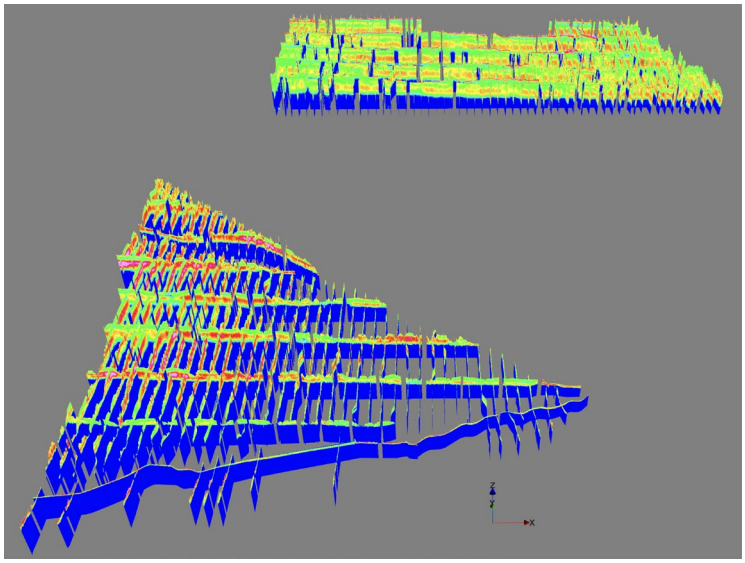
Final Spatially-Constrained Inversions Report and Data Delivery from the 2024 Airborne Electromagnetic Surveys of Block 3 and Block 4 of the Middle Republican Natural Resources District



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1.0 Introduction

This survey included the acquisition, processing, and inversion of Airborne Electromagnetic (AEM) data for two areas, Block 3 and Block 4, of the Middle Republican Natural Resources District (MRNRD). The as-flown data acquisition for Block 3 is presented in Figure 1 and for Block 4 in Figure 2.

2.0 Schedule/Timeline

Aqua Geo Frameworks, LLC (AGF) and SkyTEM mobilized to Trenton, Nebraska on June 19, 2024. The system had been ferried from a previous AEM project in Kansas and ground tests and system calibrations were conducted and verified after arrival for that project. Production began with Block 4 and was acquired from June 21 - 23, 2024, out of Trenton, Nebraska. Block 3 was acquired from June 24-26, 2024, out of Wallace, Nebraska. The MRNRD acquisition was completed on June 26, 2024. The system and crew demobilized from McCook, Nebraska on June 28, 2024.

3.0 Data Acquisition Summary

All SkyTEM systems are calibrated to a ground test site in Lyngby, Denmark prior to being used for production work (HydroGeophysics Group Aarhus University, 2010; HydroGeophysics Group Aarhus University, 2011; Foged et al., 2013). The calibration process involves acquiring data with the system hovering at different altitudes, from 5 to 50 meters (~16 to 164 ft), over the Lyngby site. Acquired data are processed and a scale factor (time and amplitude) is applied so that the inversion process produces the model that approximates the known geology at Lyngby.

The 2024 MRNRD AEM data acquisition was flown out of the Trenton Track and Field Stadium (west of town), Wallace Airport, and McCook airport. Fourteen (14) production flights took place from June 21-26, 2024. Three production flights were flown on the 22nd, 24th, and 26th of June, two production flights on the 23rd and 25th of June, and one production flight on the 21st of June. Line-km totals from each flight and day are provided in Table 3-1. A total of 2,542.8 line-km (1,580.4 line-miles) which included a bonus of 47.3 line-km (29.4 line-miles) of AEM data were acquired over the MRNRD area. Figure 3 is an “as-flown” map view of the timing and spatial orientation of the flight lines, colored by date acquired. In some locations, the as-flown lines deviate from the planned lines due to infrastructure and safety as determined by the pilot.

Table 3-1. Flight line production by flight.

Date	Flight	Distance per Flight (km)	Distance per Day (km)	Distance per Day (miles)
6/21/2024	1	148.6	148.6	92.4
6/22/2024	1	190.7	578.1	359.3
	2	193.6		
	3	193.8		
6/23/2024	1	187.9	332	206.3
	2	144.1		
6/24/2024	1	187.8	574.9	357.3
	2	236.8		
	3	150.3		
6/25/2024	2	144.4	347.5	216.0
	3	203.1		
6/26/2024	1	158.9	561.7	349.1
	2	236.5		
	3	166.3		
Total		2542.8	2542.8	1580.4

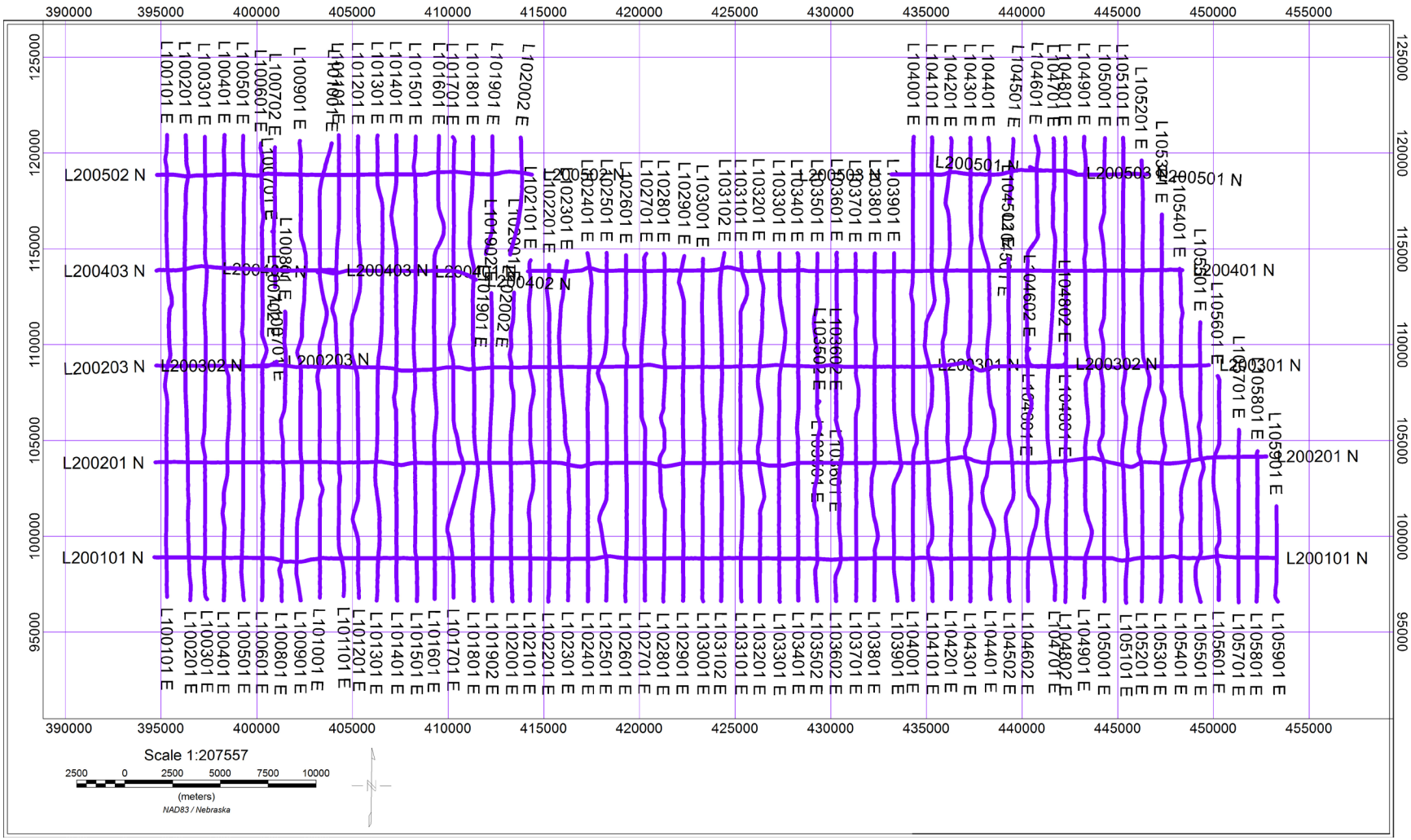


Figure 1. As-Flown MRNRD2024 Block 3 AEM acquisition displayed as purple lines with flight line labels.

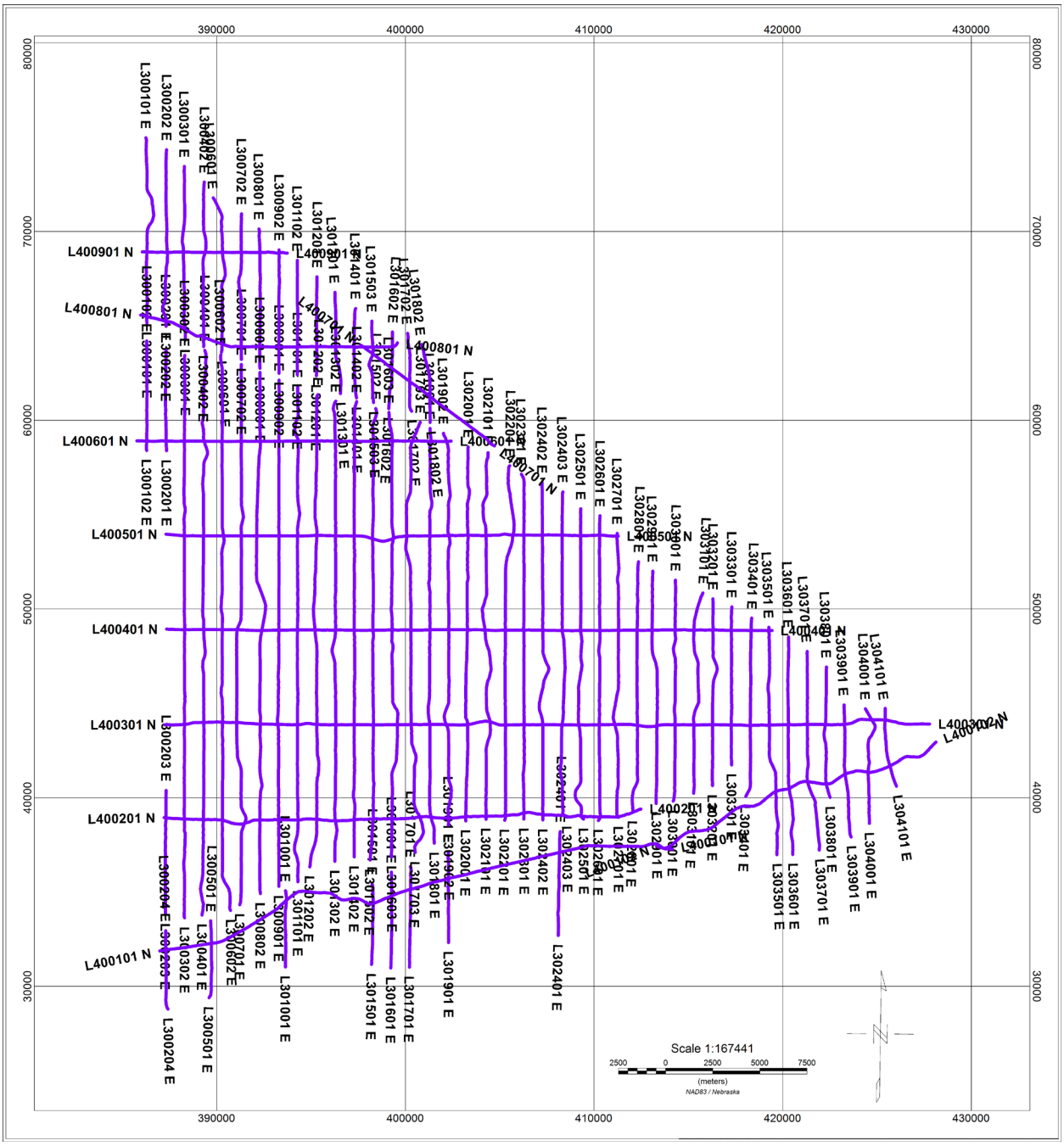


Figure 2. As-Flown MRNRD2024 Block 4 AEM acquisition displayed as purple lines with flight line labels.

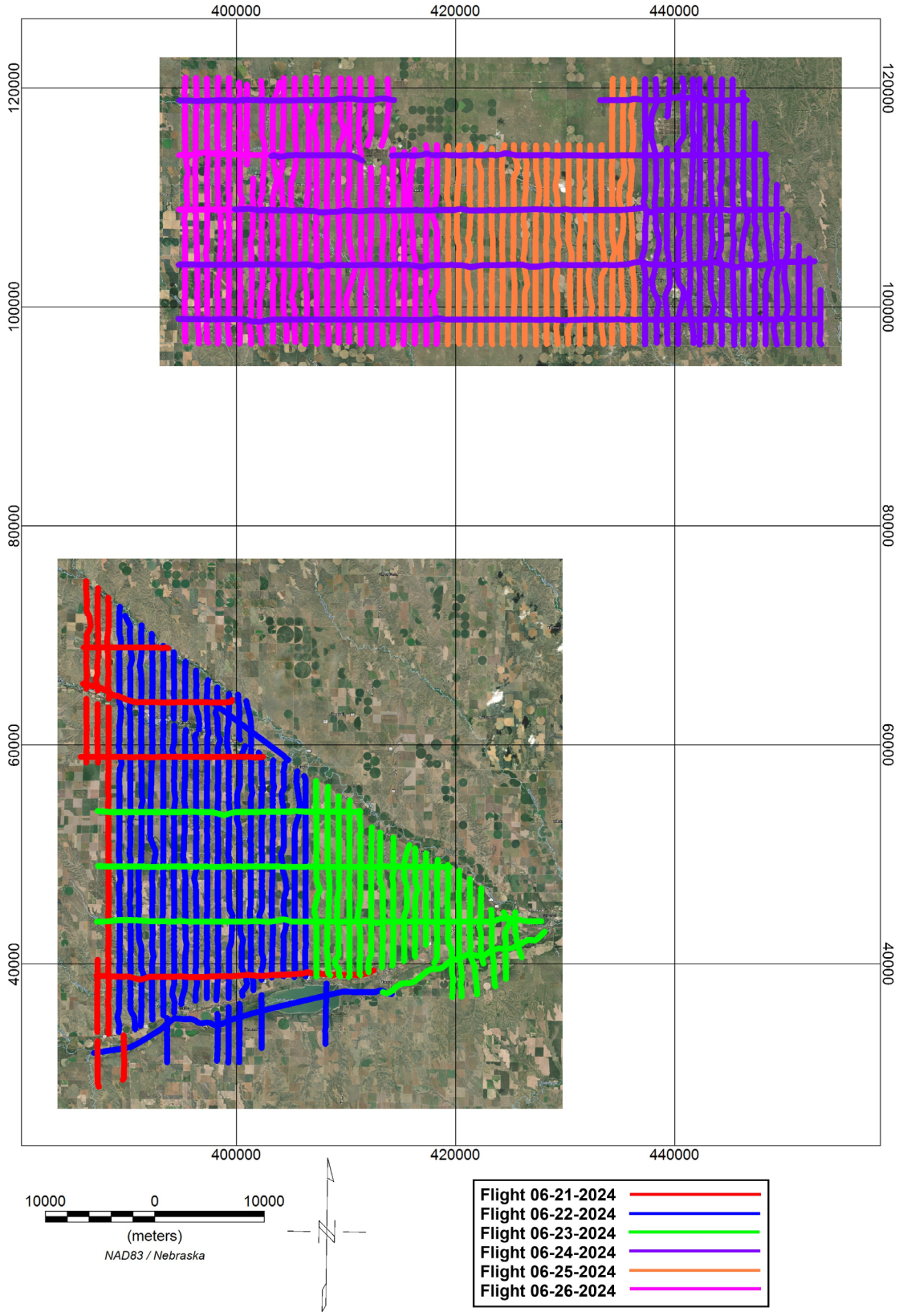


Figure 3. As-Flown map showing timing of the 2024 MRNRD AEM survey data acquisition. Map projection is NAD83 Nebraska State Plane, meters.

