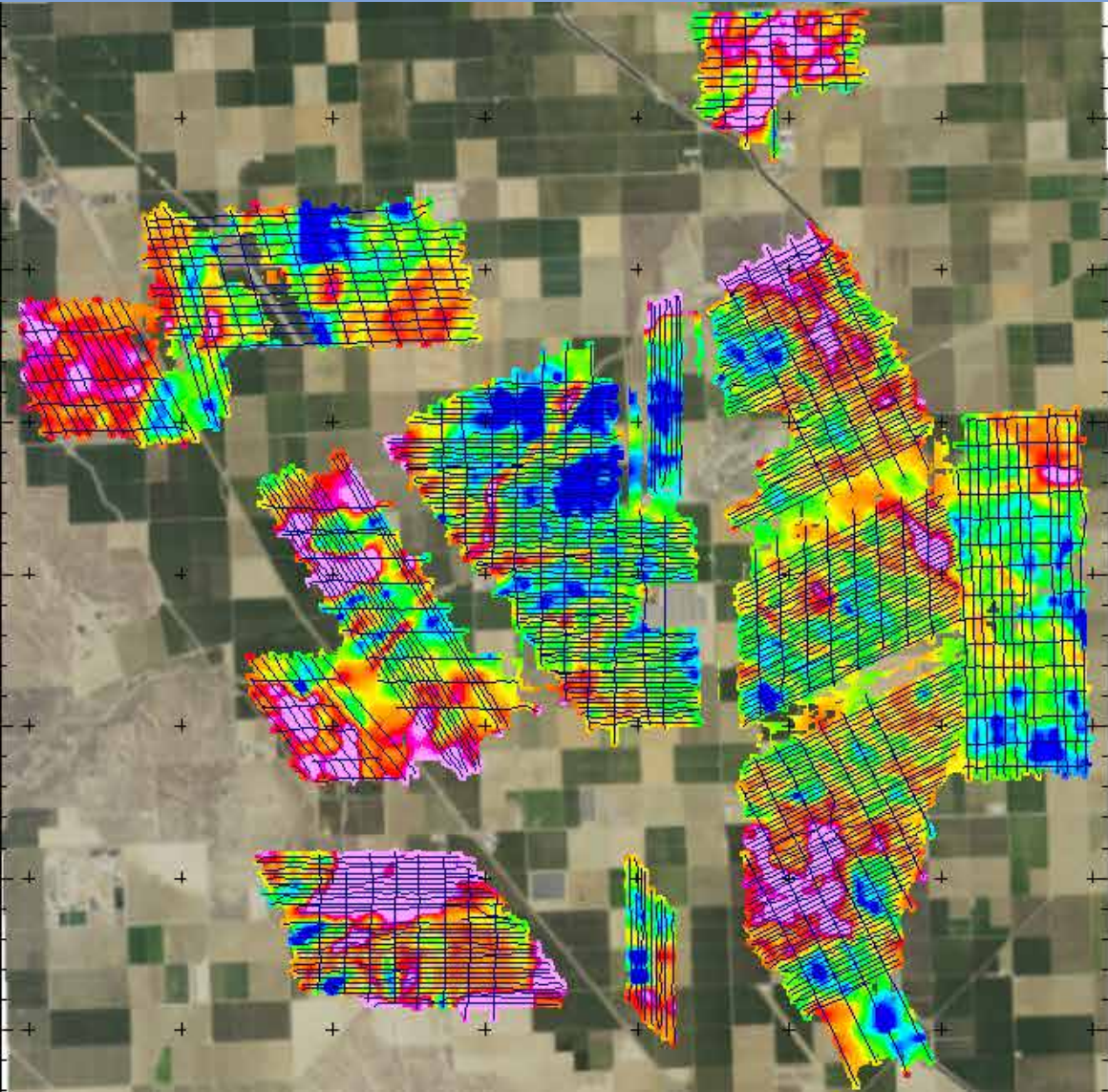
AEM Data Interpretation

Example of Resistivity-Lithology Interpretation: *Area 2, Depth Slice, 20-32 feet*



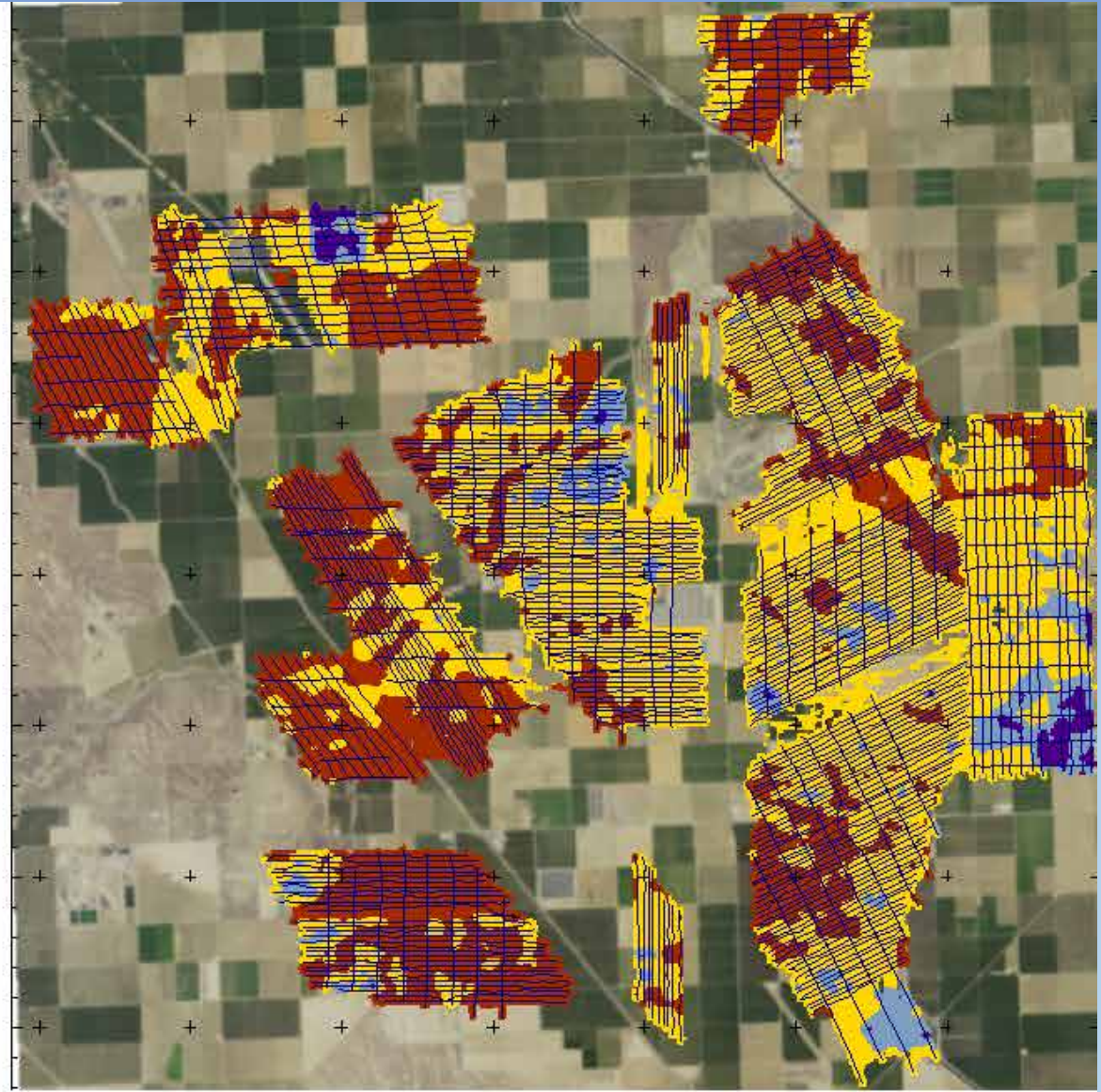
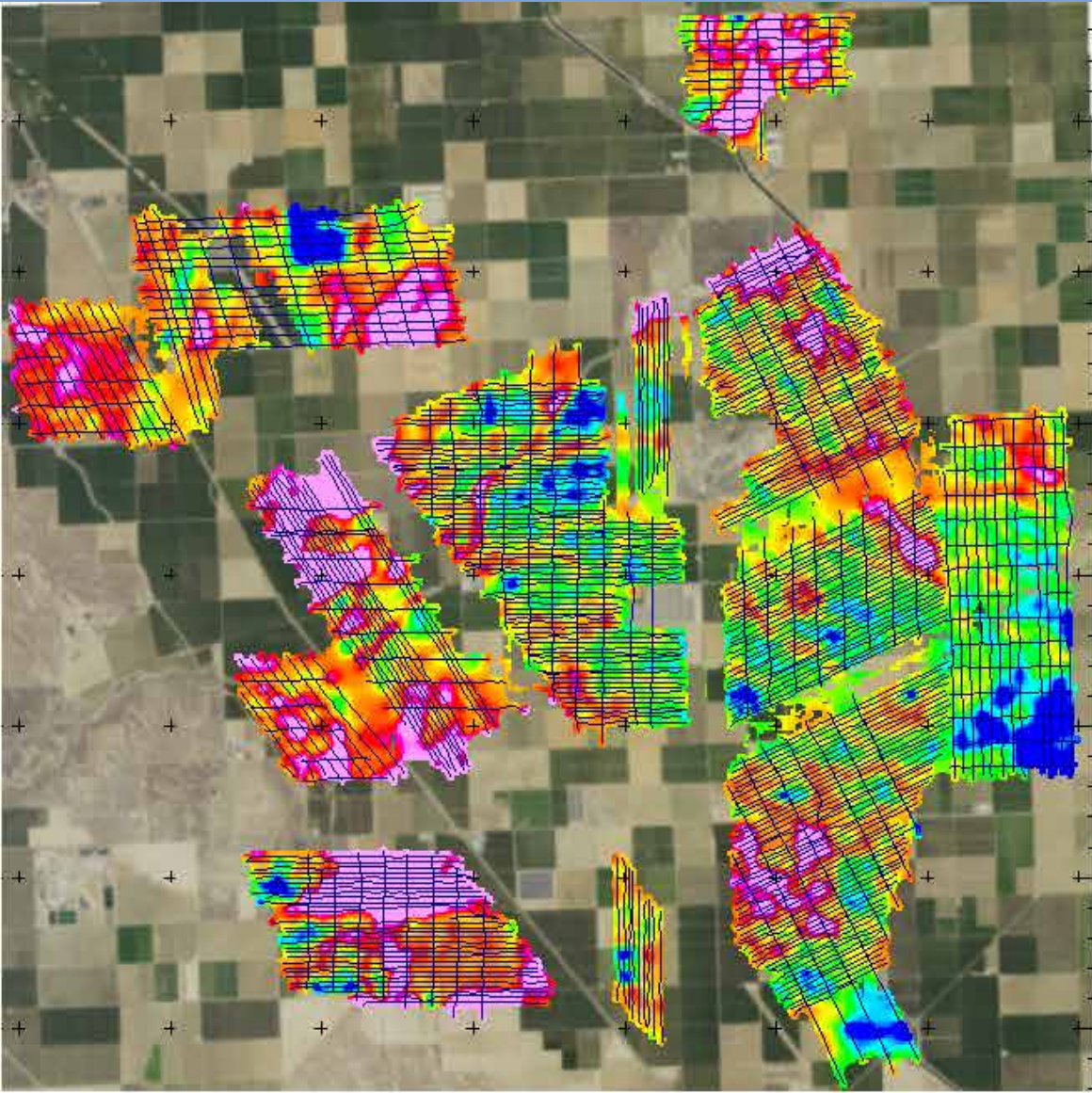
AEM Data Interpretation

