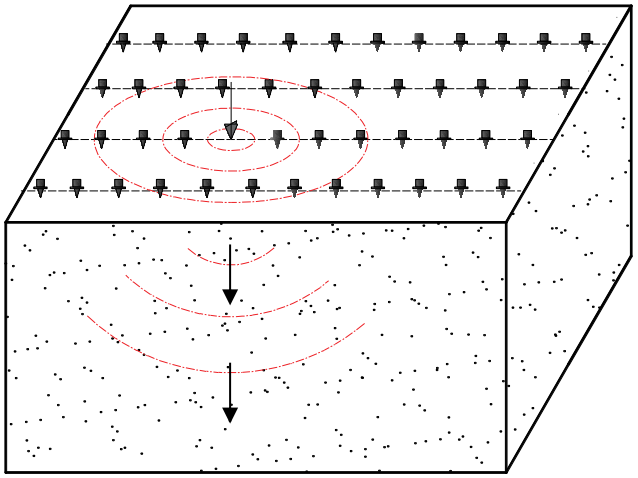
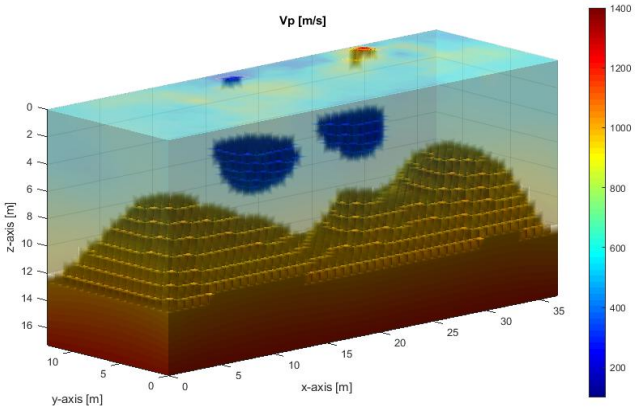
3D SPT- Seismic Testing for Geotechnical Site Characterization





by:
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Introduction

Problem

- Unexpected site conditions cause significant problems during and after construction of infrastructures.
- Structural collapses that lead to significant property damage and even fatalities

Site investigation

- Typical invasive testing SPT, CPT – tests < 0.1% of material
- SPT-seismic method can test over large volume of materials
- Soil/rock property and stratigraphy, and buried voids

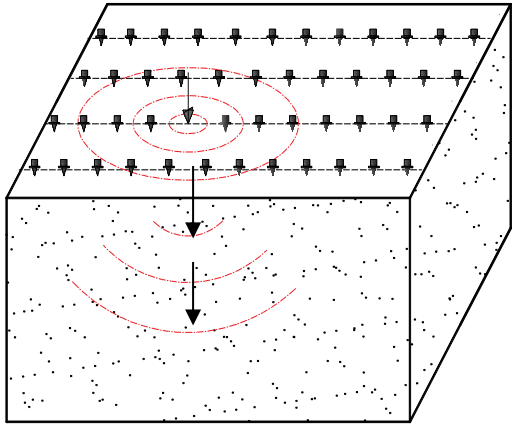
Sinkhole collapses in Florida

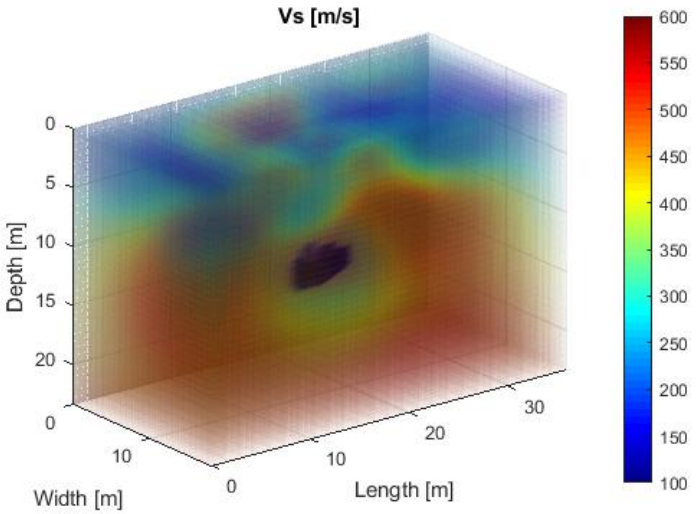
SPT-seismic approach

Leverages byproduct seismic waves generated during SPT to produce 3D imaging around the SPT borehole

As SPT spoon advances through soil and rock layers, seismic wavefields are emitted from varying depths, propagate to the surface, and are recorded by 2D grid of geophones.

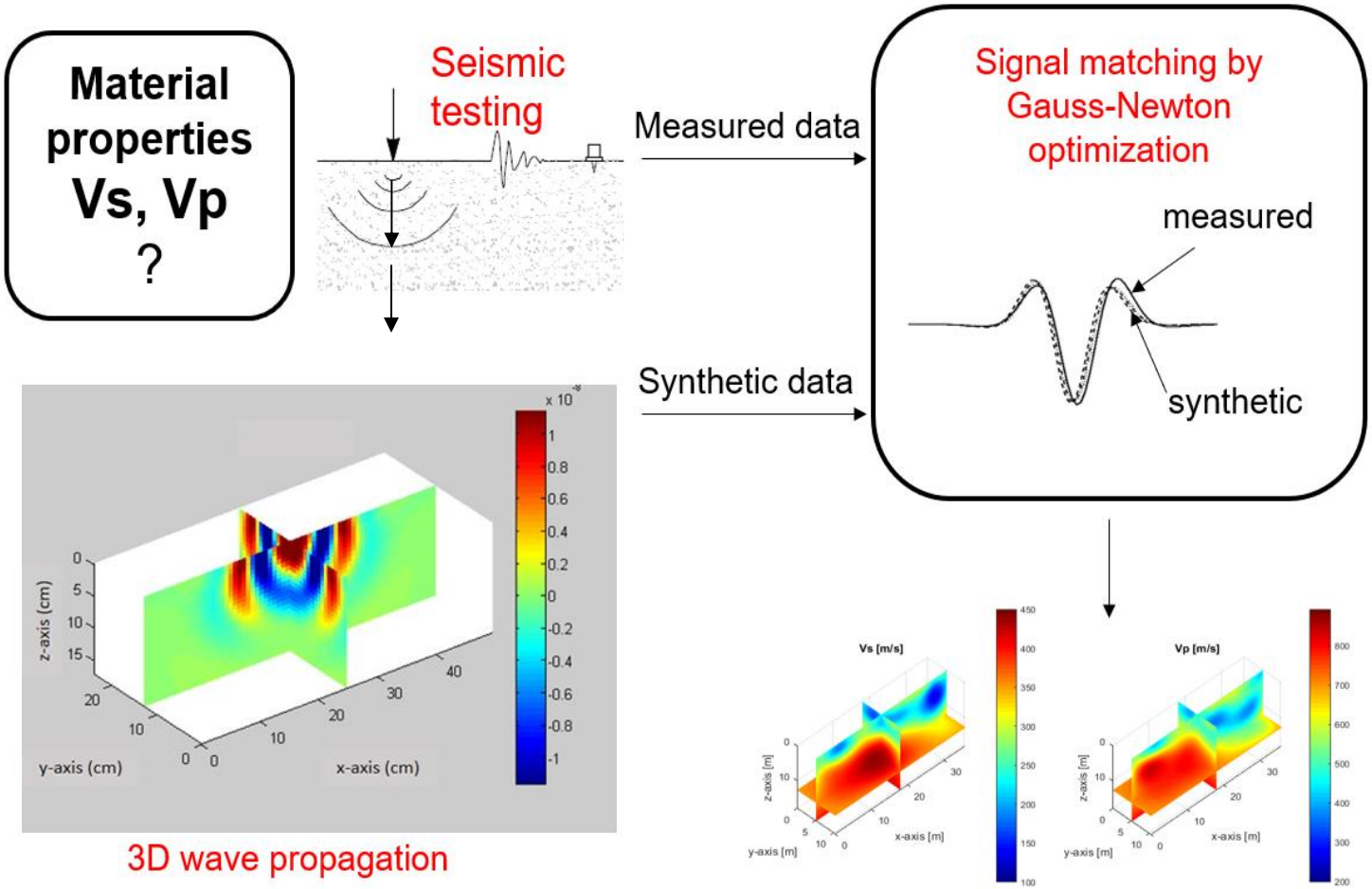
Recorded data are analyzed by 3D FWI to generate a detailed 3D subsurface image, extending up to 60 feet around SPT borehole to any SPT depth





Mirzanejad M., Tran K.T., McVay M., Horhota D. and Wasman S. (2020), "Coupling of SPT and 3D full waveform inversion for deep site characterization" *Soil Dynamics and Earthquake Engineering,* 136, 106196

Methodology



Tran K.T., Mirzanejad M., McVay M., and Horhota D. (2019), "3D Time-Domain Gauss-Newton Full Waveform Inversion for Near-Surface Site Characterization", *Geophysical Journal International*, 17, 206–218.

