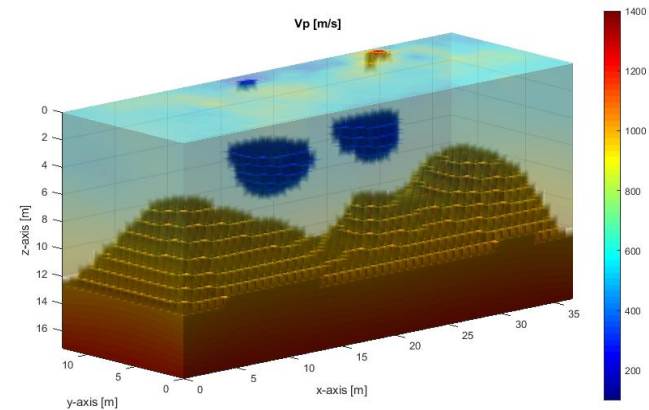
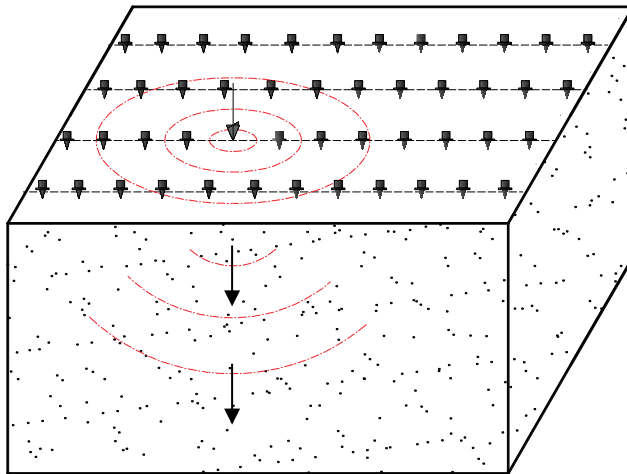


3D SPT- Seismic Testing for Geotechnical Site Characterization

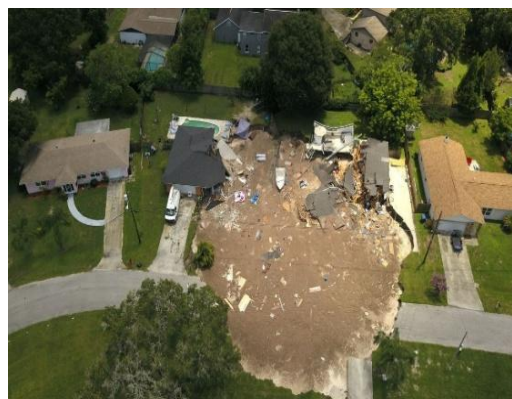


by:
 Khiem Tran, PhD.
 University of Florida

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



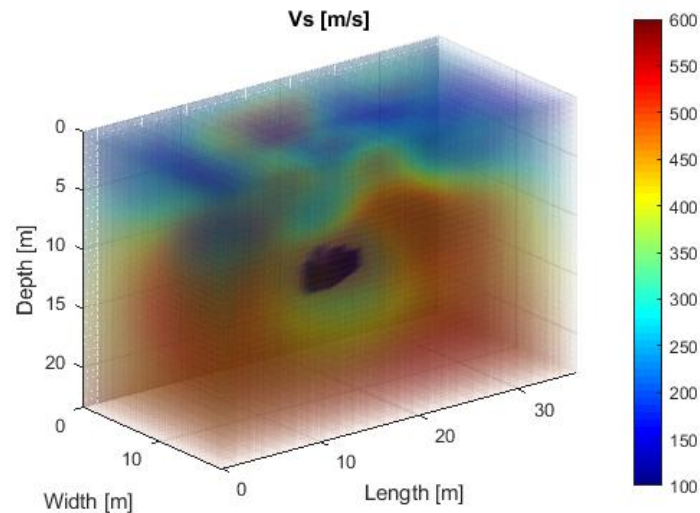
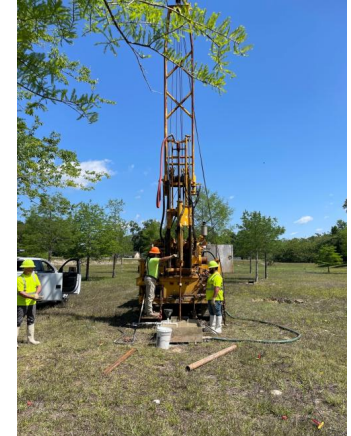
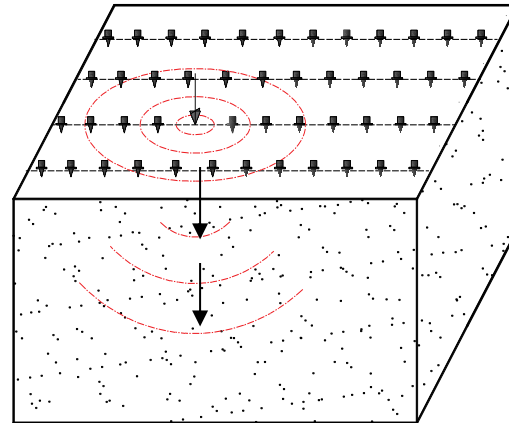
Sinkhole collapses in Florida

