Wilkes University

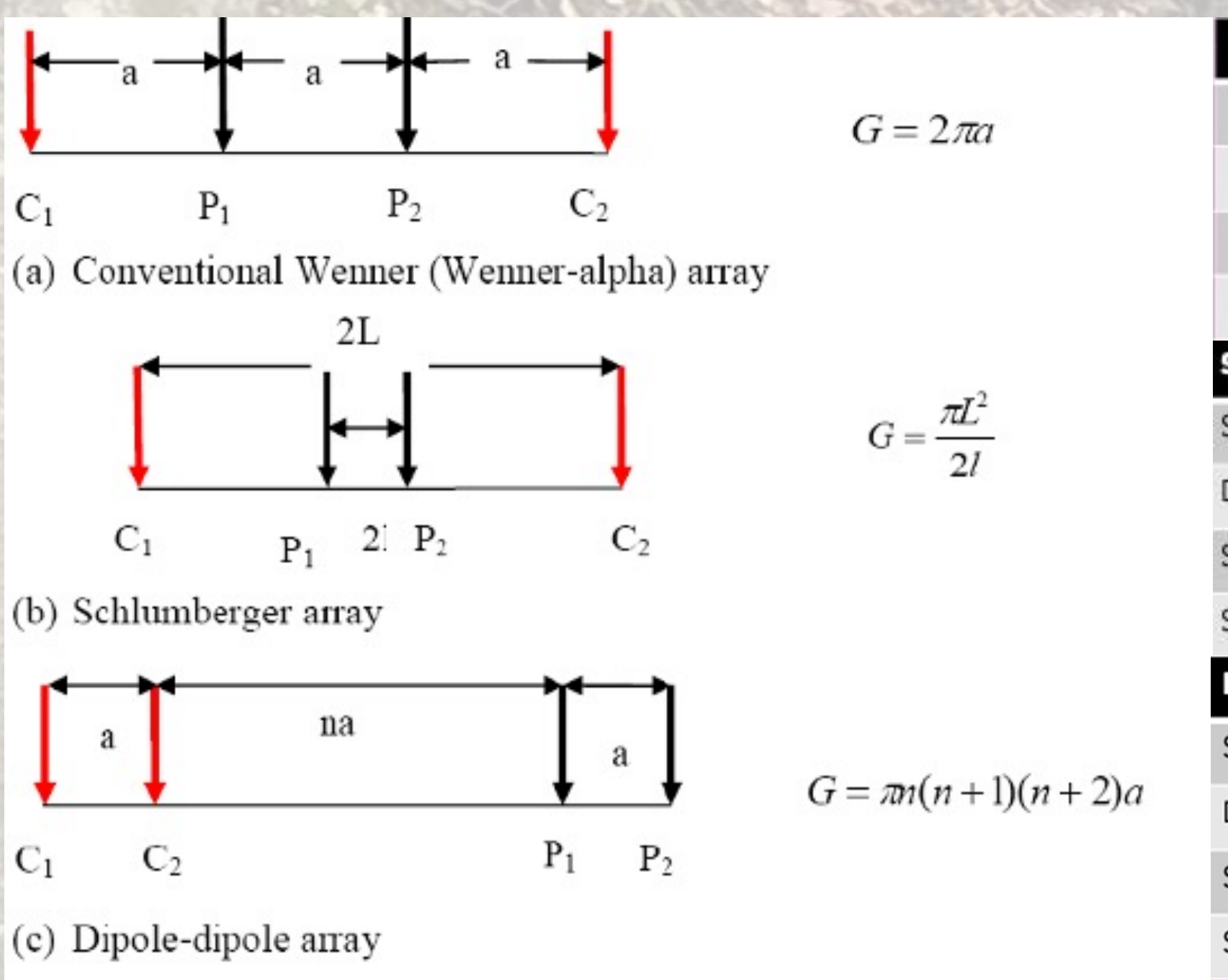
Feasibility Study Using Saline Tracers and Electrical Surveying to Track Disappearing Stream Waters in Luzerne County, PA