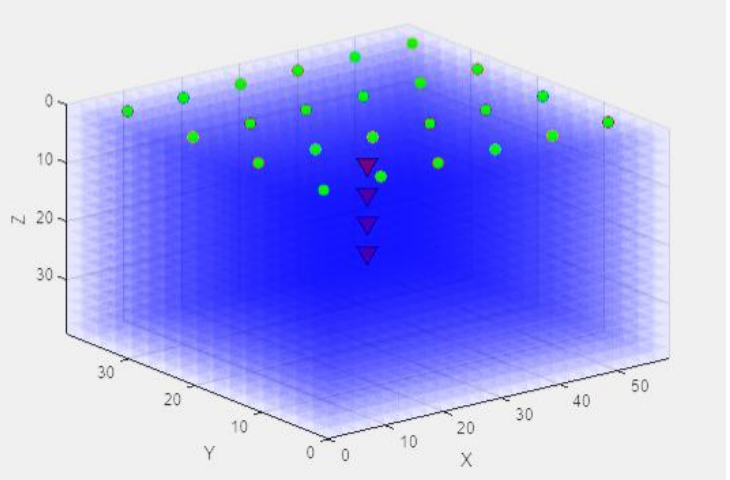
HGS Demonstration

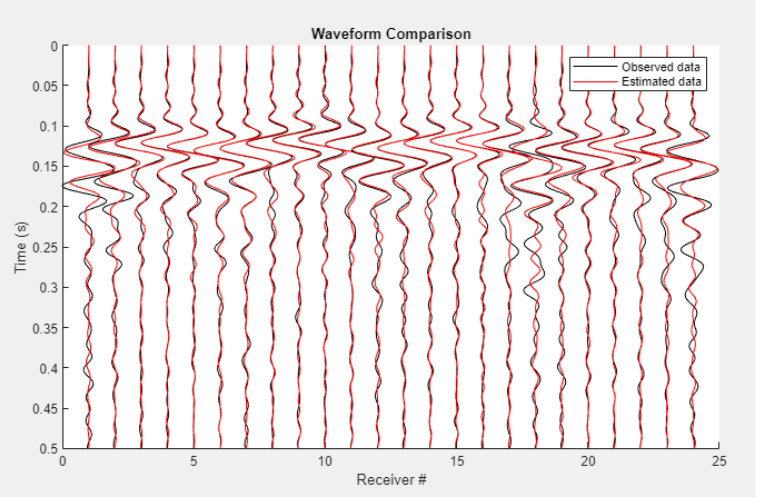
Site 1: Lawrence, KS

Data collection

- 24 channel seismic system (provided by KDOT)
- Surface area of 40 x 60 ft
- 24 geophones in 4 x 6 grid at 10 ft spacing
- SPT-seismic source at depths of 5 ft intervals to 23 ft depth
- Trigger is attached to SPT rod to activate seismograph

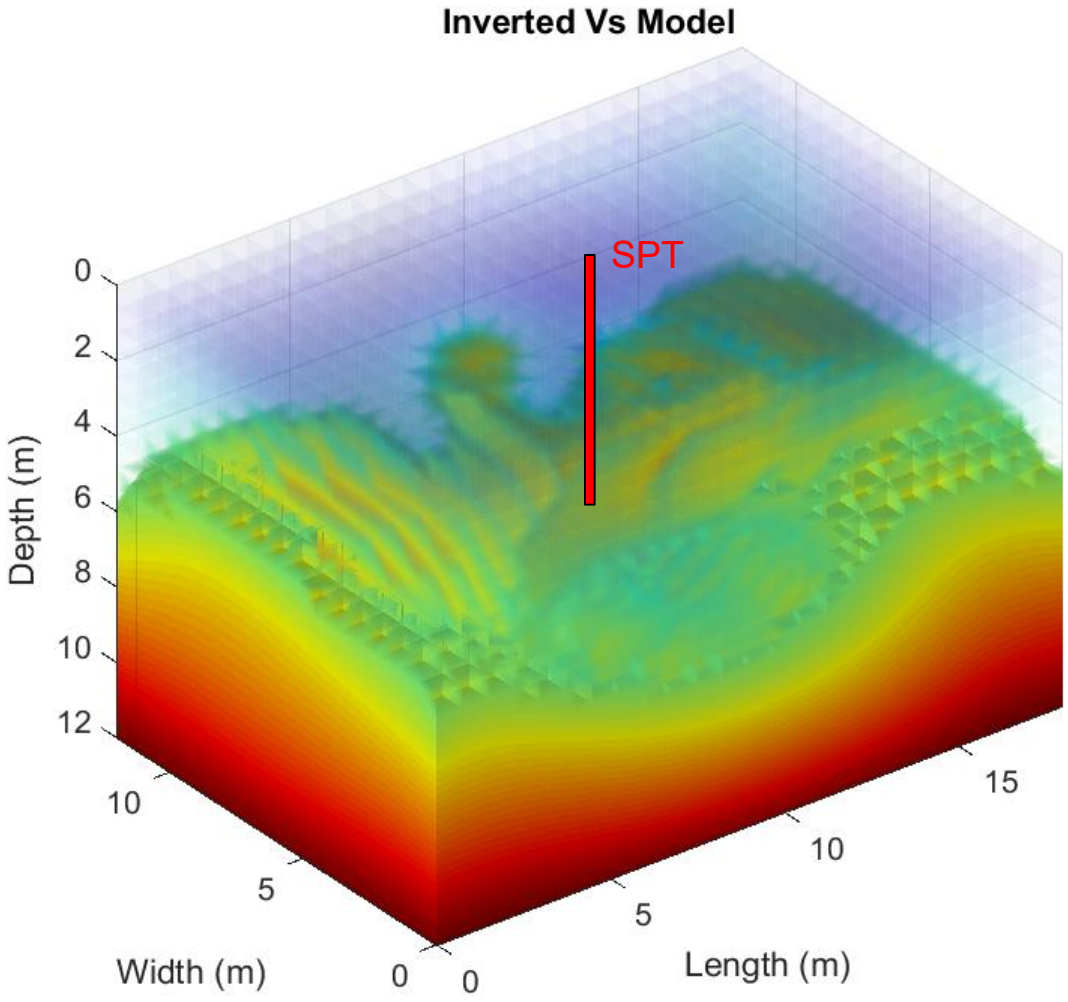
Data analysis
40 x 60 x 40 ft, 2.5 ft pixels,
3 hours of computer time

