Results From The AEM Survey-Papio-Missouri River NRD

PMRNRD Board of Directors Meeting

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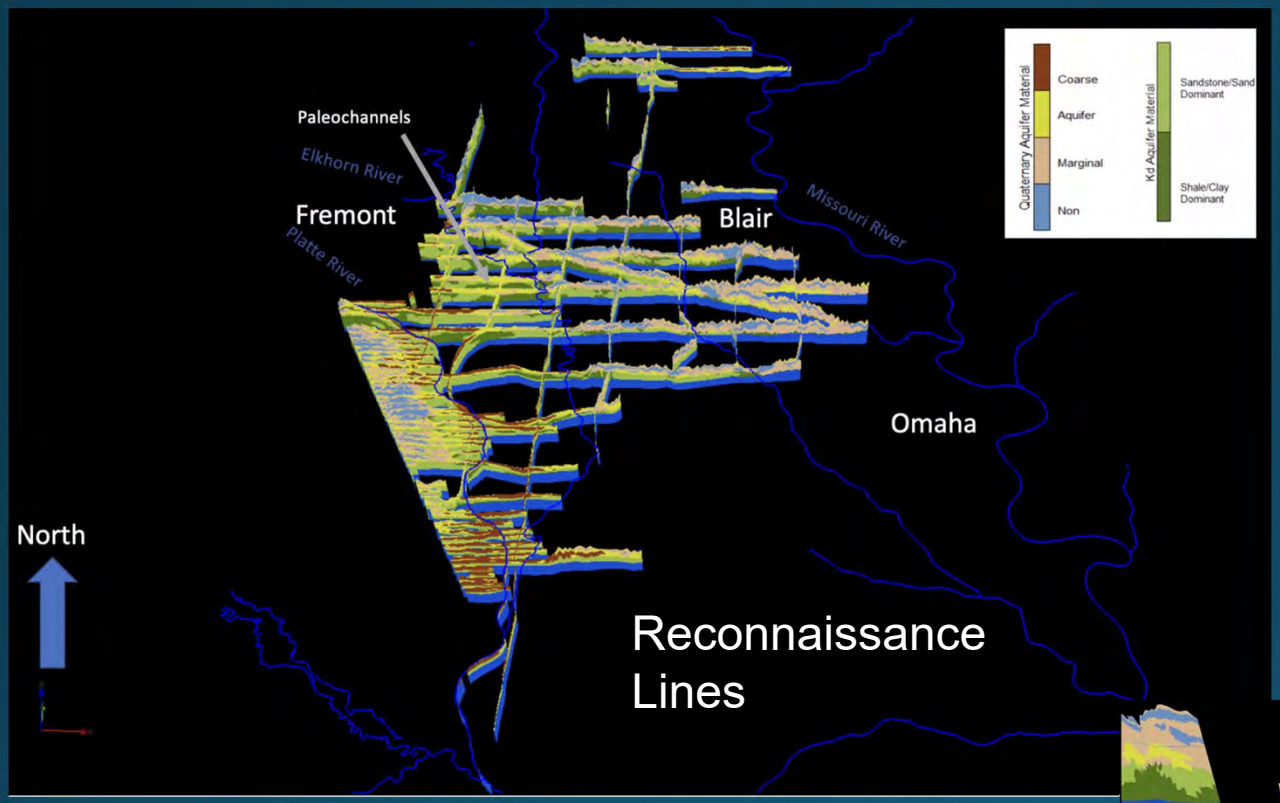
Overview

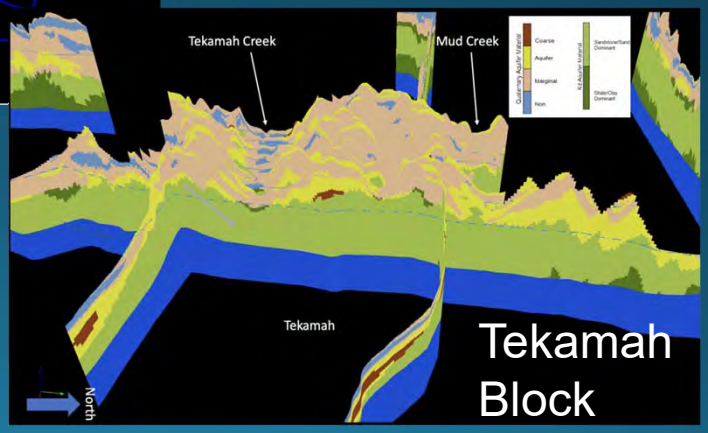
- The history of why we are doing AEM studies
- What were the objectives for this survey?
- What is an AEM survey?
- How does AEM determine geology?
- Papio-Missouri NRD AEM Survey Results
  - Reconnaissance lines
  - Tekamah Block
- Future data enhancements?
- Questions?

Papio-Missouri NRD AEM Survey History

- 2007 Ashland Block
- 2015- Reconnaissance lines
- 2016 Sarpy County Area
- 2018- Reconnaissance lines and Tekamah Block Flight

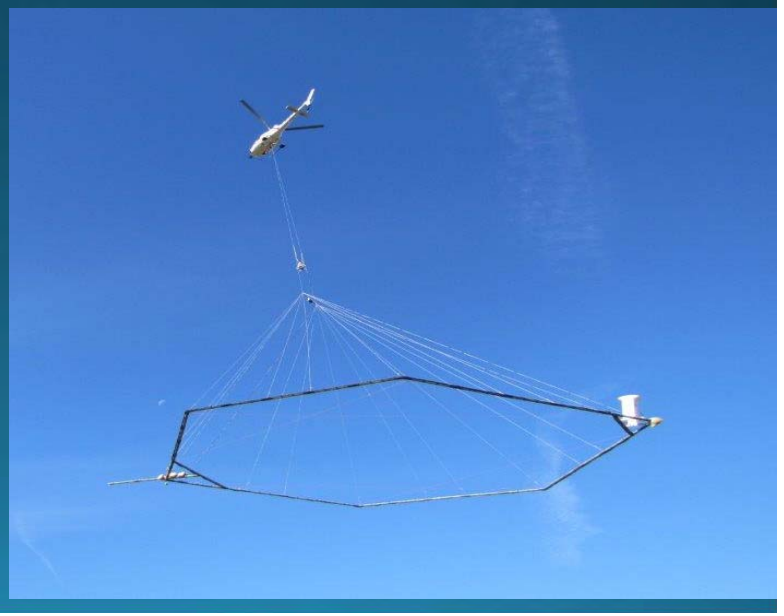
Papio-Missouri AEM Survey Area 2018





Papio-Missouri NRD AEM Survey Objectives

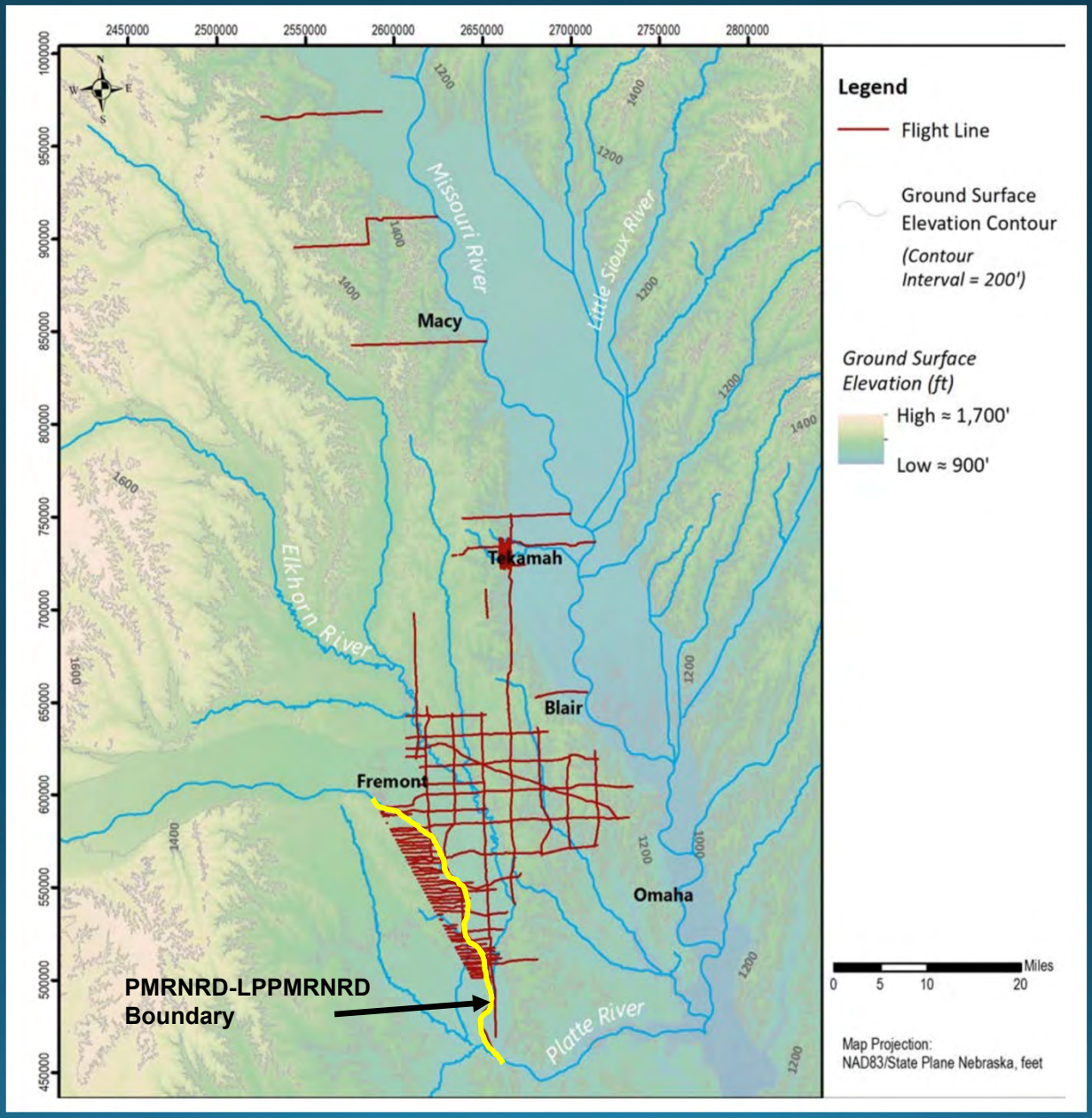
- Improve the Hydrogeologic framework of the PMRNRD
- Provide Reconnaissance Level Profiles and 3D representations of the hydrogeology
- Provide a detailed framework in the Tekamah Block flight area
- Provide information on boundary conditions within the subsurface
- What is the hydrologic connections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