Example of Resistivity-Lithology Interpretation: *Area 1, Depth Slice, 10-20 feet*



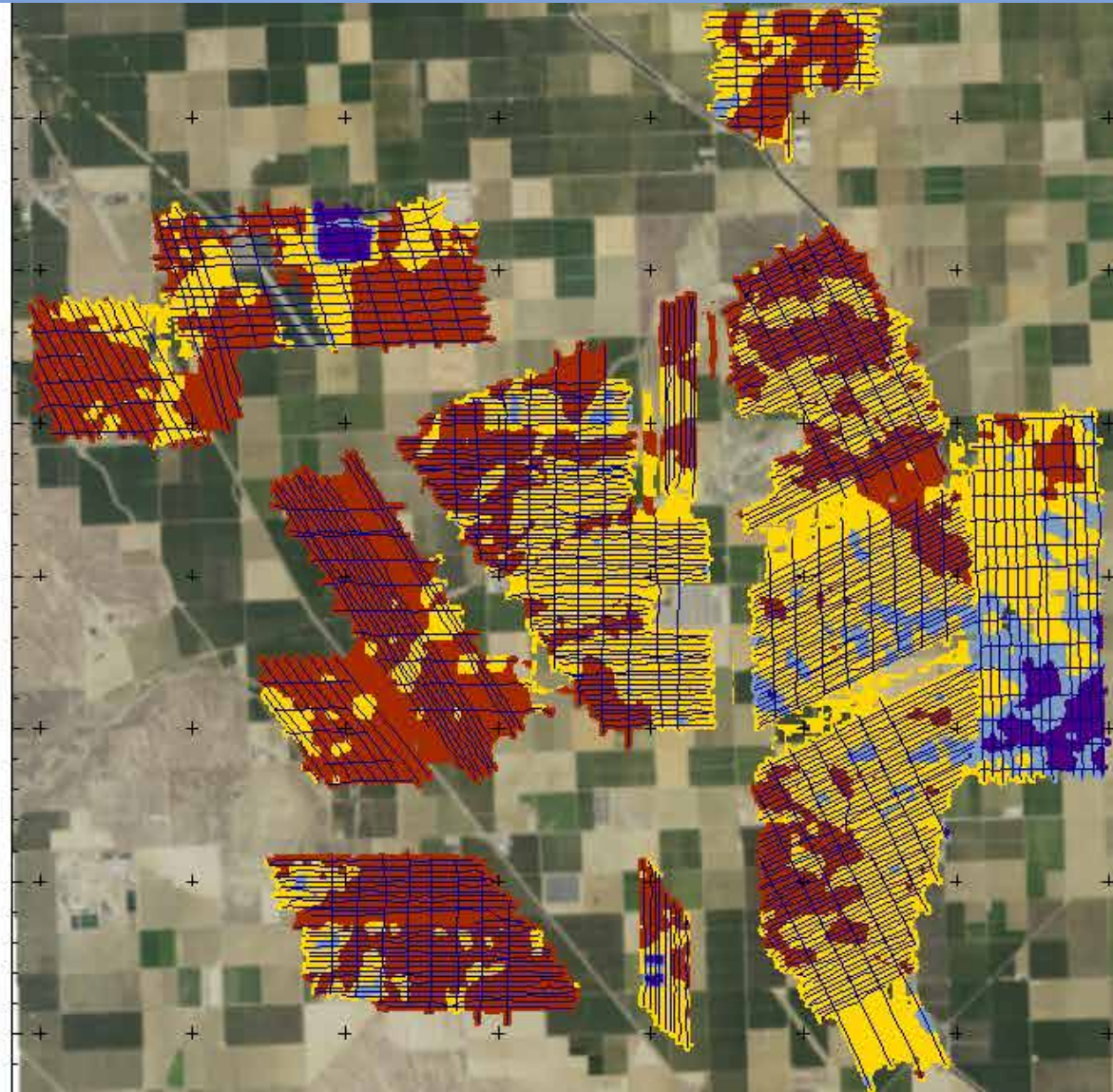
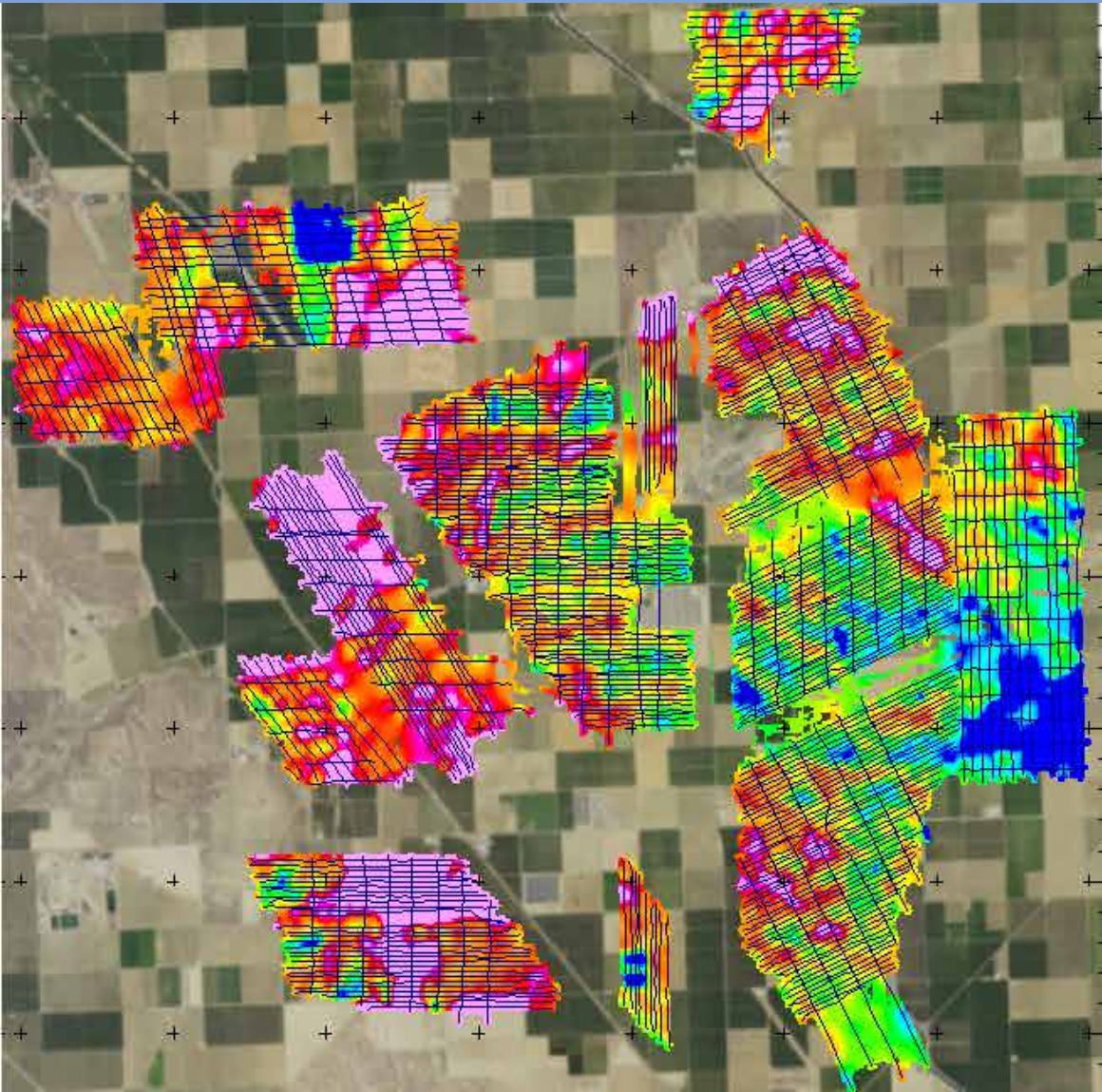
AEM Data Interpretation