SPT-seismic approach

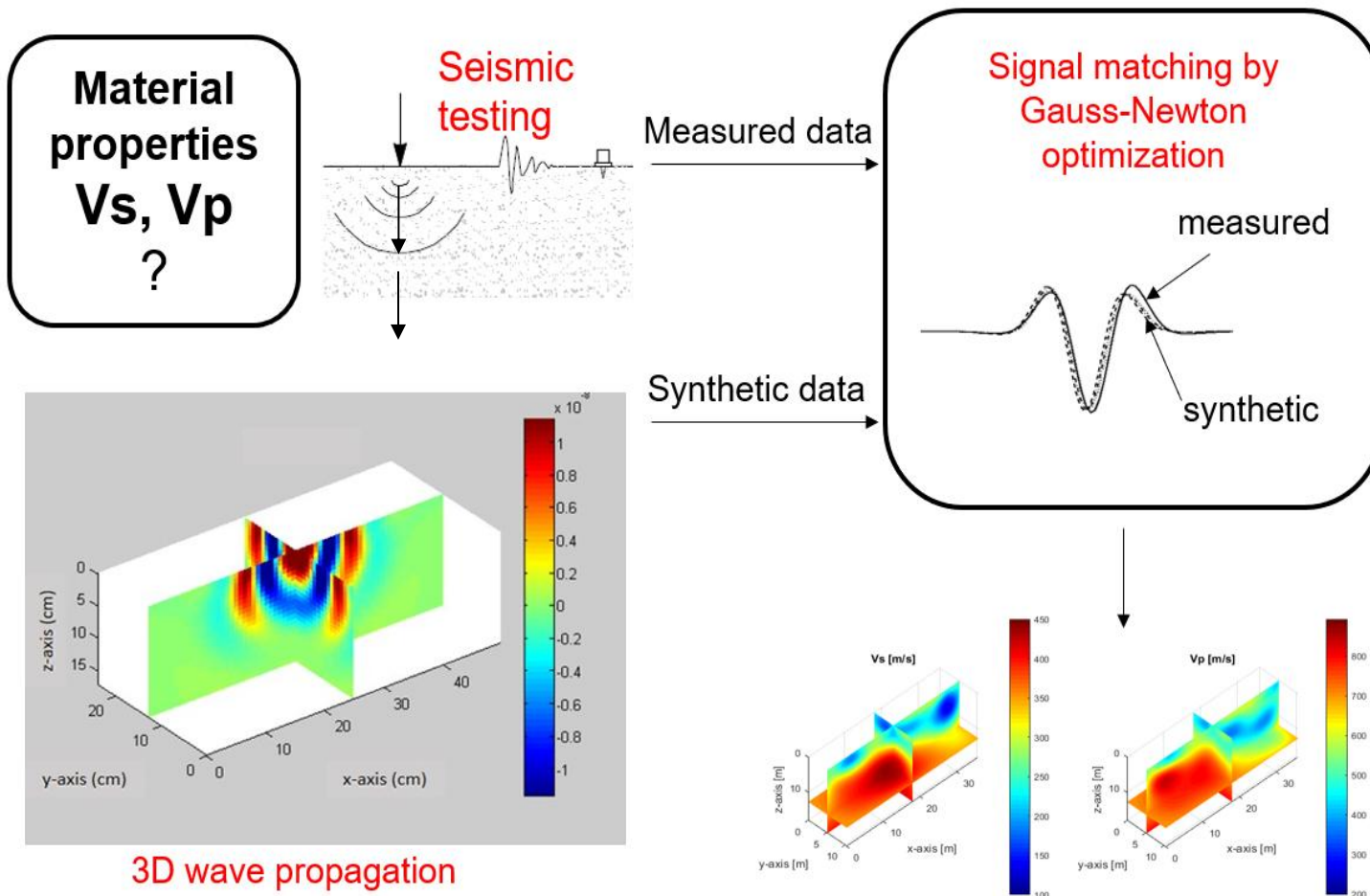
Leverages byproduct seismic waves generated during SPT to produce 3D imaging around the SPT borehole

