Results From The AEM Survey Lower Elkhorn Natural Resources District

Lower Elkhorn NRD Board of Directors Meeting

February 28,2019

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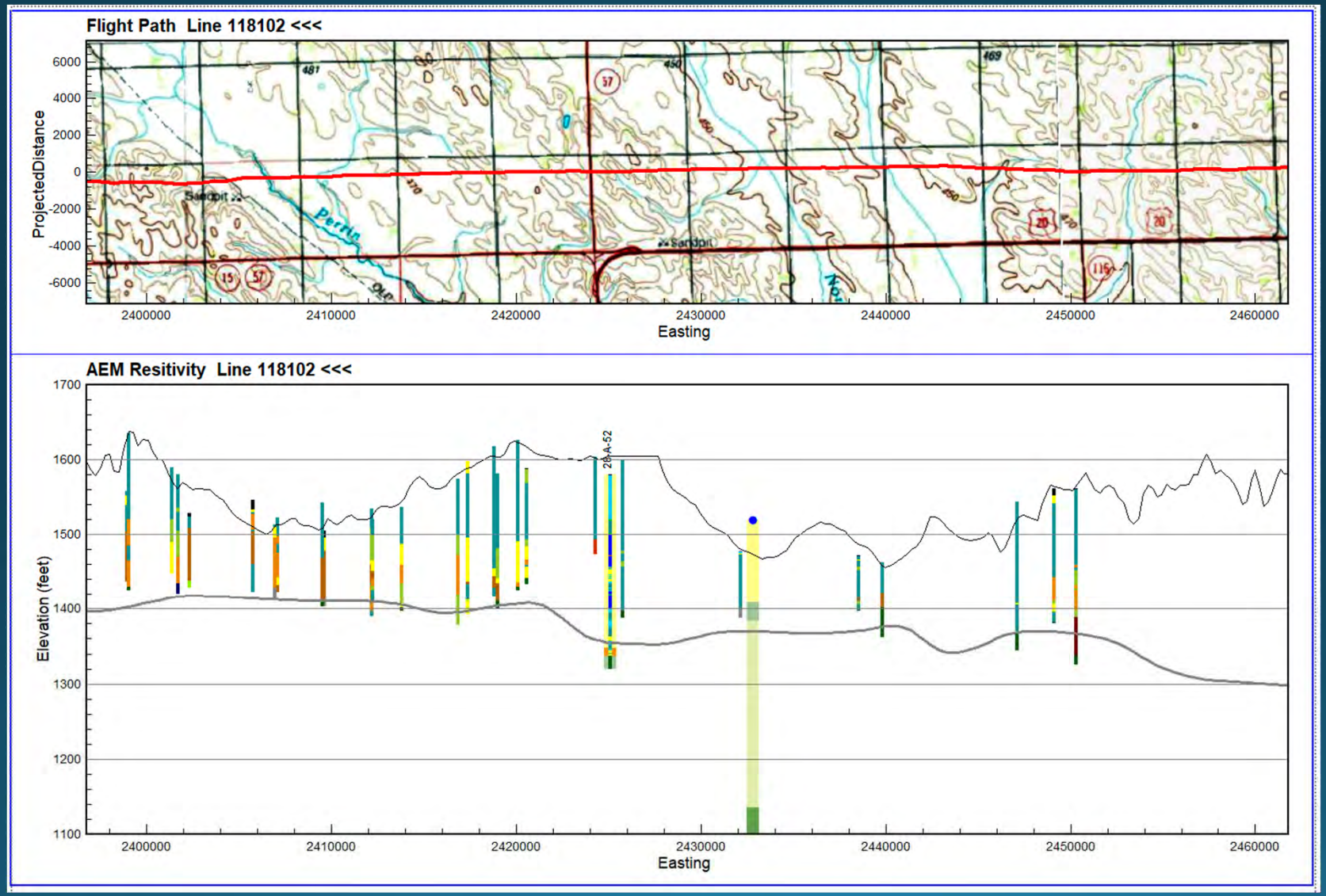
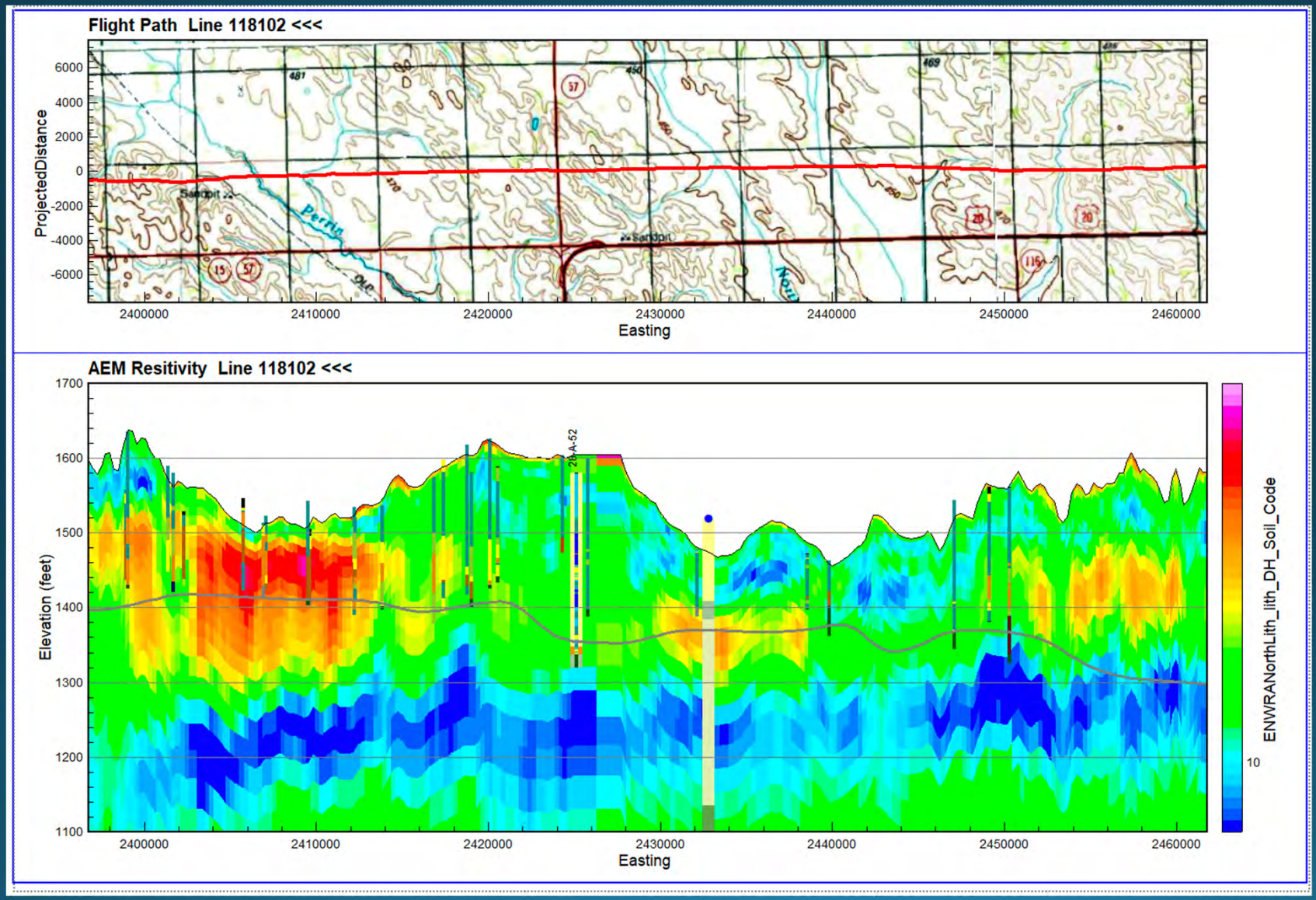
Overview

- The history of why we are doing AEM studies
- What were the objectives for this survey?
- What is an AEM survey?
- How does AEM determine geology?
- Lower Elkhorn NRD AEM Survey Results
- Data formats and uses?
- Future data enhancements?
- Questions?

Framework Without AEM

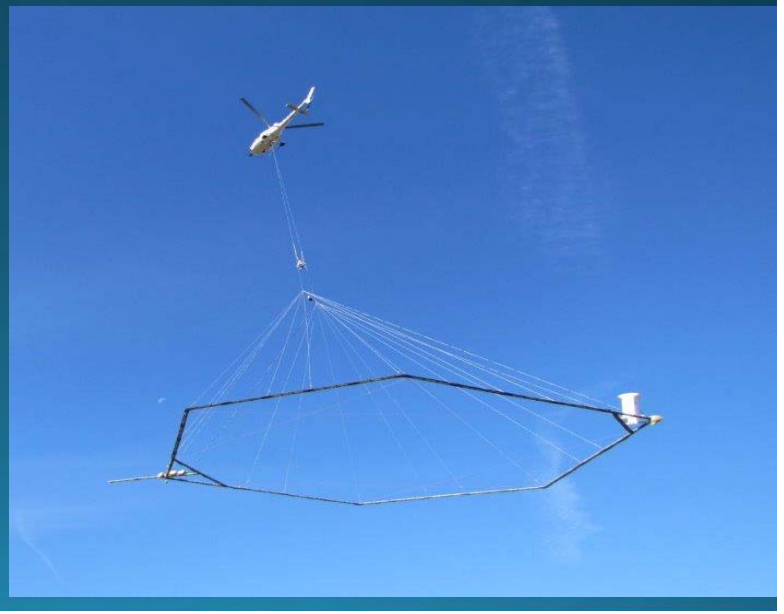


Framework With AEM

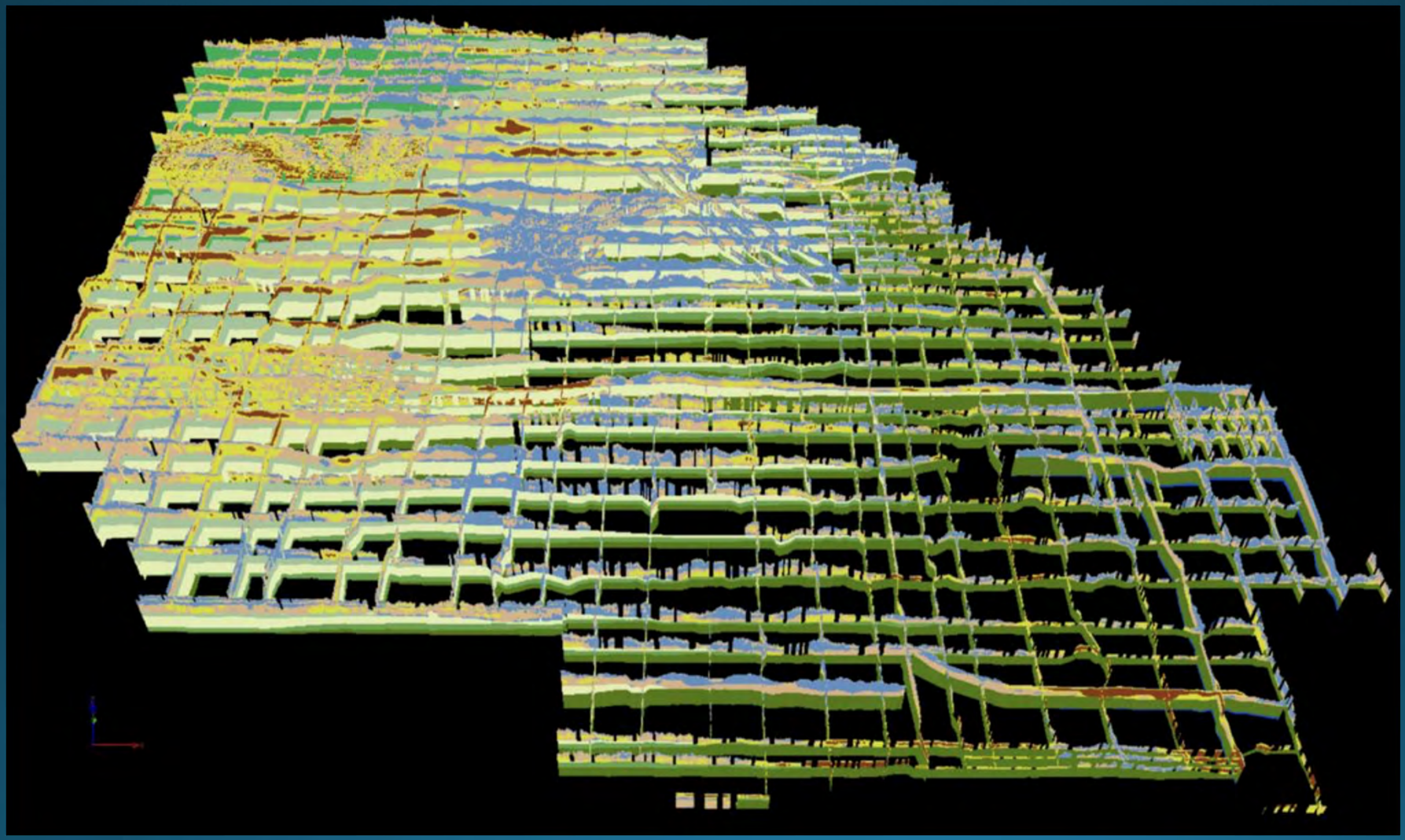


Lower Elkhorn NRD AEM Survey History

- 2007- pilot projects for ENWRA- Ashland, Firth and Oakland
- 2013- Clarkson-Howells
- 2014- Reconnaissance lines
- 2014 – Selected sites in the LENRD
- 2016- additional areas of the LENRD
- 2018- completion of the 2 mile grids in the LENRD and Pierce Block Flight