Papio-Missouri AEM Survey Area 2018

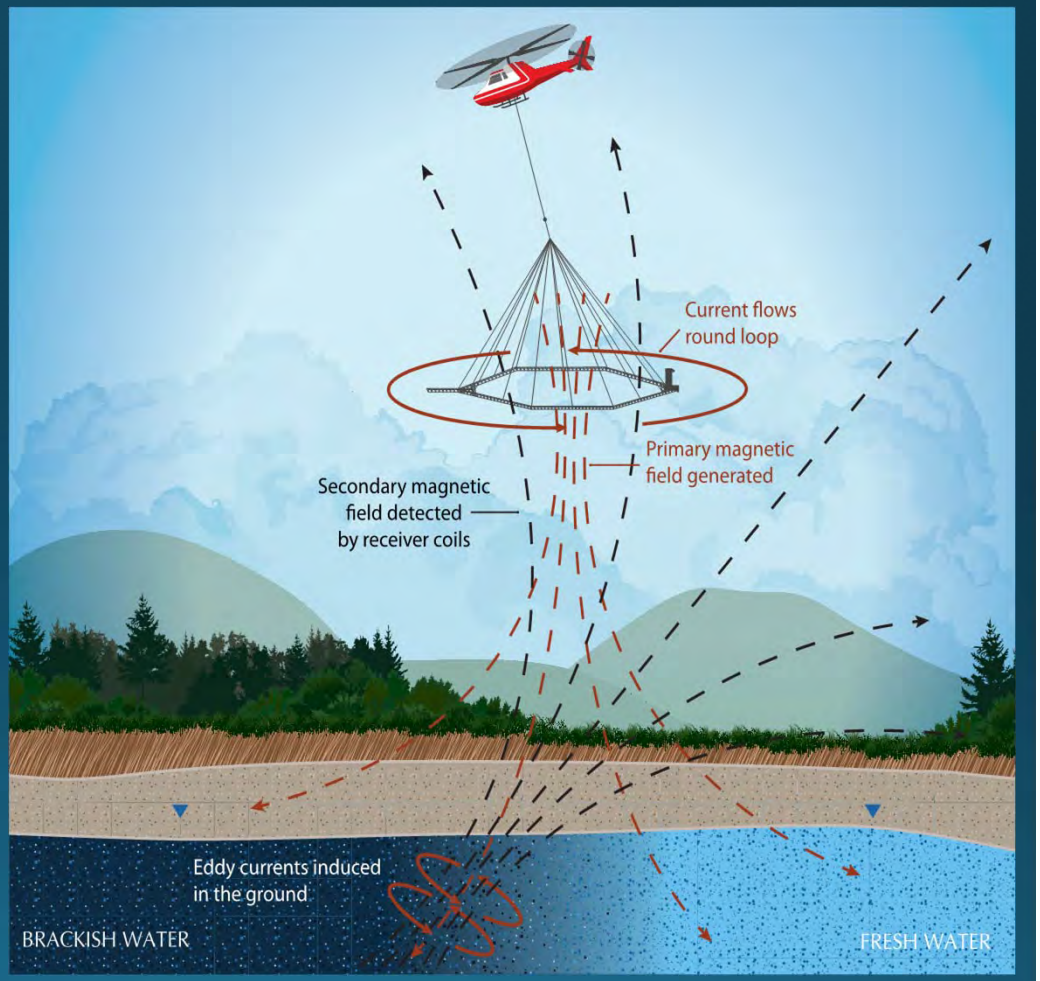
- ~608 line miles
- $230,000 total cost
- 50% additional

miles flown due to better price from vendor



AEM Fundamentals

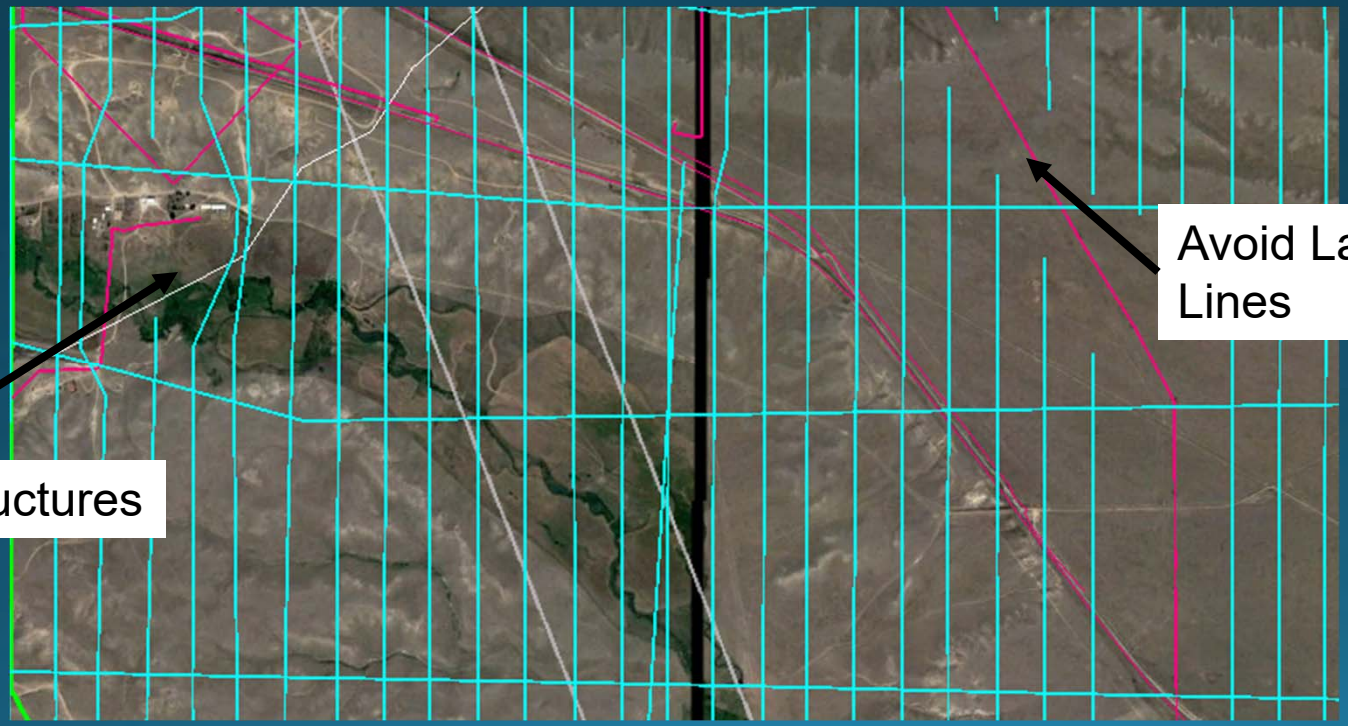
- Airborne Geophysical Techniques
  - Electromagnetic – Time Domain (TDEM) or Frequency Domain (FDEM)
  - Gravity Gradient (Tensor)
  - Magnetic Total-Field & Gradient
  - Radiometrics
- Surveys typically use multiple techniques to examine contrasts in different physical properties



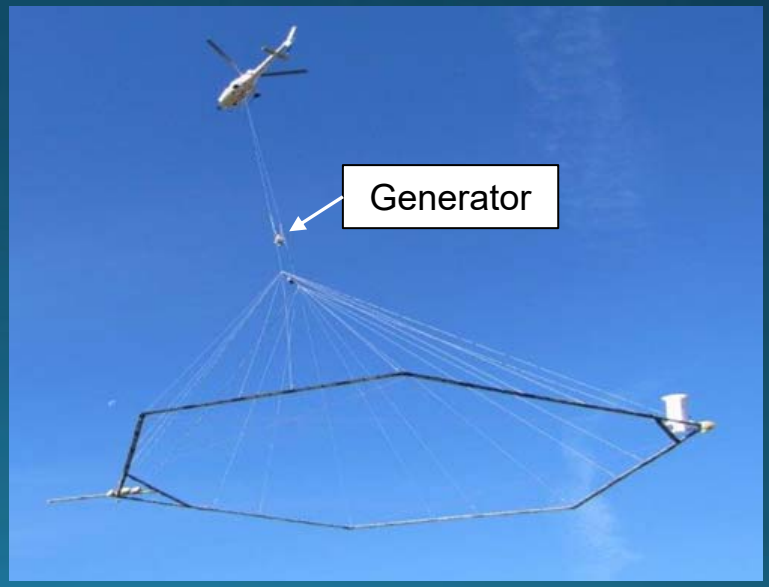
XRI, 2015

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



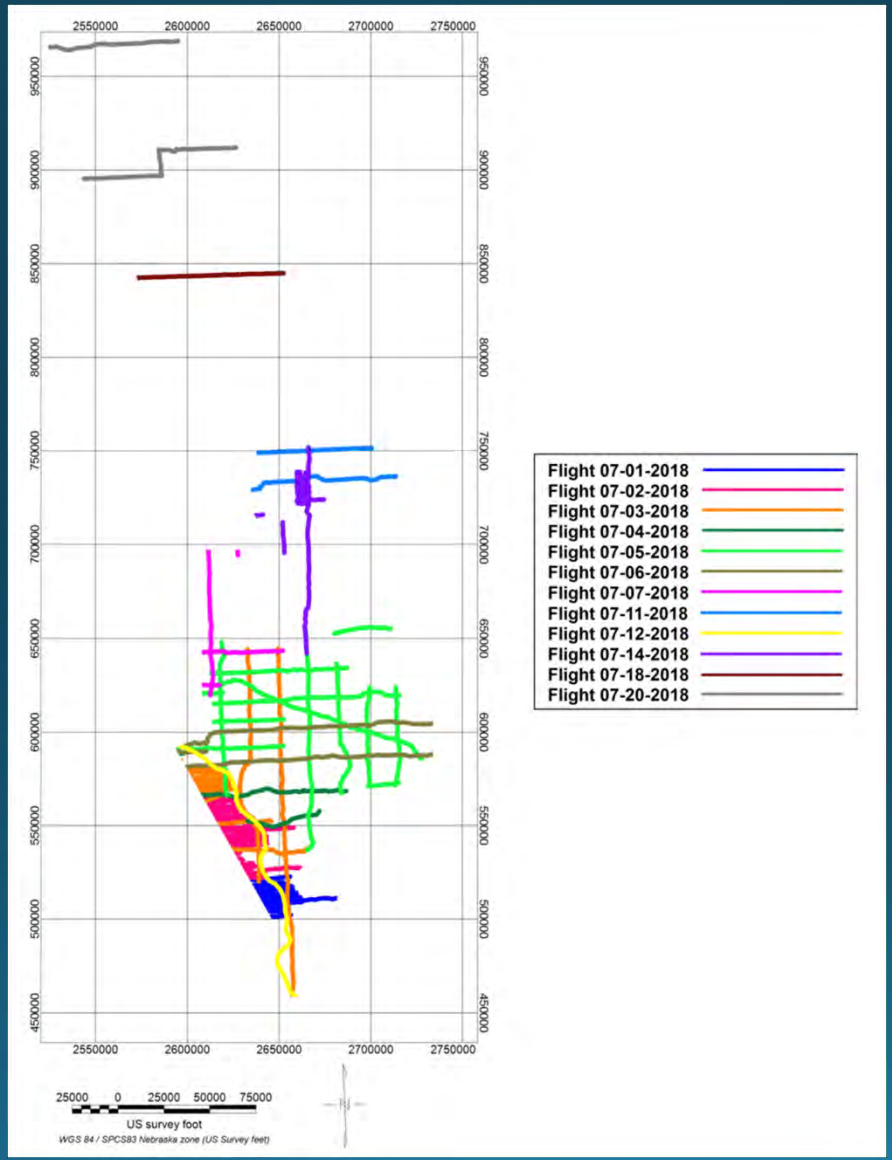
Usually 2-3 Flights/day
Totaling about 180-250 line-miles/day
Approx. 100' – 150' above ground

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

2018 Papio-Missouri NRD Acquisition Schedule

- Start date July 1, 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.