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



Methodology



HGS Demonstration

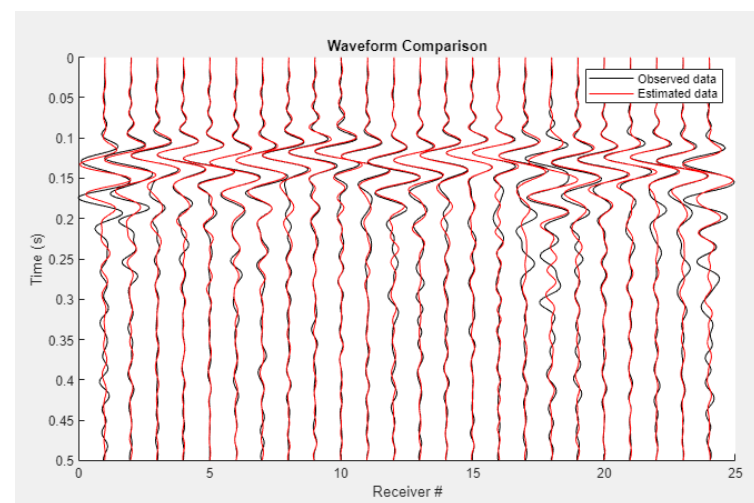
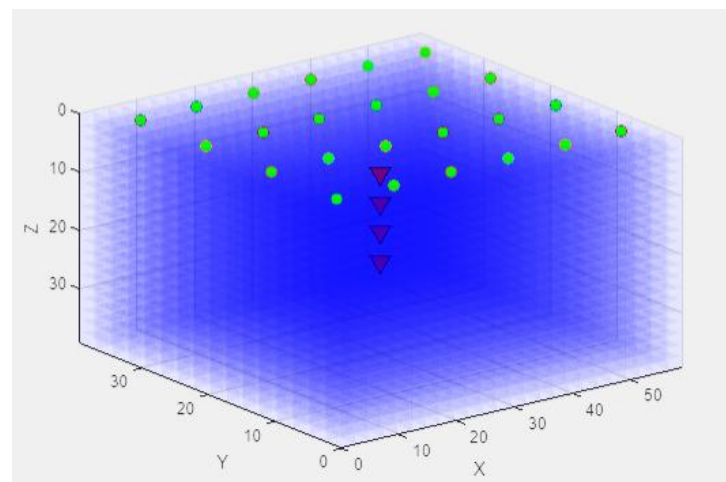
Site 1: Lawrence, KS