A map of the airborne platform's flight height during data acquisition is presented in Figure 4. Higher flight altitudes would be due to going over powerlines and other infrastructure that would need to be avoided by the pilot. In some instances, steep canyons cannot be draped due to their width and the performance of the helicopter. The term "drape" refers to the maintaining of a constant height of the system above the topography. The typical specification is 30 meters above the ground and no adverse impact is caused when the system is flown between 20 to 40 meters. A consequence of higher flight altitudes can be a degradation in the acquired data signal quality as the system gets farther from the subsurface targets of interest which cannot be avoided due to aircraft safety. This is not a simple one to one relationship due to the electromagnetic structure of the subsurface and the magnitude of the induced response. In general, the field strength drops off by the height to the power of -6.

The speed is another factor to look at with regard to data coverage as the speed dictates the effective ground sampling. As the AEM system transmitter operates at programmed time intervals, the faster the system moves, the further apart the measurements are. Figure 5 is a plot of the equivalent ground speed of the AEM system over the acquisition area.

The wind has the largest impact on the ground speed as the speed is slower into the wind and faster when traveling with the wind. This is caused by the pilot trying to keep the system as level as possible and maintaining a good drape over the ground. Figure 6 and Figure 7 are plots of the AEM system tilt pitch in the X-direction (in the direction of travel) and tilt roll in the Y-direction (perpendicular to the direction of travel) , respectively. Typically, the X-direction is subject to more changes due to changing wind speed and helicopter speed around obstacles and topographic features. Tilts of $\pm$ 10 degrees are compensated for in the inversion. Given the topography (Figure 8) of the AEM survey area, the data were successfully collected at industry-acceptable standards. To ensure that the elevation used in the project is constant for all the data sources (i.e. boreholes and AEM) a Digital Elevation Model (DEM) was downloaded and processed for the MRNRD survey. The data was downloaded from the National Elevation dataset (NED) located at the National Map Website (U.S. Geological Survey, 2024) at a resolution of 1/3 arc-second or approximately 10 m.

The estimated amplitude of the power line noise intensity (PLNI) is presented in Figure 9. The PLNI map is useful when investigating the impacts of powerlines on the data quality. While the 60 Hz powerline signals can have little impact on the Rx signal due to time-gating and proper filtering, the conductive wires that are used to transmit the power do cause electromagnetic (EM) coupling impacts on the data and those data need to be removed prior to inversion, a process known as "decoupling".

As part of the SkyTEM system a Total Field magnetometer is included in the data acquisition package. The magnetic field signal is useful for determining deep seated geological contacts and is also extremely valuable for locating intrusive bodies. However, the magnetic field is also sensitive to anthropogenic features that contain ferrous metal and so is also used in the electromagnetic decoupling process. A plot of the residual of the magnetic Total Magnetic Field (the RMF) of the survey area (corrected for diurnal drift using a ground-based station and the IGRF) is presented in Figure 10. Both geological structure and cultural features can be identified within the AEM survey area.

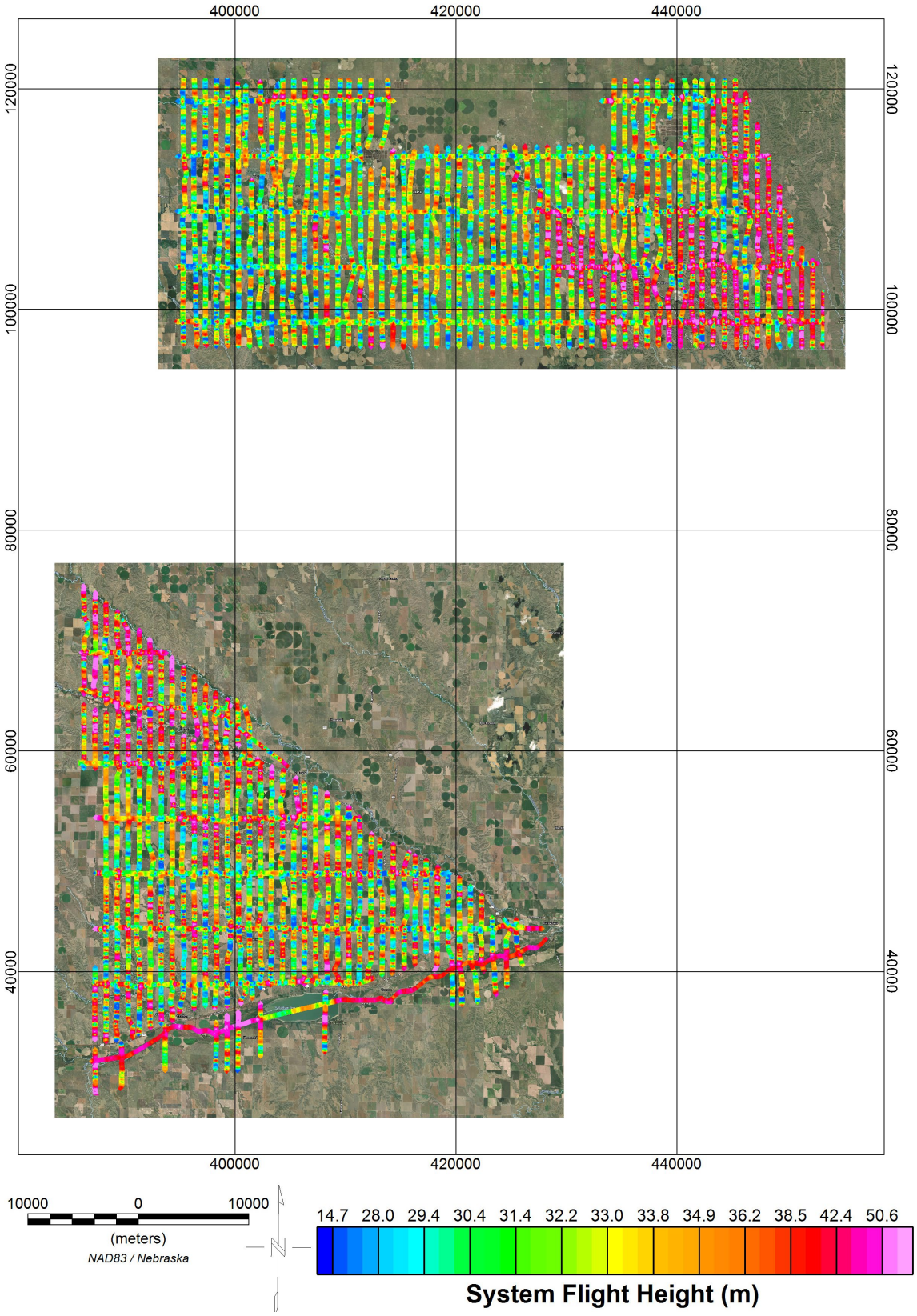


Figure 4. Map of the system height recorded during the 2024 MRNRD AEM survey. Map projection is NAD83 Nebraska State Plane, meters.

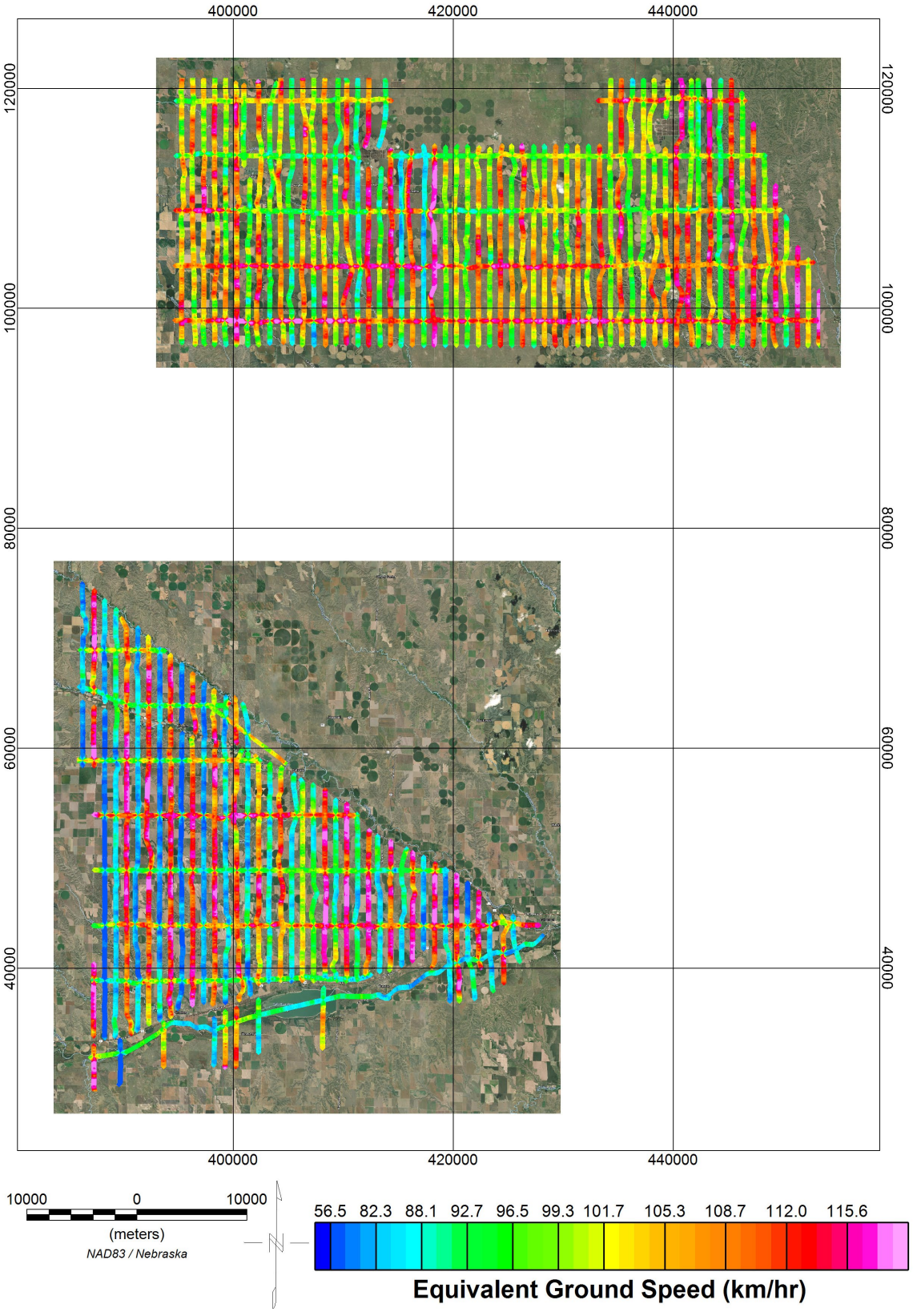


Figure 5. Map of the ground speed recorded during the 2024 MRNRD AEM survey. Map projection is NAD83 Nebraska State Plane, meters.

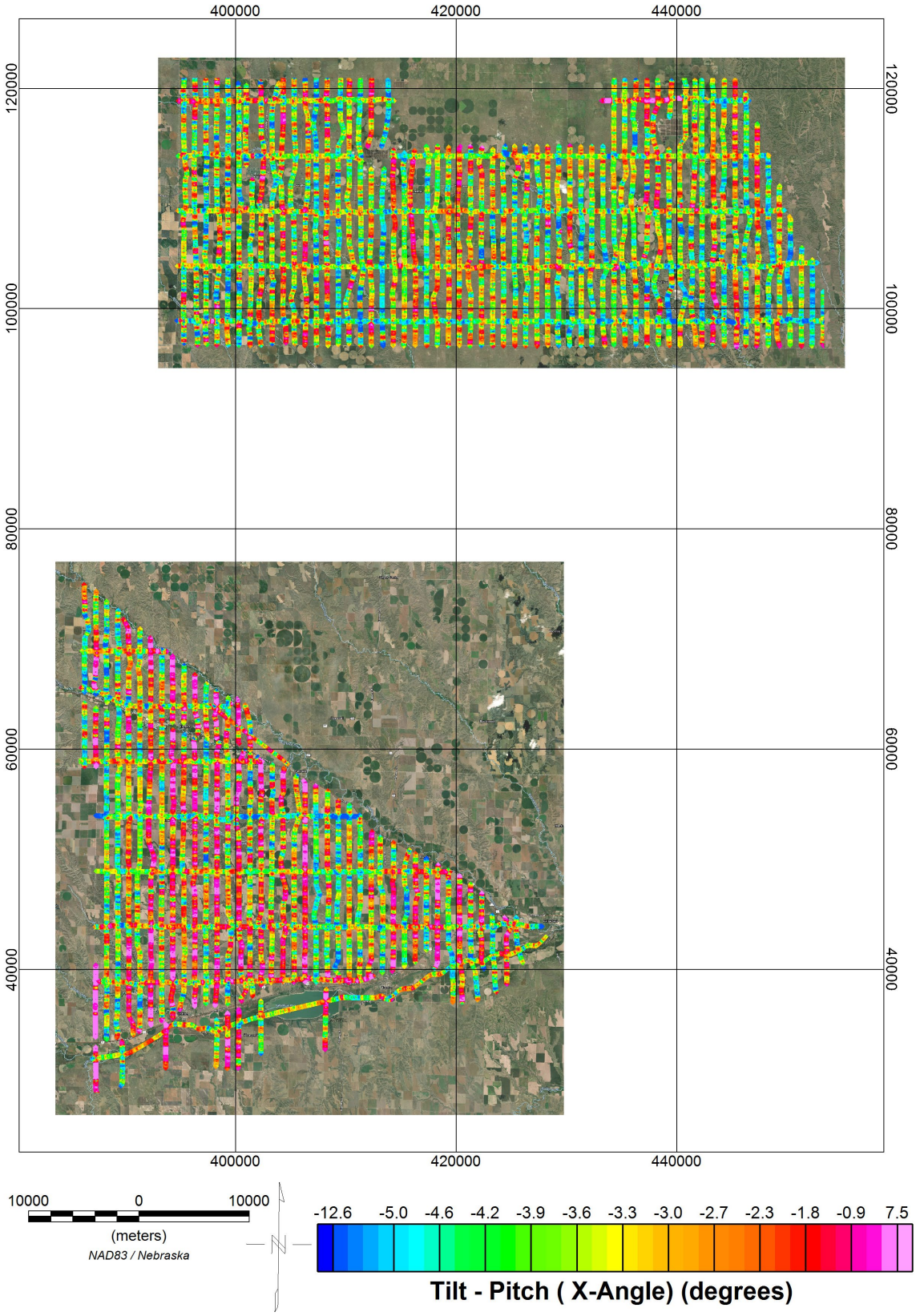


Figure 6. Map of the X-direction tilt (pitch) recorded during the 2024 MRNRD AEM survey. Map projection is NAD83 Nebraska State Plane, meters.

