ENWRA Recharge Mapping and Focus Area Assessment Project

Lewis & Clark NRD

Lower Elkhorn NRD

Lower Platte North NRD

Lower Platte South NRD

Nemaha NRD

Papio-Missouri River NRD

EASTERN NEBRASKA WATER RESOURCES ASSESSMENT

www.enwra.org

Nebraska Department of Natural Resources (NeDNR)

U.S. Geological Survey Water Science Center (USGS)

Conservation and Survey Division, School of Natural Resources, University of Nebraska-Lincoln (CSD)

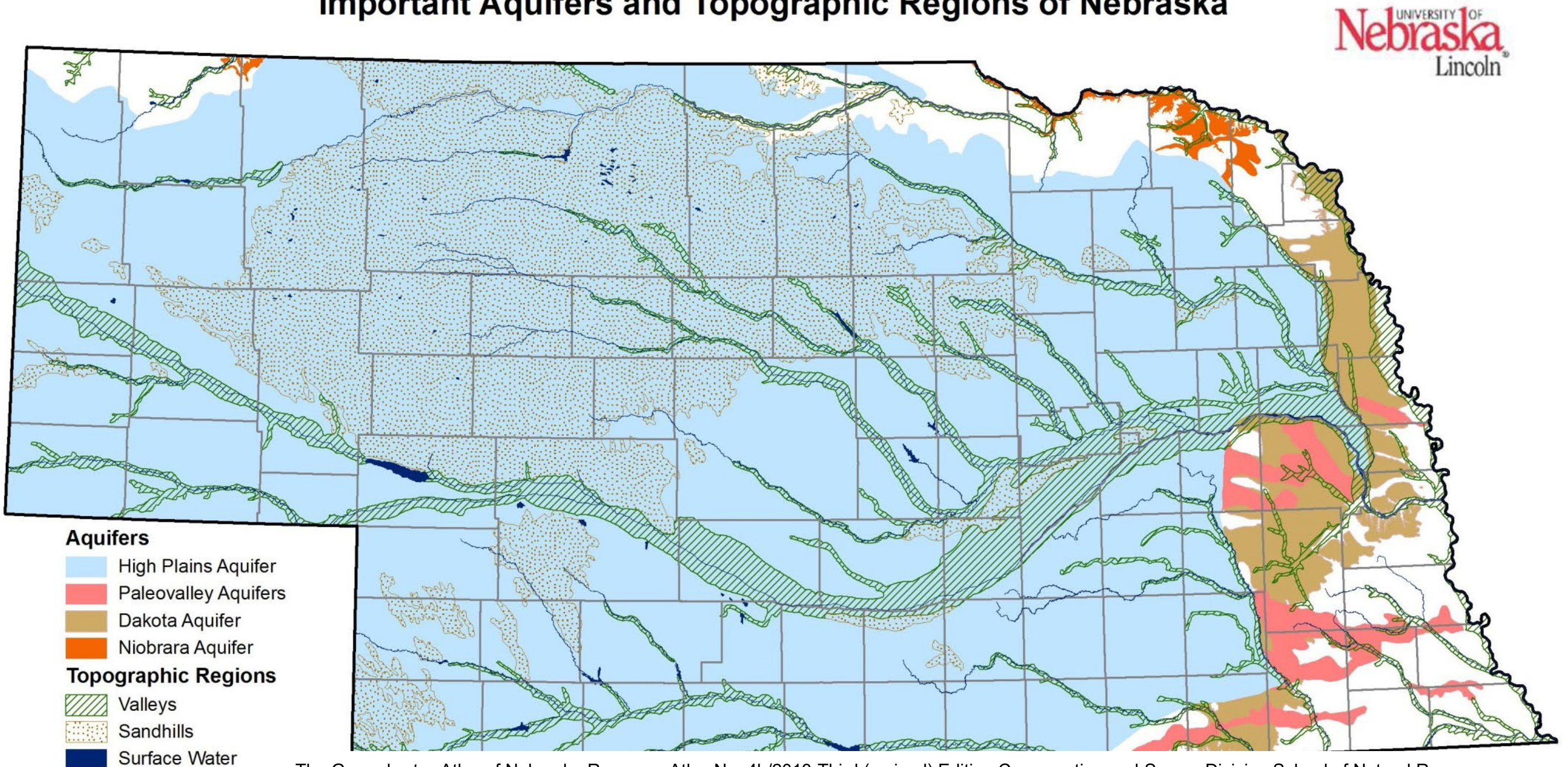
Katie Cameron, P.G.

Eastern Nebraska Water Resources Assessment (ENWRA) Coordinator / CSD Hydrogeologist

ENWRA Recharge Mapping and Focus Area Assessment Project

- Regional Setting Complexities
- ENWRA Overview and Background
  - Test-holes, AEM Surveys, Databases
  - Regional and local AEM interpretation examples
- Recharge Project Highlights
  - USGS Presentation
  - Recharge Potential Map
  - CSD Bedrock, Water Table & Cross Sections
- Website & Report Contacts

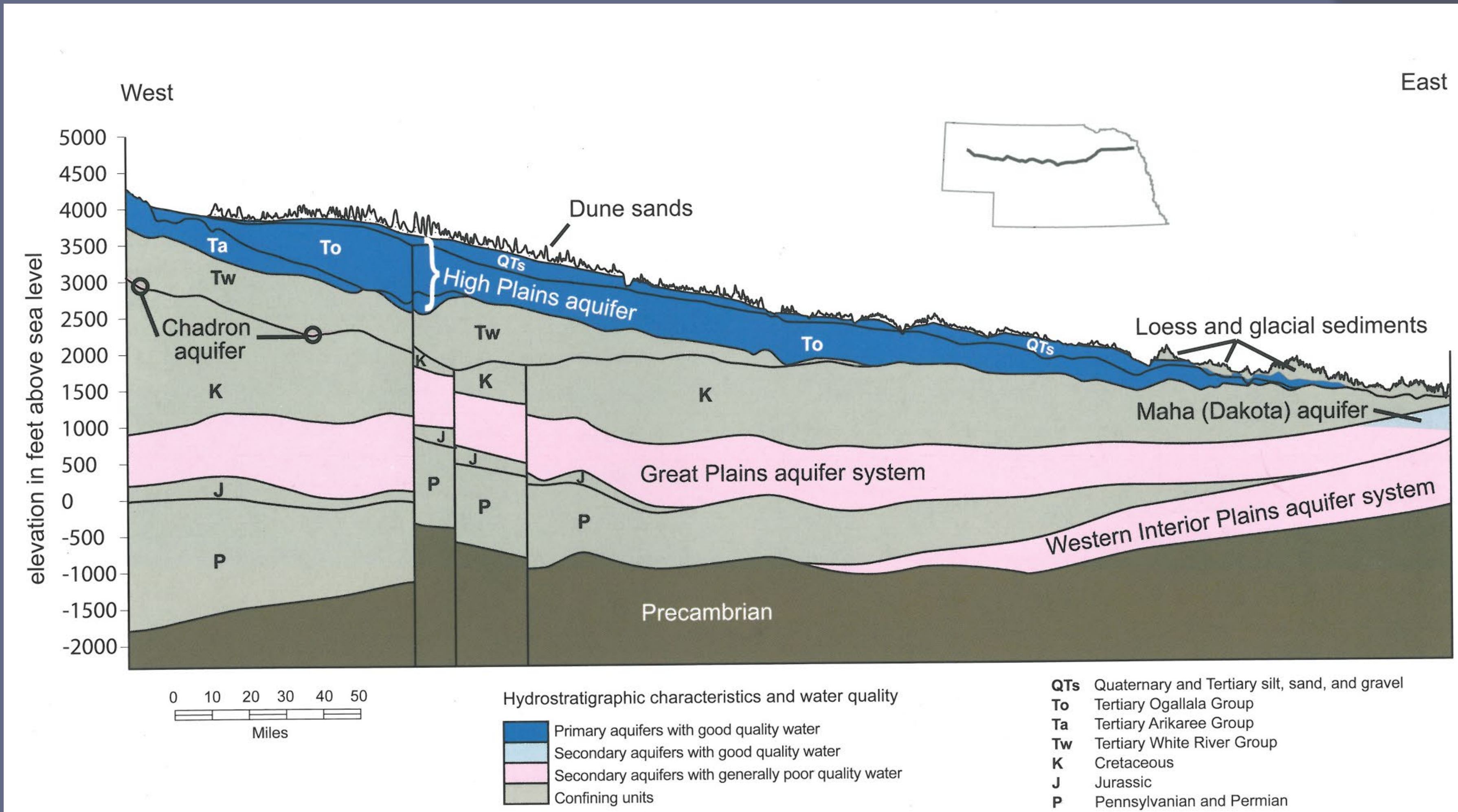
Important Aquifers and Topographic Regions of Nebraska



The Groundwater Atlas of Nebraska Resource Atlas No. 4b/2013 Third (revised) Edition Conservation and Survey Division School of Natural Resources Institute of Agriculture and Natural Resources University of Nebraska - Lincoln

- Groundwater resources are more limited in eastern Nebraska
- Much of the groundwater supply in eastern Nebraska is from aquifers that are within & below glacial deposits
- They can be laterally discontinuous, have highly variable geometry, and are heterogeneous making them very complex to map
- Delineation of these aquifers is critical for management purposes
  - The quantity of water may be limited due to the spatially confined nature of the aquifers
  - Natural water quality varies in different aquifers, human introduced contaminants on the surface (example nitrates) may infiltrate to these aquifers and degrade their water quality

Cross Section Across Nebraska

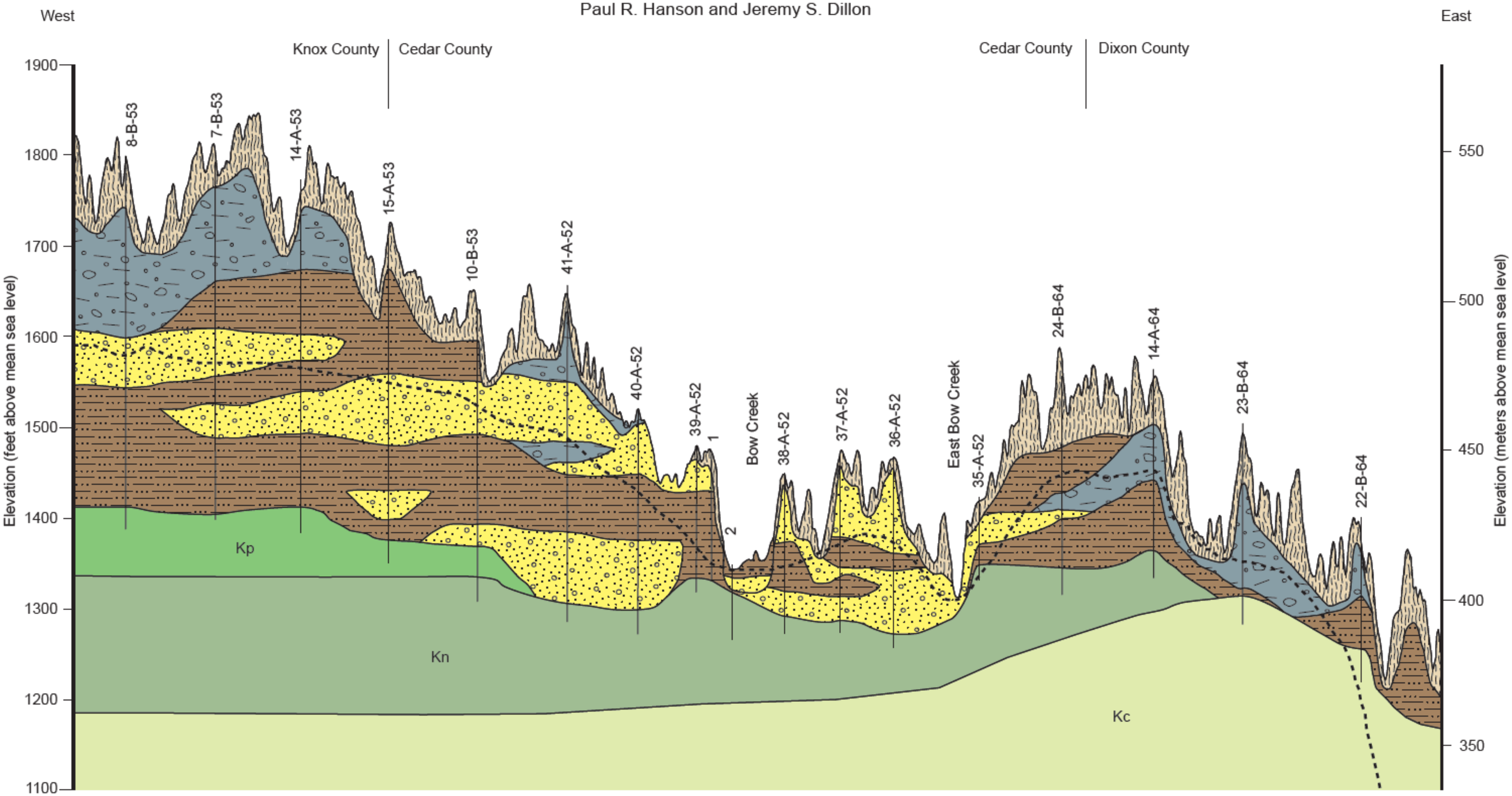


The Groundwater Atlas of Nebraska Resource Atlas No. 4b/2013 Third (revised) Edition Conservation and Survey Division School of Natural Resources Institute of Agriculture and Natural Resources University of Nebraska - Lincoln enwra.org

Open-File Report 109
Conservation and Survey Division

Interpretive Geologic Cross Section from Knox County to Dixon County, Nebraska

Paul R. Hanson and Jeremy S. Dillon



Conservation and Survey Division
School of Natural Resources
University of Nebraska–Lincoln

The University of Nebraska–Lincoln is an equal opportunity educator and employer.

System	Group or Formation
Quaternary	undifferentiated
Cretaceous	Kp Pierre Shale
	Kn Niobrara Formation
	Kc Carlile Shale

water table or potentiometric surface

test hole

lithology of Quaternary deposits

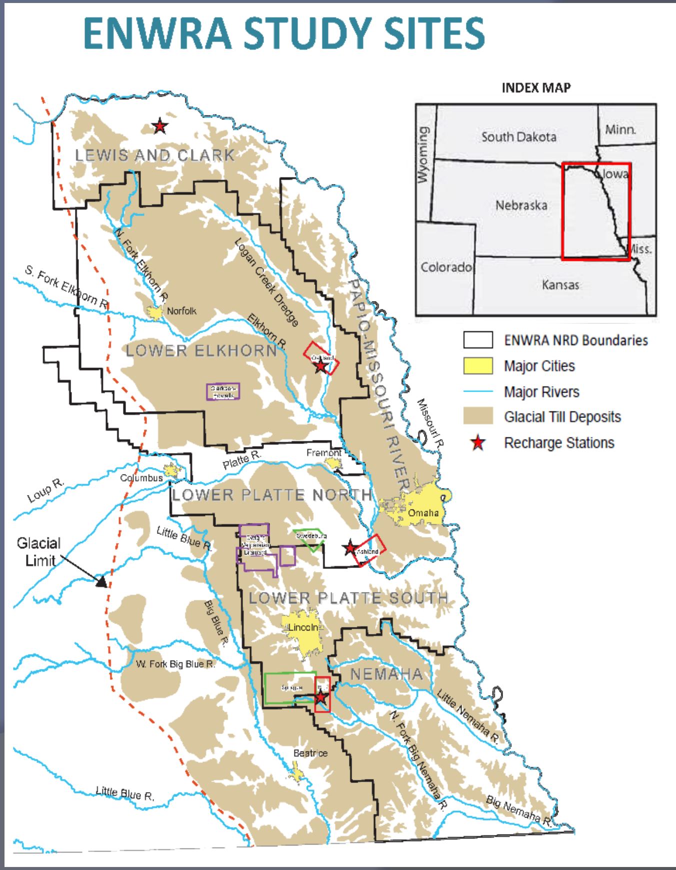
- loess
- silt & clay
- till
- sand & gravel

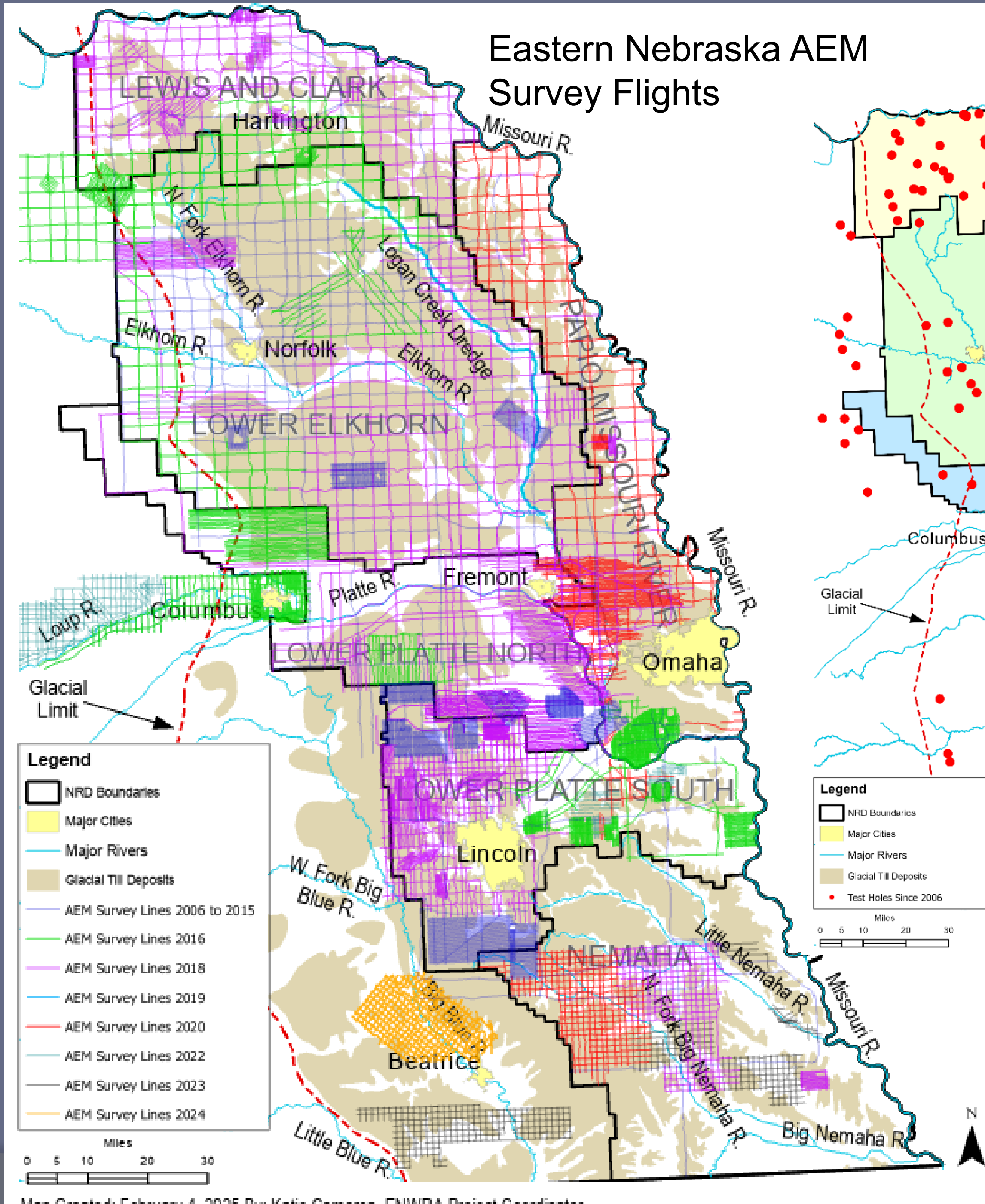
Horizontal Distance (km)
0 10 20 30
0 5 10 15 20
Horizontal Distance (mi)