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

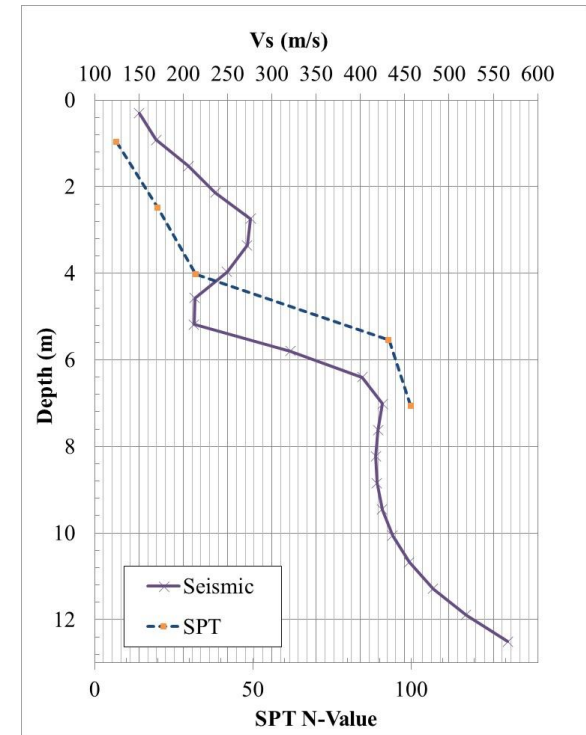
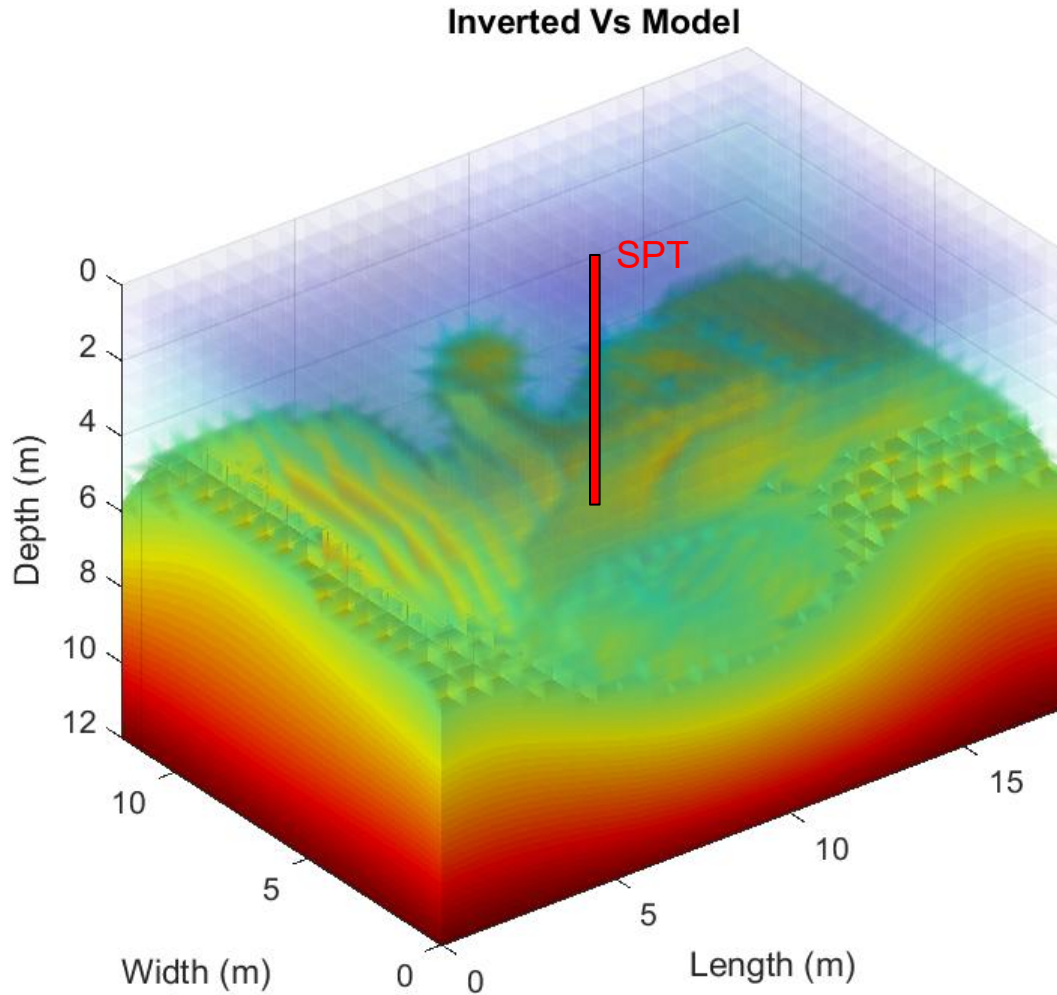
Data analysis

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



SPT spoon at 23 ft depth

Lawrence site result



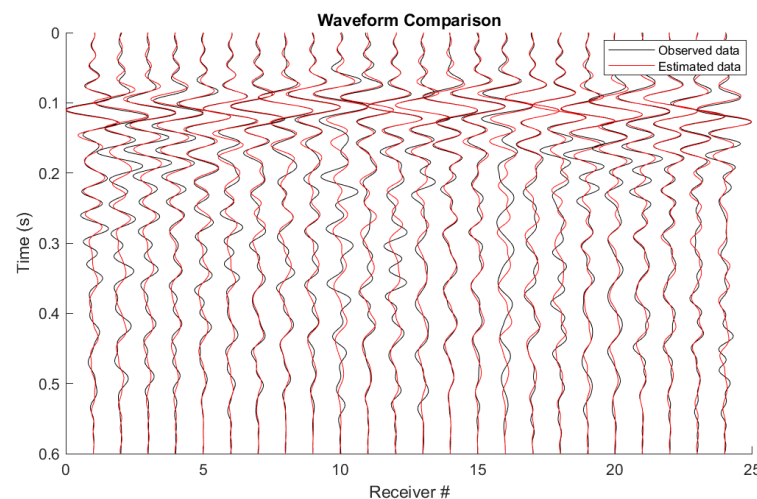
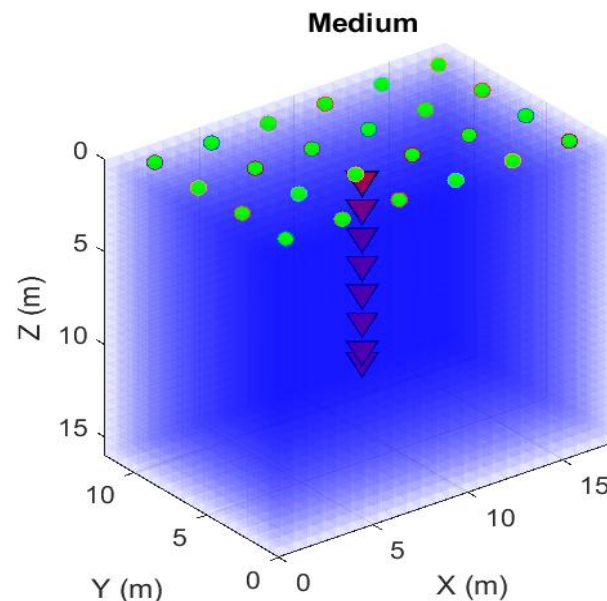
Site 2: Minnesota