Morgan Romanowski, Hope Mullins, and Dr. Bobak Karimi

Abstract

The Nanticoke Creek, located in Luzerne County, PA has been heavily altered by past coal mining operations. Waters of the creek flow into the subsurface through fractures in the bedrock, and interact with mine pools, resurfacing downstream at the Askam Borehole as Abandoned Mine Drainage (AMD). However, the exact location of these fractures and the prominent flow pathways, to and through the mine pools, are unknown - thus complicating stream restoration efforts. Without knowing these flow pathways, stream restoration would require concrete to be poured along the entire streambed. Mapping subsurface flow pathways for the stream waters can aid in reducing the cost and efficiency of stream restoration by focusing materials and efforts on targeted areas. We used a saline tracer and electrical resistivity surveying to determine the fracture locations and flow pathways of the stream waters entering the abandoned mine pools. A Syscal Kid Switch 24 with a total of 24 electrodes spaced at 5-m intervals parallel to the Nanticoke Creek bed were used in this study. Using a dipole-dipole electrical configuration a survey depth of 20-m was achieved. The streambed is usually dry, except for the upper reaches; thus, surveys were conducted following high precipitation events to ensure that water was flowing the length of the stream bed in question. Data was acquired both before and after the addition of a saline tracer to the water. The pre-salt conductivity values were subtracted from the post-salt, and processed into a single tomographic image that highlights the fracture flow pathways. Stream restoration efforts can now more efficiently focus time and material on plugging the fractures that intersect the surface or have higher flow-rates (based on fracture size). Additionally, we may be able to use fracture frequency and spacing to predict fractures along other similarly affected streams in the area by conducting a multi-scale fracture analysis

Methods



$$G = 2\pi a$$

$$G = \frac{\pi L^2}{2l}$$

$$G = \pi n(n+1)(n+2)a$$

WENNER	
Signal Strength	High
Depth	Moderate
Sensitivity to Vertical Structures	Low-Moderate
Sensitivity to Horizontal Structures	High

SCHLUMBERGER	
Signal Strength	Moderate-High
Depth	Moderate
Sensitivity to Vertical Structures	Moderate
Sensitivity to Horizontal Structures	Moderate

DIPOLE-DIPOLE	
Signal Strength	Low-Moderate
Depth	High
Sensitivity to Vertical Structures	High
Sensitivity to Horizontal Structures	Low

Figure 1. Image of the Wenner, Schlumberger, and Dipole-Dipole array configurations which can be used to conduct electrical resistivity surveying. G represents the factor of each configuration which describes the counting efficiency and general arrangement of each survey model. The strengths and weaknesses of using each configuration are listed in the tables.