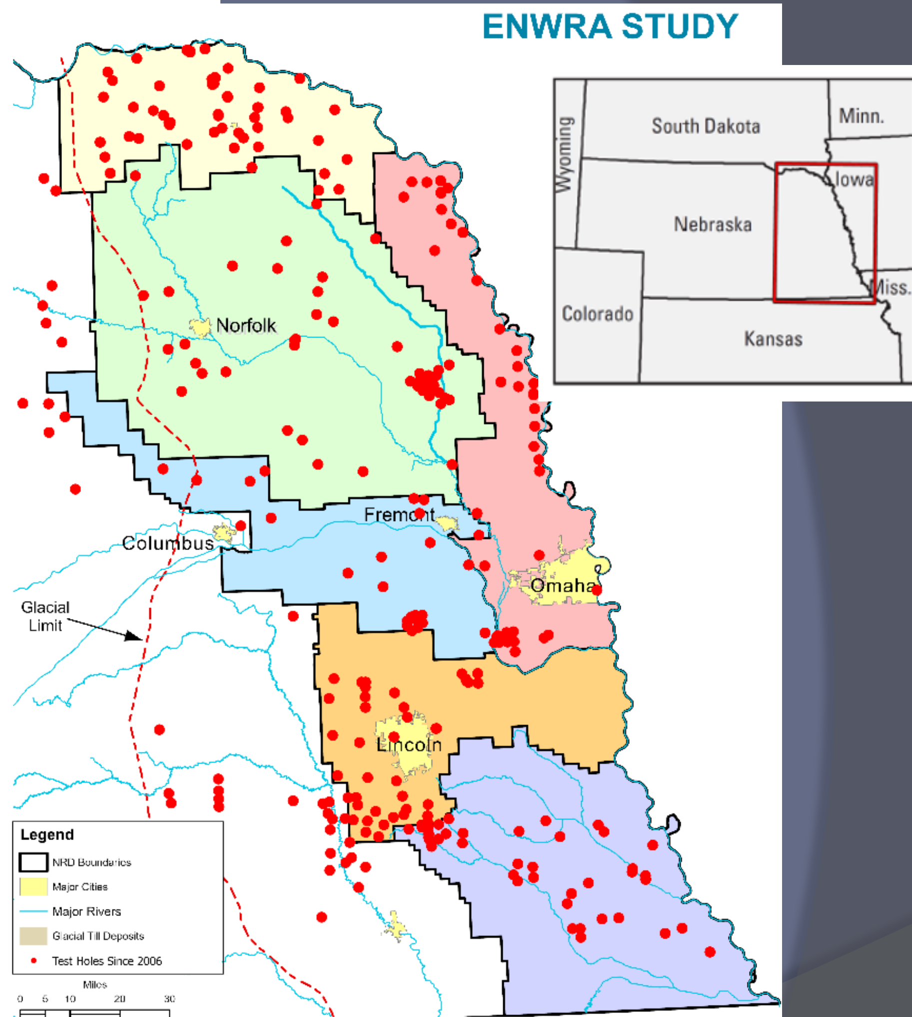
Cite as: Hanson, P.R. and Dillon, J.S., 2012, Interpretive geologic cross section from Knox to Dixon County, Nebraska. Conservation and Survey Division, University of Nebraska–Lincoln. Correlations and Cross Sections (CCS) 18.1.

ENWRA Overview

- ENWRA NRDs: Lewis and Clark, Lower Elkhorn, Papio-Missouri River, Lower Platte North, Lower Platte South (financial handling), and Nemaha
  - NRDs pay dues to the ENWRA account annually
  - Interlocal and Coordinator Agreements renewals every 5 years
- ENWRA Organization:
  - Technical Committee, Managers, and Technical Advisors
- ENWRA Objectives/Long Range Plan
  - Identify location and volume of aquifers
  - Estimate recharge rates
  - Assess gw/sw water interaction
  - Estimate water budgets
  - Characterize water quality concerns
  - Assemble, analyze and distribute data
  - Assess the applicability of new technology





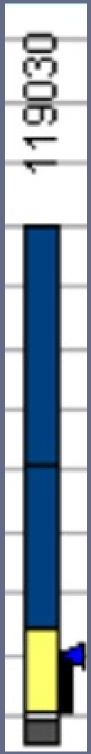


~20,000 line-miles of AEM and over 200 test holes have been drilled across ENWRA since 2006

ENWRA.ORG

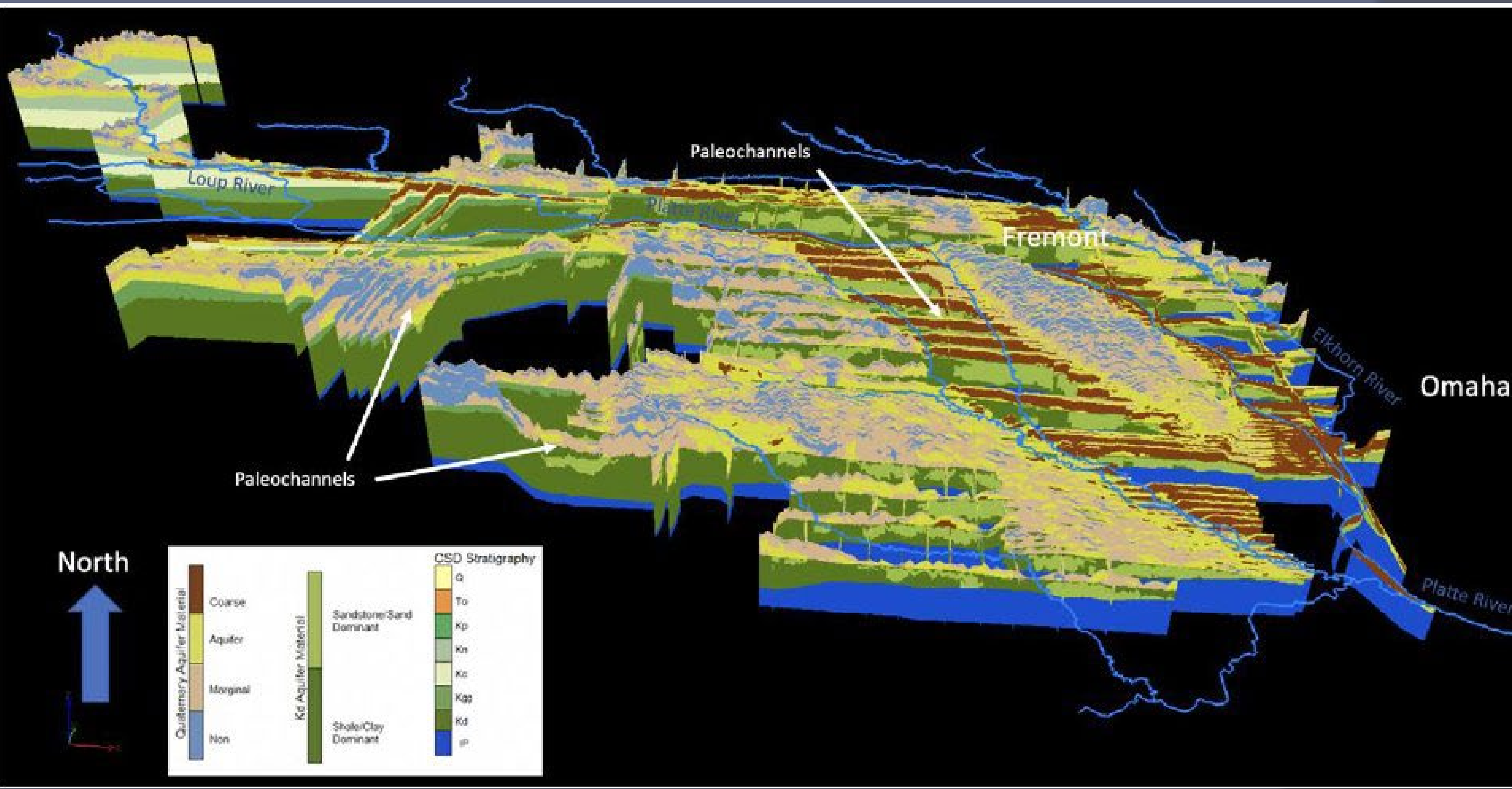
Borehole and Water Data with AEM

- CSD Logs
  - 1,610 - Lithology
  - 678 - Stratigraphy
  - Geophysics
    - 190 E Logs
    - 148 Geo Logs
    - 60 Workbench
- Oil and Gas Wells
  - 88 - Lithology/Stratigraphy
  - 3- Geophysics logs
- NeDNR Reg. Well Logs
  - borehole summary files

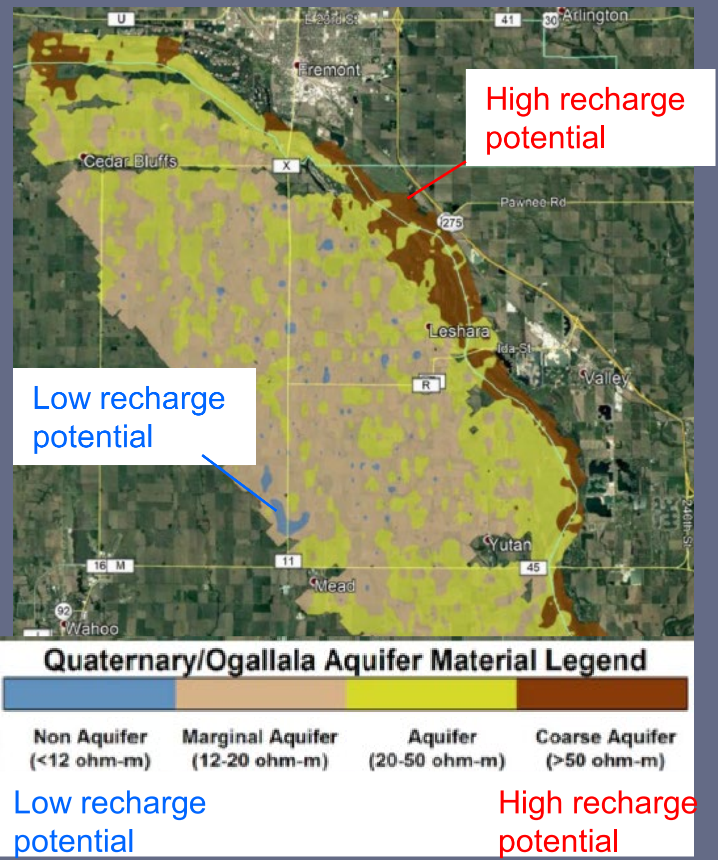


- CSD Cross Sections, Old and New Maps/ Publications, Studies
- CSD 1995 Regional Water Table – newer snapshots
- Monitoring Well Networks updates with newer water levels plus historic and new lab data
- Over 200 CSD test holes have been advanced within ENWRA since 2006

Borehole and Water Data with AEM



AEM-derived recharge potential mapping

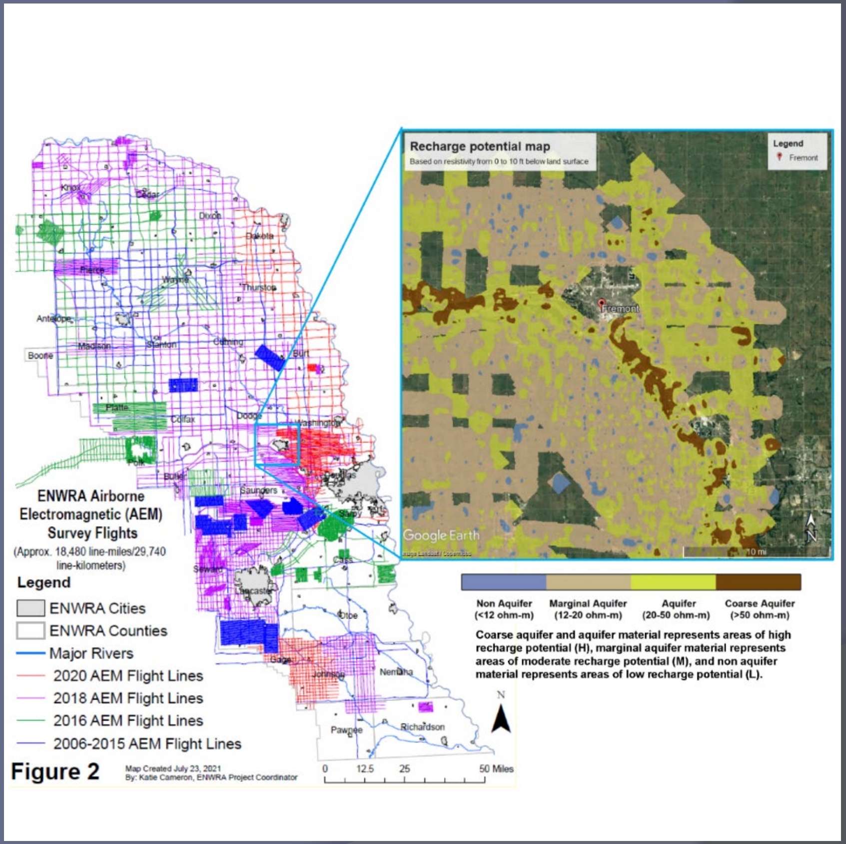


From Abraham and others, 2019

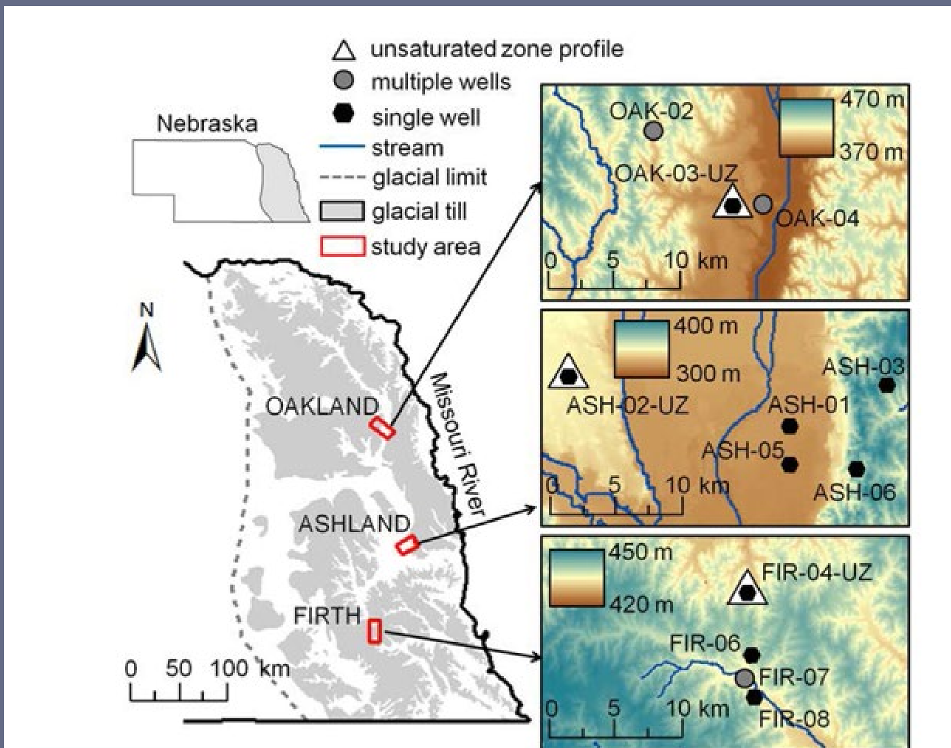
- One derivative product is <u>groundwater recharge potential</u>
- Areas mapped at low, moderate, high, or very high groundwater recharge potential
- Maps created from interpolating the near-surface (upper 10 ft) resistivity value
- Recharge potential maps largely limited to areas along flightlines or block flight areas

Water Sustainability Fund Grant (no. 5312)

- Collaborative effort with the ENWRA NRDs, UNL-CSD and the U.S. Geological Survey
- Phase 1 - focus on the entire ENWRA region deeper than top layer of AEM, quality considerations
- Phase 2 - Focus Area Work
- Phase 3 - Regional Recharge Map update incorporating what learned at Focus Areas – Recommendations