Example of Resistivity-Lithology Interpretation: *Area 1, Depth Slice, 20-32 feet*



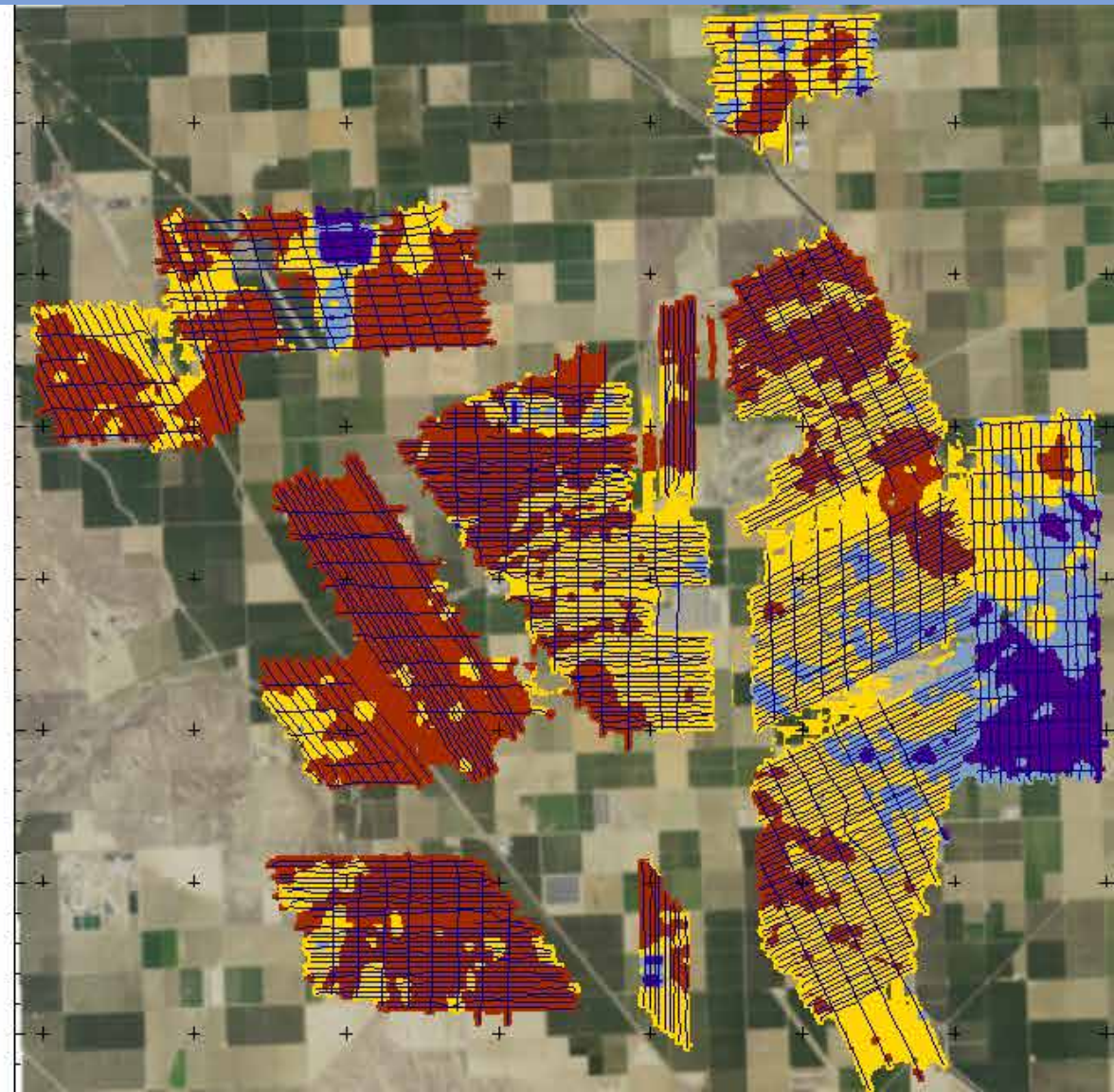
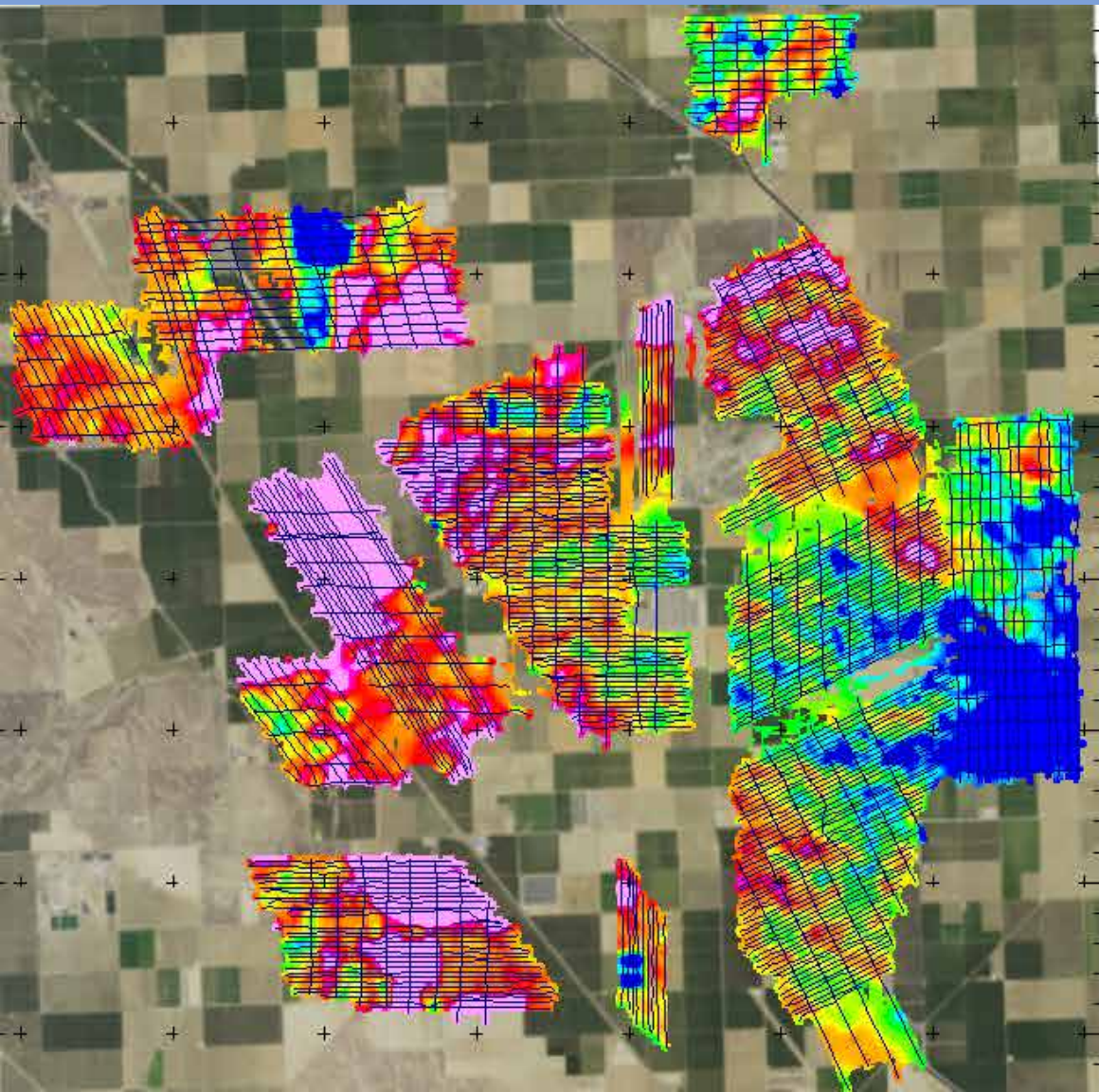
AEM Data Interpretation

Example of Resistivity-Lithology Interpretation: *Area 1, Depth Slice, 32-46 feet*