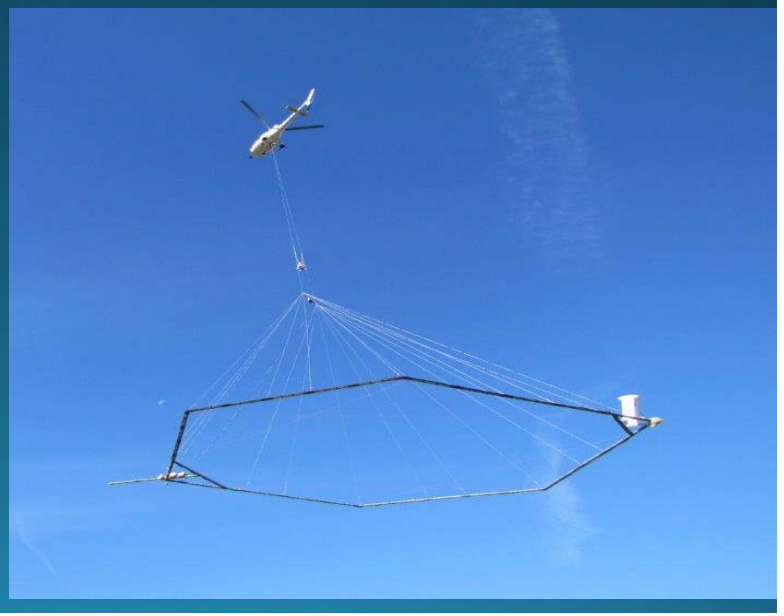


Lower Elkhorn AEM Survey Area 2007-2018



Lower Elkhorn NRD AEM Survey Objectives

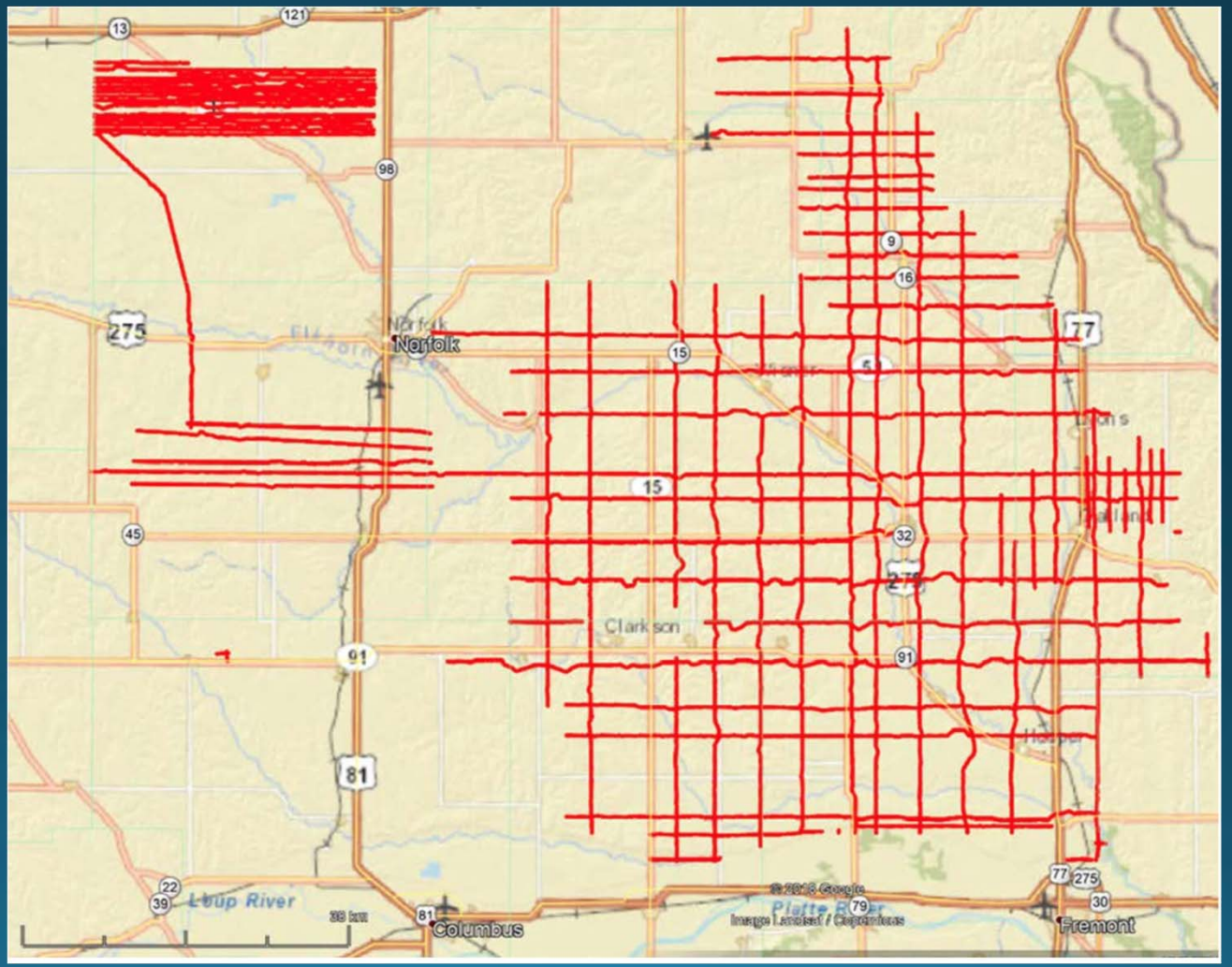
- Improve the Hydrogeologic framework of the LENRD
- Provide Reconnaissance Level Profiles and 3D representations of the hydrogeology
- Provide a detailed framework in the Pierce Block flight area
- Provide information on boundary conditions within the subsurface
- What is the hydrologic connections between groundwater and surface water in the survey areas.
- Potential of groundwater recharge areas



Lower Elkhorn AEM Survey Area 2019

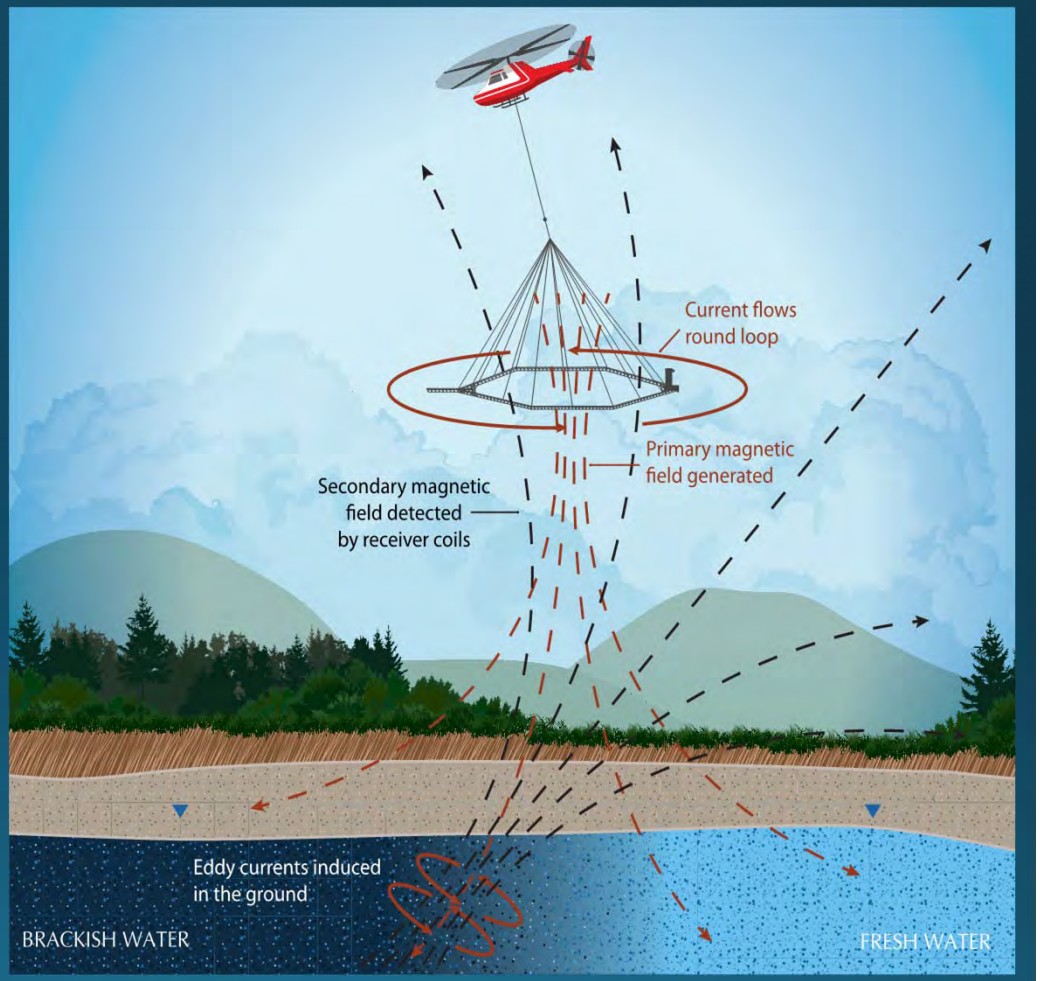
- ~1,695 line miles
- $870,000 total cost
- 50% additional

miles flown due to better price from vendor



AEM Fundamentals

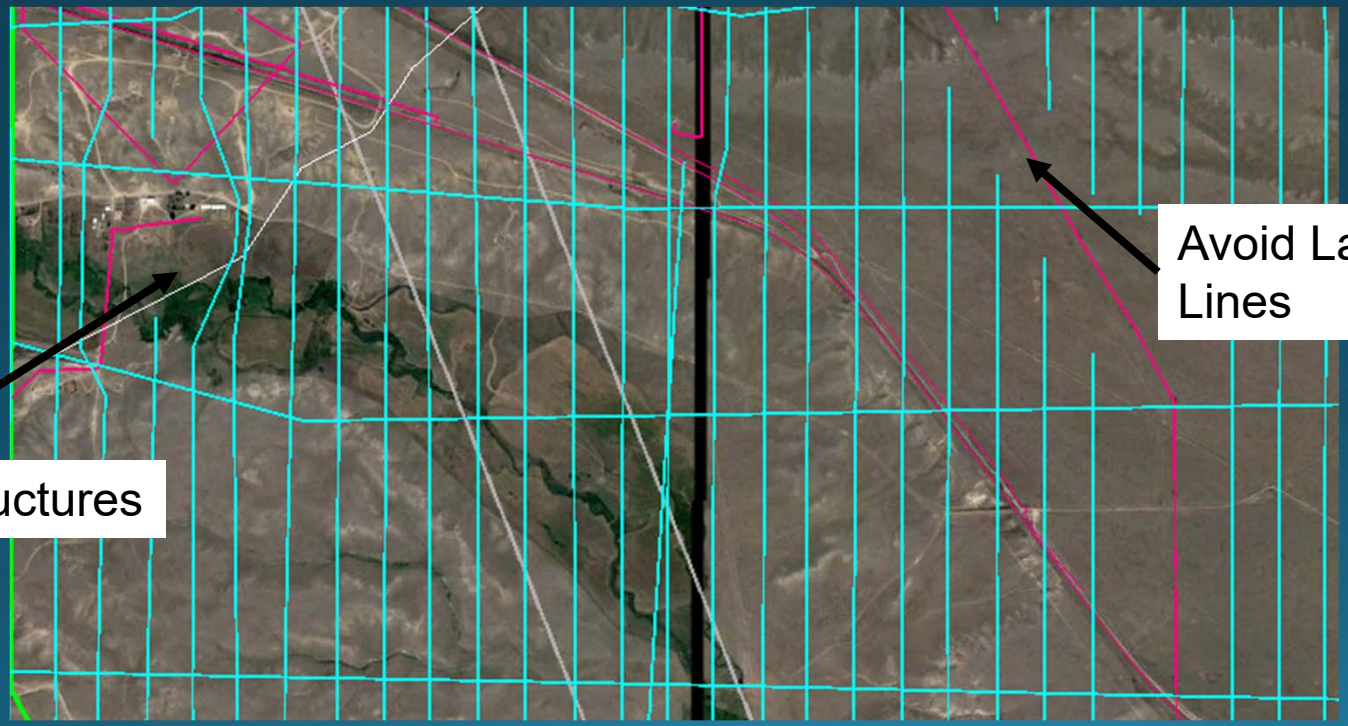
- Airborne Geophysical Techniques
  - Electromagnetic – Time Domain (TDEM) or Frequency Domain (FDEM)
  - Gravity Gradient (Tensor)
  - Total-Field Intensity Magnetics
  - Radiometrics
- Surveys typically use multiple techniques to create contrast in physical properties



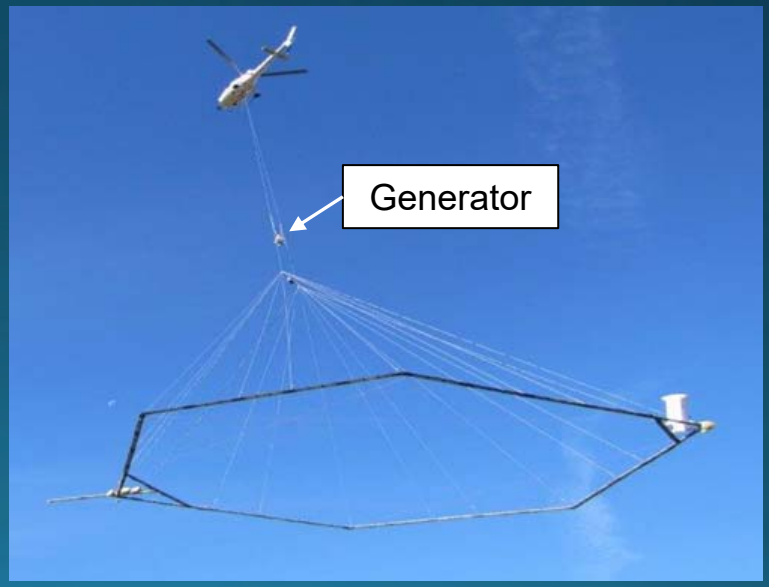
XRI, 2015

Flight Line Planning for Each Project

- Maps of electrical lines along AEM flight lines
- Maps of pipelines and other infrastructure along the AEM flight lines
- Inspection of Google Earth coverages along each flight line for dwelling, CAFOs , and other no fly objects
- Provide detailed flight lines for navigation
- Build a detailed borehole database



Helicopter AEM Operation



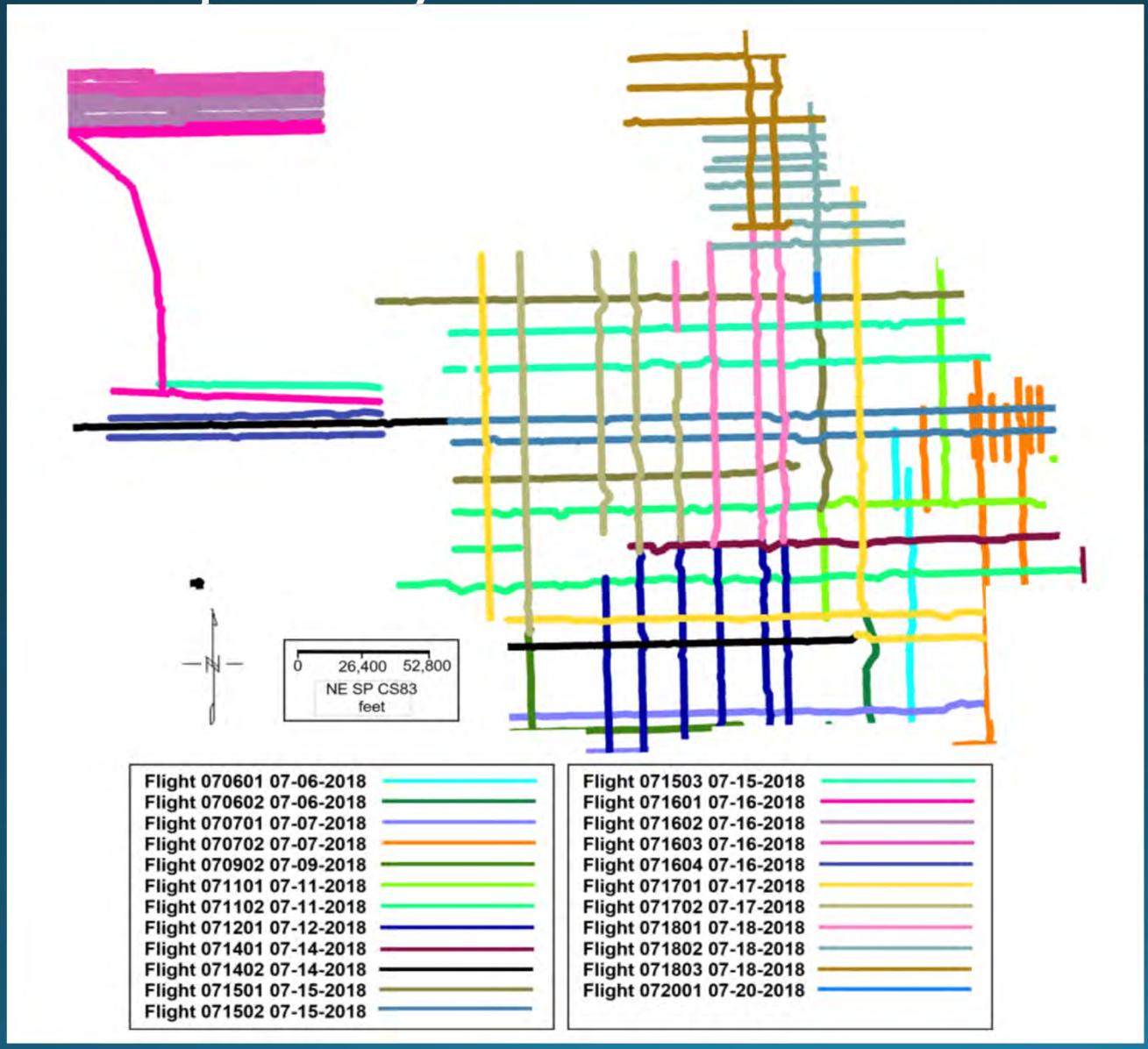
Usually 2-3 Flights/day
Totaling about 180-250 line-miles/day
Approx. 100' – 150' above ground

Along-Line Data Density,
Post Processing,
Approximately Every ~ 100 ft

2018 Lower Elkhorn NRD Acquisition Schedule

- Start date July 6, 2018
- Completion of Flights July 20, 2018
- Flights dependent on weather, contracting, equipment problems, efficiency of the subcontractor etc.
- AGF was on the ground during the entire data collection process to manage the operations.