Papio-Missouri NRD Final Flight Acquisition Plan Grouped by Date Collected



QA/QC and Initial Preliminary Inversions

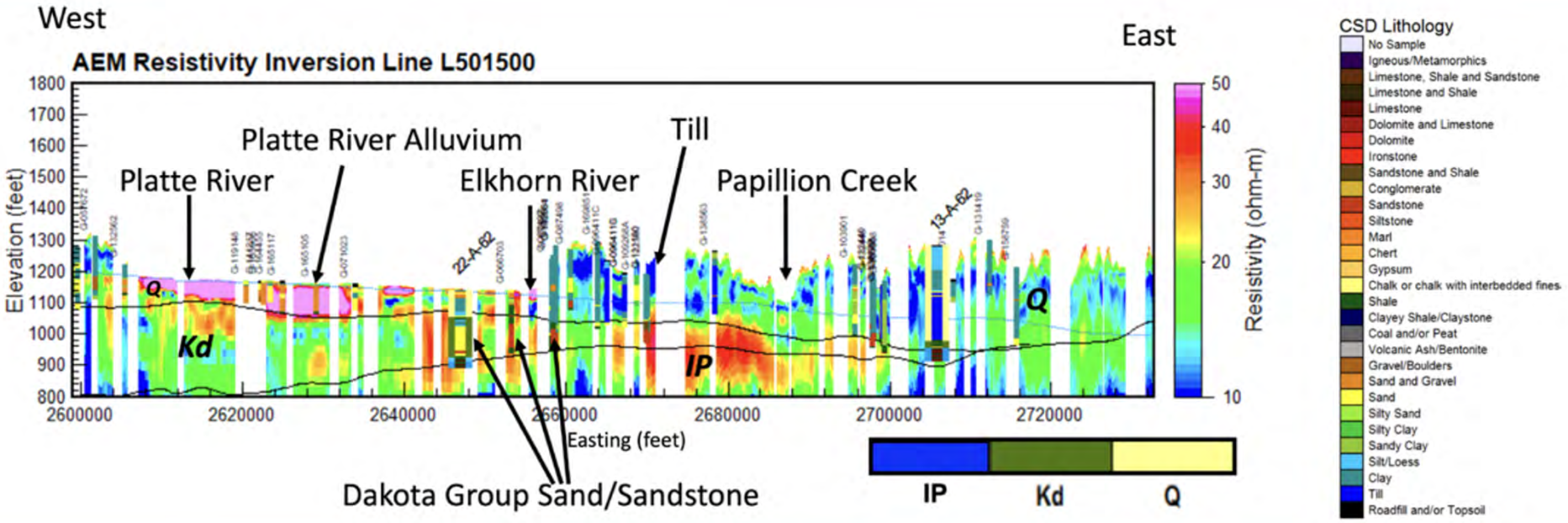
- QA/QC of collected data continued throughout the data collection process on every day's collected data
- Unacceptable data was recollected
- Initial preliminary inversions began immediately upon data availability

Existing Geologic Data

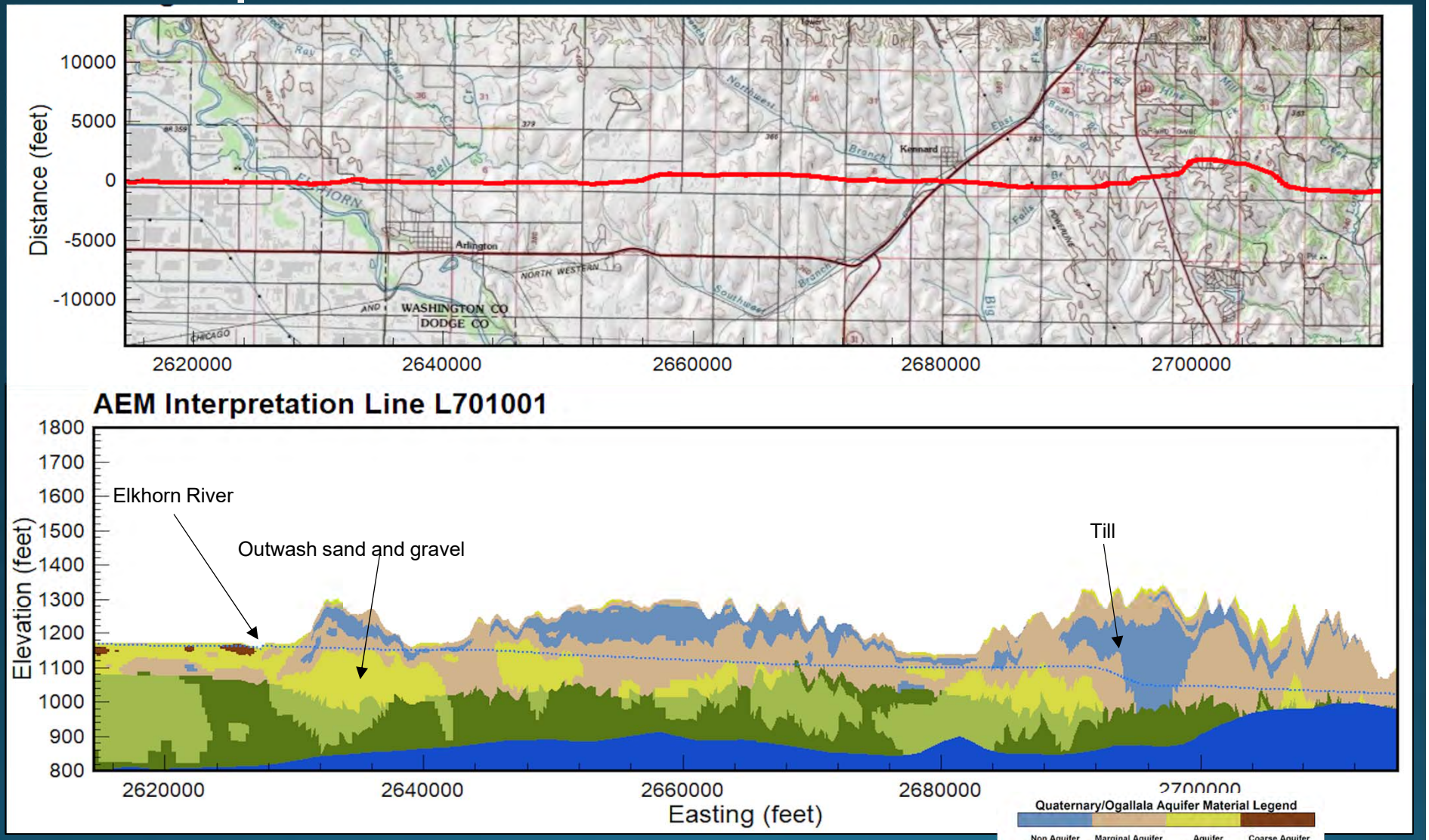
- Use CSD test-hole database
- Use CSD historical cross sections
- Use selected DNR well logs
- Use selected oil and gas well logs
- Water table elevations