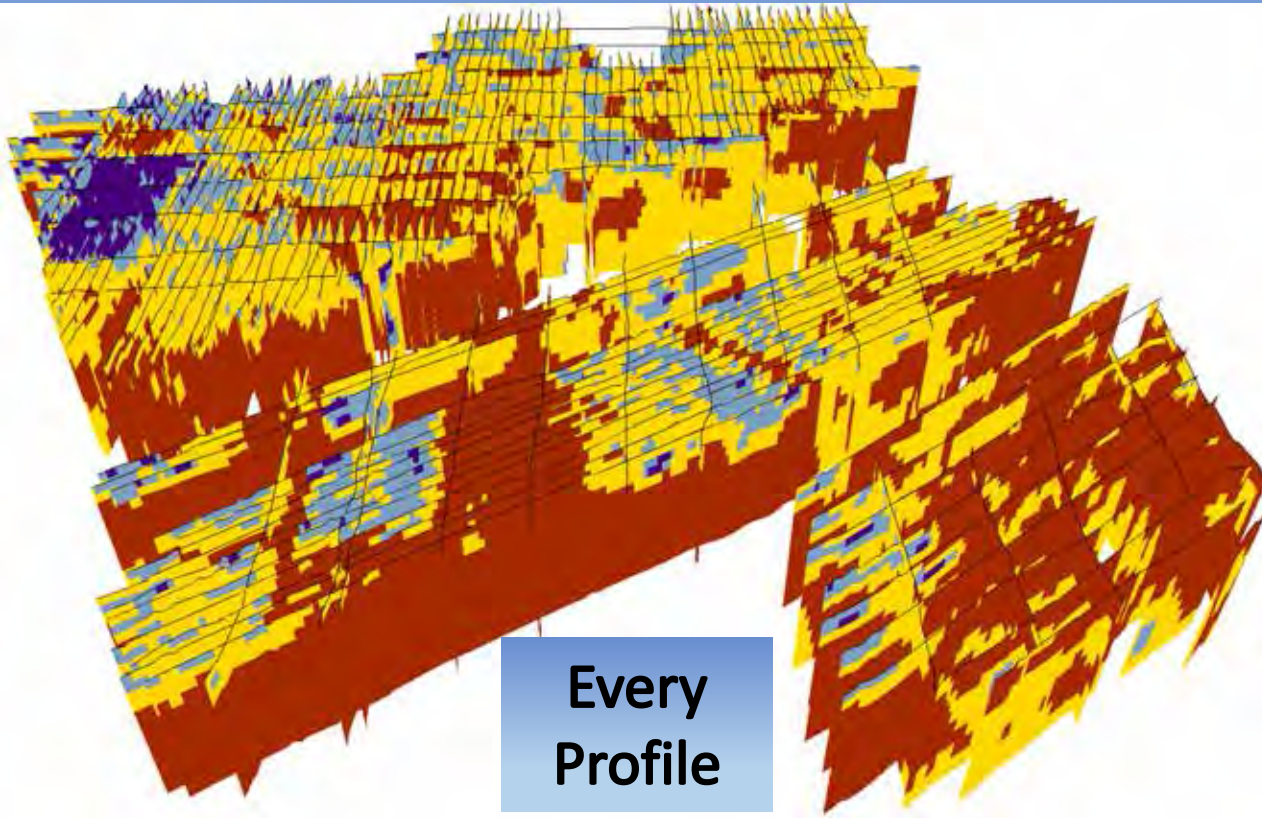
AEM Data Interpretation

Example of Resistivity-Lithology Interpretation: *Area 1, Depth Slice, 46-61 feet*

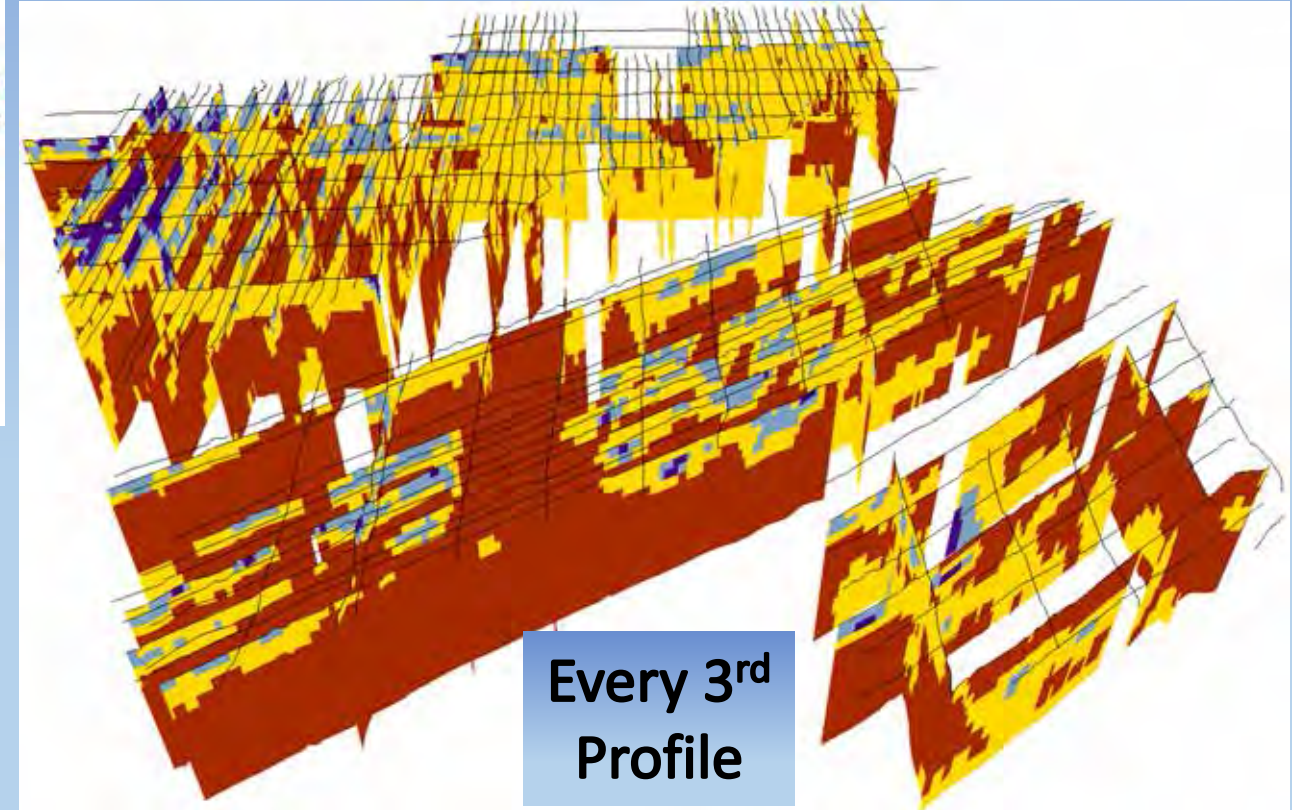


AEM Data Interpretation

Fence Diagram of Lithology Interpretation *Area 1, Looking East from the Coast Range*



Every Profile



Every 3rd Profile

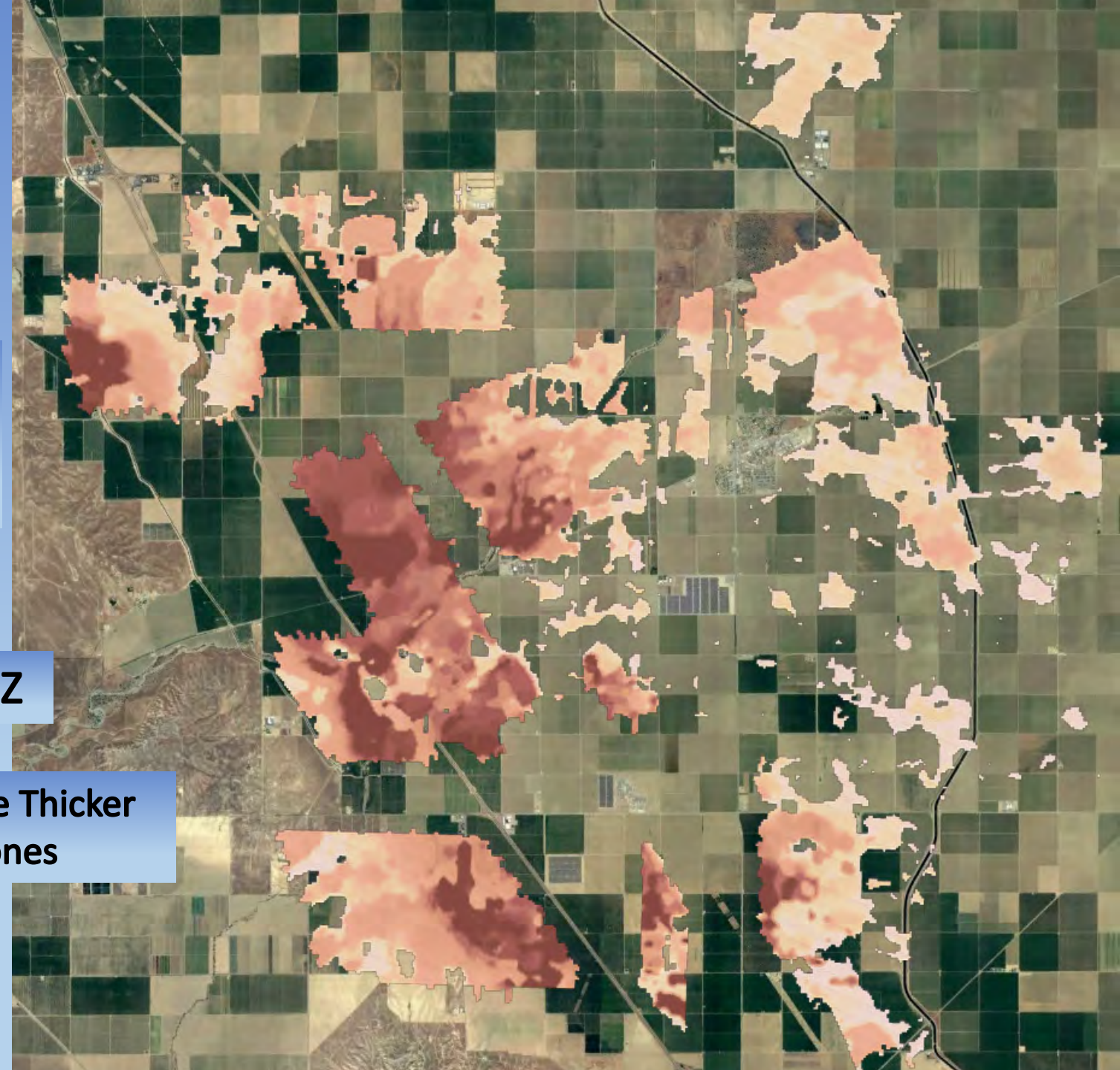
AEM Data Interpretation

Interpreted Area 1 Recharge Zones

- 0-300 ft Depth Range (Water Table is around -300 ft Depth)
- Resistivities >18 ohm-m