Lower Elkhorn NRD Final Flight Acquisition Plan Grouped by Date Collected



QA/QC and Initial Preliminary Inversions

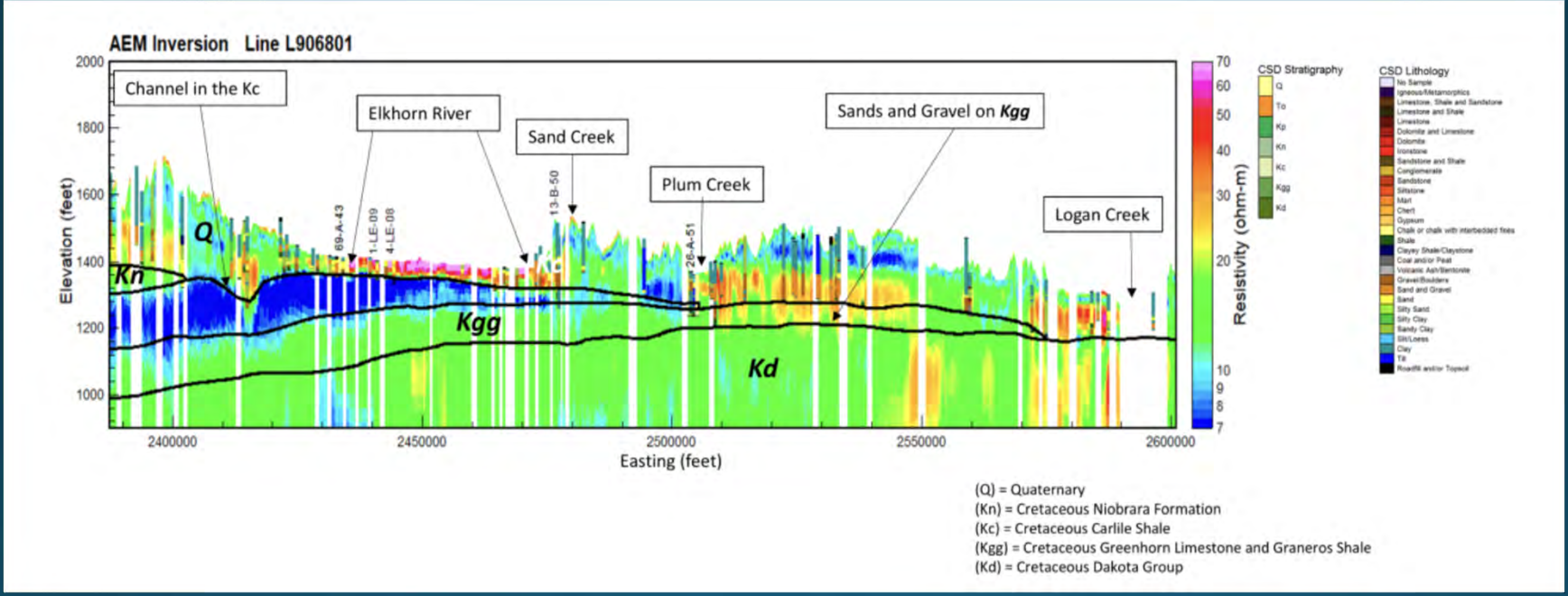
- QA/QC of collected data continued throughout the data collection process on every day's collected data
- Unacceptable data was recollected
- Initial preliminary inversions began immediately upon data availability

Existing Geologic Data

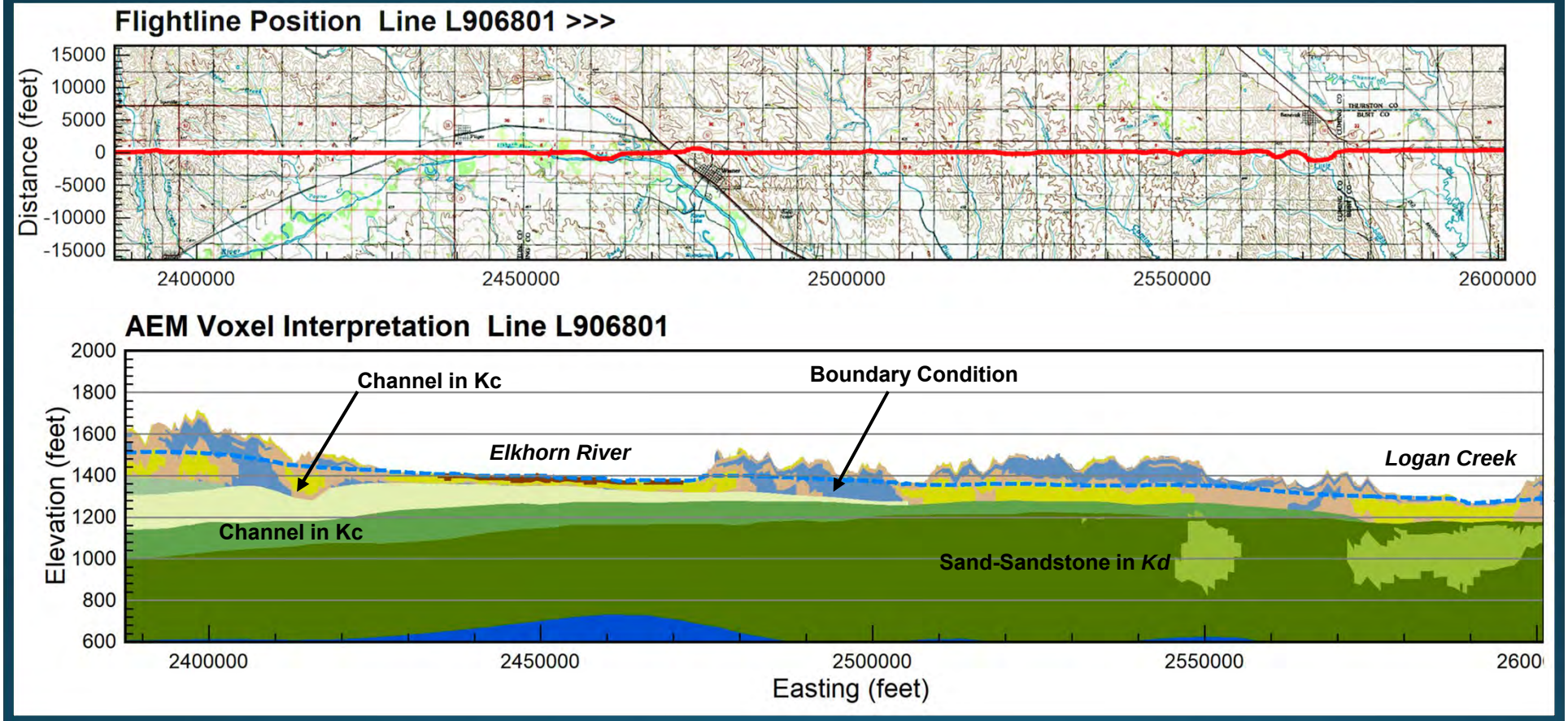
- Use CSD test-hole database
- Use CSD historical cross sections
- Use selected DNR well logs
- Use selected oil and gas well logs
- Use any other pertinent information
- Water table elevations

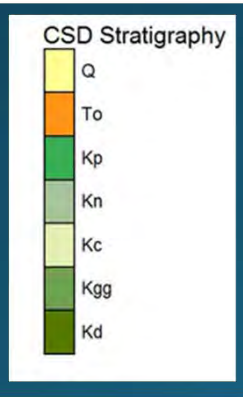
Utilize as much existing and accurate geologic test-hole data as possible!