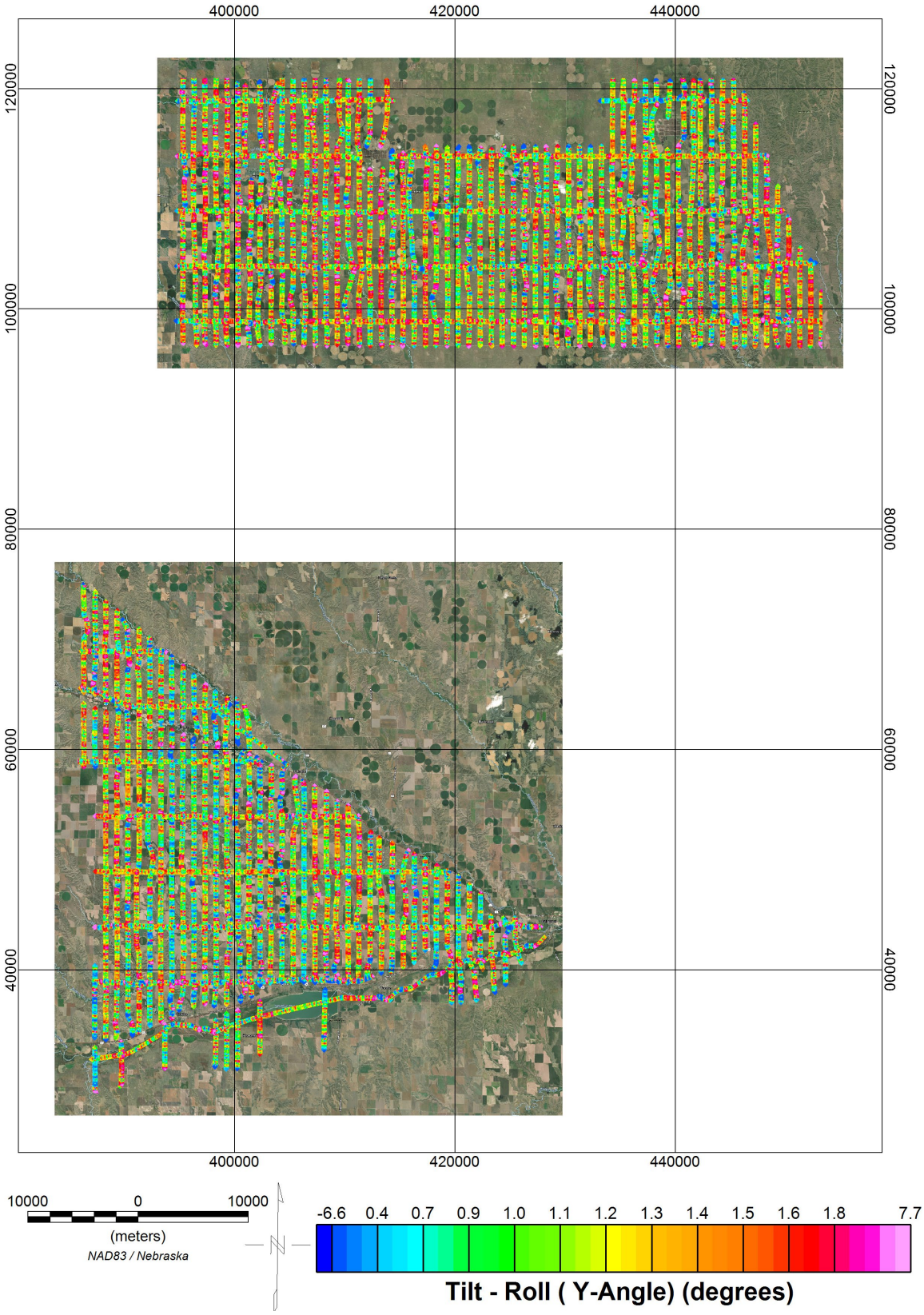


Figure 7. Map of the Y-direction tilt (roll) recorded during the 2024 MRNRD AEM survey. Map projection is NAD83 Nebraska State Plane, meters.

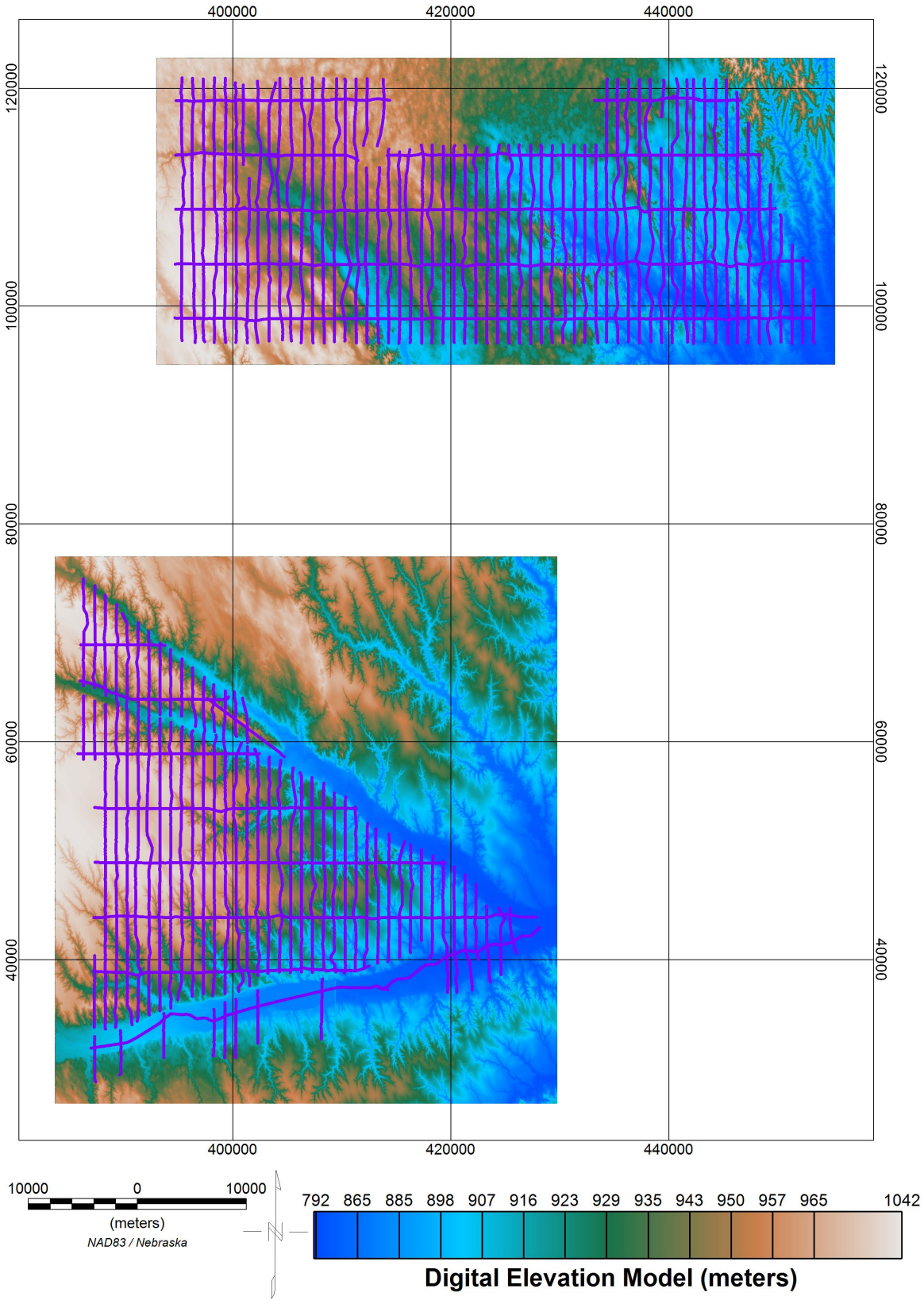


Figure 8. Map of the topography of the 2024 MRNRD AEM survey area. Map projection is NAD83 Nebraska State Plane, meters.

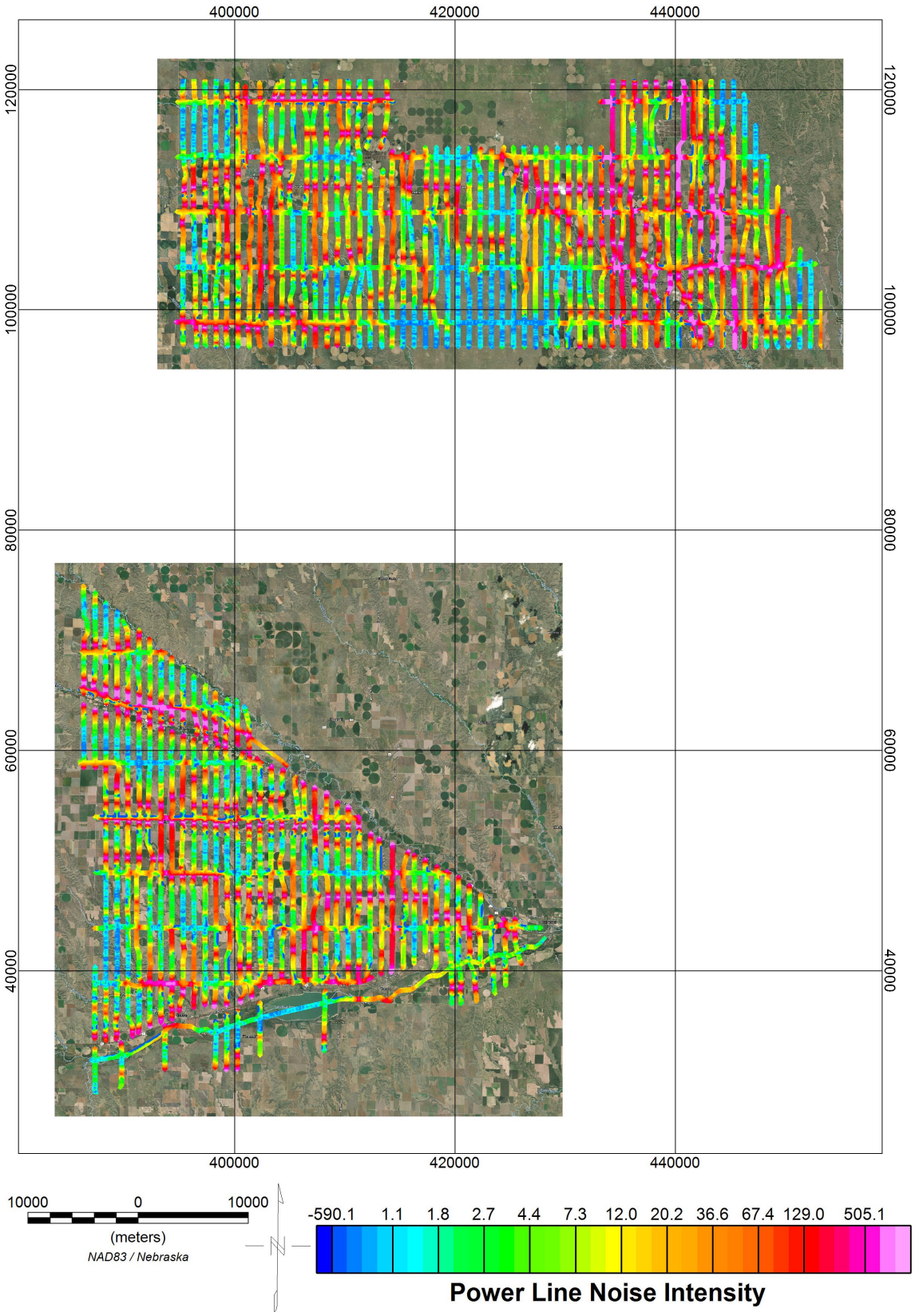


Figure 9. Power Line Noise Intensity (PLNI) for the 2024 MRNRD AEM survey area. Map projection is NAD83 Nebraska State Plane, meters.

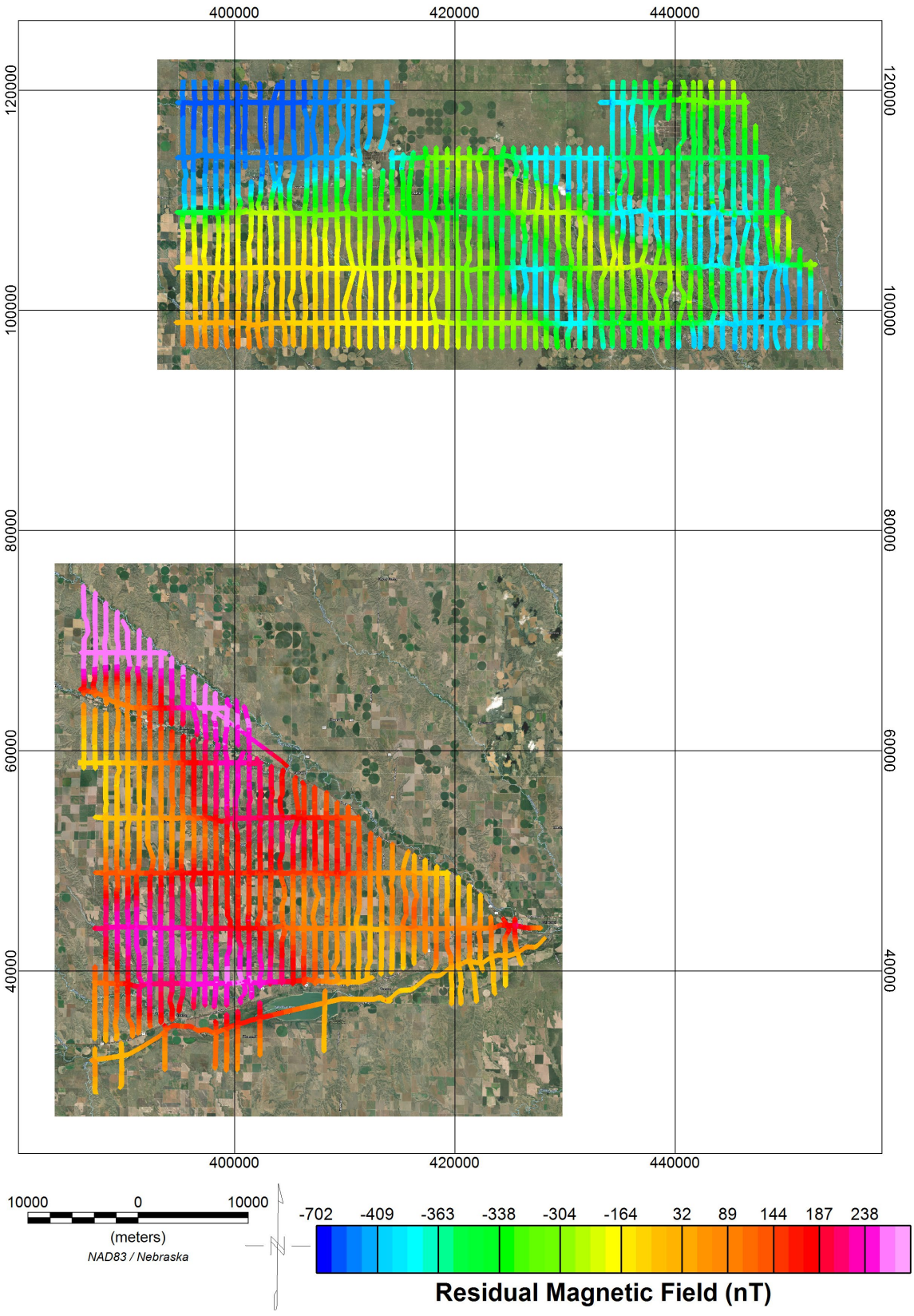


Figure 10. Residual magnetic Total Field strength for the 2024 MRNRD AEM survey area. Map projection is NAD83 Nebraska State Plane, meters.

