



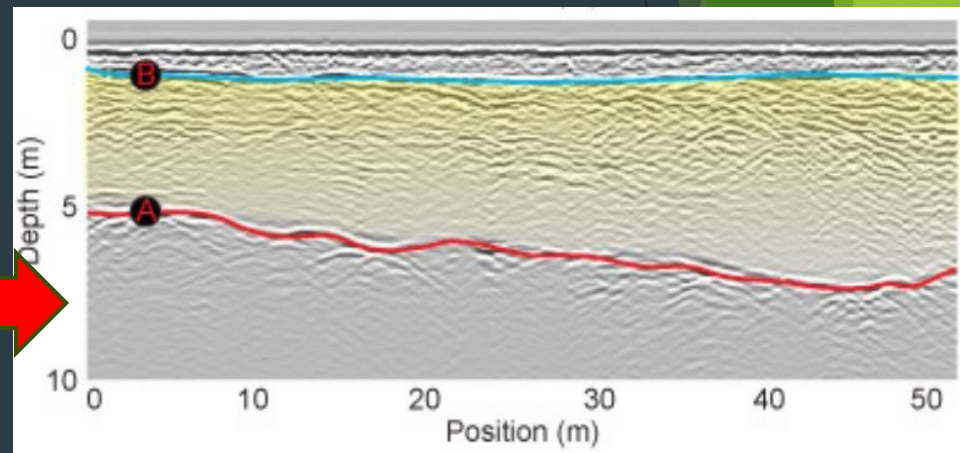
# What Lies Below: Using Geophysics for Contaminated Site Characterization

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May 2026

# “Geophysics”

- Subsurface investigations for environmental, engineering, and infrastructure needs
- Non-invasive, non-hazardous, efficient!
- Variety of tools and methods



# Targets

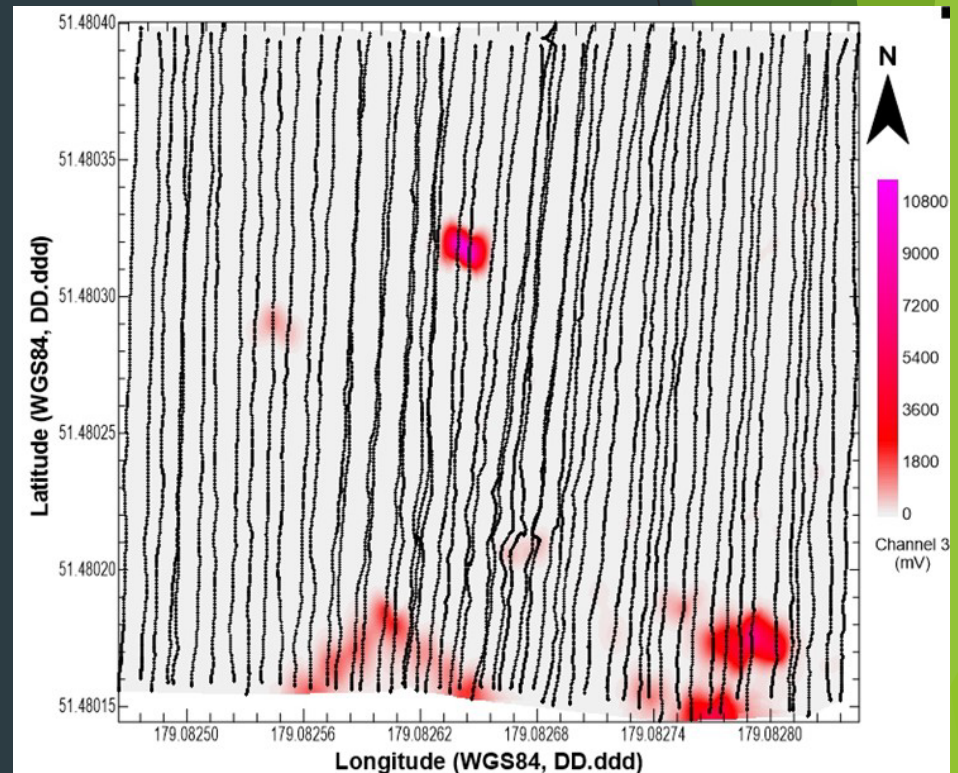
All methods depend on **contrast** between the target and the background

## Manmade:

- Utilities, Graves/Archaeology, Concrete imaging, Buried Drums and Tanks, Landfills,
- Contamination

## Natural:

- Depth to bedrock
- Permafrost
- Groundwater
- Trenches
- Material characterization



# Tools

- ▶ Ground-penetrating radar
- ▶ Electrical-resistivity meters
- ▶ EM-31, EM-61
- ▶ Seismic sensors
- ▶ Magnetometers/gravimeters
- ▶ GPS/GLONASS



# “Manmade” Targets



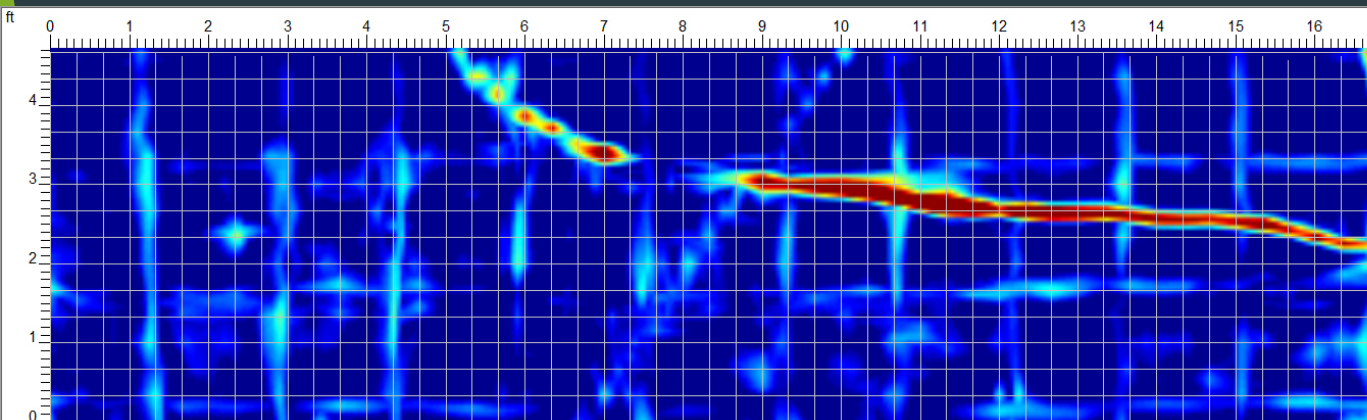
# Buried Objects

- ▶ Utilities
- ▶ Tanks and drums
- ▶ Graves
- ▶ Landfill debris
- ▶ Other?



# Utilities

- ▶ “Best-practice methods”: Gridded surveys
- ▶ Combination of GPR and electronic locators for utility detection & mapping
- ▶ On-site data processing
- ▶ Surface markings, also georeferenced for integration into project planning software



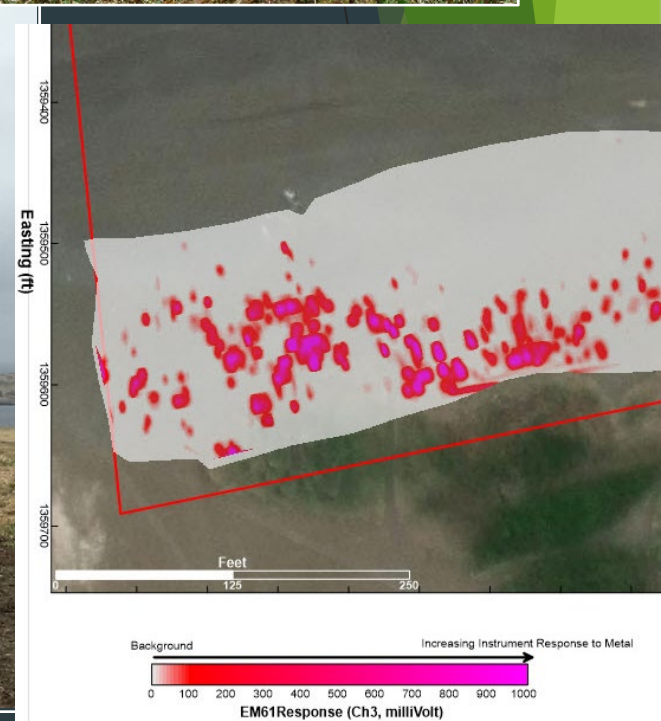
# Landfills and UST

- ▶ Delineate lateral and horizontal extent of buried debris
- ▶ Detect and georeference buried underground tanks



# Landfill & UST: EM-31 and EM-61

- ▶ Time-domain and frequency-domain electromagnetic mapping
- ▶ Respond to metallic objects and changes in ground conductivity
  - ▶ Underground storage tank location
  - ▶ Contaminant mapping
  - ▶ Landfill mapping
  - ▶ Utility locates



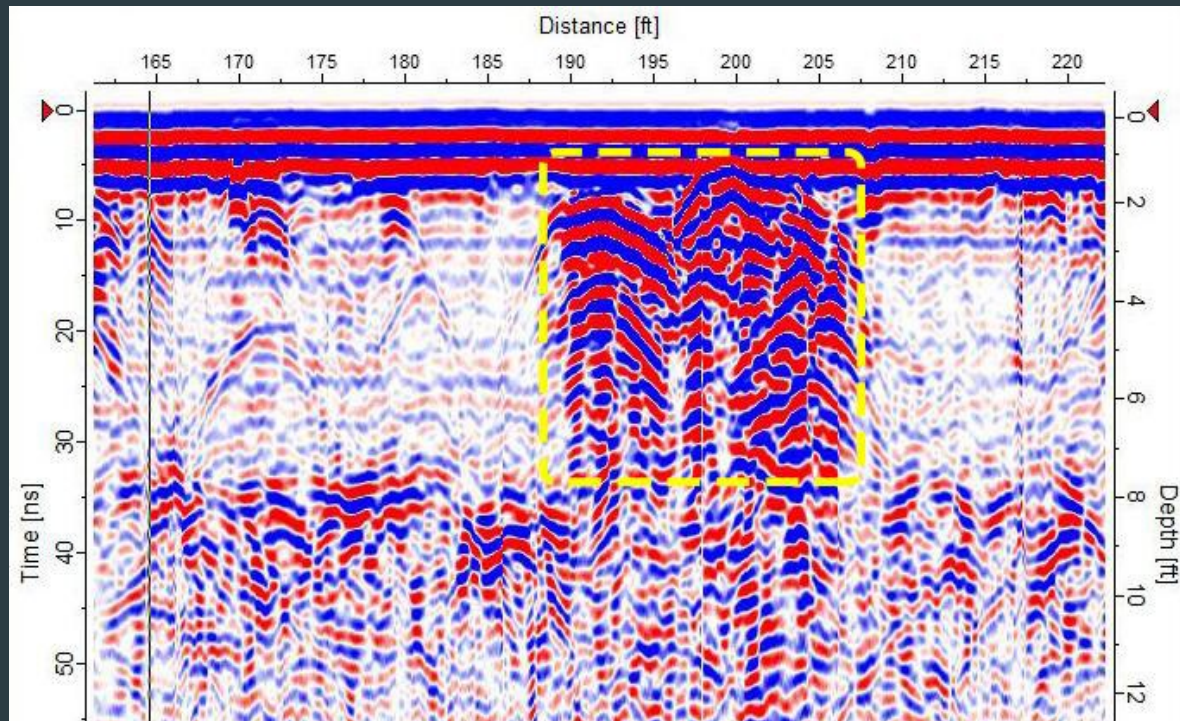
# Landfill & UST: GPR

- ▶ Can map depth and extent of debris
- ▶ Metallic and non-metallic objects
- ▶ Variety of deployment options