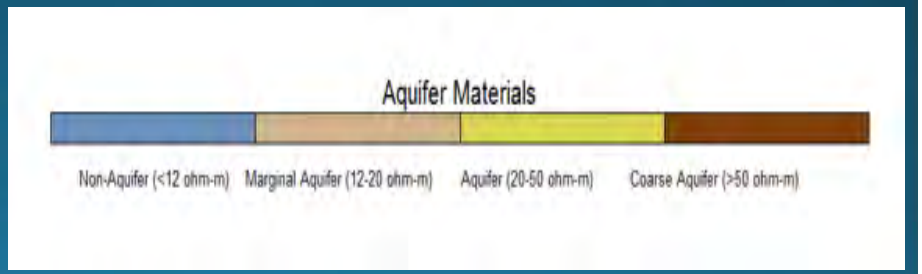
Interpreting Resistivity



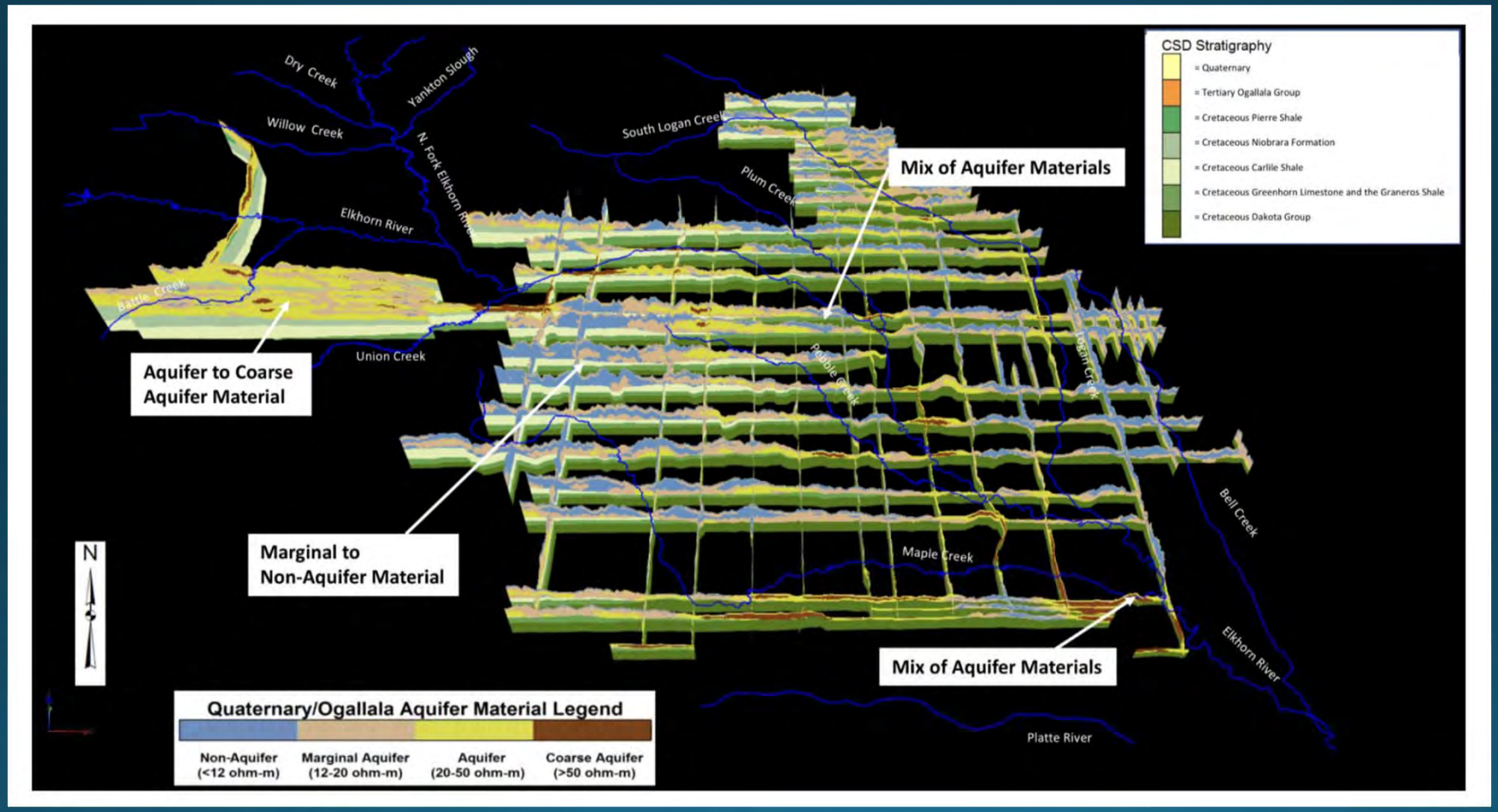
Interpreted Section



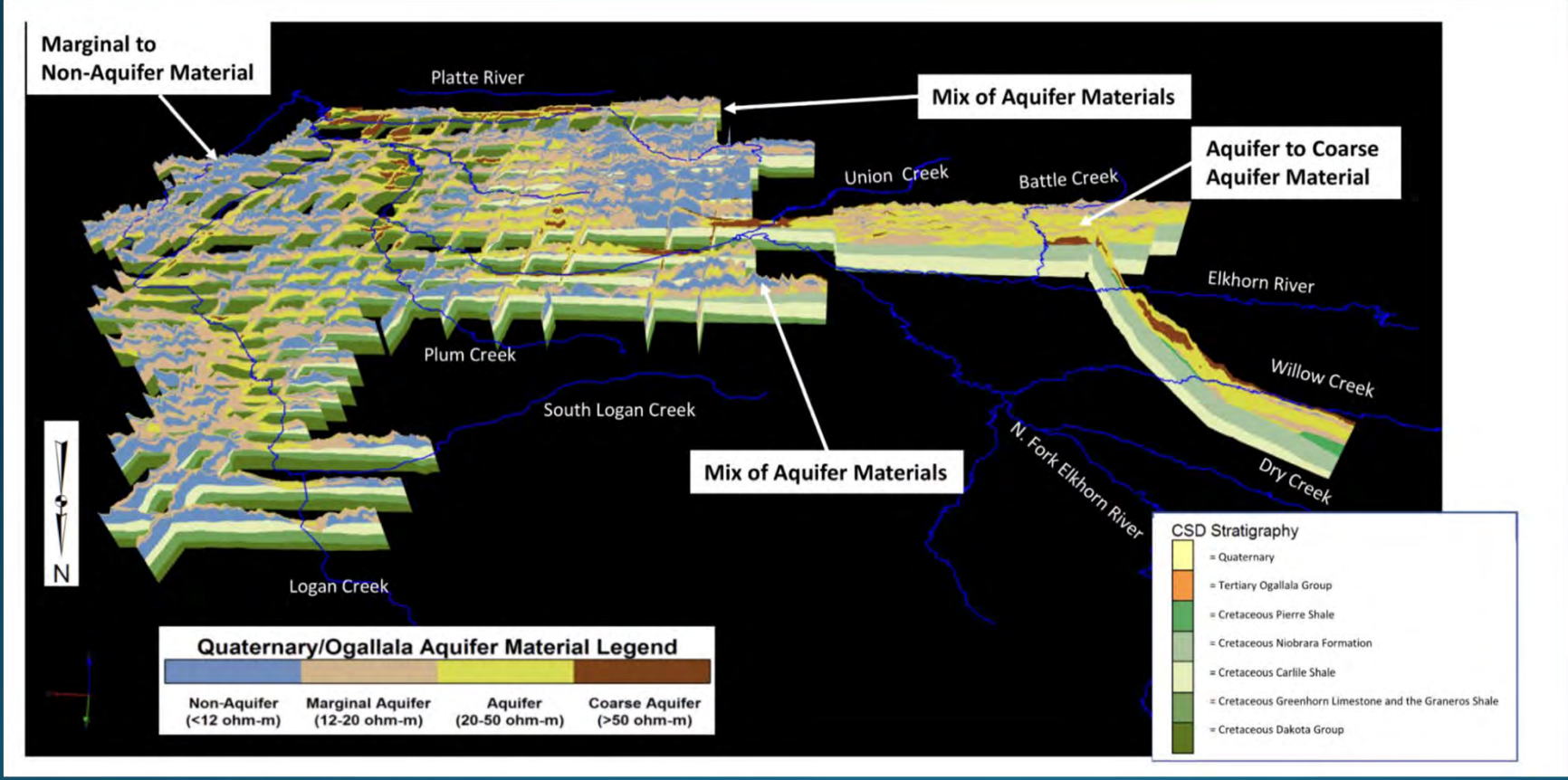




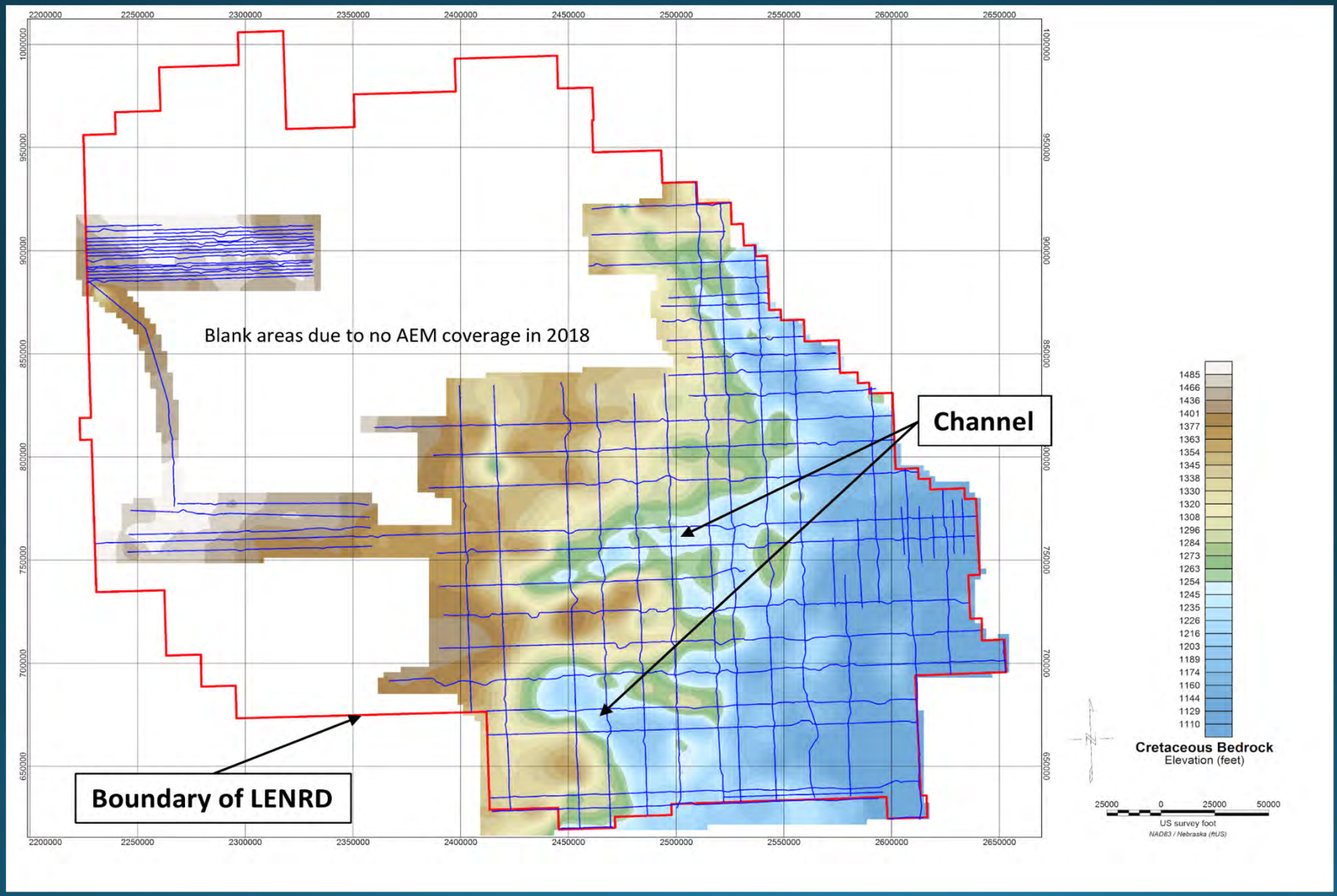
LENRD 3D View Hydrogeologic Areas- Looking North



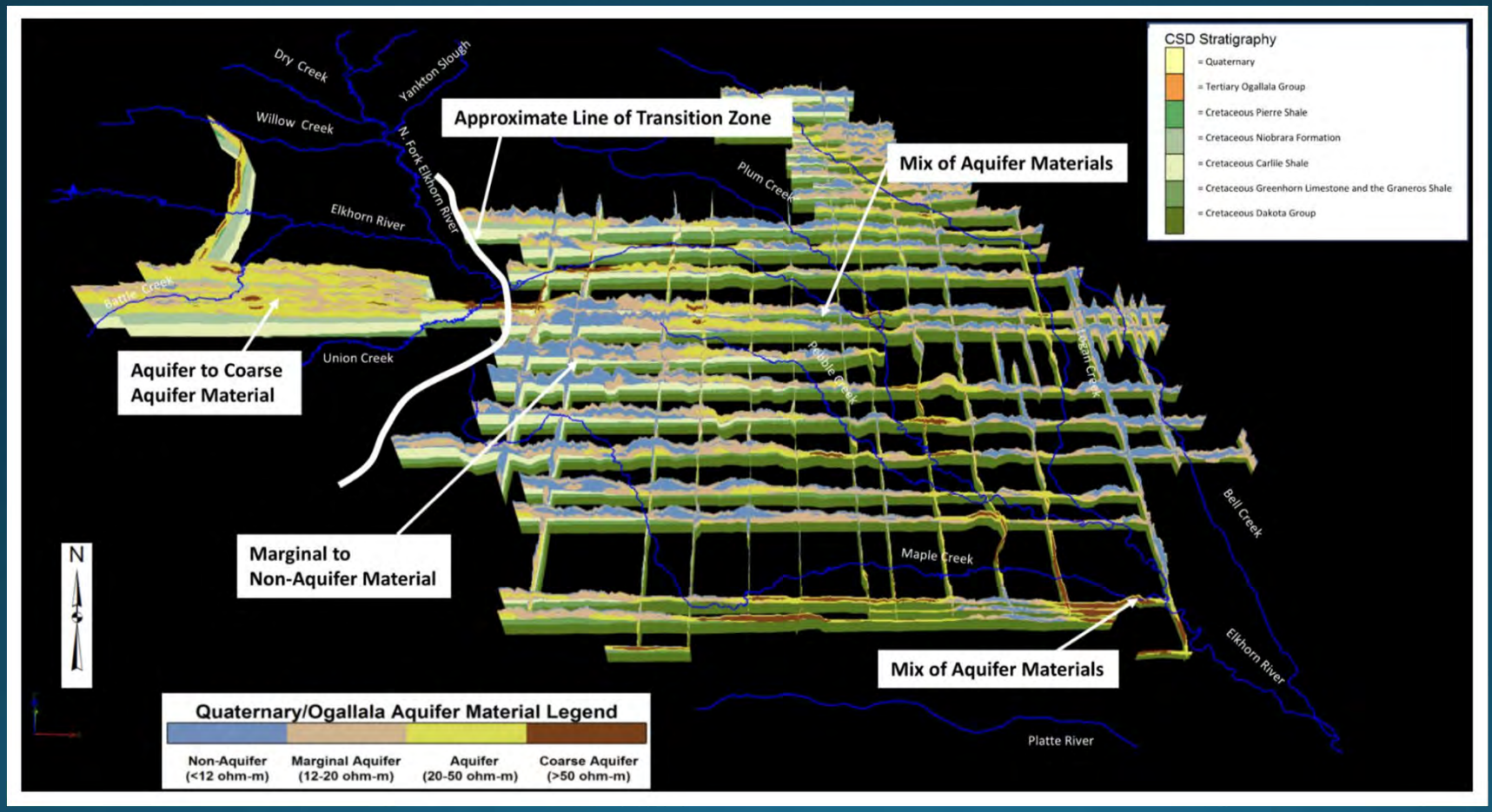
LENRD 3D View Hydrogeologic Areas—Looking South



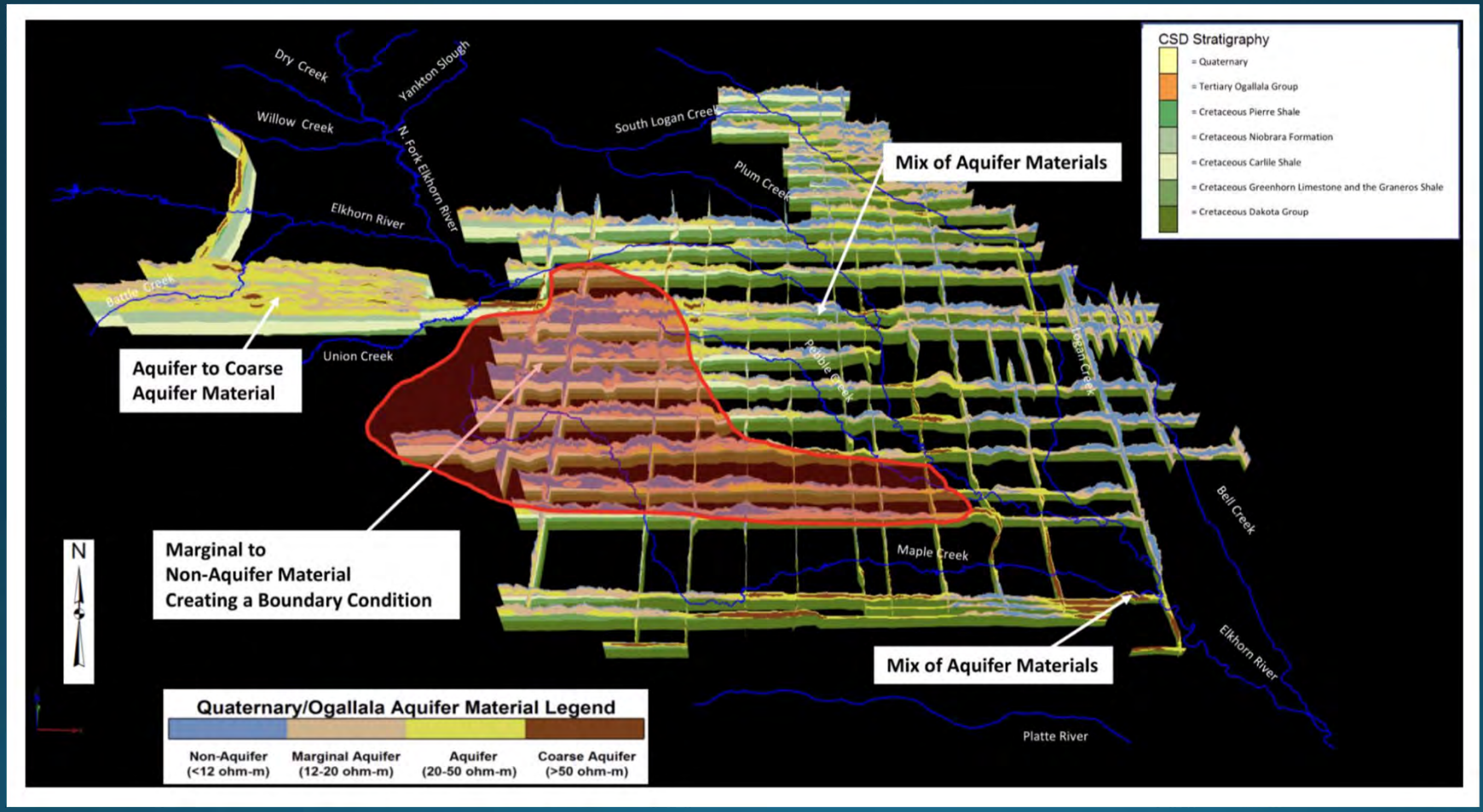
Lower Elkhorn NRD Configuration of the Bedrock Surface



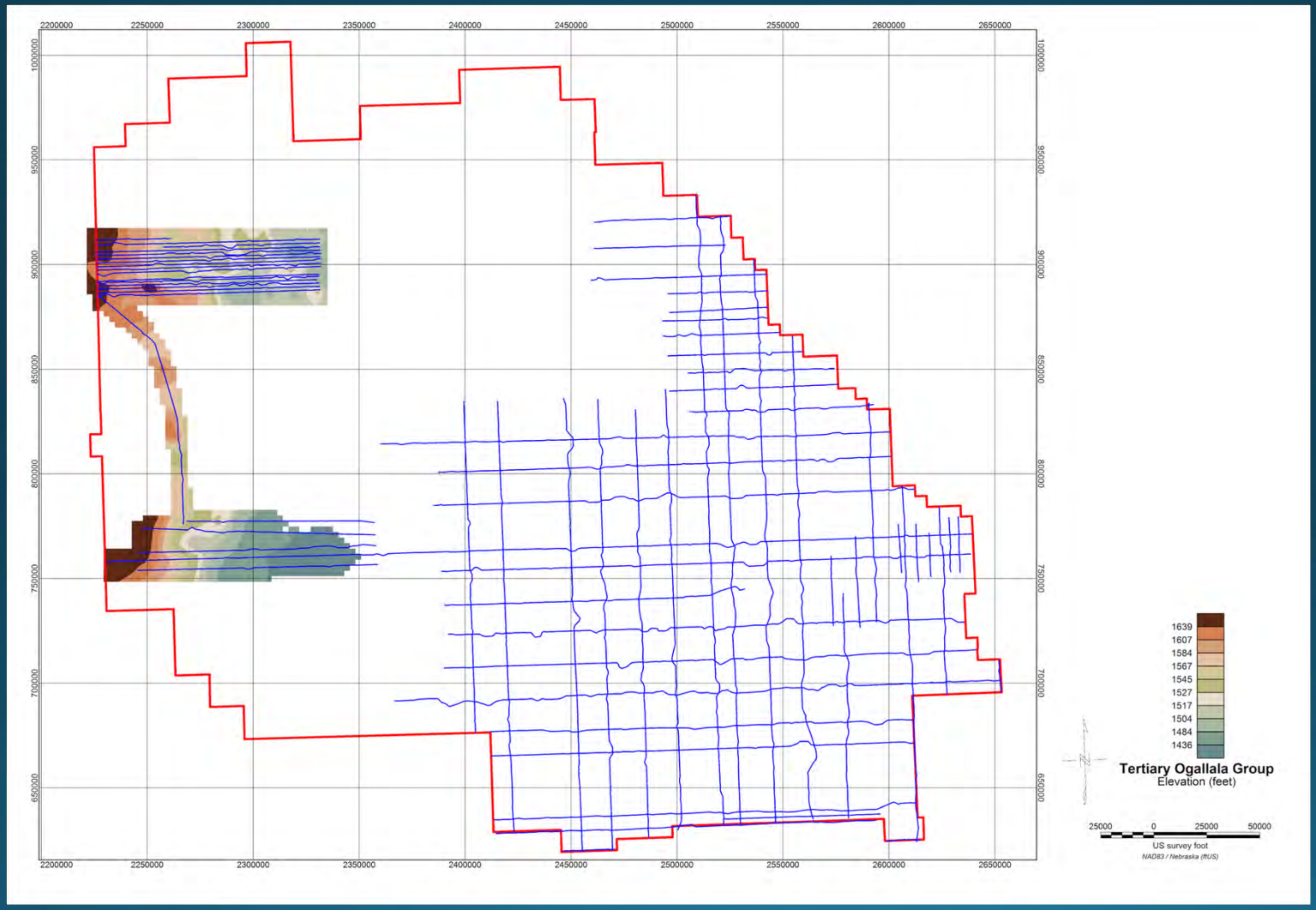
Lower Elkhorn NRD 3D Map of Aquifer Materials Showing Aquiclude Material Transition Boundary



