Results From The AEM Survey- Nemaha Natural Resources District

Nemaha NRD Board of Directors Meeting

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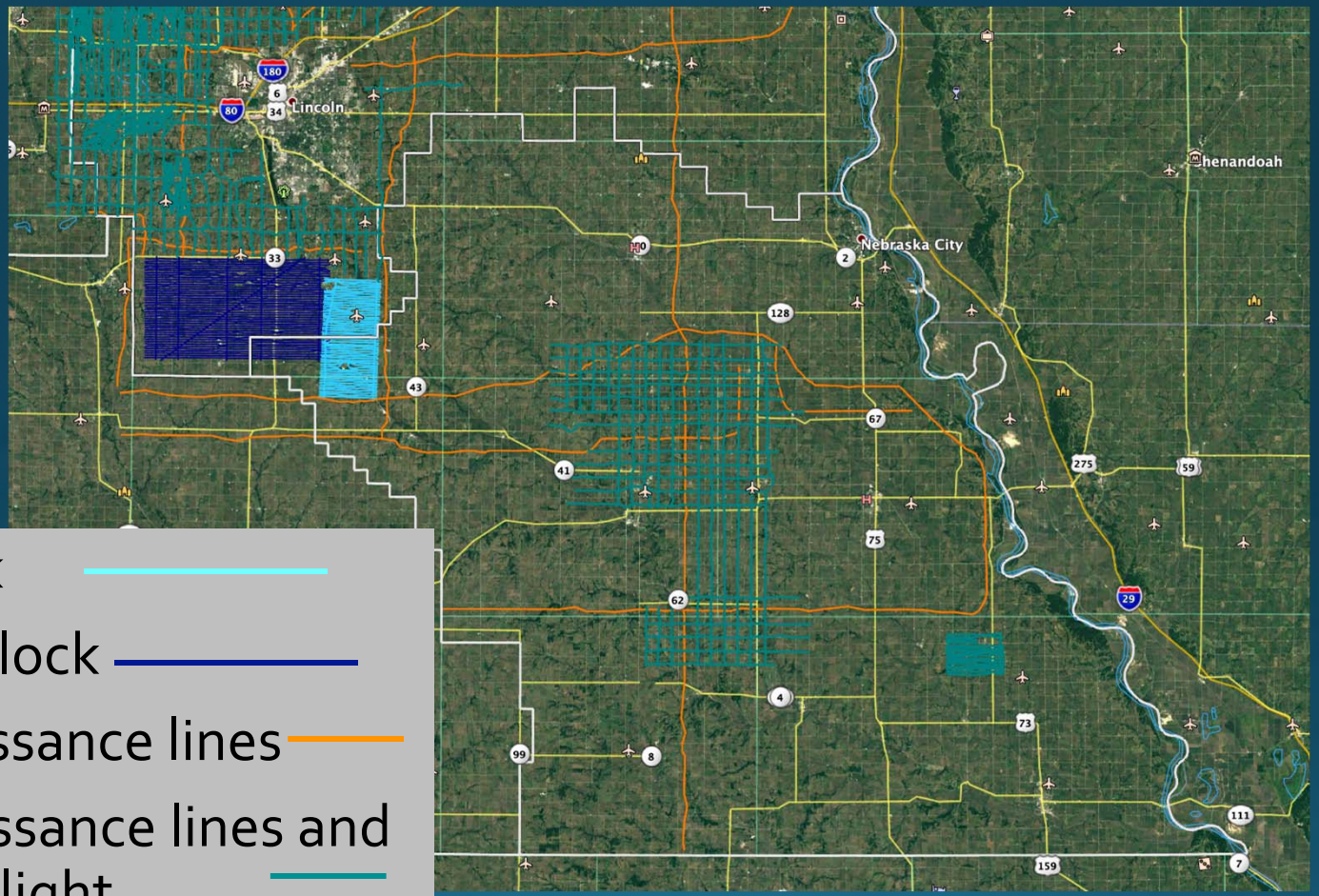
Overview

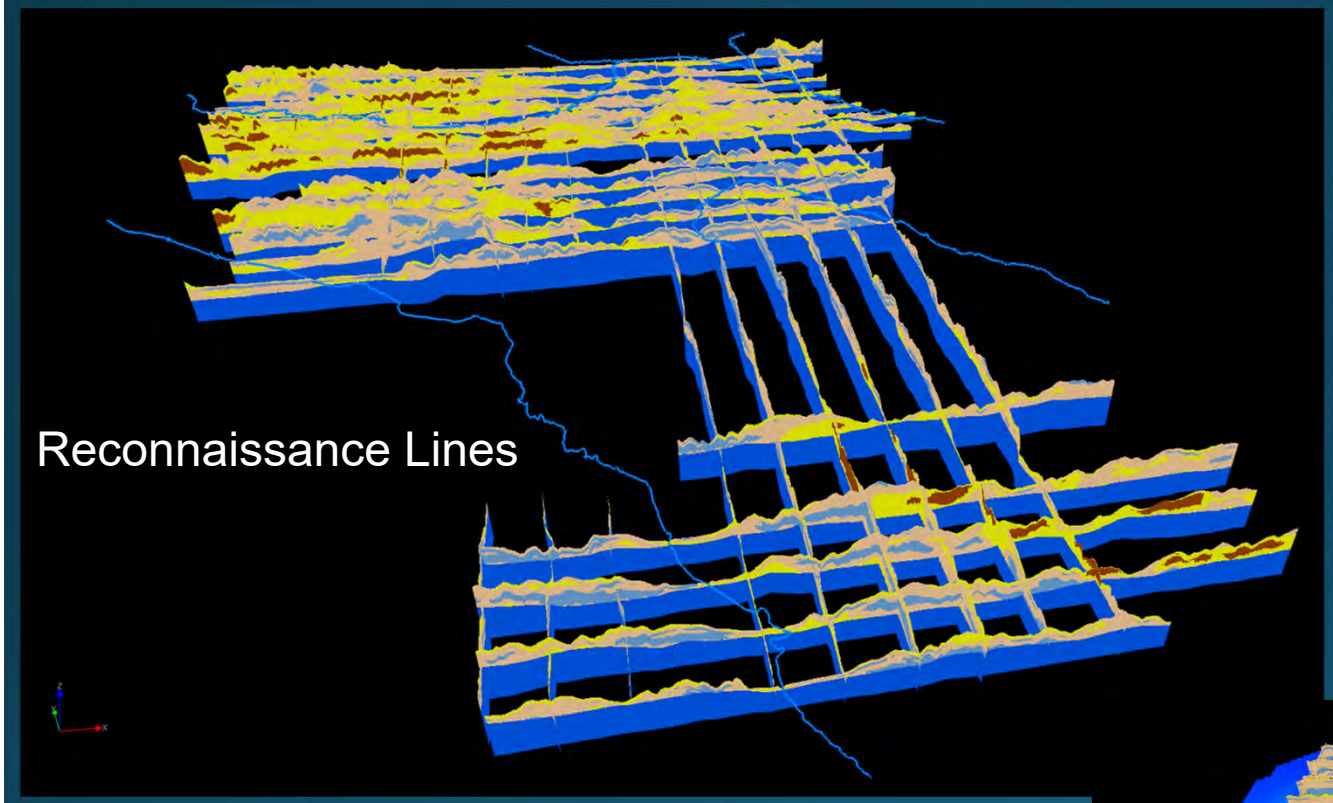
- The history of why we are doing AEM studies
- What were the objectives for this survey?
- What is an AEM survey?
- How does AEM determine geology?
- Nemaha NRD AEM Survey Results
  - Reconnaissance lines
  - Shubert Block
- Future data enhancements?
- Questions?

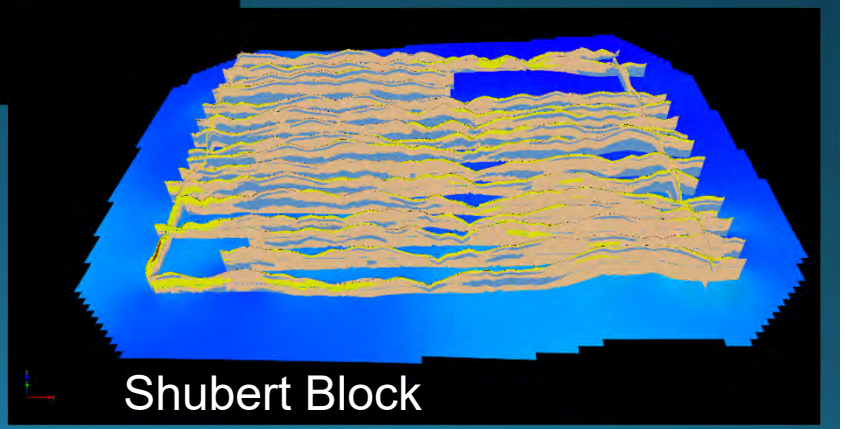
Nemaha NRD AEM Survey History



- 2007 Firth Block
- 2009 Sprague Block
- 2015- Reconnaissance lines
- 2018- Reconnaissance lines and Shubert Block Flight

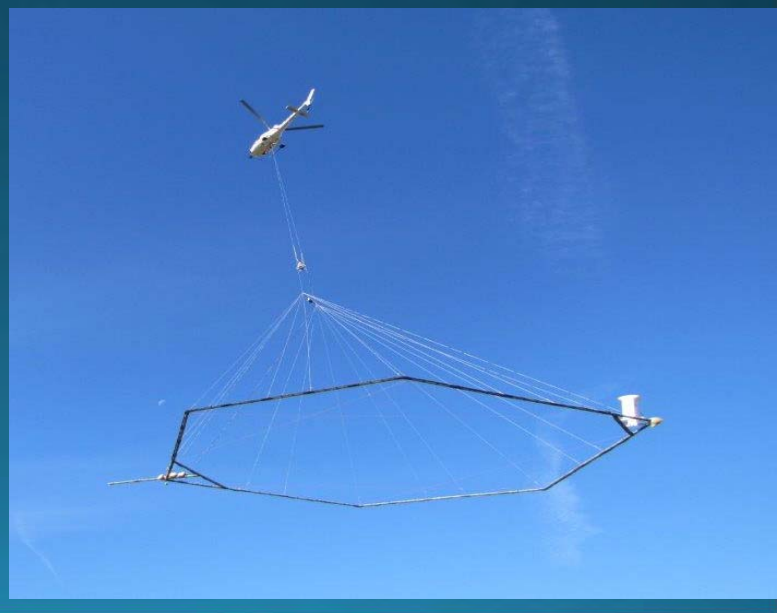
Nemaha AEM Survey Area 2018





Nemaha NRD AEM Survey Objectives

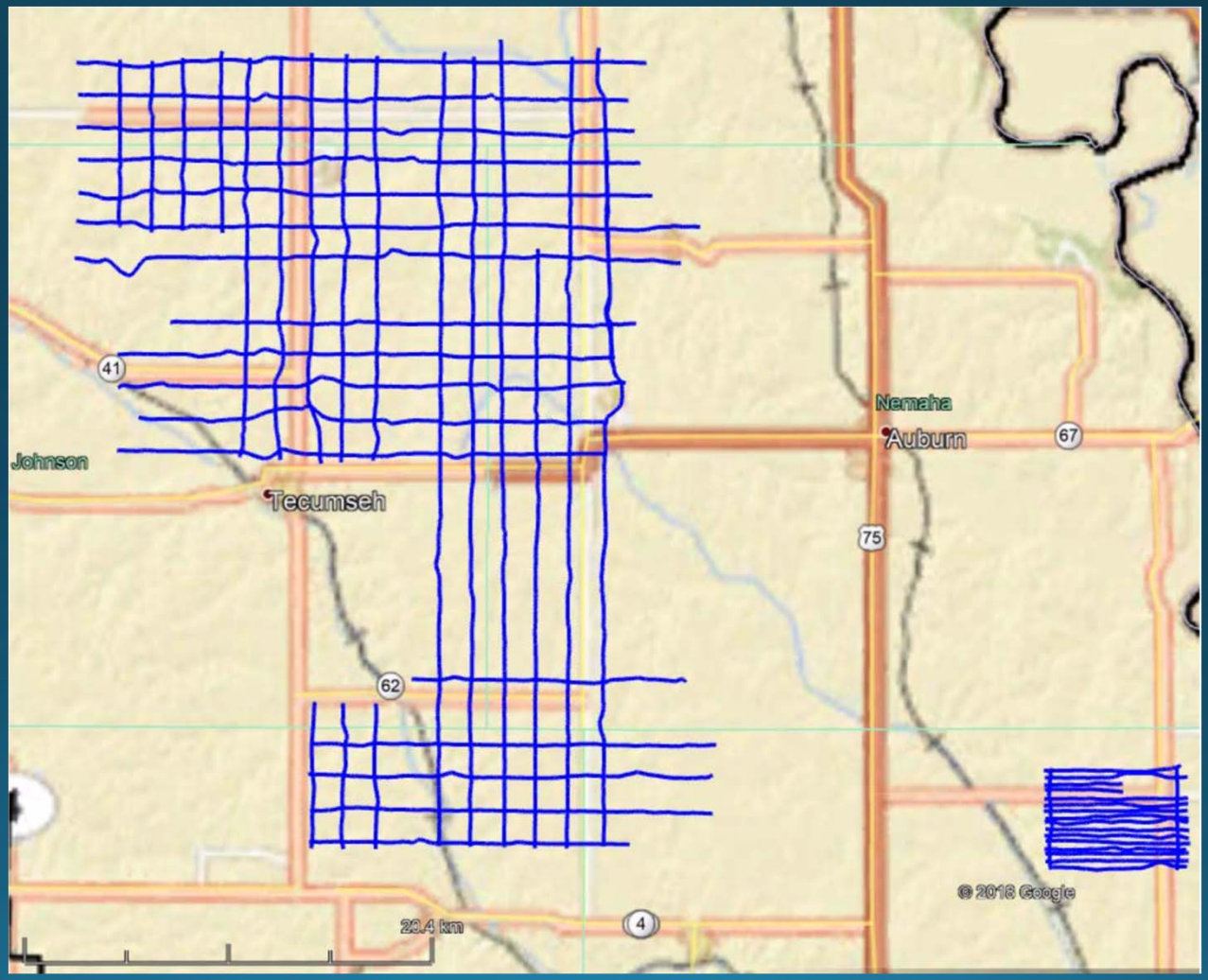
- Improve the Hydrogeologic framework of the NNRD
- Provide Reconnaissance Level Profiles and 3D representations of the hydrogeology
- Provide a detailed framework in the Shubert Block flight area
- Provide information on boundary conditions within the subsurface
- What is the hydrologic connections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