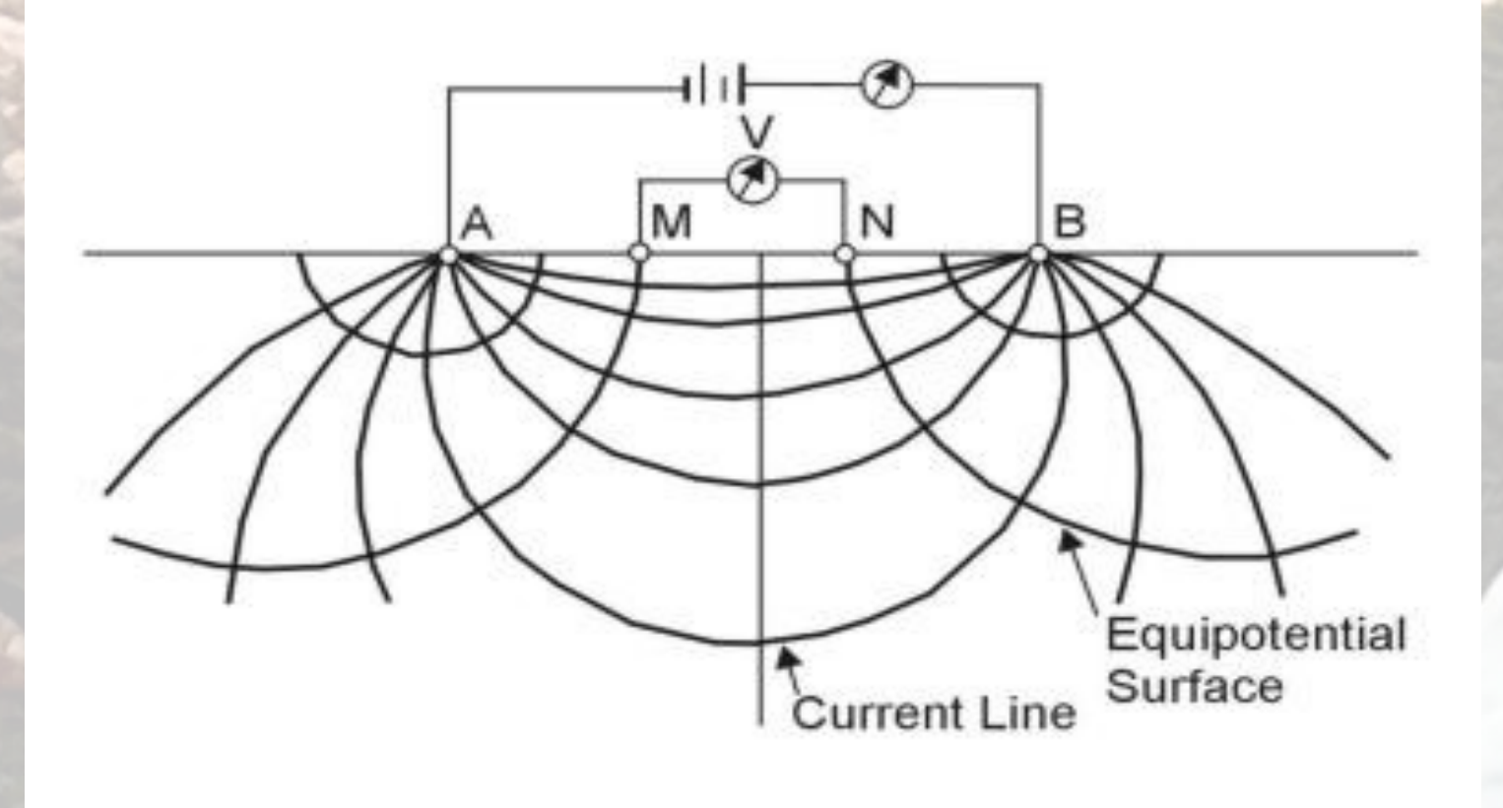


Figure 2. Equipotential surfaces of resistivity rom current electrodes to potential electrodes (Wightman et al. 2003). V represents the voltage applied to the system. Points A and B mark the position of current electrodes while M and N are potential electrodes.

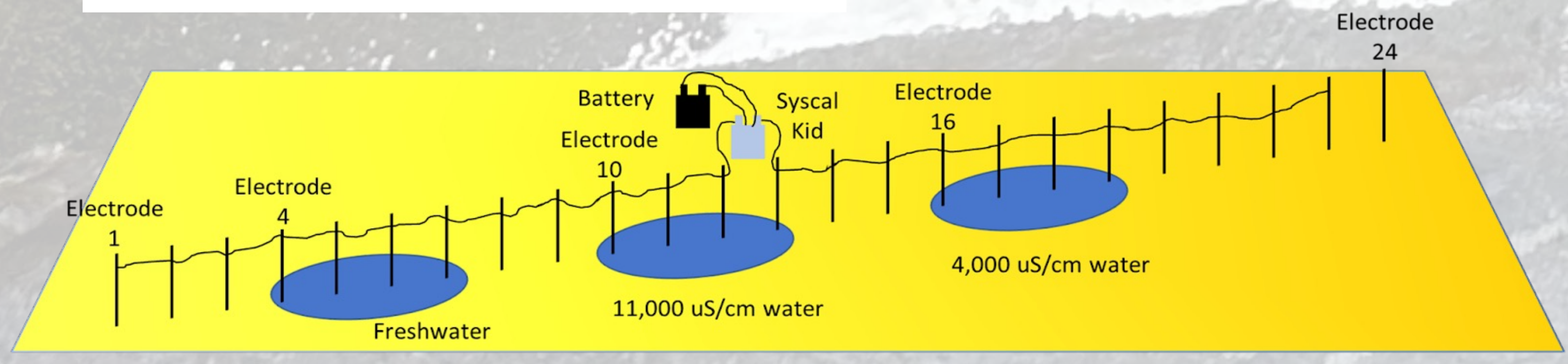


Figure 3. Conceptual image of the Wilkes University volleyball field electrical survey test (Angela Fiorentino and Brandon Whitman 2022). Freshwater was poured between electrodes 4 and 7, 11,000 uS/cm salt water was poured between electrodes 10 and 13, 4,000 uS/cm salt water was poured between electrodes 16 and 19.