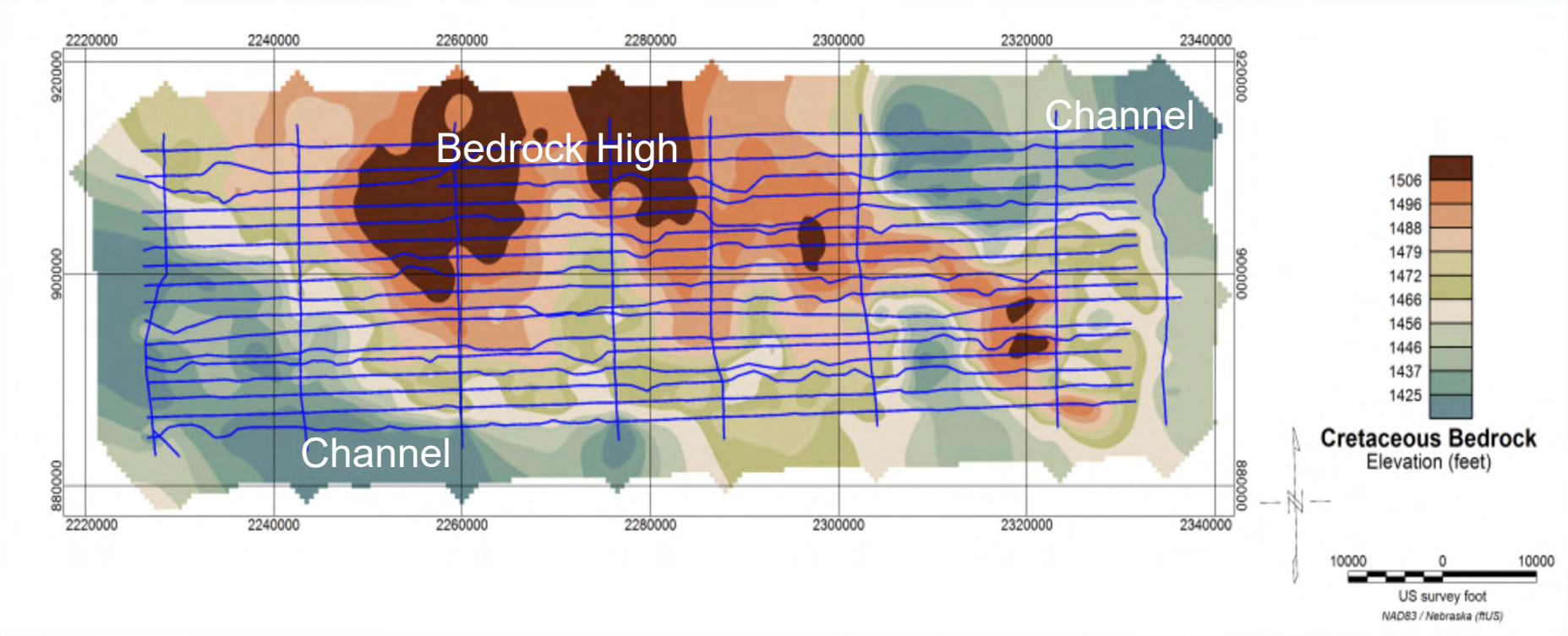
Lower Elkhorn NRD 3D Map of Aquifer Materials Showing changes in Lithology That Act as Boundary Conditions to Groundwater Flow.



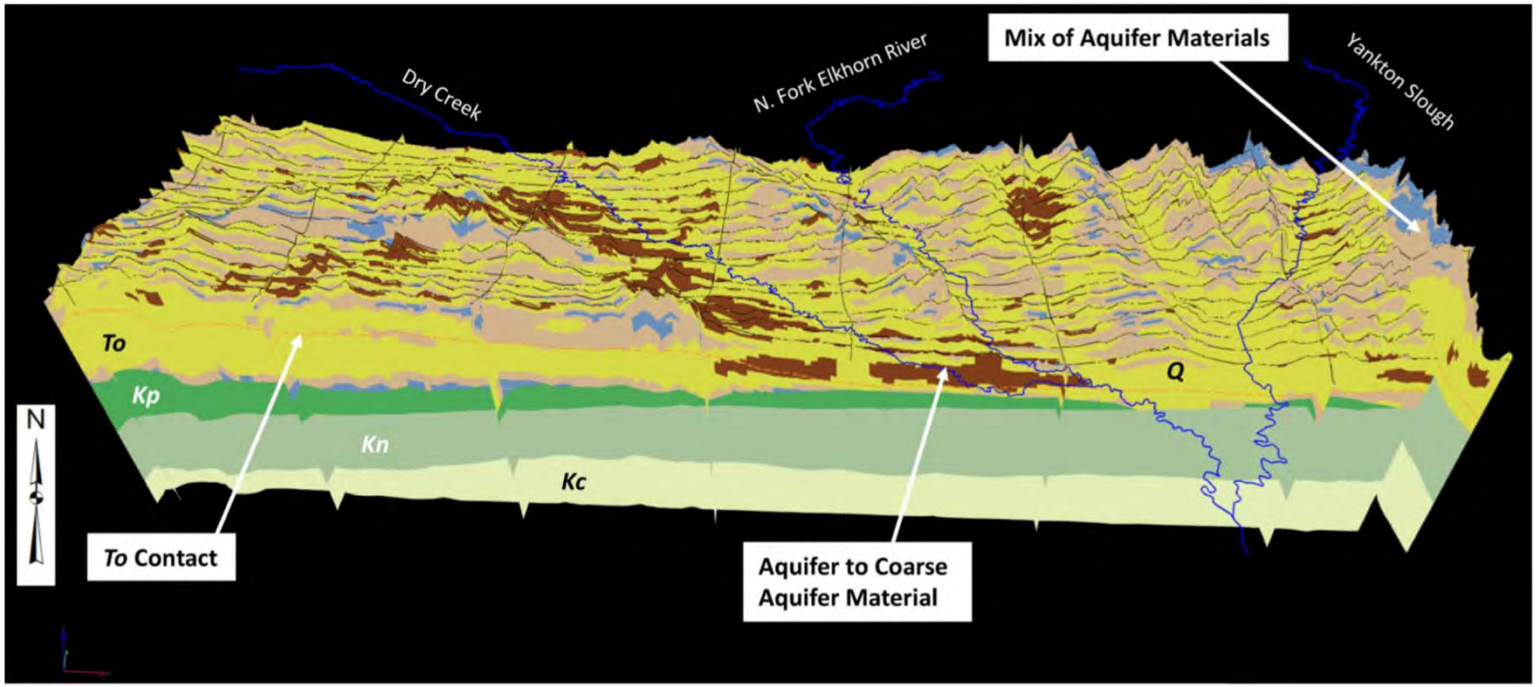
The Pierce Block Area Quaternary- Tertiary Ogallala Materials Elevation



Pierce Block Configuration of the Bedrock Surface



LENRD 3D View Hydrogeology- Pierce Block



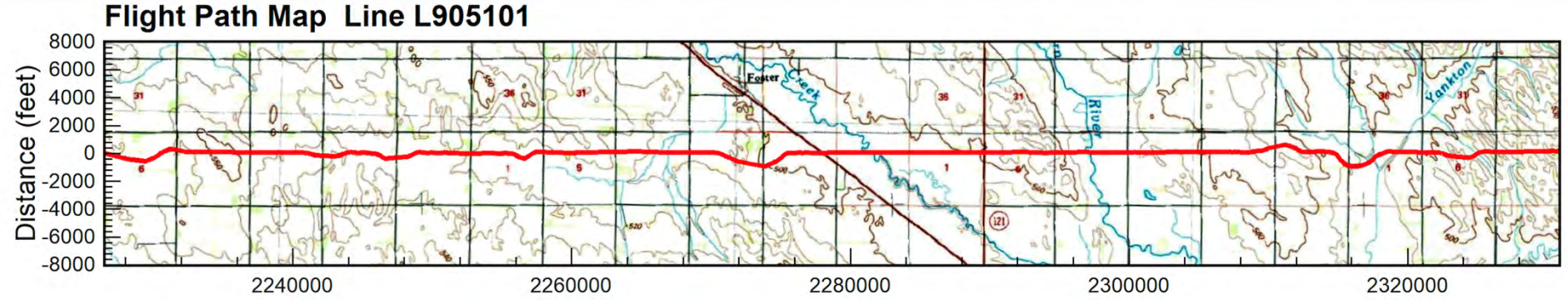
Quaternary/Ogallala Aquifer Material Legend

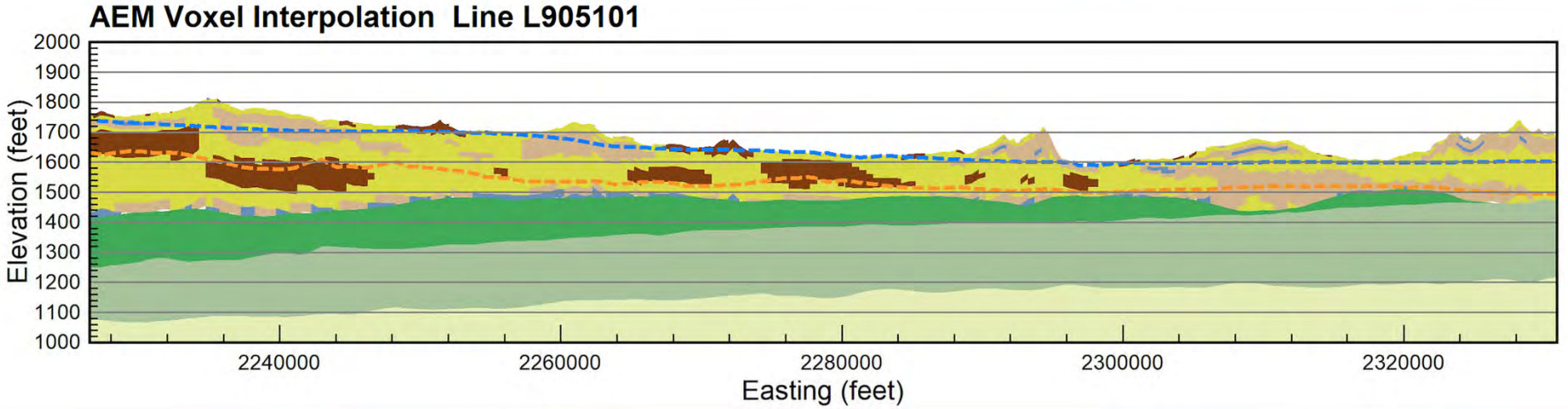
Non-Aquifer (<12 ohm-m)	Marginal Aquifer (12-20 ohm-m)	Aquifer (20-50 ohm-m)	Coarse Aquifer (>50 ohm-m)

CSD Stratigraphy

- = Quaternary
- = Tertiary Ogallala Group
- = Cretaceous Pierre Shale
- = Cretaceous Niobrara Formation
- = Cretaceous Carlile Shale
- = Cretaceous Greenhorn Limestone and the Graneros Shale
- = Cretaceous Dakota Group
- = Undifferentiated Pennsylvanian

Lower Elkhorn NRD Profile L905101





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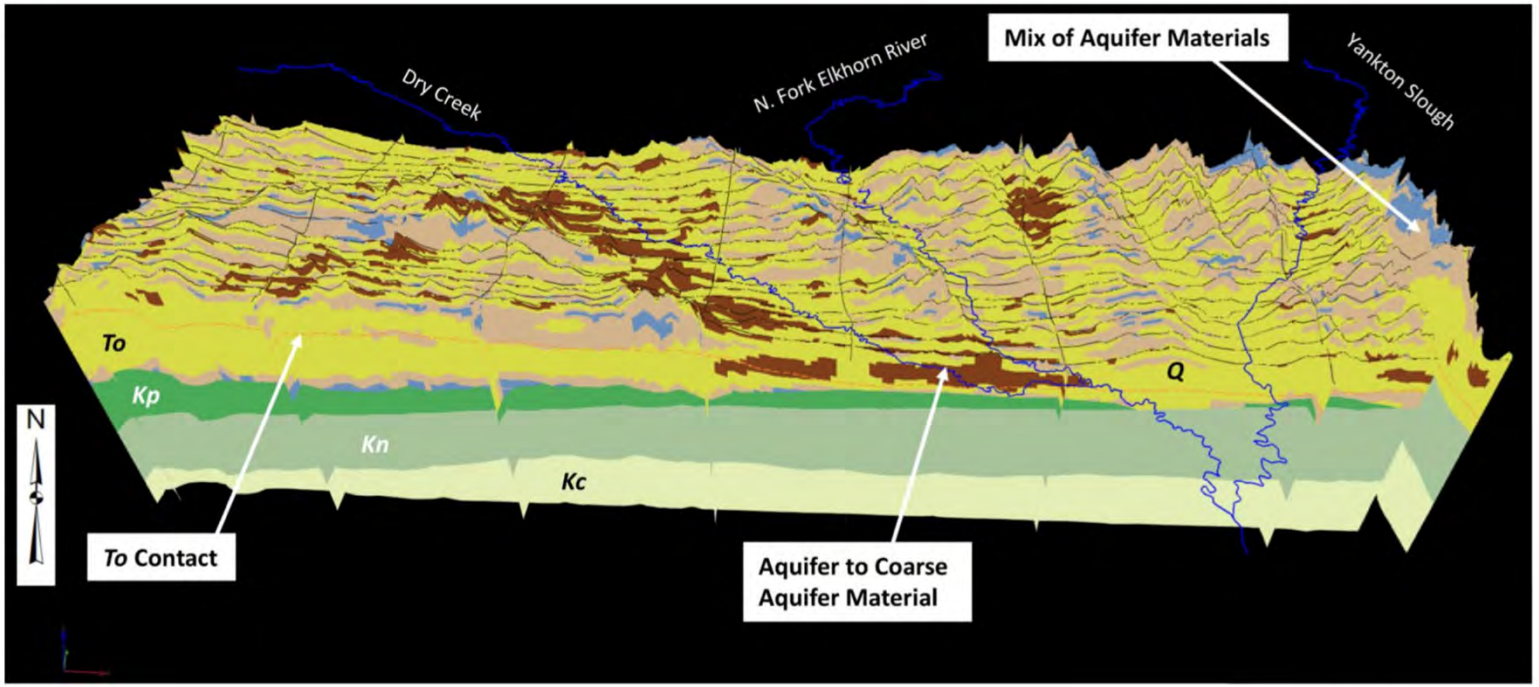