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

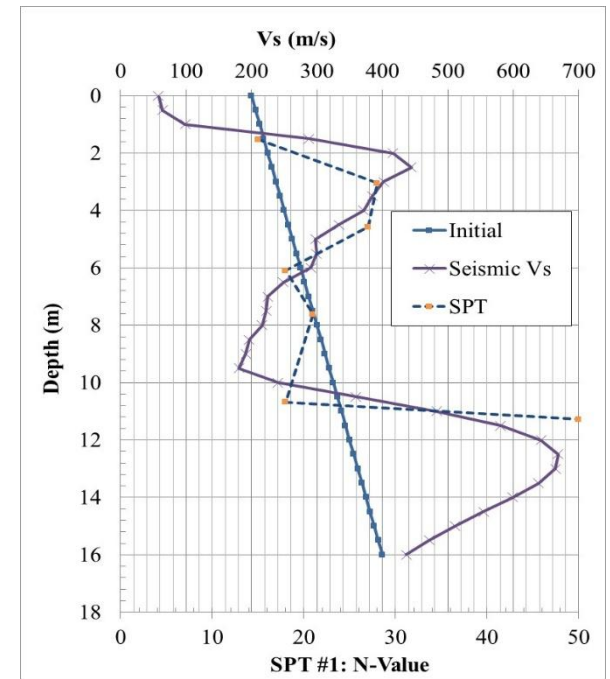
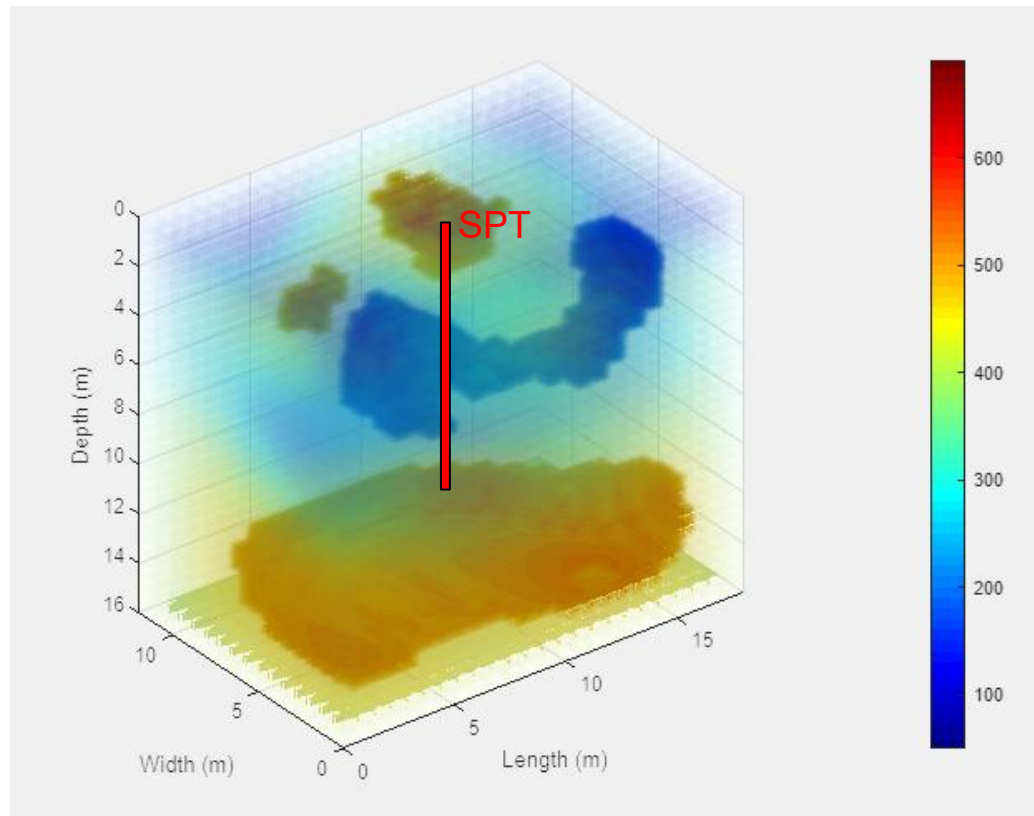
Data analysis