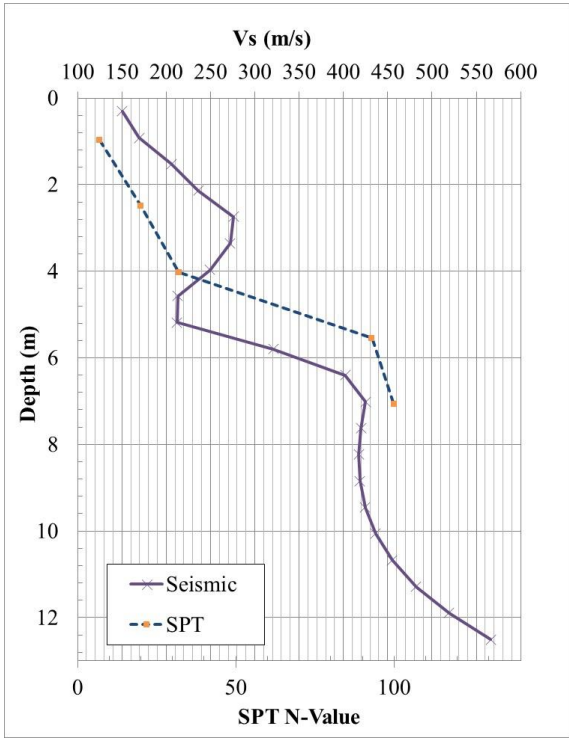




SPT spoon at 23 ft depth

Lawrence site result



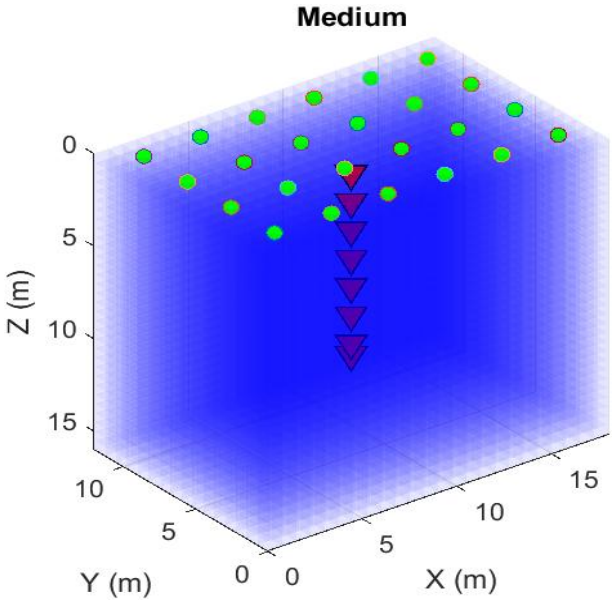


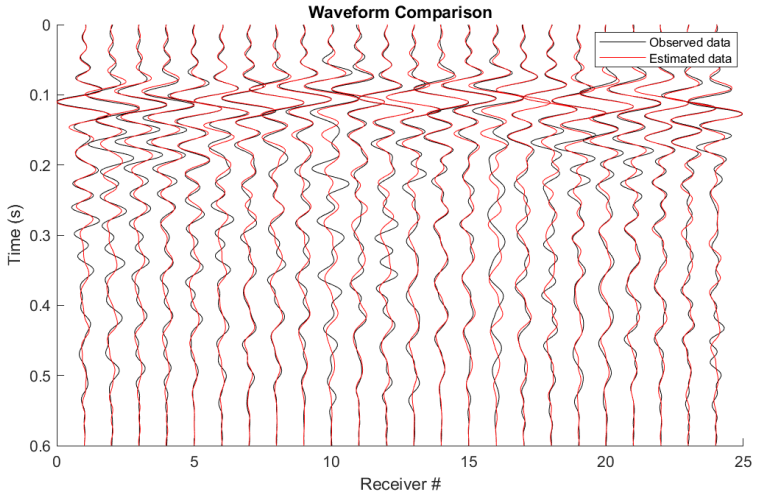
Site 2: Minnesota

Data collection

- Data collected by MnDOT
- 24 channel seismic system
  Surface area of 40 x 60 ft
- 24 geophones in 4 x 6 grid
  at 10 ft spacing
- SPT-seismic source at
  depths of 5 ft intervals to 35
  ft depth

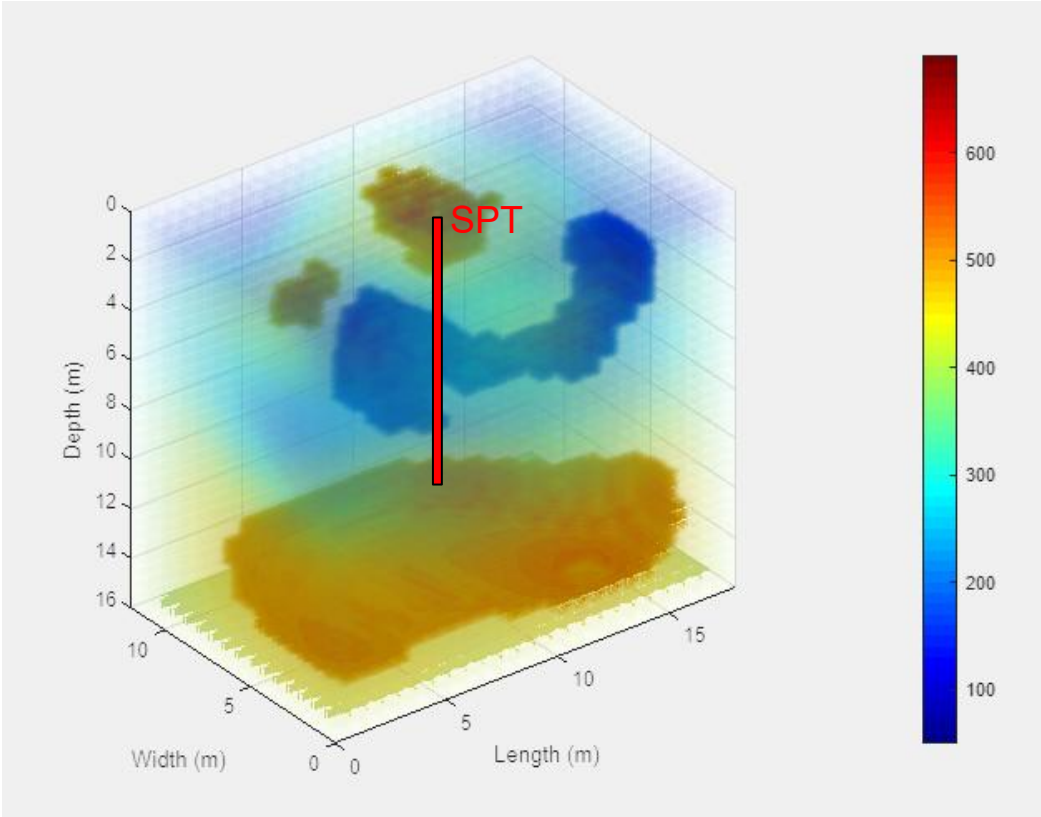
Data analysis
40 x 60 x 55 ft, 2.5 ft pixels,
4 hours of computer time