# Landfill & UST: GPR

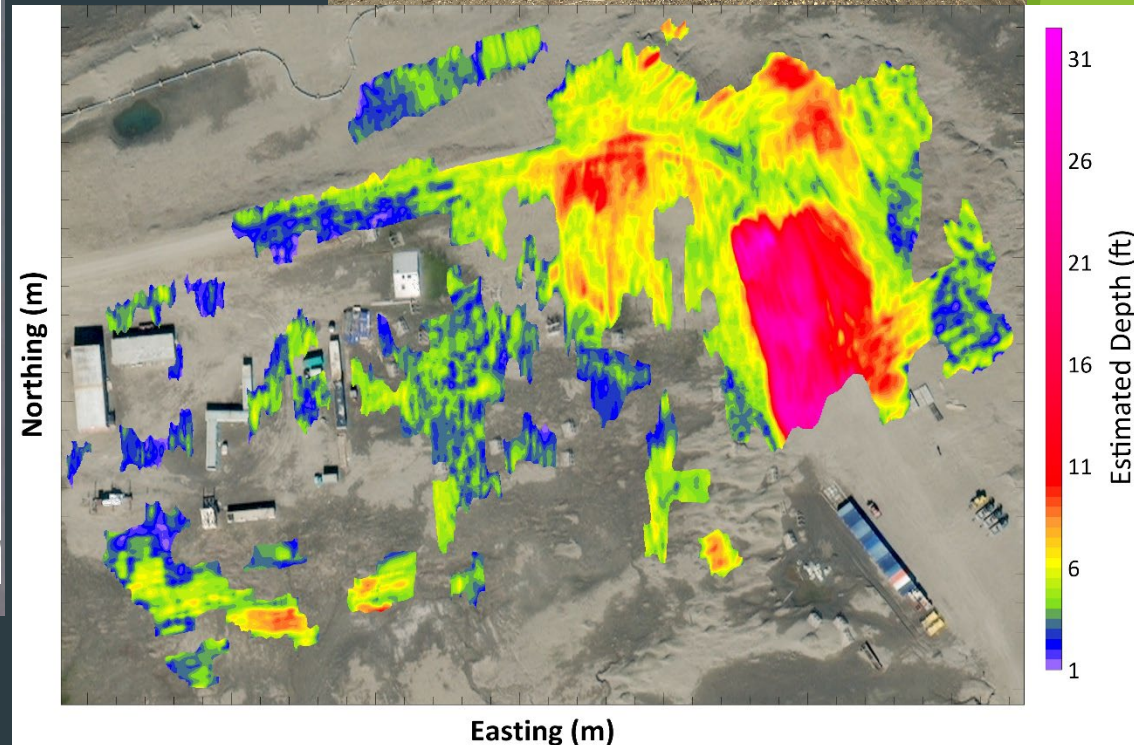
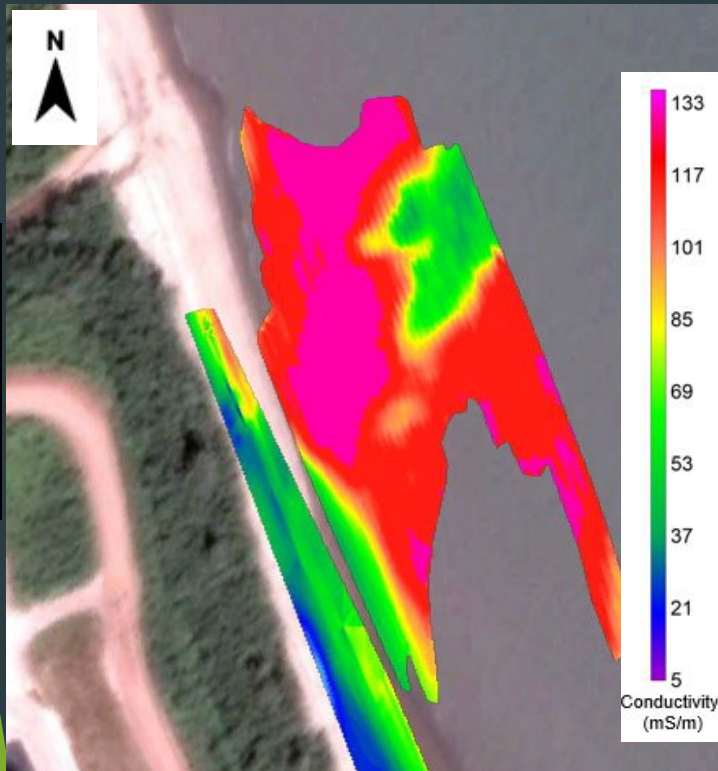
- ▶ Can map depth and extent of debris
- ▶ Metallic and non-metallic objects
- ▶ Variety of deployment options



# Contamination

## ► Mapping subsurface contaminants

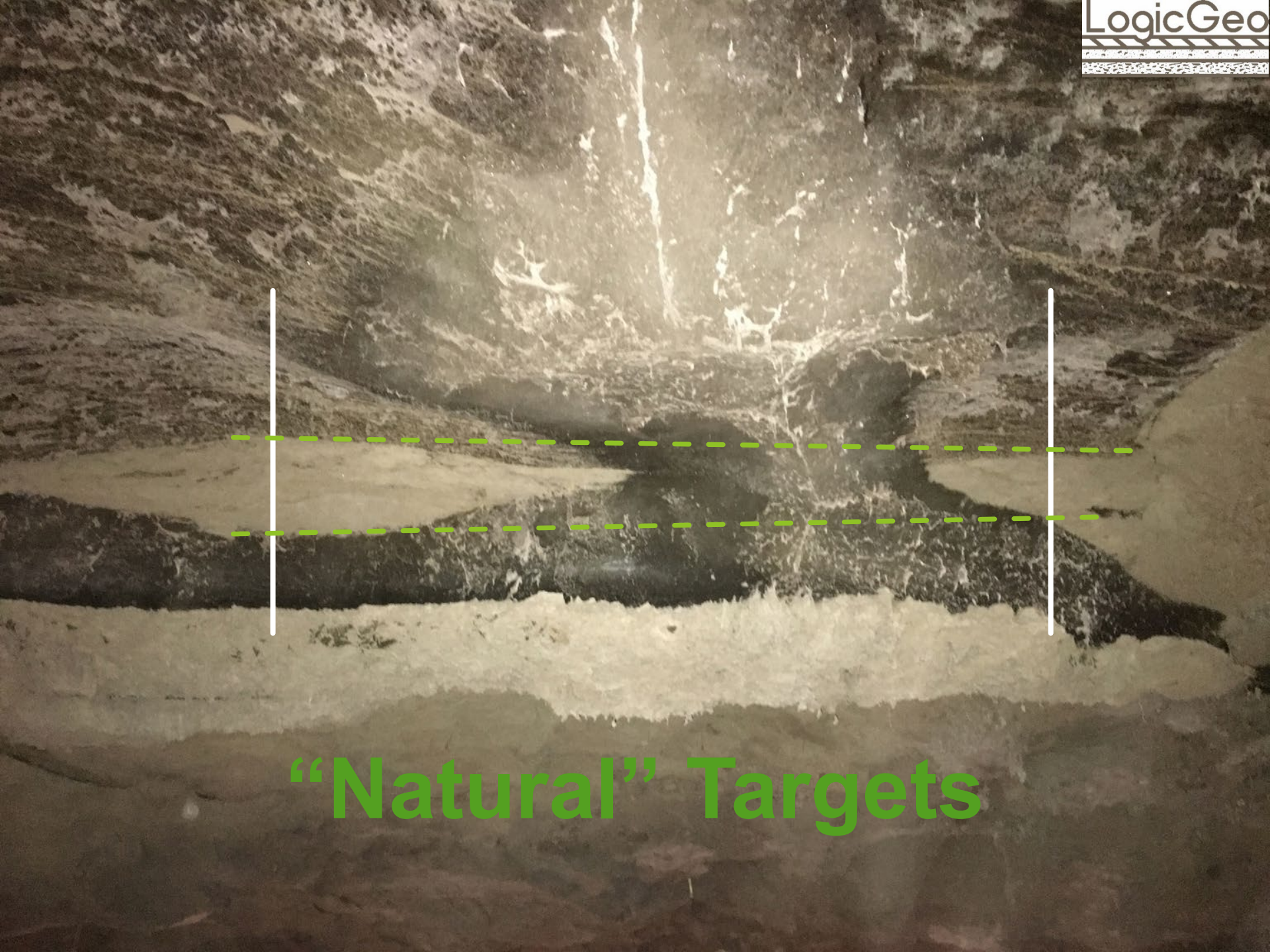
- Hydrocarbons
- Chlorinated solvents
- Debris



Latitude (WGS84)

Longitude (WGS84)