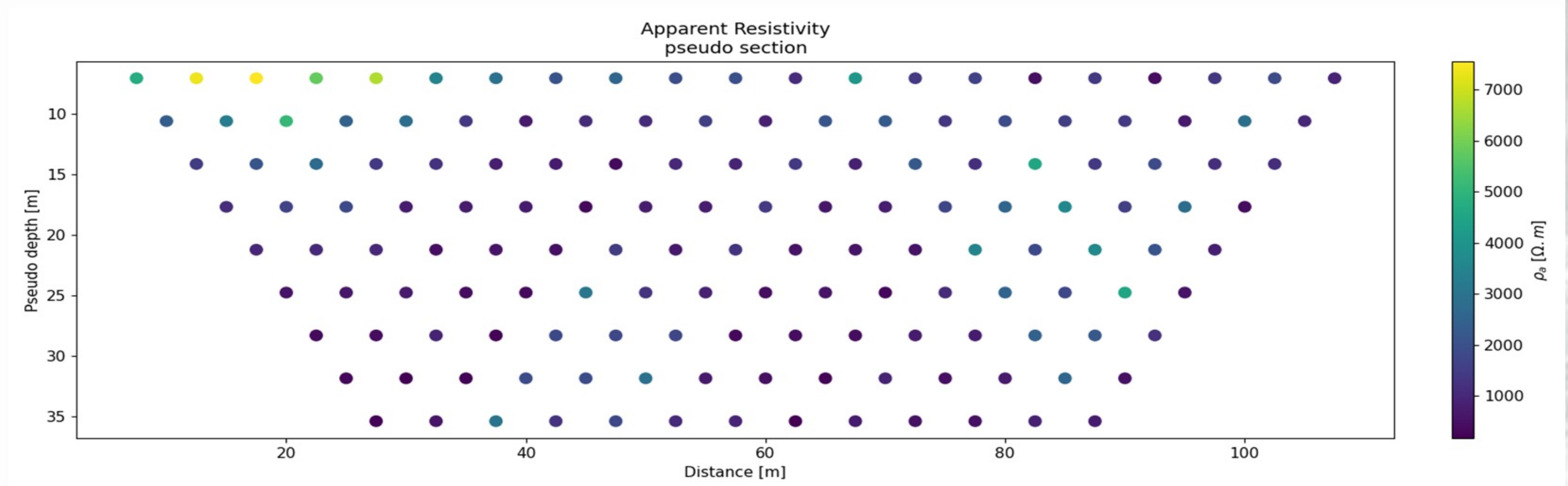


Figure 4. Data as resistivity points within the subsurface of the Nanticoke Creek using the software ResIPY. ResIPY creates a quadrilateral mesh as an input for the model's algorithm which results in the image above. The depth is represented on the x-axis and the distance is represented on the y-axis. The apparent resistivity scale bar is on the right side of the image, with brighter yellow data points representing higher apparent resistivities and darker purples representing lower apparent resistivities.