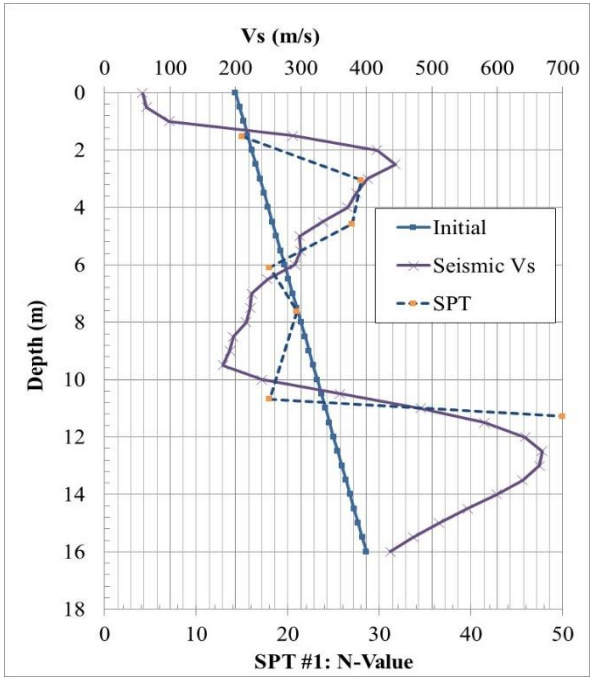




Sample data at 30 ft depth

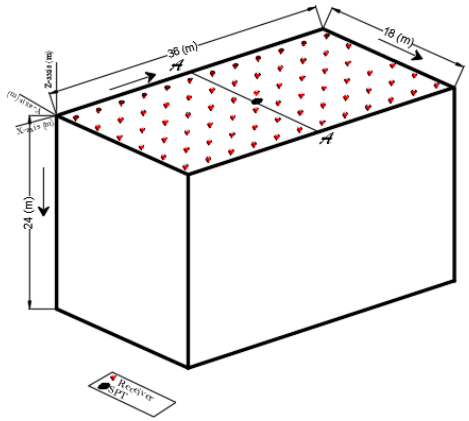
Minnesota site result

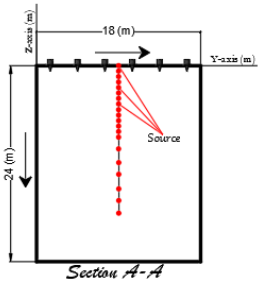




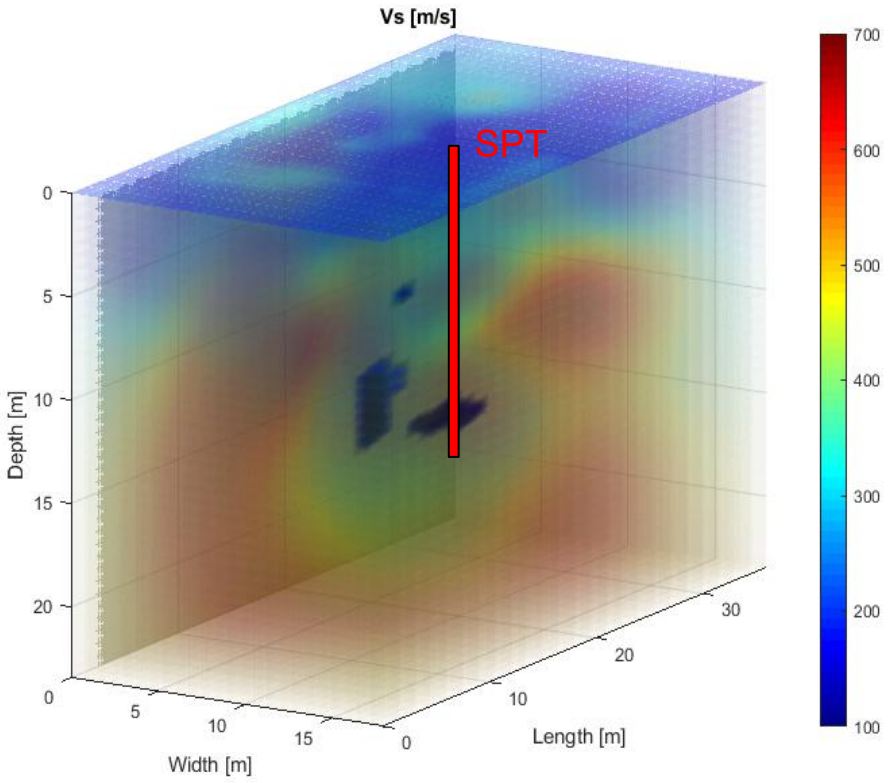
Site 3: Newberry site

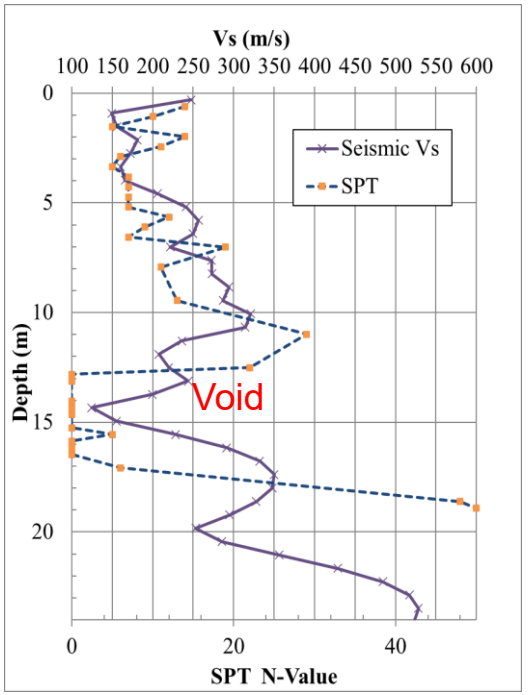
- area of 120 x 60 ft (36 x 18 m)
- 72 geophones located in 6 x 12 grid at 10 ft spacing
- SPT-seismic source at depths of 2-5 ft intervals to 62 ft depth





Newberry result

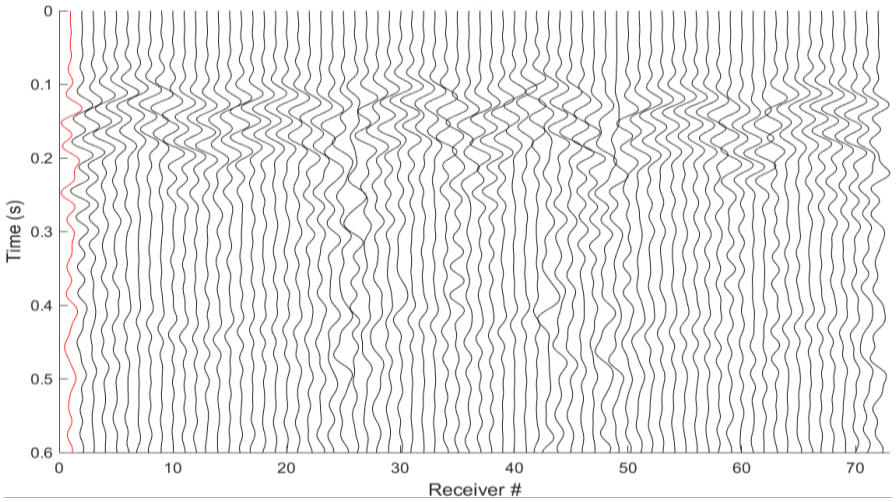




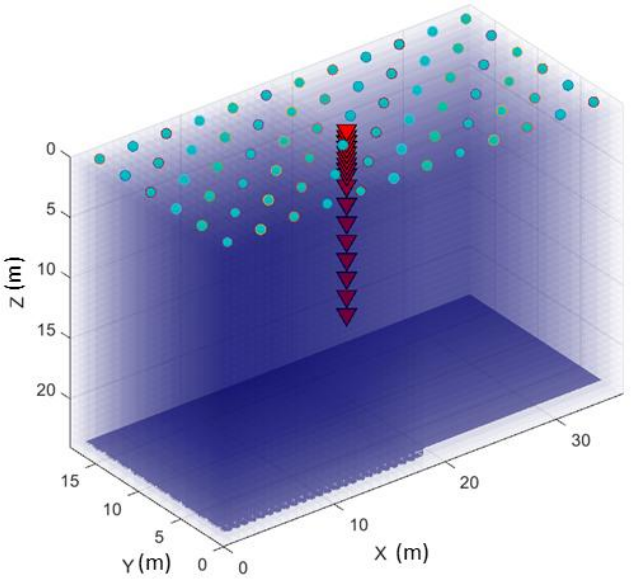
Tran K.T., Mirzanejad M., Horhota D. and Wasman S. (2024), 3D full-waveform tomography of SPT-seismic wavefields in karst Florida limestone" *Journal of Transportation Research Board*

Site 4: Bell site

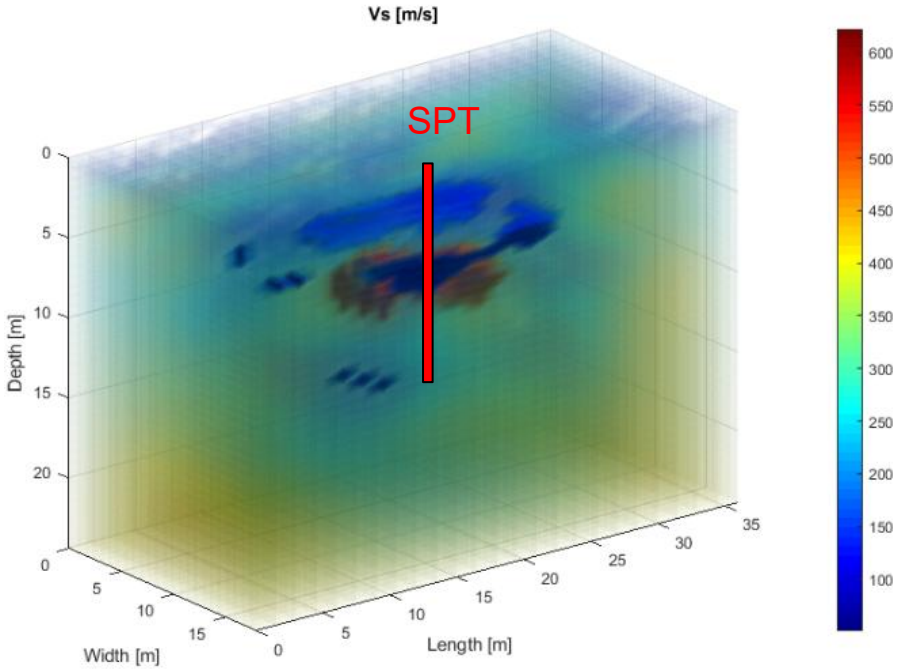
- 72 geophones located in 6 x 12 grid at 10 ft spacing
- SPT to 52 ft

