Geotechnical, Geophysical, Geoenvironmental
Engineering Technology Transfer Conference

Session 2B: Geophysical 1, Moderator: John Stewart

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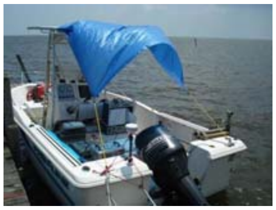
Keys to Successfully Using Geophysics to Detect Mine Voids and Covered Sinkholes

Introduction

- What is geophysics and why use it?
- Which geophysical methods are best for mine void detection?
- Example Case Studies

What is Geophysics?

Geophysics is the applied science of inferring subsurface conditions by non-invasively measuring one or more physical properties of the earth.



Geophysical surveys can be carried out on land, on water, on ice, from the air, and in boreholes.

Why Use Geophysics?

Geophysical surveys compliment traditional methods (i.e. drilling and sampling) used in earth science and engineering investigations.

Benefits:

- Allow exploration of large subsurface volumes continuously
- Non-invasive, non-intrusive, and non-destructive
- Enhance the level of confidence
- Identify targets for intrusive investigation
- Fill the gaps between intrusive sampling points
- Cost effective - Adds value to a project

Geophysical Methods for Void Detection

EM Methods / Electrical Methods

- Electromagnetics (EM)
- Radio Detection
- Magnetics
- Very Low Frequency EM (VLF)
- Ground Penetrating Radar (GPR)
- Electrical Resistivity Imaging (ERI)
- Induced Polarization (IP)
- Spontaneous Potential (SP)
- Liner Leak Detection (LLD)

Seismic Methods / Other

- Seismic Refraction / Reflection / Crosshole
- Surface Wave Methods
- Marine Seismic
- Side-Scan Sonar
- Gravity/Microgravity
- Borehole Logging
- Borehole Camera / Televiewer Imaging

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Ground Penetrating Radar (GPR)

- GPR uses high frequency electromagnetic pulses to image features within the subsurface
- Reflections are generated from material interfaces in the subsurface
- GPR is an effective tool for small, shallow voids but:
  - Depths of investigation are limited (less than 60 feet in sandy soil)
  - Depths of investigation are very limited in clayey soils (< 2 feet) and in the presence of saline groundwater
  - Other variables (boulders, irregular stratigraphy, anthropomorphic features) may mask the presence of voids
- Probably the best use is small-scale subsidence voids beneath roads or surrounding culverts or tunnels.
- Can be used as a fast, large area, and cost effective field interrogation method

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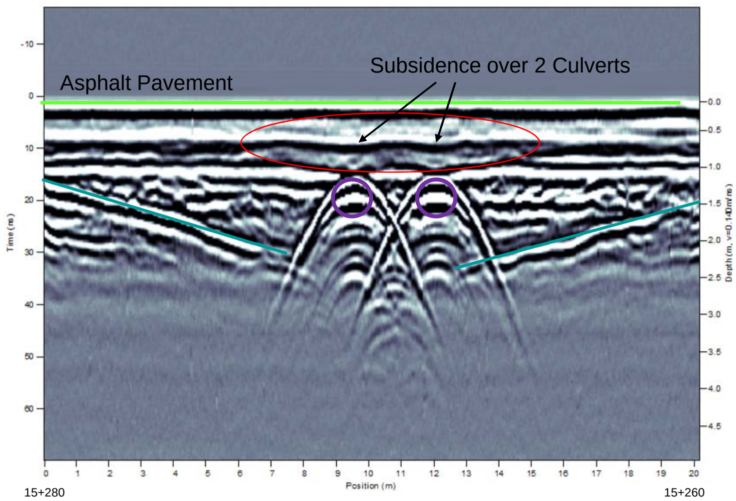
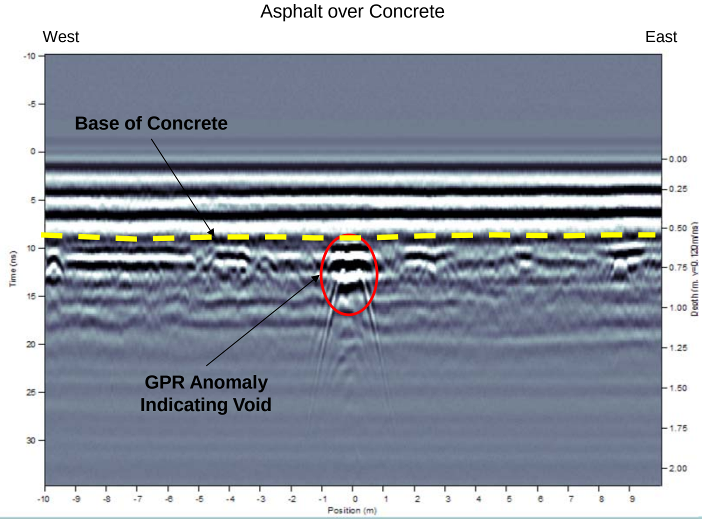
Detecting Small Voids Beneath Asphalt Using Ground Penetrating Radar (GPR)