Nemaha AEM Survey Area 2018

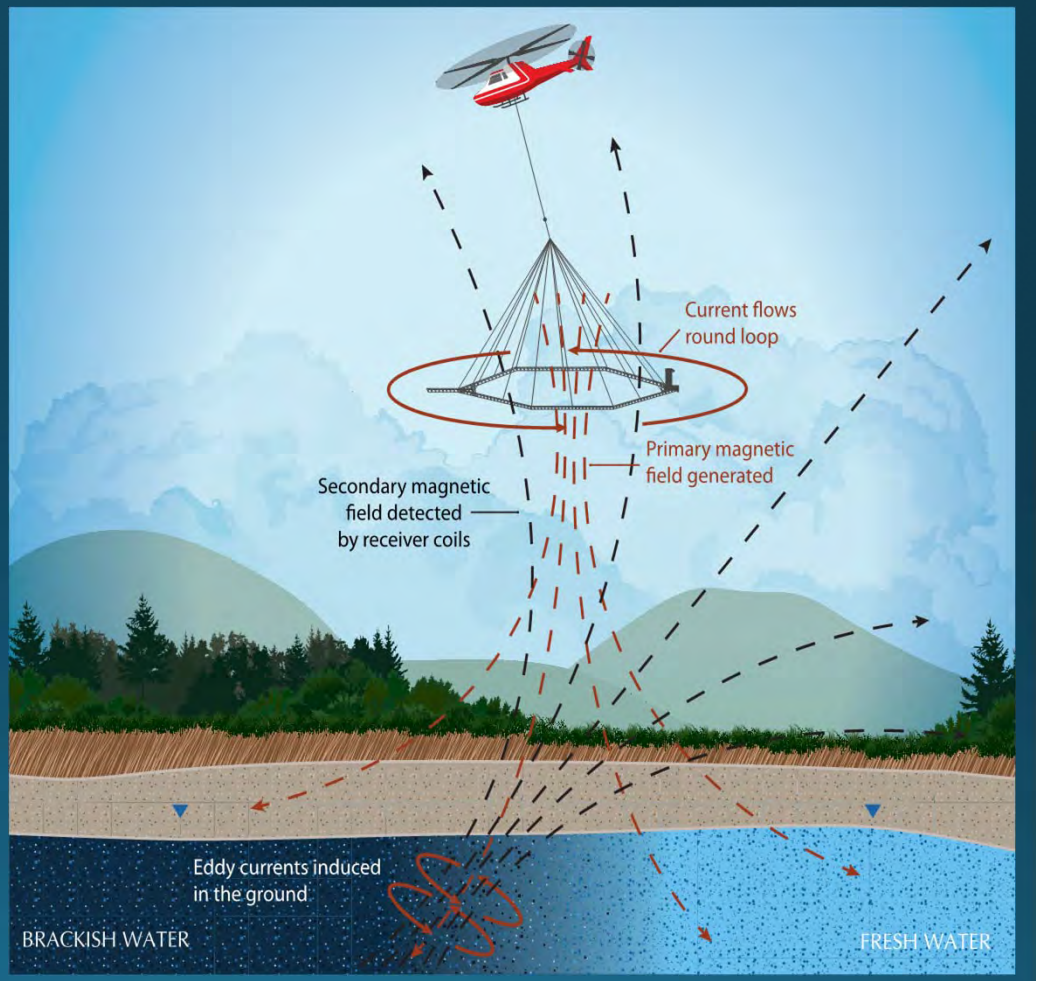
- ~579.8 line miles
- $300,000 total cost
- 50% additional

miles flown due to better price from vendor



AEM Fundamentals

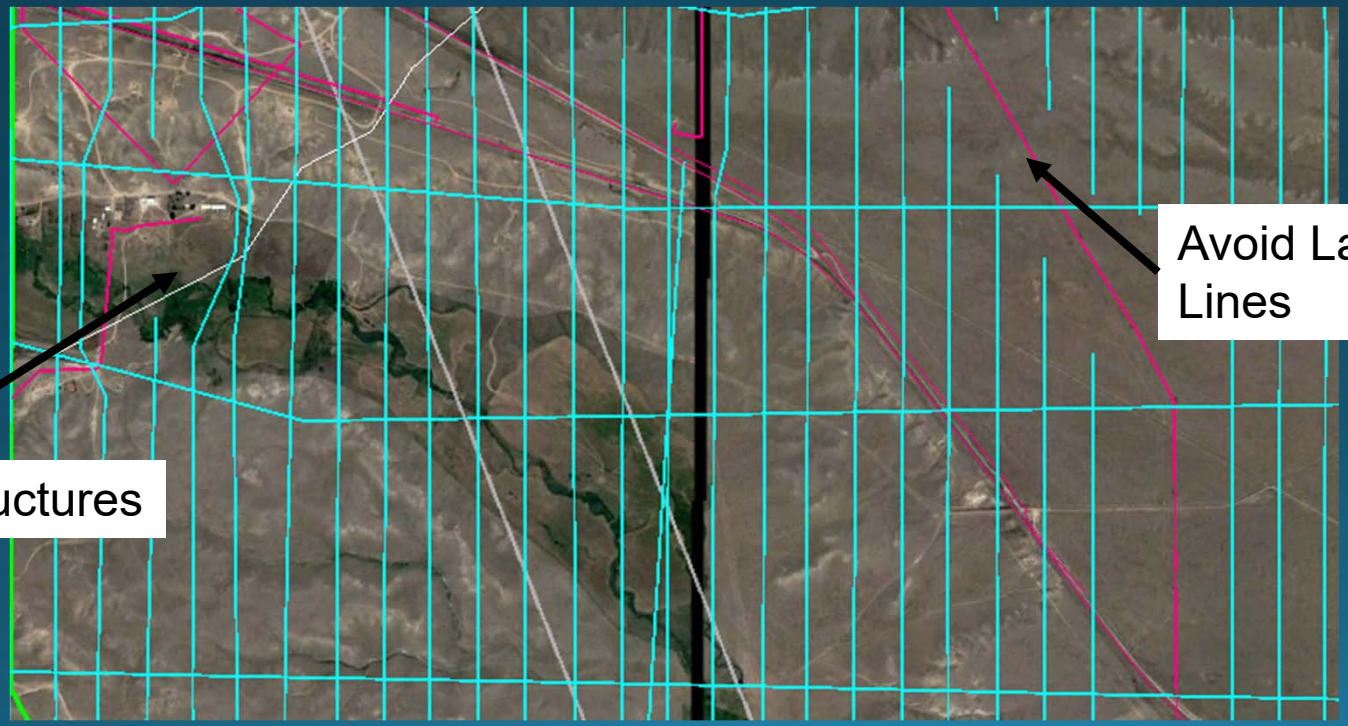
- Airborne Geophysical Techniques
  - Electromagnetic – Time Domain (TDEM) or Frequency Domain (FDEM)
  - Gravity Gradient (Tensor)
  - Magnetic Total-Field & Gradient
  - Radiometrics
- Surveys typically use multiple techniques to examine contrasts in different physical properties



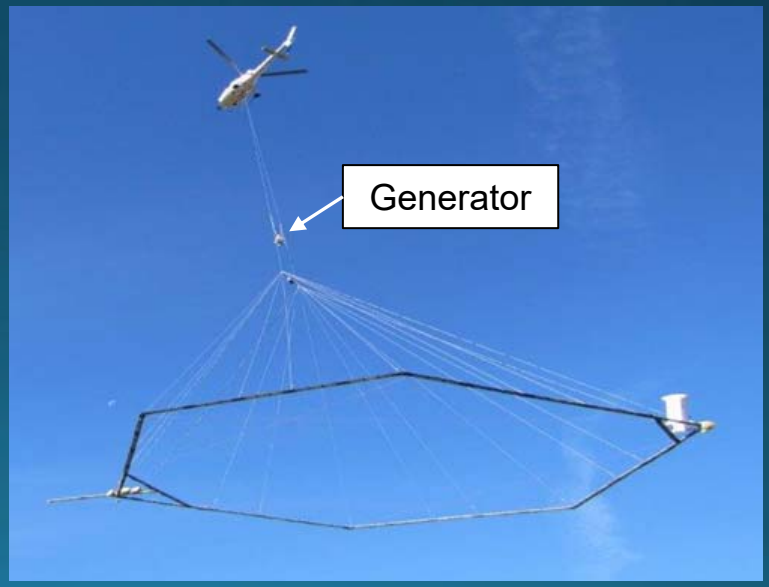
XRI, 2015

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



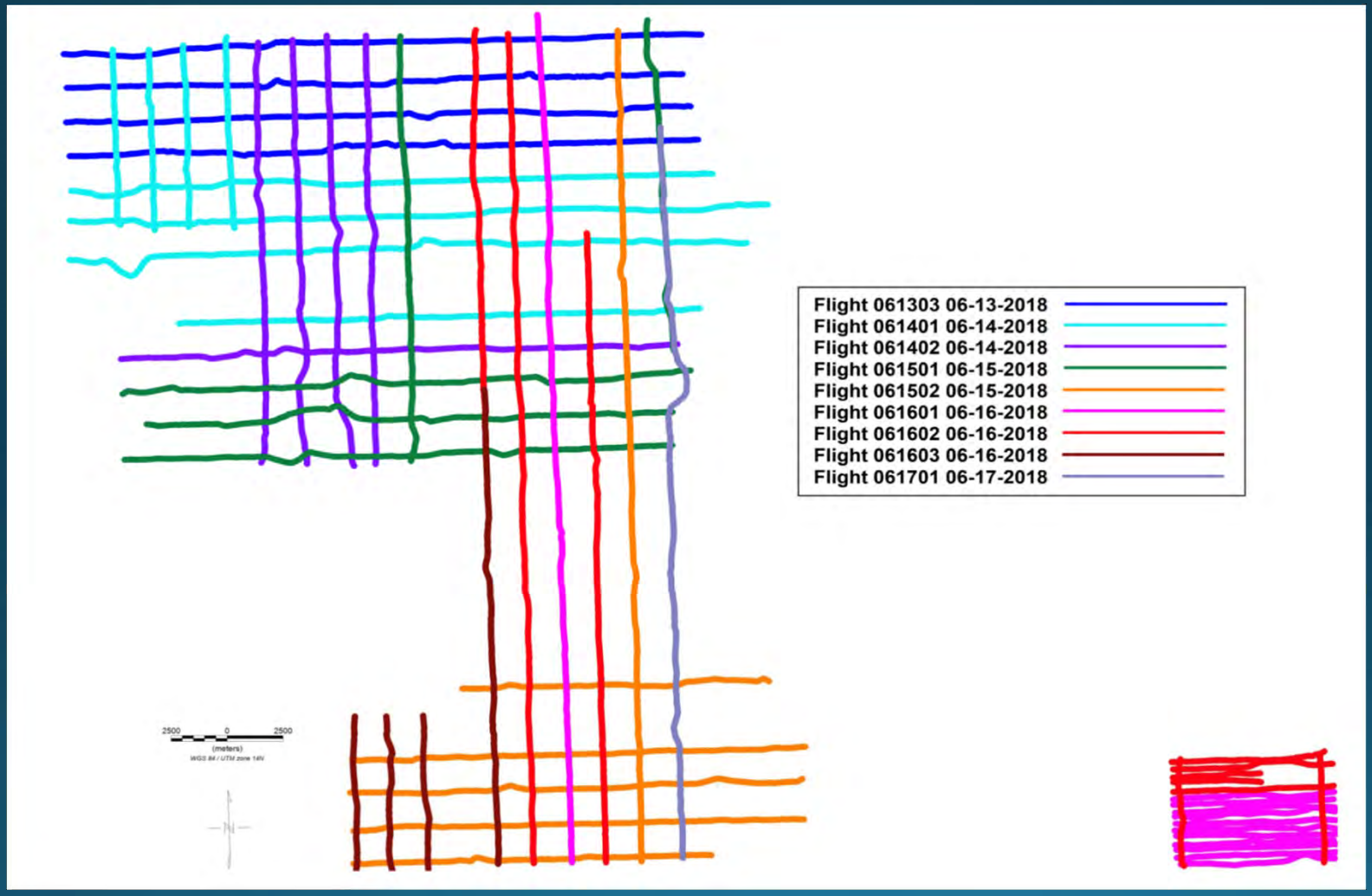
Usually 2-3 Flights/day
Totaling about 180-250 line-miles/day
Approx. 100' – 150' above ground

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

2018 Nemaha NRD Acquisition Schedule

- Start date June 13, 2018
- Completion of Flights June 17, 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.

Nemaha NRD Final Flight Acquisition Plan Grouped by Date Collected



QA/QC and Initial Preliminary Inversions

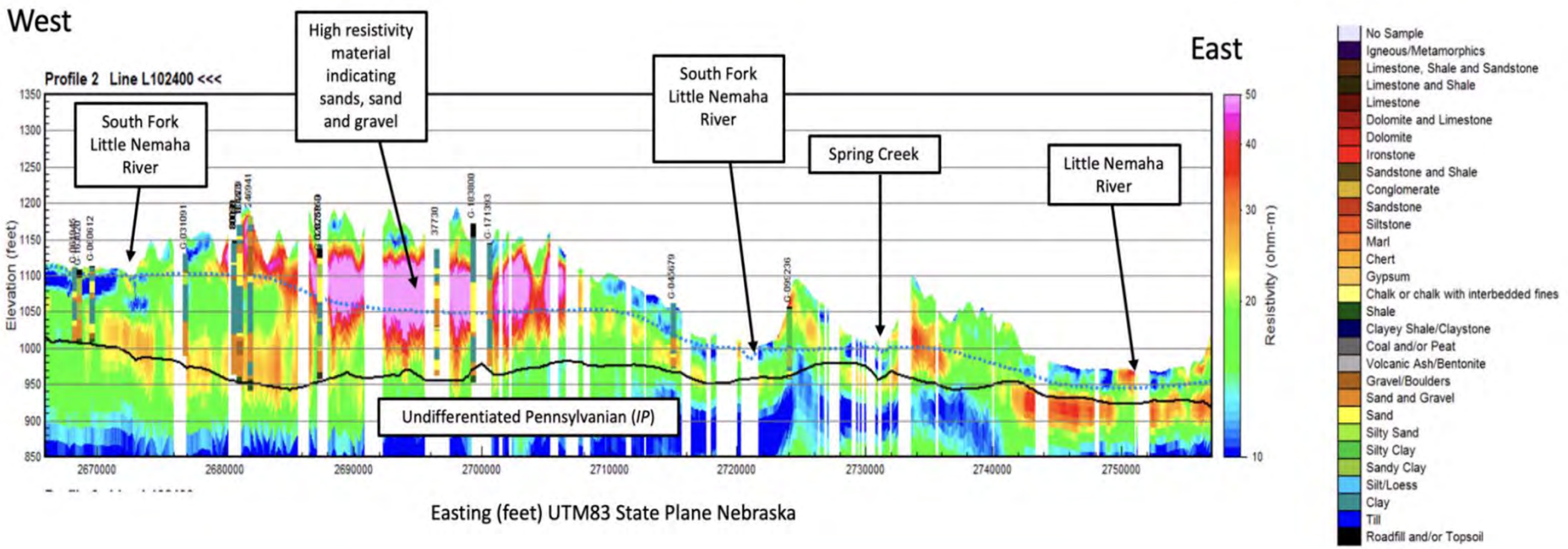
- QA/QC of collected data continued throughout the data collection process on every day's collected data
- Unacceptable data was recollected
- Initial preliminary inversions began immediately upon data availability

Existing Geologic Data

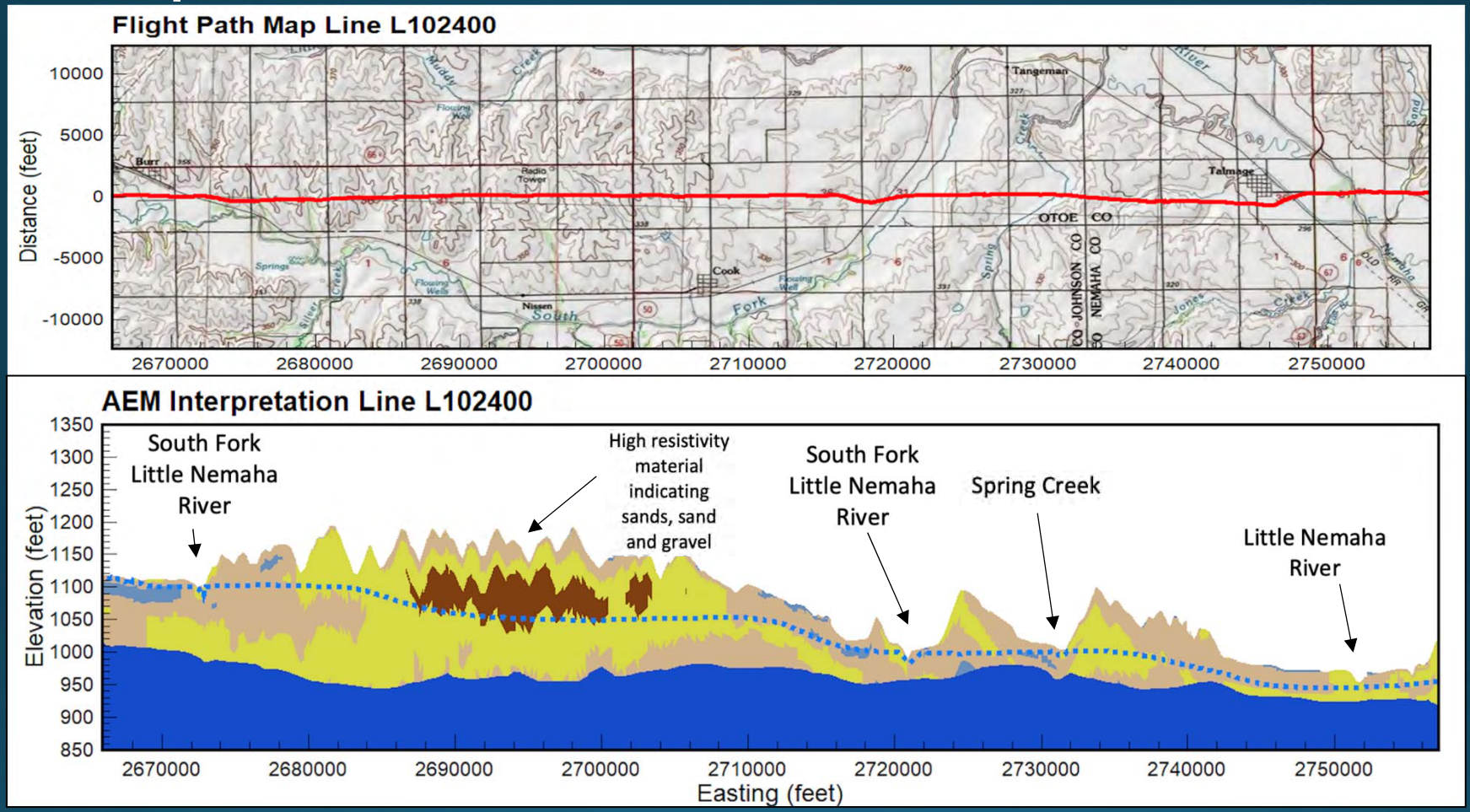
- Use CSD test-hole database
- Use CSD historical cross sections
- Use selected DNR well logs
- Use selected oil and gas well logs
- LBG Report
- Water table elevations

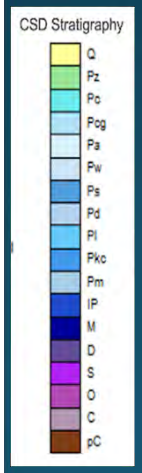
Utilize as much existing and accurate geologic test-hole data as possible!