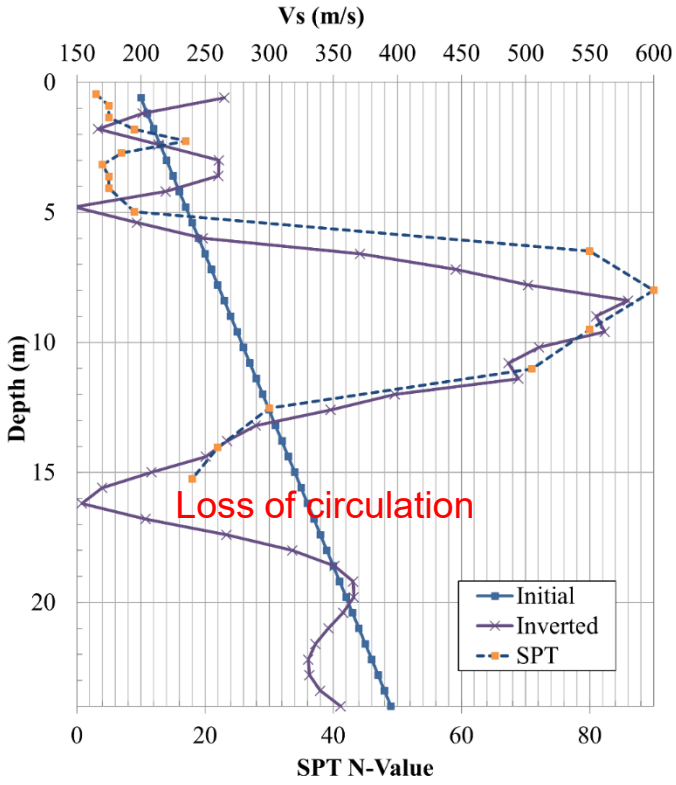


Data at 52 ft depth



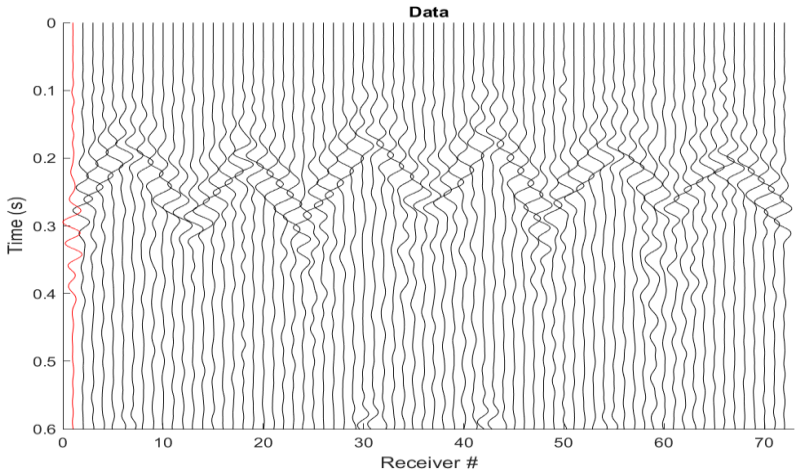
Bell site result

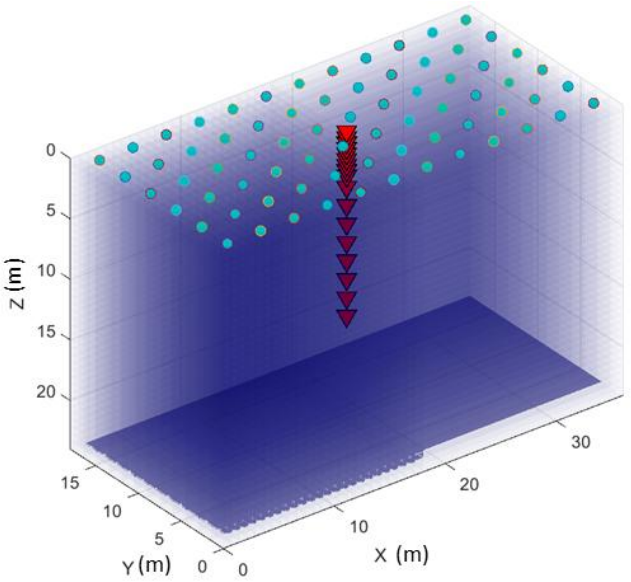




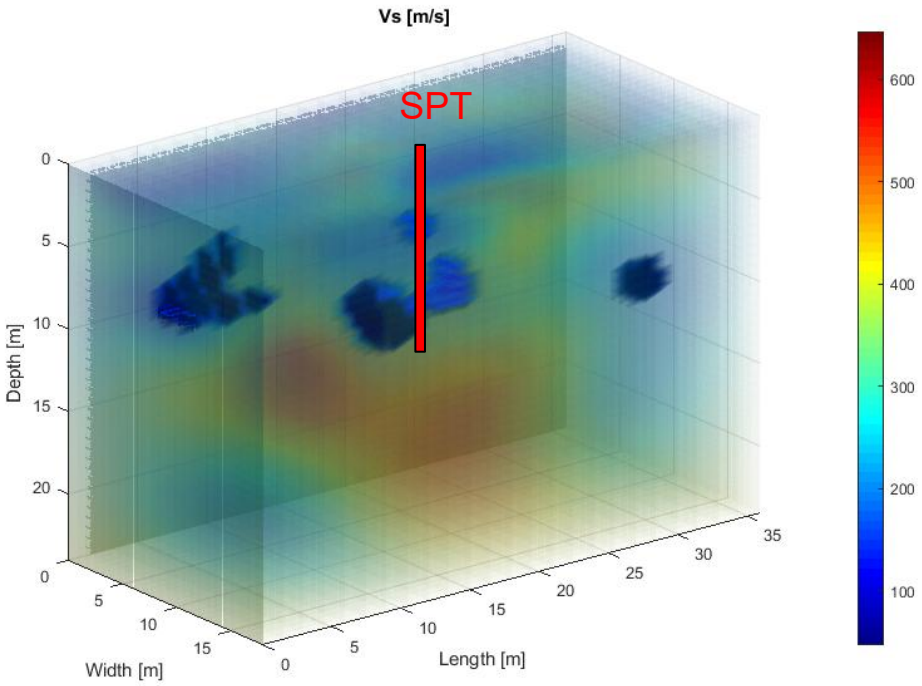
Site 5: Kanapaha site

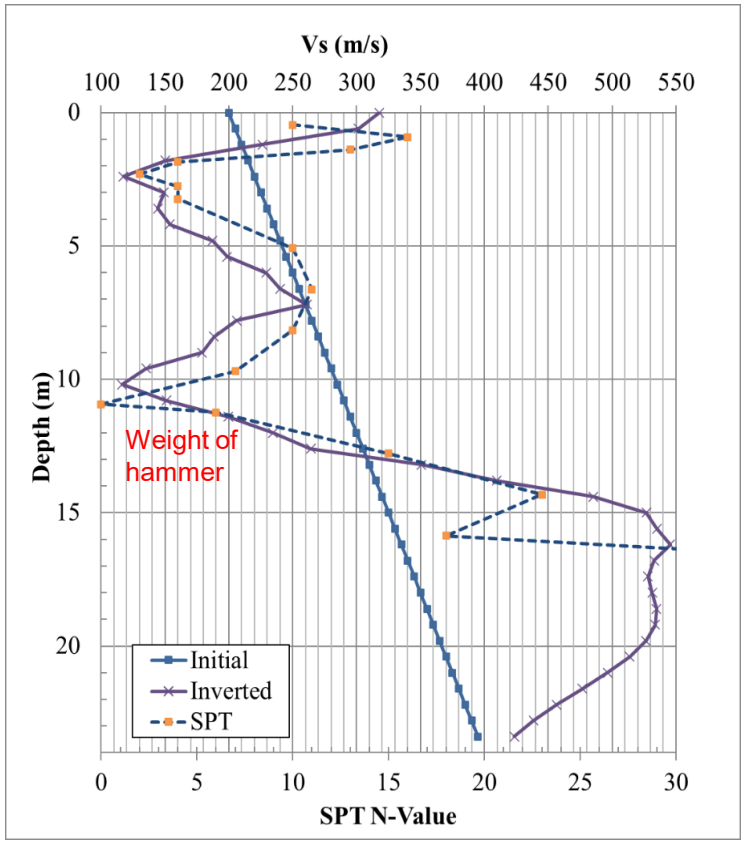
- 72 geophones located in 6 x 12 grid at 10 ft spacing
- SPT to 58 ft