Results

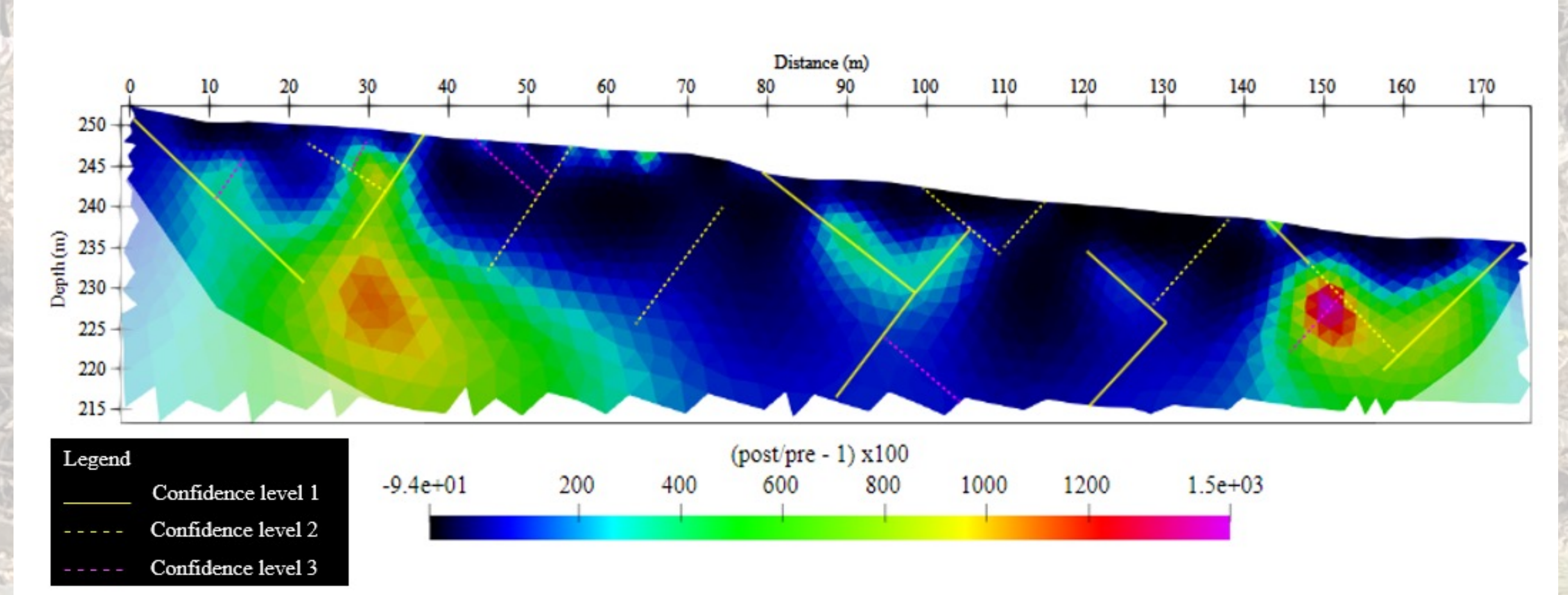


Figure 6. Image of the subsurface of the Nanticoke Creek created after data collection in November of 2023. Results show post conductivity values divided by pre-conductivity values subtracted by one and then multiplied by 100. The solid yellow lines represent a fracture with a confidence level of 1, the dashed yellow line represents a fracture with a confidence level of 2, and the dashed pink line represents a confidence level of 3. The faded portions of the image represent areas that have assumed data, not data that was collected.