4.0 Processing and Laterally- and Spatially-Constrained Inversions

4.1 Primary Field Compensation

A standard SkyTEM data acquisition procedure involves review of acquired raw data by SkyTEM for Primary Field Compensation (PFC) prior to continued data processing by AGF (Schamper et al., 2014). The primary field of the transmitter affects the recorded early time gates which, in the case of the Low Moment (LM), are helpful in resolving the near surface resistivity structure of the ground. The LM waveform is calculated and then used in the PFC correction to correct the early time gates.

4.2 Automatic Processing

The AEM data collected by the SkyTEM304M were processed using Aarhus Workbench version 6.9.0.0 (at Aarhus Geosoftware (https://www.aarhusgeosoftware.dk/aarhus-workbench) described in HydroGeophysics Group, Aarhus University (2011).

Automatic processing algorithms provided within the Workbench program are initially applied to the AEM data. Differential global positioning system (DGPS) locations were filtered using a stepwise, second-order polynomial filter of seven seconds with a beat time of 0.5 second, based on flight acquisition parameters. The AEM data are corrected for tilt deviations from level and so filters were also applied to both tilt meter readings with a median filter of three seconds and an average filter of two seconds. The altitude data were corrected using a series of two polynomial filters. The lengths of both eighth-order polynomial filters were set to 15 seconds with shift lengths of 12 seconds. The lower and upper thresholds were 1 and 100 meters, respectively.

Trapezoidal spatial averaging filters were next applied to the AEM data. The times used to define the trapezoidal filters for the LM were $1.0x10^{-5}$ sec, $1.0x10^{-4}$ sec, and $1.0x10^{-3}$ sec with widths of 3, 6, and 18 seconds. The times used to define the trapezoid for the High Moment (HM) were $1.0x10^{-4}$ sec, $1.0x10^{-3}$ sec, and $1.0x10^{-2}$ sec with widths of 3, 6, and 18 seconds. The trapezoid sounding distance was set to 1.0 seconds and the left/right setting, which requires the trapezoid to be complete on both sides, was turned on. The spike factor and minimum number of gates were both set to 20 percent for both soundings. Lastly, the locations of the averaged soundings were synchronized between the two moments.

4.3 Manual Processing and Laterally-Constrained Inversions

After the implementation of the automatic filtering, the AEM data were manually examined using a sliding two-minute time window. The data were examined for possible electromagnetic coupling with surface and buried utilities and metal (Figure 9), as well as for late time-gate noise. Data affected by these were removed. Areas were also cut out where the system height was flown greater than approximately 65 m (213 ft) above the ground surface which caused too great a decrease in the signal level (Figure 4).

The AEM data were then inverted using a LCI algorithm (HydroGeophysics Group Aarhus University, 2011). The profile and depth slices were examined, and any remaining electromagnetic couplings were masked out of the data set. Vertical constraints on the resistivity were set at 2.7 and at 1.6 for the horizontal resistivity constraints with a reference distance of 100 m (328 ft).

Borehole data were gathered from both the Nebraska Department of Natural Resources (NE-DNR) Registered Well Database (NE-DNR, 2024) and Nebraska School of Natural Resources Conservation and Survey Division (CSD) Nebraska Statewide Test Hole Database (UNL, 2024a). These boreholes were used in the QA/QC process to determine the system's calibration and ability to resolve the formations, geological units, and lithologies of interest. These do not serve as interpretations but only as checks in the acquisition and inversion process. Figure 11 is a map of Block 4 and Figure 12 is a map of Block 3 displaying the locations of NE-DNR and CSD lithology and stratigraphy logged-boreholes.

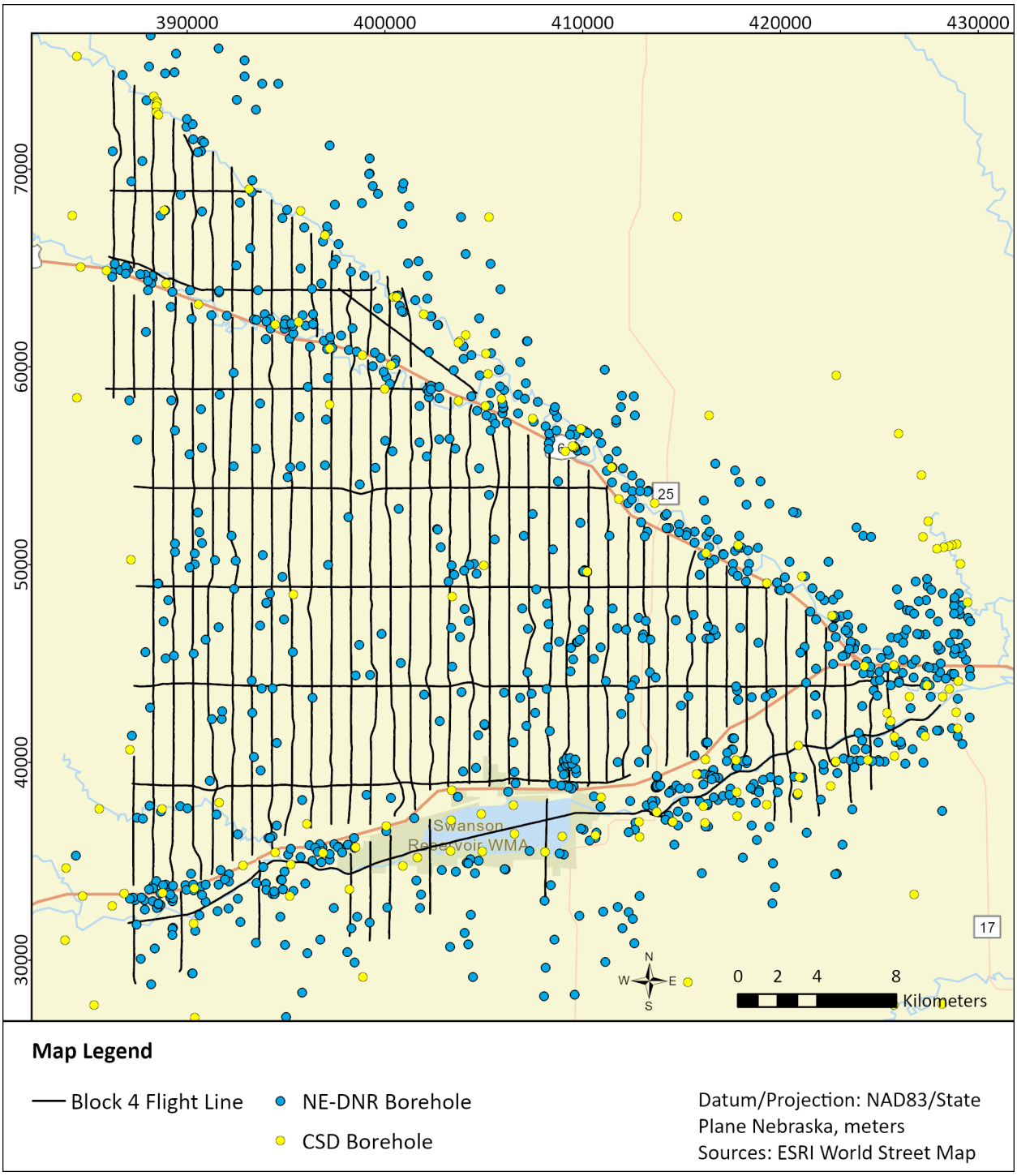


Figure 11. Map of the MRNRD flight lines (black lines) with the Nebraska Department of Natural Resources (NE-DNR) and Conservations and Survey Division (CSD) boreholes indicated. Map projection is NAD83 Nebraska State Plane, meters.

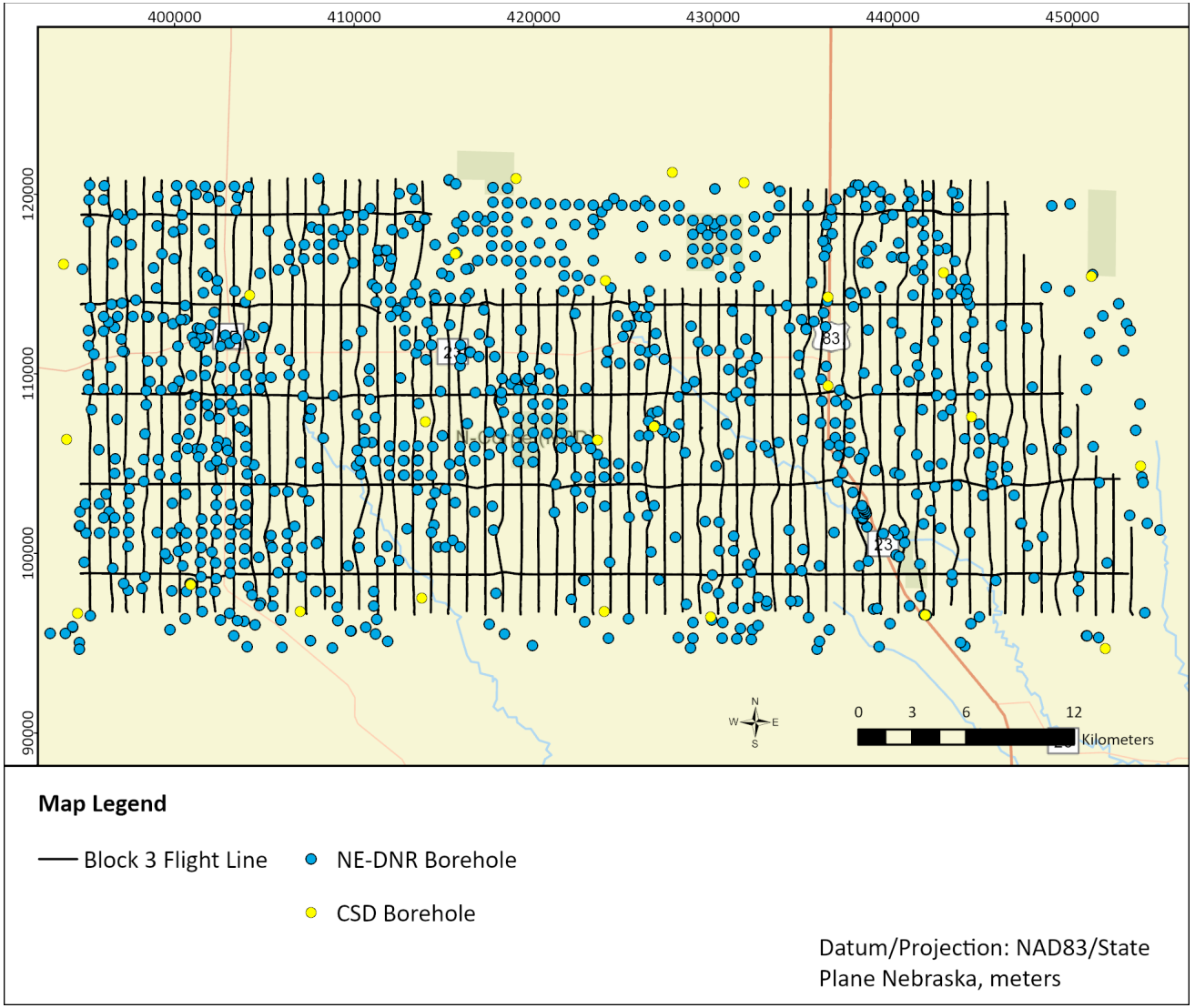


Figure 12. Map of the MRNRD flight lines (black lines) with the Nebraska Department of Natural Resources (NE-DNR) and Conservations and Survey Division (CSD) boreholes indicated. Map projection is NAD83 Nebraska State Plane, meters.

4.4 Spatially-Constrained Inversions

Following the initial decoupling and LCI analysis, Spatially-Constrained Inversions (SCI) were performed. SCIs use EM data along, and across, flight lines within user-specified distance criteria (Viezzoli et al., 2008).

The 2024 MRNRD data were inverted using SCI smooth models with 40 layers, each with a starting resistivity of 10 ohm-m (equivalent to a 10 ohm-m halfspace). The thicknesses of the first layers of the models were about 6 ft (2 m) with the thicknesses of the consecutive layers increasing by a factor of about 1.08. The depths to the bottoms of the 39th layers were set to 1,066 ft (325 m), with thicknesses up to about 93 ft (28 m). The thicknesses of the layers increase with depth (Table 4-1) as the resolution of the technique decreases. The spatial reference distance, ***s***, for the constraints was set to 328 ft (100 m) with power law falloff of 0.75. The vertical and lateral constraints, ***ResVerSTD*** and ***ResLatStD***, were set to 2.4 and 1.4, respectively, for all layers.

After final processing, 2,310.4 line-km (1,435.9 line-miles) of data were retained for the final inversions for the MRNRD survey. This amounts to a data retention of about 90.9%. This high retention percentage is due to the careful optimization of flight line design for the MRNRD AEM surveys. An image of the comparison between the as-flown and the data retained for inversion is presented in Figure 13.