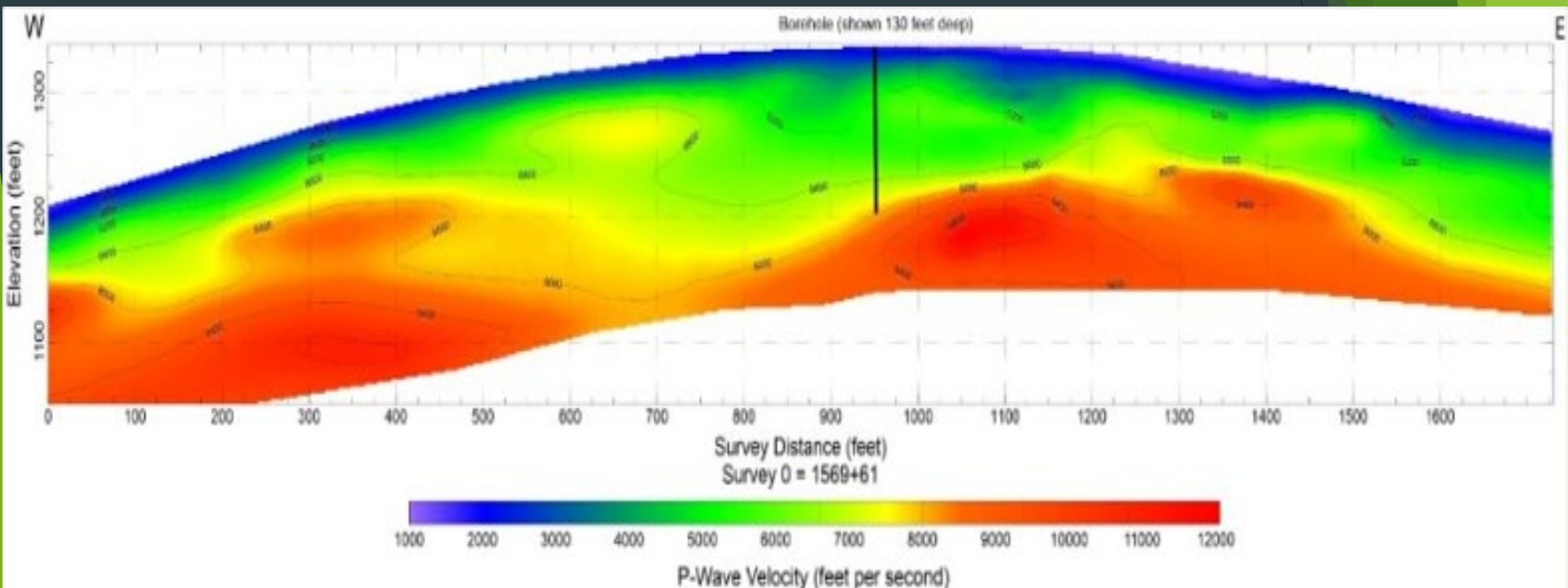
Easting (m)



**“Natural” Targets**

# Geologic Mapping

- ▶ **Geophysical methods applied:**
  - ▶ Detection and delineation of massive ice, thaw bulbs, permafrost
  - ▶ Mapping depth to bedrock, bedrock competency, subsurface stratigraphy
  - ▶ Bathymetry and ice/snow thickness