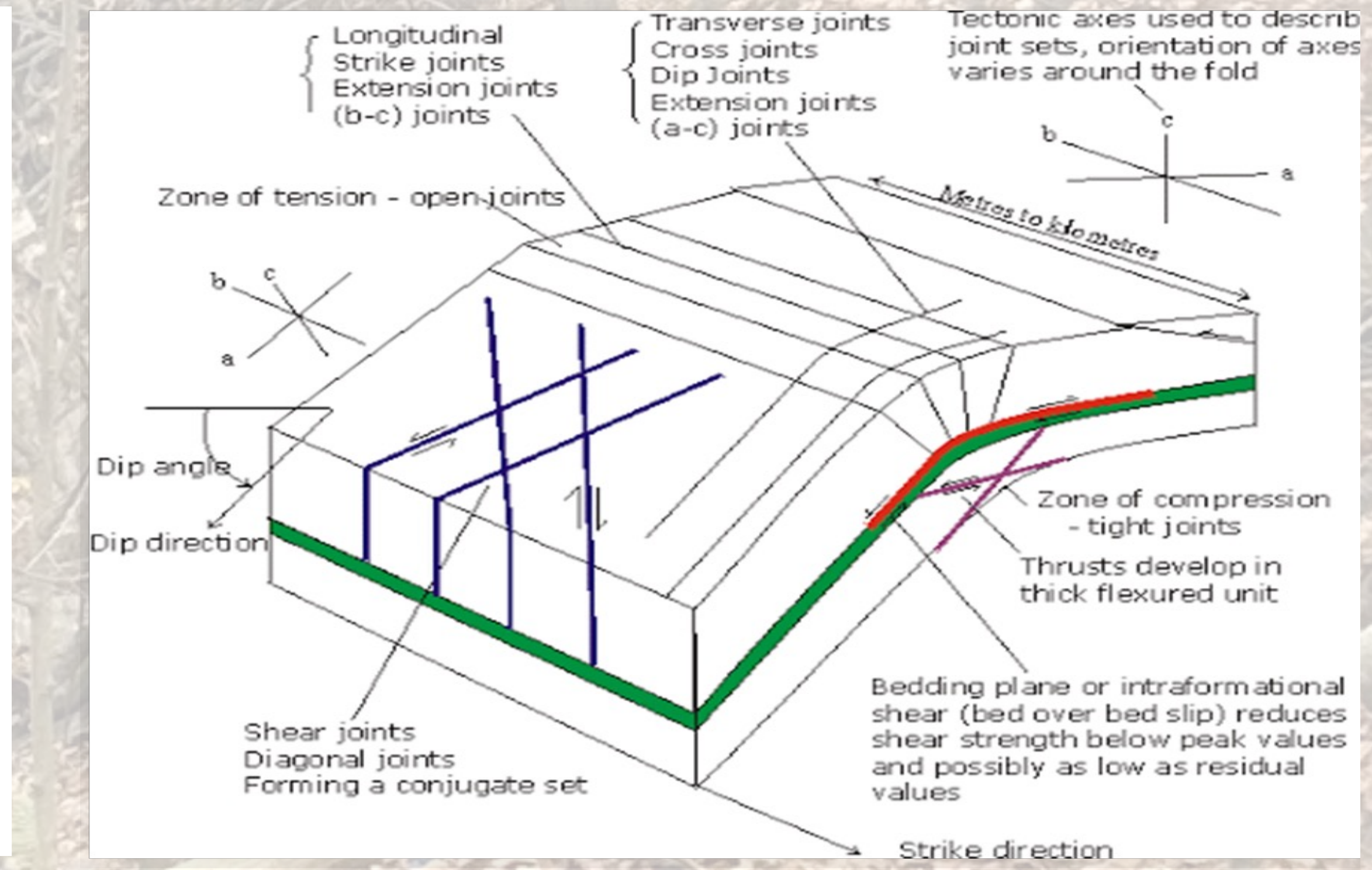


Figure 7. Image displaying longitudinal, transverse, and bedding fractures along with tectonic axes which describe joint sets and orientation around the fold. Important properties like dip angle/direction and strike are also shown.