In addition to the recovered resistivity models the SCIs also produce data residual error values (single sounding error residuals) and Depth of Investigation (DOI) estimates. The data residuals compare the measured data with the response of the individual inverted models (Christensen et al., 2009). The DOI provides a general estimate of the depth to which the AEM data are sensitive to changes in the resistivity distribution at depth (Christiansen and Auken, 2012). Two DOI's are calculated: a "Conservative" DOI at a cumulative sensitivity of 1.2 and a "Standard" DOI set at a cumulative sensitivity of 0.6. A more detailed discussion on the DOI can be found in Asch et al. (2015).

Figure 14 presents a histogram of the 2024 MRNRD Block 3 SCI inversion data/model residuals and a similar histogram of the SCI for Block 4 is presented in Figure 15. A map of the data/model residuals for the 2024 MRNRD AEM study area is presented in Figure 16. The histogram shows a good tight distribution of the inversion residuals with no obvious bias. The map of the residuals clearly shows the areas around the powerlines and the infrastructure are causing the increased noise in the inversions. Any residual below 1.0 is below the errors of the stacking of the raw AEM signals and is considered to be within the data error window. The areas above 1.0 are generally caused by increased noise from EM couplings, but are still usable as long as caution is exercised in interpretation of deeper structures.

Table 4-1. Thickness and depth to bottom for each layer, in meters and feet, in the Spatially Constrained Inversion (SCI) AEM earth models. The thickness of the model layers increases with depth as the resolution of the AEM technique decreases.

Layer	Depth to Bottom (ft)	Thickness (ft)	Depth to Bottom (m)	Thickness (m)	Layer	Depth to Bottom (ft)	Thickness (ft)	Depth to Bottom (m)	Thickness (m)
1	6.6	6.6	2.0	2.0	21	276.8	23.0	84.3	7.0
2	13.6	7.0	4.1	2.1	22	301.2	24.4	91.8	7.5
3	21.0	7.4	6.4	2.3	23	327.3	26.0	99.7	7.9
4	28.9	7.9	8.8	2.4	24	355.0	27.7	108.2	8.4
5	37.4	8.4	11.4	2.6	25	384.5	29.5	117.2	9.0
6	46.3	9.0	14.1	2.7	26	415.9	31.4	126.7	9.6
7	55.9	9.6	17.0	2.9	27	449.3	33.4	136.9	10.2
8	66.1	10.2	20.1	3.1	28	484.9	35.6	147.8	10.9
9	76.9	10.8	23.4	3.3	29	522.8	37.9	159.3	11.6
10	88.4	11.5	26.9	3.5	30	563.2	40.4	171.6	12.3
11	100.7	12.3	30.7	3.7	31	606.1	42.9	184.7	13.1
12	113.8	13.1	34.7	4.0	32	651.9	45.7	198.7	13.9
13	127.7	13.9	38.9	4.2	33	700.6	48.7	213.5	14.8
14	142.5	14.8	43.4	4.5	34	752.4	51.8	229.3	15.8
15	158.3	15.8	48.2	4.8	35	807.6	55.2	246.1	16.8
16	175.1	16.8	53.3	5.1	36	866.3	58.8	264.0	17.9
17	192.9	17.9	58.8	5.4	37	928.9	62.5	283.1	19.1
18	212.0	19.0	64.6	5.8	38	995.5	66.6	303.4	20.3
19	232.2	20.3	70.8	6.2	39	1066.4	70.9	325.0	21.6
20	253.8	21.6	77.3	6.6					

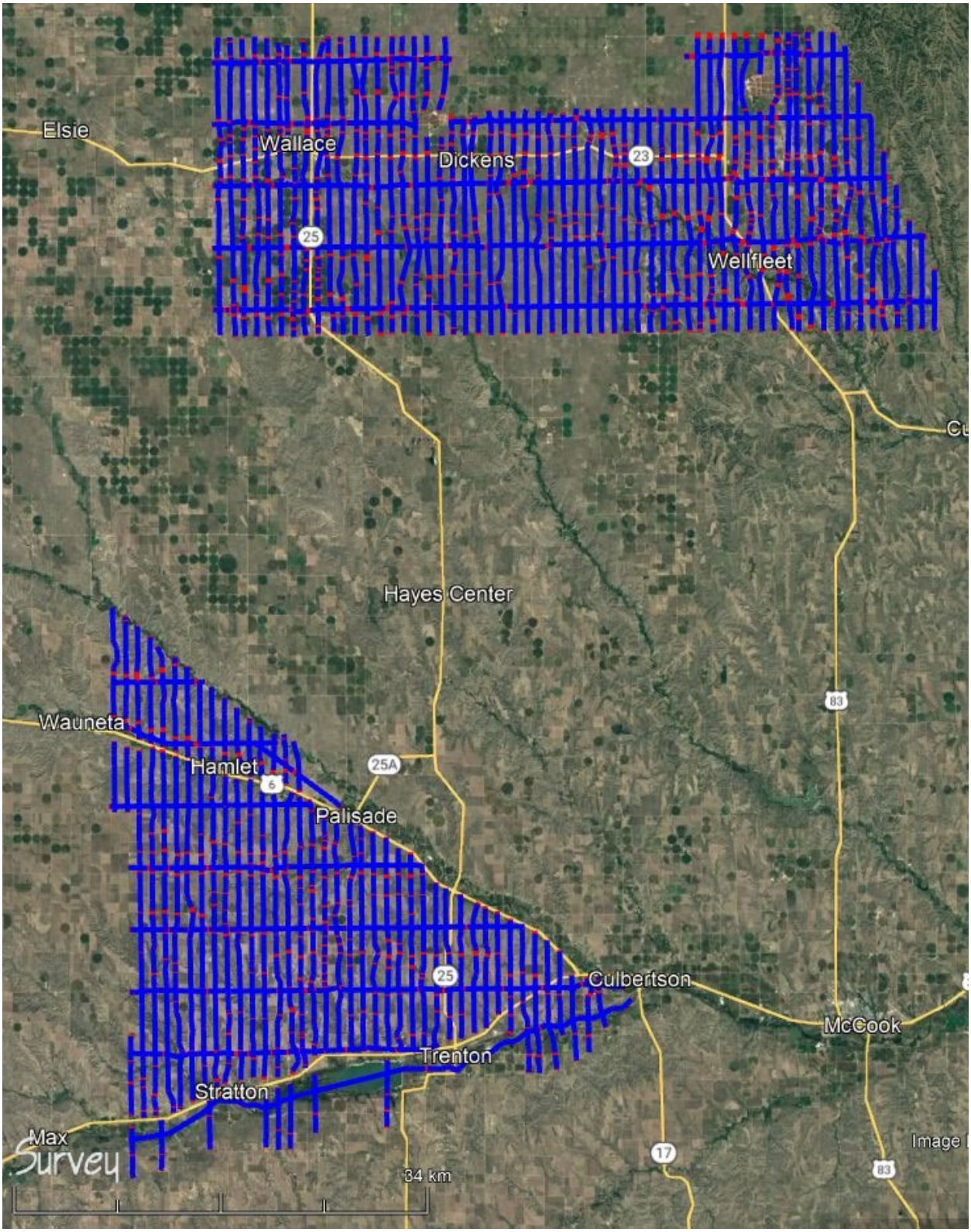


Figure 13. Locations of inverted data (blue lines) along the AEM flight lines (red lines) in the 2024 MRNRD survey area plotted in Google Earth. Where blue lines are not present indicates decoupled (removed) data. These data are included as Google Earth KMZ files in Appendix 3.

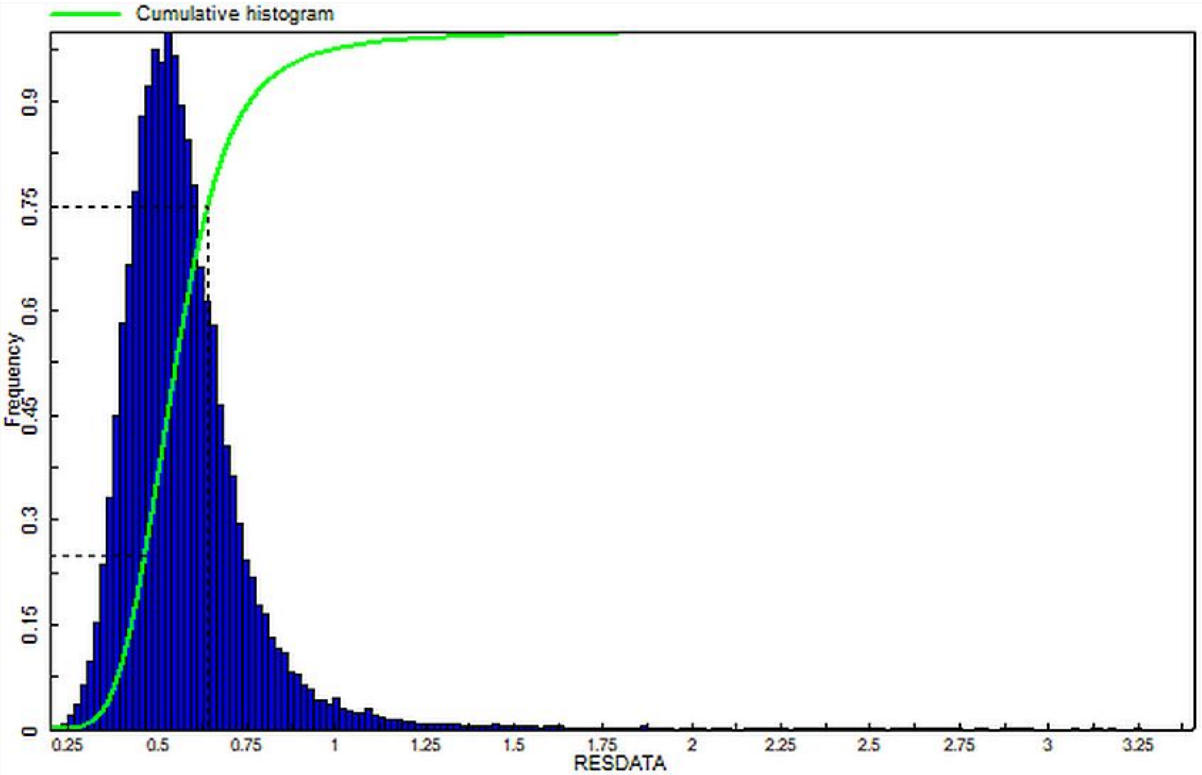


Figure 14. Data/model residual histogram for the 2024 MRNRD Block 3 SCI inversion results. The average ResData for the 2024 Block 3 MRNRD Spatially-Constrained Inversion equals 0.61.

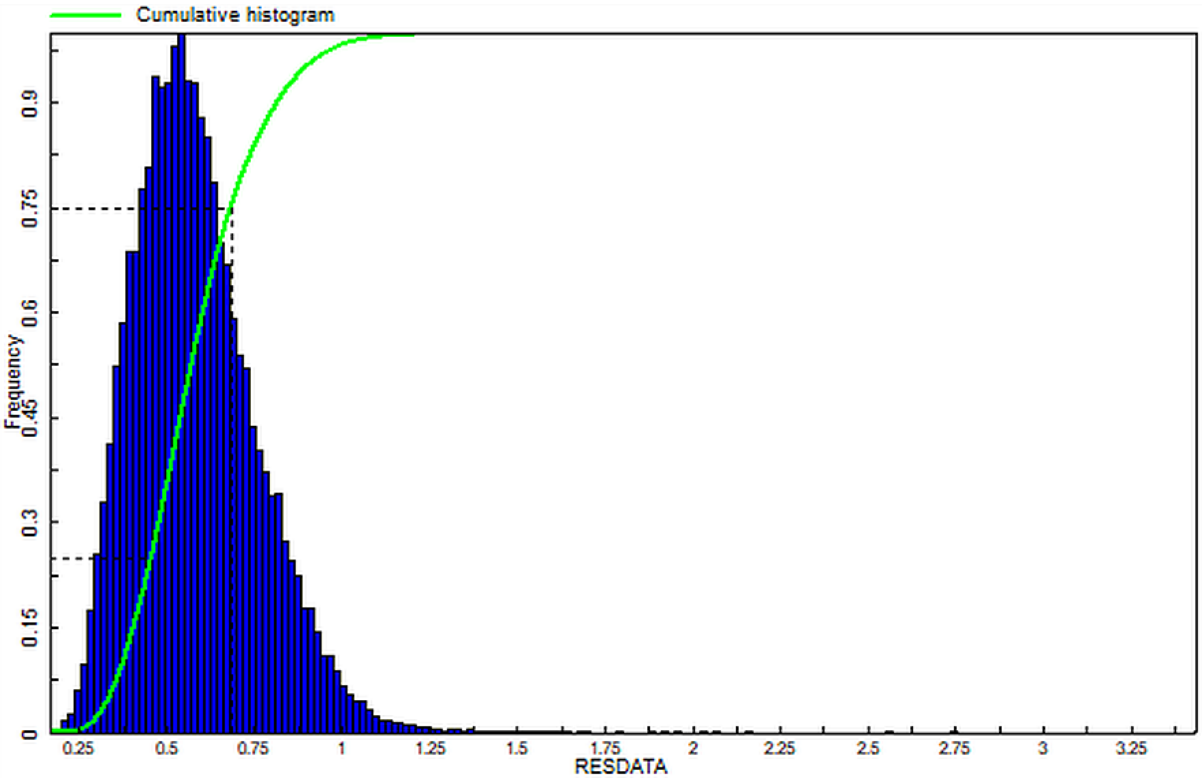


Figure 15. Data/model residual histogram for the 2024 MRNRD Block 4 SCI inversion results. The average ResData for the 2024 Block 3 MRNRD Spatially-Constrained Inversion equals 0.61.

