AIRBORNE ELECTROMAGNETIC GEOPHYSICAL SURVEYS AND HYDROGEOLOGIC FRAMEWORK DEVELOPMENT FOR GROUNDWATER-SURFACE WATER MANAGEMENT

Nebraska Water Resources Association
Water Round Table
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AGENDA

- Why AEM surveys for groundwater-surface water management?
- History of AEM surveys in Nebraska
- Example from Lower Elkhorn Natural Resources District
- Example of Eastern Nebraska Water Resources Assessment
- The future for this Technology
- Questions
Why AEM Surveys for Groundwater-Surface Water Management?

- Nebraska Has **Great** Variability in Water Resources!
  - Variability in precipitation
  - Variability in elevation
  - Variability in geology
  - Variability in stream-aquifer relationships
  - Variability in aquifer recharge
  - Variability in aquifer characteristics
  - To name a few......
WHY AEM SURVEYS FOR GROUNDWATER-SURFACE WATER MANAGEMENT?

• Nebraska Has **Great** Information for Water Resources!
  • CSD Test Hole Database
  • DNR Registered Well Database
  • USGS and DNR Stream Gauge Program
  • Soils Maps
  • Many water and geology publications
  • Groundwater and surface water quality databases
  • To name a few…….

**SO WHY DO WE NEED MORE INFORMATION FROM AEM SURVEYS?**
With the variability across Nebraska in resources and information, we continue to need better and up-to-date information on the subsurface. From riparian area groundwater-surface water relationships to how much groundwater we have in storage, only an accurate hydrogeologic framework will allow us to represent the natural system for our management purposes.

How about an example: Western Canal?
**WHY AEM SURVEYS FOR GROUNDWATER-SURFACE WATER MANAGEMENT?**

- Along the flight line AEM provides a higher density of data points than drill holes alone.
- Allows for an accurate 3-dimensional delineation of groundwater management areas.
- Data is compatible and transferable as surfaces for groundwater models, research, or studies.
- Visualization delineates a detailed characterization of surface/groundwater relationship along streams.
- Detailed 2-D and/or 3-D mapping of source and sink areas to help characterize recharge/discharge points related to water balance.
- A detailed AEM survey is the best way to site future water supplies for communities including a detailed well head protection area delineation.
Why AEM Surveys for Groundwater-Surface Water Management?

• 2-D and/or 3-D representations of areas where aquifer's could be vulnerable to water quality impacts

• Detailed aquifer visualization for sighting drill holes, aquifer tests, water-quality samples and well head protection areas.

• All data are collected and interpreted using a multidisciplinary program of investigation

• The general public can use AEM results in programs such as Google Earth

• The cost of AEM collection is approximately 25 percent of drilling test holes and interpolating between them
**AIRBORNE ELECTROMAGNETIC (AEM) SURVEYS**

- A method of collecting information about changes in electrical resistivity beneath the land surface that can be related to lithology in a geospatially referenced dataset.
- High density of data points.
- Non-invasive.
- Cost-effective compared to drilling alone.
- Designed to cover large areas in relatively short periods of time.
- Depth of investigation can exceed 1,400 feet, dependent upon geology.

SKYTEM, LLC, AARHUS, DK
RESISTIVITY APPLIED TO SEDIMENTS

- Increase in resistivity
  - Finer-grained sediment

- Decrease in resistivity
  - Coarser-grained sediment

Increase in resistivity
Decrease in resistivity
Coarser-grained sediment
Finer-grained sediment
All data available to improve understanding of the subsurface is used.

Higher resistivities indicate coarse-grained deposits.

Less resistive signal indicates clay-rich materials or brackish/saline/high TDS groundwater.

SKYTEM, LLC, AARHUS, DK
We use many tools to provide the best possible information for water exploration. For medium to large projects we have found that AEM is the best choice.
**History of AEM in Nebraska**

- **2007** ENWRA
- **2008** NPNRD and SPNRD
- **2009** ENWRA
- **2009** NPNRD and SPNRD
- **2009** USGS Sand Hills Study
- **2010** USGS Western NE Study
- **2010** NPNRD, SPNRD, and TPNRD
- **2011** USACE Mead
- **2013** LENRD, LPSNRD, and Madison
- **2014** LENRD, ENWRA
- Spring **2015** ENWRA

Total: 15,252 line-km

(9,477 line-miles)
Western Nebraska AEM Flights

Sand Hills AEM
AEM EASTERN NEBRASKA 2014
October 11-19\textsuperscript{th}, 2015
7 days of data collection
1 weather day (wind 10-17-2015)

Airports used in survey:

- Norfolk, NE
- Wayne, NE
- Willow Creek State Park/Rec Area
- Fremont, NE
- Powder Creek State Park/Rec Area
- Tekemah, NE
- David City, NE
- Martin Field, NE
- Hartington, NE
IN FIELD QA/QC AND INVERSION