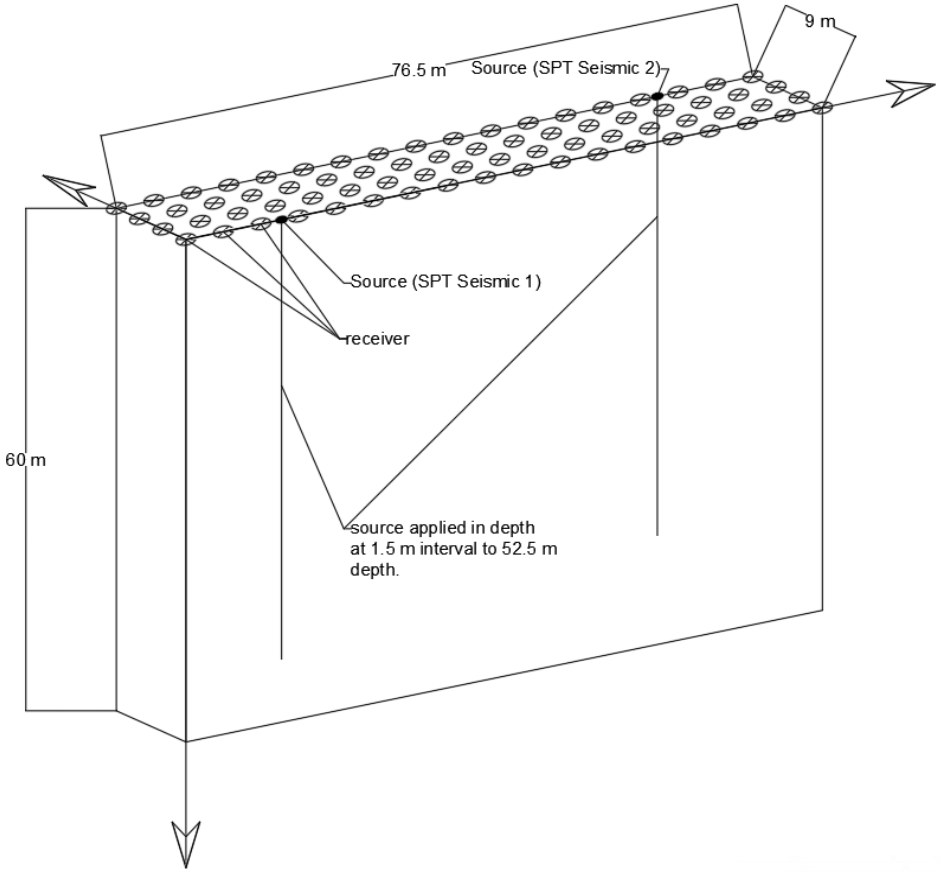
Kanapaha site result



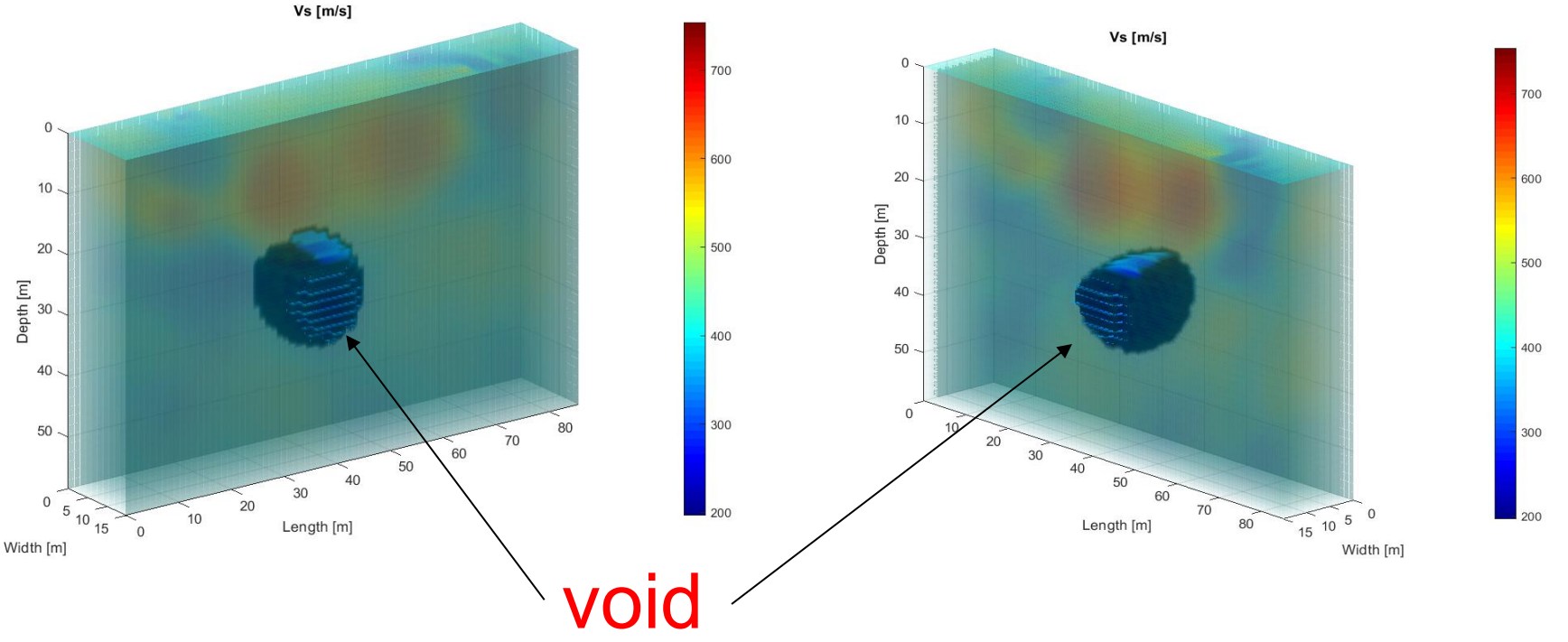


Site 6: Miami site

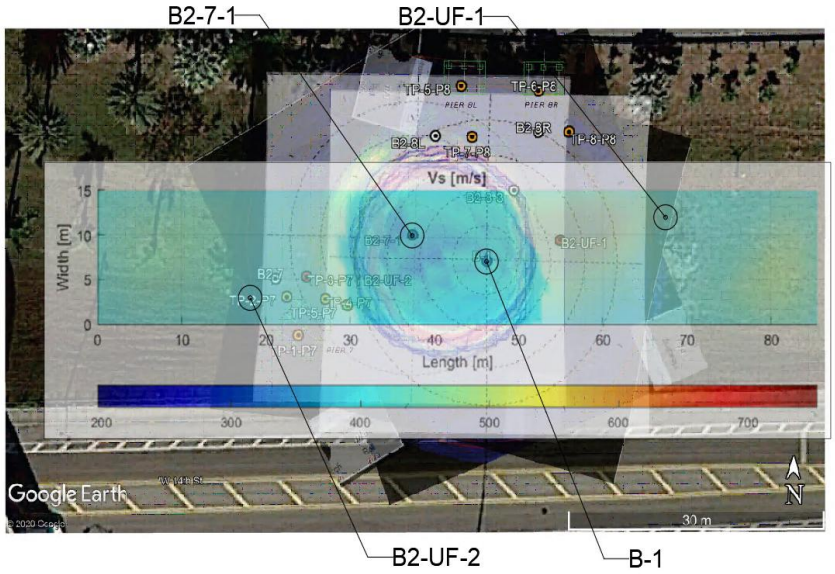
- 2 SPTs to 175 ft depth, 150 ft apart
- 72 geophones located in 18 x 4 grid at 15’x10’ spacing