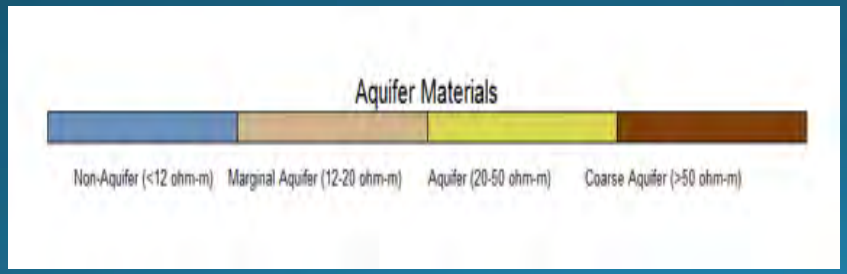
Interpreting Resistivity



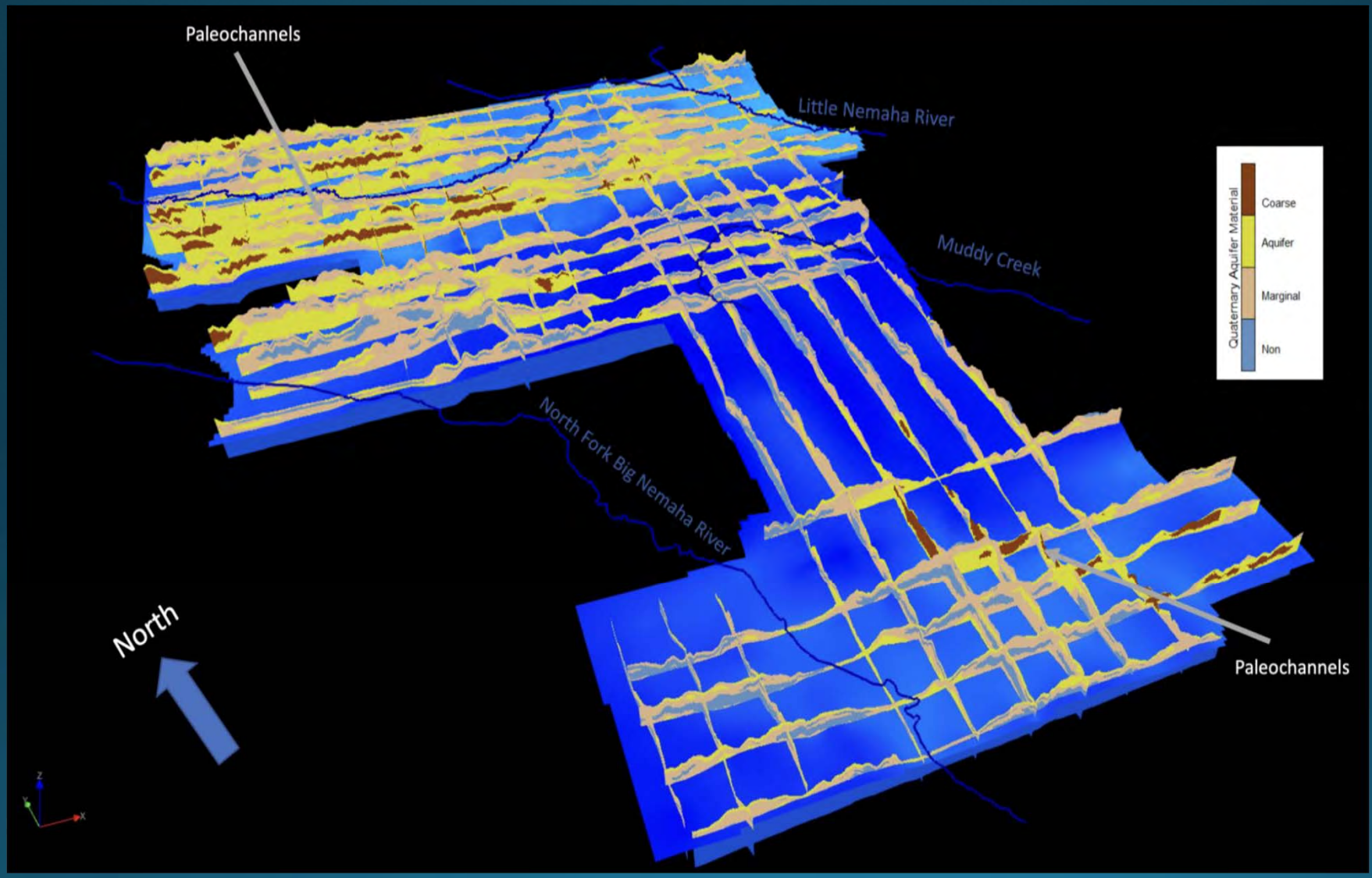
Interpreted Section



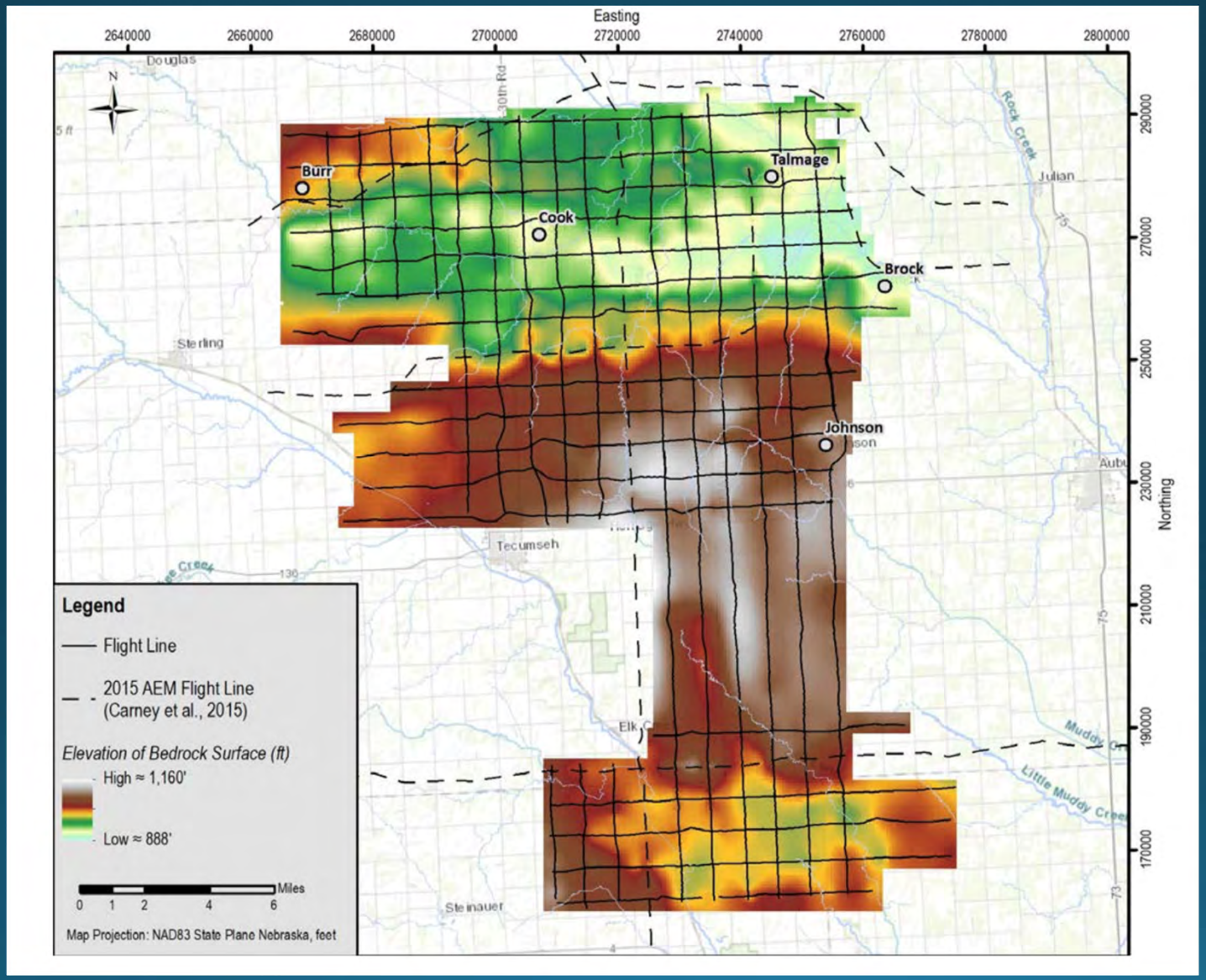




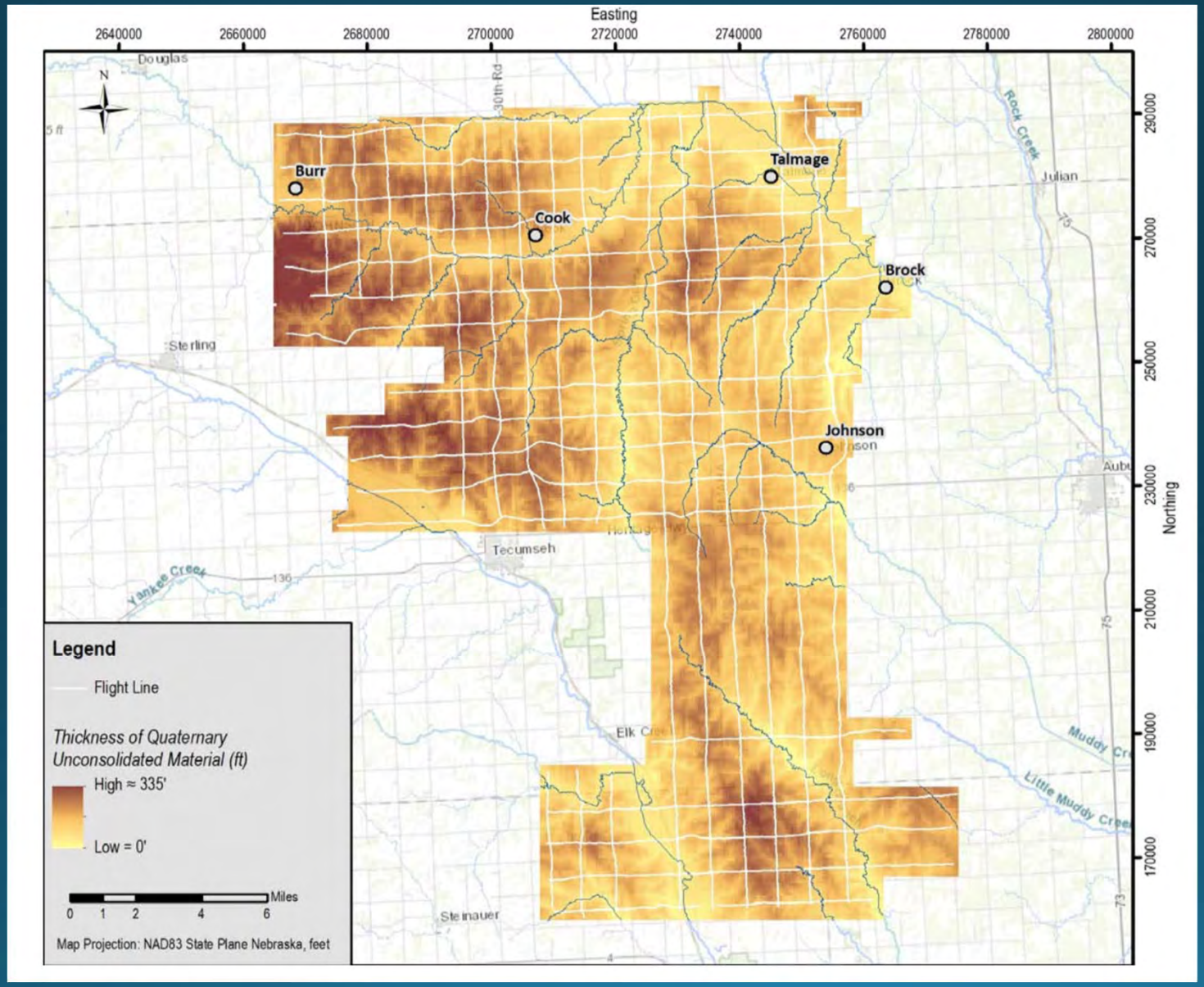
NNRD 3D View Hydrogeologic Areas- Looking North



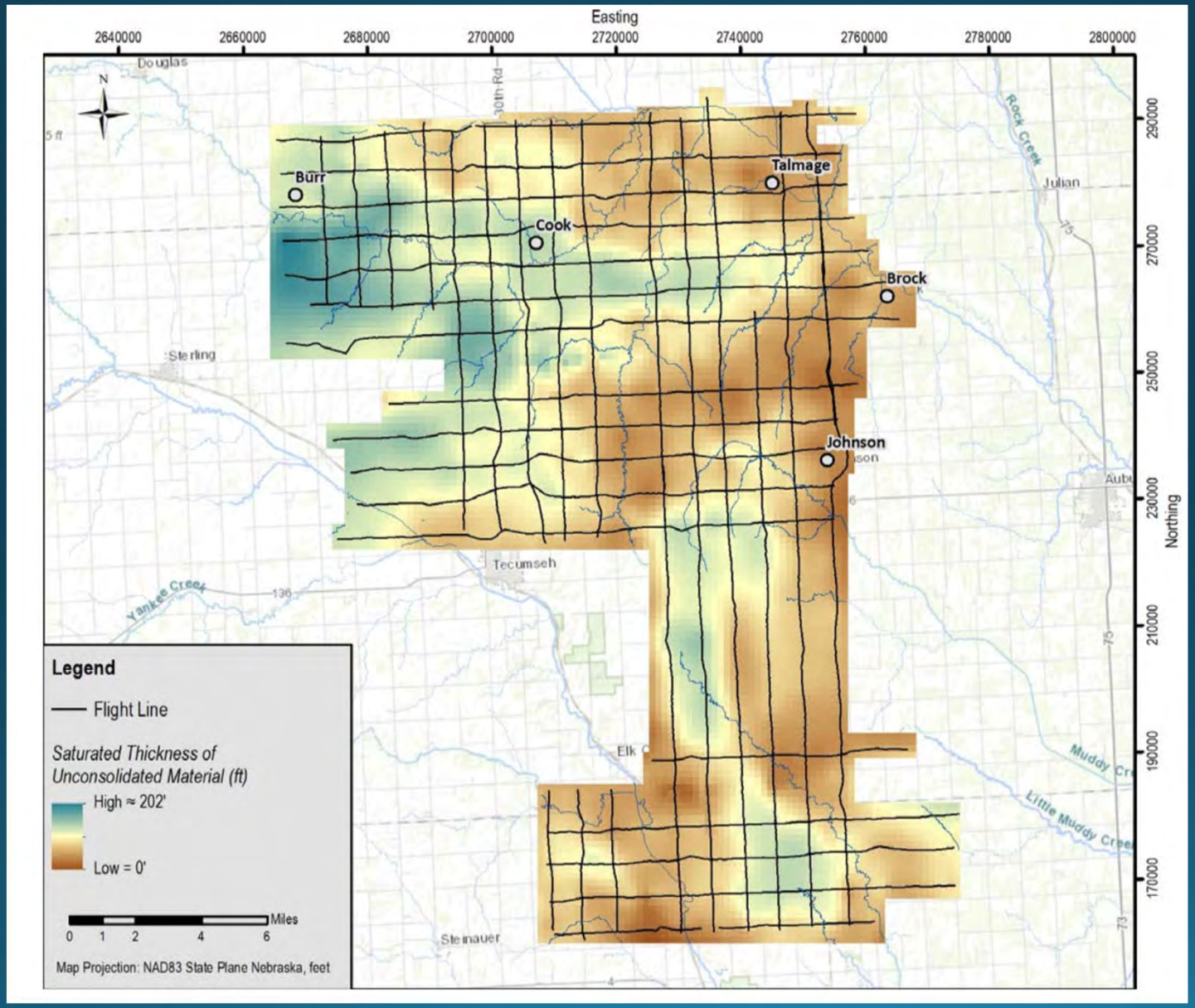
NNRD Configuration of the Bedrock Surface-Reconnaissance Lines