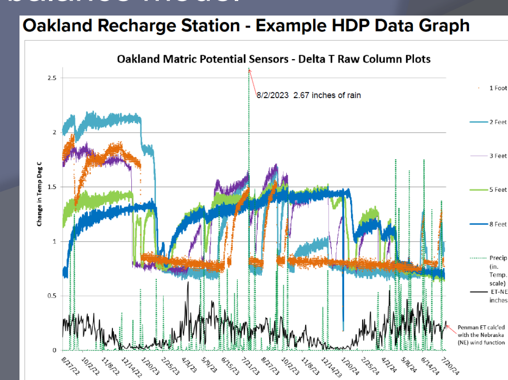


Estimating groundwater recharge in eastern Nebraska



Gates and others, 2014

- One of the primary goals of ENWRA is to improve water budgets
- Groundwater recharge rates were estimated within three pilot areas (Oakland, Firth, and Ashland)
- Recharge rates compared across 3 scales:
  - Nested profile - matric potentials, Cl-, 3H
  - Aquifer – age tracers CFC-12 and SF6
  - Regional – remote sensing-based water balance model



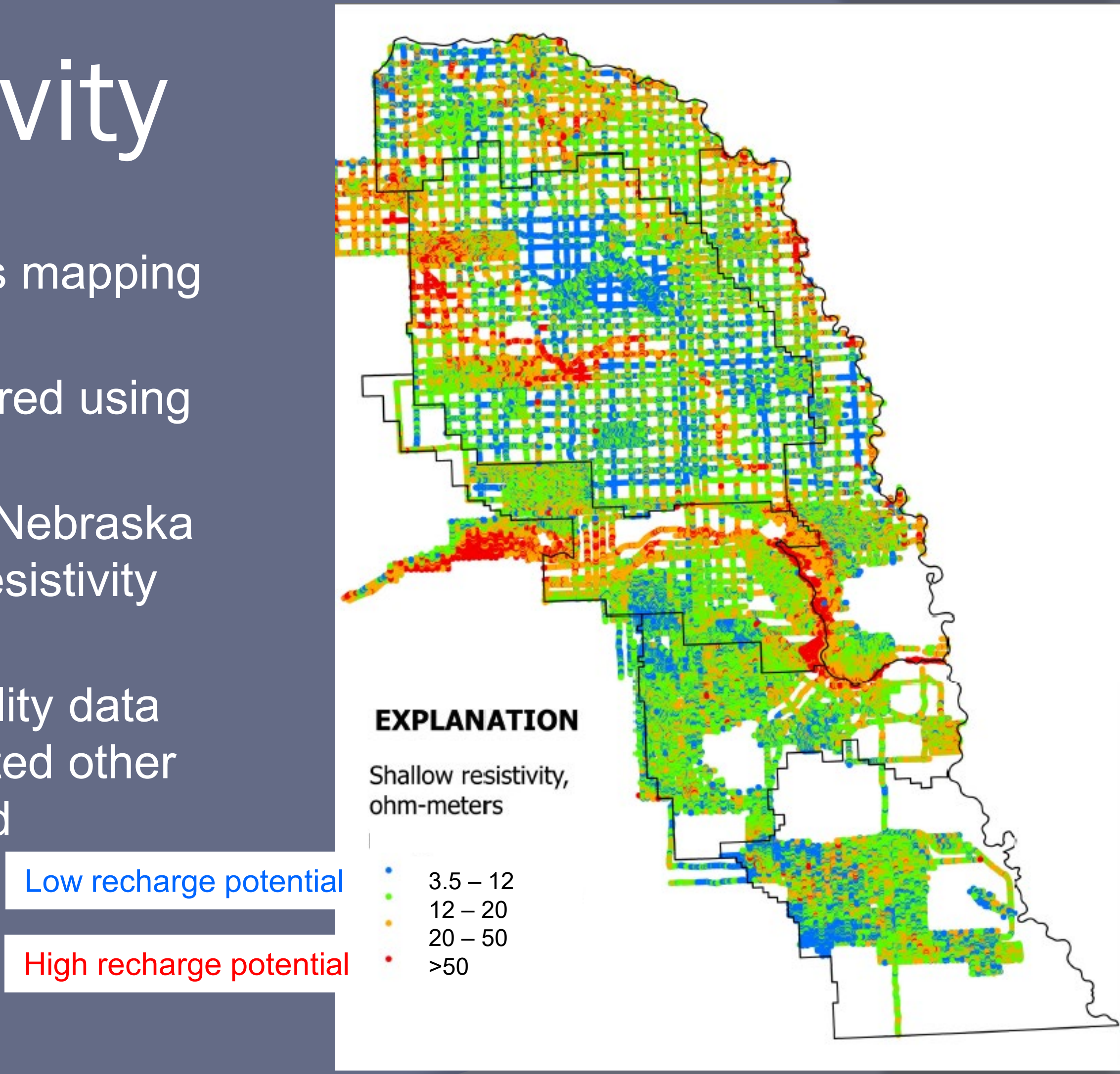
ENWRA recharge study highlights

- Glacial till thickness biggest control on groundwater recharge rates
  - Minimal diffuse recharge in clay-rich uplands
  - More recharge in incised lowlands and river valleys
- Average regional groundwater recharge greater than nested or profile recharge rates
  - Nested profile and aquifer scale ranged 0-1.7 in/yr
  - Regional recharge 2.3 in/yr across study area using water balance model
- Comparison of scaled recharge estimates suggests:
  - Diffuse recharge accounts for 60% of total recharge
  - 40% of recharge is “focused” through preferential flow conduits or local lowlands receiving overland flow

USGS

Shallow resistivity

- Method used in previous studies mapping groundwater recharge potential
- Glacial till thickness not considered using shallow-resistivity approach
- Downloaded all AEM data from Nebraska Geocloud and plotted shallow resistivity values
- Initial comparisons to water-quality data and recharge estimates suggested other approaches should be examined



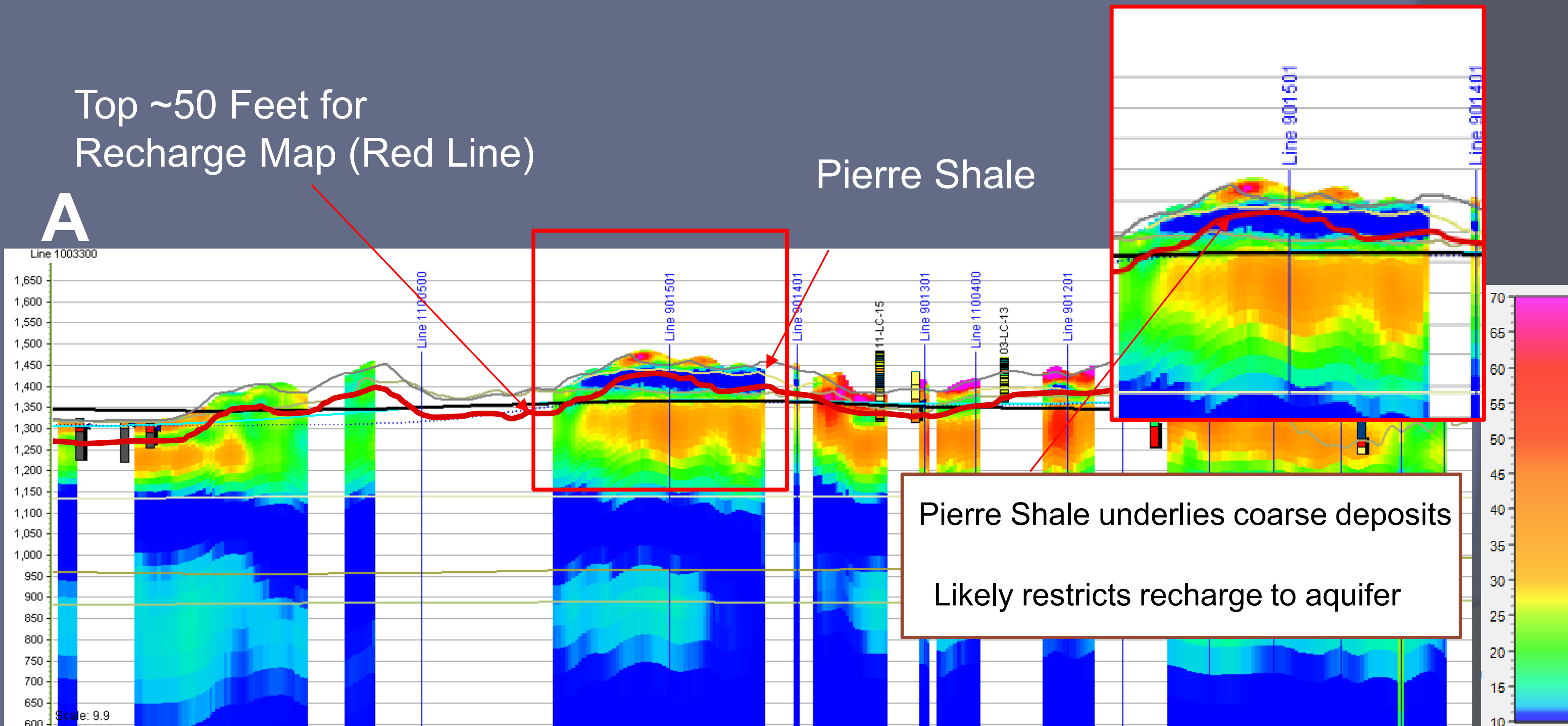
USGS

Mapping recharge with near-surface resistivity

Top ~50 Feet for Recharge Map (Red Line)

Pierre Shale

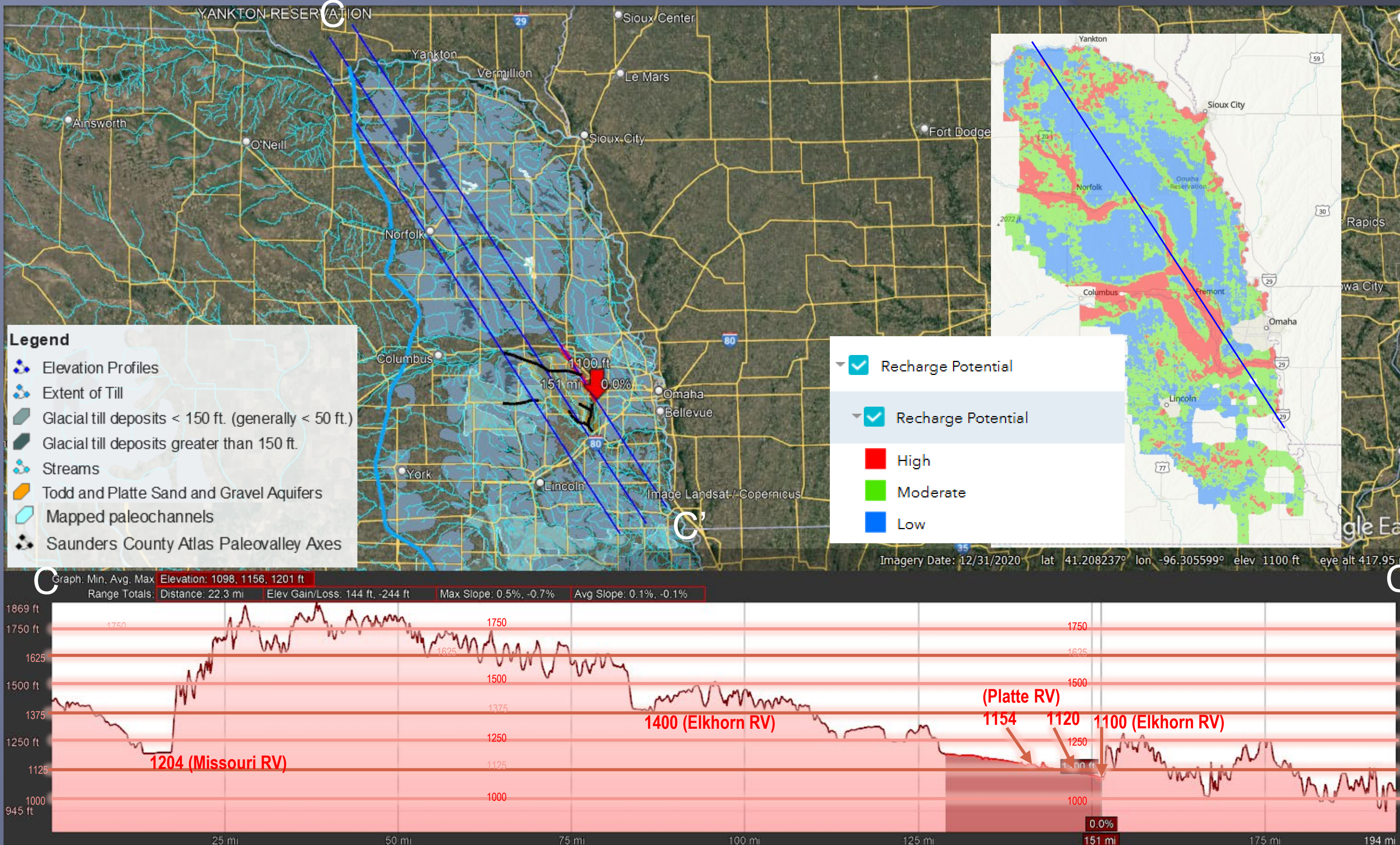
A



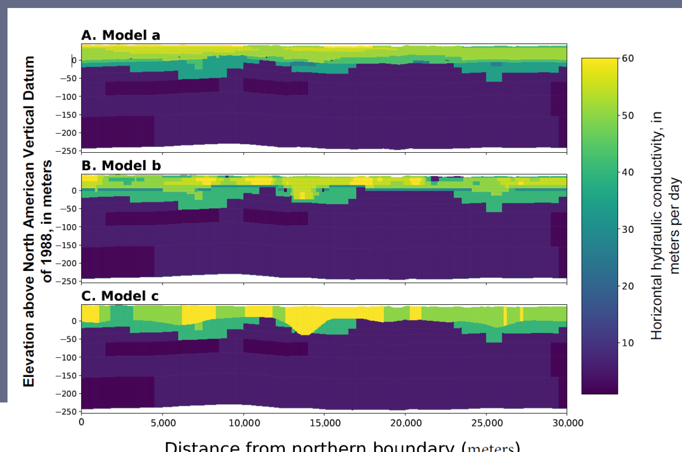
Preliminary Information-Subject to Revision. Not for Citation or Distribution

USGS

GOOGLE EARTH – PROFILES & RECHARGE



Alternate approaches considered - VIC



communications earth & environment

ARTICLE

https://doi.org/10.1038/s43247-021-00200-z OPEN

Check for updates

Airborne geophysical surveys of the lower Mississippi Valley demonstrate system-scale mapping of subsurface architecture

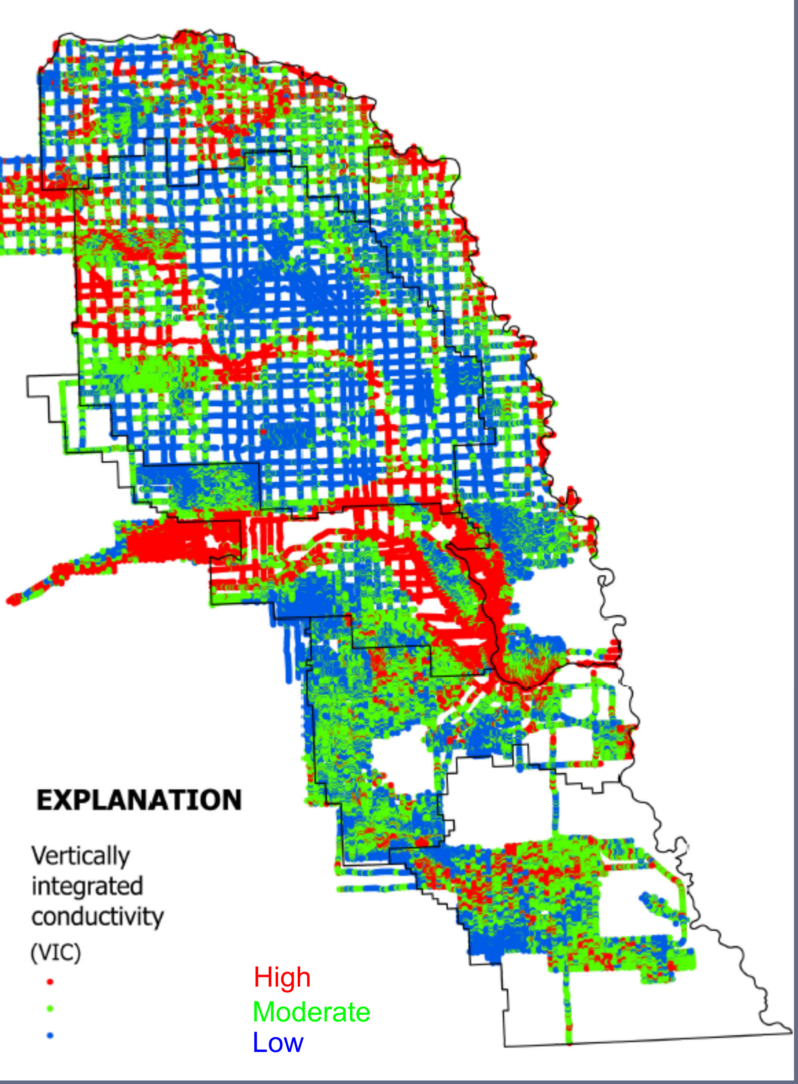
Burke J. Minsley[1✉], J. R. Rigby[2], Stephanie R. James[1], Bethany L. Burton[1], Katherine J. Knierim[3], Michael D. M. Pace[1], Paul A. Bedrosian[1] & Wade H. Kress[4]

The Mississippi Alluvial Plain hosts one of the most prolific shallow aquifer systems in the United States but is experiencing chronic groundwater decline. The Reelfoot rift and New Madrid seismic zone underlie the region and represent an important and poorly understood seismic hazard. Despite its societal and economic importance, the shallow subsurface architecture has not been mapped with the spatial resolution needed for effective management. Here, we present airborne electromagnetic, magnetic, and radiometric observations, measured over more than 43,000 flight-line-kilometers, which collectively provide a system-scale snapshot of the entire region. We develop detailed maps of aquifer connectivity and shallow geologic structure, infer relationships between structure and groundwater age, and identify previously unseen paleochannels and shallow fault structures. This dataset demonstrates how regional-scale airborne geophysics can close a scale gap in Earth observation by providing observational data at suitable scales and resolutions to improve our understanding of subsurface structures.