Google Earth KMZ

Darker Colors Are Thicker
Recharge Zones



AEM Data Interpretation

Area 1 Recharge Zones

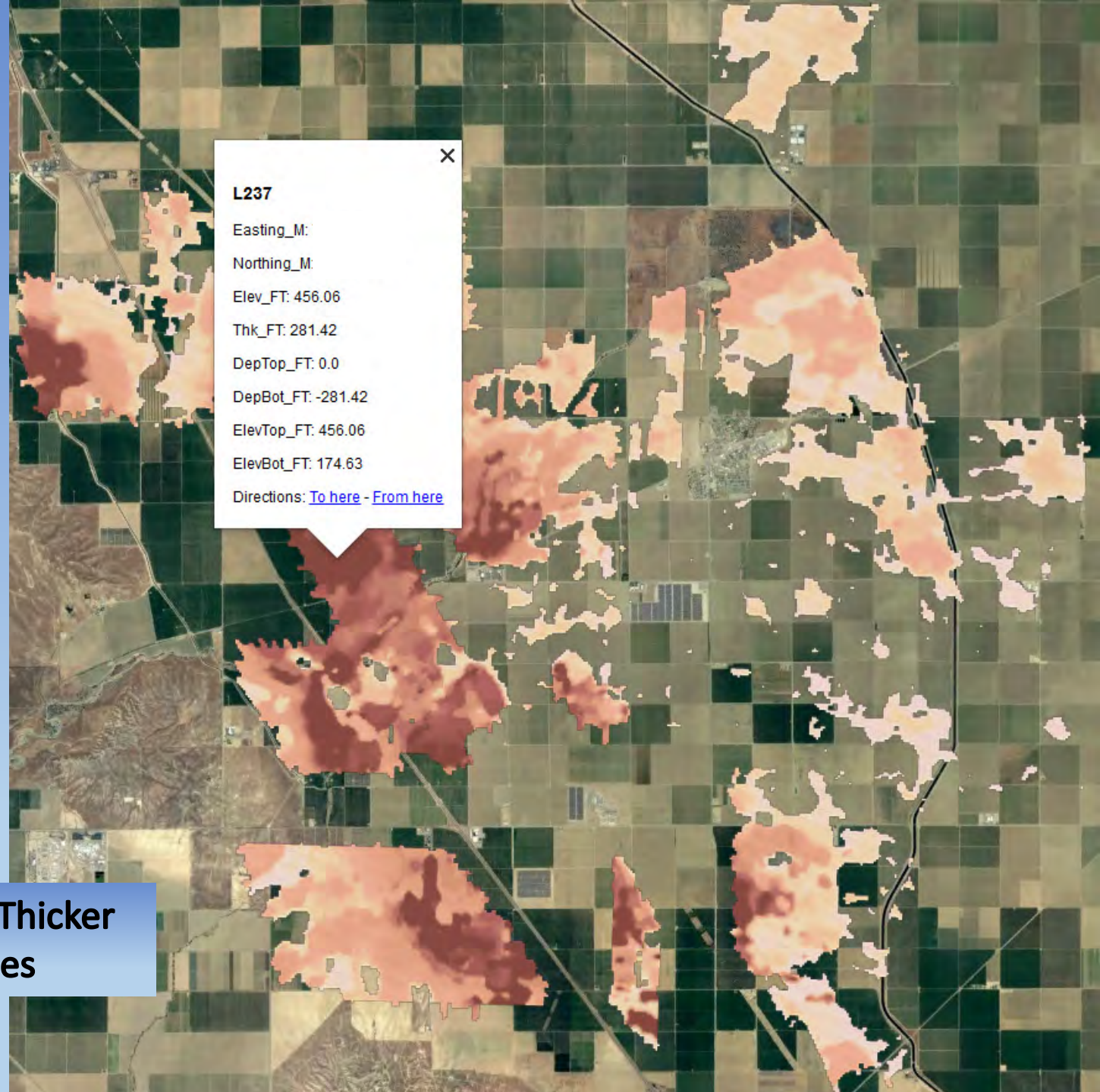
Google Earth KMZ

Clicking on a Location Shows:

- Location (X,Y,Z)
- Thickness of Recharge Material
- Depth to Top, Bottom
- Elevation of Top, Bottom

Darker Colors Are Thicker Recharge Zones

21 March 2017



AEM Data Interpretation

Estimate Recharge Yield

Local Porosity and Specific Yield Values For the Aquifer Materials

Resistivity range excluding Bedrock	Lithology Description	Porosity Value	Specific Yield
Volume >18 ohm-m	Sand and Gravel	0.3	0.25
Volume 18-9 ohm-m	Interbedded	0.2	0.1
Volume 9-6 ohm-m	Clay silt	0.4	0.06
Volume <6 ohm-m	Clay	0.4	0.02

Example of **Unsaturated Recharge Estimates** in AF of Volume, Total Water, Total Yield For Subset Area 1

Subset 1	Area (ft ²)	Area (Acre)	Depth Range -300<x<0	Volume (Ft ³)	Volume (AF)	Total Water (AF)	Total Yield (AF)
	289,863,305	6,654					
Resistivity range excluding Bedrock	Lithology Description	Porosity Value	Specific Yield	Volume (Ft ³)	Volume (AF)	Total Water (AF)	Total Yield (AF)
Volume >18 ohm-m	Sand and Gravel	0.3	0.25	24,647,920,800	565,838	169,752	42,438

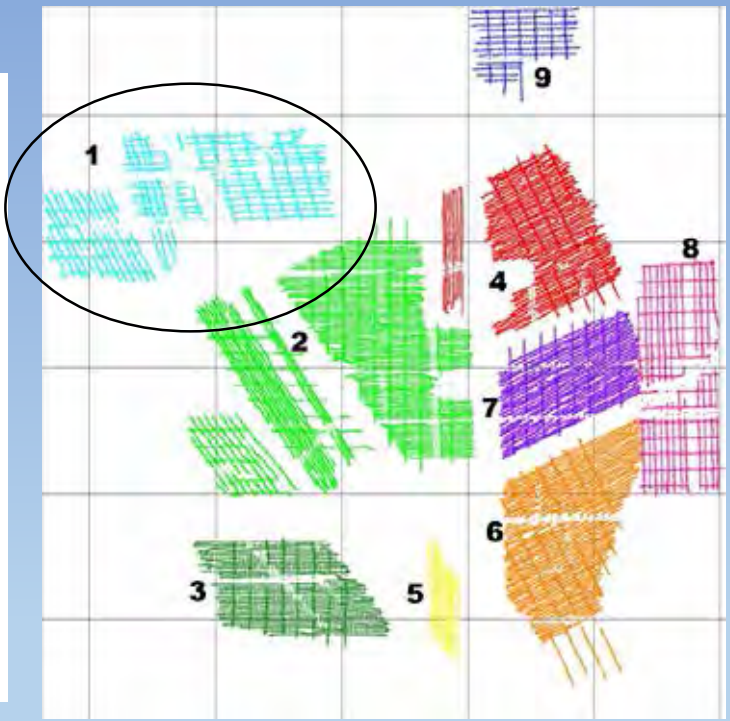


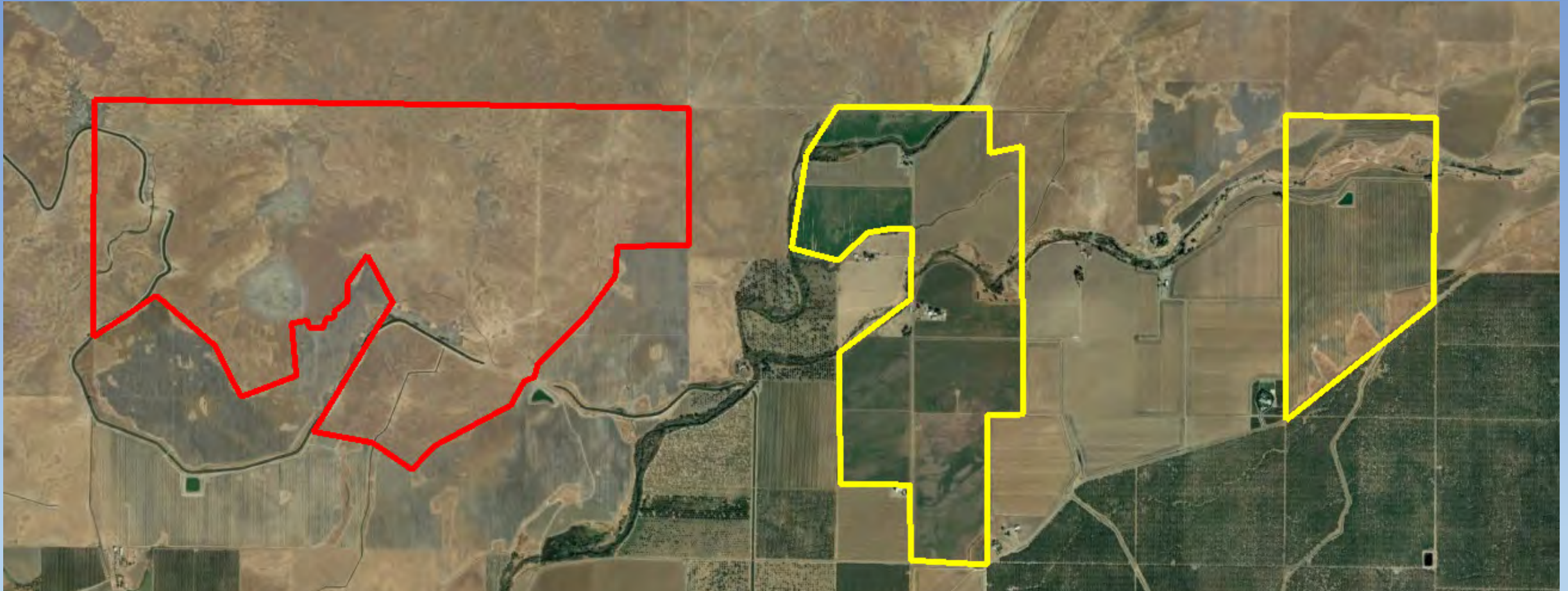
AEM Data Interpretation



**Subset Area 1 Estimates in AF of
Volume, Total Water, Total Yield
 For **Saturated** Aquifer Materials**

	Area (ft ²)	Area (Acre)					
	289,863,305	6,654		Depth Range -1543<x<-300			
Resistivity range excluding Bedrock	Lithology Description	Porosity Value	Specific Yield	Volume (Ft ³)	Volume (AF)	Total Water (AF)	Total Yield (AF)
Volume >18 ohm-m	Sand and Gravel	0.3	0.25	1,651,481,640	37,913	11,374	2,843
Volume 18-9 ohm-m	Interbedded	0.2	0.1	110,623,602,240	2,539,568	507,914	50,791
Volume 9-6 ohm-m	Clay silt	0.4	0.06	210,527,408,440	4,833,044	1,933,218	115,993
Volume <6 ohm-m	Clay	0.4	0.02	30,908,419,080	709,560	283,824	5,676