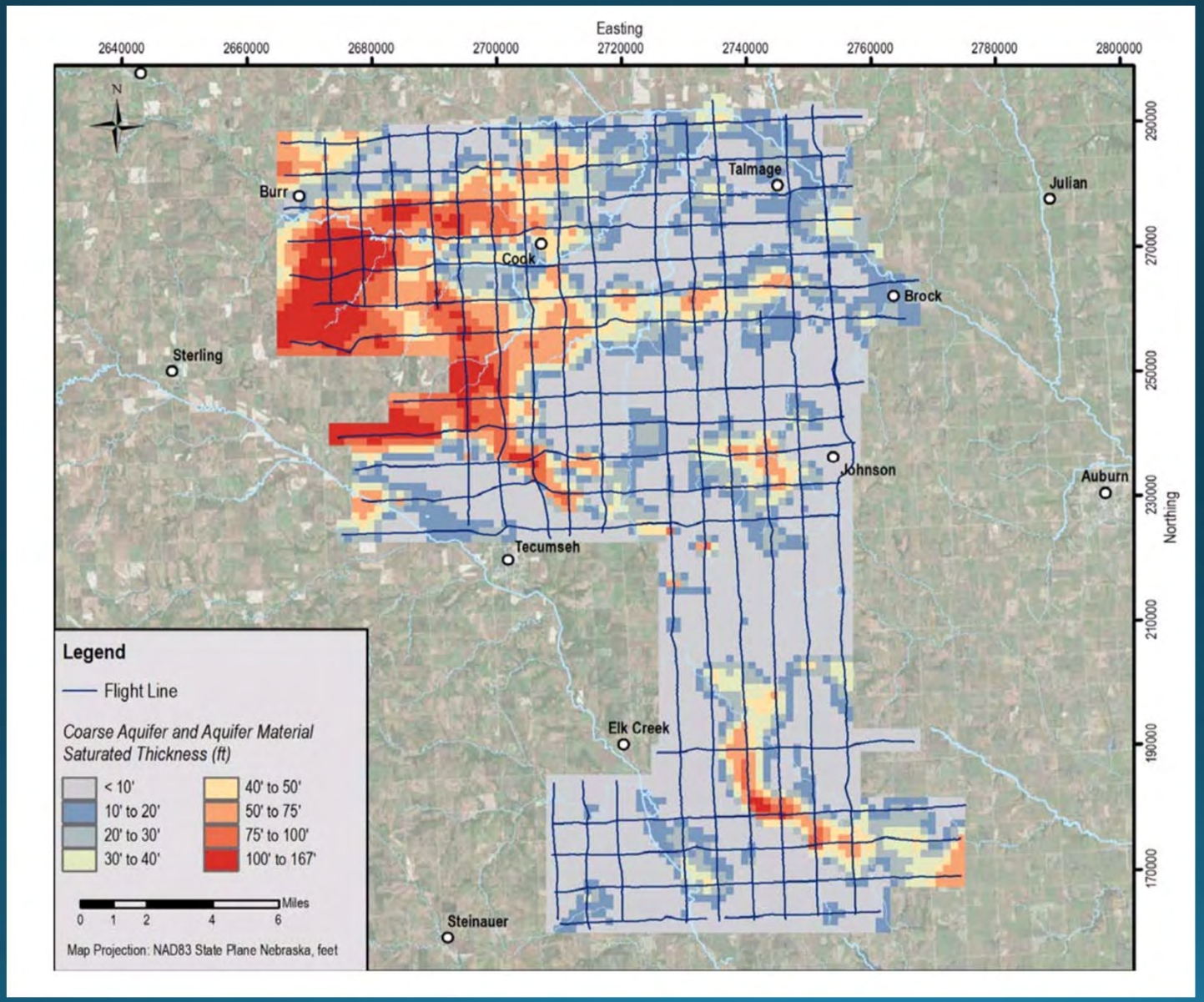
NNRD Map of the Total Thickness of Quaternary Deposits -Reconnaissance Lines



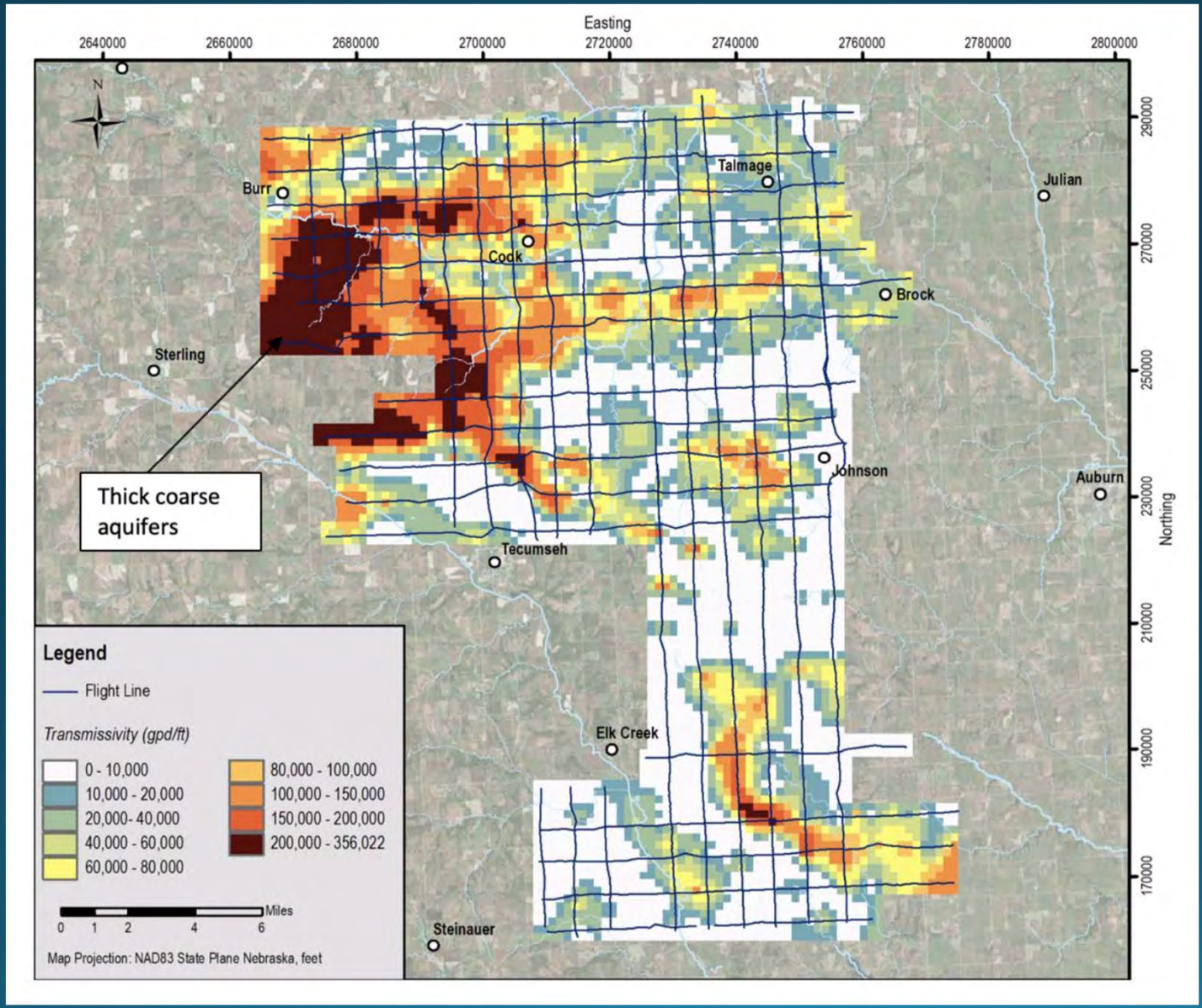
NNRD Map of of the Saturated Thickness of Quaternary Deposits -Reconnaissance Lines



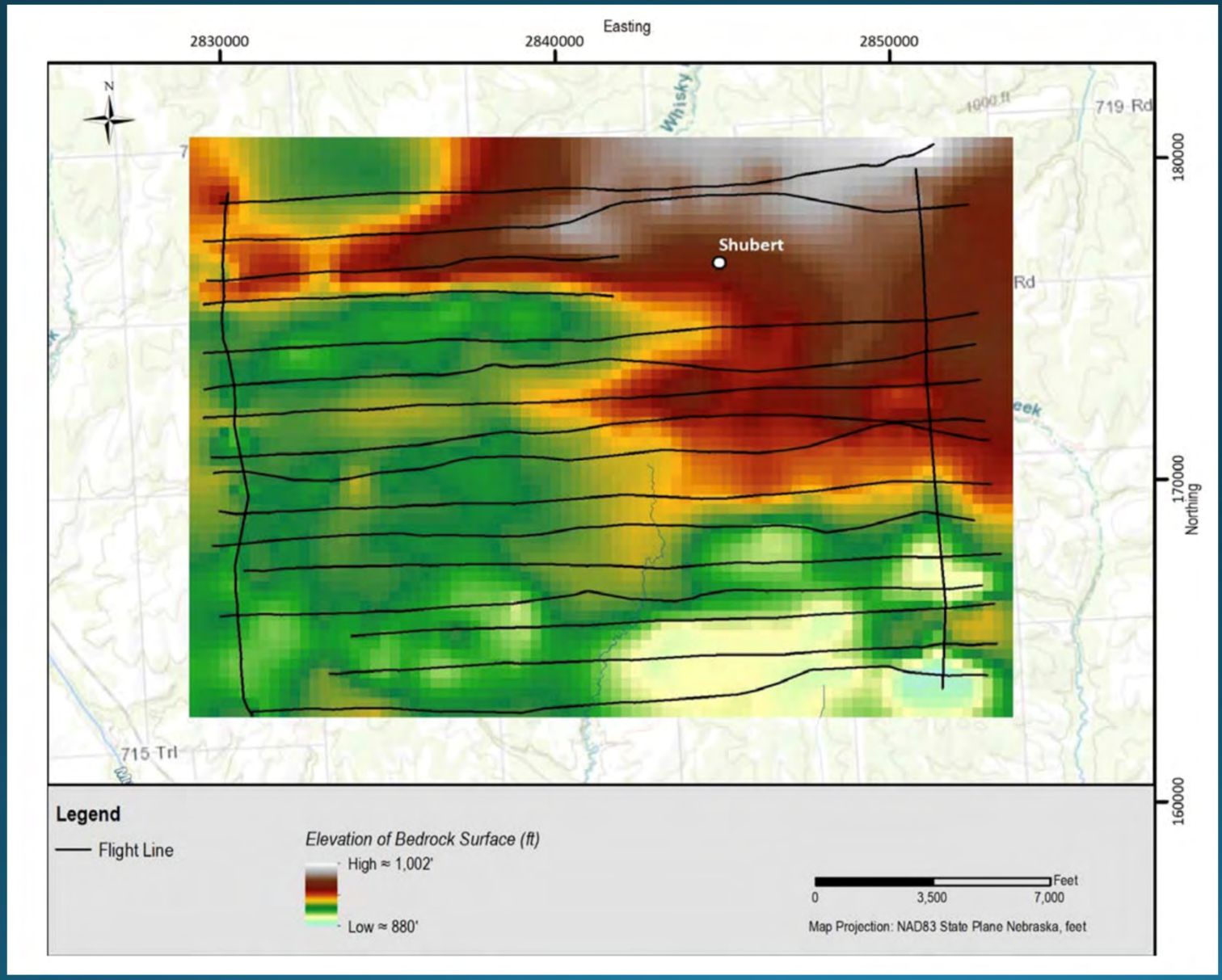
NNRD Saturated Thickness of Marginal Aquifer, Aquifer Material and Coarse Aquifer Material-Reconnaissance Lines



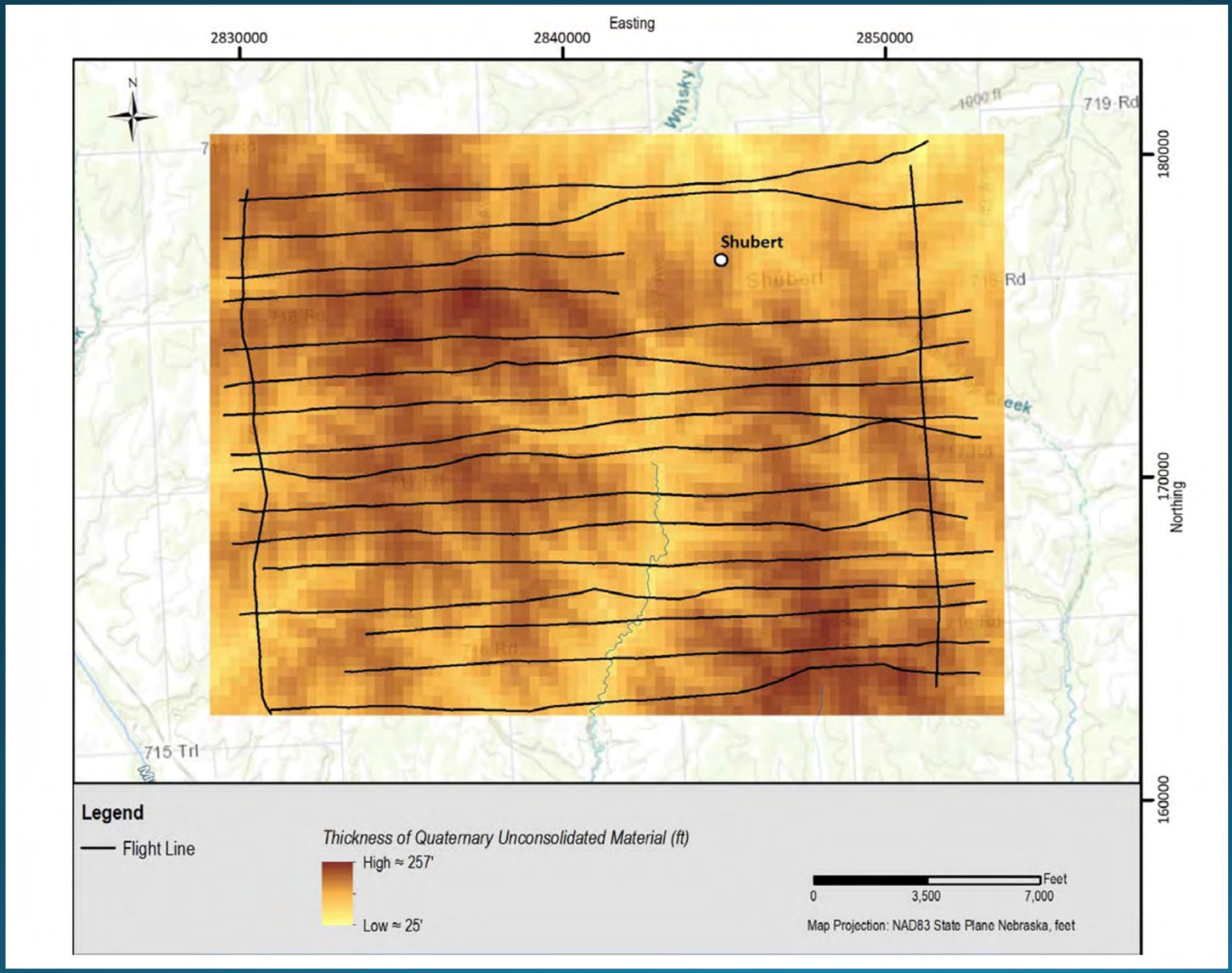
NNRD Estimated Transmissivity-Reconnaissance Lines