- Vertically integrated conductivity (VIC) approach first used and developed for 43,000 line-km of Mississippi Alluvial aquifer
  - metric analogous to groundwater recharge potential

$$VIC = \sum_{i=1}^{n} \frac{t_i}{\rho_i}$$

  - Conductance is summed for each layer to the top 15 m (or bottom of next deepest row)
- Use of VIC as a metric for surface connectivity improved groundwater model calibration (Guira and others, 2025 *in press*)



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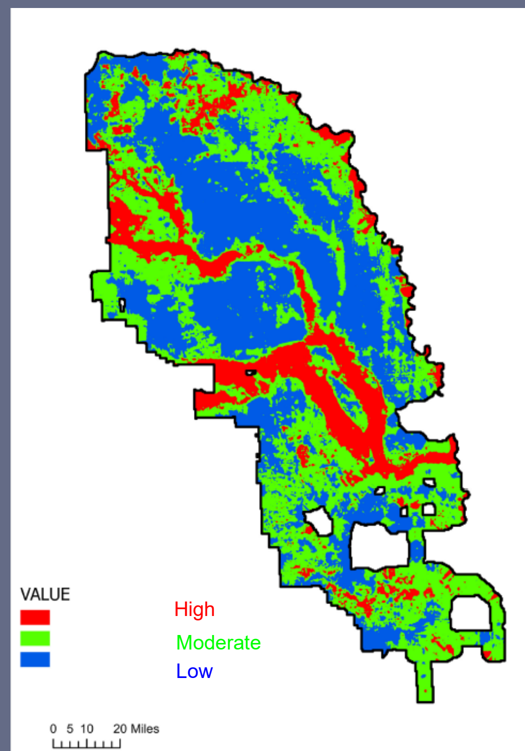
Raw Vertically Integrated Conductivity (VIC) values

- VIC values translated to groundwater recharge potential (high, moderate, and low) using resistivity ranges provided by contractor AEM reports
- Major geologic features (Platte Valley, Todd Valley, near-surface sands, thick till areas) are well mapped
- Improved definition of geologic features over the near-surface resistivity
- Considers glacial till thickness, which is a major control on recharge (Gates and others, 2014)

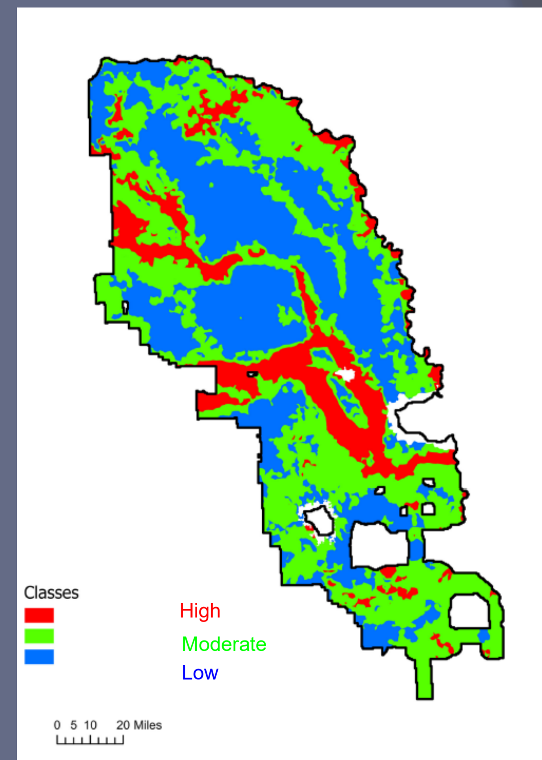
USGS

Comparing raster output vs. polygon shapefile

- Interpolated using ArcGIS Pro Geostatistical Analyst
- Produced 2 interpolations: 500-m cell raster and filled contour shapefile
- Both versions of groundwater recharge potential maps further evaluated

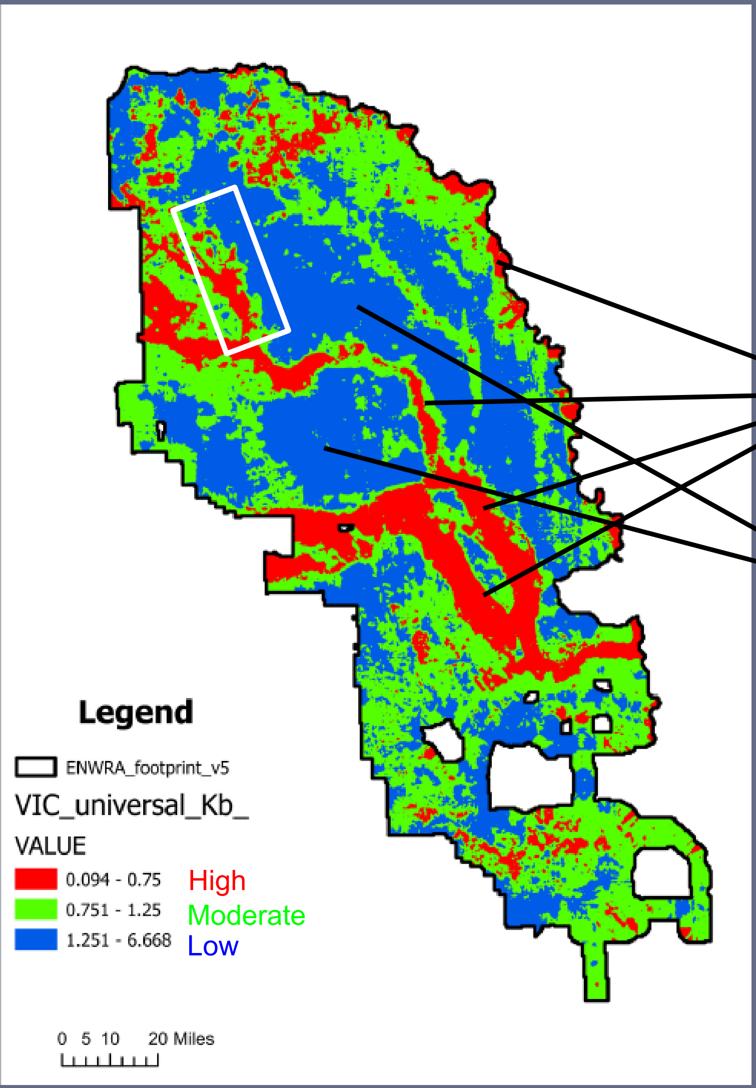


Raster



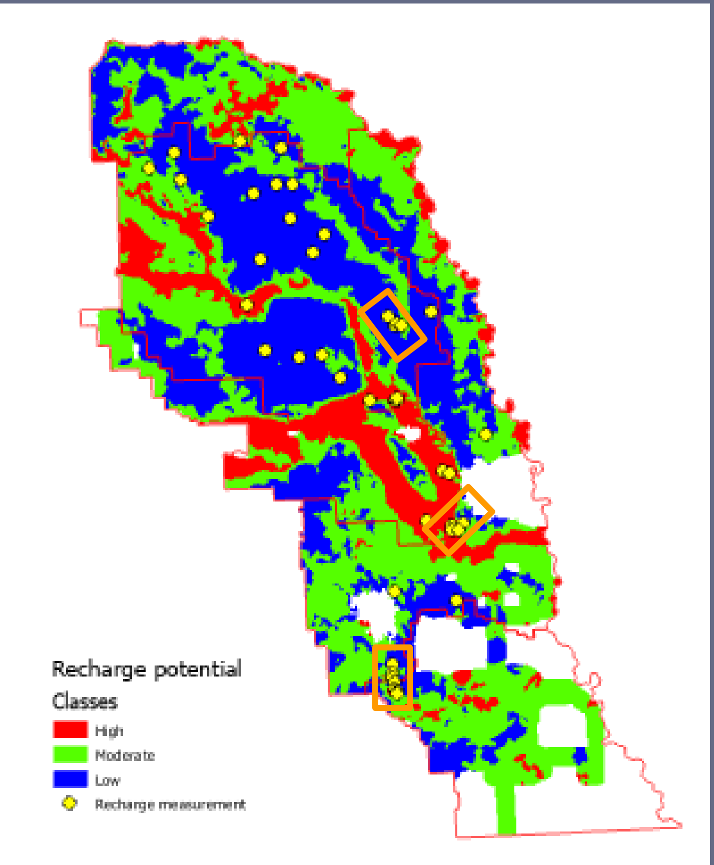
Filled-contour

Comparison to geologic features



- High recharge potential areas delineated within alluvial valleys of major river systems (Platte, Elkhorn, Missouri River) and Todd Valley
- Low recharge potential areas mapped where fine-grained glacial till caps upland areas
- Mapped high recharge potential till-covered areas along principal till margins, discussed in Korus and Abraham (2021)

Comparison to recharge measurements



- Estimates from pilot sites (Oakland, Firth, and Ashland) from Gates and others, 2014
- Additional measurements using age tracer and water-level data
  - USGS Ag land use study
  - USGS Maple Creek Flow Path study
  - PMRNRD groundwater monitoring
  - LWS well field monitoring
  - Unpublished water-level change work from 2017
- 46 recharge estimates across ENWRA area

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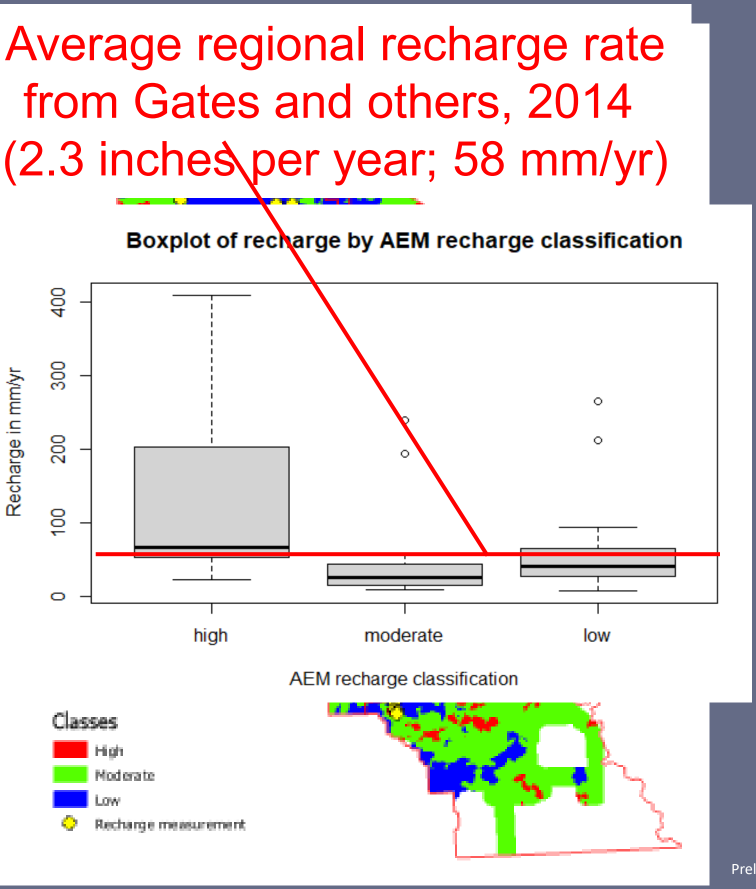
Comparison to recharge measurements



- More generalized filled contour version of groundwater recharge potential map better compared well with measured groundwater recharge rates
  - Statistically significant differences of distributions of groundwater recharge rates mapped using filled contour version (p=0.03)
  - Not statistically significant difference in recharge rates using more detailed raster version of groundwater recharge potential map (p=0.2)

USGS

Comparison to selected water-quality data

Welcome to the new Water Quality Portal

The Water Quality Portal (WQP) is the premiere source of discrete water-quality data in the United States and beyond. This cooperative service integrates publicly available water-quality data from the United States Geological Survey (USGS), the Environmental Protection Agency (EPA), and over 400 state, federal, tribal, and local agencies. Learn More

To download data complete the query below. Returning and experienced users may wish to use the Advanced Download.

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Basic | Advanced

Download Water Quality Data

1 of 3 **Location Parameters**

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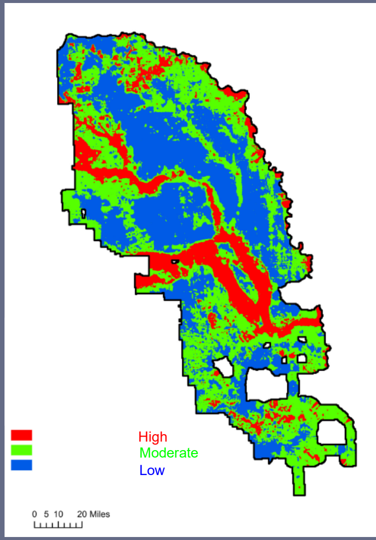
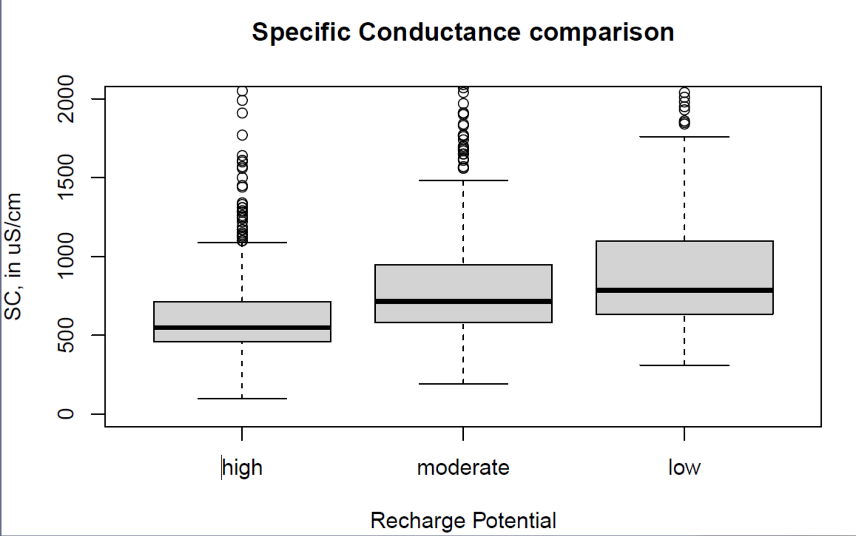
- Aggregated and compared water-quality data, tritium, and pesticide detections to areas mapped as low, moderate, and high groundwater recharge potential
- Compared sample concentration distributions for areas mapped as high, moderate, low using Kruskal-Wallis test and Kendall's Tau (raster version only)
- Statistical comparisons highlighted important differences in water-quality between areas covered by glacial till vs. areas where till was absent

Example comparison and statistical evaluation

- Specific conductance is a field parameter typically collected in the field during sampling and is a proportional to the amount of dissolved ions in groundwater
- Groundwater typically 500 to 1,500 uS/cm whereas precipitation is around 8 uS/cm
- High recharge areas show lower specific conductance, indicates replenishment from low specific conductance precipitation





Specific conductance data greater than 2,000 uS/cm not shown

$p = 2.2\ e^{-16}$

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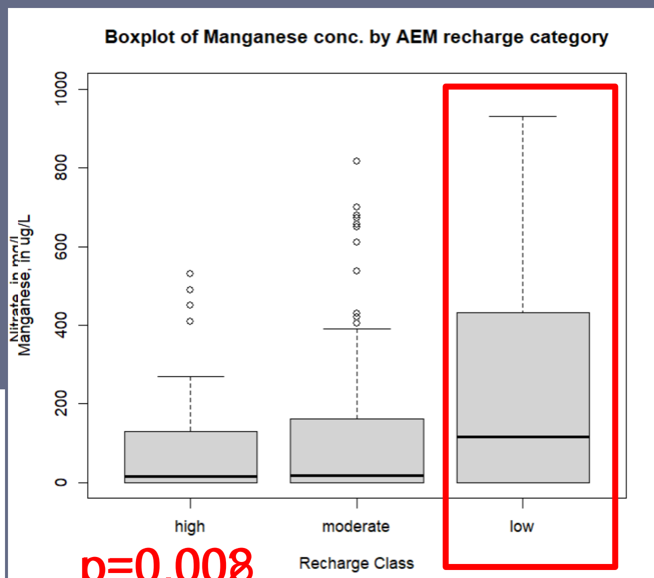
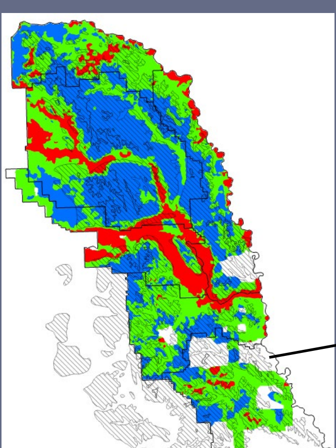
Groundwater recharge potential and water-quality





Glacial till

- Till-covered areas mapped as Low recharge potential
  - Significantly lower nitrate and dissolved oxygen compared to high or moderate recharge potential areas
  - Significantly higher specific conductance, manganese, and iron
  - Suggests areas covered with fine-grained till (recharge restricted areas), results in different geochemistry and water-quality compared to other areas

Assumptions and limitations

- Recharge potential is not the same as groundwater recharge
  - AEM-derived maps predominantly influenced by sediment texture
  - Groundwater recharge affected by land use, precipitation rates, etc.
  - Field study from CPNRD (non-glaciated) indicated land use was major control on recharge rates (Steele and others, 2014)
- Limited number of field measured groundwater recharge rates with spotty spatial distribution
- Maps provided cannot be scaled to recharge measurements, but can be first or approximation of groundwater recharge rates