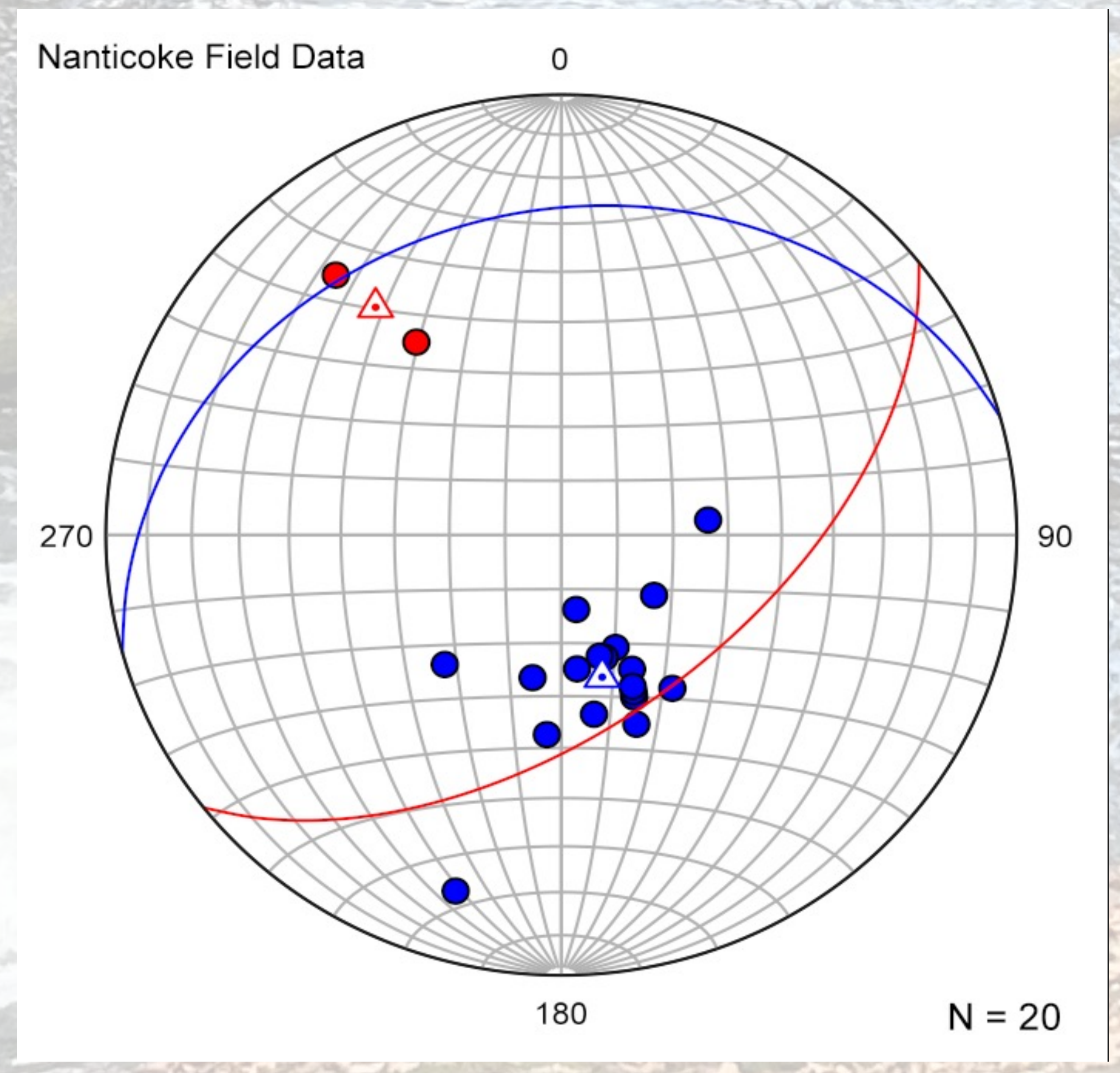


Figure 8. Stereonet constructed from field data collected by the 2024 GIS 272 project group of Novak, Hornbaker, Mullins and Romanowski. The blue points represent bedding fractures and the red points represent longitudinal fractures. The average strike/dip of the longitudinal fractures was 052/56 and the strike/dip of the bedding fractures is 255/27.

Figure 9. Map of the Nanticoke Creek survey site made from data collected by the Wilkes GIS 271 class of October 2023. The map displays the electrodes as points, the ERT line, and the fractures as horizontal lines of varying colors. Red lines represent longitudinal fractures, blue represents bedding fractures, purple represents an area that has both fracture types.