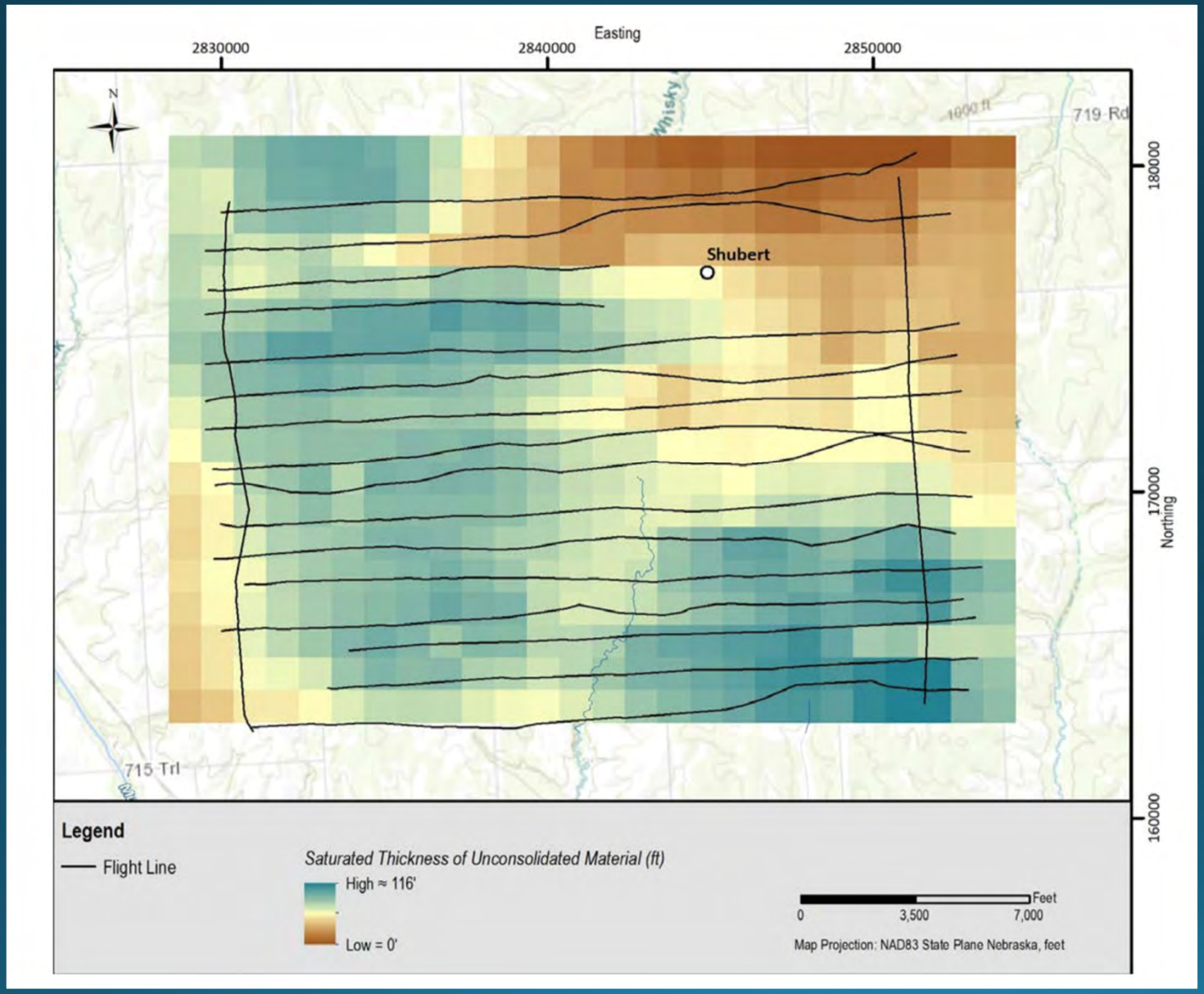
NNRD Shubert Block Elevation of the Bedrock Surface



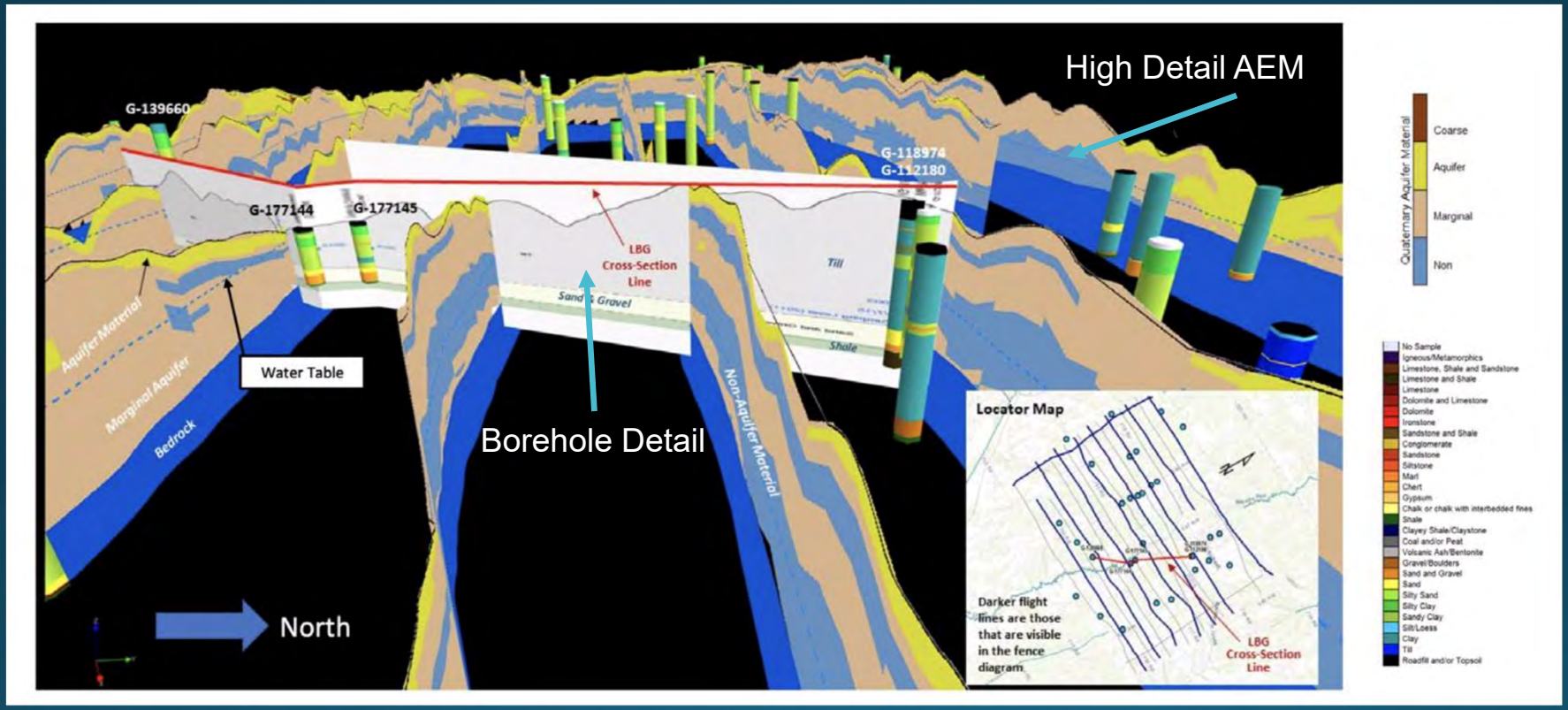
NNRD Map of the Total Thickness of Quaternary Deposits –Shubert Block



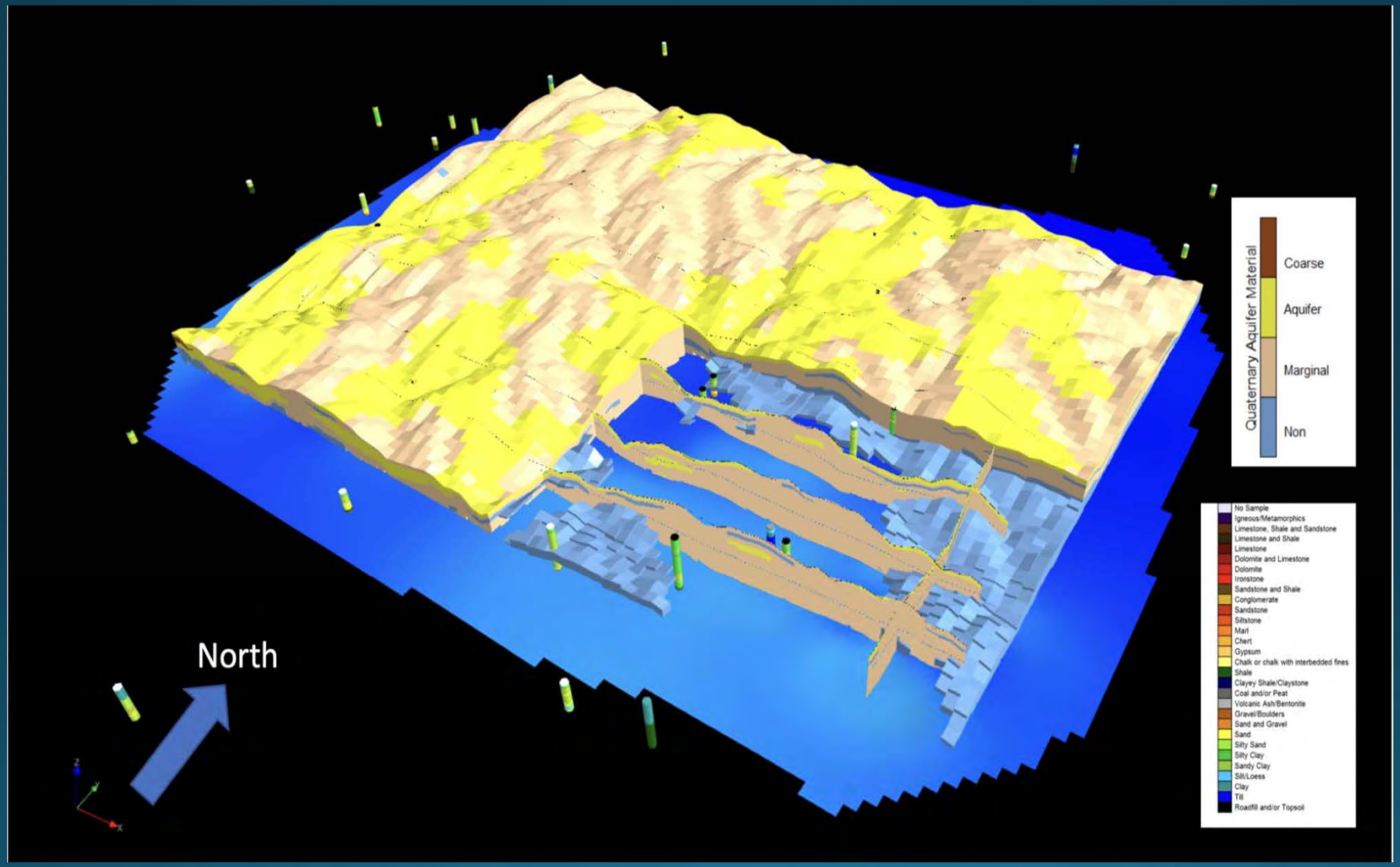
NNRD Map of of the Saturated Thickness of Quaternary Deposits –Shubert Block



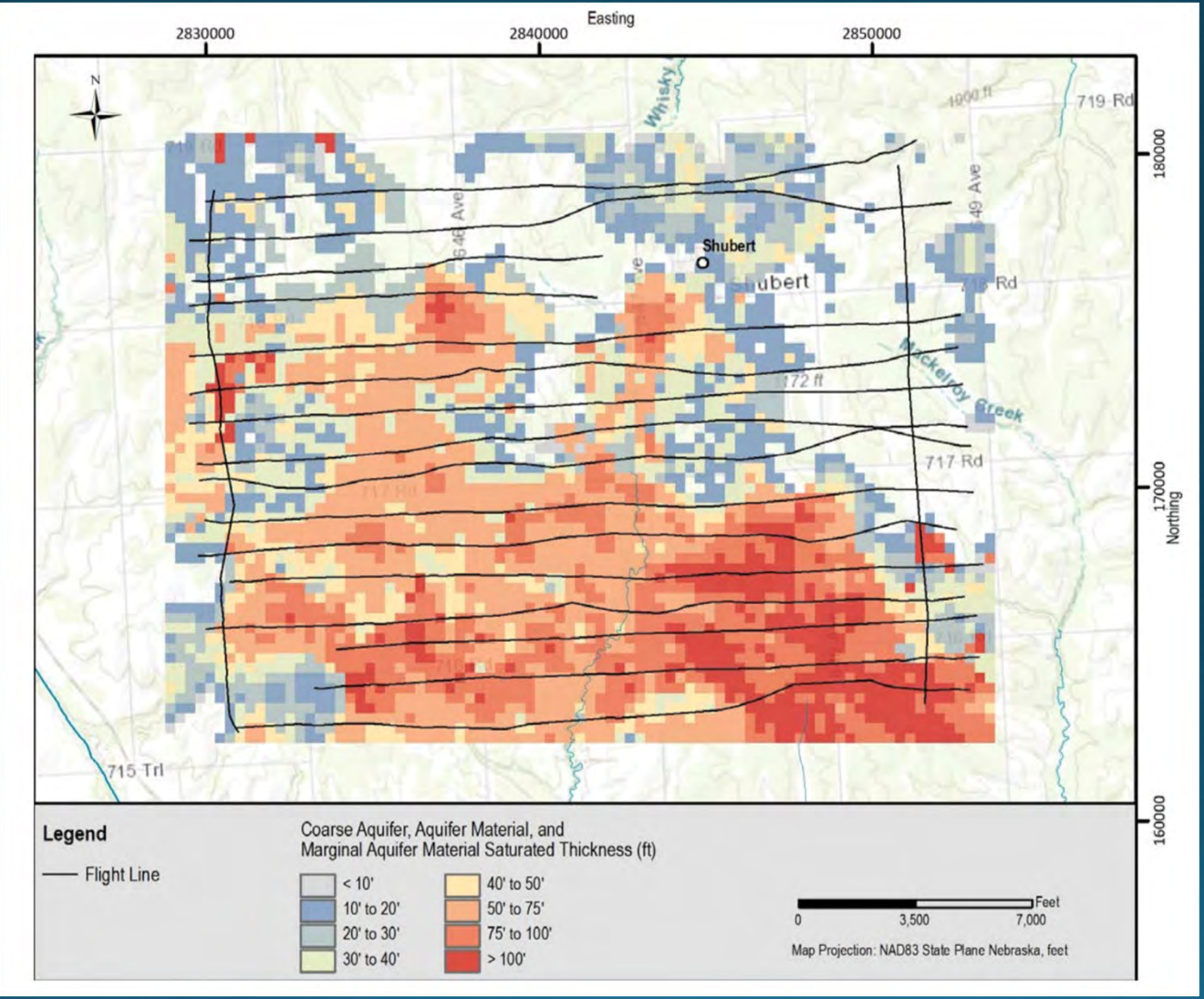
NNRD 3D Fence Diagram of Interpreted AEM Profiles including LBG profiles (boreholes only)- Shubert Block