Summary and conclusions

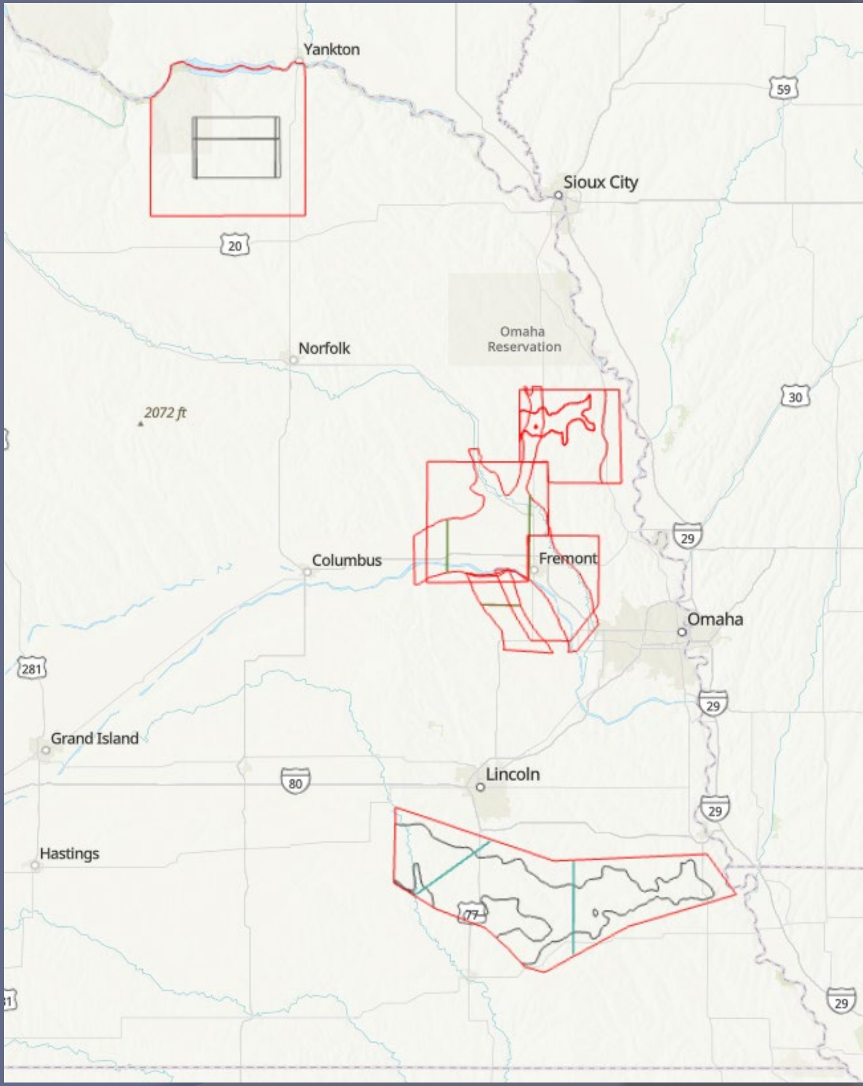
- AEM-derived groundwater recharge potential maps created using vertically integrated conductivity provide an accurate picture of groundwater recharge potential and groundwater vulnerability
- Comparisons indicate AEM-derived recharge potential maps could be used to examine differences in water-quality and geochemistry across ENWRA area
- Presented work further reinforces major findings from Gates and others (2014), glacial till appears to be major control on recharge and in turn, groundwater quality and geochemistry

USGS

Focus Areas: Locations and Methods

Maps created:

- Bedrock elevation surface
  - Test holes/down hole geophysics
  - AEM data
  - DNR registered well data
- Water table elevation surface
  - CSD Water Level database
    - Spring 2021 measurements
  - USGS NWIS data
  - Non-reported NRD water level data/DNR registered well data
- Saturated thickness
  - Calculated by subtracting the bedrock elevation from the water table elevation

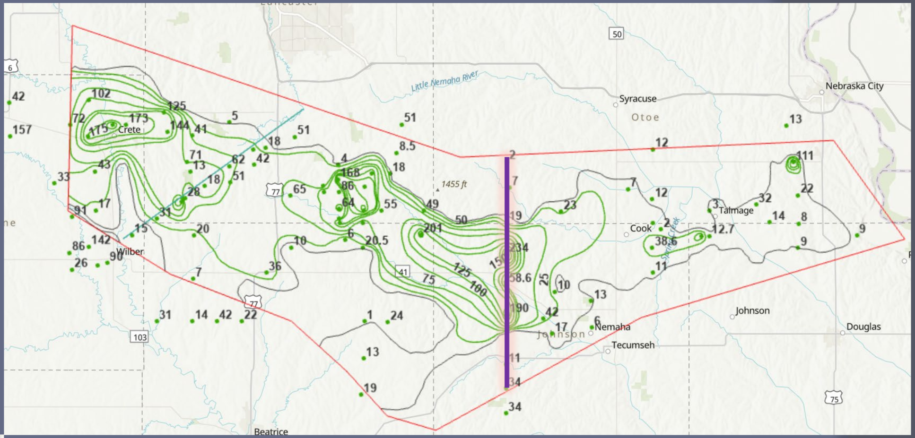


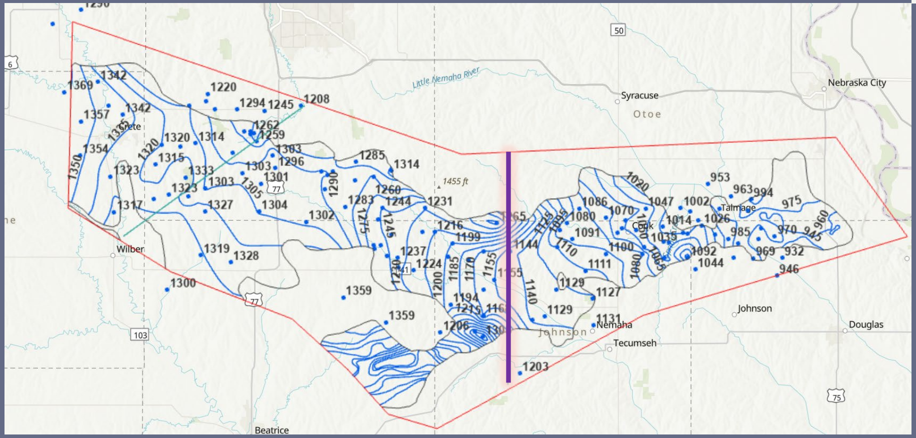
Conservation and Survey Division
132 YRS
CSD
1893-2025
Studying Nebraska and Serving Nebraskans for 132 years

Focus Areas: Dorchester-Sterling Paleovalley

Saturated thickness:

- Saturated thickness ranges from <10 ft to more than 225 feet
- Saturated sediments are generally sand to coarse sand and gravel
- >25 feet of saturated thickness will generally support an irrigation well
- Thickest area of saturated sediments currently supports 2-4 wells per square mile

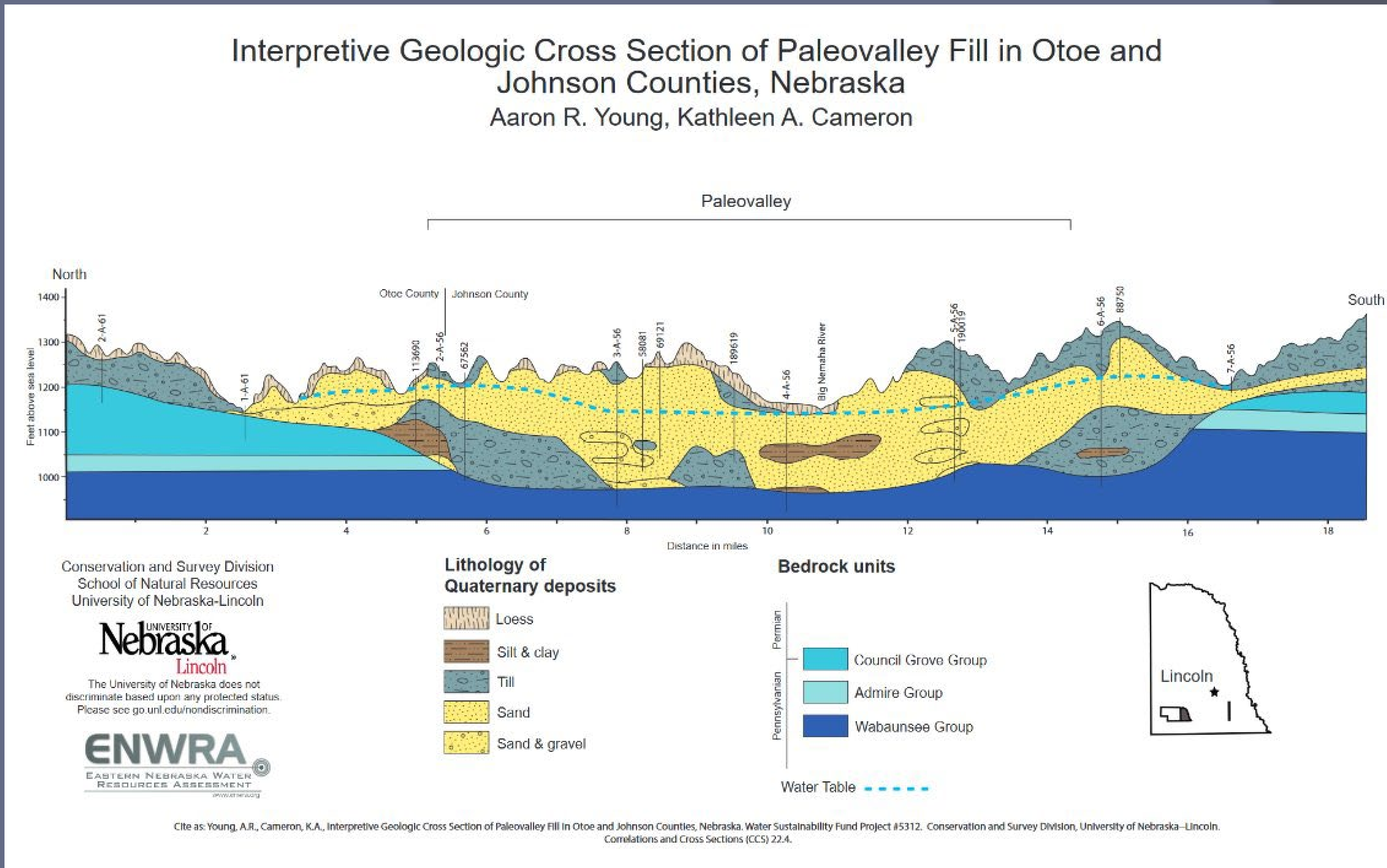




Water table elevation:

- Elevation slopes from about 1370 ft in the west to 960 feet in the east
- Direction of flow generally follows the deepest portion of the paleo channel
- Improves on the 1995 WT map

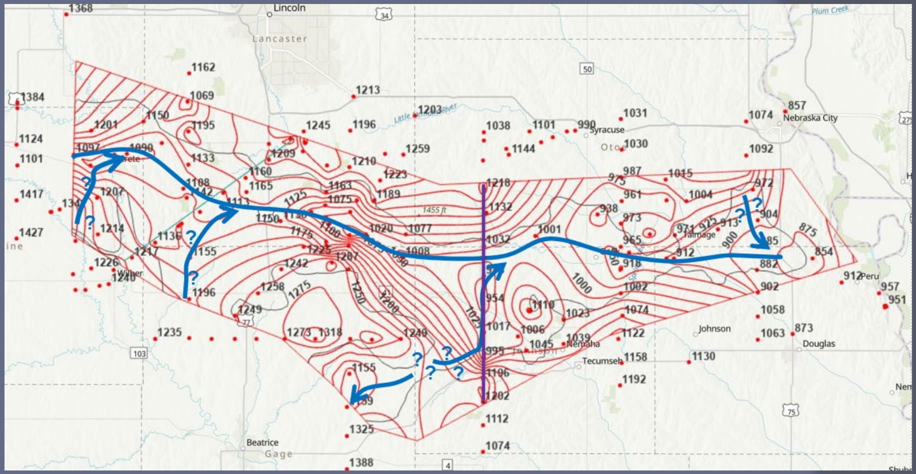
Dorchester-Sterling Paleovalley

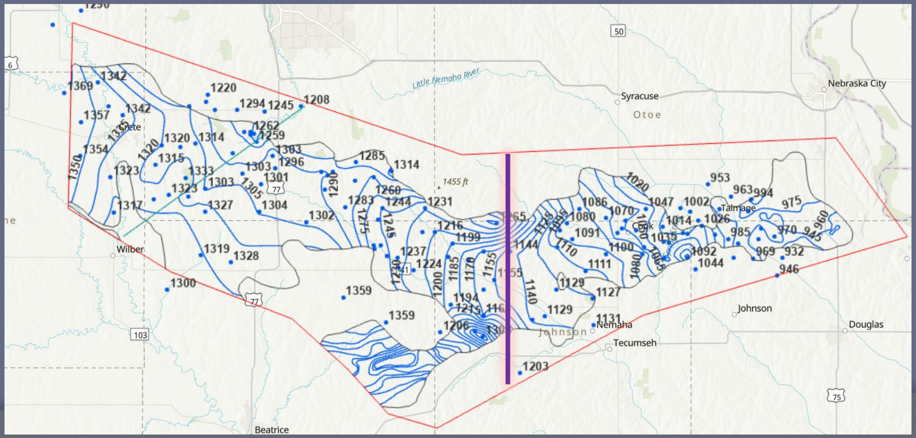


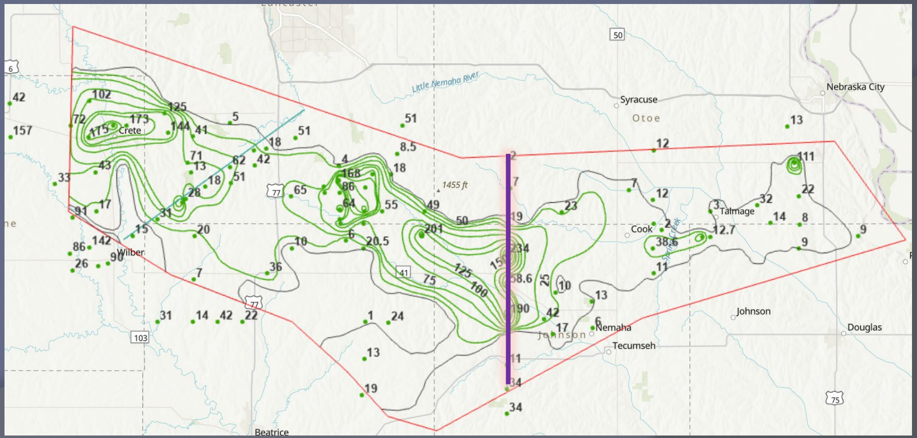
Focus Areas: Dorchester-Sterling Paleovalley

Future studies needed:

- Additional test holes and AEM data
  - Southern side channels are poorly understood
    - In particular, possible connections to other paleochannels are not clear
  - Mapping areas of little or no saturated thickness

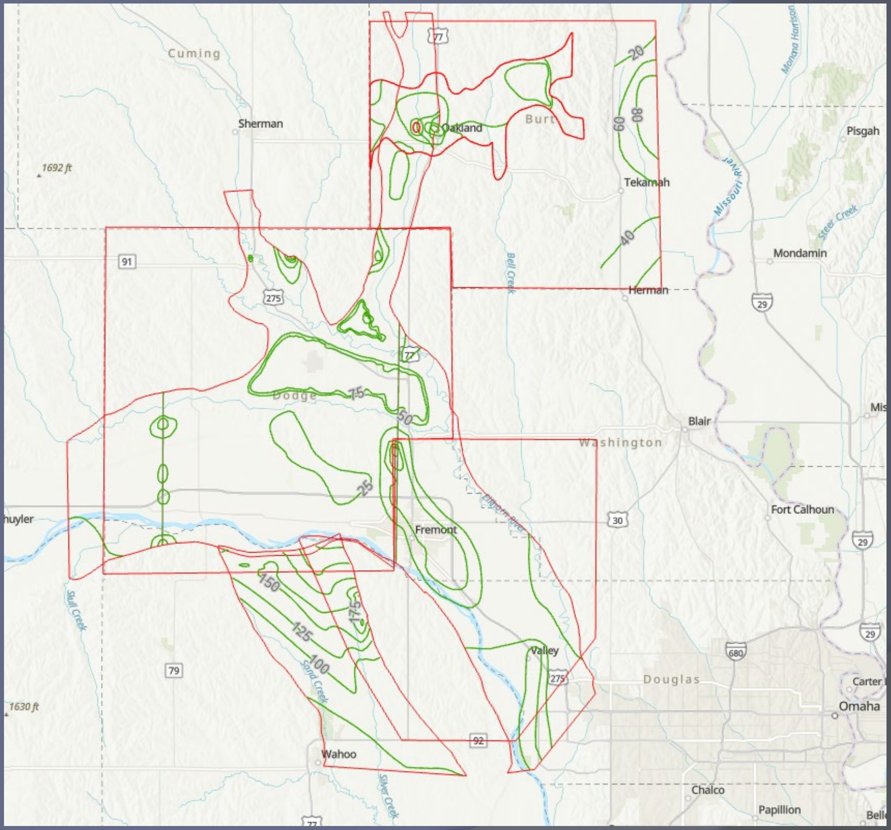






Focus Areas: Burt, Dodge, Fremont-Arlington-Leshara Water Table and Saturated Thicknesses

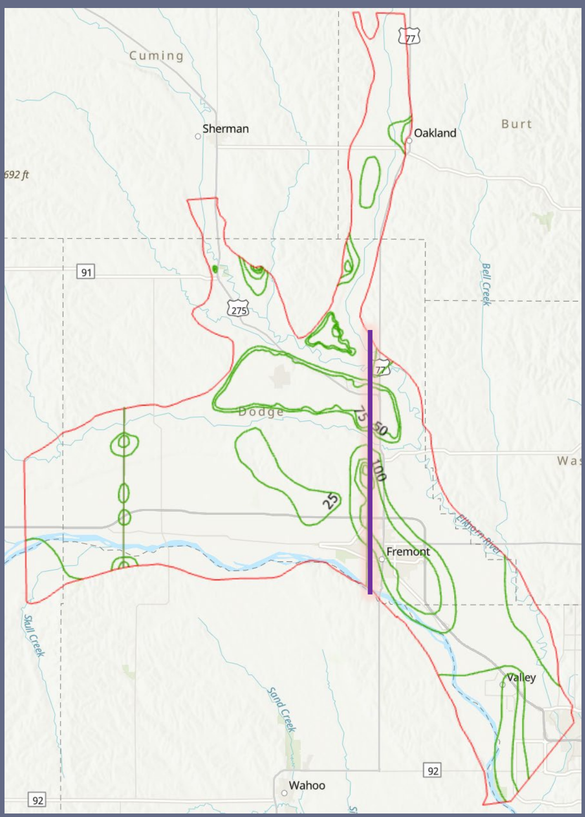
- Water table elevation surface
  - CSD Water Level database
    - Spring 2021 measurements
- Saturated thickness
  - Calculated by subtracting the bedrock elevation from the water table elevation