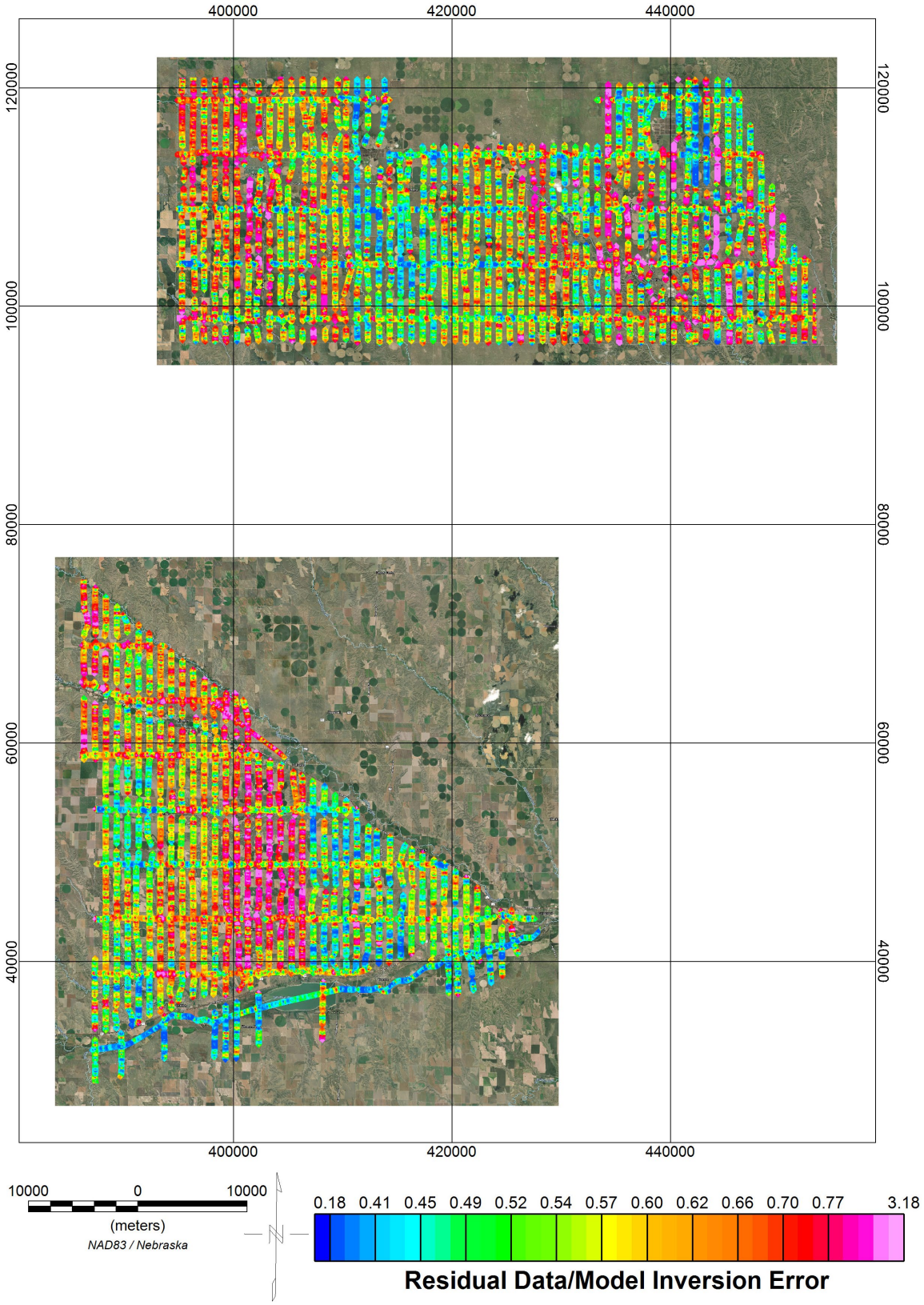


Figure 16. Map of data residuals for the 2024 MRNRD AEM SCI inversion results plotted with an Esri Satellite background. These data are included as a Google Earth KMZ file in Appendix 3.

5.0 Profiles and 3D Images

Two-dimensional (2D) and three-dimensional (3D) images of the final SCI inversion results have been developed using Datamine Discover Profile Analyst (DatamineDiscover, 2024). The 2D profiles were constructed so that each one has a small index map showing the location of the survey with the red line indicating the current profile being displayed. The resistivity color scale is in log-space and stretches from 10 to 100 ohm-m. Each profile is a unique length and the profiles are fitted with the size of the profile page. Examples of east-west and north-south lines within Block 3 are presented in Figure 17 (east-west 2D profile L200201) and Figure 18 (north-south 2D profile L101101). Examples of east-west and north-south lines within Block 4 are presented in Figure 19 (east-west 2D profile L400401) and Figure 20 (north-south 2D profile L302201). Boreholes from the CSD Nebraska Statewide Test Hole Database (UNL, 2024a), and Nebraska Department of Natural Resources (NE-DNR) Registered Well Database (NE-DNR, 2024) used in the QA/QC process are plotted on the figures when they are within 500 meters of the flight line. On curved lines the projection line is from the ends of the flight line and may not accurately reflect the 500-meter projection distance. The lithology color scale is from the recommendation from the Nebraska Geocloud (UNL, 2024b). 3D fence diagrams were constructed from the 2D profiles using a vertical exaggeration of 1:10. An example 3D fence diagram is presented in Figure 21 for Block 3 and Figure 22 for Block 4 with views to the north with the same resistivity color scale used in the 2D Profiles

Inspection of the profiles indicates that the SkyTEM system was performing within specification and the inversions were successful. The MRNRD AEM survey area is characterized by conductive to resistive materials of Quaternary (***Q***) with resistivities ranging from approximately 20 to 500 ohm-m. These ***Q*** deposits are overlaying the Tertiary Ogallala Group (***To***) with relatively resistive materials ranging from 15 to 100 ohm-m. Care will need to be used to separate out the ***Q*** from the ***To*** using boreholes and geological knowledge of the area. The basement of the area is predominantly Cretaceous Pierre Shale (***Kp***) with low resistivities on the order of 3-15 ohm-m. This provides both a hydrogeological as well as a geophysical basement in the area. On the southeastern side of the survey area, the ***Kp*** is eroded off and the basement is the more resistive Cretaceous Niobrara Formation (***Kn***) with resistivities in the range of 20-40 ohm-m. The ***Kn*** is the bedrock unit in approximately 1/3 of the survey area. Below the ***Kn*** there appears to be a low resistivity unit that may be the Cretaceous Carlile Shale (***Kc***). However, both the ***Kn*** and the ***Kc*** are below the Depth of Investigation (DOI) as indicated by the gray dashed lines in many areas. Using the borehole information, the top of the ***Kn*** should be interpretable. The basic geology and hydrology are summarized in Korus and Howard (2019). They provide the original references to the geological mapping in the area. Further interpretation will occur in the future as part of a University of Nebraska Conservation Survey Division led project.

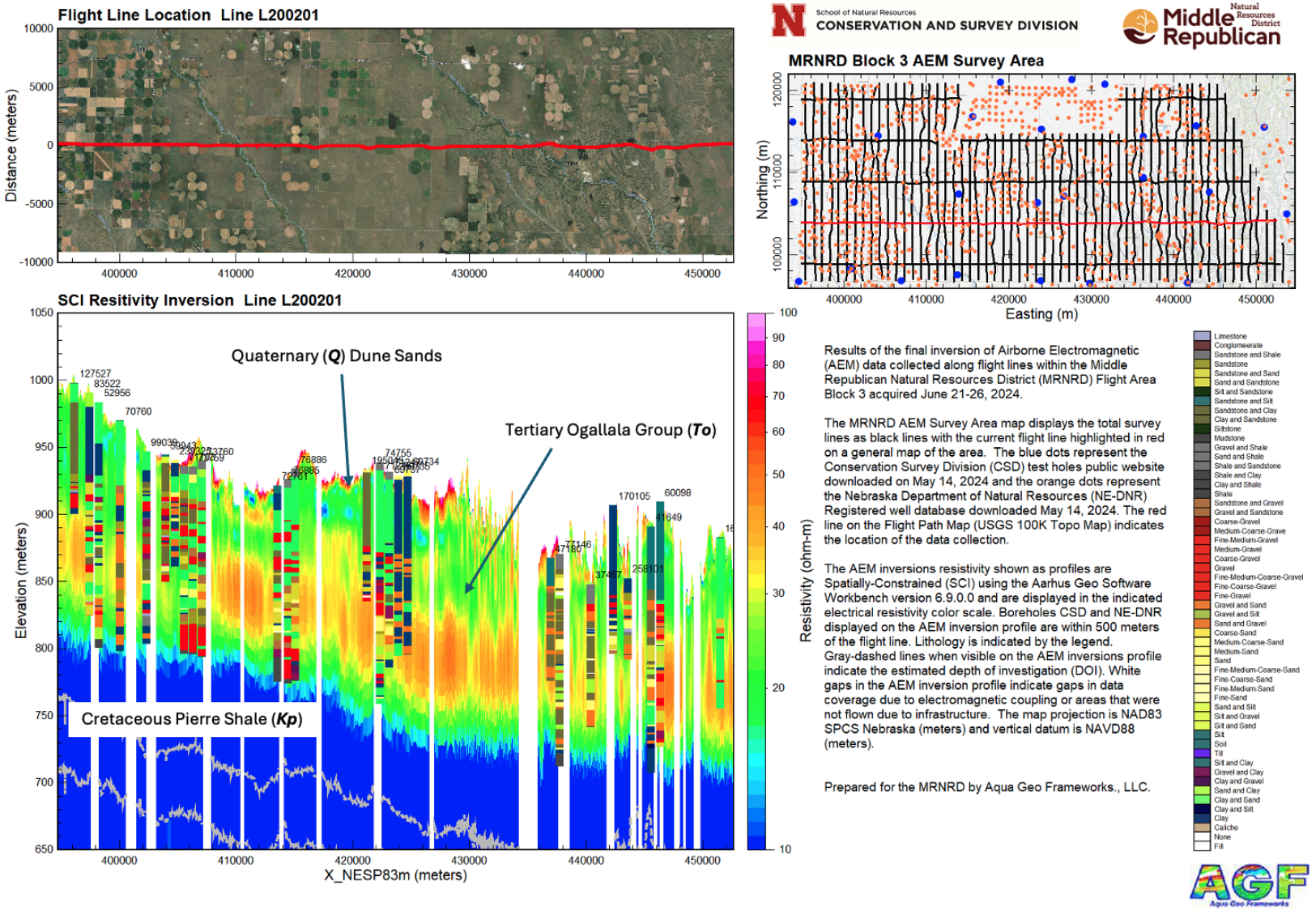


Figure 17. Example of 2D profile displaying the final SCI results of the 2024 MRNRD Block 3 AEM survey along an approximately east-west flight line, L200201. The resistivity and lithology color scales are on the right side of the profile. The MRNRD SCI inversion results plotted as 2D profiles are included in *Appendix 1 – 2D Profiles*.

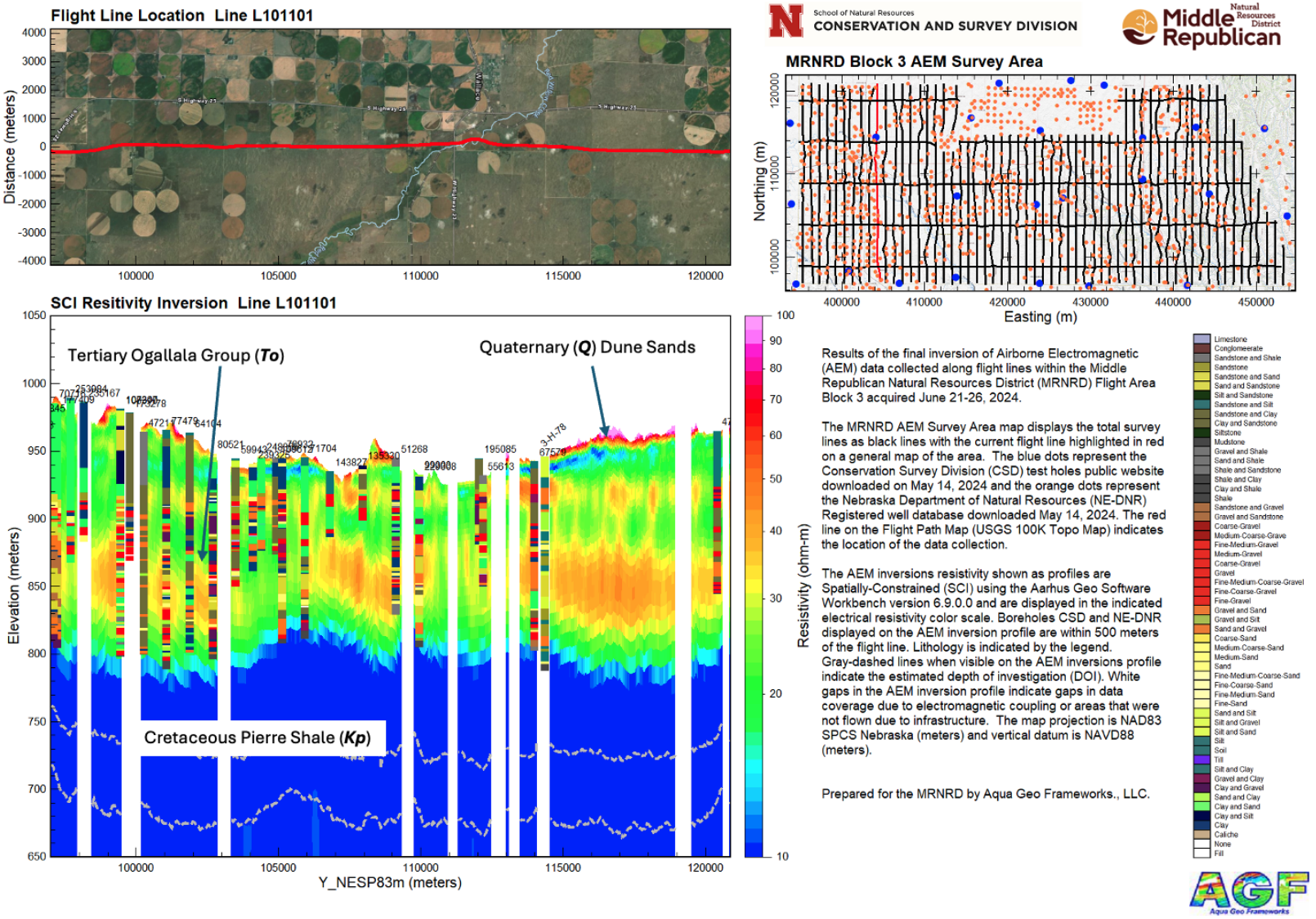


Figure 18. Example of 2D profile displaying the final SCI results of the 2024 MRNRD Block 3 AEM survey along a north-south flight line, L101101. The resistivity color scale is on the right side of the profile. The MRNRD SCI inversion results plotted as 2D profiles are included in *Appendix 1 – 2D Profiles*.