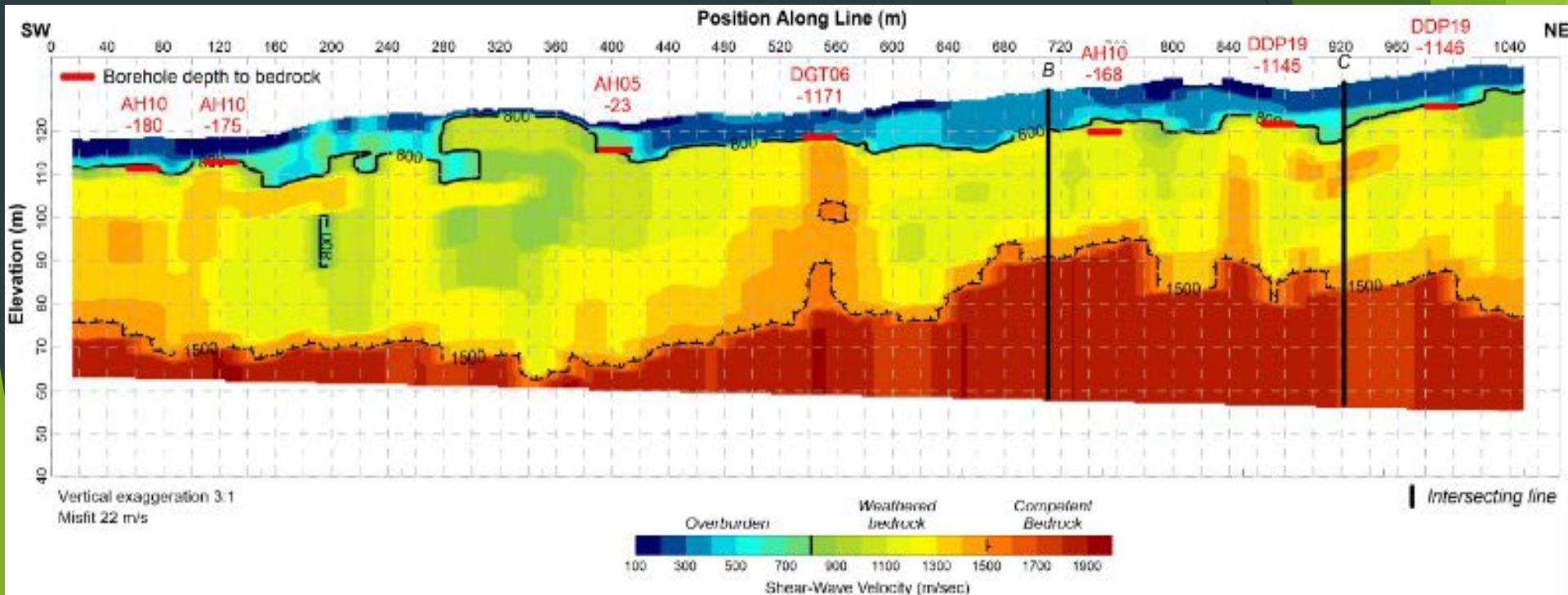
# Geologic Mapping

- ▶ Depth to bedrock – may be a constraint for contaminant flow and transport



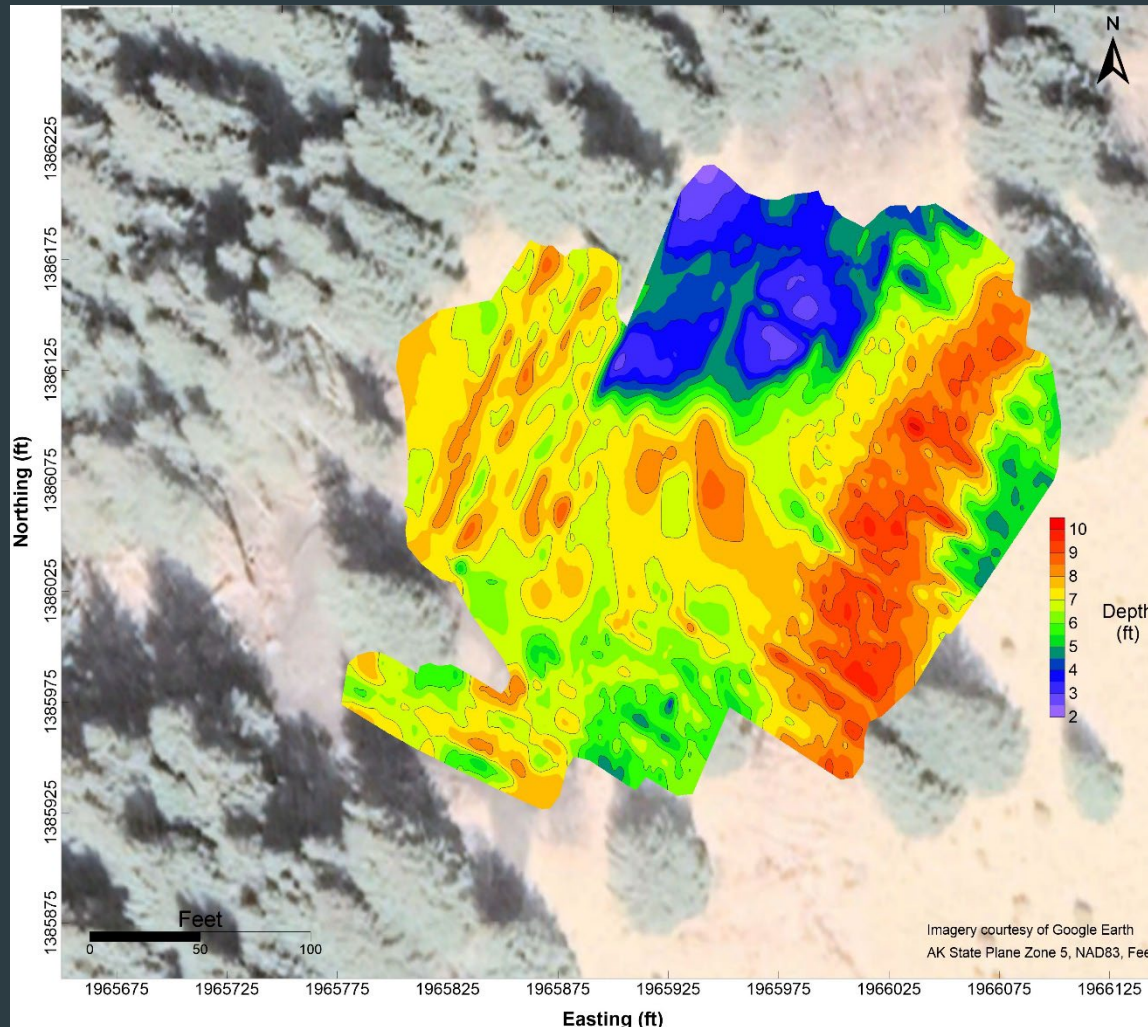
# Geologic Mapping

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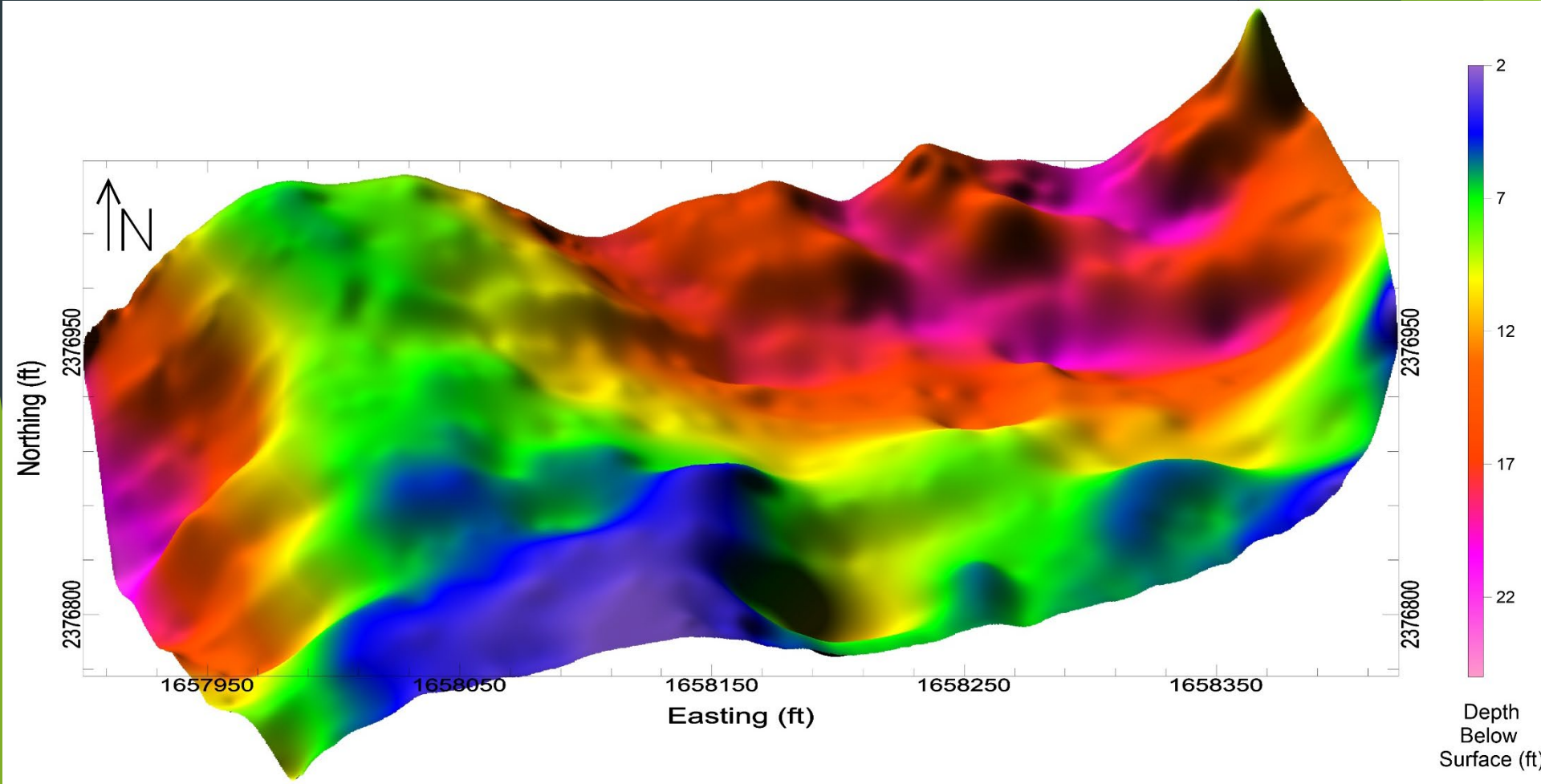
# Geologic Mapping

- ▶ Depth to bedrock – pseudo 3D model example



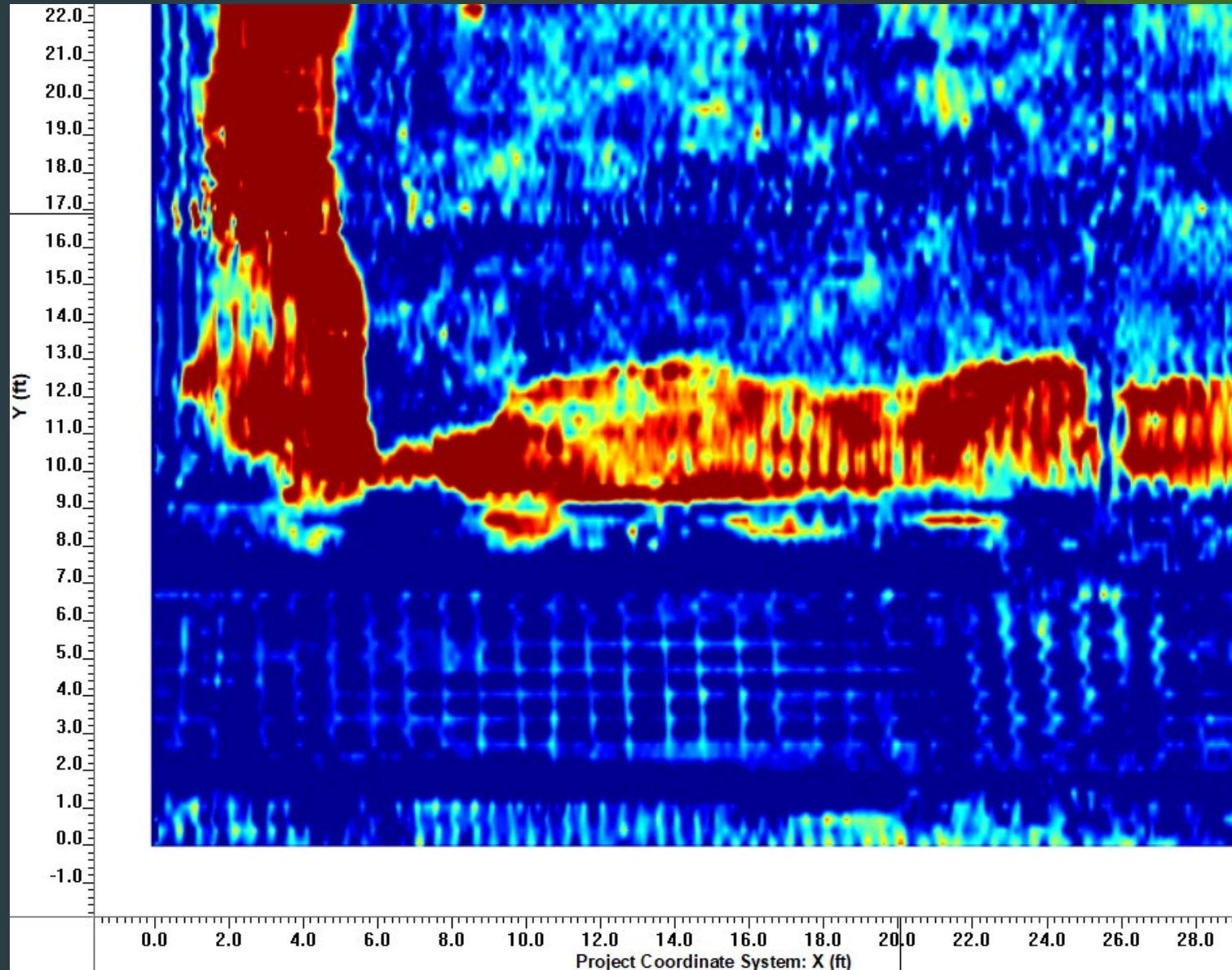
# Geologic Mapping

## ► Depth to bedrock – model visualization

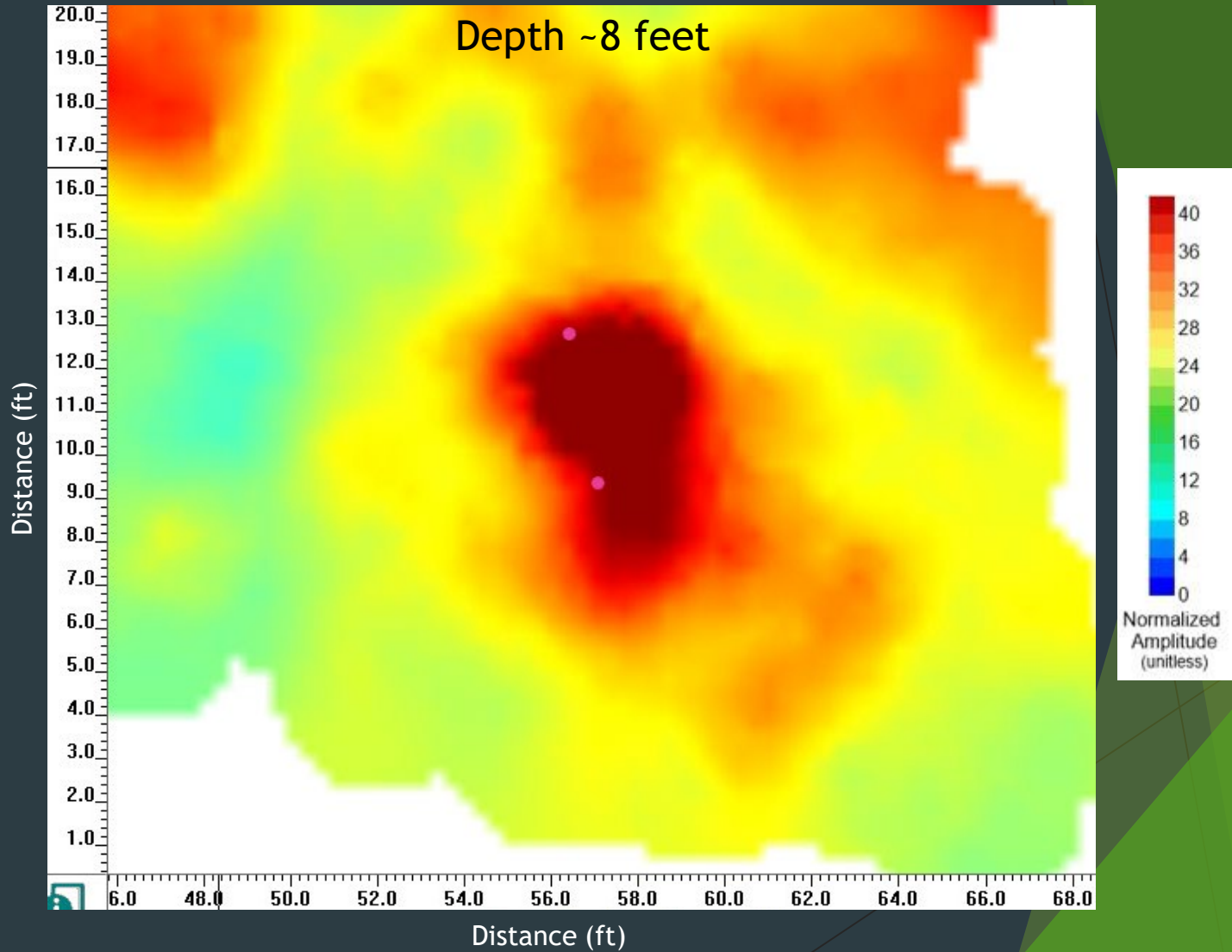


Depth  
Below  
Surface (ft)