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

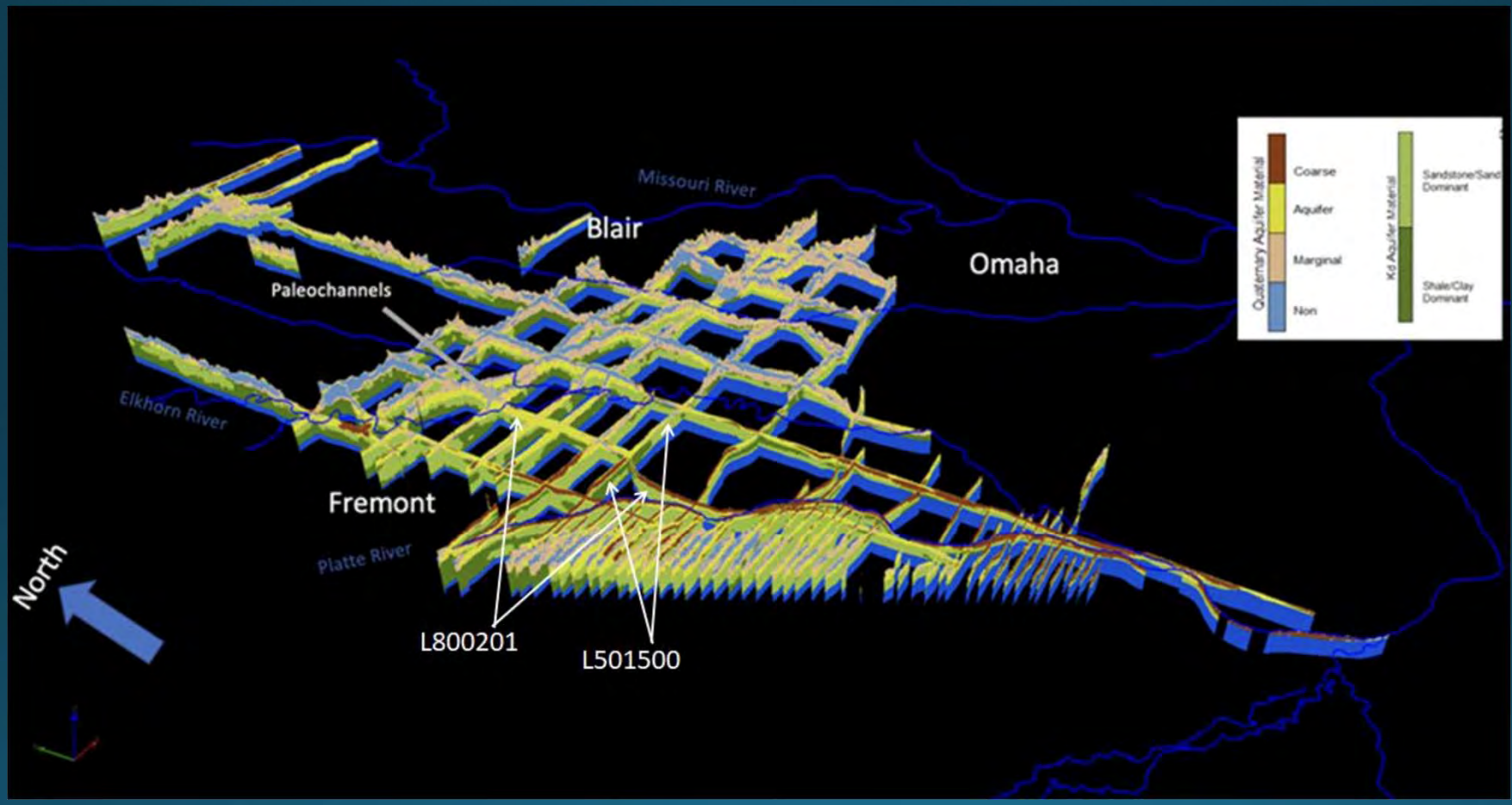
Interpreting Resistivity



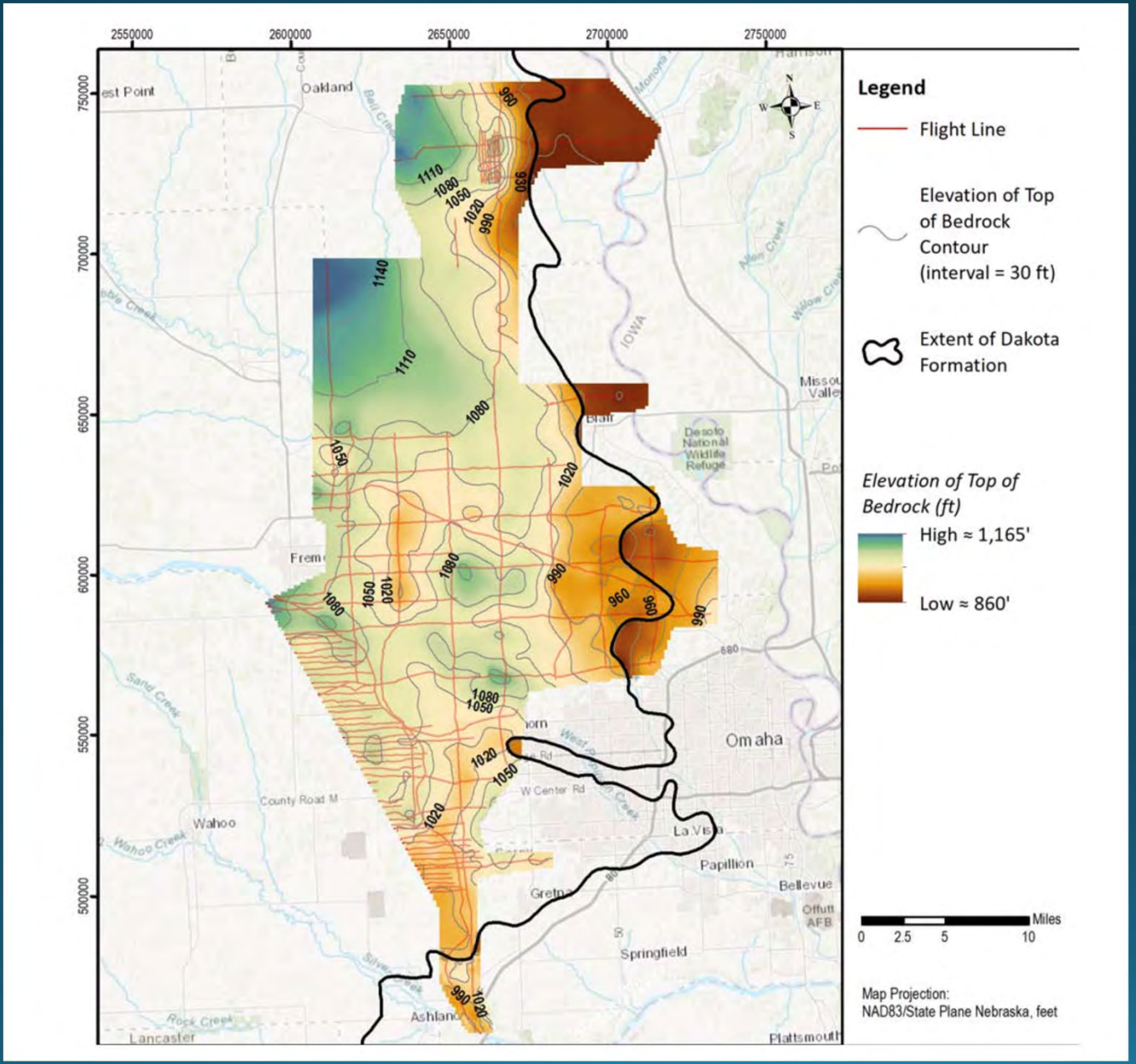
Interpreted Section



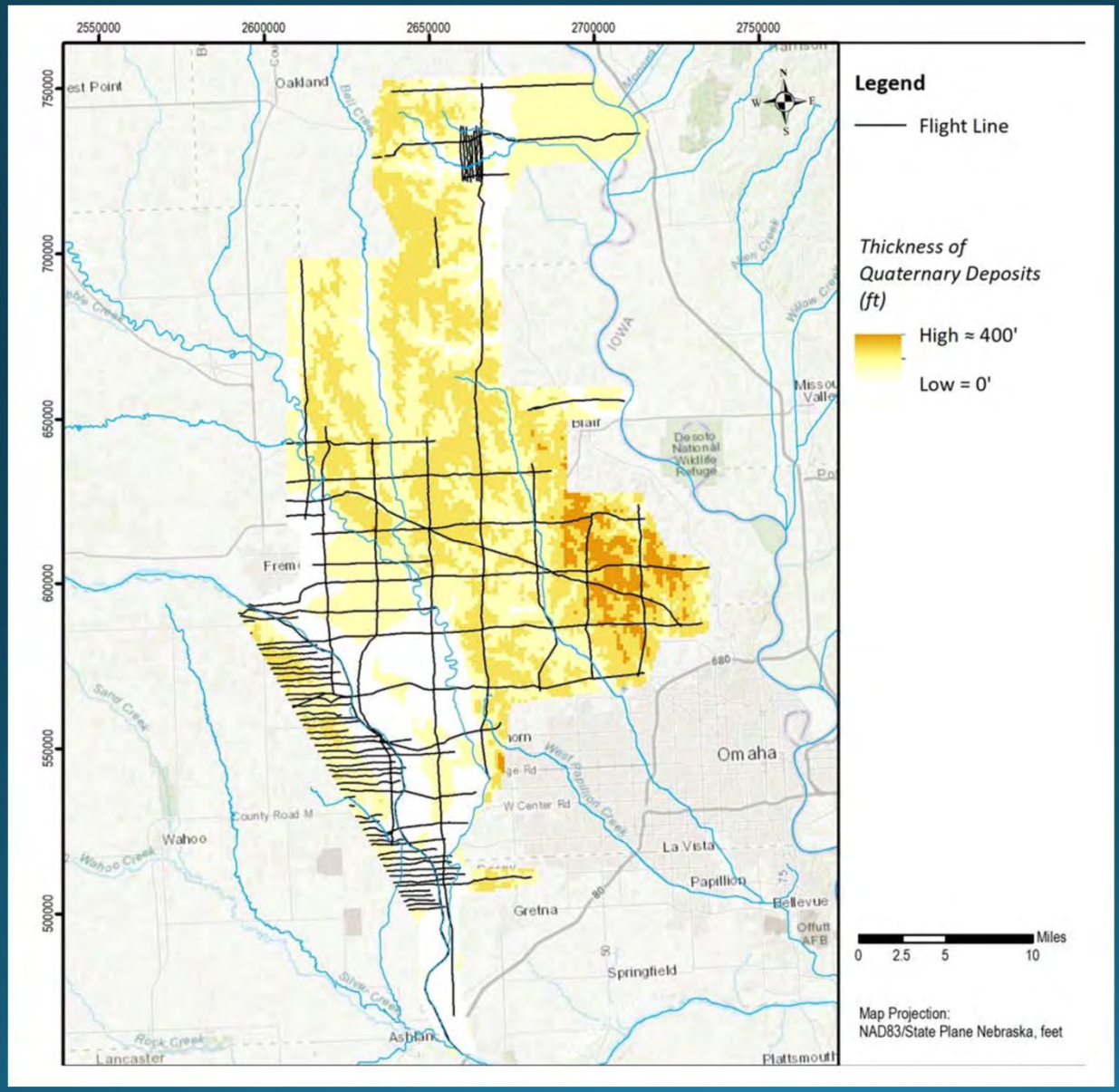
PMRNRD 3D View Hydrogeologic Areas- Looking North



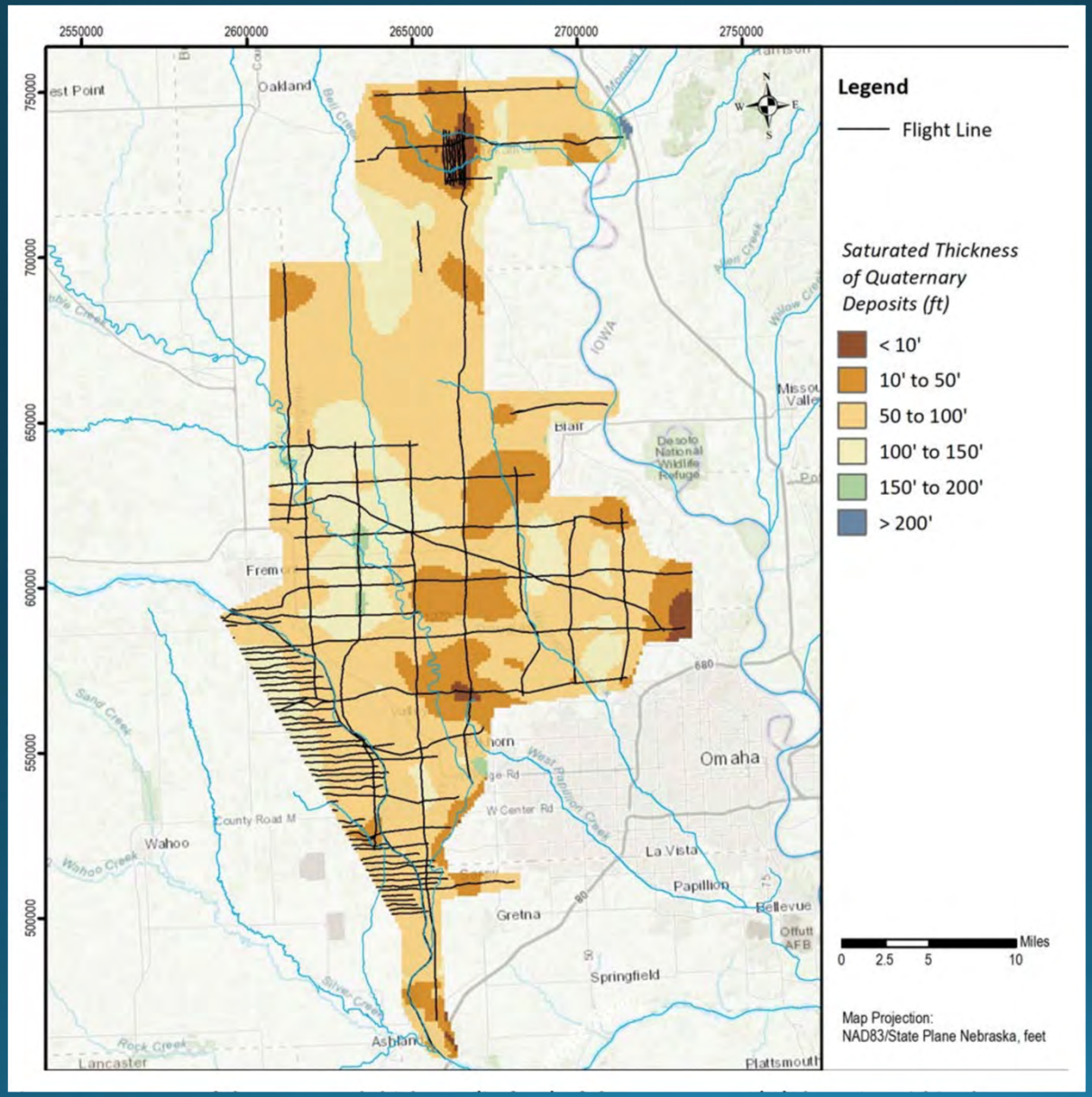
PMRNRD Configuration of the Bedrock Surface-Reconnaissance Lines