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



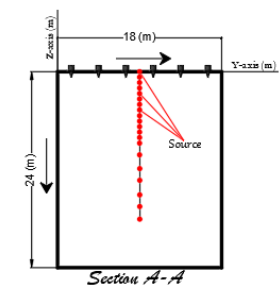
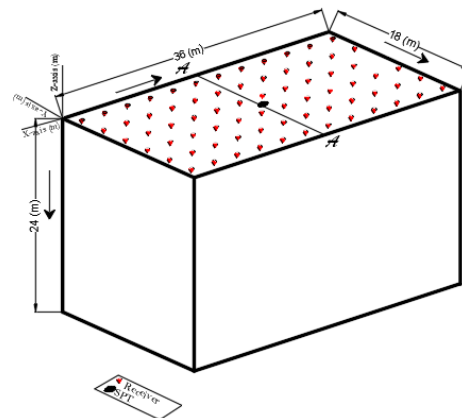
Sample data at 30 ft depth

Minnesota site result

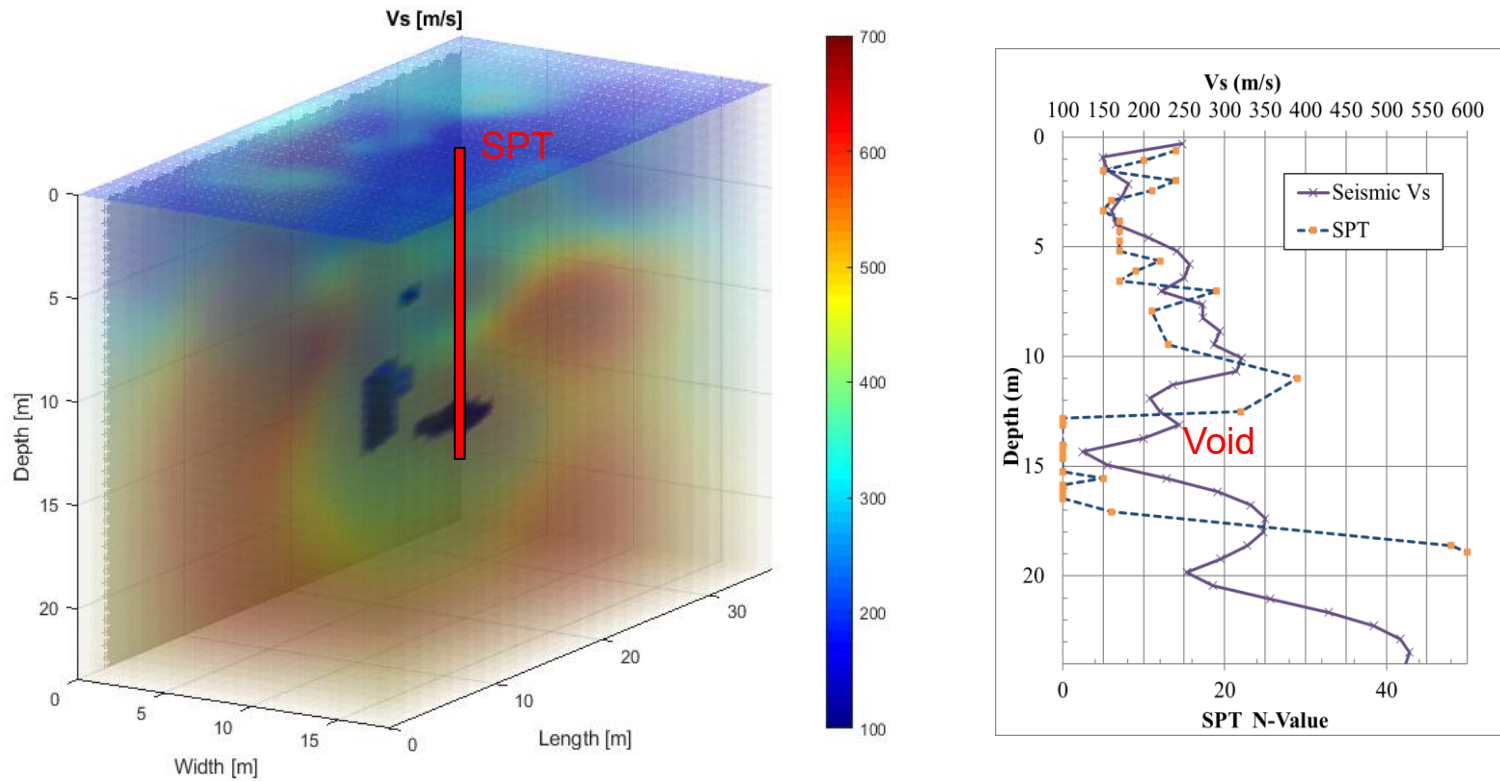


Site 3: Newberry site

- 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