# Void Detection & Mapping

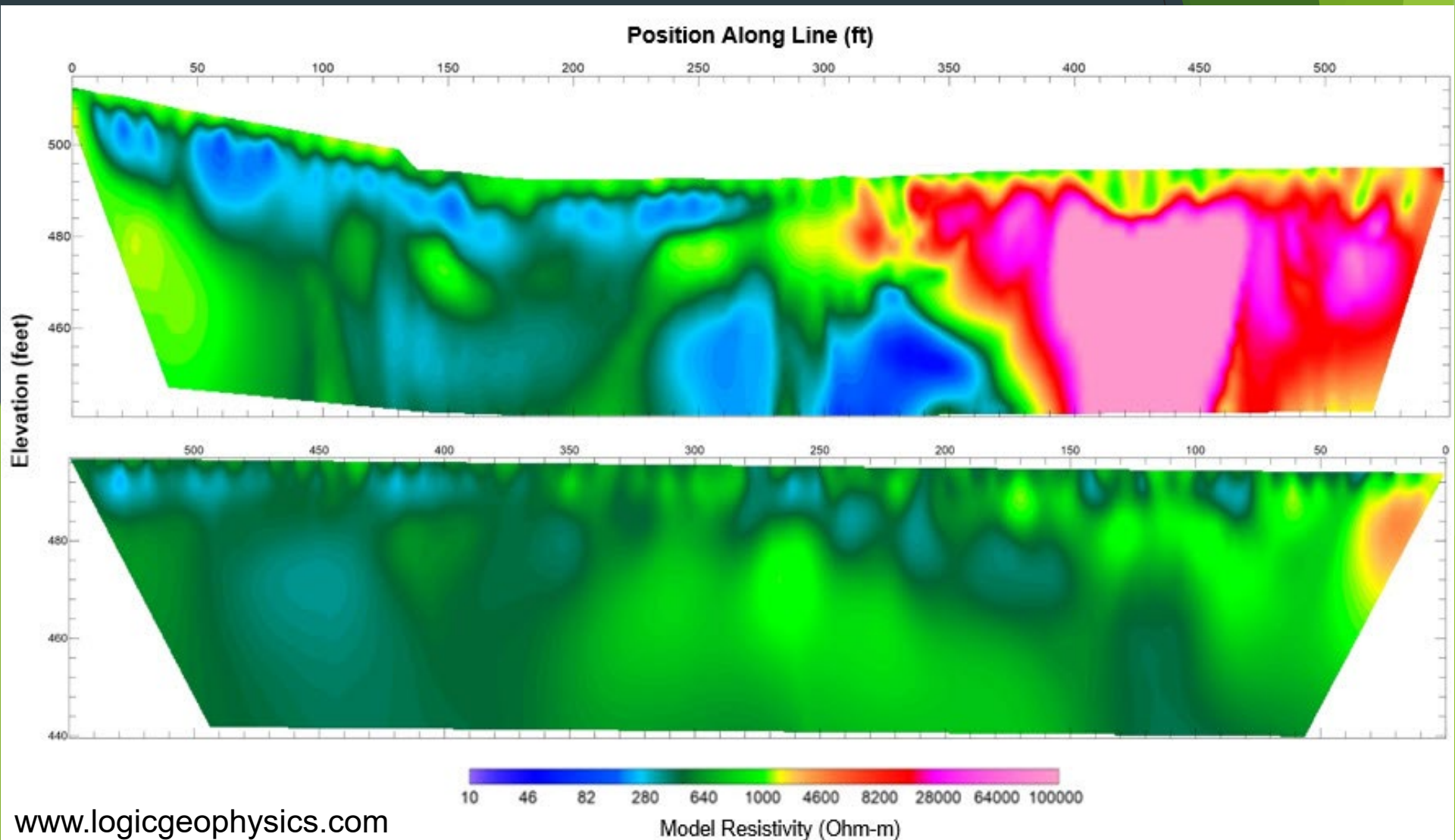


# Void Detection & Mapping



# Geologic Mapping

- ▶ Permafrost: frozen vs thawed, massive ice, lithology



# Resistivity



## ▶ Geological surveys

- ▶ Gravel exploration
- ▶ Depth to bedrock
- ▶ Clay layers

## ▶ Contaminant mapping

- ▶ Leachate plums
- ▶ Landfills

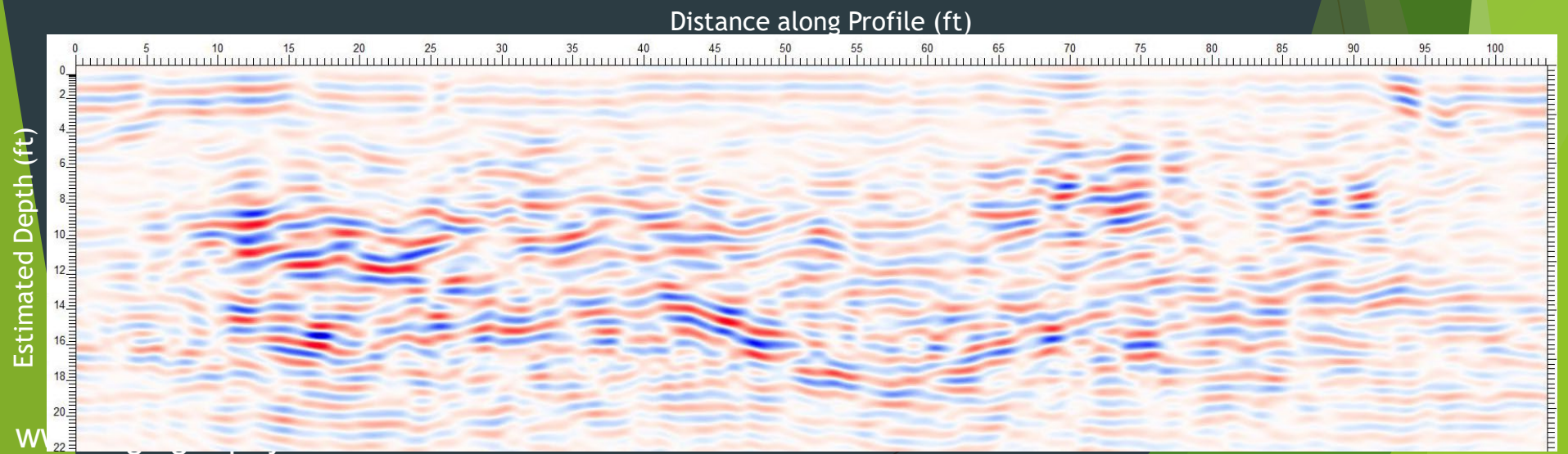
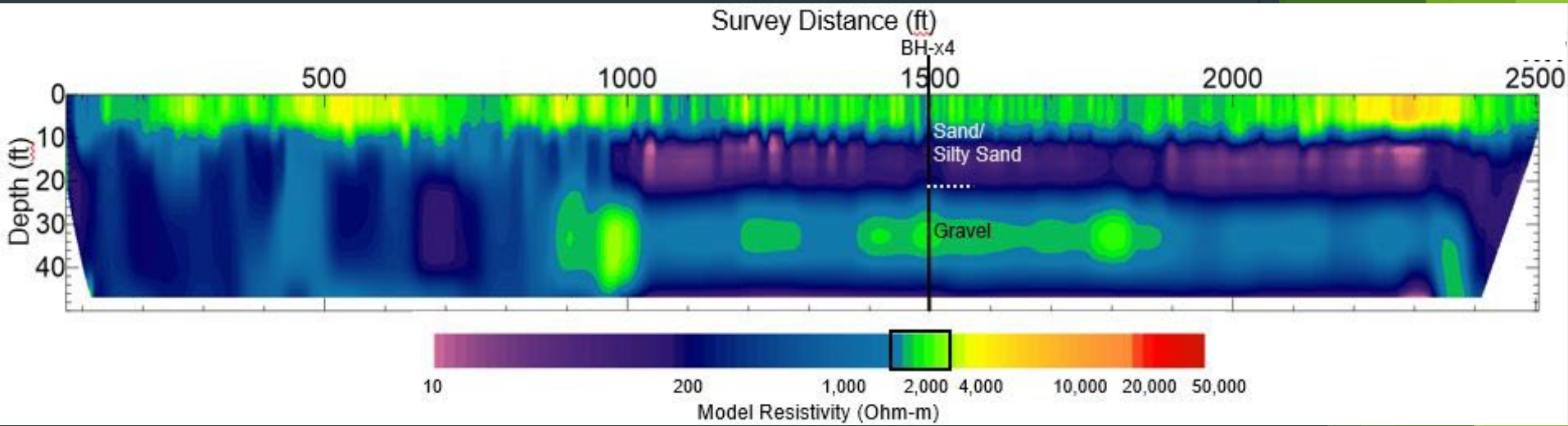
## ▶ Permafrost imaging

- ▶ Mass ice
- ▶ Thaw bulbs



# Geologic Mapping

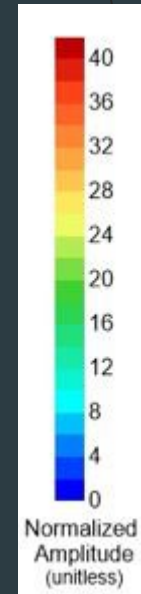
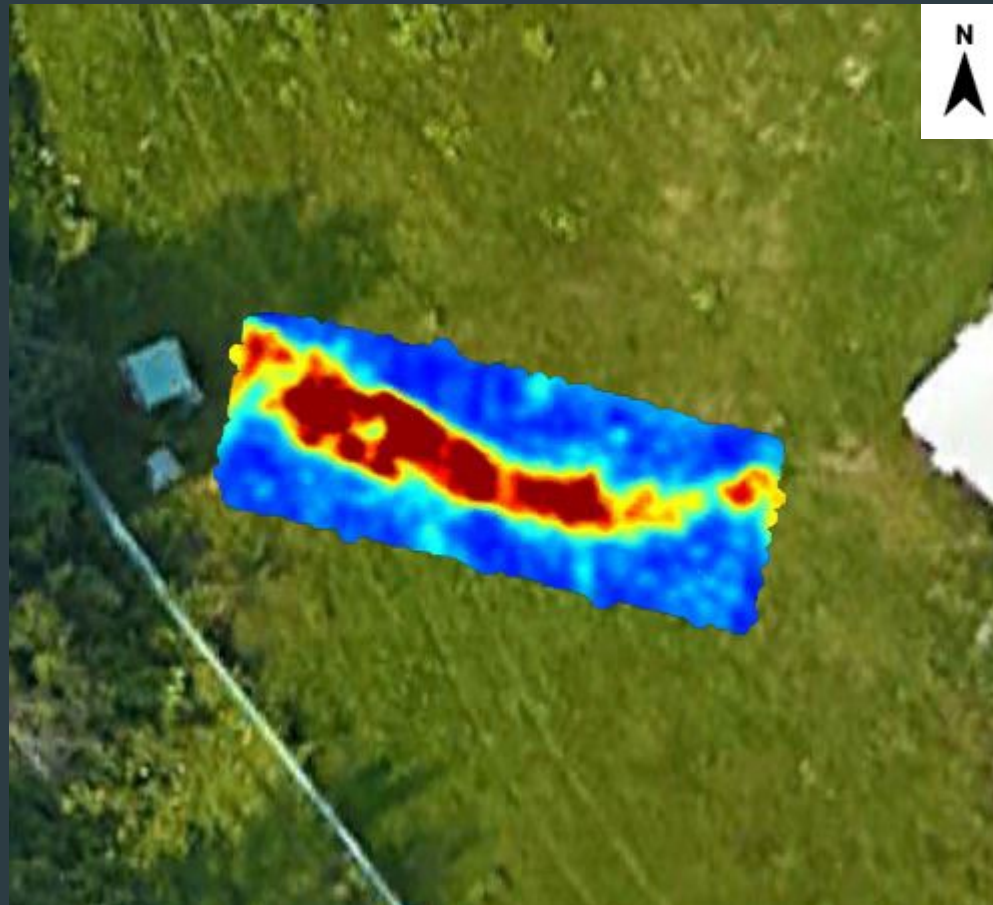
- ▶ Stratigraphic mapping – relevant to contaminant fate and transport