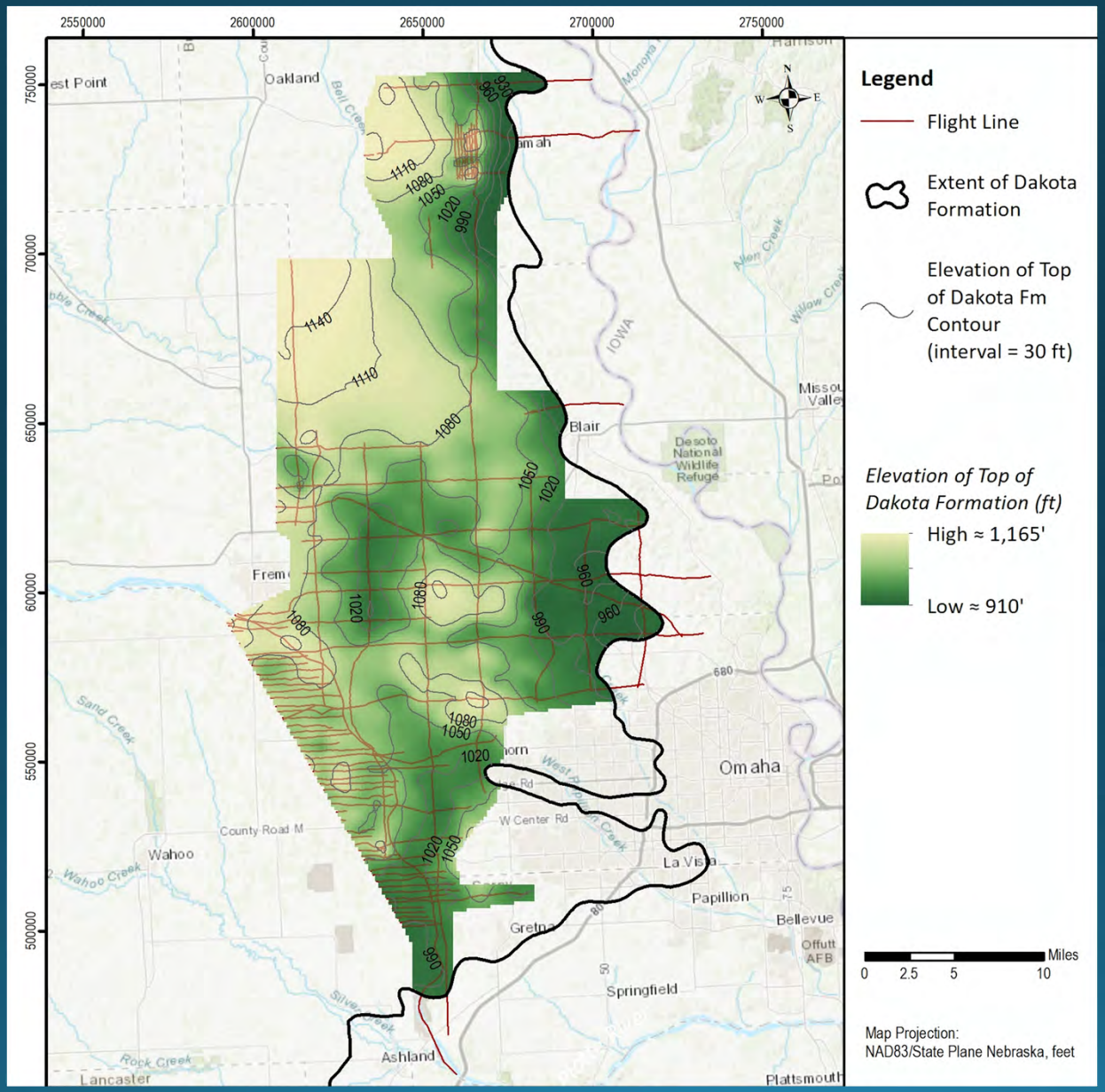
PMRNRD Map of the Total Thickness of Quaternary Deposits -Reconnaissance Lines



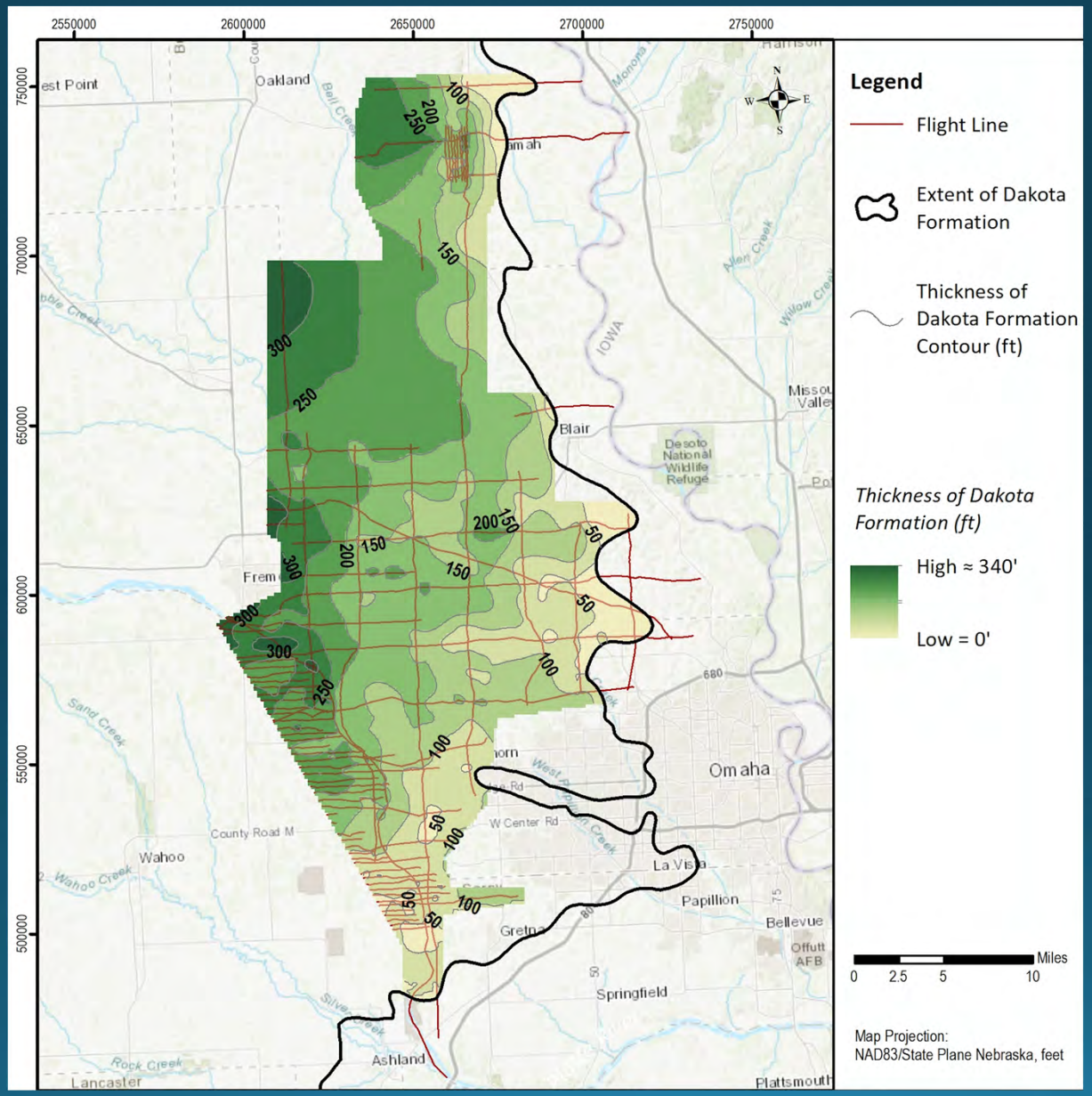
PMRNRD Map of of the Saturated Thickness of Quaternary Deposits -Reconnaissance Lines



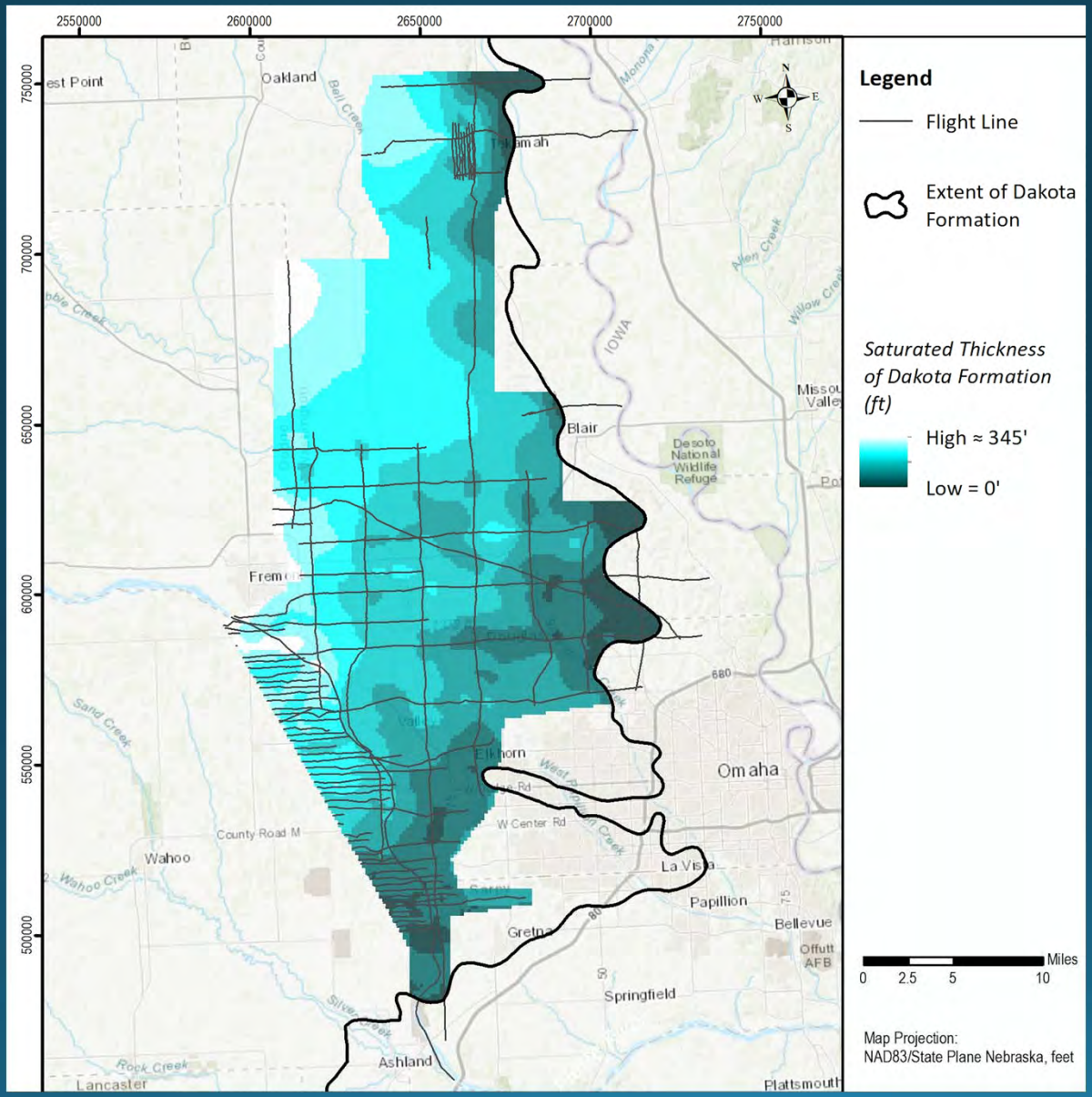
PMRNRD Configuration of the Top of Cretaceous Dakota Surface-Reconnaissance Lines