Additional work needed:

- Additional test holes needed in the Fremont area to properly differentiate between alluvium and Dakota
- Additional observation wells or annual water level readings in the uplands between the Elkhorn and Platte Rivers
- Reporting maps for the Missouri River Valley and Fremont area

Focus Areas: Alluvial Valleys

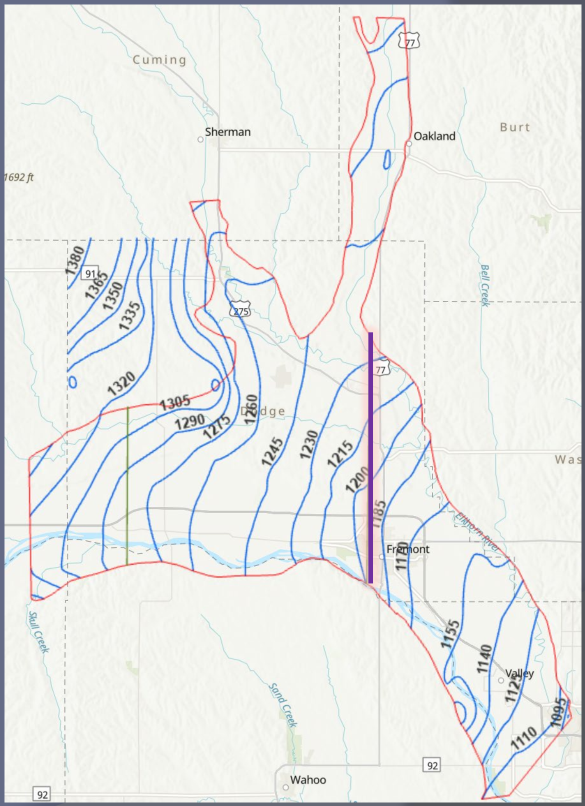


Saturated thickness:

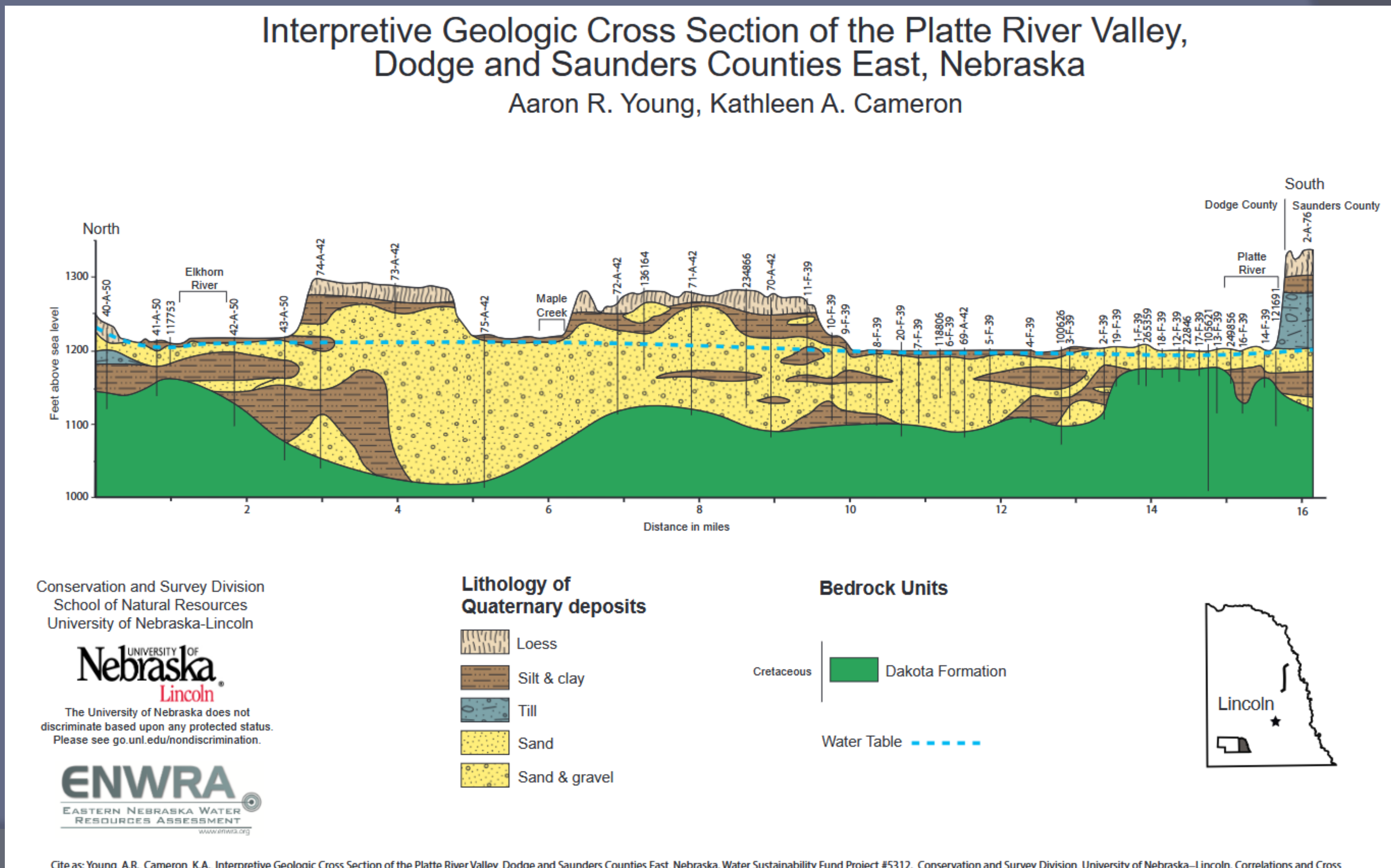
- Saturated thickness ranges from about <20 ft to more than 150 feet, average 50 ft.
- Saturated sediments consist of fine sand to coarse gravel
- Thickest area of saturated sediments currently supports 2-10+ wells per square mile
- Despite heavy pumping, long-term groundwater level changes are minimal

Water table elevation:

- Elevation slopes from about 1350 ft in the northwest to 1100 feet in the east



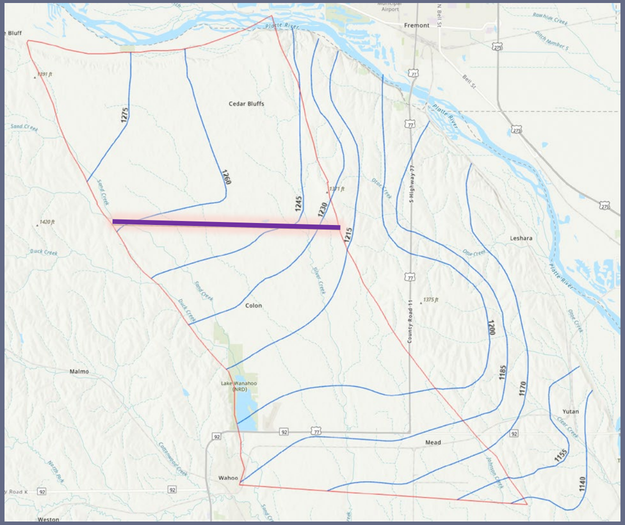
Focus Areas: Dodge Co. Cross Section

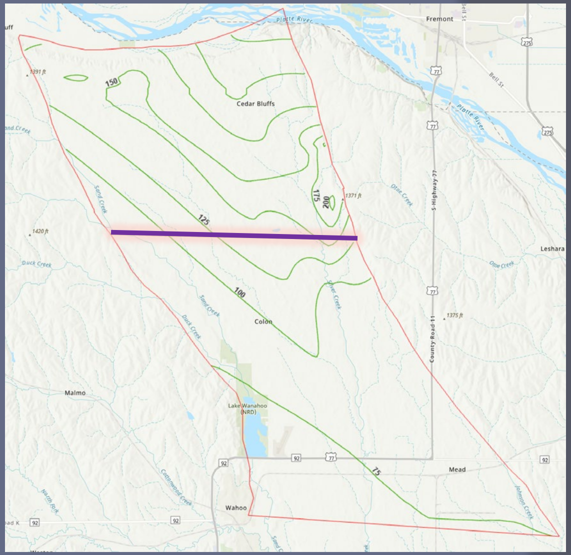


Focus Areas: Todd Valley

Saturated thickness:

- Saturated thickness ranges from about 50 ft to more than 200 feet
- Saturated sediments are eolian sand over coarse sand and gravel
- Thickest area of saturated sediments supports 2-4+ wells per square mile
- Despite heavy pumping, long-term groundwater level changes are minimal

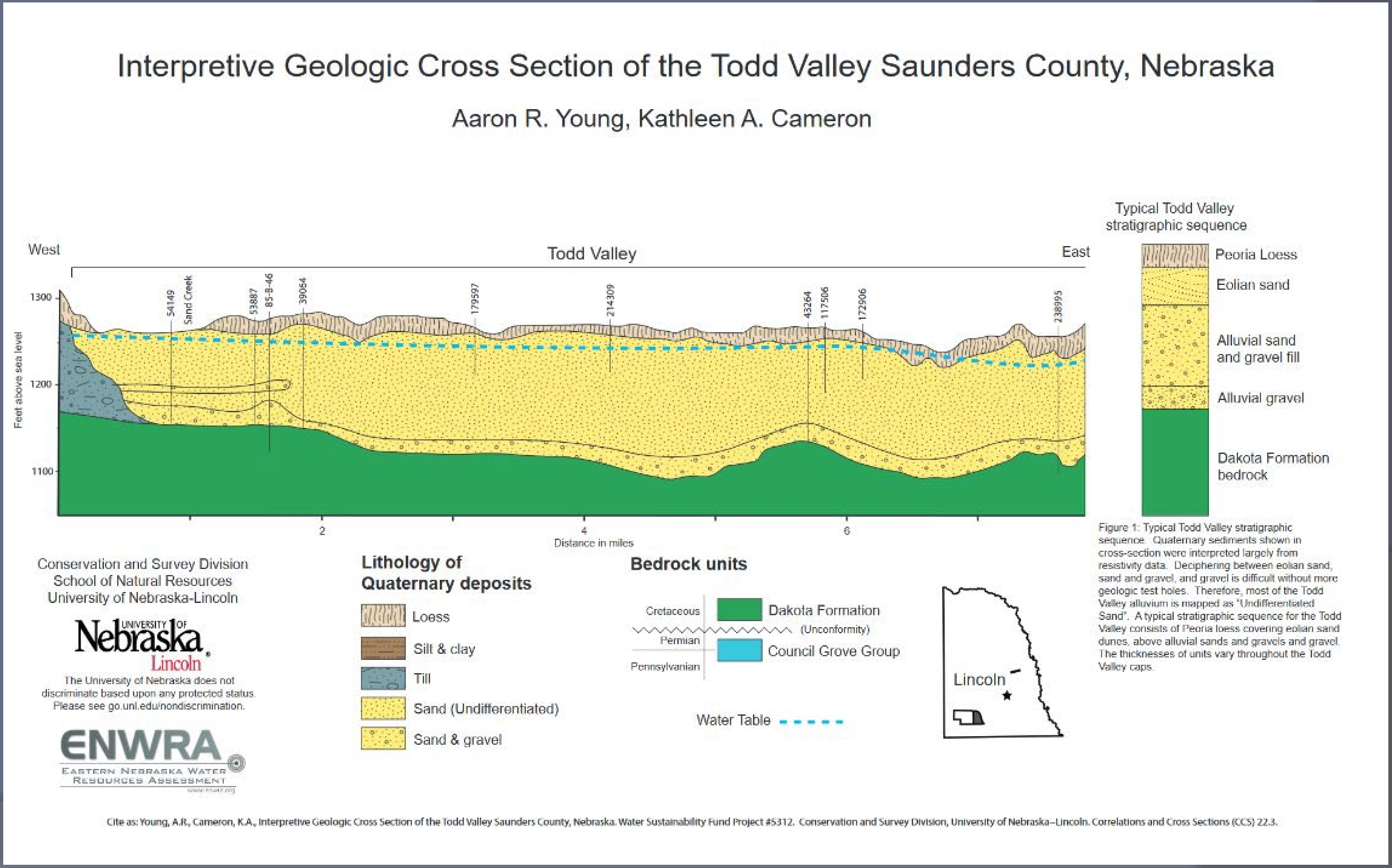




Water table elevation:

- Elevation slopes from about 1275 ft in the northwest to 1140 feet in the east
- Saturated sediments may extend under the uplands to the east extending to the Platte River.

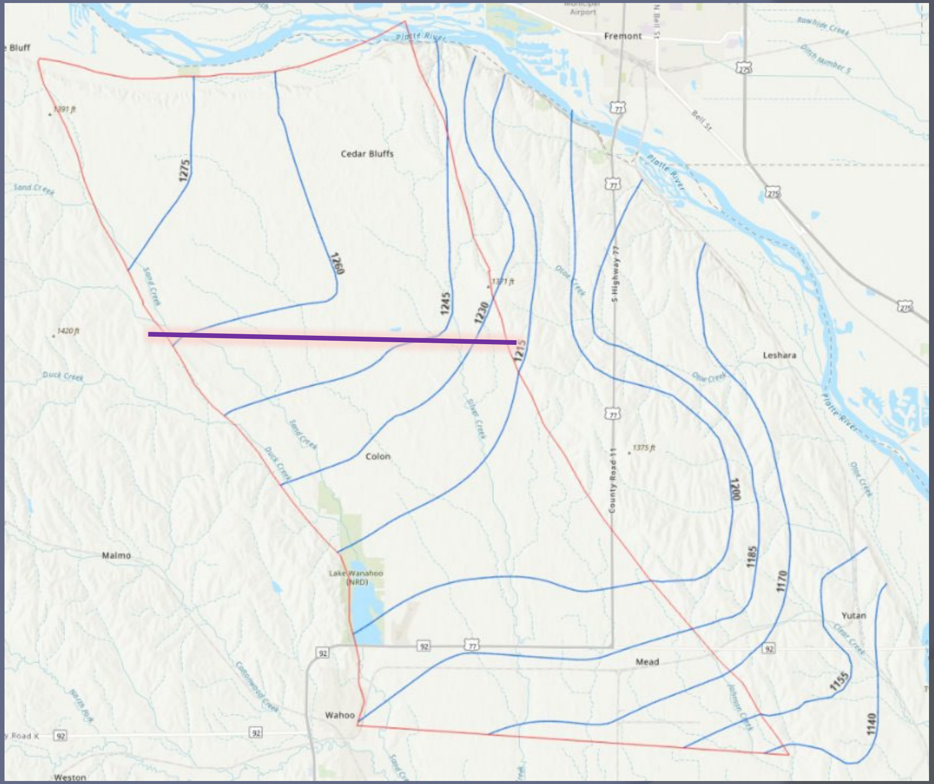
Focus Areas: Todd Valley



Focus Areas: Todd Valley

Future studies needed:

- Additional test holes:
  - In uplands between the Todd and Platte Valley
  - Along the western and northern boundary of the Todd Valley
    - Better understand recharge methods of the Todd Valley
- Additional AEM/Geophysical studies:
  - Along the boundary between the Platte-Todd Valley
- Geochemical study to better understand the source of recharge to the Todd Valley



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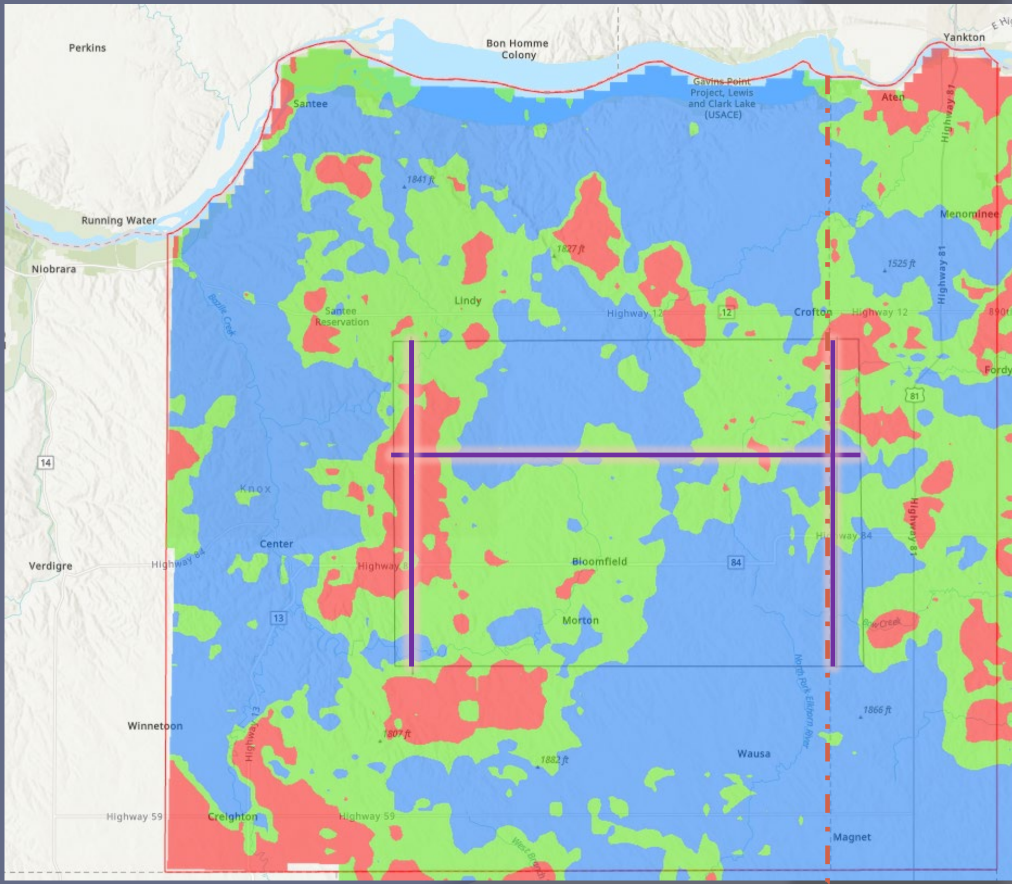
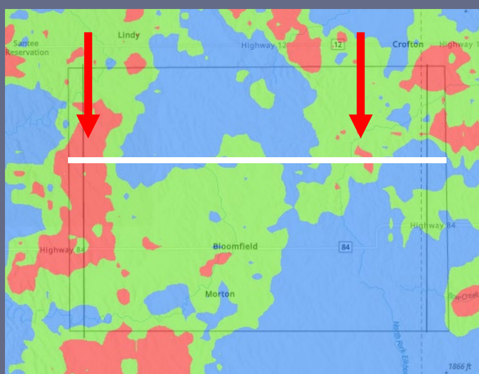
Focus Areas: East Knox County