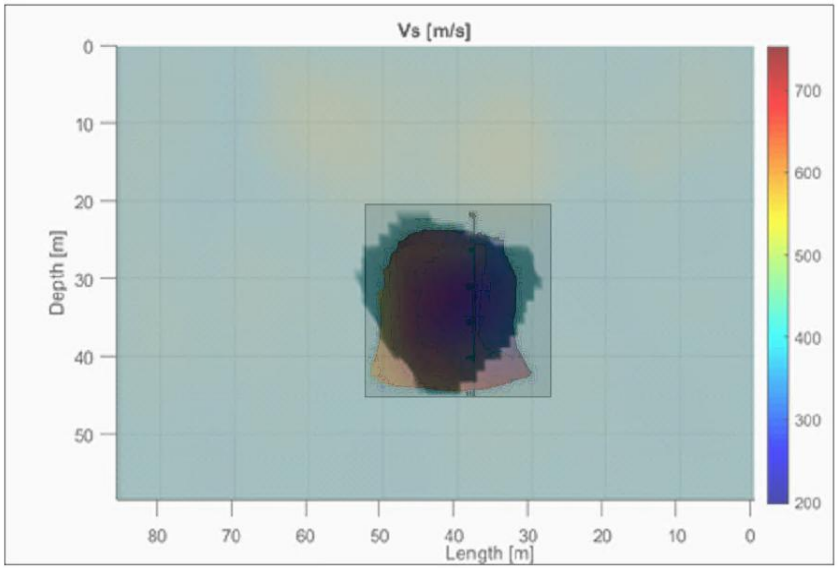
Miami site results



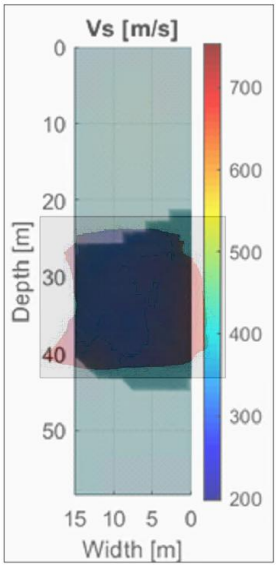
Miami site: SPT-seismic vs Sonar



Top-down overlay



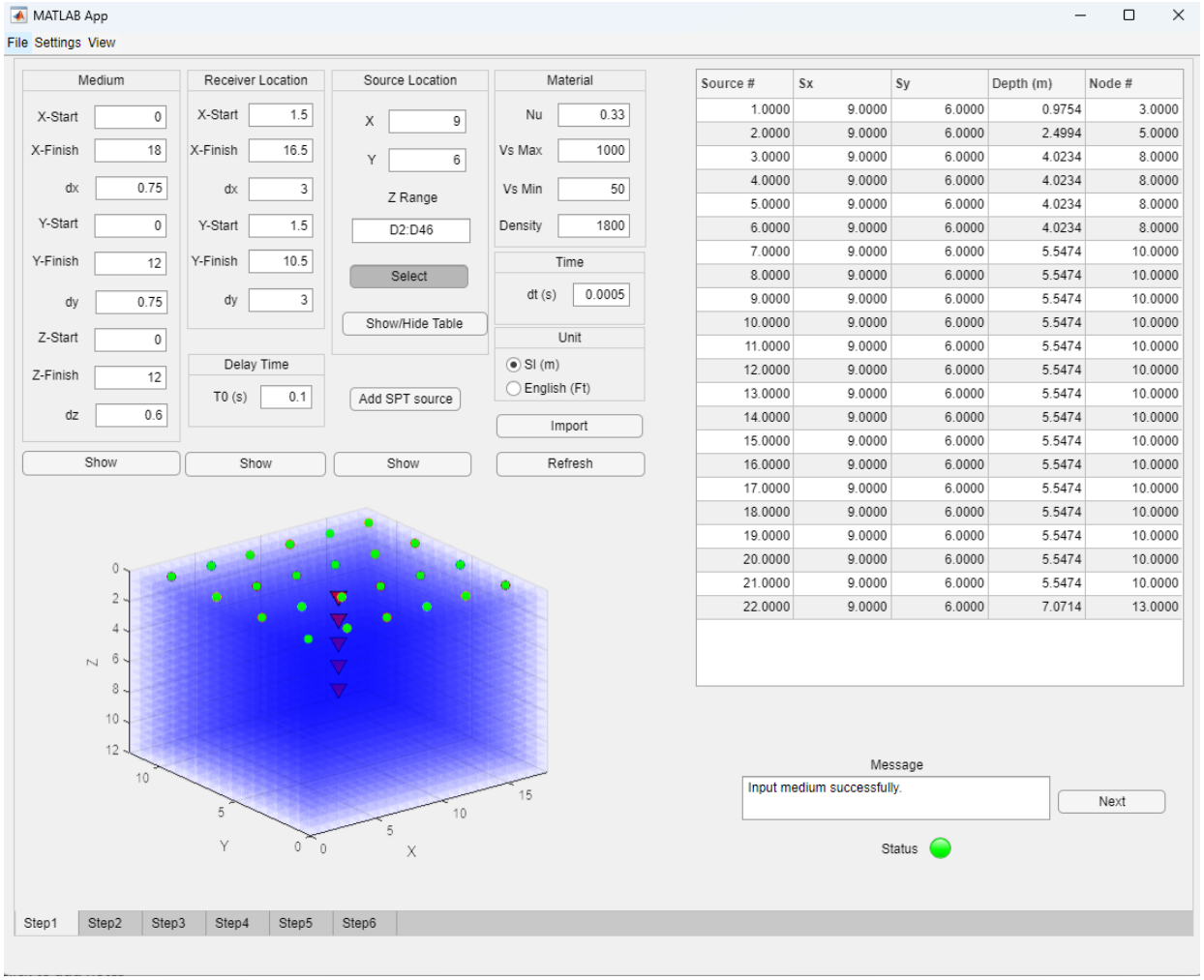
North-south overlay



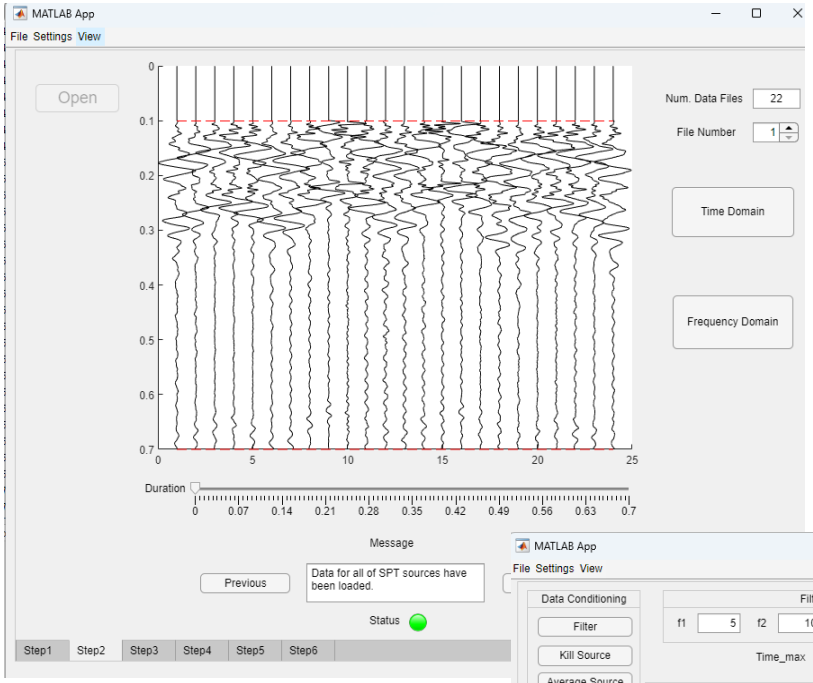
East-west overlay

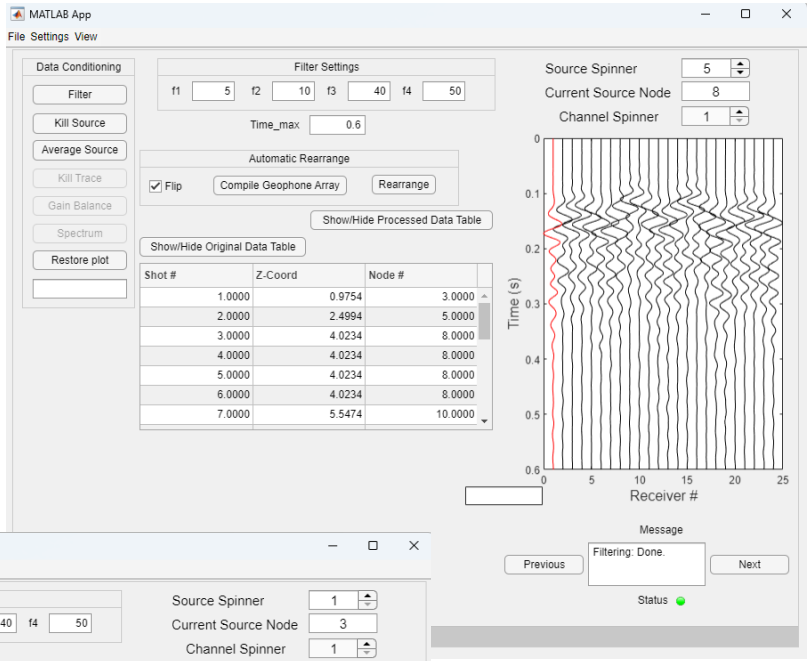
3D SPT-Seismic Software

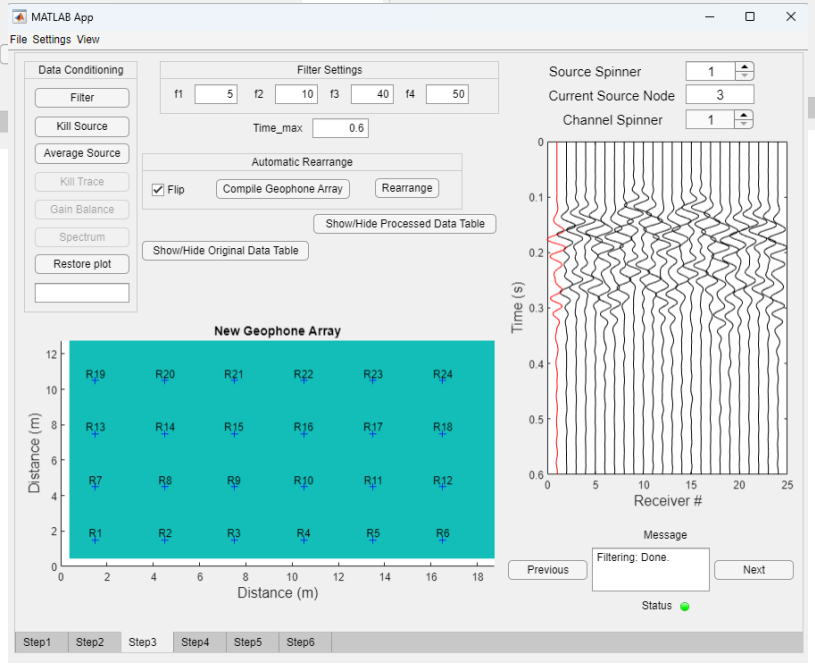
- **Define Required Parameters for Data Analysis Including 3D Visualizations**



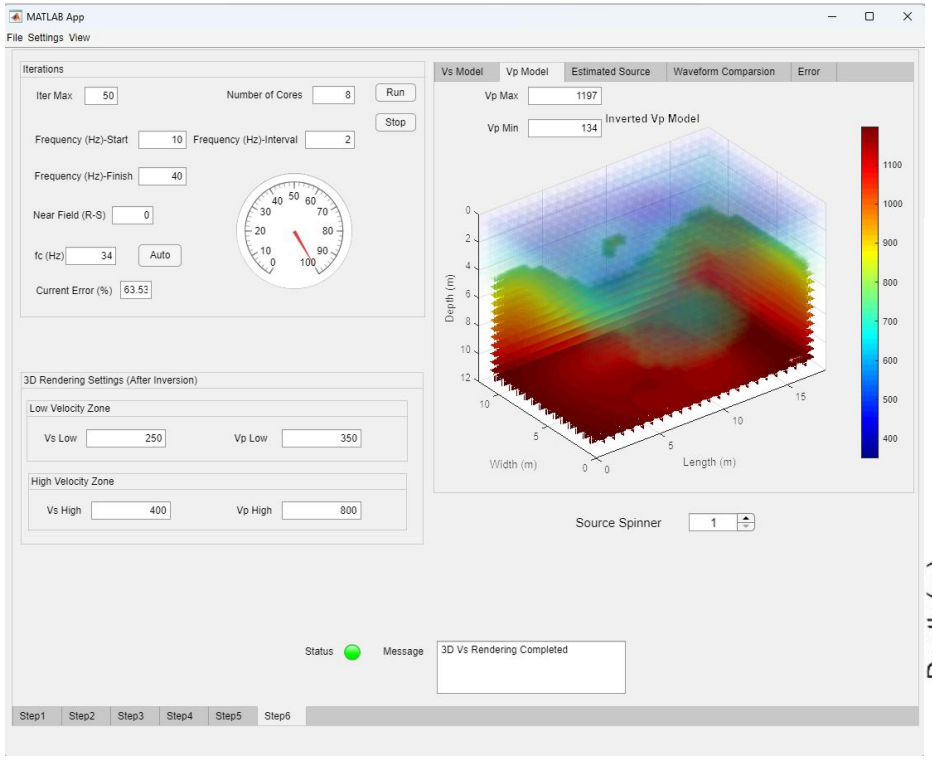
Data conditioning

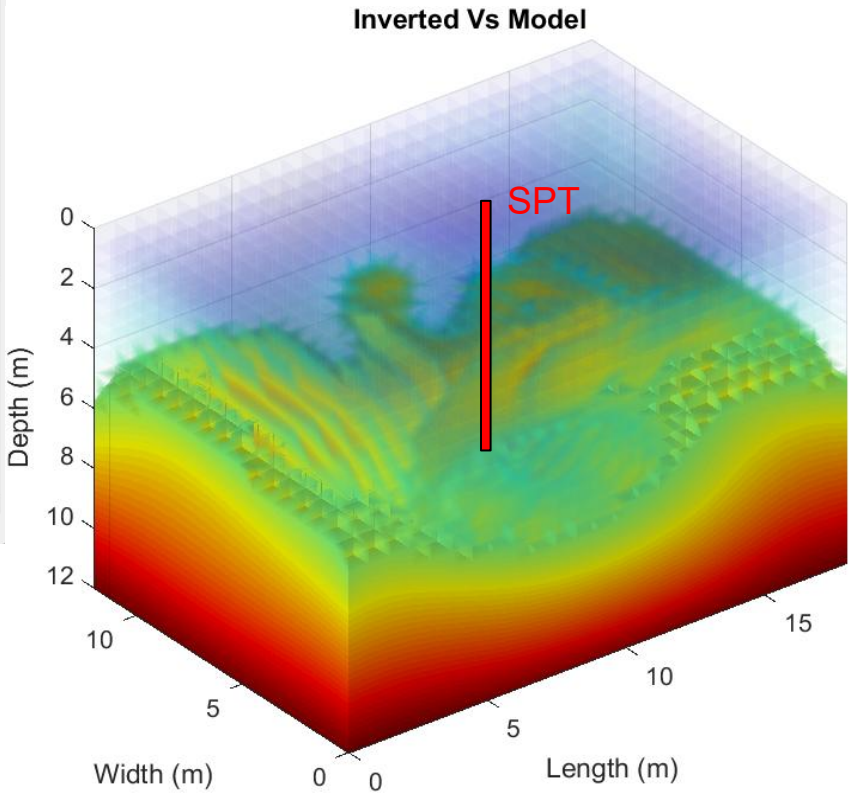






Data Analysis





Summary

- The 3D SPT-seismic method provides new capabilities for subsurface imaging.
- Soil/rock properties and voids can be characterized at 2-ft pixels over a large 3D volume, extending up to 60 ft around SPT borehole.
- Requiring a single borehole for 3D imaging, SPT-seismic method is a cost effective and efficient tool for site characterization.

Transportation Pooled Fund Study

Objectives and Tasks

The objectives of this TPF are to automate SPT-seismic method and validate its applicability across various geological conditions for widespread use in site characterization.

Task 1: Automation of 3D SPT-seismic algorithm

Task 2: Implementation of automated 3D SPT-seismic software

Task 3: Validation of 3D SPT-seismic method at State DOT sites

Task 4: Technology transfer and training

Deliverable

A user-friendly 3D SPT-seismic software package will be delivered to participating members. The software will analyze SPT-seismic data with minimal human efforts and generate 3D images of soil/rock properties around SPT boreholes.

Budget and Schedule

The estimated total project cost is $500 k, and the estimated duration is 4 years. Funding requested: $100 k ($25 k per year for 4 years) from each participating state/agency.