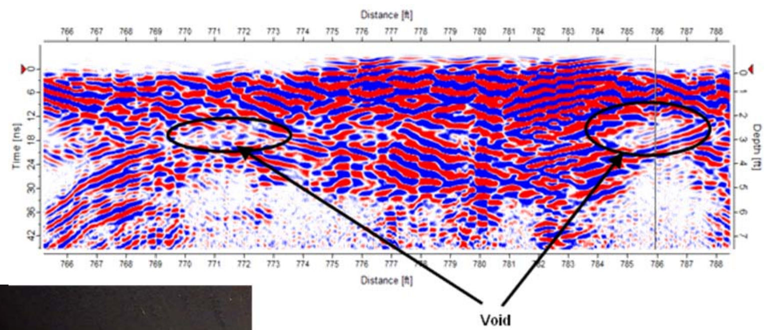


Detecting Small Voids Beneath Asphalt Using Ground Penetrating Radar (GPR)

Asphalt over Concrete

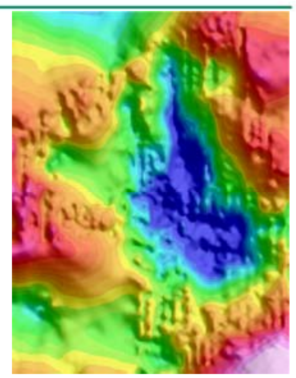


Detecting Small Voids Behind Pipes and Tunnels Using GPR



Microgravity

- Delineate buried valleys, karst and sinkhole voids, tunnels and abandoned mine workings
- Pros: The method can be very effective for shallow voids with large density contrasts or areas with cultural interference such as inside buildings and along roadways
- Cons: Data collection is slow and expensive. Topographic corrections require extensive processing and other variables may mask the presence of voids.



Micrograviy was used to investigate potential karst features. Drilling confirmed that the gravity low in blue identified by the survey was a large karst feature more than 80m deep.