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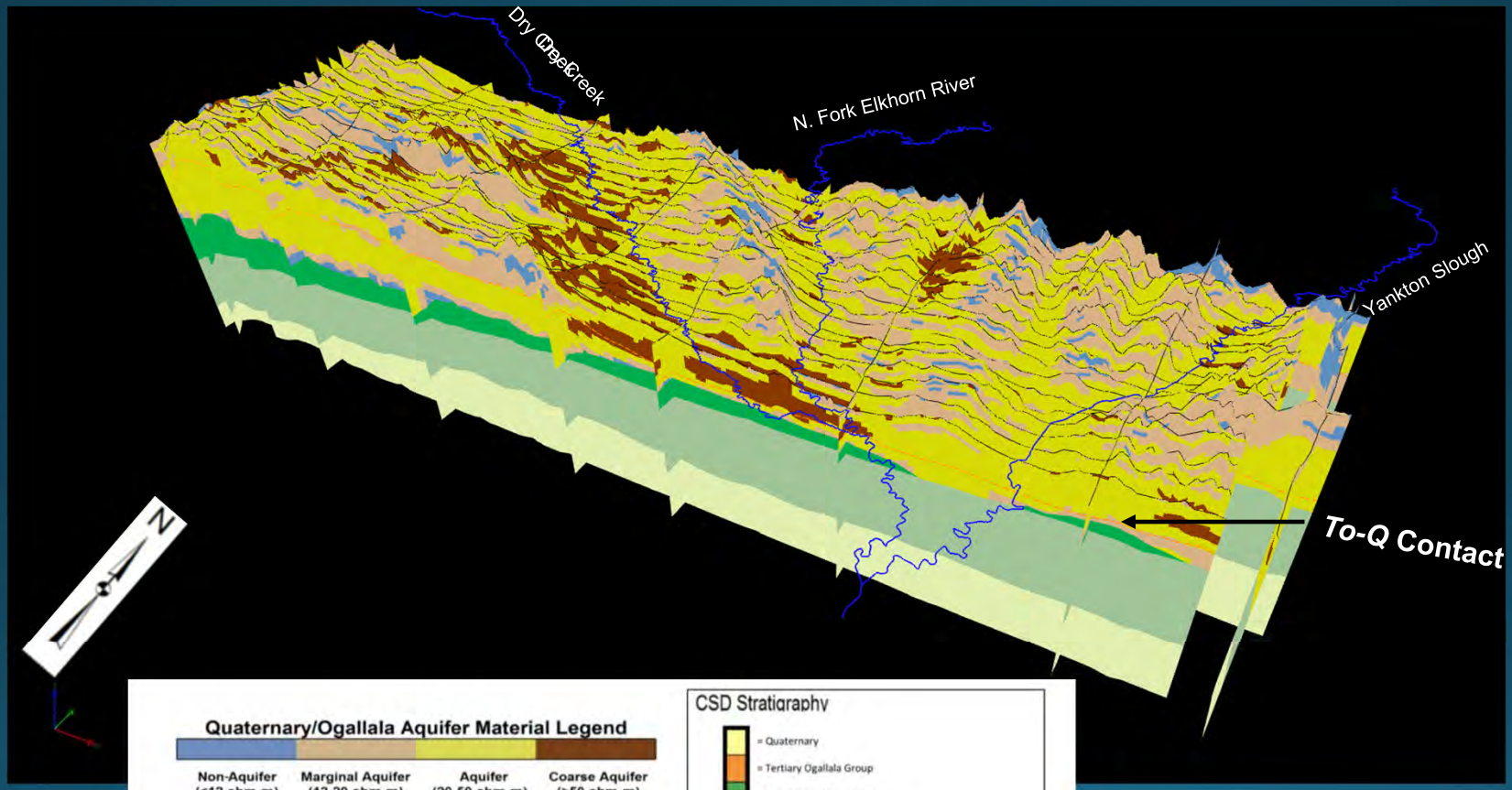
Water Quality Related to Changes in Aquifer Materials and Stratigraphy in Pierce Block



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Pierce Block Estimates of Groundwater in Storage

Table 3-4. Saturated *Q* aquifer materials underlying the Pierce County Block area

Aquifer Material Type	Aquifer Volume (ft^3)	Aquifer Volume (acre-ft)	Average Porosity	Groundwater in Storage Volume (acre-ft)	Average Specific Yield	Extractable Water Volume (acre-ft)
Non-Aquifer	3,686,553,750	84,632	0.40	33,853	0.02	677
Marginal	81,385,098,750	1,868,348	0.35	653,922	0.05	32,696
Aquifer	190,819,082,500	4,380,610	0.20	876,122	0.22	192,747
Coarse Aquifer	45,465,576,250	1,043,748	0.25	260,937	0.19	49,578
TOTAL	321,356,311,250	7,377,337		1,824,834		275,698

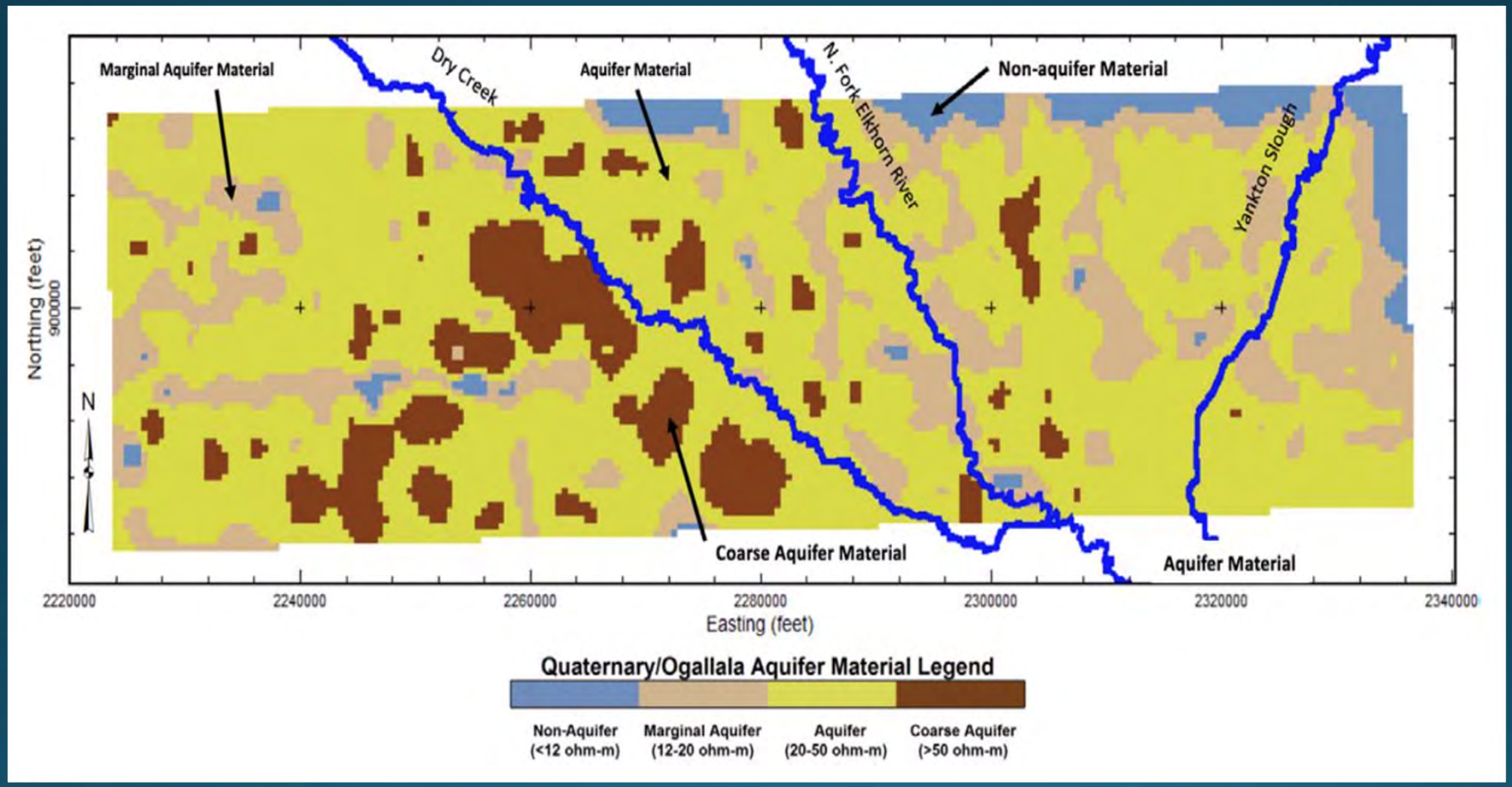
Table 3-5. Unsaturated *Q* aquifer materials underlying the Pierce County Block area.

Aquifer Material Type	Aquifer Volume (ft^3)	Aquifer Volume (acre-ft)	Average Porosity	Groundwater in Storage Volume (acre-ft)	Average Specific Yield	Extractable Water Volume (acre-ft)
Non-Aquifer	11,901,002,500	273,210	0.40	109,284	0.02	2,186
Marginal	71,154,426,250	1,633,483	0.35	571,719	0.05	28,586
Aquifer	77,192,245,000	1,772,093	0.20	354,419	0.22	77,972
Coarse Aquifer	10,855,091,250	249,199	0.25	62,300	0.19	11,837
TOTAL	171,102,765,000	3,927,985		1,097,722		120,581

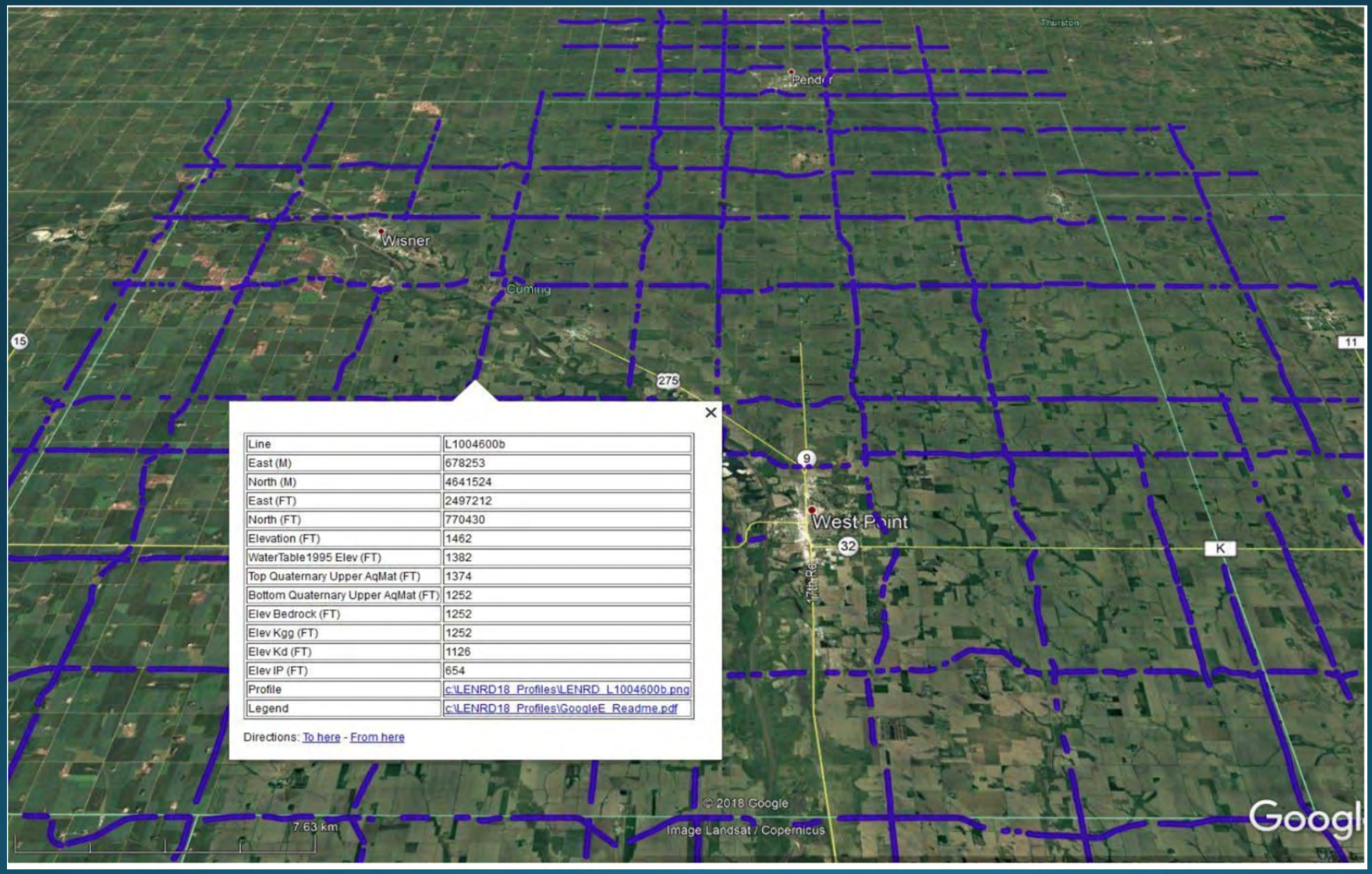
Table 3-6. Fully saturated *To* aquifer materials underlying the Pierce County block area.

Aquifer Material Type	Aquifer Volume (ft^3)	Aquifer Volume (acre-ft)	Average Porosity	Groundwater in Storage Volume (acre-ft)	Average Specific Yield	Extractable Water Volume (acre-ft)
Non-Aquifer	37,357,511,250	857,610	0.40	343,044	0.015	5,146
Marginal	76,179,342,500	1,748,837	0.35	612,093	0.038	23,259
Aquifer	135,557,392,500	3,111,969	0.20	622,394	0.17	105,807
Coarse Aquifer	11,725,067,500	269,170	0.25	67,292	0.14	9,421
TOTAL	260,819,313,750	5,987,586		1,644,823		143,633