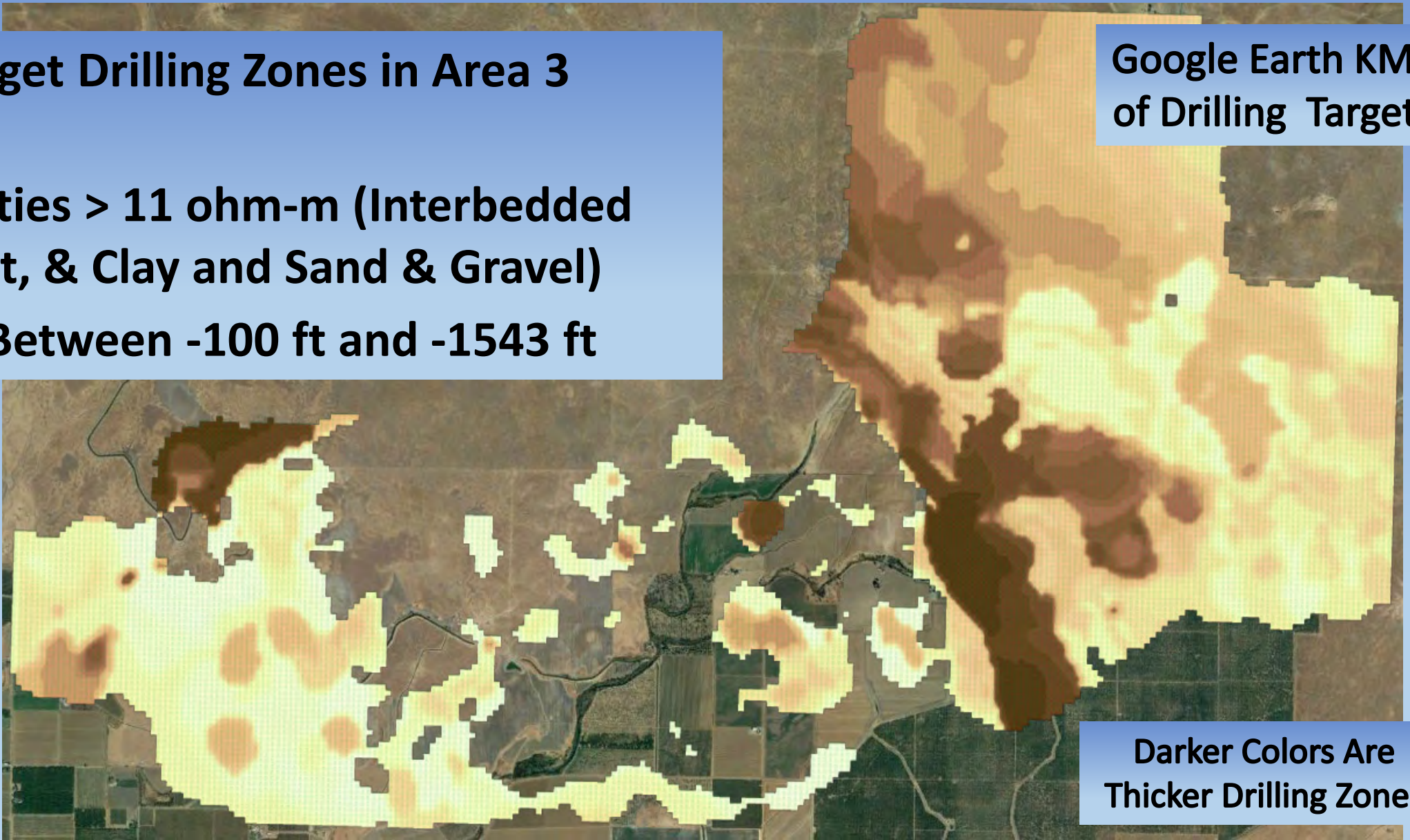
**Area 3 Client Requested AGF to Select Best Drilling Target Locations
The Client Selected The Drilling Areas of Interest**



Created Target Drilling Zones in Area 3 based on:

- Resistivities > 11 ohm-m (Interbedded Sand, Silt, & Clay and Sand & Gravel)
- Depths Between -100 ft and -1543 ft

Google Earth KMZ of Drilling Targets



Darker Colors Are Thicker Drilling Zones

Target Zones Based on:

- Resistivities > 11 ohm-m (Interbedded Sand, Silt, & Clay and Sand & Gravel)
- Depths Between -100 ft and -1543 ft

Google Earth KMZ of Drilling Targets

Clicking on a Location Shows:

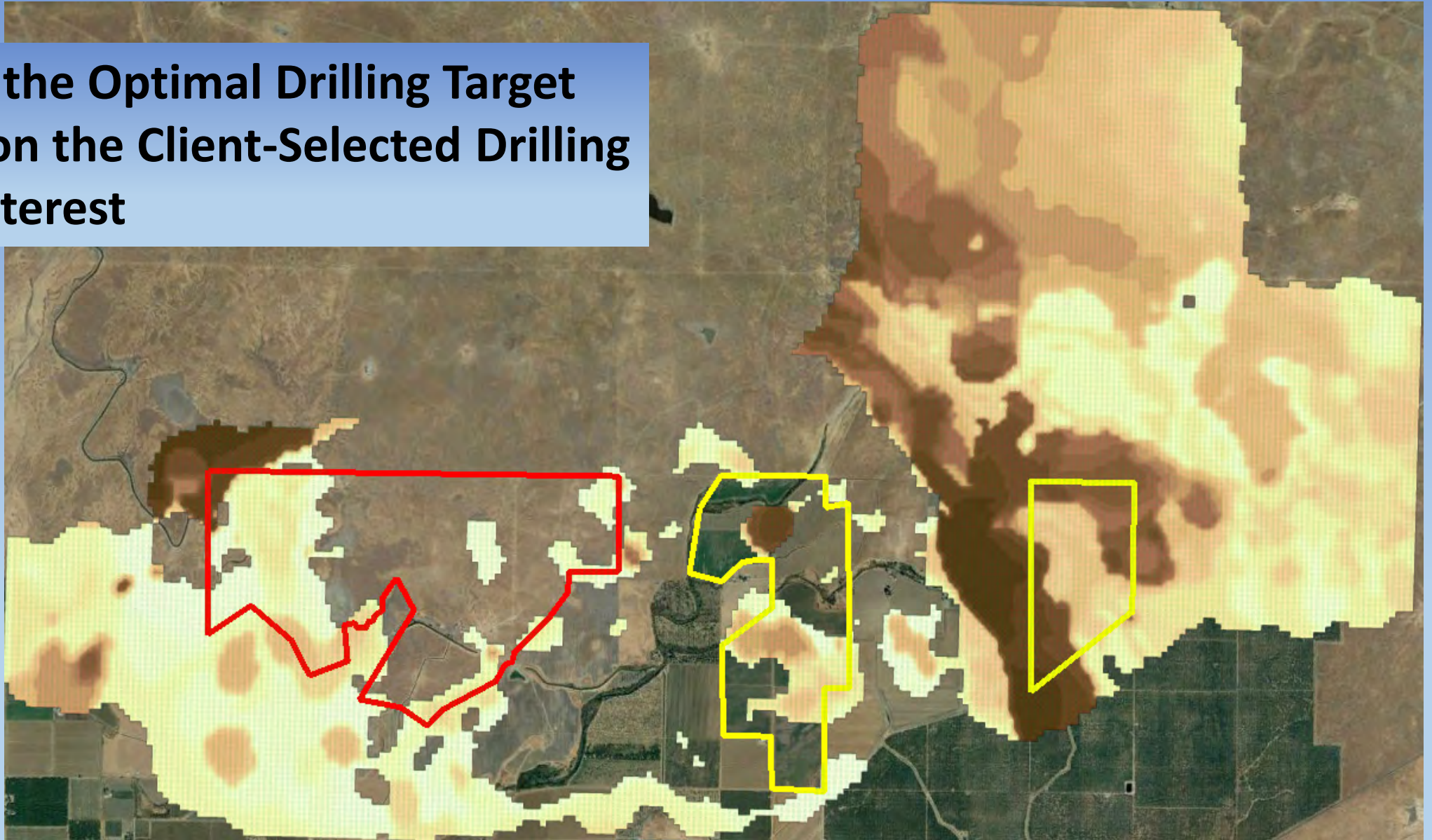
- Location (X,Y,Z)
- Thickness of Drilling Target Material
- Depth to Top, Bottom
- Elevation of Top, Bottom