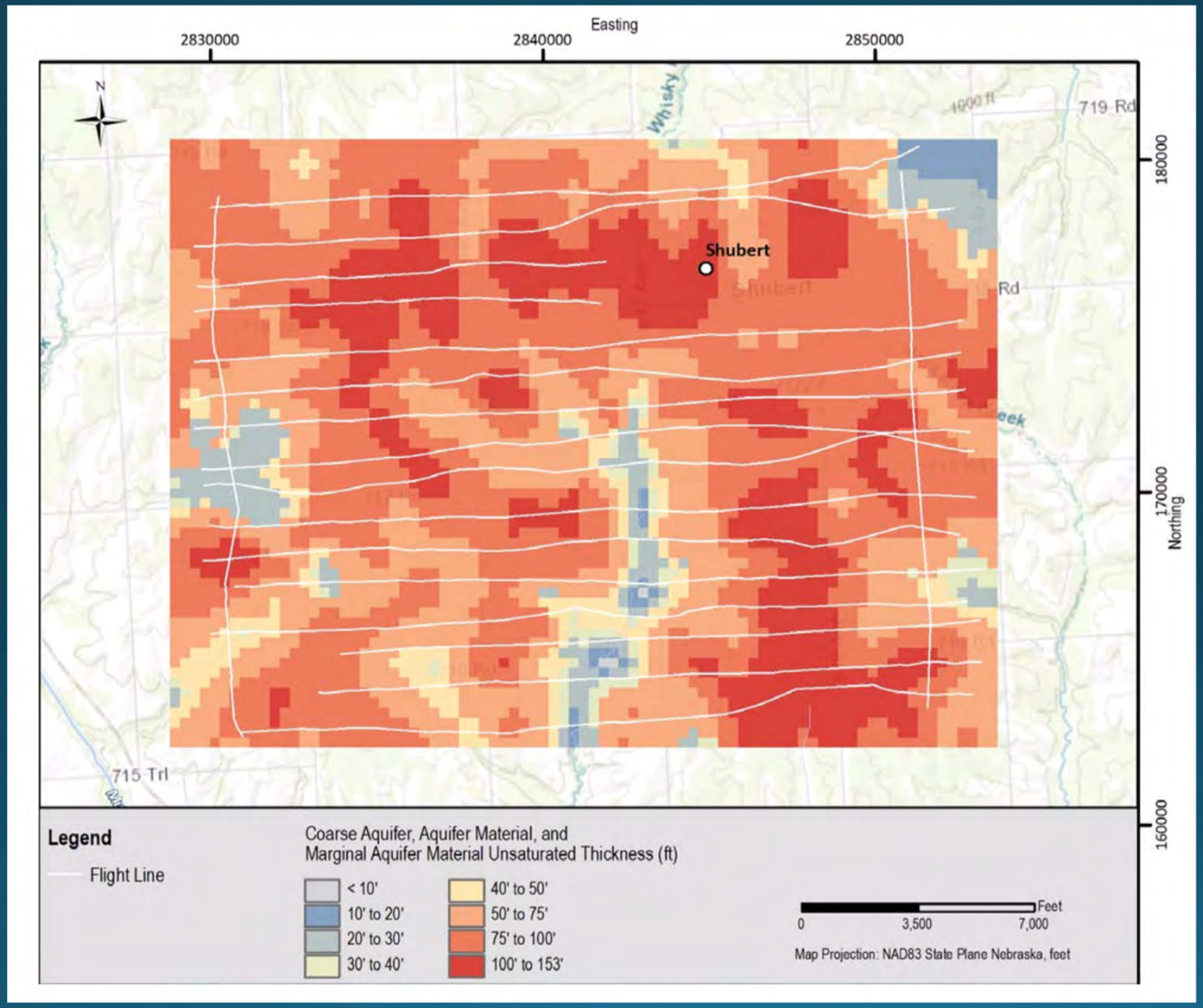
NNRD 3D Voxel Model of Aquifer Material Types- Shubert Block



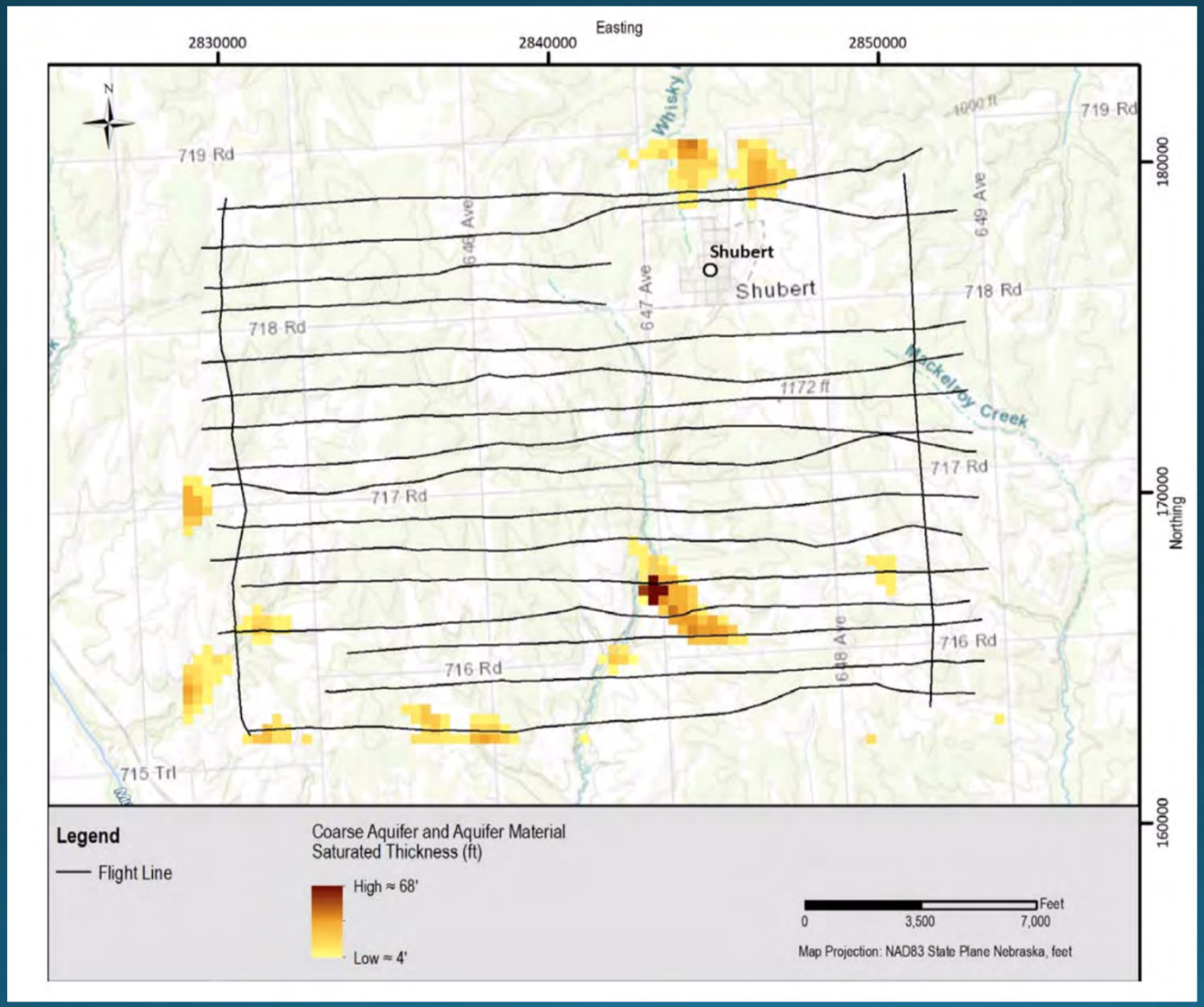
NNRD Saturated Thickness of Marginal Aquifer, Aquifer Material and Coarse Aquifer Material- Shubert Block



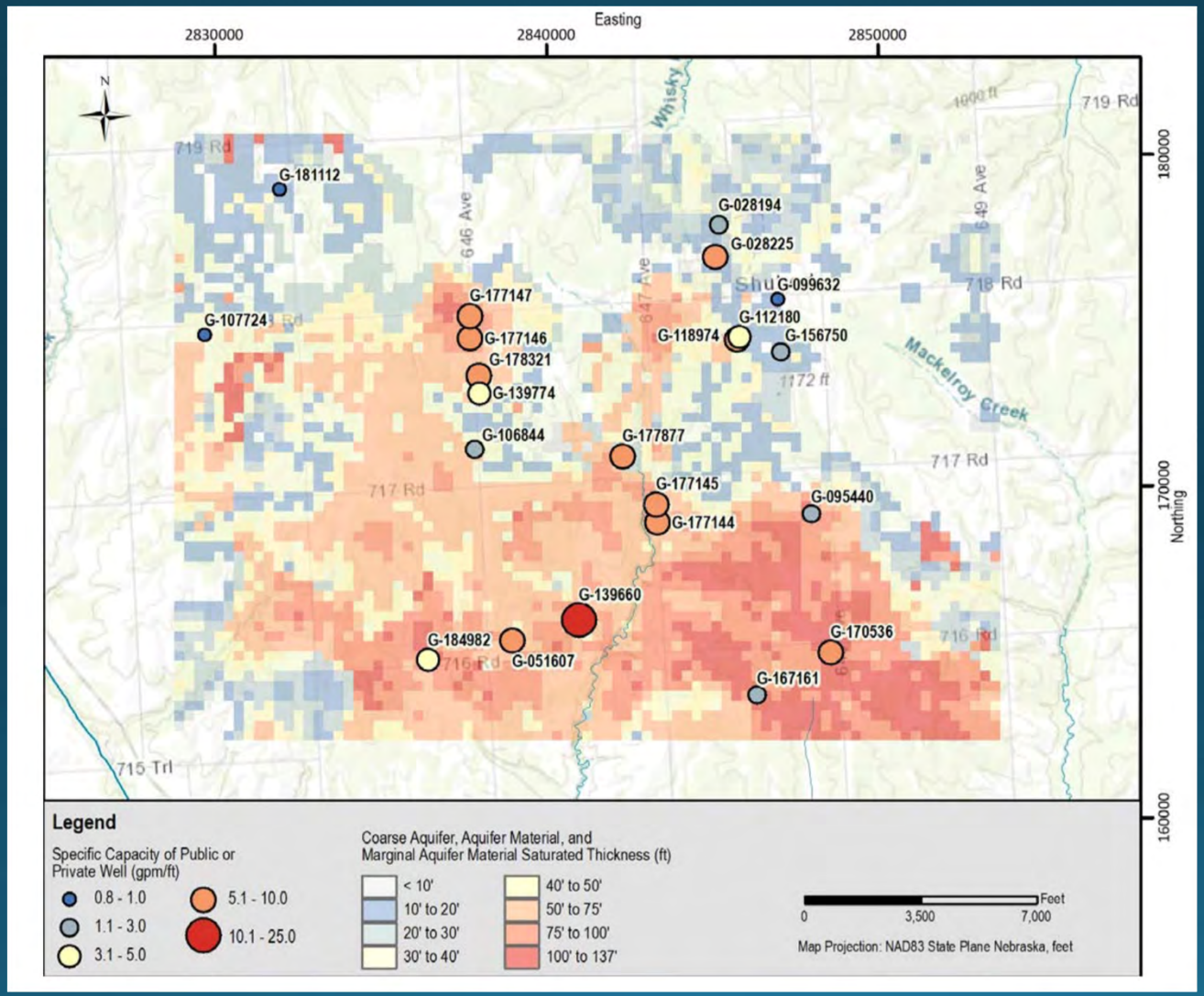
NNRD Unsaturated Thickness of Marginal Aquifer, Aquifer Material and Coarse Aquifer Material- Shubert Block



NNRD Saturated Thickness of Coarse Aquifer Material- Shubert Block



NNRD Unsaturated Thickness of Marginal Aquifer, Aquifer Material and Coarse Aquifer Material- Shubert Block



Shubert Block Estimates of Groundwater in Storage

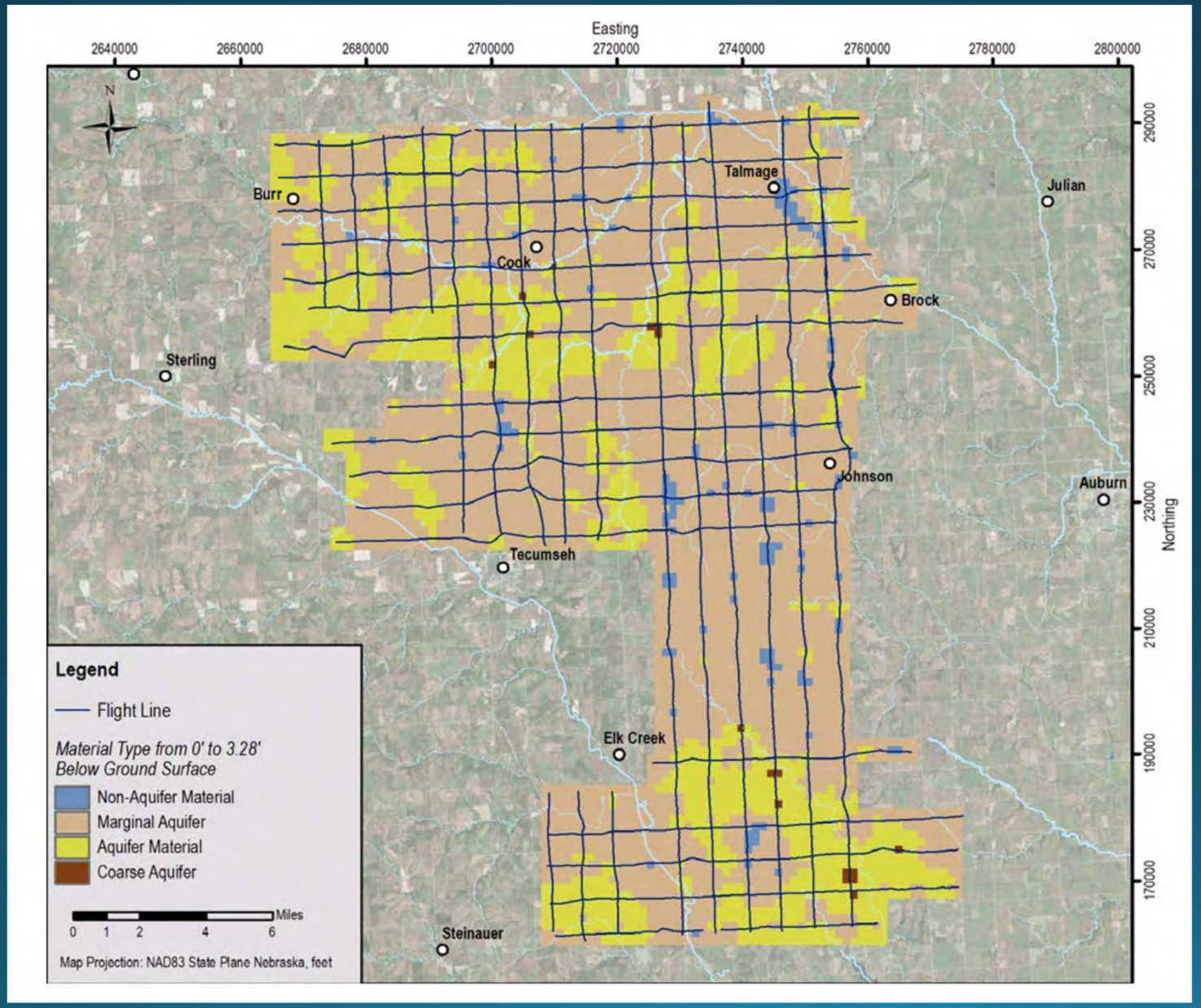
Table 3-2. Fully saturated Quaternary aquifer materials underlying the Shubert Block area.