# Other Subsurface Features

## ► Ground Disturbances

Latitude (WGS84)



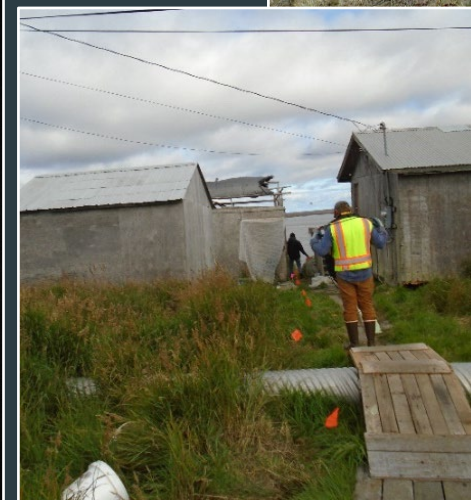
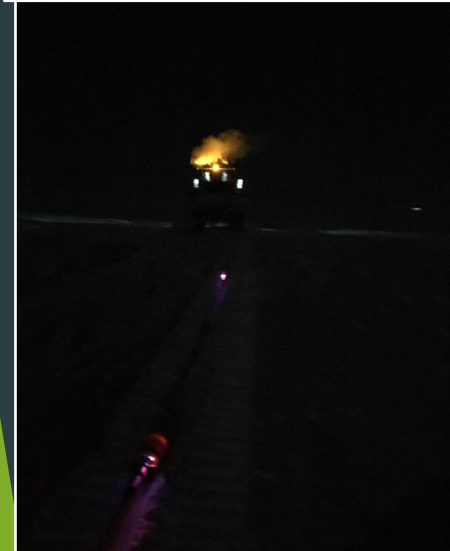
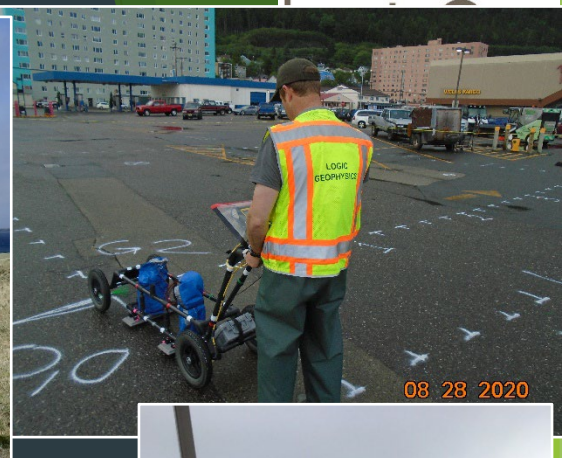
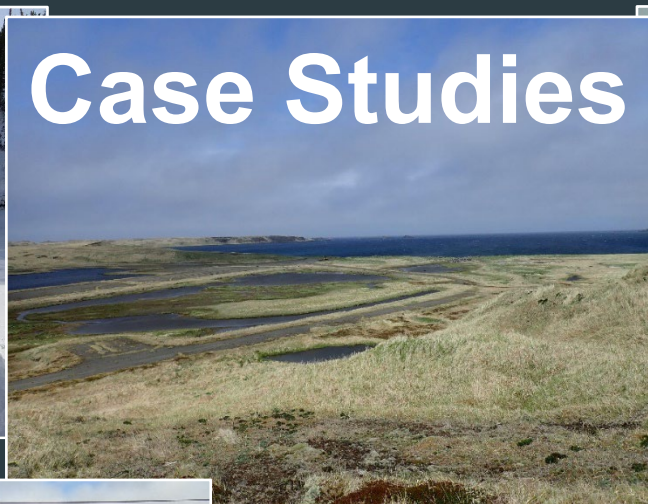
Longitude (WGS84)

# GPS

WGS84  $\pm 16\text{ft}$  57.12177, -170.27225  $\pm 12$  °T SW220

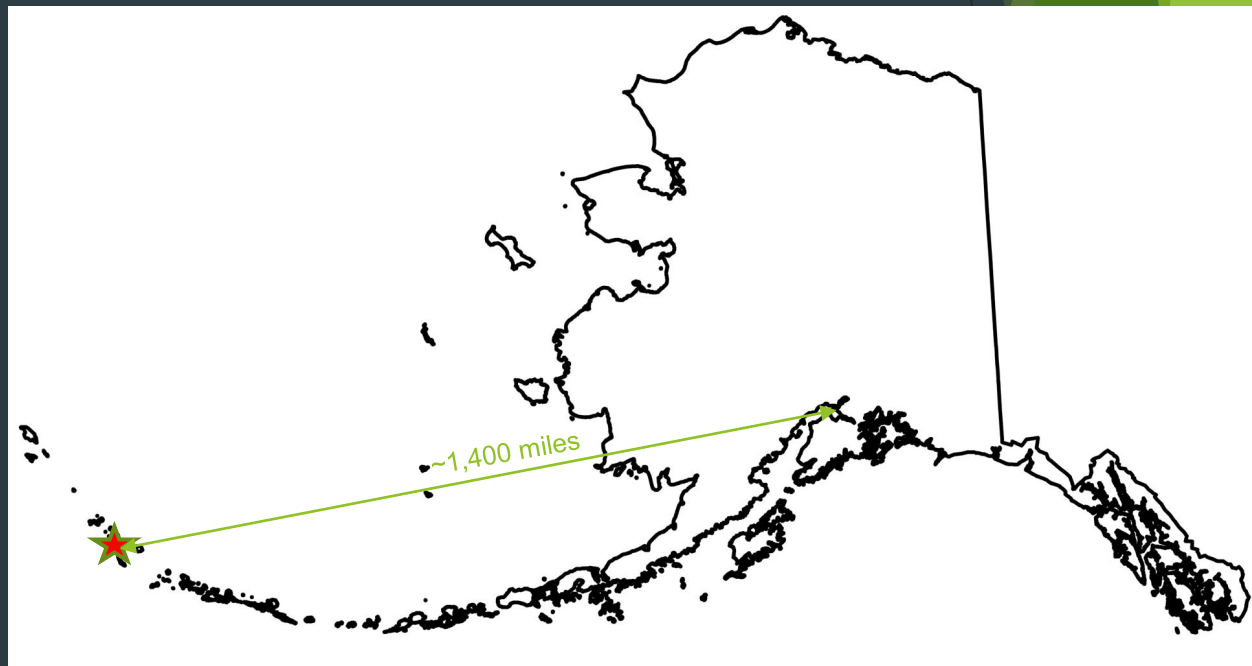


# Case Studies

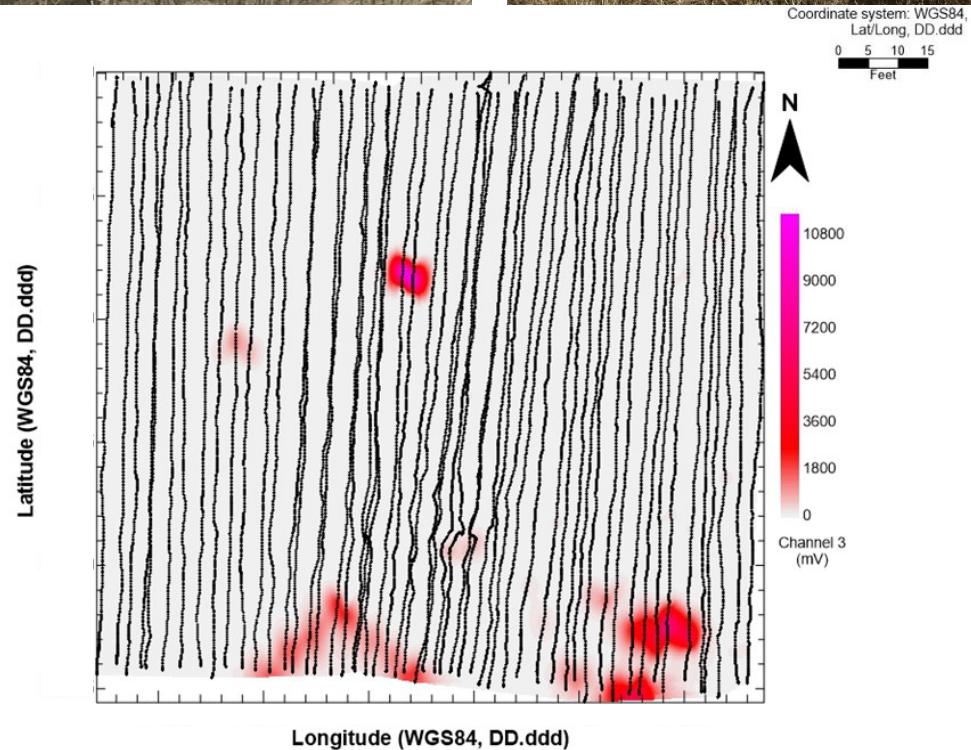


# Case Study: Buried Tanks/Drums

- ▶ Location: remote Aleutian Island (population 0)
- ▶ Method: EM61
- ▶ Logistics: ~3-hr commercial flight + 24-hr boat ride
  - ▶ Or \$20,000-\$30,000 charter flight...logistics logistics logistics!
- ▶ Lodging: Landing craft
- ▶ HSE: Remote site