Gravimeter directly measures gravity in microgals

Forward Model of Microgravity Response over an Underground Mine

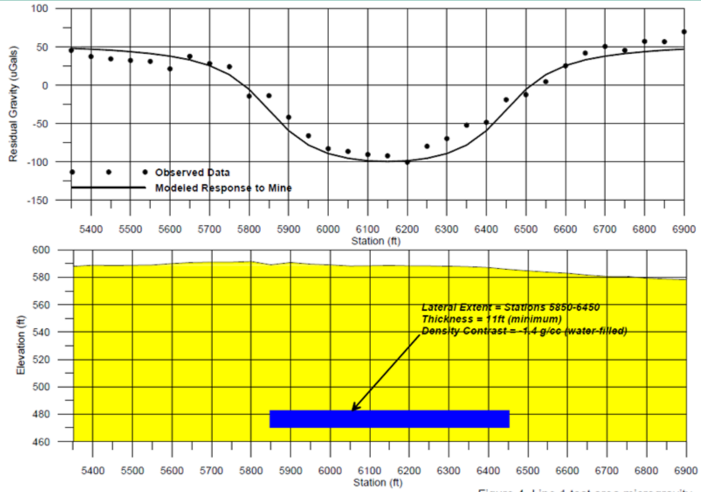


Figure 4. Line 1 test area microgravity data and modeled response to simplified mine conditions

Source: Technos

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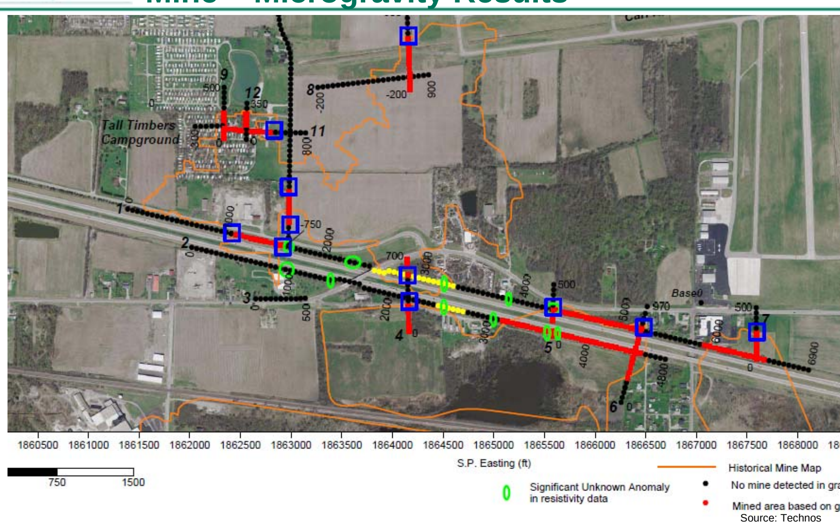
Geophysical Imaging of an Underground Salt Mine – Microgravity Results



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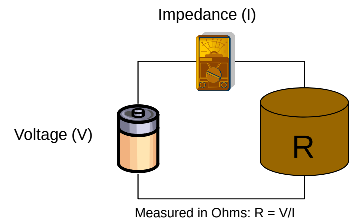
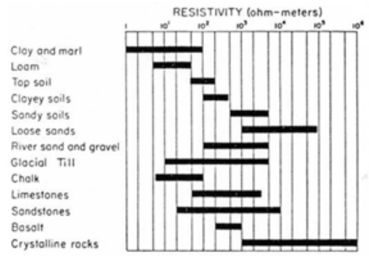
Electrical Resistivity

- Electrical Resistivity is a measure of how easily electricity flows through a material
- Primary properties that affect the resistivity:
  - Porosity: shape, size and interconnection of pores
  - Water content
  - Pore water salinity (electrolytes)
  - Conductivity of minerals (clay mineral and metal content)
- Resistivity of mine voids will either be very high if air-filled or very low if filled with water or clayey sediment

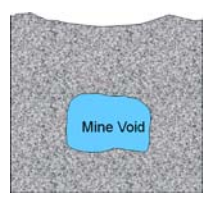


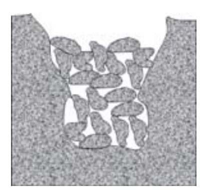


Modified After Culley et al. (1975)