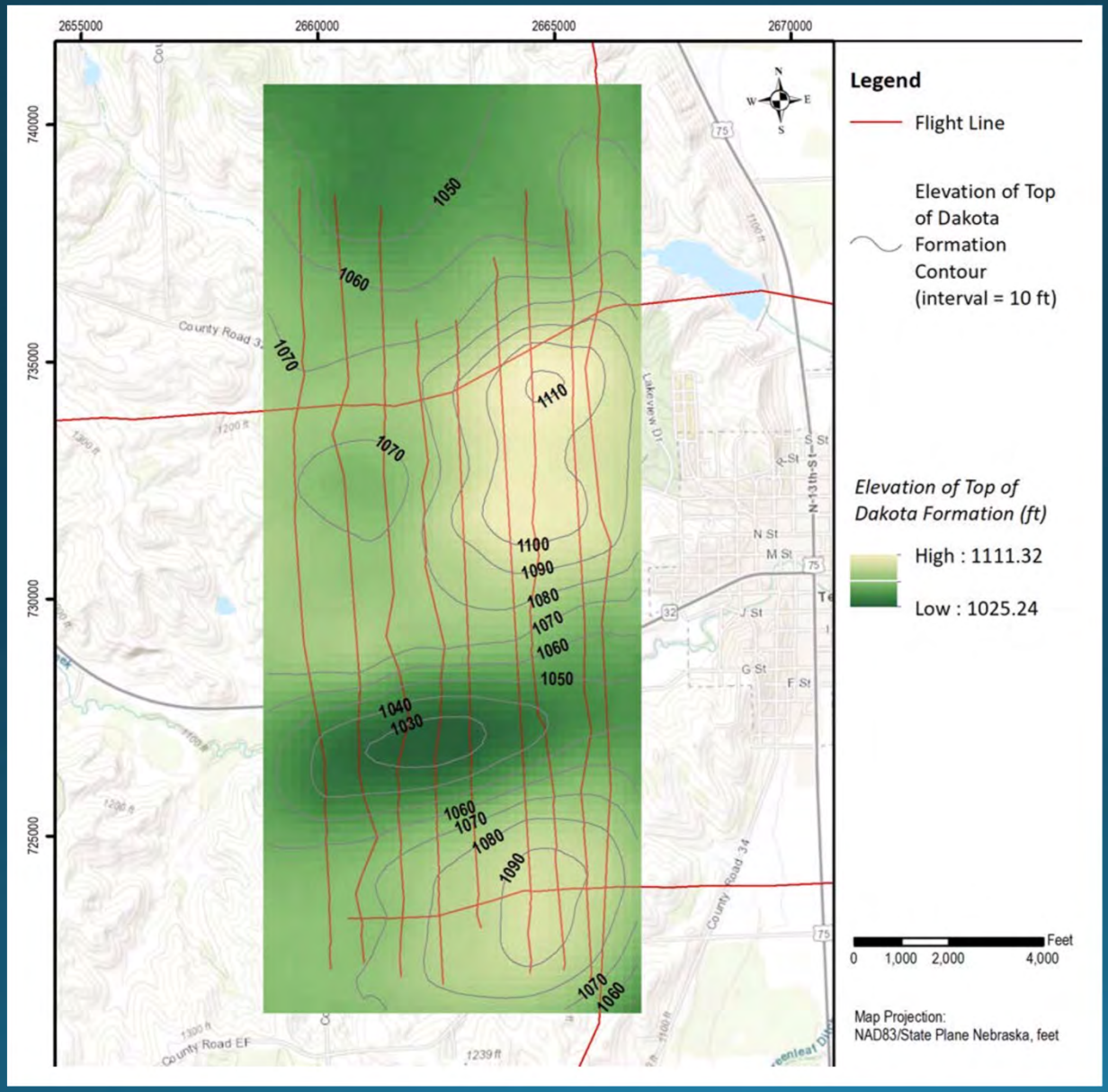
PMRNRD Configuration of the Thickness of Cretaceous Dakota - Reconnaissance Lines



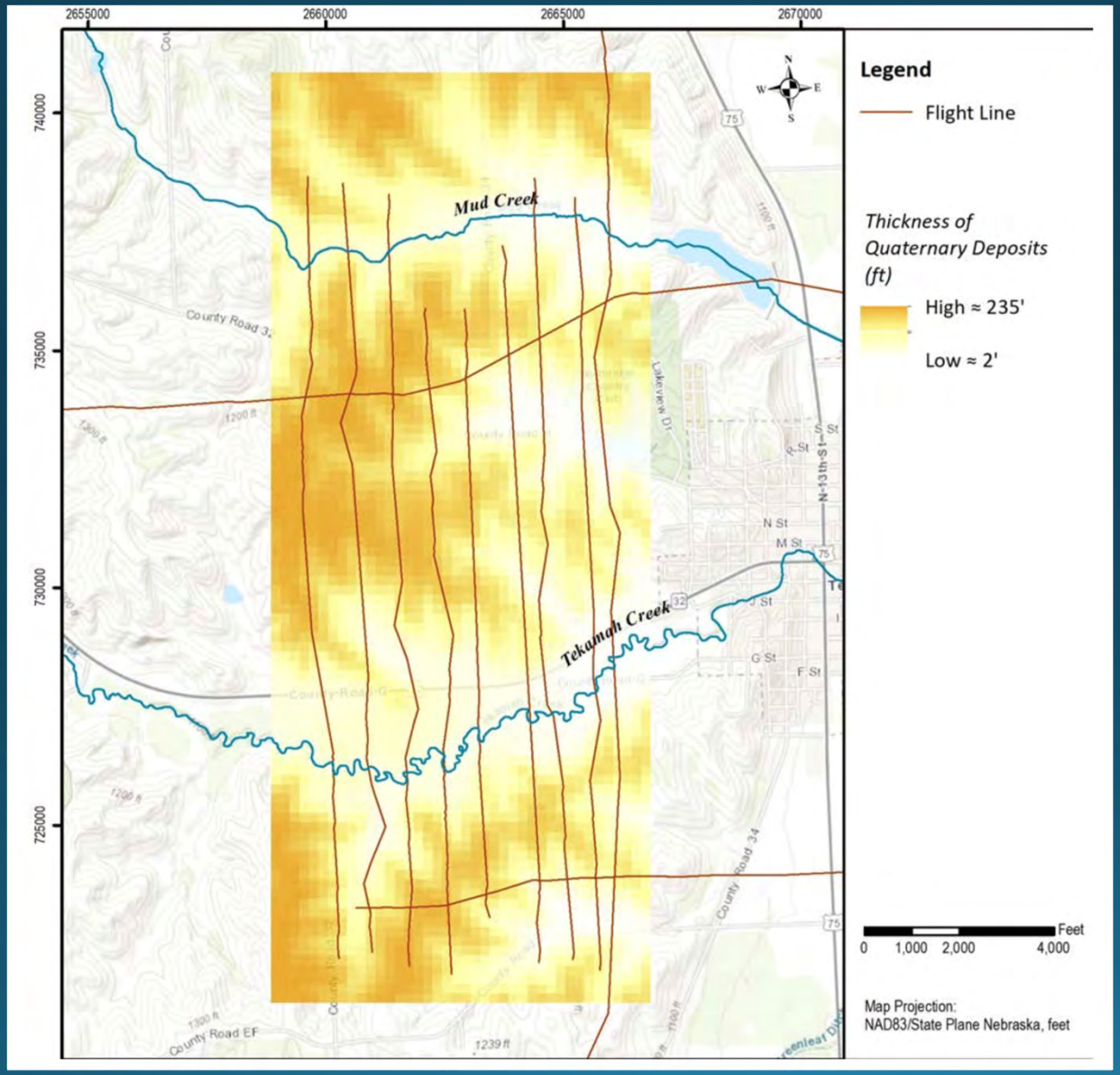
PMRNRD Map of the Total Saturated Thickness of Cretaceous Dakota -Reconnaissance Lines



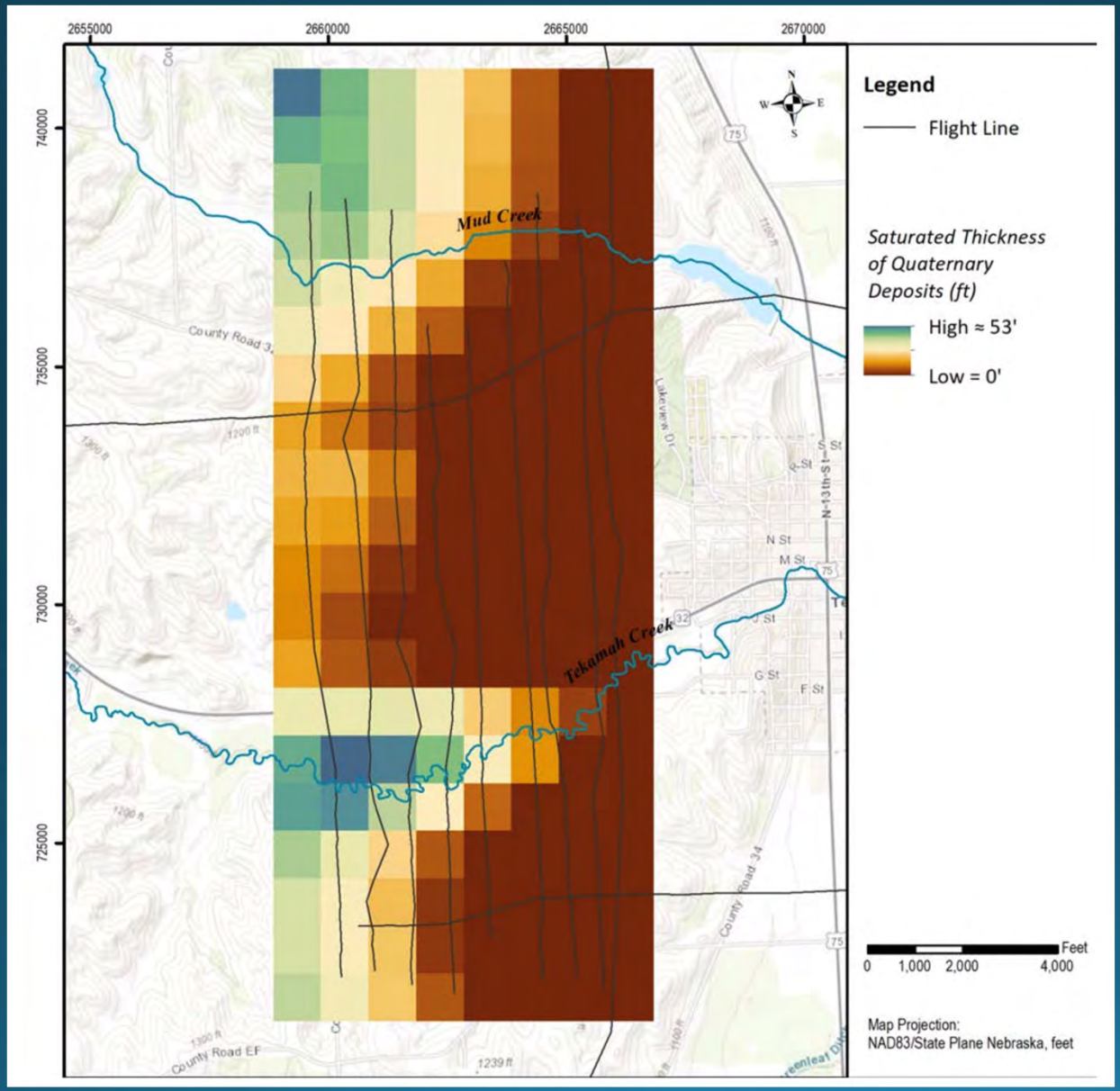
PMRNRD Tekamah Block Elevation of the Cretaceous Dakota Surface