# Case Study: Buried Tanks/Drums

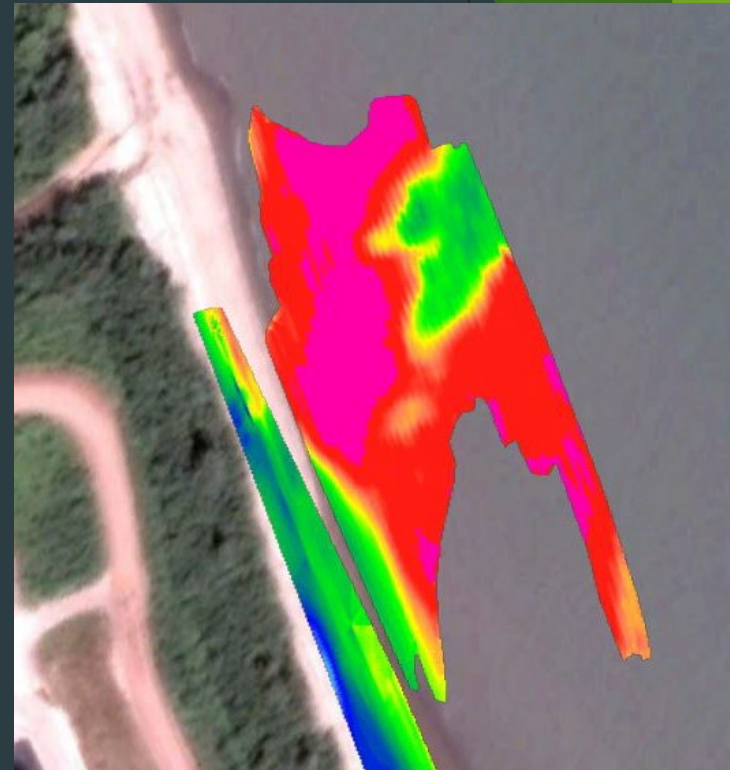
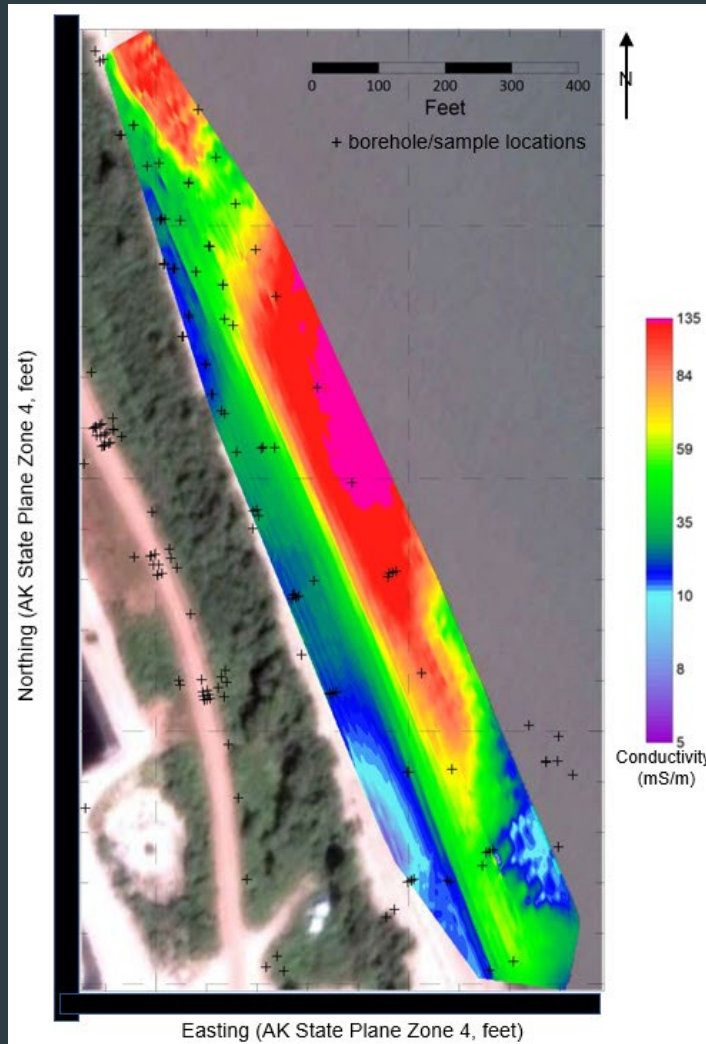


# Case Study: Contaminant Mapping

- ▶ Location: remote oil & gas facility
- ▶ Method: EM31
- ▶ Logistics: ~1-hr charter flight
- ▶ Lodging: Fixed camp
- ▶ HSE: Wildlife/oil & gas facility



# Case Study: Contaminant Mapping

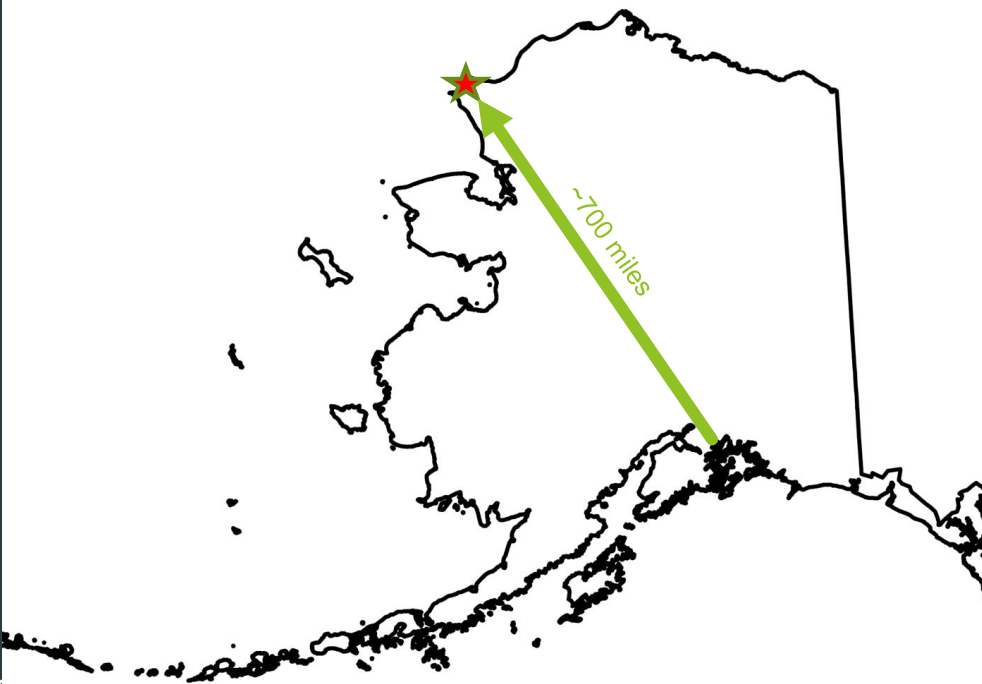


Latitude (WGS84)

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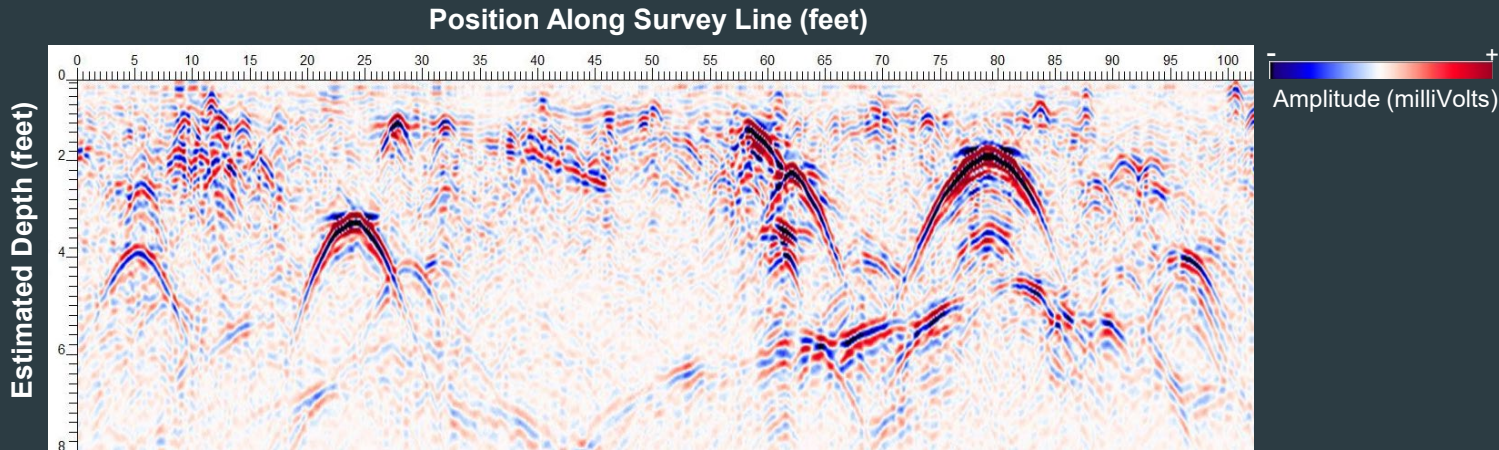
# Case Study: Utility Locating

- ▶ Location: Alaskan village
- ▶ Method: GPR
- ▶ Logistics: Alaska Air and village carrier
- ▶ Lodging: NSB camp
- ▶ HSE: Cold weather and darkness

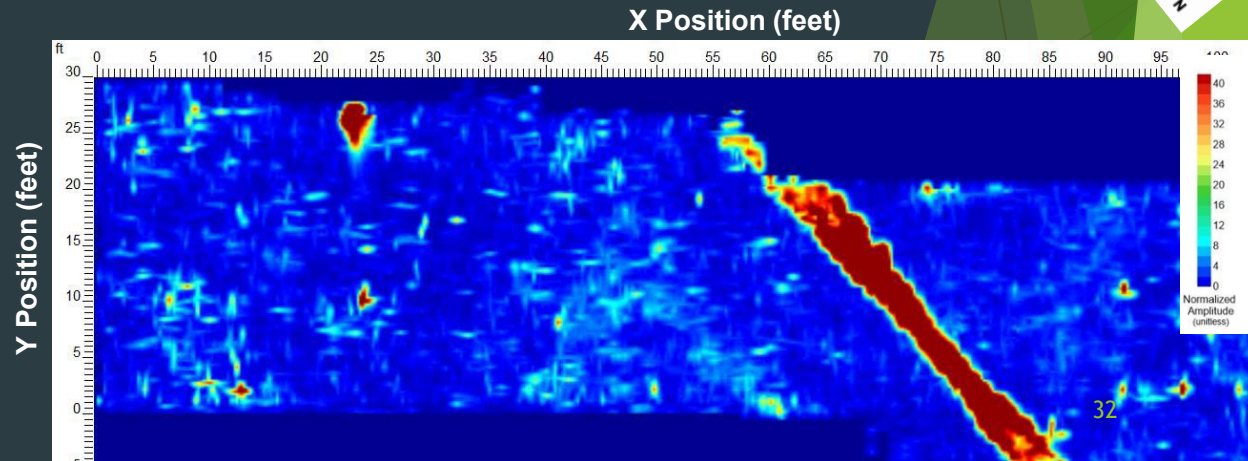


# Case Study: Utility Locating

- ▶ Results – everything georeferenced as well as marked on the surface
- ▶ Identified utilities that could not be located with any other method – nonconductive, no tracer