Electrical Resistivity

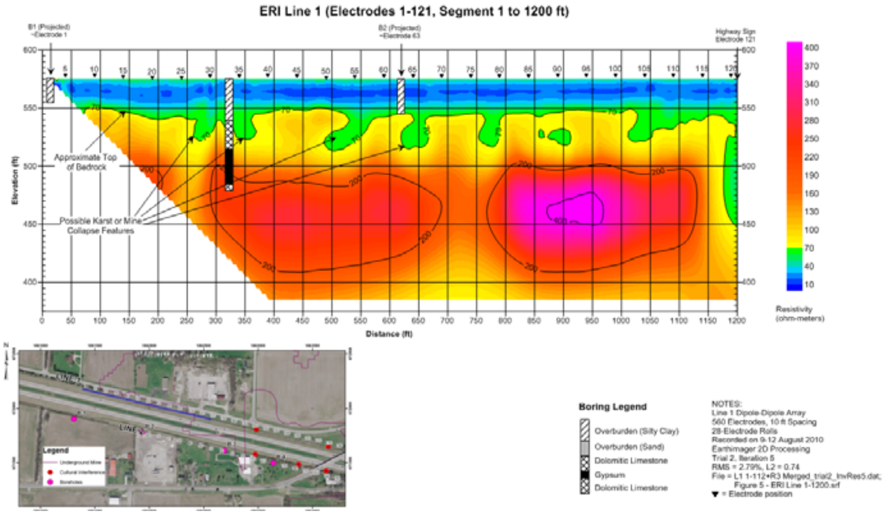
- Pros: Typically, there is a high contrast in subsurface electrical properties between air, water, rock, and clay content.
- Automated multi-electrode 2-D and 3-D imaging allows rapid collection of 1,000s of data points leading to more detailed and accurate predictions of subsurface conditions even in complex and highly irregular geology.
- The method can be very effective for small shallow voids to large deep voids with significant electrical contrasts
- Cons: Data collection can be labor intensive but less than seismic and microgravity
- Resolution decreases as depth increases
- Variable geology may mask the presence of voids





Collapsed Mine Void

Electrical Resistivity Imaging of an Underground Salt Mine



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Geophysical Imaging of an Underground Coal Mine

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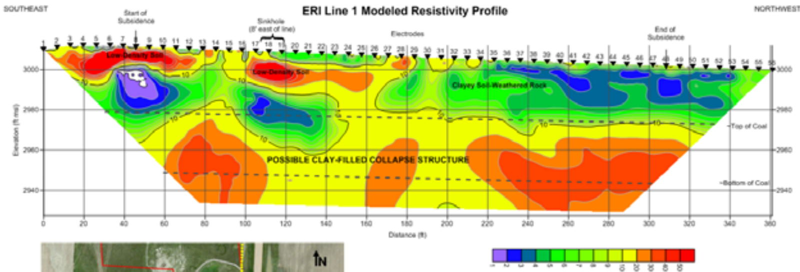
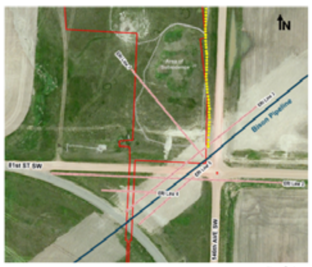
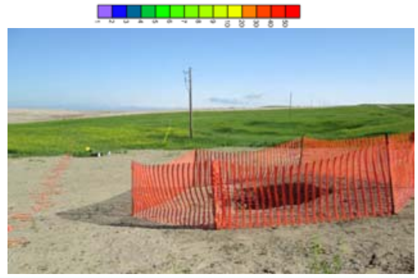
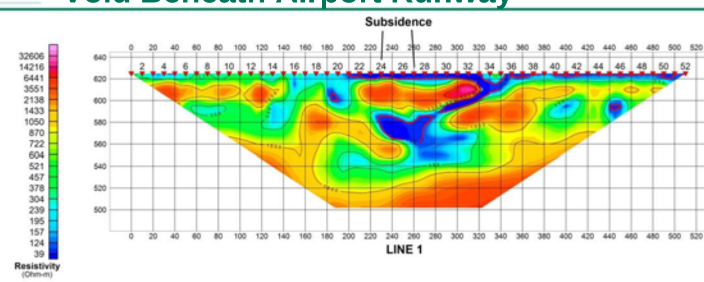
Geophysical Imaging of an Underground Coal Mine