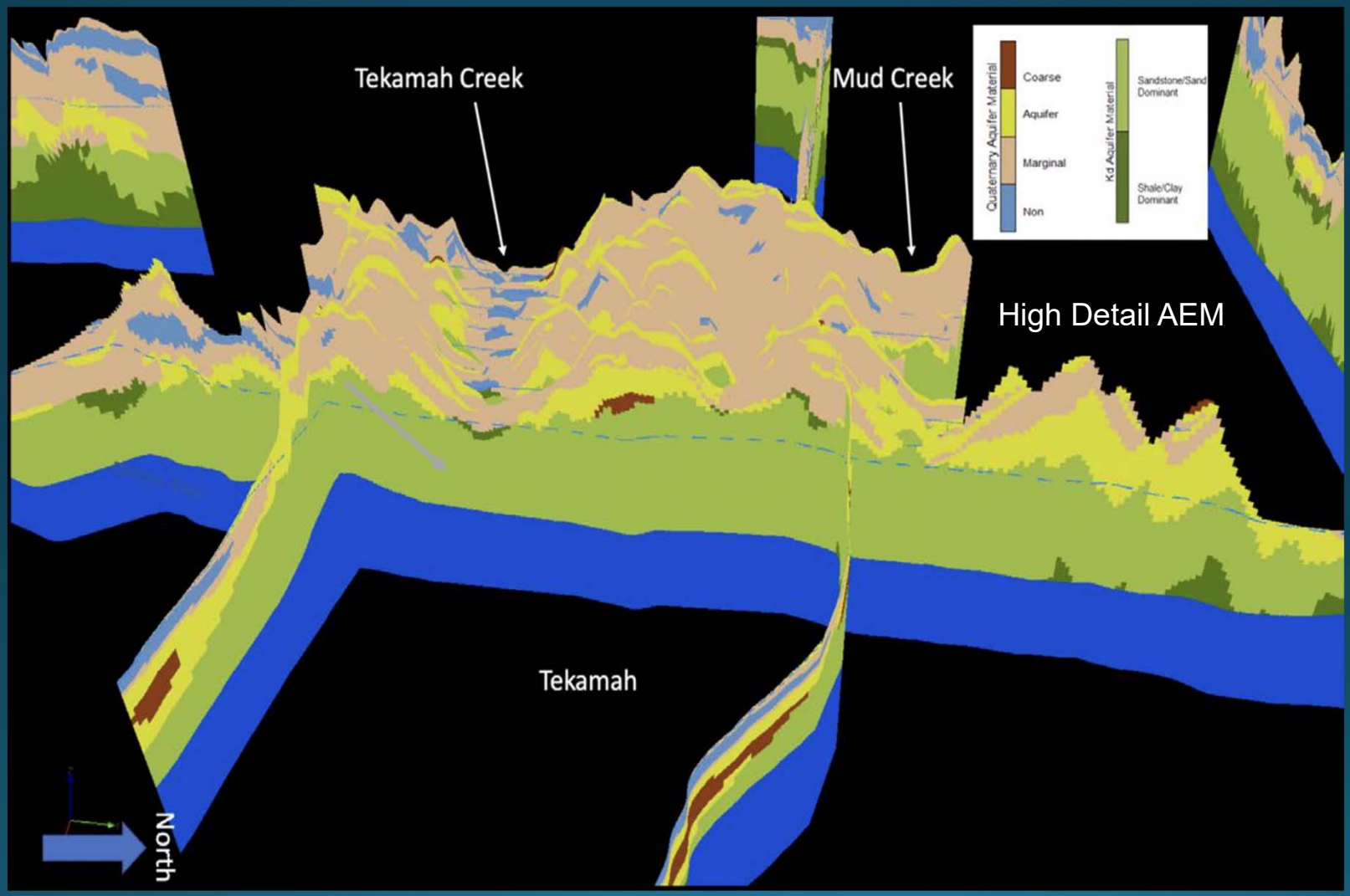
PMRNRD Map of the Total Thickness of Quaternary Deposits –Tekamah Block



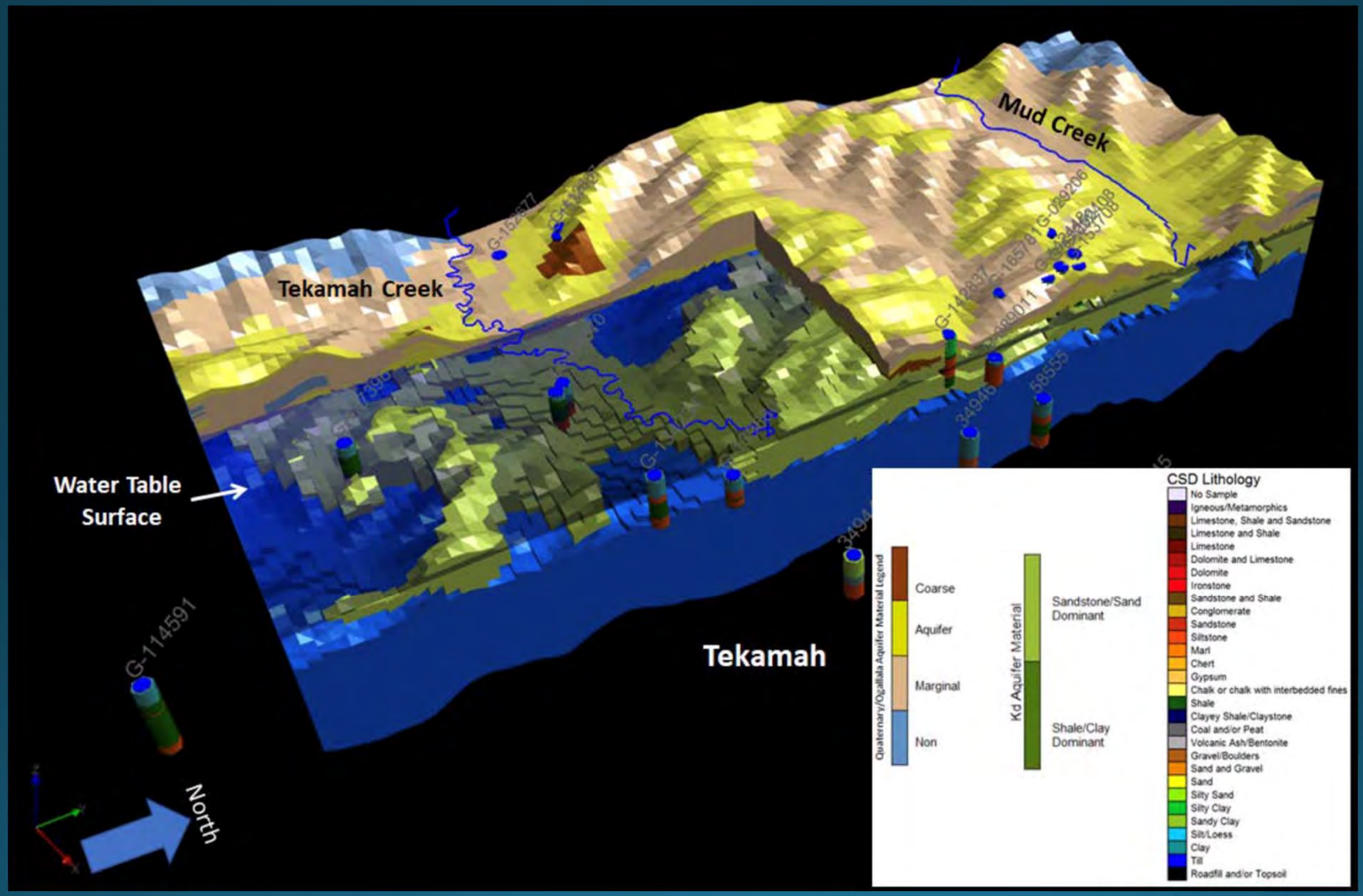
PMRNRD Map of of the Saturated Thickness of Quaternary Deposits –Tekamah Block



PMRNRD 3D Fence Diagram of Interpreted AEM Profiles -Tekamah Block



PMRNRD 3D Voxel Model of Aquifer Material Types- Tekamah Block



Tekamah Block Estimates of Groundwater in Storage

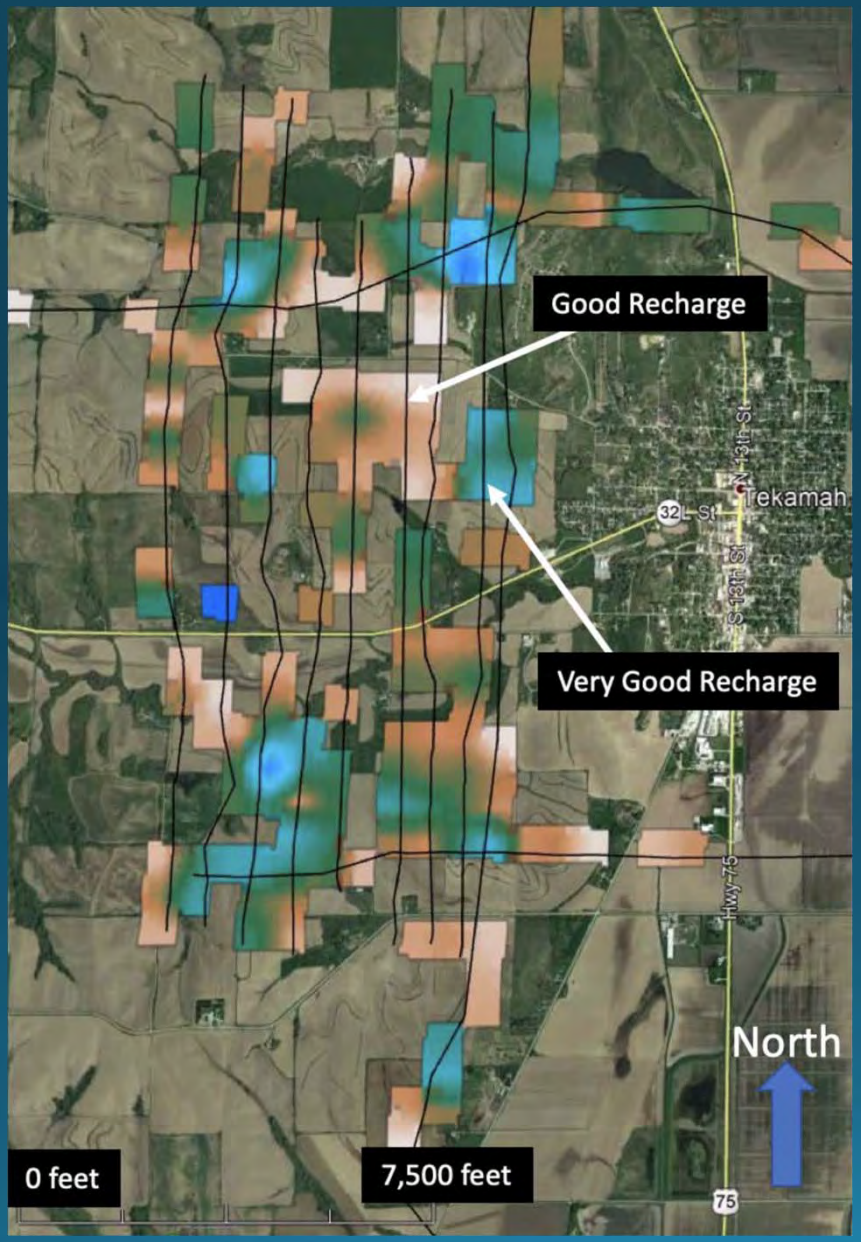
Table 3-1. Fully saturated Quaternary (*Q*) aquifer materials within the Tekamah Block area.