L52

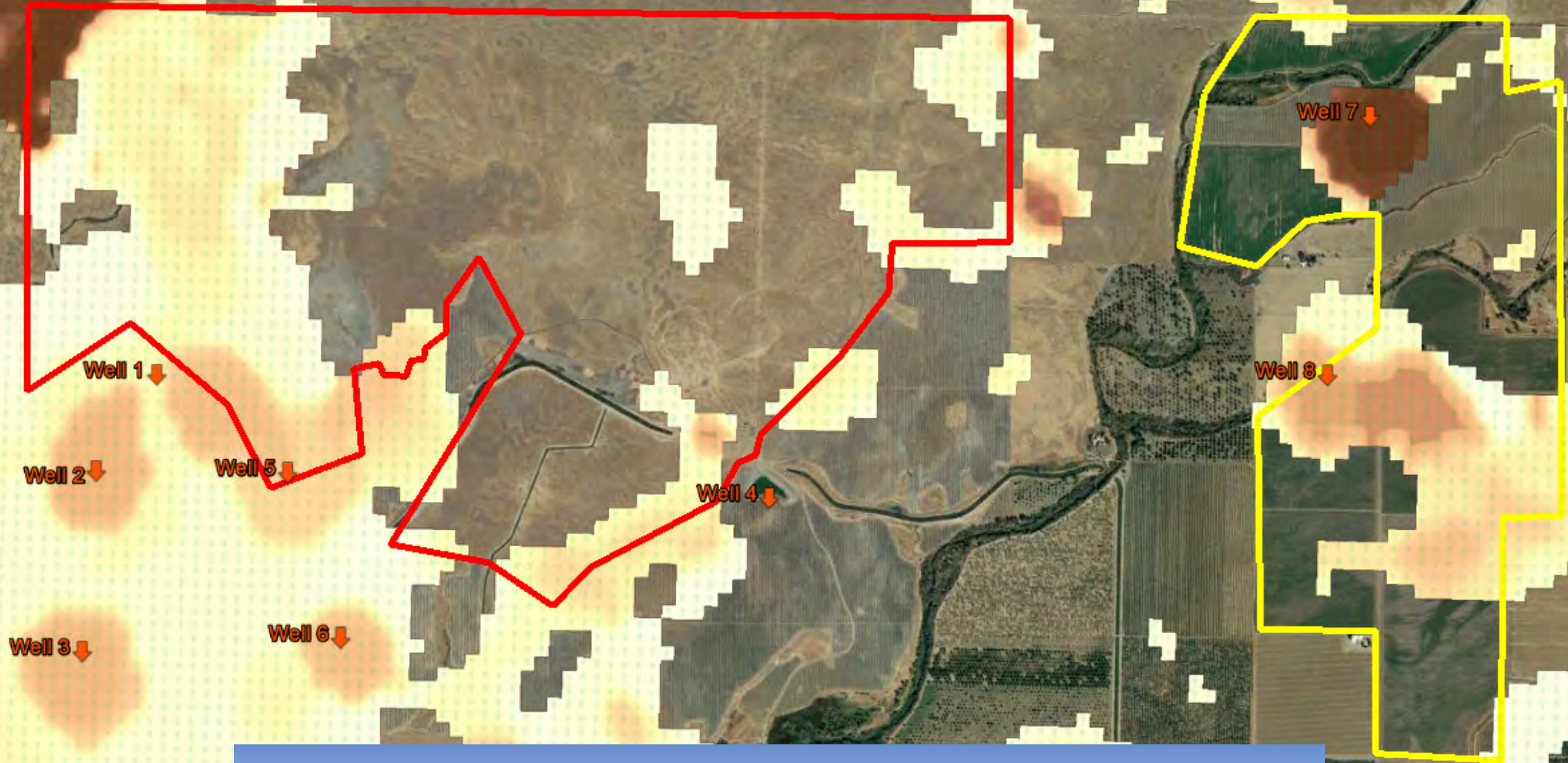
Easting_M:
Northing_M
Elev_FT: 298.57
Thk_FT: 1220.32
DepTop_FT: -322.92
DepBot_FT: -1543.24
ElevTop_FT: -24.34
ElevBot_FT: -1244.67
Directions: [To here](#) - [From here](#)

Darker Colors Are Thicker Drilling Zones

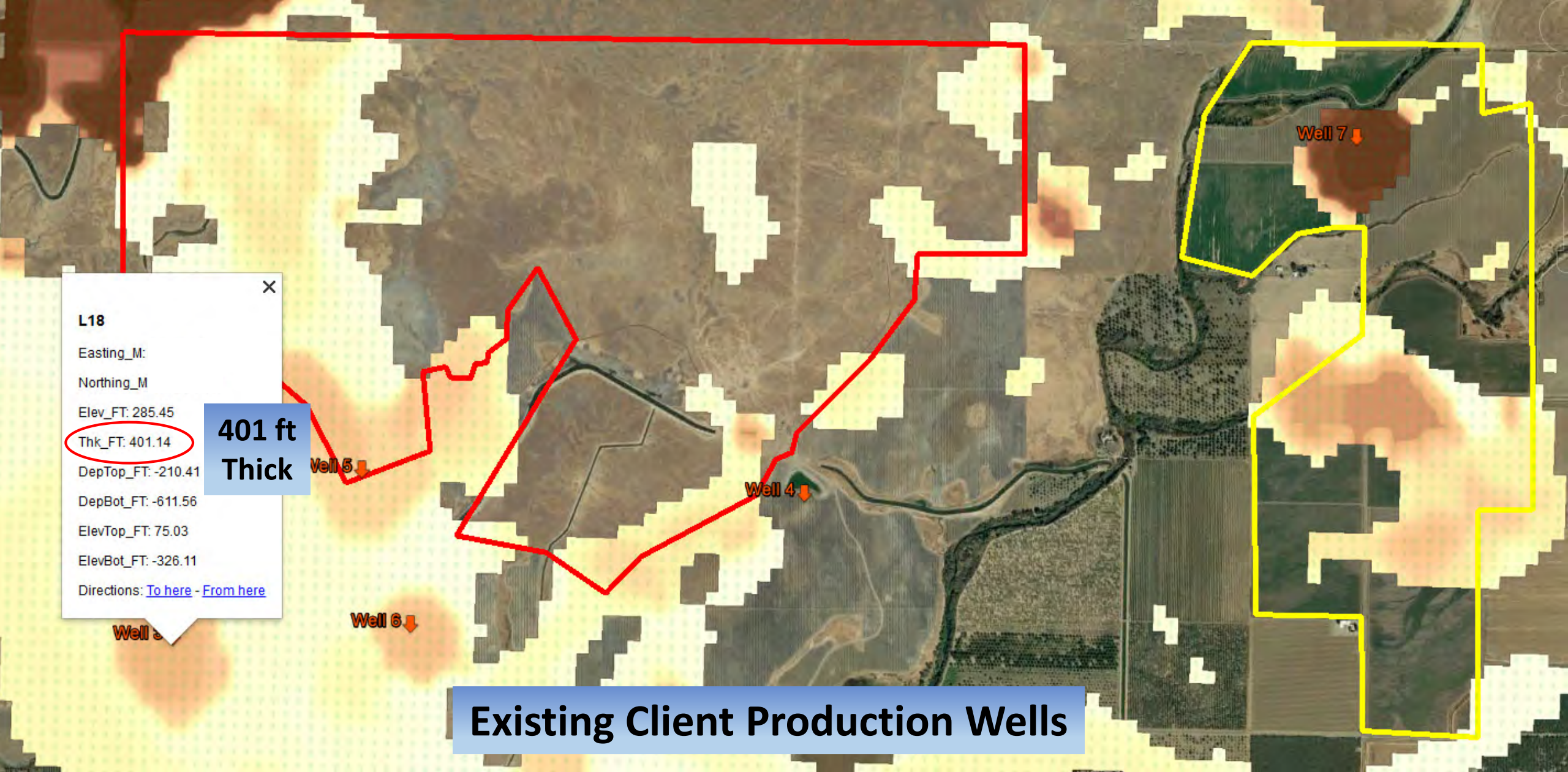
Overlay of the Optimal Drilling Target Locations on the Client-Selected Drilling Areas of Interest



Area 3 Potential Drilling Targets



Overlay of Locations of Existing Client Production Wells on Drilling Target Material Grid



L18
Easting_M:
Northing_M
Elev_FT: 285.45
Thk_FT: 401.14
DepTop_FT: -210.41
DepBot_FT: -611.56
ElevTop_FT: 75.03
ElevBot_FT: -326.11
Directions: [To here](#) - [From here](#)

**401 ft
Thick**

Existing Client Production Wells

Area 3 Potential Drilling Targets

Well 1 ↓

Well 2 ↓

Well 3 ↓

Well 5 ↓

Well 6 ↓

Well 4 ↓

Well 7 ↓

L59

Easting_M:

Northing_M

Elev_FT: 288.73

Thk_FT: 1002.37

DepTop_FT: -540.8

DepBot_FT: -1543.2

ElevTop_FT: -252.14

ElevBot_FT: -1254.51

Directions: [To here](#) - [From here](#)