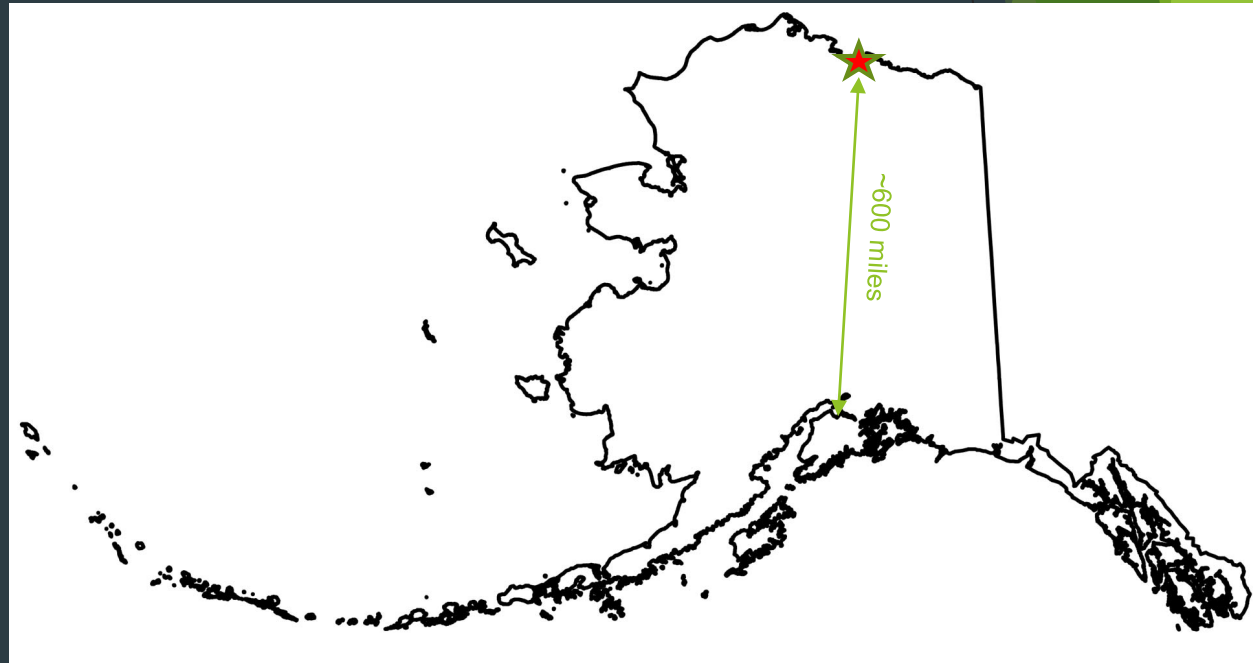


Vertical exaggeration ~5:1



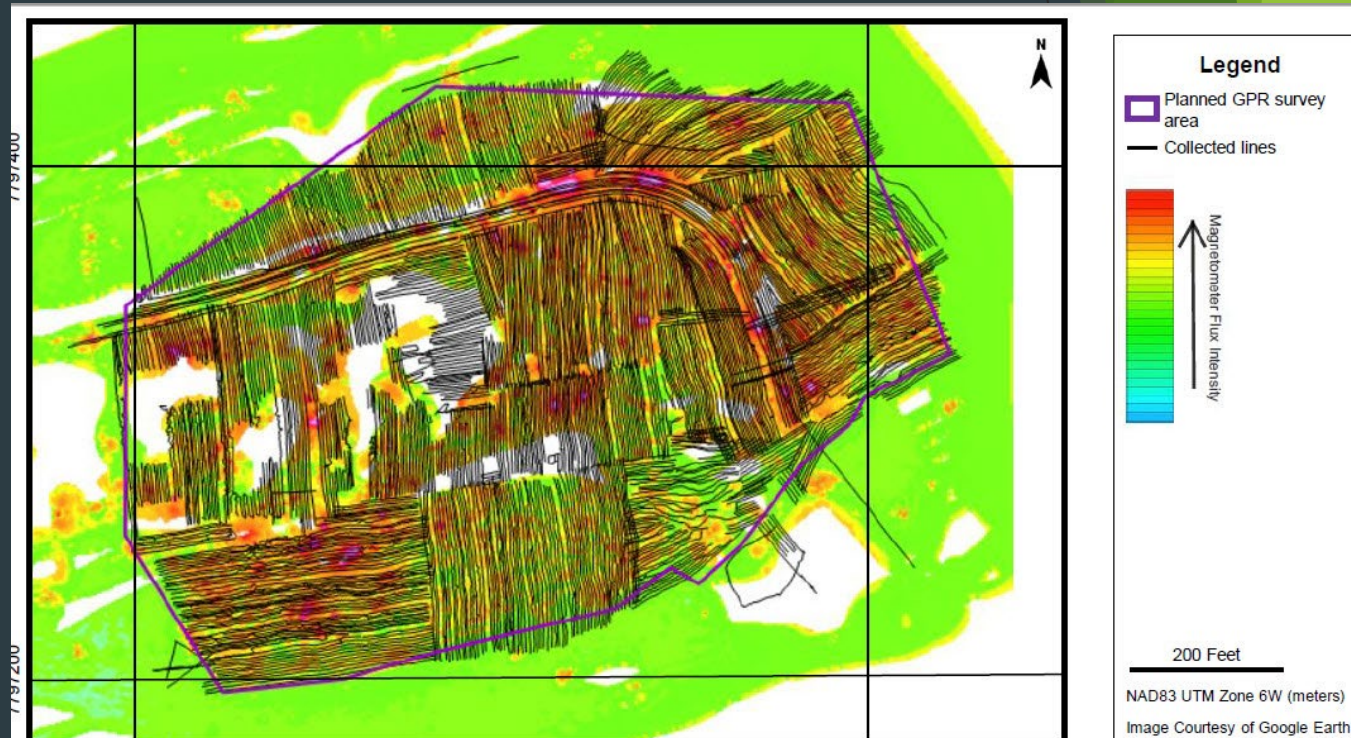
# Case Study: Landfill

- ▶ Location: northern Alaska
- ▶ Method: Low-frequency Ground-penetrating-radar
- ▶ Logistics: ~2-hr commercial flight
- ▶ Lodging: “Hotel”
- ▶ HSE: Bears/wildlife



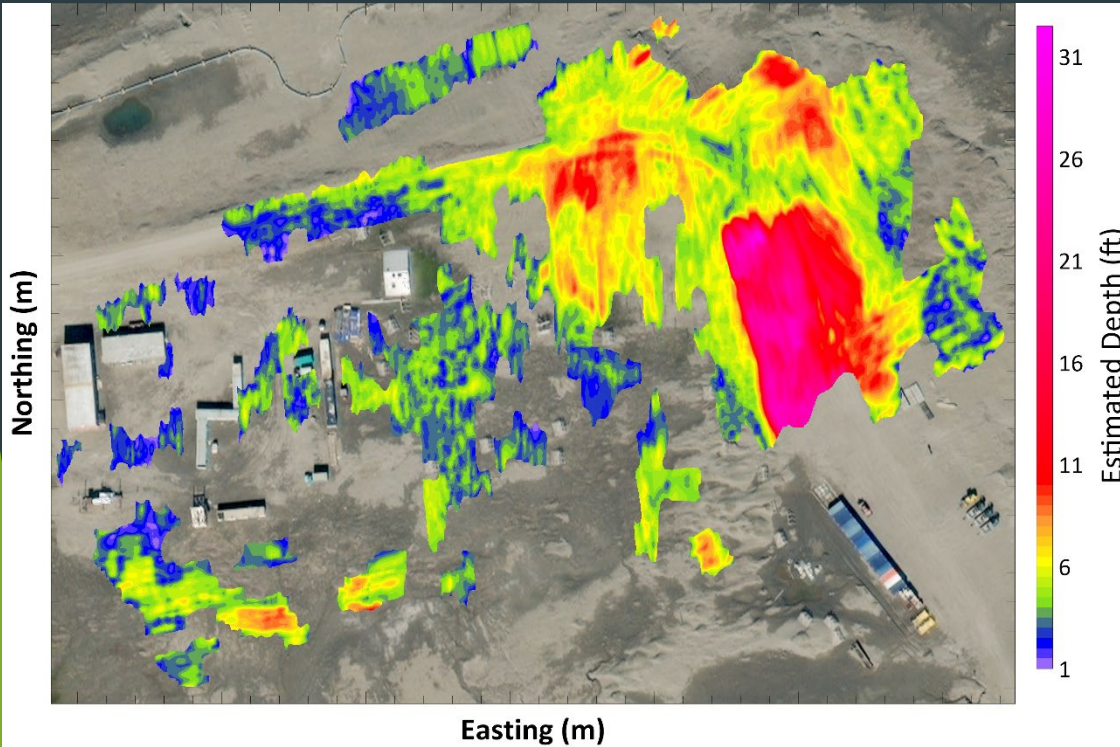
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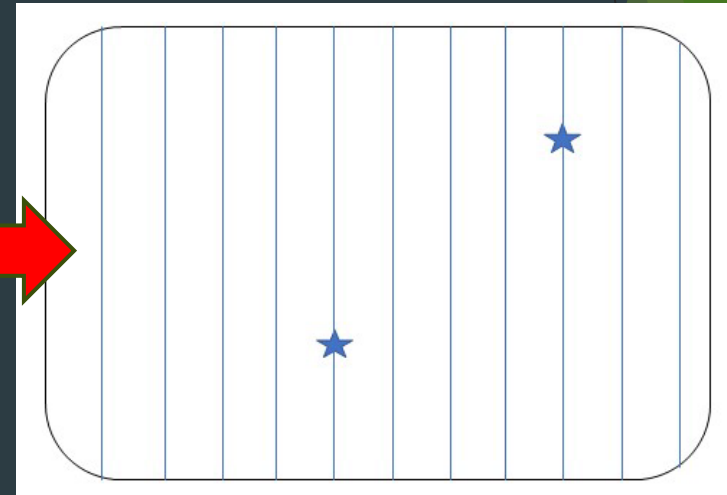
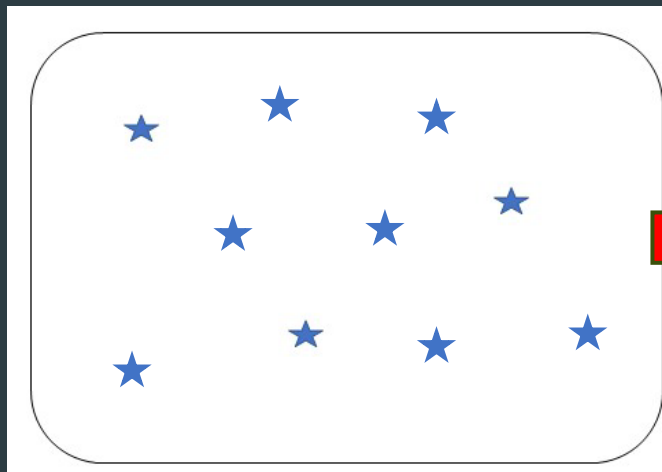
- ▶ Results - Lateral extent and volume estimate of buried debris



# "Best Practices"

## Strengths:

- ▶ Reduces overall cost by minimizing the number of boreholes, excavations, etc.
- ▶ More, higher-quality information at a lower price
- ▶ Non-invasive: reduced ground disturbance in sensitive areas (cultural sites, protected areas)
- ▶ Safer due to limited exposure to digging hazards



# Caveats

- ▶ Geophysics is useful for a wide range of applications
- ▶ Geophysical methods are not infallible
- ▶ Geophysics is an exercise in interpretation
  - Still requires “ground truth” in the form of boreholes



# Questions?