Potential Recharge Areas In the Pierce Block



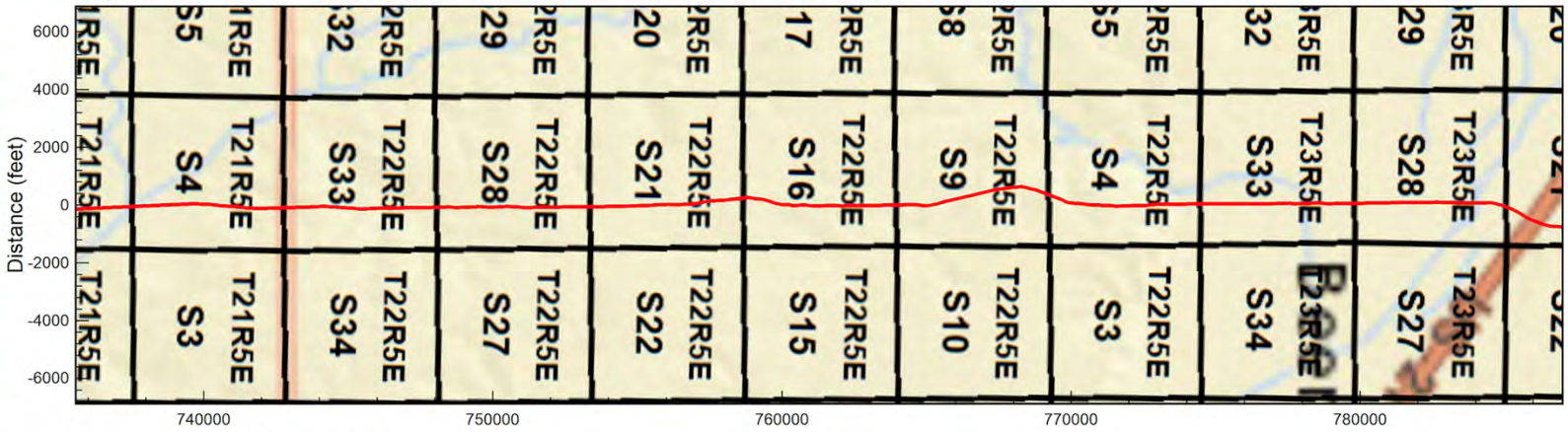
Lower Elkhorn NRD Google Earth



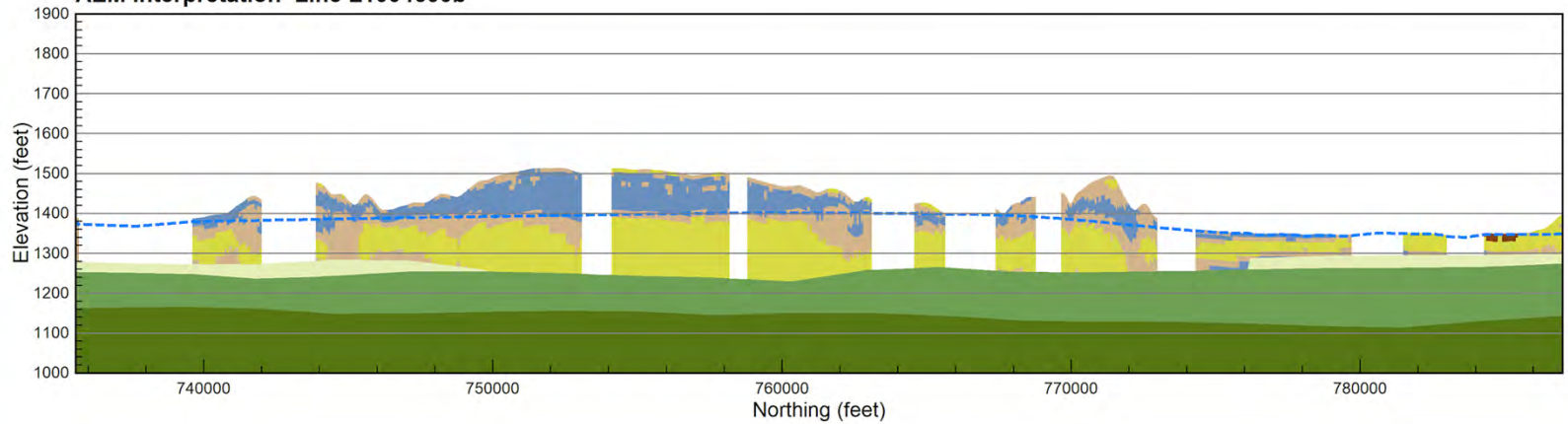
Line	L1004600b
East (M)	678253
North (M)	4641524
East (FT)	2497212
North (FT)	770430
Elevation (FT)	1462
WaterTable1995 Elev (FT)	1382
Top Quaternary Upper AqMat (FT)	1374
Bottom Quaternary Upper AqMat (FT)	1252
Elev Bedrock (FT)	1252
Elev Kgg (FT)	1252
Elev Kd (FT)	1126
Elev lP (FT)	654
Profile	c:\LENRD18_Profiles\LENRD_L1004600b.png
Legend	c:\LENRD18_Profiles\GoogleE_Readme.pdf

Directions: To here - From here

Flight Path Map Line L1004600b



AEM Interpretation Line L1004600b



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Stratigraphy Interpretation

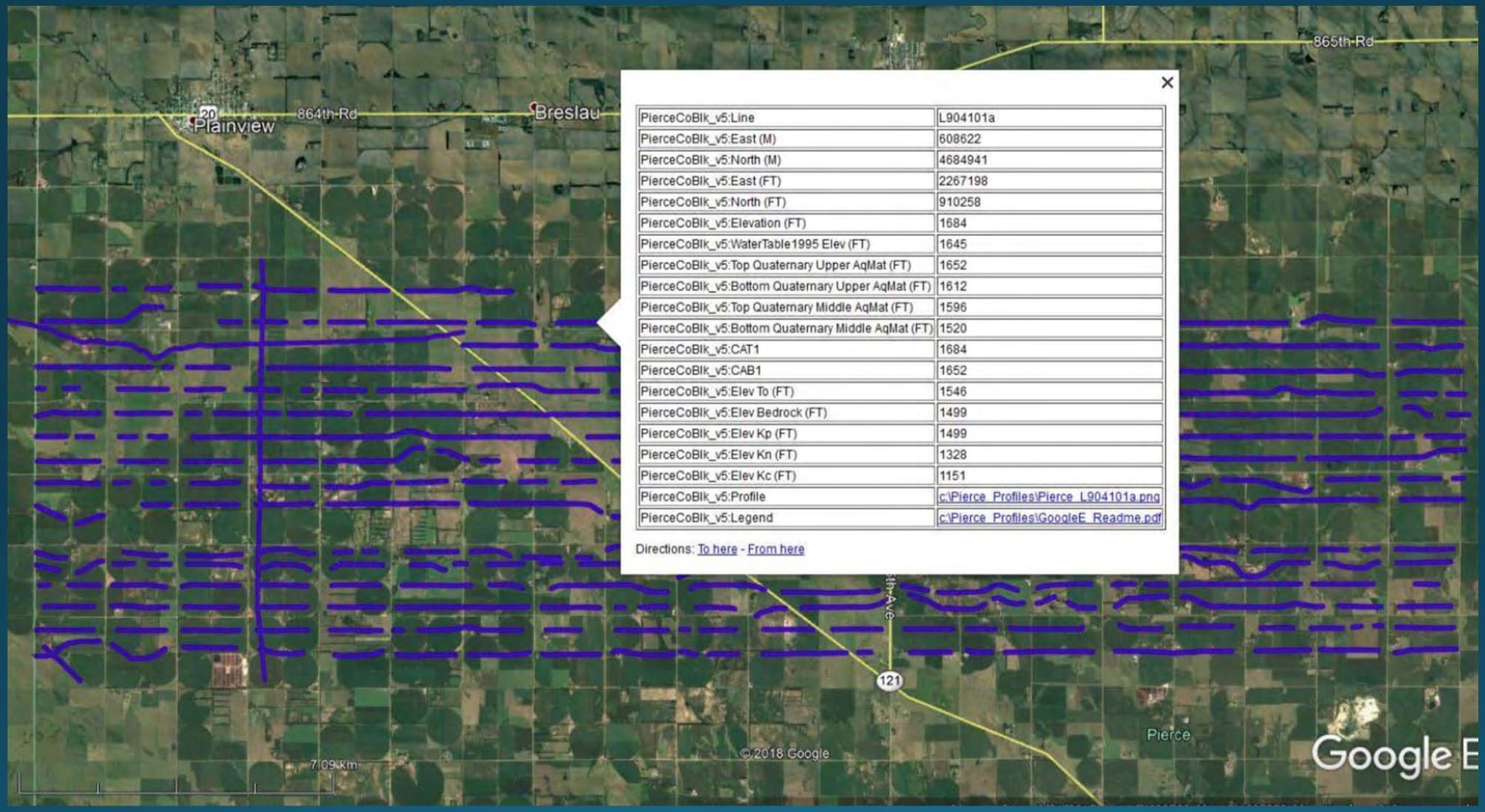
IP Kd Kgg Kc Kn Kp To

Interpreted geological sections from AEM data and flight path location map provided in conjunction with the Google Earth kmz file. The projected downline distance is equal for the flight path (top image) and the AEM data interpretation (bottom image). The flight path is displayed as a red line on the flight path map. The 1995 Conservation and Survey Division (CSD) water table is shown as a dashed blue line on the AEM data interpretation profile. The Quaternary (Q) section is divided into aquifer material categories as indicated by the legend. The Tertiary Ogallala Group (To) estimated contact is represented as an orange-dashed line where present. The Cretaceous Pierre Shale (Kp), Cretaceous Niobrara Formation (Kn), Cretaceous Carlile Shale (Kc), Cretaceous Greenhorn Limestone and Graneros Shale (Kgg), Cretaceous Dakota Group (Kd), and the undifferentiated Pennsylvanian (IP) are indicated by the legend. Additional information regarding the use of this figure and the AEM data may be found in the report titled " Airborne Electromagnetic mapping and Hydrogeologic Framework of Selected Areas of the Eastern Nebraska Water Assessment Area" chapter on the Lower Elkhorn Natural Resources District.

Lower Elkhorn Natural Resources District

ENWRA Eastern Nebraska Water Resources Assessment

Lower Elkhorn NRD Google Earth



PierceCoBlk_v5:Line	L904101a
PierceCoBlk_v5:East (M)	608622
PierceCoBlk_v5:North (M)	4684941
PierceCoBlk_v5:East (FT)	2267198
PierceCoBlk_v5:North (FT)	910258
PierceCoBlk_v5:Elevation (FT)	1684
PierceCoBlk_v5:WaterTable1995 Elev (FT)	1645
PierceCoBlk_v5:Top Quaternary Upper AqMat (FT)	1652
PierceCoBlk_v5:Bottom Quaternary Upper AqMat (FT)	1612
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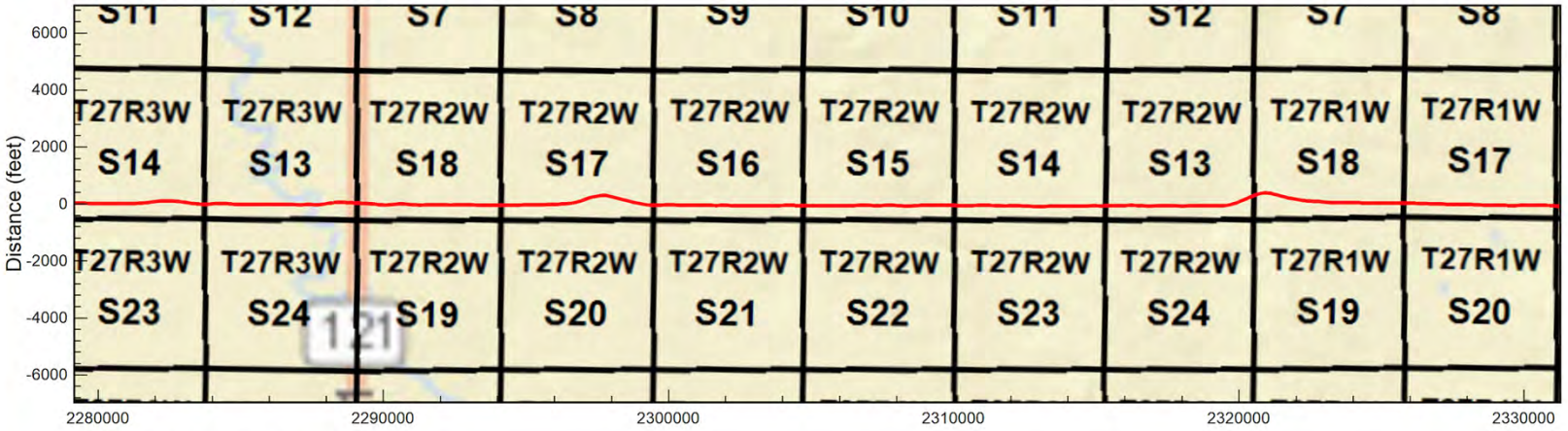
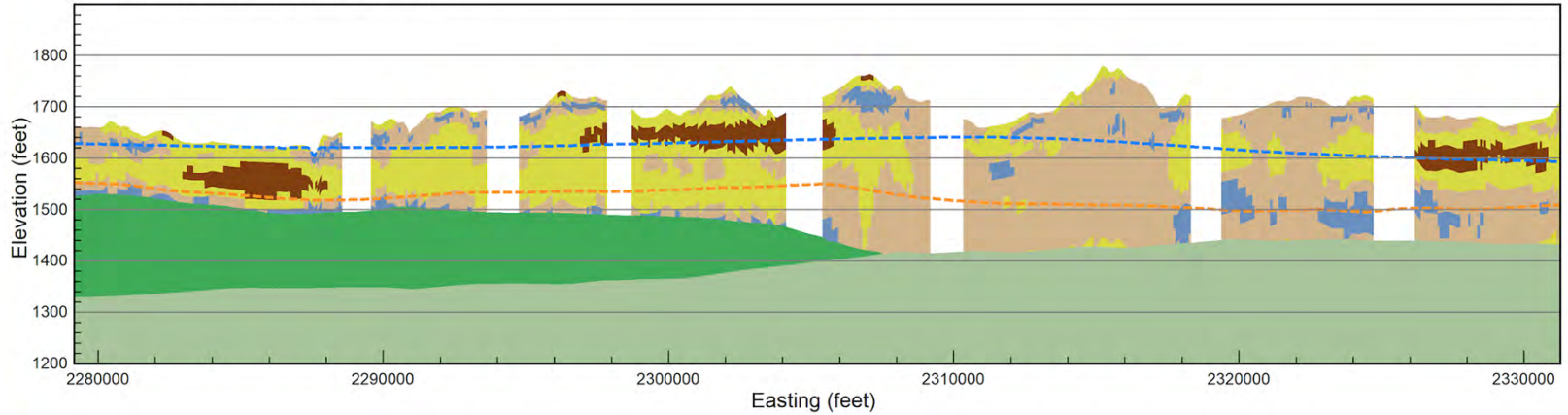
PierceCoBlk_v5:Elev Bedrock (FT)	1499
PierceCoBlk_v5:Elev Kp (FT)	1499
PierceCoBlk_v5:Elev Kn (FT)	1328
PierceCoBlk_v5:Elev Kc (FT)	1151
PierceCoBlk_v5:Profile	c:\Pierce_Profiles\Pierce_L904101a.png
PierceCoBlk_v5:Legend	c:\Pierce_Profiles\GoogleE_Readme.pdf

Directions: To here - From here

Flight Path Map Line L904101b



AEM Interpretation Line L904101b



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LOWER ELKHORN
Natural Resources District

ENWRA
Eastern Nebraska Water Resources Assessment

Key Findings

- **Boreholes -** Information from boreholes was used to analyze the AEM inversion results and was important for several areas in the LENRD that had limited or no contrast in the electrical resistivity between the different geologic formations.
- **Digitizing Interpreted Geological Contacts** - Characterization and interpretation of the subsurface was performed in cross-section and derived surface grid formats. Contacts between the geologic units were digitized in 2D including: Quaternary (***Q***), Tertiary Ogallala Group (***To***), Cretaceous Pierre Shale (***Kp***), Niobrara Formation (***Kn***), Carlile Shale (***Kc***), Greenhorn Limestone and Graneros Shale (***Kgg***), Dakota Group (***Kd***) undifferentiated Pennsylvanian (***IP***).

Key Findings

- **Resistivity/Lithology Relationship -**A numerically robust assessment of the resistivity thresholds was used to characterize non-aquifer (<12 ohm-m), marginal (12-20 ohm-m), and aquifer (20-50 ohm-m), including coarse sand-rich intervals (>50 ohm-m) was determined.
- **Resistivity/Lithology Relationship -**A numerically robust assessment of the resistivity thresholds was used to characterize non-aquifer (<12 ohm-m), marginal (12-20 ohm-m), and aquifer (20-50 ohm-m), including coarse sand-rich intervals (>50 ohm-m) was determined.

Key Findings

- **Hydrogeological Framework of the LENRD -** The 2018 LENRD AEM survey reveals variability in the Quaternary (***Q***) deposits across the LENRD AEM survey area. When combined with the ***To***, they represent the aquifer materials in the AEM survey area, where saturated.
- **Potential Recharge Zones within the LENRD AEM Survey Area -** The use of block flights in Pierce County illustrates the preferred method to use AEM to identify areas where the potential for recharge to the aquifer can be high and low.