1002 ft
Thick

Existing Client Production Wells

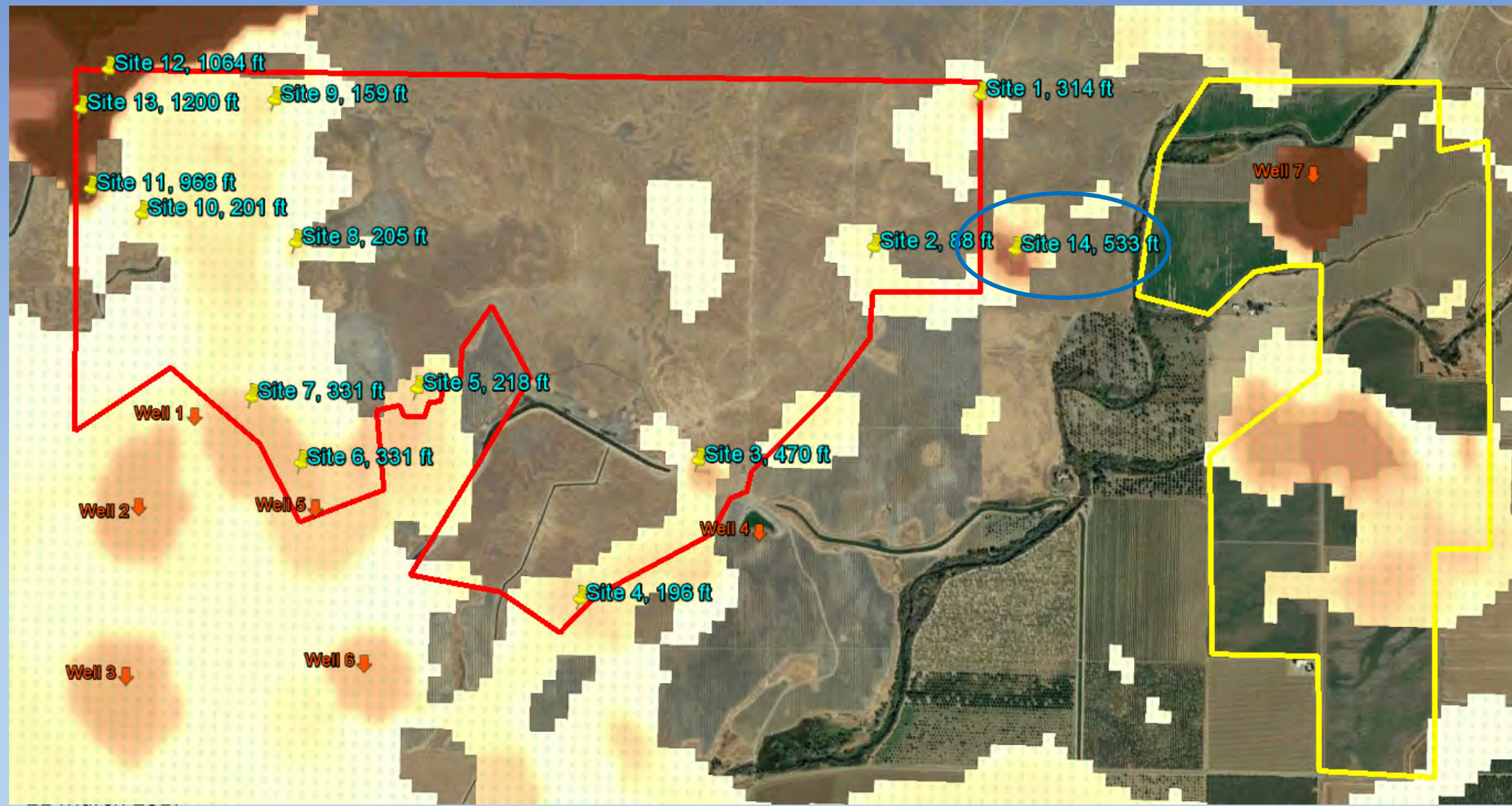
Area 3 Potential Drilling Targets

L38
Easting_M
Northing_M:
Elev_FT: 298.57
Thk_FT: 112.5
DepTop_FT: -210.4
DepBot_FT: -322.92
ElevTop_FT: 88.16
ElevBot_FT: -24.34
Directions: To here - From here

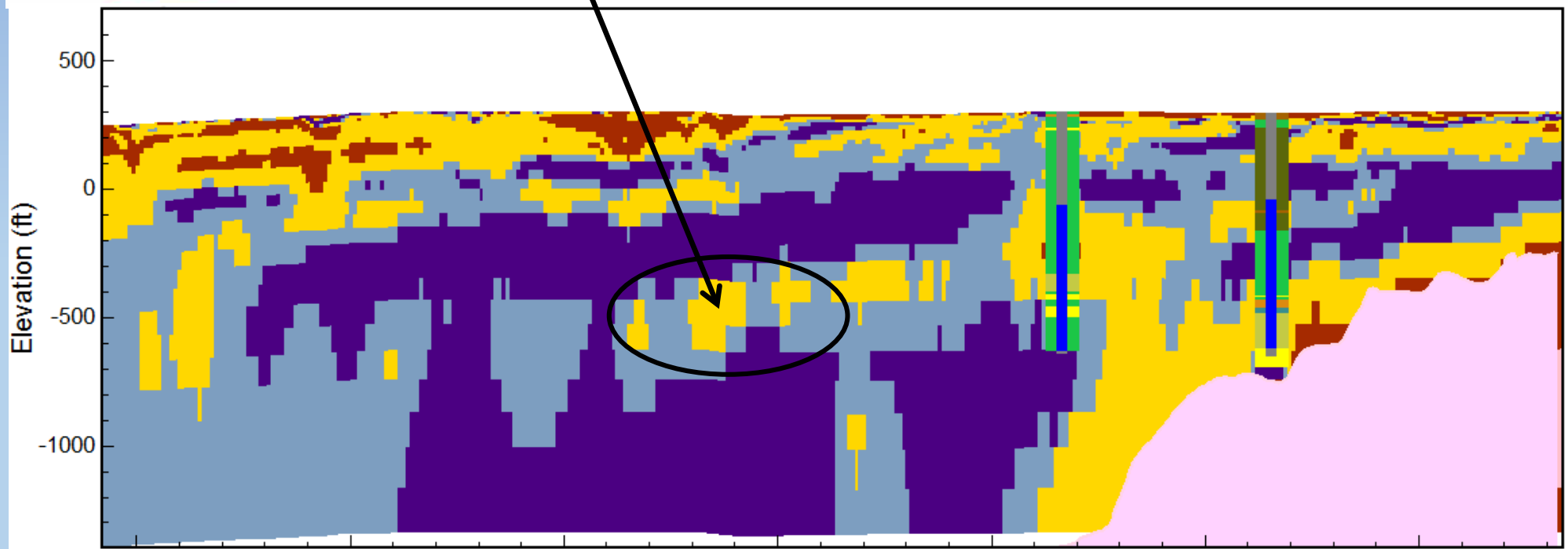
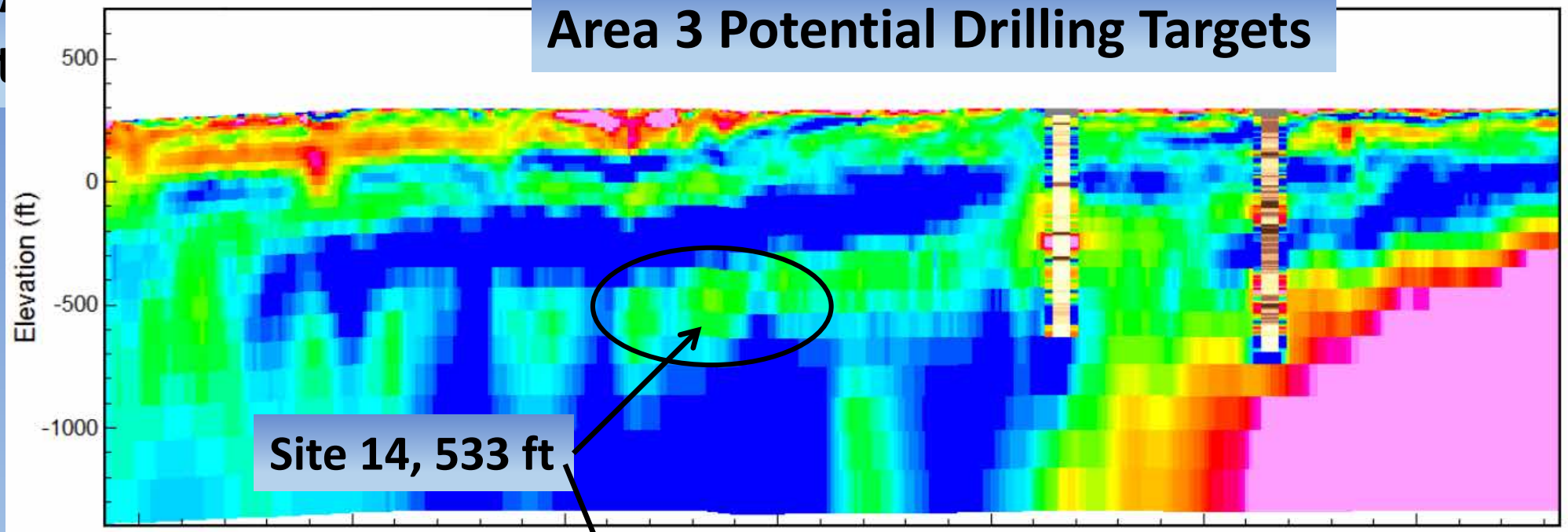
**113 ft
Thick**



Existing Client Production Wells



Area 3 Potential Drilling Targets



Summary

1. 2,255 line-kilometers of airborne time-domain acquired
2. The AEM data were processed, edited, and inverted with LCI and SCI inversions
3. The results were examined and studied as 2D and 3D profile sections, fence diagrams, and voxels
4. Correlation was made between the AEM-inverted resistivity and local lithology based on inversion results, known local geology, and borehole logs.
5. Managed Aquifer Recharge zones were identified and Saturated and Unsaturated Volume, Total Volume, and Total Yield of water were estimated.
6. Voxels, Grids, and KMZ's were developed for identifying potential new drilling targets.
7. Similar AEM investigations in the Central Valley are forthcoming in the near future.

Questions?
Comments?



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