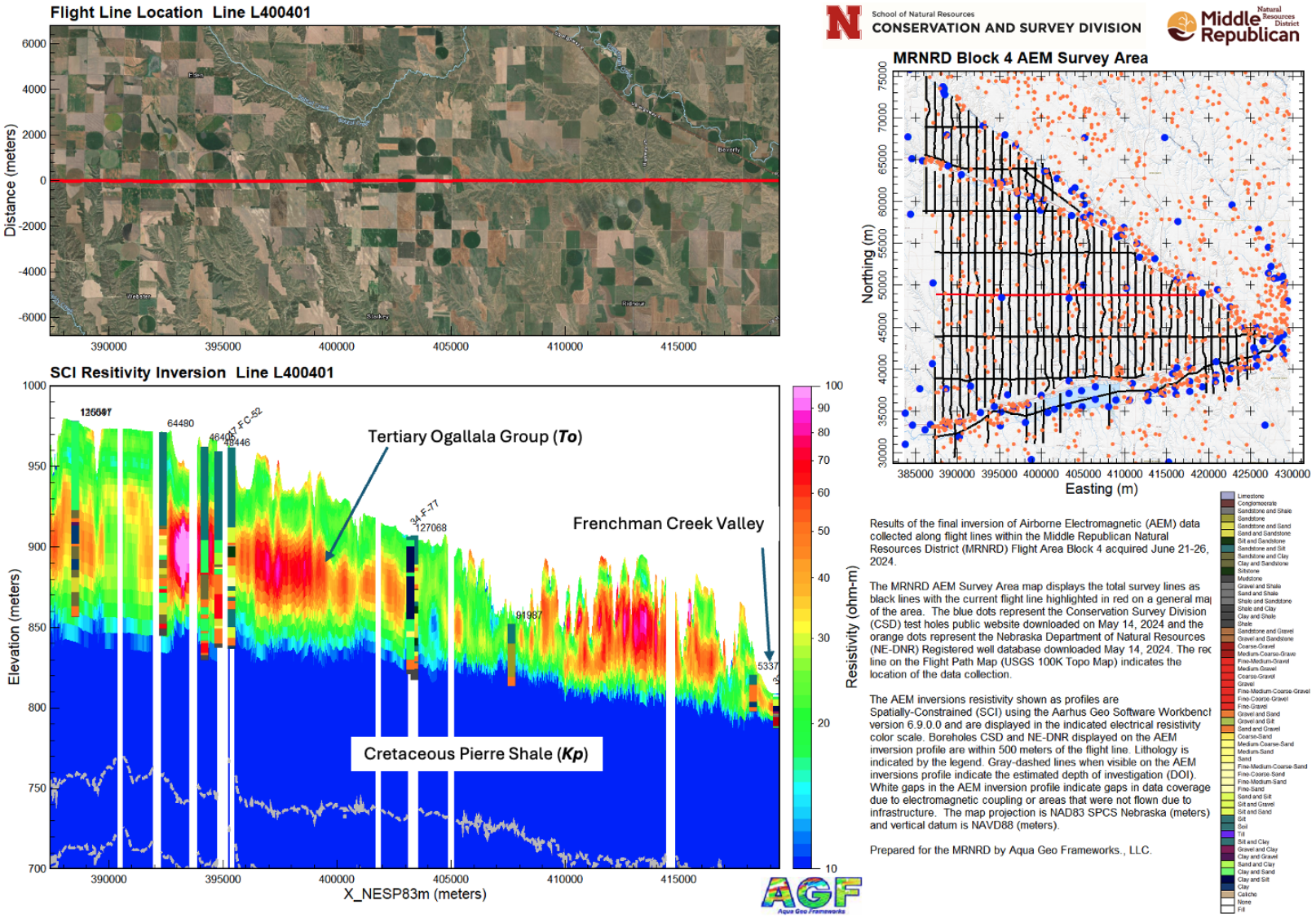


Figure 19. Example of 2D profile displaying the final SCI results of the 2024 MRNRD Block 4 AEM survey along an approximately east-west flight line, L400401. The resistivity and lithology color scales are on the right side of the profile. The MRNRD SCI inversion results plotted as 2D profiles are included in *Appendix 1 – 2D Profiles*.

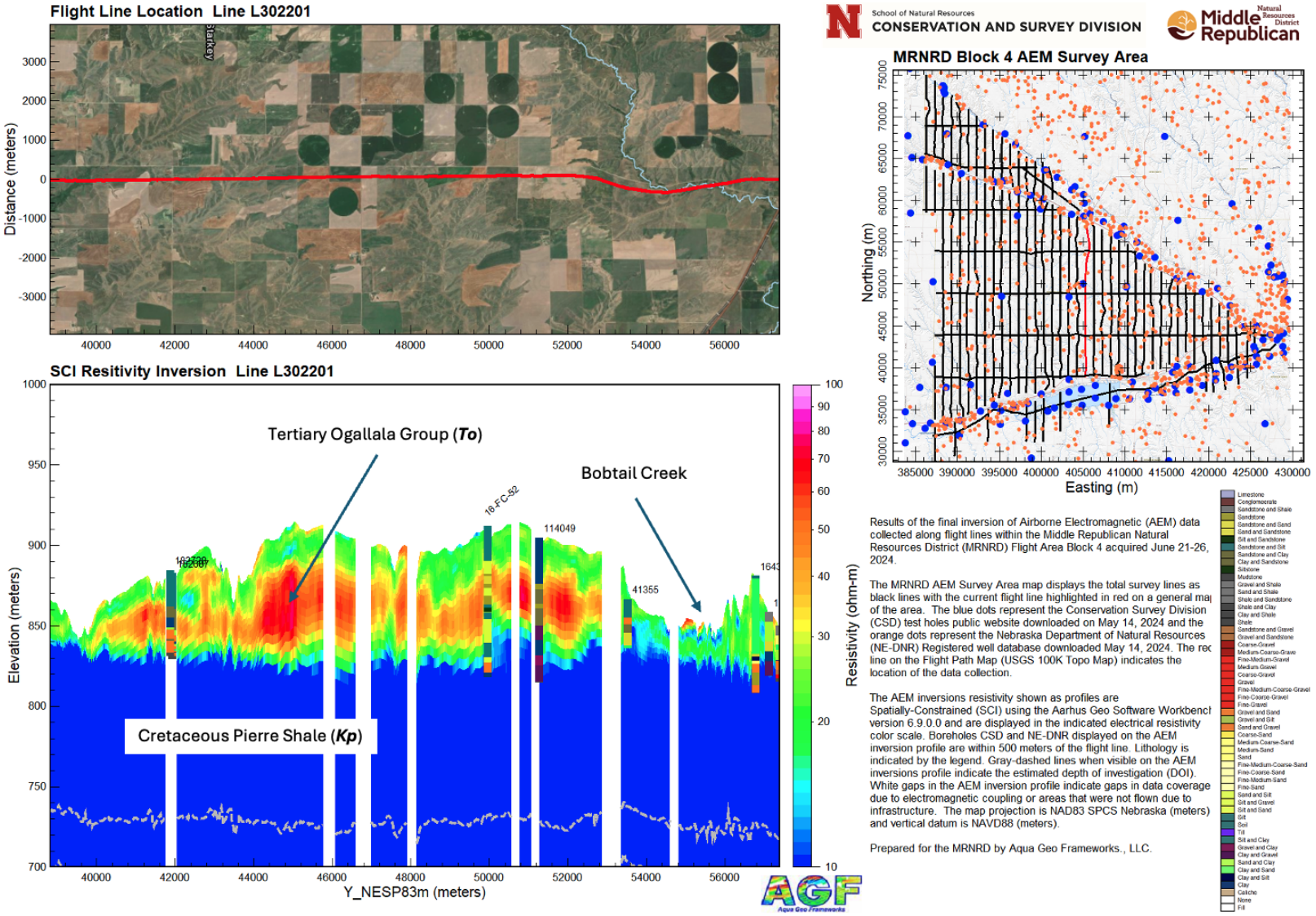


Figure 20. Example of 2D profile displaying the final SCI results of the 2024 MRNRD Block 4 AEM survey along a north-south flight line, L302201. The resistivity color scale is on the right side of the profile. The MRNRD SCI inversion results plotted as 2D profiles are included in *Appendix 1 – 2D Profiles*.

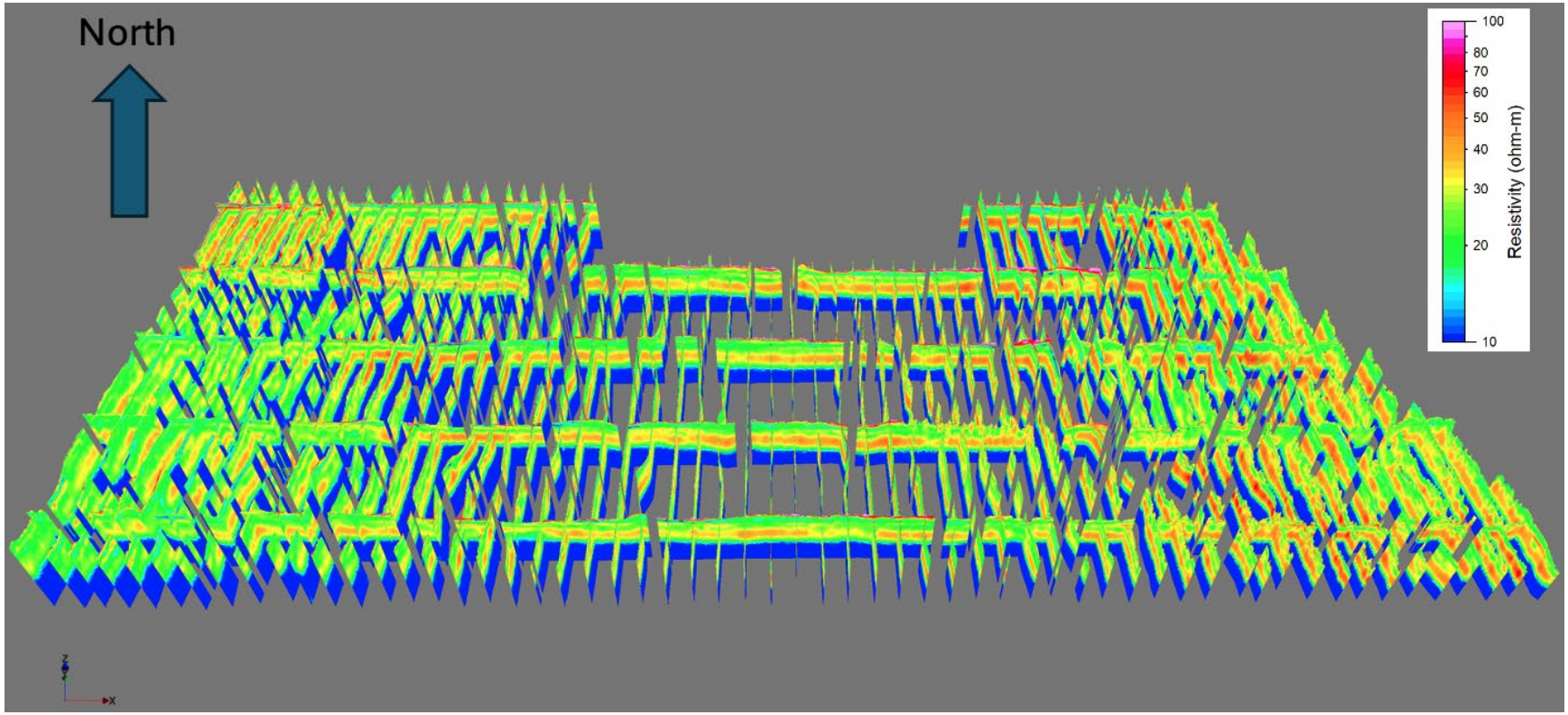


Figure 21. Example of 3D fence diagram displaying the final SCI results of the 2024 MRNRD Block 3 AEM survey. The view is to the north. The color scale is the same as for the profiles. The MRNRD SCI inversion results plotted as 3D fence diagrams are included in *Appendix 2 – 3D Images*.

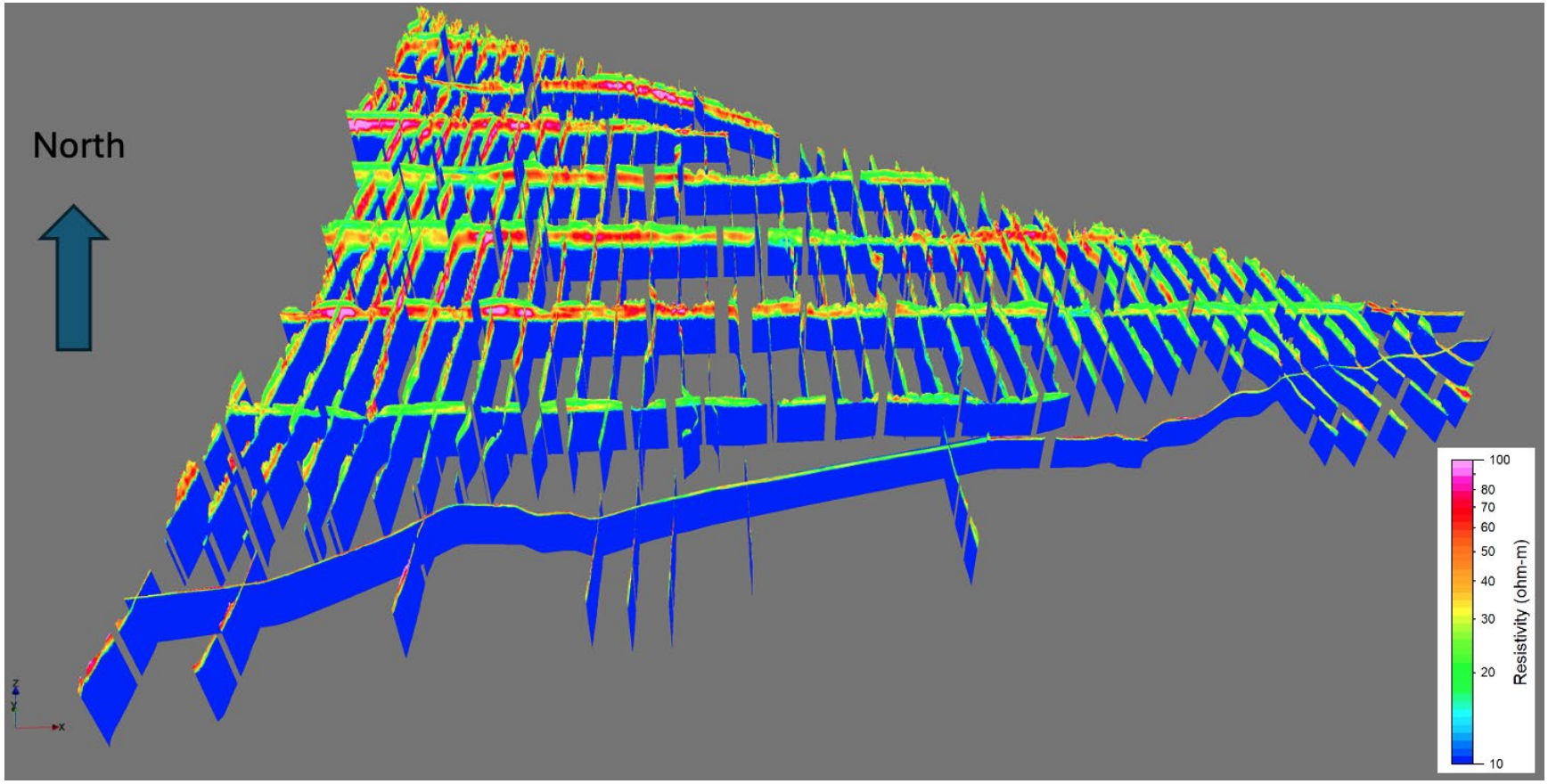


Figure 22. Example of 3D fence diagram displaying the final SCI results of the 2024 MRNRD Block 4 AEM survey. The view is to the north. The color scale is the same as for the profiles. The MRNRD SCI inversion results plotted as 3D fence diagrams are included in *Appendix 2 – 3D Images*.