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	184,444,746	4234	0.40	1,693	0.02	34
Marginal	622,917,754	14,300	0.35	5,005	0.05	250
Aquifer	746,709,902	17,142	0.20	3,428	0.10	343
TOTAL	1,554,072,402	35,676		10,126		627

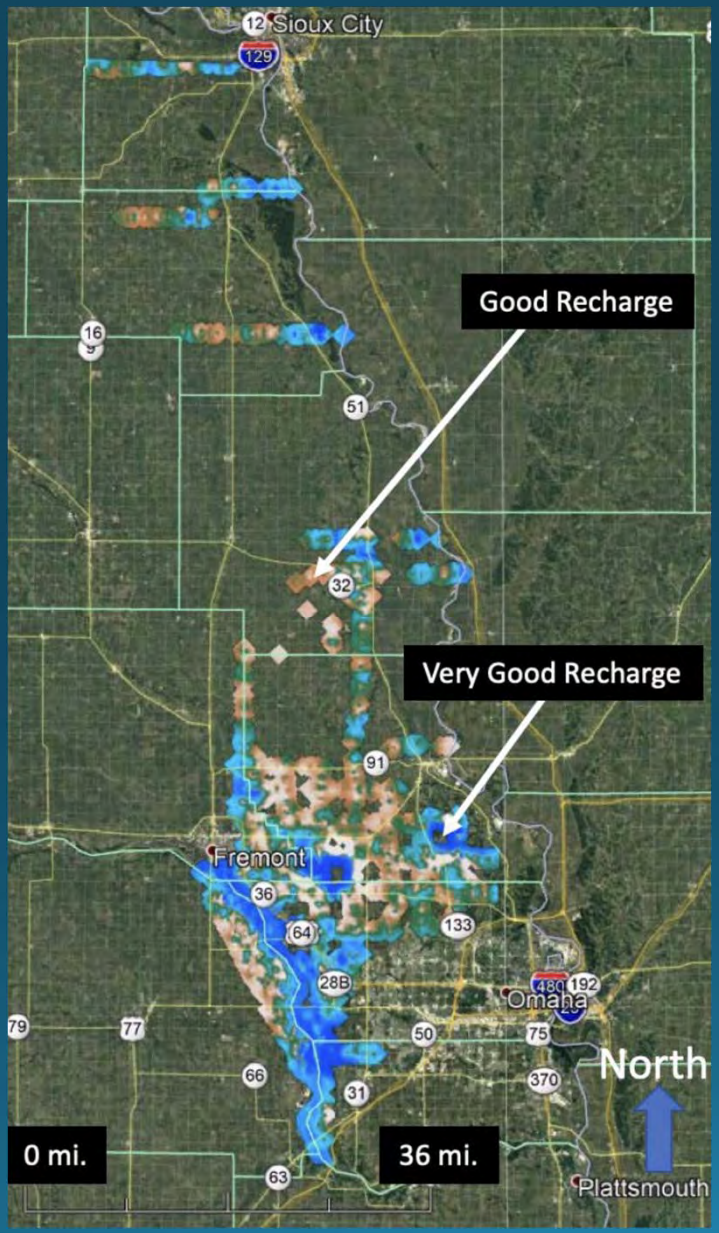
Table 3-2. Fully saturated Cretaceous Dakota Group (*Kd*) aquifer materials within the Tekamah Block area.

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)
Shale/clay	900,096,148	20,663	0.40	8,265	0.02	165
Sandstone/sand	20,267,523,876	465,279	0.11	51,180	0.06	3,071
TOTAL	21,824,464,402	485,942		59,445		3,236

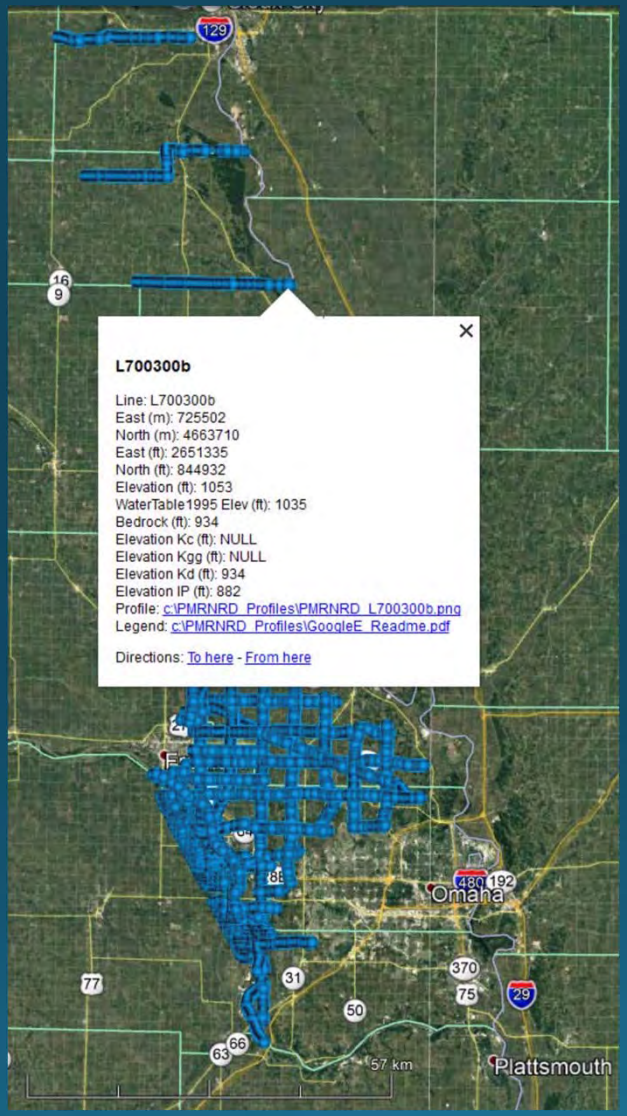
Potential Recharge by Aquifer Material Type From 0-3.28 Feet BLS- Tekamah Block



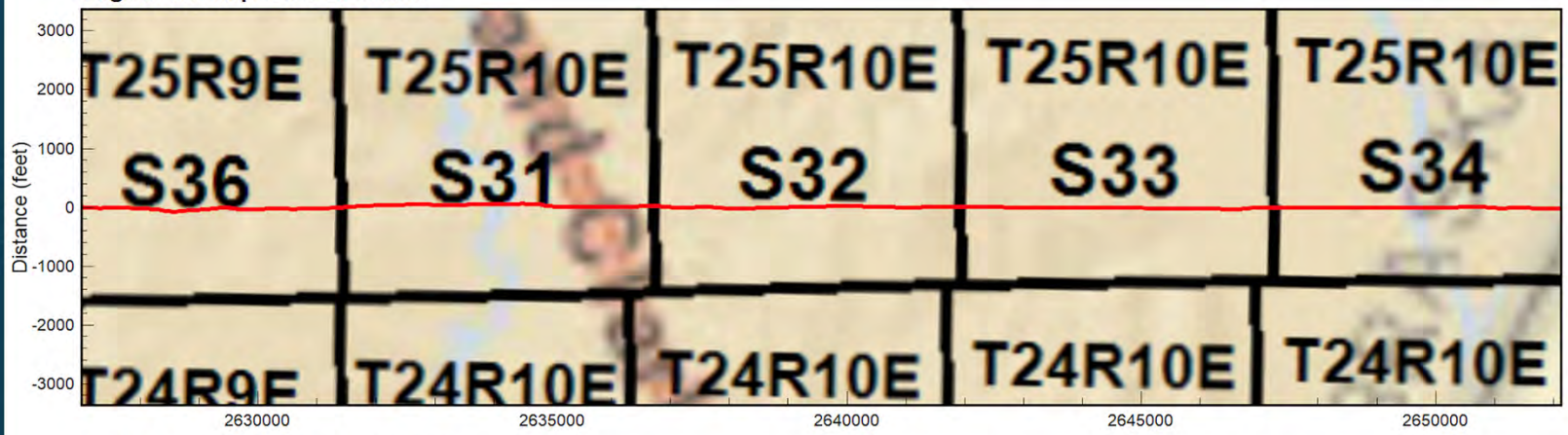
Potential Recharge by Average Aquifer Material Type From 0-3.28 Feet BLS- Reconnaissance Lines



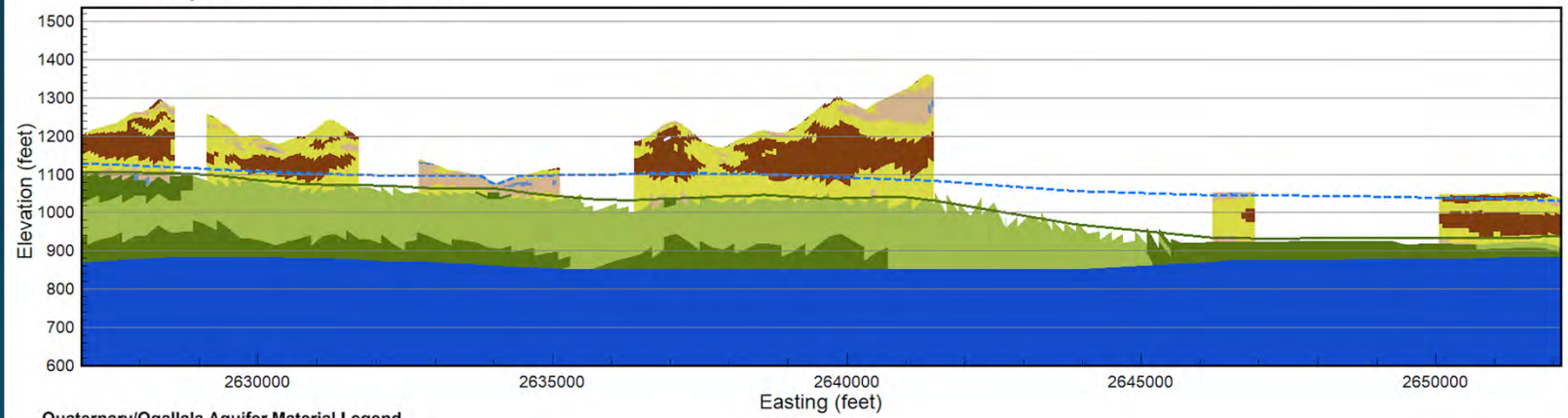
Papio-Missouri NRD Google Earth- Reconnaissance Lines



Flight Path Map Line L700300b



AEM Interpretation Line L700300b



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)

Stratigraphy Interpretation

IP	Kd	Kgg	Kc	Q

Kd Aquifer Material

Sandstone/Sand Dominant	Shale/Clay Dominant

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 Cretaceous Dakota Group (Kd) is split into Sandstone/Sand dominant and Shale/Clay dominant sections as indicated by the legend. The Cretaceous Carlile Shale (Kc), Cretaceous Greenhorn Limestone and Graneros Shale (Kgg), 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 Papio-Missouri River Natural Resources District.

PAPIO-MISSOURI RIVER NATURAL RESOURCES DISTRICT

ENWRA
EASTERN NEBRASKA WATER RESOURCES ASSESSMENT

Key Findings

- **Boreholes -** Information from boreholes was an important to analyze the AEM inversion results. However, dependence on just boreholes for geologic interpretation can sometimes have these limitations the boreholes are wrong, improperly located, have improper stratigraphic/lithology picks, and/or other errors.

- **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),*** Cretaceous Dakota (***Kd***)and undifferentiated Pennsylvanian (***IP***). The interpretive process benefited from the use of CSD, , Nebraska Oil and Gas Conservation Commission (NEOGCC), and NE-DNR borehole logs.

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.
- **Hydrogeological Framework of the PMRNRD** - The 2018 PMRNRD AEM survey reveals variability in the Quaternary (***Q***) deposits across the PMRNRD AEM survey area. The ***Q*** make up the aquifer materials overlying the undifferentiated Cretaceous Dakota (***Kd***) and Pennsylvanian (***IP***) bedrock units.

Key Findings

- **Potential Recharge Zones within the PMRNRD AEM Survey Area -** The use of block flights in Tekamah area illustrates the preferred method to use AEM to identify areas where the potential for recharge to the aquifer can be high and low. Locations where the flight lines are closely spaced showing either aquifer or coarse aquifer material at the land surface should be considered as locations for higher likelihood for recharge. Recharge estimates along the Reconnaissance lines is less confident due to the spacing between the lines.

Future Work using AEM Results

- Bring all previous work into a single projection and framework components.
- Design future AEM survey plans for the 2019 WSF Grant period for the mapping around Fremont and Arlington.
- 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 PMRNRD
- 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
- Possible Definition of Perched Water areas
- The list is long

Acknowledgments

- Paul Woodward- PMRNRD
- Katie Cameron - ENWRA

Questions??