- Within 24 hours we invert
- SkyTEM 508 system-first time gate 12 μsec 3.0 μsec wide and last time gate of 10.0 msec
- Aarhus Workbench SCI was used with 30 layer smooth inversion. First layer 16 ft.
BACKGROUND BOREHOLE DATA
CSD HISTORICAL CROSS SECTIONS
CSD CROSS SECTIONS
RESISTIVITY VERSUS LITHOLOGY AND AQUIFER MATERIALS

- 39 CSD boreholes with lithology and resistivity geophysical logs
- ~209,000 individual measurements
LITHOLOGY VERSUS AQUIFER MATERIAL

**Principal Aquifer**
- Sand
- Silty Sand
- Sandy Clay
- Silt/Loess
- Clay
- Till
- Sand and Gravel
- Gravel / Boulders

**Coarse Aquifer**
- Sand
- Silty Clay
- Silt/Loess
- Clay
- Till
- Sand and Gravel
- Gravel / Boulders
EXAMPLE CROSS SECTION
3D OF THE 2014 AEM IN LENRD
### L100602

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Profile: L100602

Legend: Legend
**SURVEY CONCLUSIONS**

- Aquifer resources vary considerably within the Quaternary and Tertiary system.
- The principal aquifer is thicker in the western and southern third of the LENRD.
- The Quaternary and Tertiary material act as the principal aquifer in the west.
- Non-aquifer (aquitard) materials are abundant in the central and eastern portions of the survey area, with till and loess sequences exceeding 200 ft.
- The full sequence of Cretaceous strata present in eastern Nebraska was detected by the AEM system.
- The full thickness of the $K_d$ is revealed in the AEM survey. The AEM indicated potential areas of development.
- The SkyTEM301 system demonstrated adequate resolution providing greater detail in the near surface along the Elkhorn river.
- The line spacing at 3 miles reveals mappable areas of similar geology.
- The reconnaissance line spacing for the ENWRA flights shows areas of interest for future work.
AEM COLLECTED BY THE LENRD
Clarkson Survey

Completed Flight Lines
3-D VOXEL DISPLAY OF 20 OHM-M OR GREATER RESISTIVITY ZONES OVERLYING THE CRETACEOUS BEDROCK SURFACE
AEM EASTERN NEBRASKA WATER RESOURCES ASSESSMENT 2014
SURVEY CONCLUSIONS

- Aquifer resources vary considerably within the Quaternary and Tertiary system with the principal aquifer in the west sub region.

- The principal aquifer is thicker in the west sub region and the east sub region is mostly marginal aquifer material.

- Non-aquifer (aquitard) materials are abundant in the eastern portions of the survey area, with till and loess sequences exceeding 200 ft.

- The Cretaceous Carlisle, Greenhorn and Graneros are not geophysically distinct in all locations and are considered as one unit for purposes of the framework.

- The full sequence of Cretaceous strata present in eastern Nebraska was detected by the AEM system. Resistive sections of the Dakota formation are interpreted to be filled with non-saline water making these sections potential water supply depending on the aquifer characteristics.

- The paleozoic sections of the geology were detected but not completely resolved during this work due to limited test hole information.

- The line spacing between reconnaissance lines was 15 miles or more and allowed for a general interpretation of the geology across the project area with detailed information along the flight lines.

- The reconnaissance line spacing for the ENWRA flights shows areas of interest for future work.

Lower Elkhorn Natural Resources District
**Spring Flights**

- 684 line miles
- 11 flights
- Using Airports:
  - Crete, NE
  - Tecumseh, NE
  - Pawnee City, NE
  - Plattsmouth, NE
  - Wahoo, NE
  - David City, NE
- Test flights
  - April 14-15
- Production began
  - April 16
2D (As of April 19, 2015)
2D FIRST LOOK (AS OF APRIL 19, 2015)
2D (As of April 19, 2015)
2D (AS OF APRIL 19, 2015)
2D (As of April 19, 2015)
2D (As of April 19, 2015)
2D (As of April 19, 2015)
2D (As of April 19, 2015)
FUTURE OF AEM IN NEBRASKA

Norfolk, NE

20.9 line-miles (33.6 line-km)

Flight Height
Mean: 145 ft (44.2 m)
Min: 116.5 ft (35.5 m)
Max: 204.7 ft (62.4 m)
Streambed Hydrology Tests in the Lower Elkhorn River and its Tributaries, Nebraska
2010
Susan Olafsen Lackey and Xun-Hong Chen
Conservation and Survey Division
School of Natural Resources
University of Nebraska-Lincoln
CSD Elkhorn River Site 7

Lackey and Chen, 2010
SkyTEM 301 Data (L100201)

- Niobrara Fm (Kn), Shale/Limestone
- Elkhorn River Alluvium (Qal), Sands/Gravels
- Greenhorn Graneros Fm (Kgg), Limestone/Shale
- Paleochannel
- Carlile Fm (Kc), Shale

2,000 ft
100 ft
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