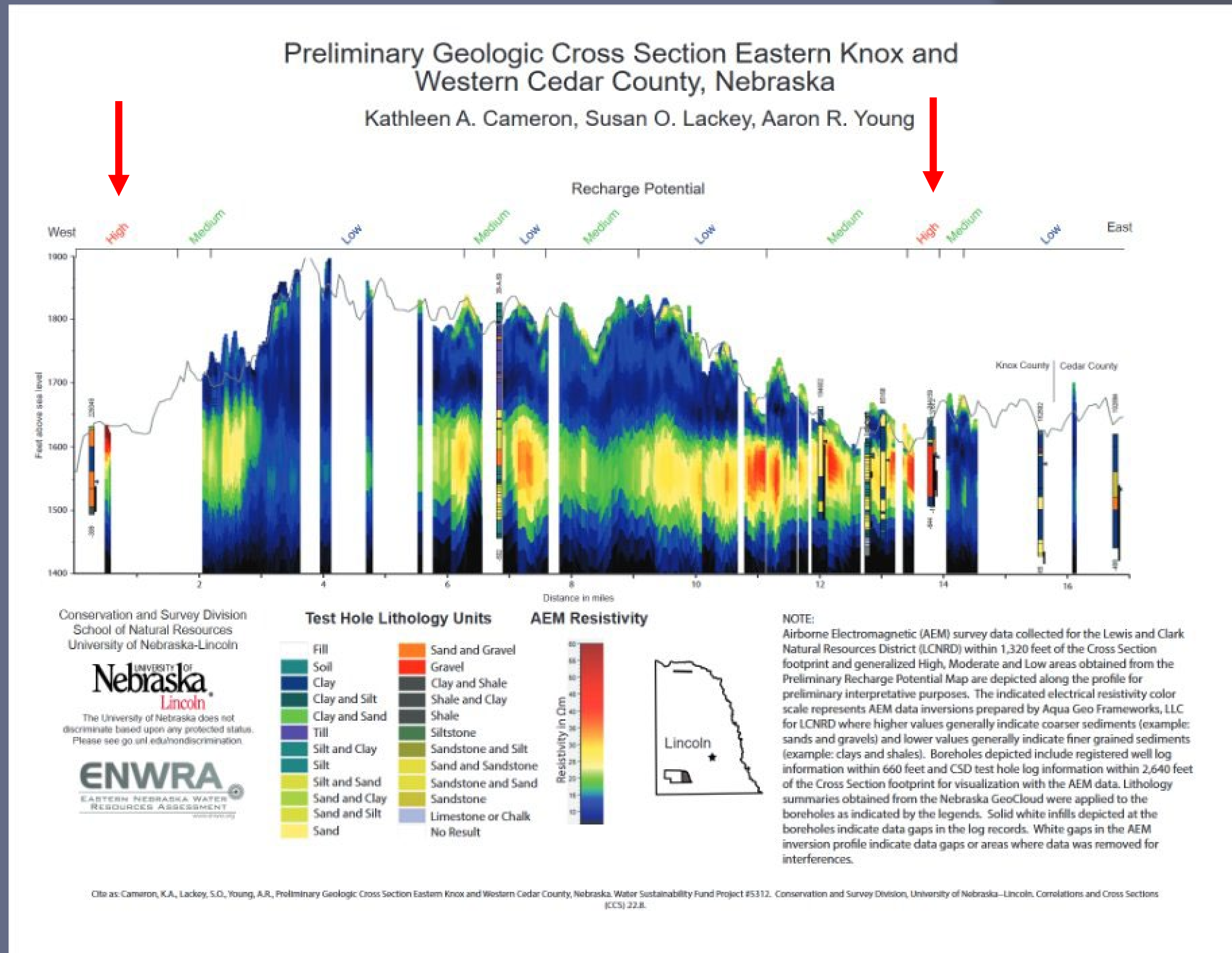
Maps:

- Bedrock elevation surface
  - 78 Test holes/down hole geophysics
  - AEM data & interp. in GeoScene3D
  - 1,951 DNR registered well data (Sue Lackey Cedar Knox Co. binders)
    - 1m LiDAR ground [extract values to points] minus bedrock elev. call
    - display x y z points based on the state plane feet X, Y, Z columns we use on GeoScene3D projects
    - "**points to raster**" tool, "**raster to topo**“ , "**contour**" 3D analyst ESRI tools
- Saturated thickness
  - Calculated by subtracting the bedrock elevation from the water table elevation

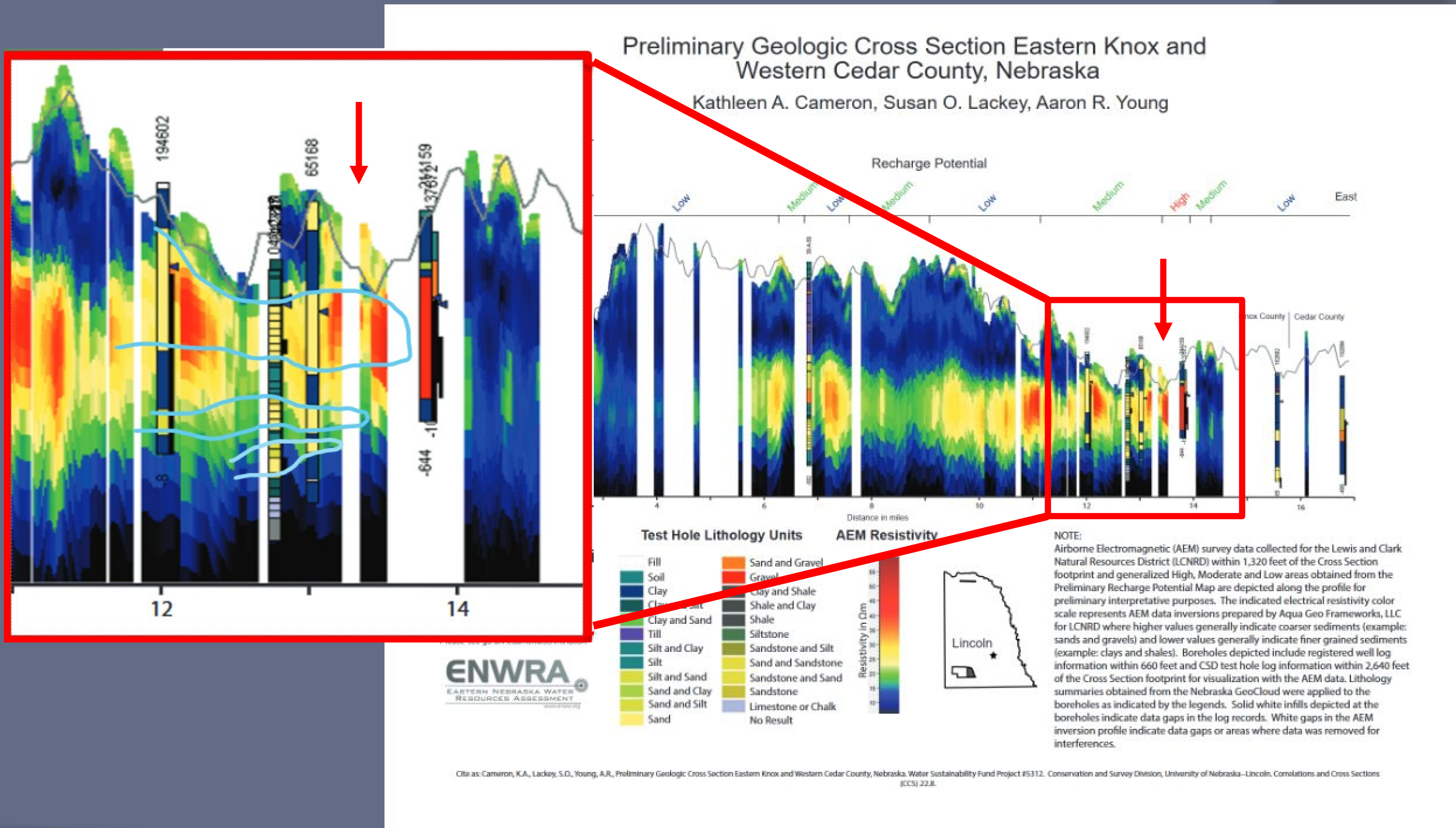


East Knox County





East Knox County



Focus Areas: East Knox County

Status of current work:

- Locations of all test holes (78) and registered wells (1951) have been confirmed or adjusted and LiDAR elevations of each were determined.
- Initial vertical bounds of multiple aquifers have been determined at each of these locations.
- Assessment of water level data has been started to produce water table and saturated thickness maps.

Future work needed:

- Additional AEM refinement to properly map the surface of the Ogalalla Gp.
- Refine bedrock surface and stratigraphy through future test hole drilling and assessment of existing data.

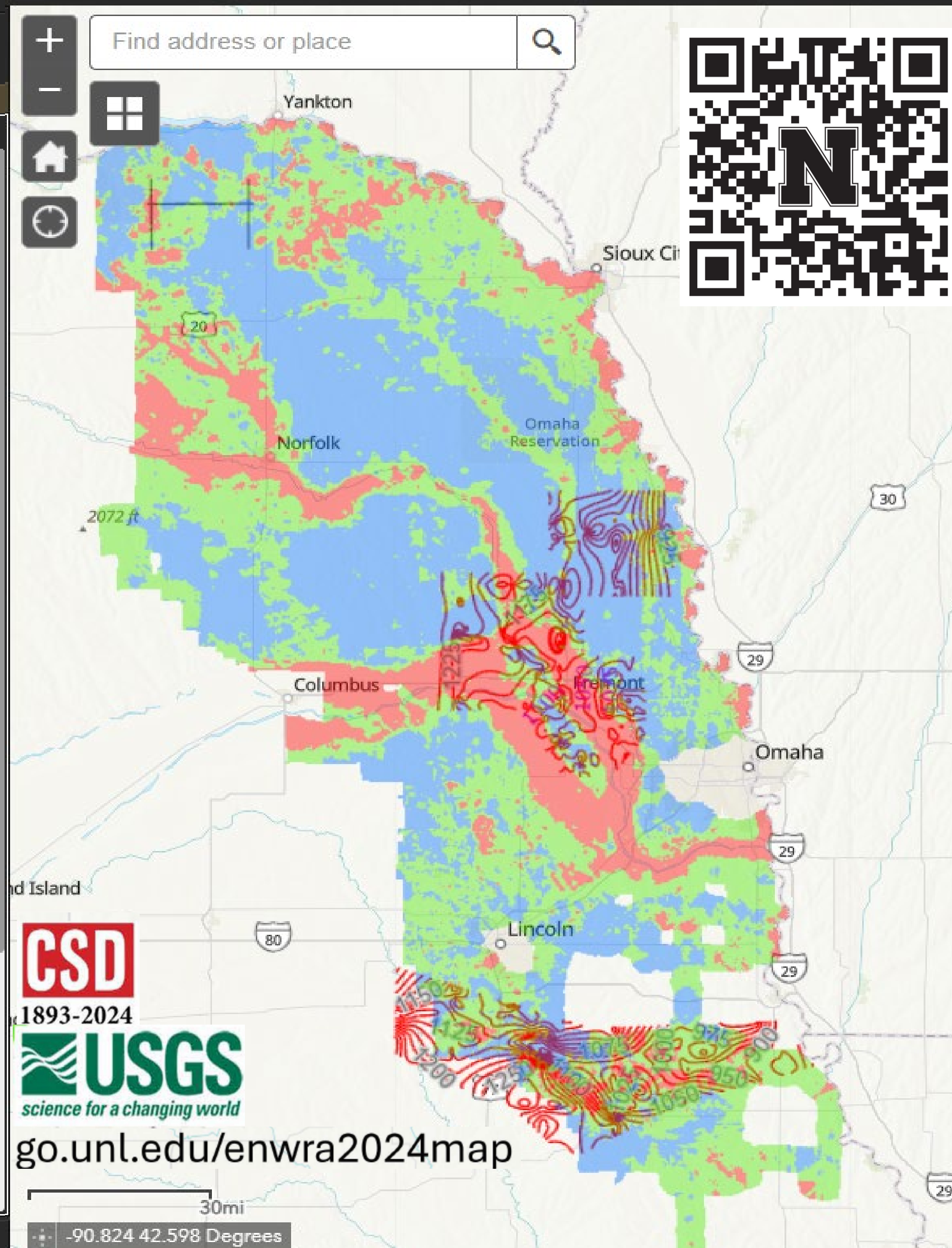
ENWRA 2024 Project **Preliminary** Results

Knox Draft Project Preview | BDFAL Draft Project Preview | DSP Project Preview

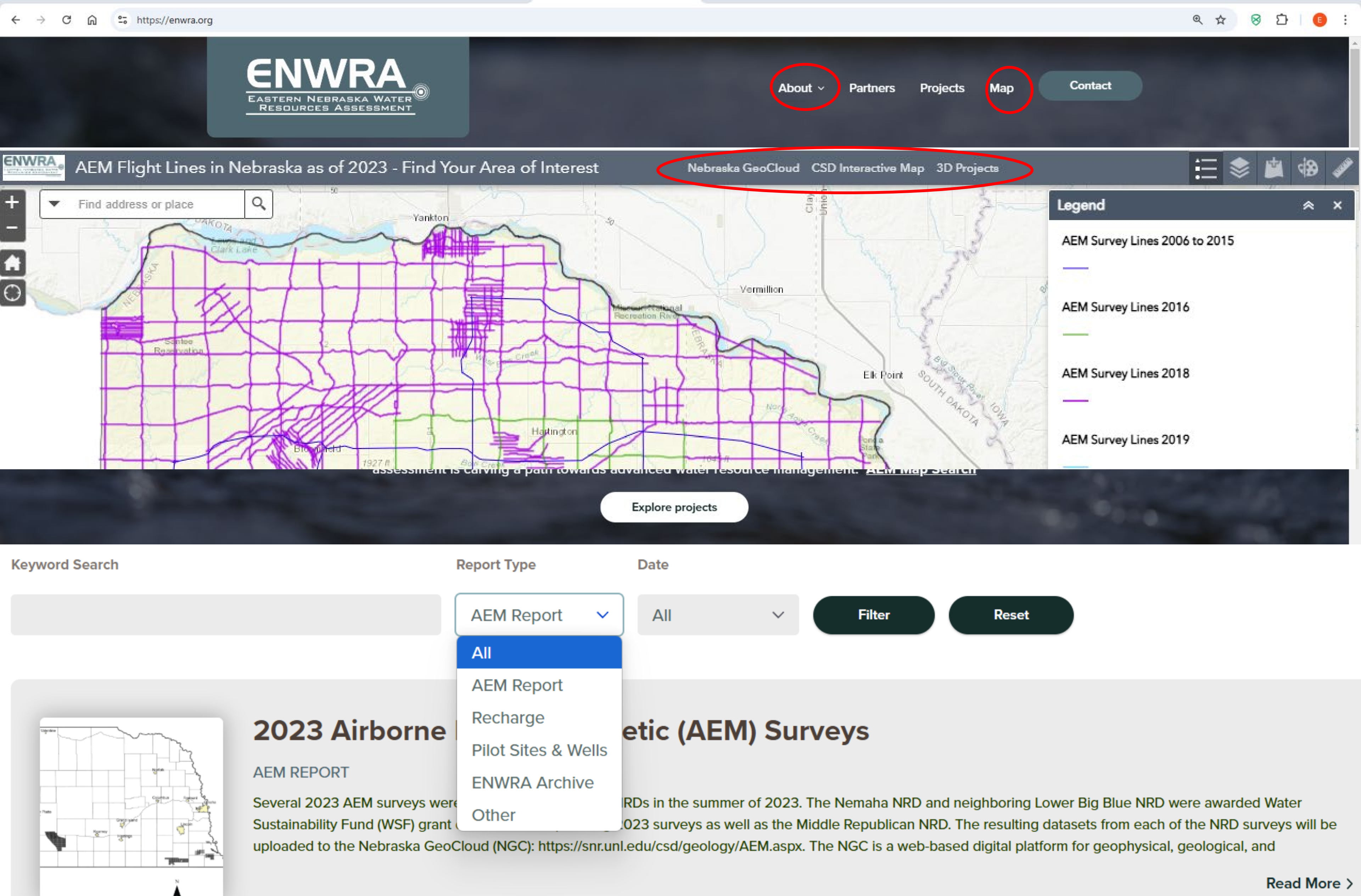
Layer List

Layers

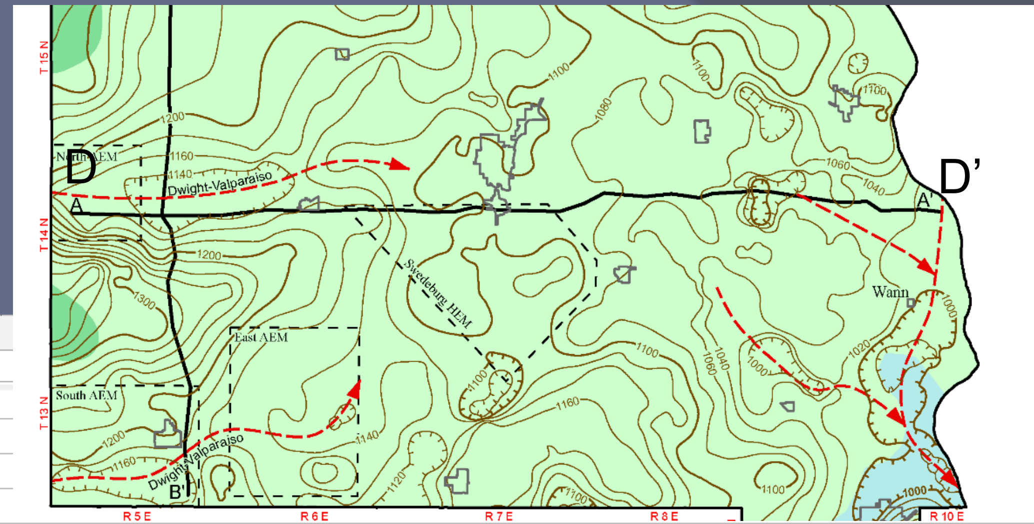
- Recharge Potential
  - Recharge Potential
    - High
    - Moderate
    - Low
- Focus Areas (Click here for options)
  - BDFAL Focus Areas (Click here for options)
    - Focus Area Boundaries (Click here for options)
    - Test Holes and Observation Wells (Click here for options)
    - Todd Valley (Click here for options)
    - Platte River Alluvium (Click here for options)
  - Knox Focus Area (Click here for options)
    - Knox FA Cross Sections
    - Updated Knox Focus Area
    - Knox Focus Area Boundary
    - Site Locations
  - DSP Focus Area (Click here for options)