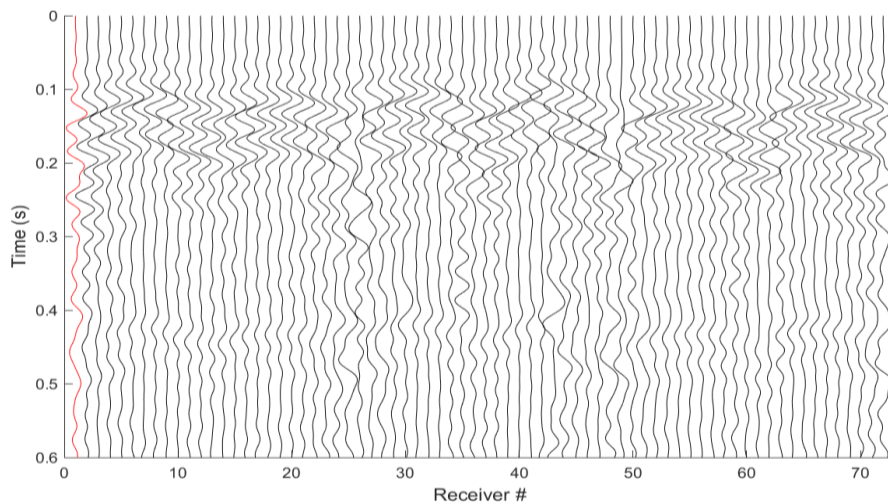
Newberry result



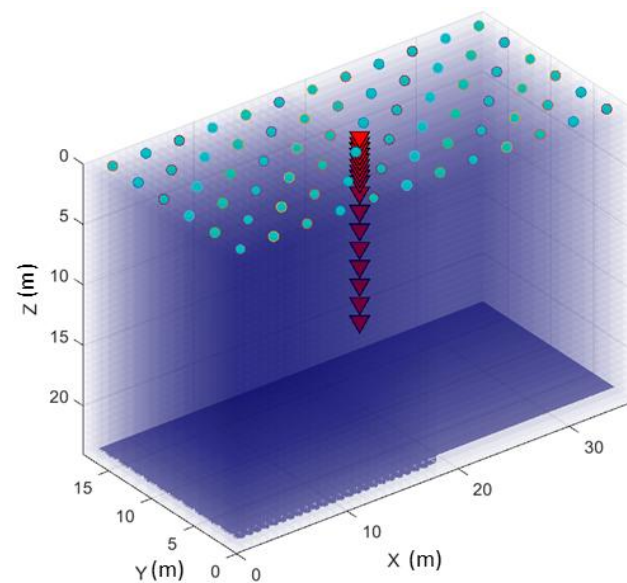
Tran K.T., Mirzanejad M., Horhota D. and Wasman S. (2024), 3D full-waveform tomography of SPT-seismic wavefields in karst Florida limestone” *Journal of Transportation Research Board*