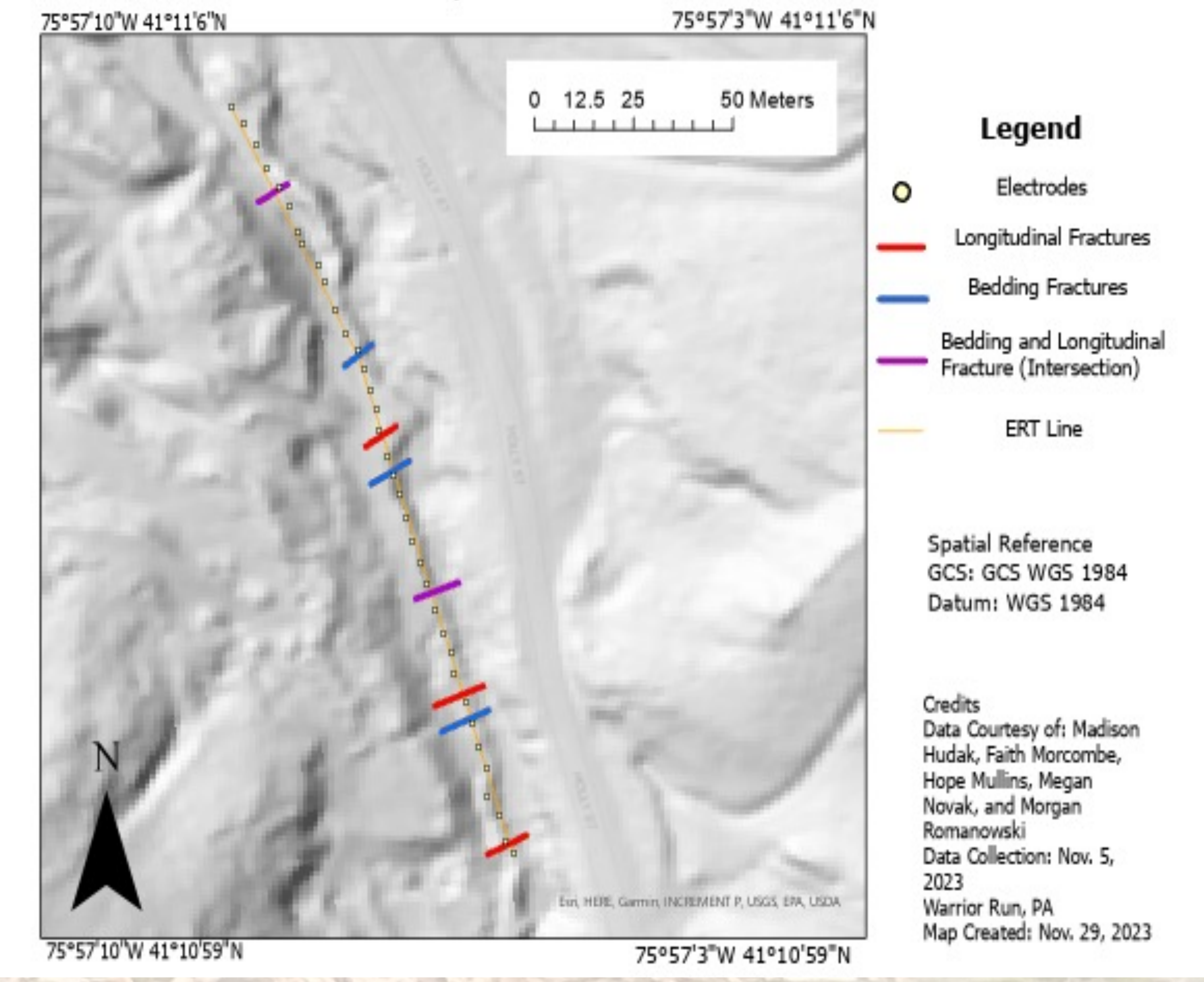


Figure 5. Photographs of the Nanticoke Creek taken in November of 2023, including A) John Watkins pouring rock salt into the Creek to act as a saline tracer, B) The main fracture site at the Nanticoke Creek, and C) the Syscal Kid Switch Electrical Resistivity Meter set up along the side of the Nanticoke Creek

Conclusions

- By understanding the physical properties of salt along with the water and rock at the Nanticoke Creek, we are able to use commercial rock salt in conjunction with a resistivity meter to track the flow pathways of water beneath the subsurface.
- The data collected from the field can be processed in ResIPy and Paraview to create the images like those in **Figure 7**. Analyzing these images allows us to draw in the possible fracture locations and infer the type of fractures present.
- Coordinates of the electrodes from the field can be imported into ArcGIS and used to create a map of the surface location of fractures as shown in **Figure 9**.
- Strike and dip of the drawn fractures can be inferred and compared to field measurements in a Seteronet as seen in **Figure 9**.
- Future work includes creating a map of additional areas of the Nanticoke Creek that can be surveyed with the techniques we used.

Acknowledgements

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