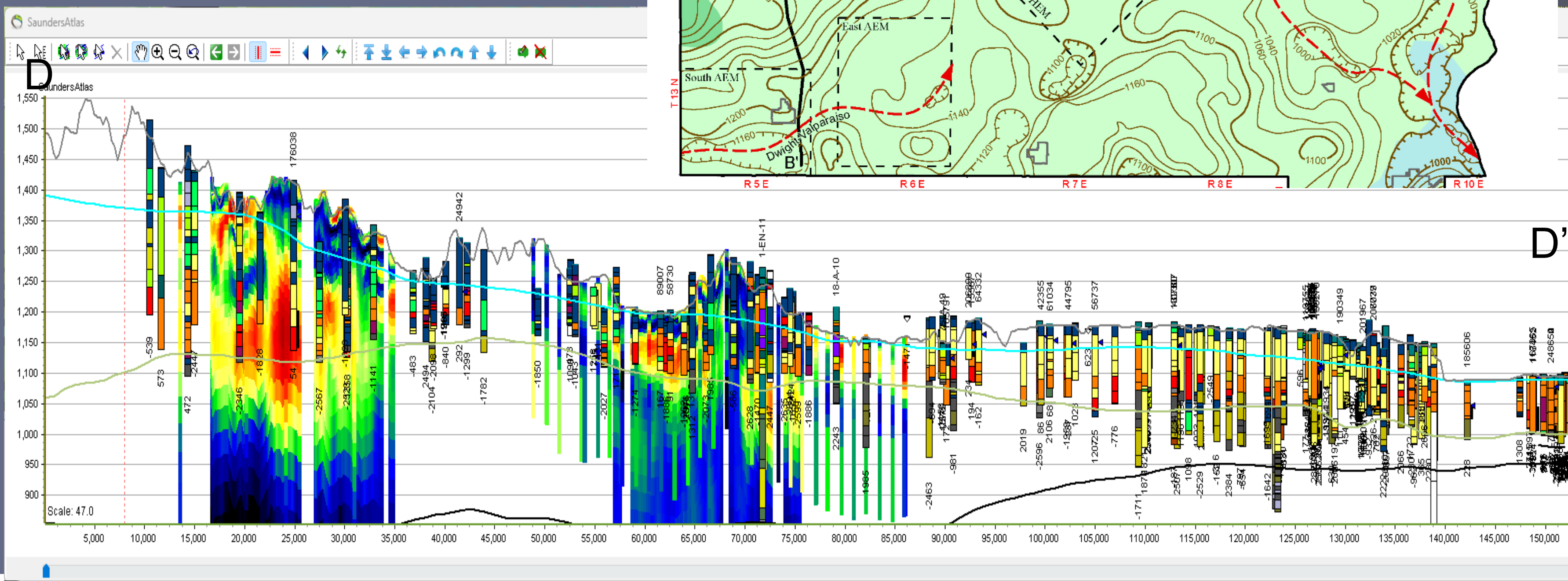


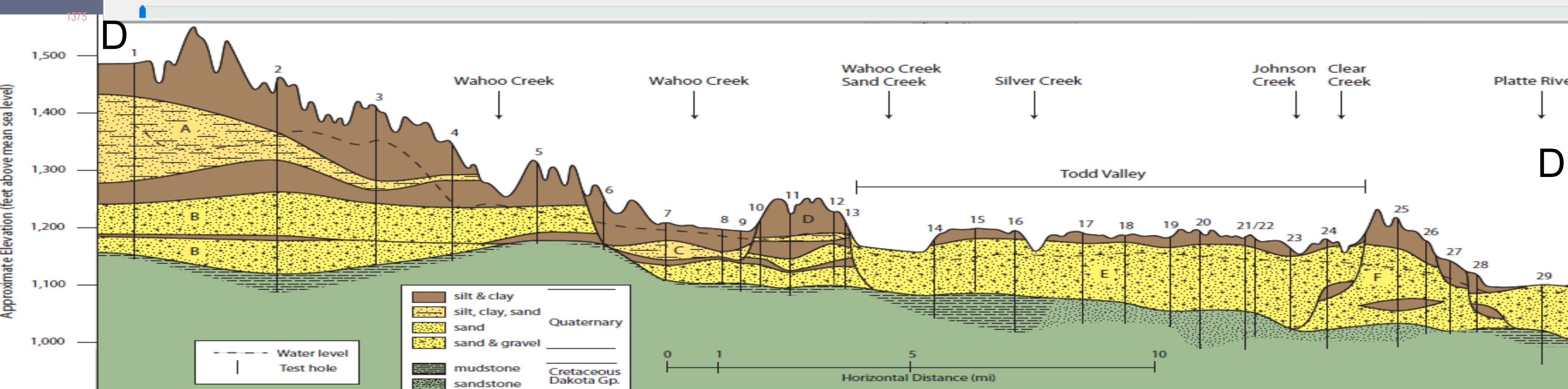
Website and Outreach



Geoscene3d With County Atlas

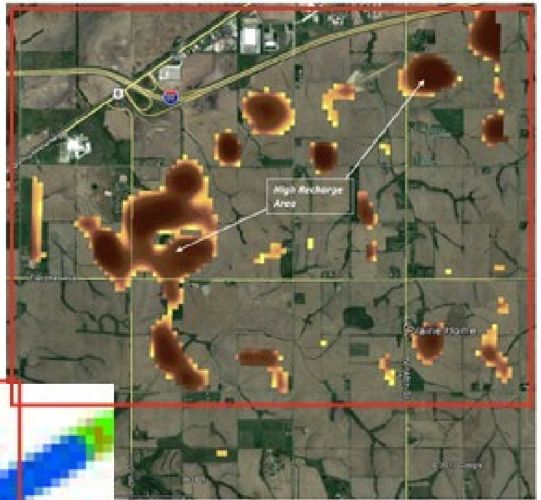






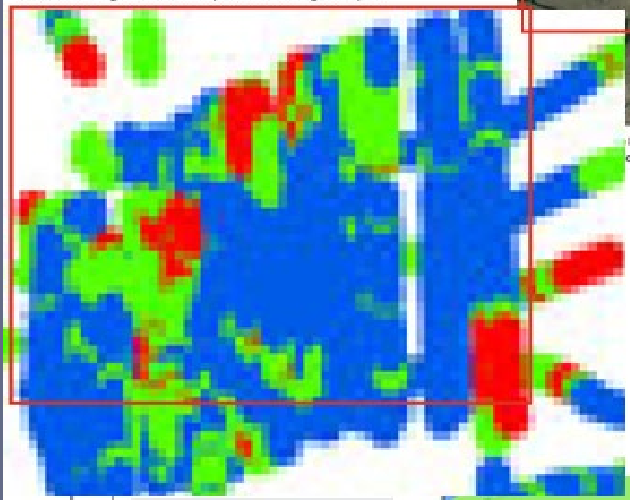
WHPAs and Recharge Potential Map

2016 AEM Waverly Example Top 10 feet from AGF Report:



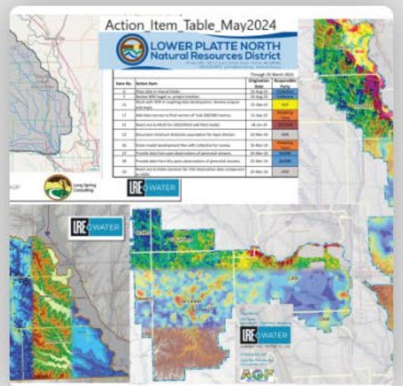
Earth recharge kmz of aquifer material and coarse aquifer material displayed over
ock flight survey area.

Top 50 feet April 2024 HML Recharge Potential along AEM without continuous surface grid & last processing steps:



Interactive Map -WSF5312 Recharge Reporting (will be final in June 2025):

https://csdportal.unl.edu/csdportal/apps/webappviewer/index.html?id=49c6ff4674254a87a72b5d2e68549ddd



Model Building Reports

OTHER

HYDROGEOLOGIC ASSESSMENT, FRAMEWORK and MODEL-related Projects are at different stages of development for the ENWRA NRDs. Please refer to the 2018 AEM survey report for the Lewis and Clark NRD, the 2023 AEM survey Report for the Nemaha NRD and the 2020 AEM

Read More >

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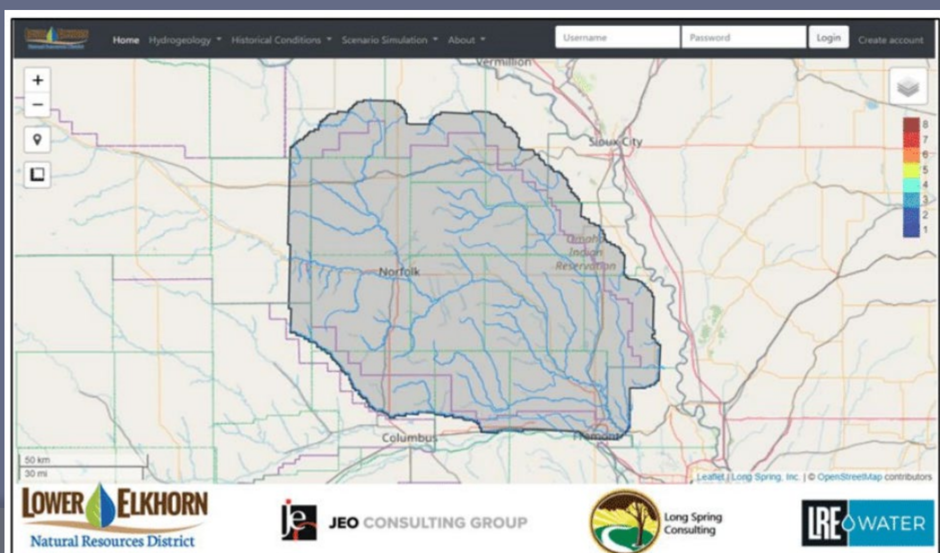

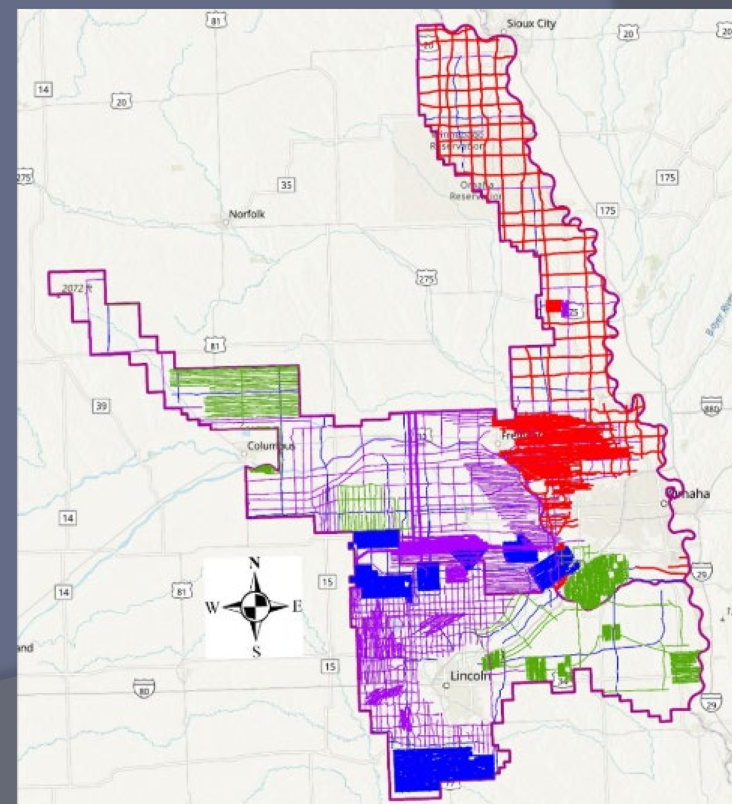

Background for Proposed Grant Scope

- Middle Republican NRD Example – 3.2 Million data points to a 200 x 200 x 1 meter grid cells
- AEM & Lithologic Data processing (good boreholes, cleaning and QC ready for model)
- Data Prep, Model performance evaluation and Tuning
- Technique uses multiple decision trees algorithm to create one powerful algorithm
- Flexibility in setting up Training and Testing so it is applicable to Eastern Nebraska
- Model results include Hydrostrat Unit & Hydraulic Conductivity (K) Predictions

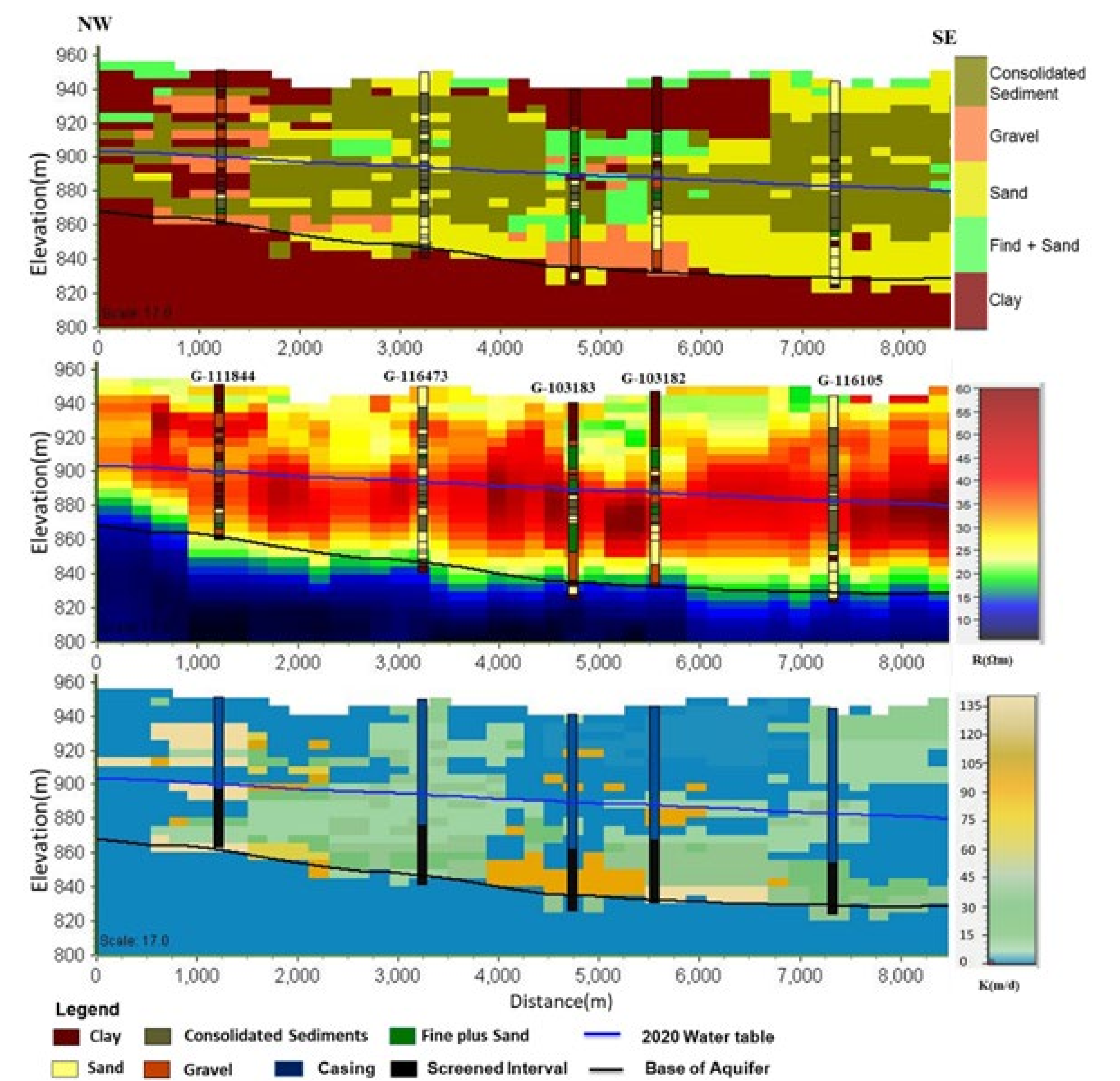

Fig. 9. Various models for the same line of cross section (see Fig. 8 for location). a) Predicted hydrostratigraphic units (HSUs, in background) and HSUs in borehole logs (vertical sticks). b) Interpolated resistivity-depth model from airborne electromagnetic survey (in background) and HSUs in boreholes logs (vertical sticks). C) Predicted hydraulic conductivity (K) and boreholes (vertical sticks) showing well screens and casings. Legend at the bottom is for the boreholes. Legends on the right are for the models.

Review

- About 20,000 line-miles of AEM have been collected and over 200 test holes have been drilled across ENWRA
- NRDs and ENWRA Partners are using AEM with existing supporting data as scientific backbone to evaluate groundwater permitting and other management decisions and monitoring network designs
- CSD and USGS incorporating AEM into publications
- ENWRA and others handling public inquiries with AEM and supporting data
- Data uses
  - map extent and thickness of buried paleo valley aquifers
  - estimate water in storage
  - regional and local eval. with recharge potential map
  - assess hydrologic connectivity between units and to surface water
- Nebraska GeoCloud developed to serve AEM data and derivative products (geologic surfaces, models etc.)