6.0 Summary

This report presents the final SCI for the 2024 AEM survey of Block 3 and Block 4 of the MRNRD as 2D resistivity profiles and as 3D fence diagrams. The complete collection of the 2D SCI profiles is contained in Appendix 1 – 2D Profiles and the 3D fence diagrams, viewed from multiple angles, are contained in Appendix 2.

In addition, the processed data and the SCI inversion results are presented as ASCII xyz files. Google Earth KMZ files of the As Flown flight lines, the data retained for inversion, and the inverted residual data model error have also been provided. All the raw SkyTEM data are included with the Aarhus Geosoftware Workbench v.6.9.0.0 Workspace files that are included in the deliverable as Workbench session WB_MRNRD2024. In addition, a GeoScene3D Project has been created to facilitate the interpretation of the inversions by CSD. A link to the DropBox location of these data files is presented in the report Transmittal Letter.

As discussed on previous occasions, we believe that these results provide a good, solid starting point for development of a hydrogeologic framework in the MRNRD AEM survey area.

7.0 Deliverables

The data report and deliverables provided by SkyTEM describing the MRNRD2024 AEM survey and system acquisition parameters is also included in *Appendix-3 - Deliverables* under *From_SkyTEM*. The format of what is in the *Appendix 3 - Deliverables**From_SkyTEM* folder is listed in Table 7-1.

Table 7-2 describes the raw data files included in the zip file in Appendix-3 - Deliverables\From_SkyTEM\ that were delivered by SkyTEM. As discussed above, fourteen (14) flights were required to acquire the 2024 MRNRD AEM data (Table 3-1). Grouped by flight date, there are four (4) native-format data files for each flight in the 01_RawData section. These files have extensions of ".sps" and ".skb". The ".sps" files include navigation and DGPS location data and the ".skb" files include the raw AEM data that have been PFC-corrected (discussed in Section 4.1). Two additional files are used for all the flights. These are the system description and specifications file (with the extension "*.gex") and the 'mask' file (with the extension "*.lin") which correlates the flight dates, flight numbers, and assigned line numbers in the 02_MASK_GEX subdirectory. The original gex and lin files were slightly modified prior to import of the raw skb data into WorkBench.

Table 7-3 describes the data columns in the processed ASCII EM_MAG *.xyz files for the MRNRD 2024 AEM survey area. This file, 20079_Nebraska_MRNRD_EM_MAG_FINAL_CSV.zip contains two Excel CSV files with the electromagnetic raw data plus the magnetic and navigational data as supplied from SkyTEM in an ASCII format (versus the Geosoft gdb format in the SkyTEM deliverable).

Table 7-4 lists the processed and edited AEM data used in the SCI inversion. Files BLK3_SCI01_MOD_dat.xyz and BLK4_SCI01_MOD_dat.xyz exported from the Aarhus Workbench from the final SCI inversion run. Each sounding consists of two rows of this table. The first being the Low Moment data and the second row being the High Moment data, which may be noted in the RECORD and and SEGMENT columns. The RECORD column indicates the sounding number. The SEGMENT column

indicates which channel (LM-1, HM-2) the data line refers to. Note also that the X and Y values are the same for both the LM and HM. Line 34 in the header of the MRNRD_SCI03_MOD_dat.xyz data file lists the time gates, in seconds, that match up with the dB/dt DATA array listed in Table 7-3. The *.dat files are located in *Appendix-3 – Deliverables\ProcessedData*.

The final SCI inversion results, BLK3_SCI01_inv and BLK4_SCI01_inv, are delivered as both Geosoft "gdb" and ASCII "xyz" files. The data columns of these databases are described in Table 7-5 (SCI) and are included in *Appendix-3 - Deliverables\SCI*. Table 7-6 describes the format of the MRNRD2024 SCI results organized into a Nebraska GeoCloud format.

AGF has also included an I-GIS GeoScene3D project (Table 7-7) containing the DEM and the AEM data for the MRNRD2024 survey. The project was built using GeoScene3D version 12.0.0.712. This was included to expedite the use of this data by CSD and other users of I-GIS GeoScene3D.

In addition, Google Earth KMZ files of the As Flown flight lines, the data retained for inversion, and the SCI residual data errors. These KMZ's can be found in *Appendix 3 – Deliverables\KMZ*s.

In the Appendix-3_Deliverables is the folder 'WorkBench' that contains a zip file created by 7-Zip, WB_MRNRD2024.zip, of the Aarhus Geosoftware v6.9.0.0 Workspace used to import, process, edit, and invert the data. The folder contains a zip file of the Workspace and also system description GEX and production LIN (lists the times and flight lines) files that were slightly modified prior to importation of the raw skb data. The changes made were the LoopType changed from 72 to 73, the CalculateRawDataSTD changed from 1 to 0, and the LM RemoveInitialGates changed from 7 to 5 in the standard gex file (not the SR2 gex). All the inversions are included in the WorkBench workspace.

In summary, the following are included as deliverables:

- Raw Data Files - SkyTEM files *.gex, *skb, *.lin
- Processed data used in the SCI inversion as an ASCII *.xyz
- SCI results including Geosoft database and ASCII *.xyz files
- SCI results in Nebraska GeoCloud import format
- Google Earth KMZ files of AsFlown, Retained, and BLK3 and BLK4 SCI01 ResData plots
- Aarhus Geosoftware Workbench Version 6.9.0.0 WB_MRNRD2022_CSD Workspace
- The SkyTEM delivery to AGF including all files and report
- IGIS GeoScene 3D projects for Block 3 and Block 4

Table 7-1. SkyTEM data delivery to AGF

Folder Name:	Description of files
01_RawData	SkyTEM provided raw data files as Workbench_SKB and SPS (Aarhus Workbench files), by Flight Date
02_MASK_GEX	SkyTEM production file (LIN) and system description files (GEX)
03_Geosoft	SkyTEM provided raw data in Geosoft format
04_Workbench_XYZ_Data	SkyTEM provided Workbench XYZ data in ASCII format
05_Report	SkyTEM report to AGF as a *.pdf

Table 7-2. Raw SkyTEM data files

Folder	File Name	Description
Data	..NavSys.sps, …PaPc.sps, ...RawData_PFC.skb, …DPGS.sps	Raw data files included for each flight used in importing to Aarhus Workbench
Geo	*.gex, SR2.gex & SR2.sr2.	SkyTEM304 System Description
Mask	*.lin	Production file listing dates, flights, and assigned line numbers

Table 7-3. Raw Data - Channel name, description, and units for 20079_Nebraska_MRNRD_EM_MAG_FINAL_CSV.zip with EM, magnetic, DGPS, Inclinometer, altitude, and associated data.

Parameter	Description	Unit
Line	Line Number	
X_NESP83m	Easting, Nebraska State Plane NAD83	Meters [m]
Y_ NESP83m	Northing, Nebraska State Plane NAD83	Meters [m]
X_UTM14Nm	Easting, WGS84 UTM Zone 14N	Meters [m]
Y_UTM14Nm	Northing, WGS84 UTM Zone 14N	Meters [m]
DEM_M	Digital Elevation	Meters [m]
Fid	Unique Fiducial Number	
Flight	Name of Flight	yyyymmdd.ff
DateTime	DateTime Format	Decimal days
Date	DateTime Format	yyyymmdd
Time	Time UTC	hhmmss.sss
AngleX	Angle (in flight direction)	Degrees
AngleY	Angle (perpendicular to flight direction)	Degrees
Height	Filtered Height Measurement	Meters [m]
Lon	Longitude, WGS84	Decimal Degrees
Lat	Latitude, WGS84	Decimal Degrees
Alt	DGPS Altitude above sea level	Meters [m]
GDSpeed	Ground Speed	Kilometers/hour [km/h]
LMcurrent	Current, Low Moment	Amps [A]
HMcurrent	Current, High Moment	Amps [A]
LM_Z_dBdt [Gates 0-27]	Normalized (PFC-Corrected) Low Moment Z-RxCoil value	pV/(m^4*A)
HM_Z_dBdt [Gates 0-36]	Normalized (PFC-Corrected) High Moment Z-RxCoil value	pV/(m^4*A)
HM_X_dBdt [Gates 0-36]	Normalized (PFC-Corrected) High Moment X-RxCoil value	pV/(m^4*A)
_60Hz_Intensity	Power Line Noise Intensity monitor	
bmag_Raw	Raw Base Station Mag Data filtered	nanoTesla [nT]
Diurnal	Diurnal Drift corrections	nanoTesla [nT]
Mag_raw	Raw Total Magnetic Field Intensity	nanoTesla [nT]
TMI	Total Field Magnetic Field Intensity	nanoTesla [nT]
RMF	Residual Magnetic Field	nanoTesla [nT]
IGRF	International Geomagnetic Reference Field	nanotesla (nT)
INC	Magnetic Inclination	degrees
DEC	Magnetic declination	degrees
RelUnc_LM_Z_dBdt	dB/dt Relative Uncertainty, LM Z	pV/(m^4*A)
RelUnc_HM_Z_dBdt	dB/dt Relative Uncertainty, HM Z	pV/(m^4*A)
RelUnc_HM_X_dBdt	dB/dt Relative Uncertainty, HM X	pV/(m^4*A)

Table 7-4. Processed Data Used in Inversion - Channel name, description, and units for BLK3_SCI01_MOD_dat.xyz and BLK4_SCI01_MOD_dat.xyz data files.

Parameter	Description	Unit
LINE_NO	Line Number	
UTMX	Easting WGS84, UTM Zone 14	Meters [m]
UTMY	Northing WGS84, UTM Zone 14	Meters [m]
DATE	Date	
TIME	Date Time Format	Decimal days
RECORD	Data record number, in two's	
ELEVATION	Recorded topography from system GPS	Meters [m]
ALTITUDE_A-PRIORI_[M]	Altitude of system above ground	Meters [m]
ALTITUDE_A-PRIORI_STD_[FACT]	Altitude STD of system above ground	Meters [m]
ALTITUDE_[M]	Inverted Altitude of system above ground	Meters [m]
ALTITUDE_STD_[FACT]	Inverted Altitude Standard Deviation of system above ground	Meters [m]
NUMDATA	Number of data in record	
SEGMENT	Waveform segment number	
RESDATA	Residual of individual sounding	
RESTOTAL	Total residual for inverted section	
DATA[1] THROUGH DATA[47]	dB/dt data for each channel	V/(A*m**4)
DATASTD[1] THROUGH DATASTD[47]	Standard Deviation for dB/dt data for each waveform resistivity error per layer	

NOTE: Line 34 in the header of the *_dat.xyz data files list the time gates, in seconds, that match up with the dB/dt DATA array listed in Table 7-3.

Table 7-5. Inversion Results - Channel name, description, and units for SCI\BLK3_SCI01_inv.gdb and xyz and BLK4_SCI01_inv.gdb and xyz.

Parameter	Description	Unit
LINE	Line Number	
X_UTM14Nm	Easting WGS84, UTM 14N	Meters [m]
Y_UTM14Nm	Northing WGS84, UTM 14N	Meters [m]
X_NESP83m	Easting, Nebraska State Plane NAD83	Meters
Y_NESP83m	Northing, Nebraska State Plane NAD83	Meters
DEM_M	Digital Elevation Model	Meters [m]
ALTITUDE_A_PRIORI__M_	Measured flight altitude	Meters (m)
ALTITUDE_A_PRIORI_STD	Standard Deviation of measured flight altitude	Meters (m)
ALTITUDE__M_	Inverted Altitude of system above ground	Meters [m]
ALTITUDE_STD	Inverted Altitude Standard Deviation of system above ground	Meters (m)
RESDATA	Residual of individual sounding	
RESTOTAL	Total residual for inverted section	
RHO[0] THROUGH RHO[38]	Inverted resistivity of each layer	Ohm-m
RHO_STD[0] THROUGH RHO_STD[38]	Inverted resistivity error per layer	
DEP_TOP[0] THROUGH DEP_TOP[38]	Depth to the top of individual layers	Meters (m)
DEP_BOT[0] THROUGH DEP_BOT[38]	Depth to the bottom of individual layers	Meters (m)
THK[0] THROUGH THK[38]	Thickness of individual layers	Meters (m)
DOI_UPPER	More conservative estimate of DOI (CumSens=1.2)	Meters (m)
DOI_LOWER	Less conservative estimate of DOI (CumSens=0.6)	Meters (m)

Table 7-6. ASCII SCI XYZ File for Nebraska GeoCloud Import: BLK3_SCI01_GeoCloud.xyz and BLK4_SCI01_GeoCloud.xyz

Parameter	Description	Unit
LINE	Line Number	
X_SP_FT	Easting Nebraska NAD83, State Plane	Feet (ft)
Y_SP_FT	Northing Nebraska NAD83, State Plane	Feet (ft)
DEM_FT	Elevation in Feet	Feet (ft)
X_NESP83m	Easting, Nebraska NAD83, State Plane	Meters [m]
Y_NESP83m	Northing, Nebraska NAD83, State Plane	Meters [m]
DEM_M	Elevation in Meters	Meters [m]
Altitude_FT	Inverted Altitude	Feet (ft)
RESDATA	Residual of individual sounding	
RESTOTAL	Total residual for inverted section	
RHO[0] THROUGH RHO[39]	Inverted resistivity of each layer	Ohm-m
RHOSTD[0] THROUGH RHOSTD[39]	Inverted resistivity error per layer	
DEP_TOP_FT[0] THROUGH DEP_TOP_FT[39]]	Depth to the top of individual layers	Feet (ft)
DEP_TOP_M[0] THROUGH DEP_TOP_M[39]]	Depth to the top of individual layers	Meters (m)
DEP_BOT_FT[0] THROUGH DEP_BOT_FT[39]	Depth to the bottom of individual layers	Feet (ft)
DEP_BOT_M[0] THROUGH DEP_BOT_M[39]	Depth to the bottom of individual layers	Meters (m)
DOI_UPPER_FT	More conservative estimate of DOI (CumSens=1.2)	Feet (ft)
DOI_LOWER_FT	Less conservative estimate of DOI (CumSens=0.6)	Feet (ft)
DOI_UPPER_M	More conservative estimate of DOI (CumSens=1.2)	Meters (m)
DOI_LOWER_M	Less conservative estimate of DOI (CumSens=0.6)	Meters (m)

Table 7-7. I-GIS Geoscene3D Project Files MRNRD2024_GeoScene_Project.zip

File Name:	Description of files
BLK3.gsmod, BLK4.gsmod	MRNRD2024 AEM GeoScene3D Project files
BLK3_SCI01_Geoscene_Ungapped BLK4_SCI01_Geoscene_Ungapped	Inverted AEM data from the SCI inversions
MRNRD24_BLK03_DEM_NESP83m_Srfv7 MRNRD24_BLK04_DEM_NESP83m_Srfv7	Surfer 7.0 Digital Elevation Model (DEM) for the 2024 MRNRD AEM survey area in NAD83 State Plane Nebraska meters with a 25 m grid cell size

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