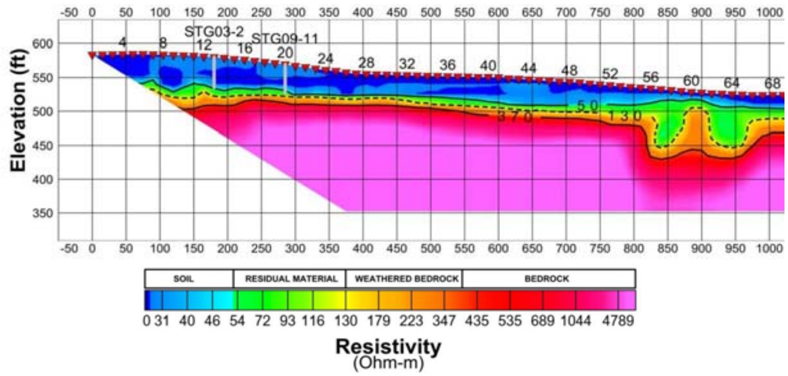




Geophysical Imaging of a Karst Sinkhole and Void Beneath Airport Runway



Geophysical Imaging of Sinkholes and Underground Voids



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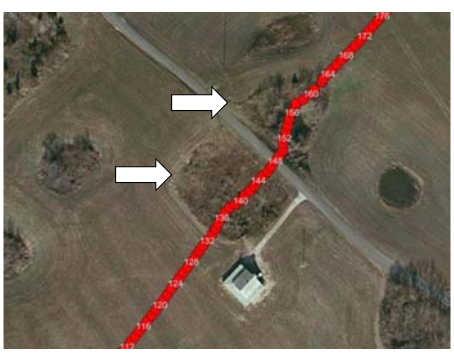
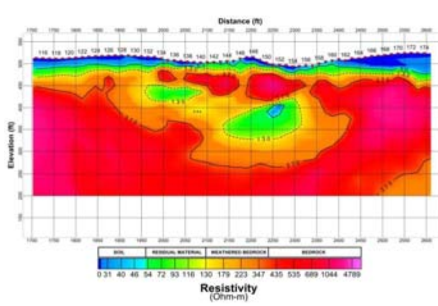
Geophysical Imaging of a Sinkhole

Aerial Photo
Sink - Electrodes 130 – 170



ERI Profile
Sink - Electrodes 130 – 170



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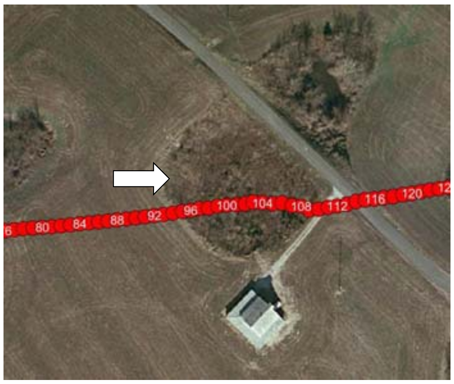
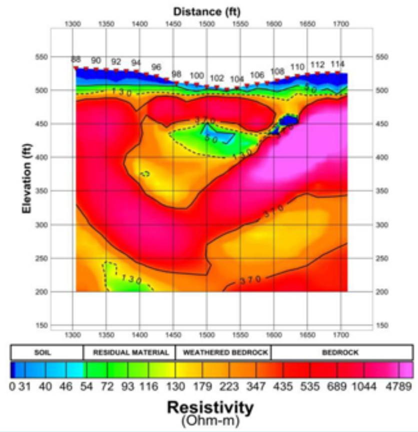
Geophysical Imaging of a Sinkhole

Aerial Photo
Sink - Electrodes 92 – 110



ERI Profile
Sink - Electrodes 92 – 110



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