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	21,987,278,946	504,760	0.4	201,904	0.02	4,038
Marginal	45,901,187,303	1,053,749	0.35	368,812	0.05	18,441
Aquifer	6,252,544,377	143,539	0.2	28,708	0.22	6,316
Coarse Aquifer	107,972,789	2,479	0.25	620	0.19	118
TOTAL	74,248,983,414	1,704,526		600,044		28,912

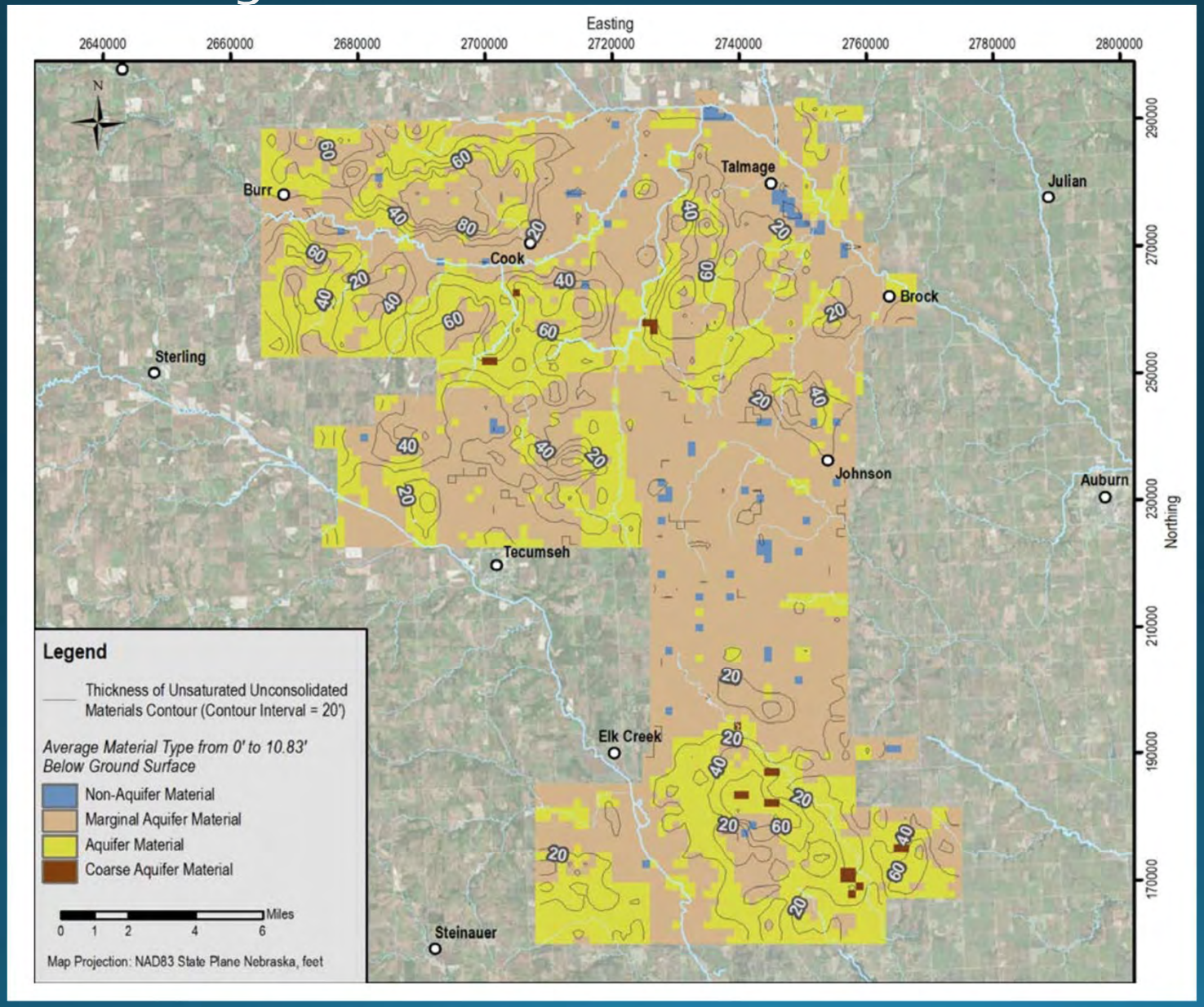
Table 3-3. 1995 CSD water table saturated Quaternary aquifer materials underlying the Shubert Block area.

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	14,762,147,945	338,893	0.4	135,557	0.02	2,711
Marginal	17,252,029,481	396,053	0.35	138,619	0.05	6,931
Aquifer	311,663,921	7,155	0.2	1,431	0.22	315
Coarse Aquifer	2,140,853	49	0.25	12	0.19	2
TOTAL	32,327,982,198	742,150		275,619		9,959

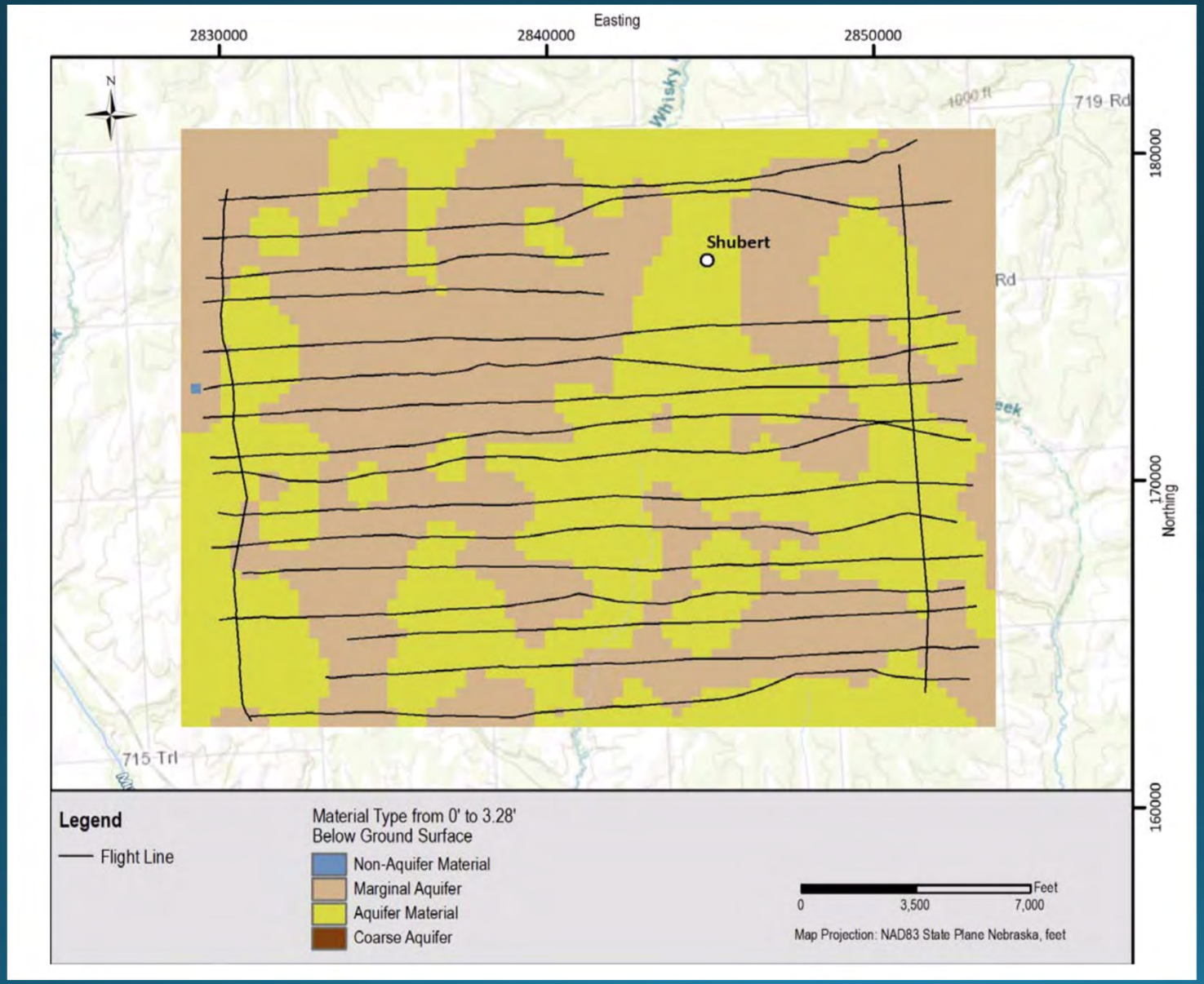
Potential Recharge by Aquifer Material Type From 0-3.28 Feet BLS- Reconnaissance Lines



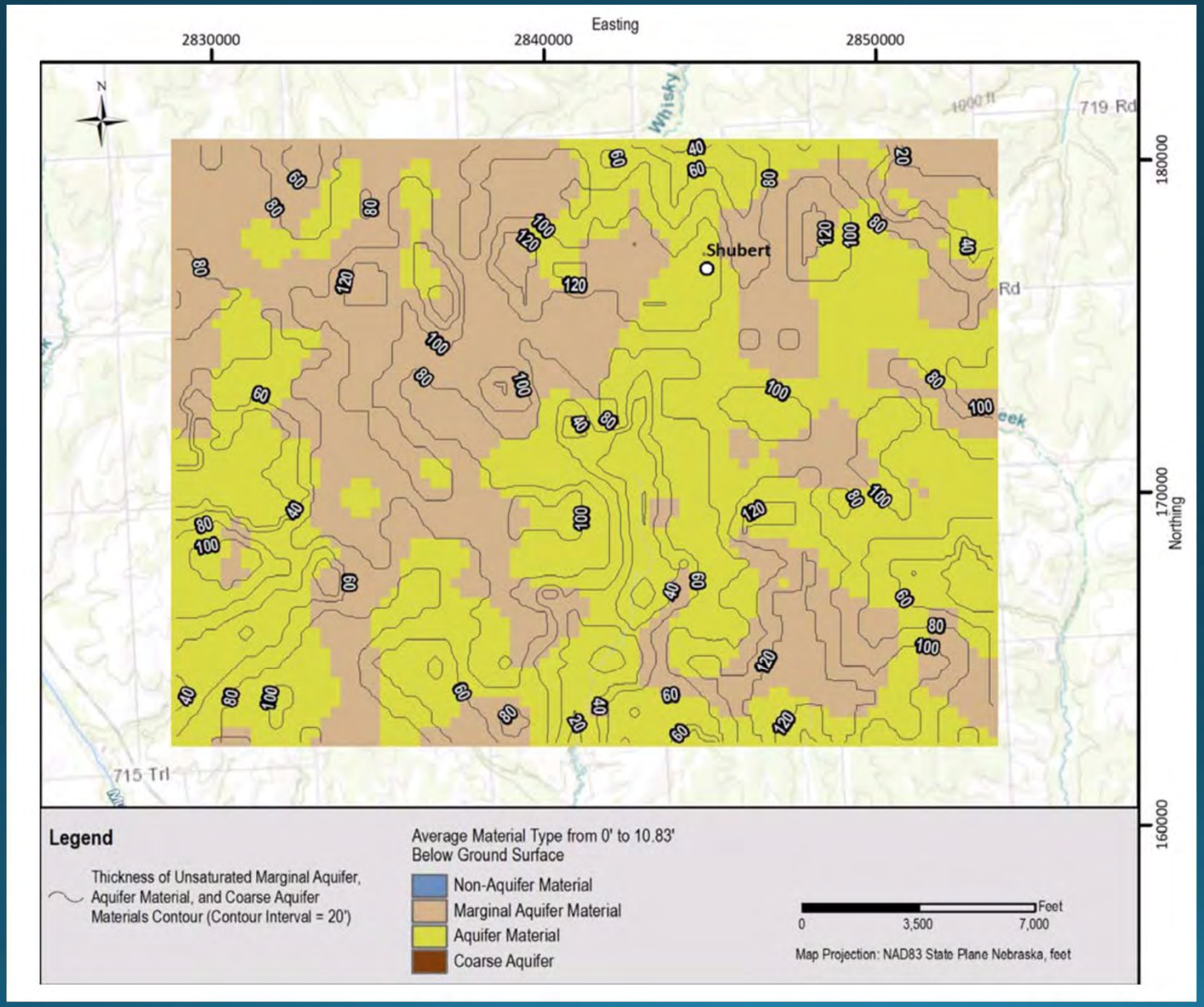
Potential Recharge by Average Aquifer Material Type From 0-10.83 Feet BLS- Reconnaissance Lines



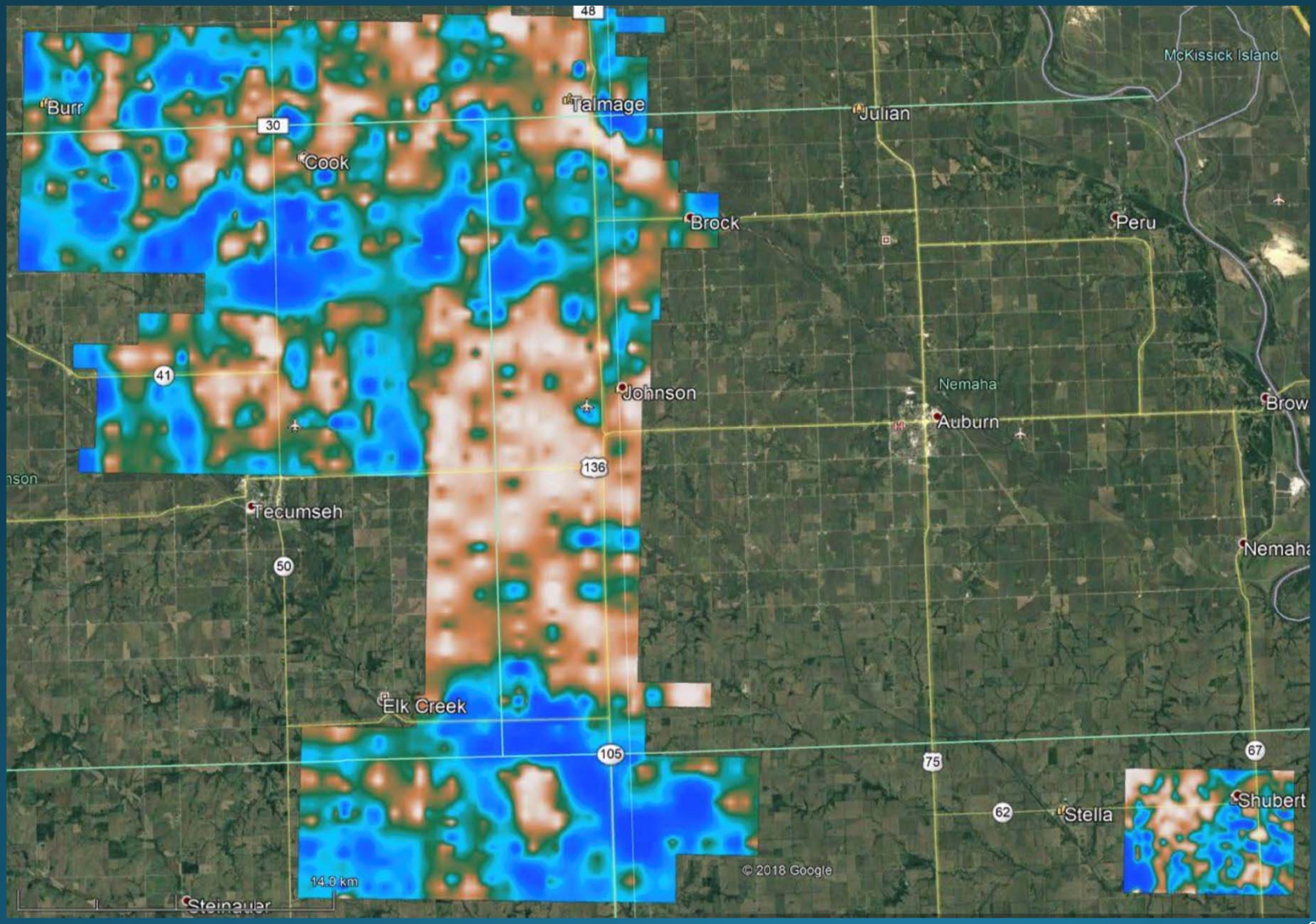
Potential Recharge by Aquifer Material Type From 0-3.28 Feet BLS- Schubert Block