Future Work using AEM Results

- Bring all previous work into a single projection and framework components.
- Improve water table data – add water level monitoring wells to network
- Determine wells for additional water quality testing based on their location and depth
- Provide additional information to groundwater modeling/management efforts in LENRD
- Refine transmissivity and specific yield (storativity) maps district-wide.
- Inform landowners and well drillers of the new geology maps
- Provide info to communities and update WHPA plans
- Perform aquifer tests in appropriate locations based on AEM results
- Select recharge and vadose zone study locations
- Design future AEM survey plans
- Possible Definition of perched Water areas
- The list is long

Acknowledgments

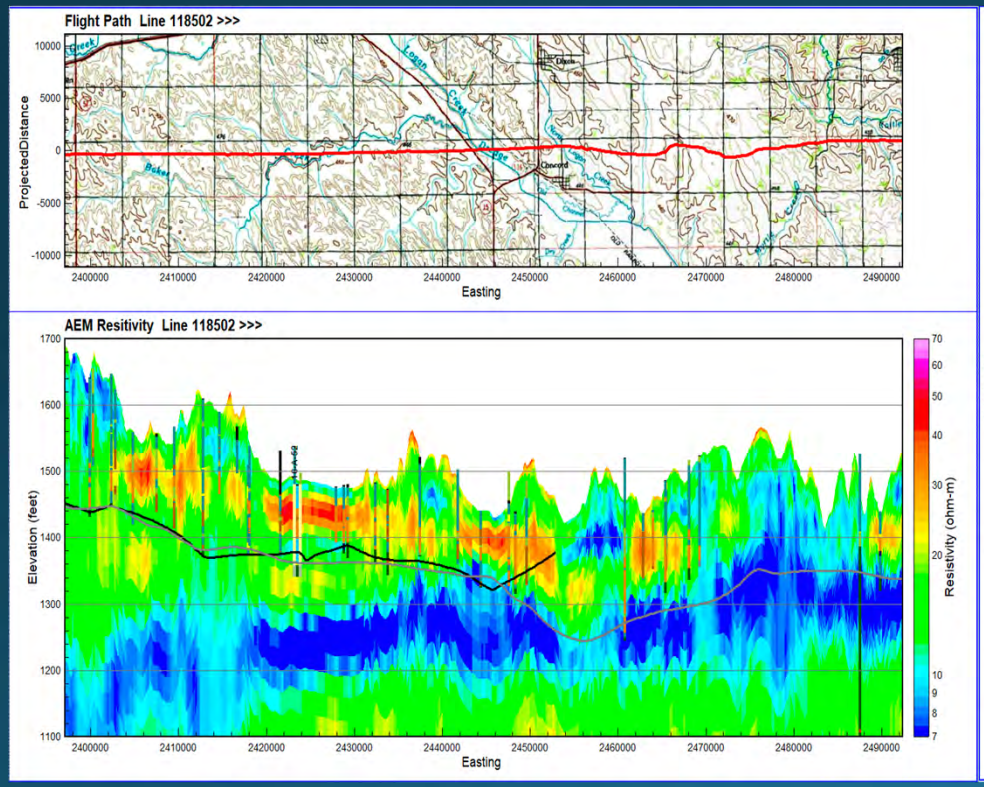
- Brian Bruckner- LENRD
- Sue Lackey - CSD
- Katie Cameron - ENWRA

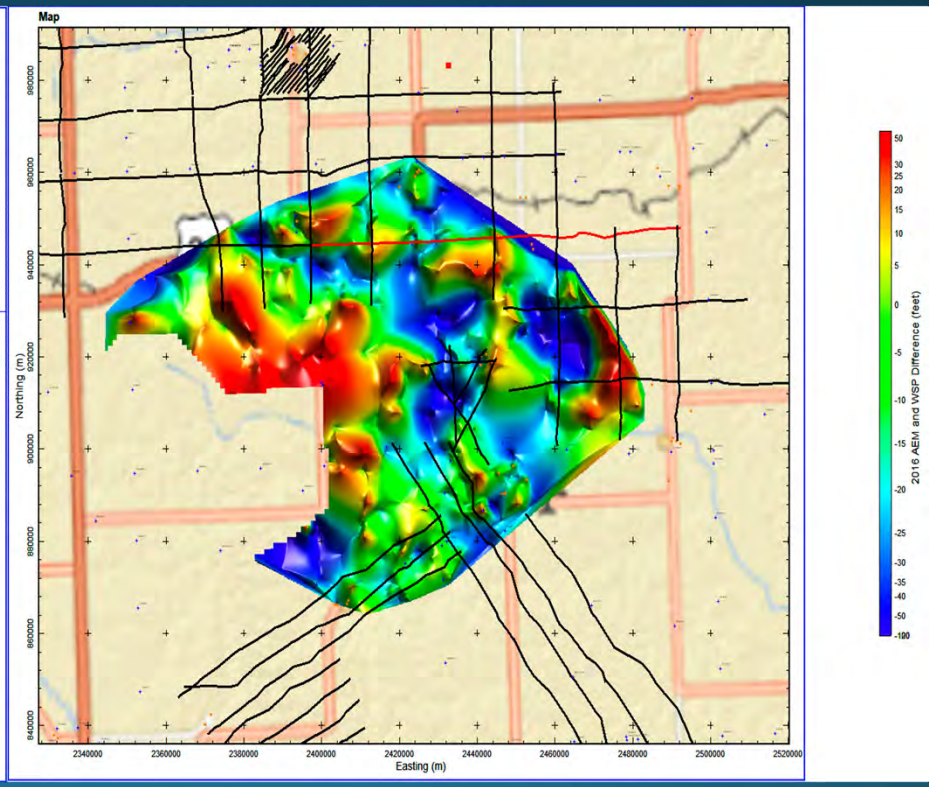
Questions??

2016 AEM vs WSP Bedrock

Gray Line is AEM Bedrock
Black line WSP Borehole Bedrock

Red Line is Current Flight Line
Black lines are 2014 Flight Lines





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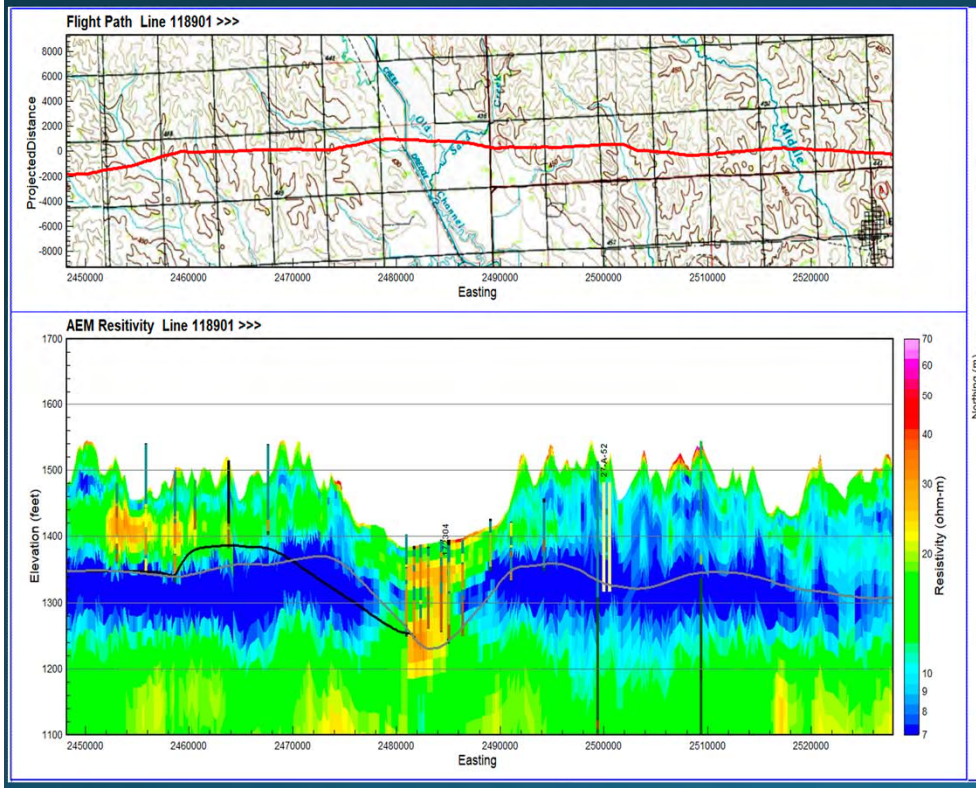

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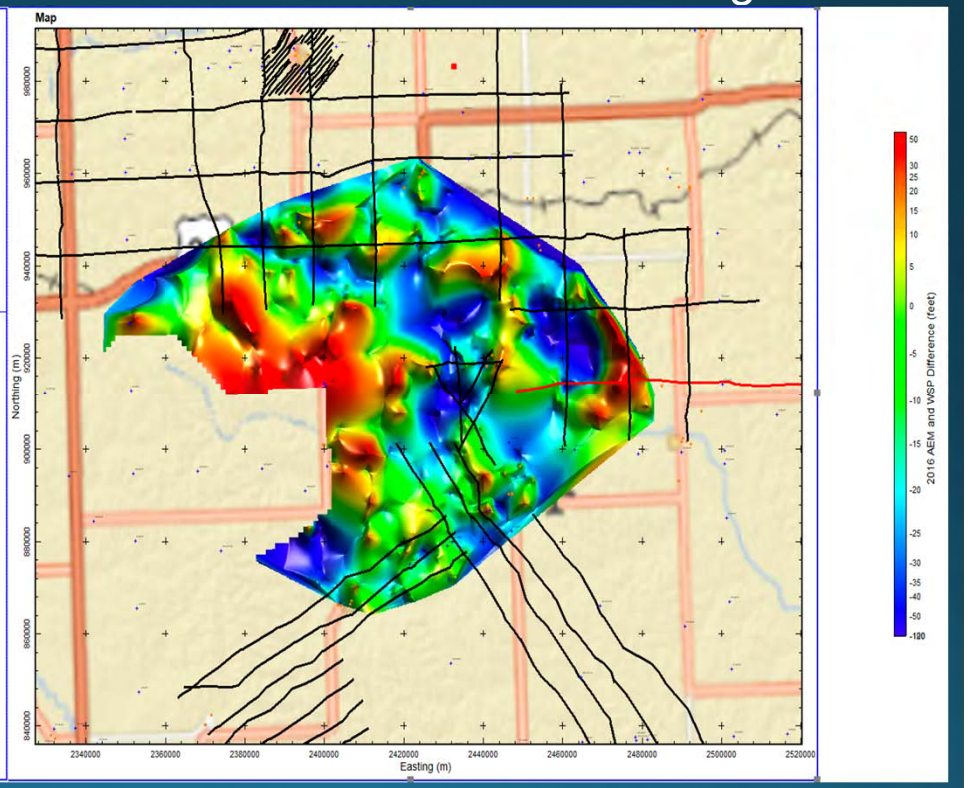

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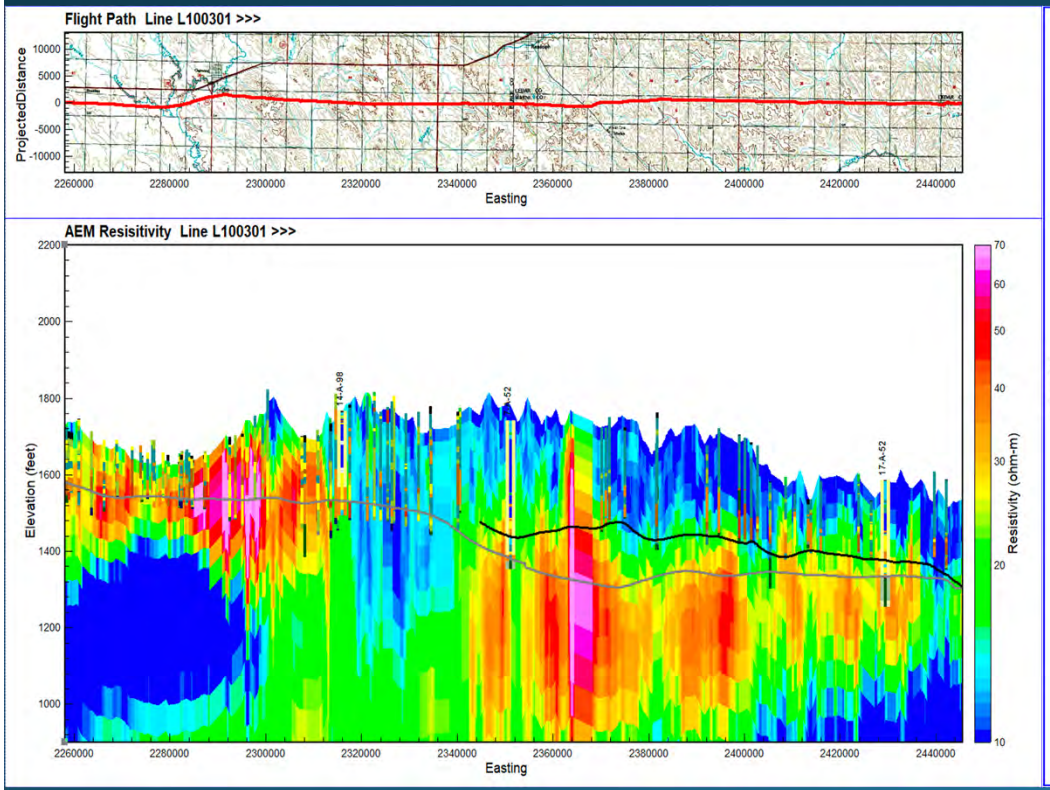

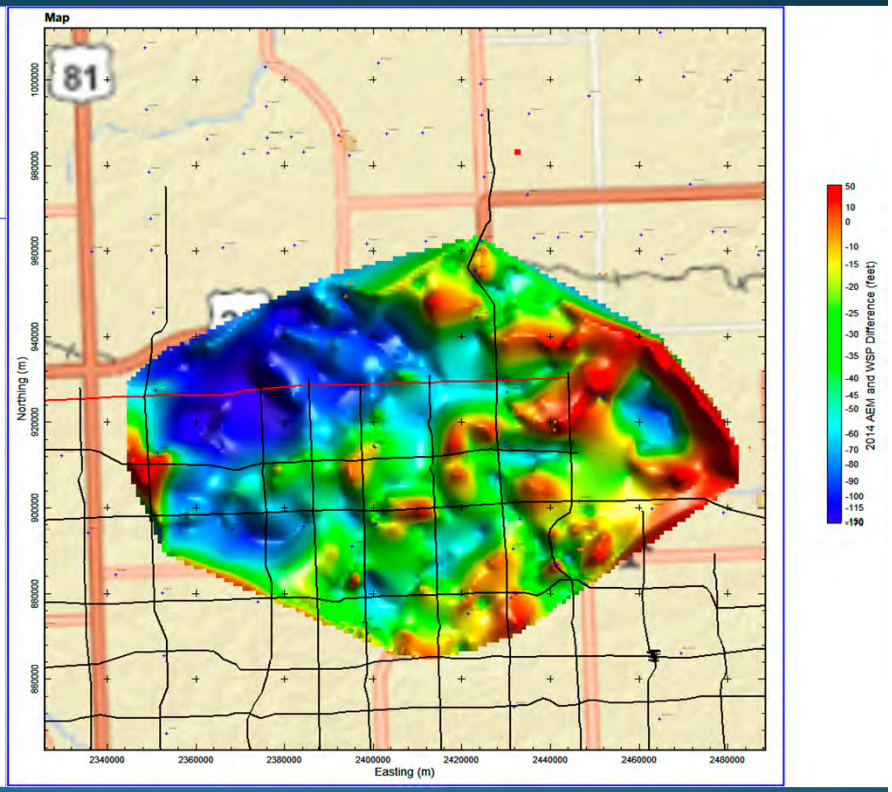

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