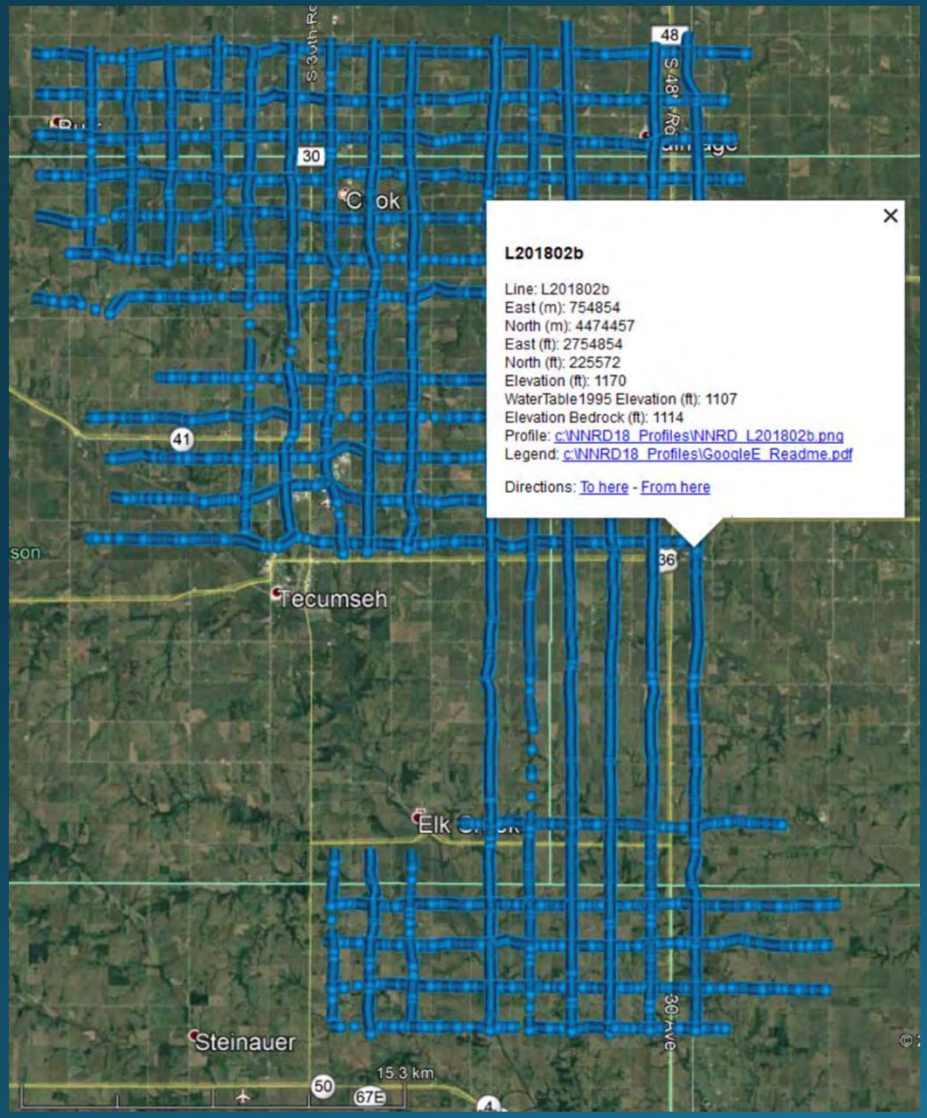
Potential Recharge by Average Aquifer Material Type From 0-10.83 Feet BLS- Shubert Block



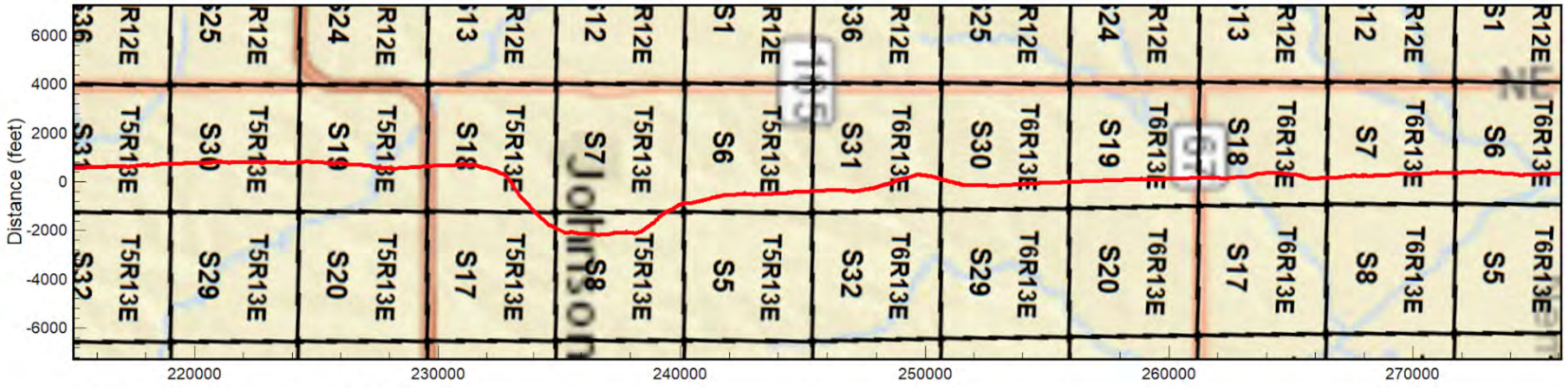
Greatest Potential Recharge for Reconnaissance Lines and Shubert Block



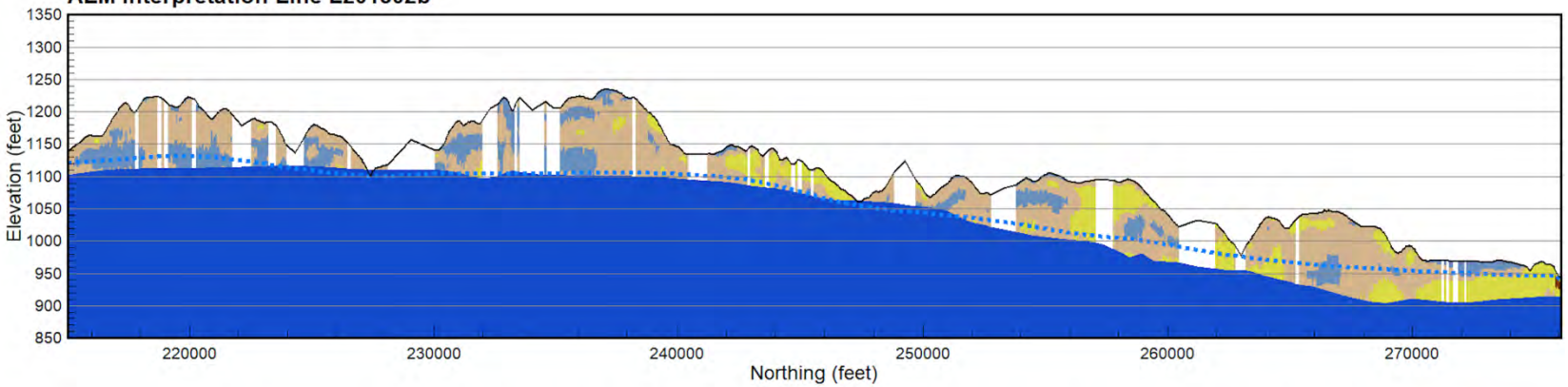
Nemaha NRD Google Earth- Reconnaissance Lines



Flight Path Map Line L201802b



AEM Interpretation Line L201802b



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 undifferentiated Pennsylvanian (IP) is indicated by the blue area. 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 Regions of the Eastern Nebraska Water Resources Assessment Area" Chapter on the Nemaha Natural Resources District.

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)

NEMAHA NRD

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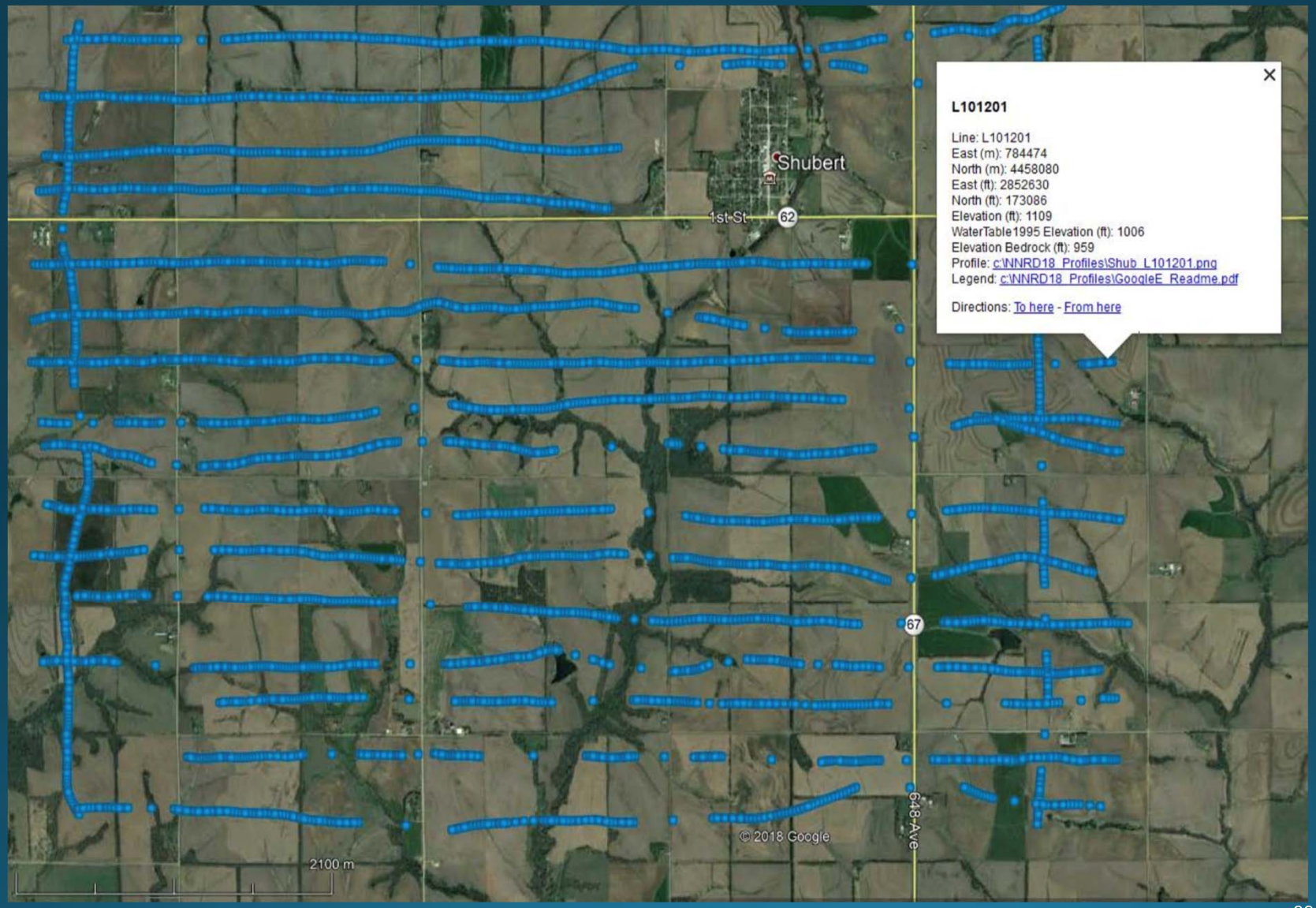
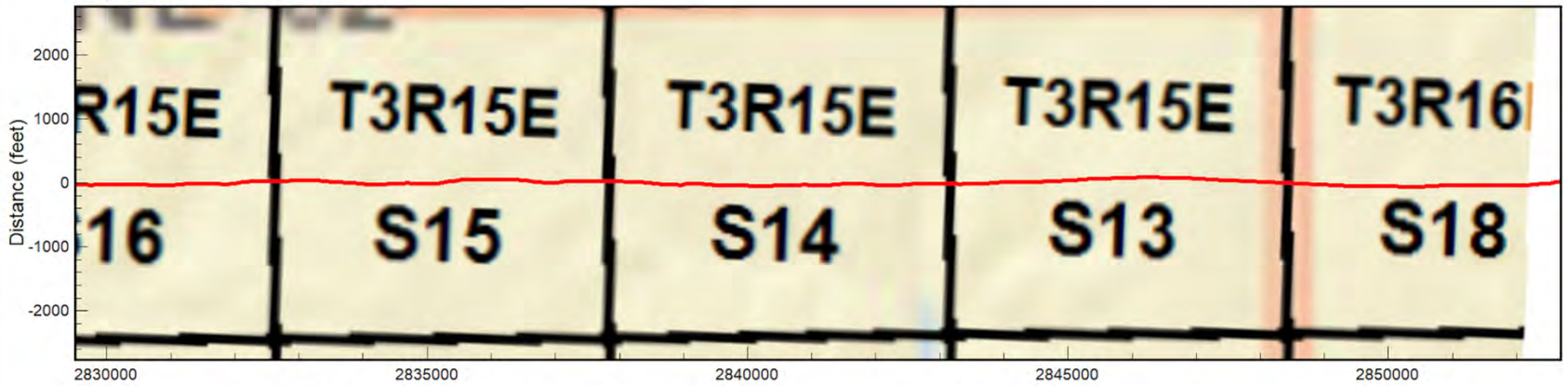
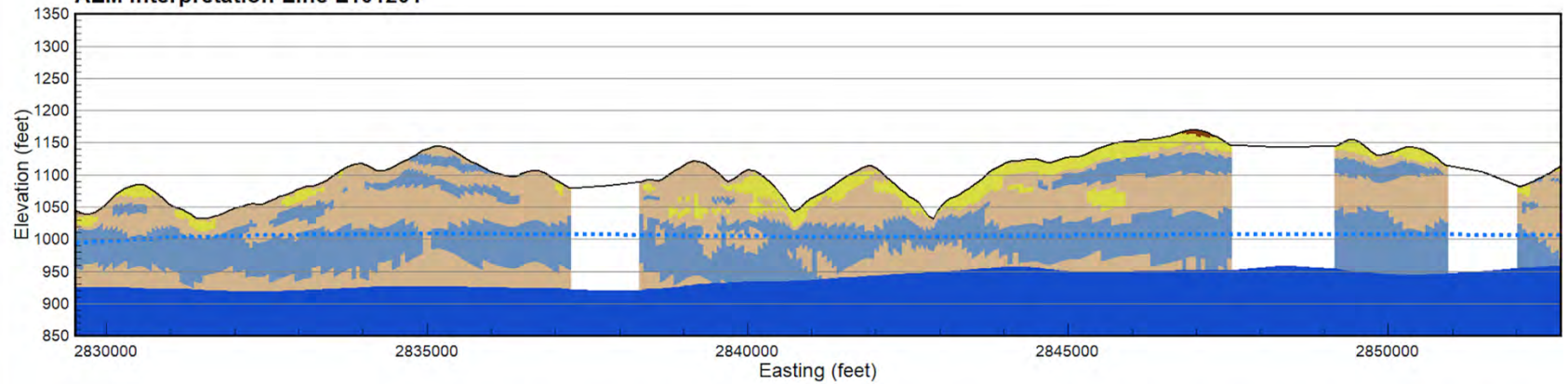
Nemaha NRD Google Earth- Shubert Block



Flight Path Map Line L101201



AEM Interpretation Line L101201



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)

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 undifferentiated Pennsylvanian (IP) is indicated by the blue area. 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 Regions of the Eastern Nebraska Water Resources Assessment Area" Chapter on the Nemaha Natural Resources District.

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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)*** 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 NNRD** - The 2018 NNRD AEM survey reveals variability in the Quaternary (***Q***) deposits across the NNRD AEM survey area. The ***Q*** make up the aquifer materials overlying the undifferentiated Pennsylvanian (***IP***) bedrock units.

Key Findings

- **Potential Recharge Zones within the NNRD AEM Survey Area -** The use of block flights in Shubert 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
- 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 NNRD
- 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

- Chuck Wingert- NNRD
- Katie Cameron - ENWRA

Questions??