Site 4: Bell site

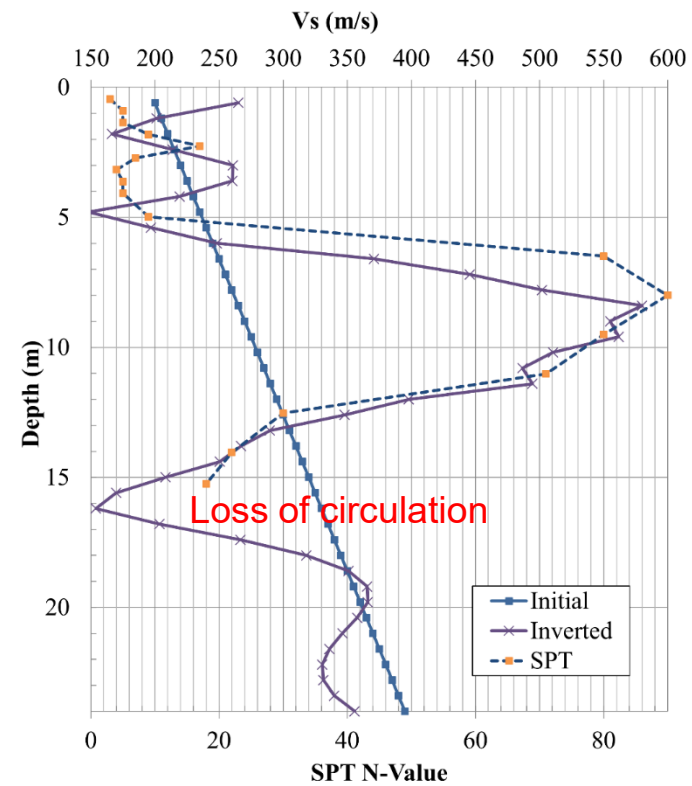
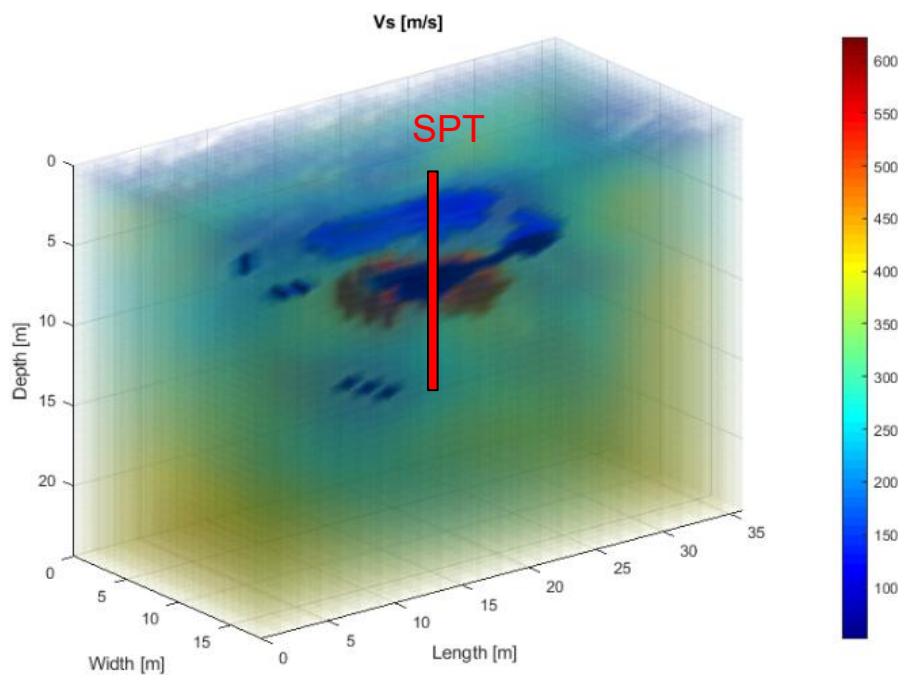
- 72 geophones located in 6 x 12 grid at 10 ft spacing
- SPT to 52 ft



Data at 52 ft depth

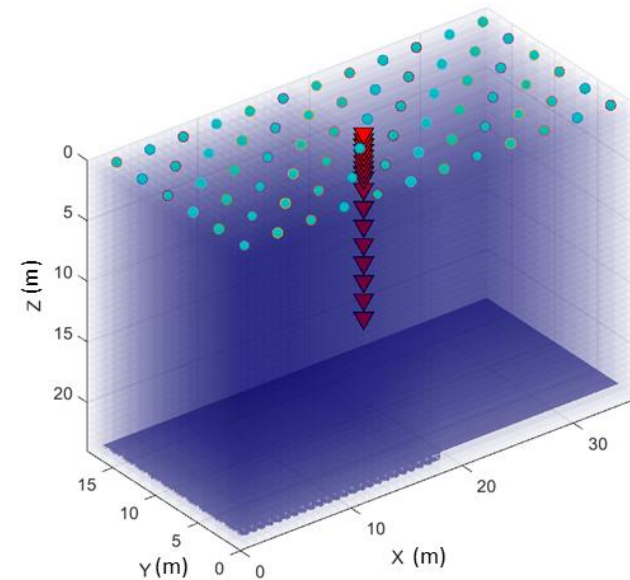
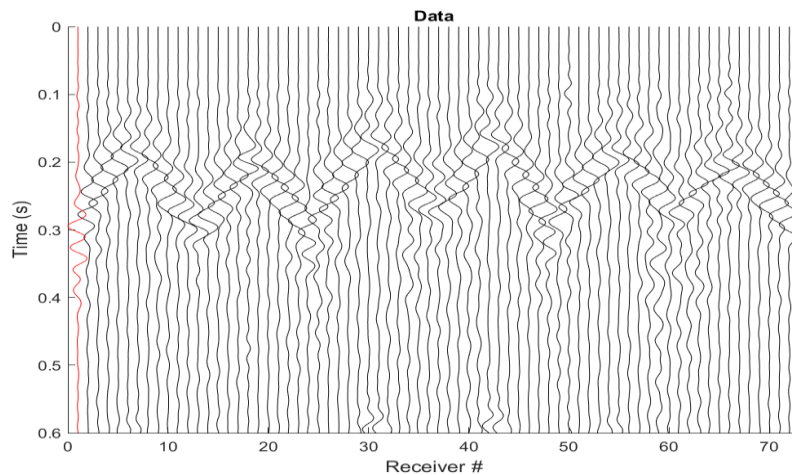


Bell site result

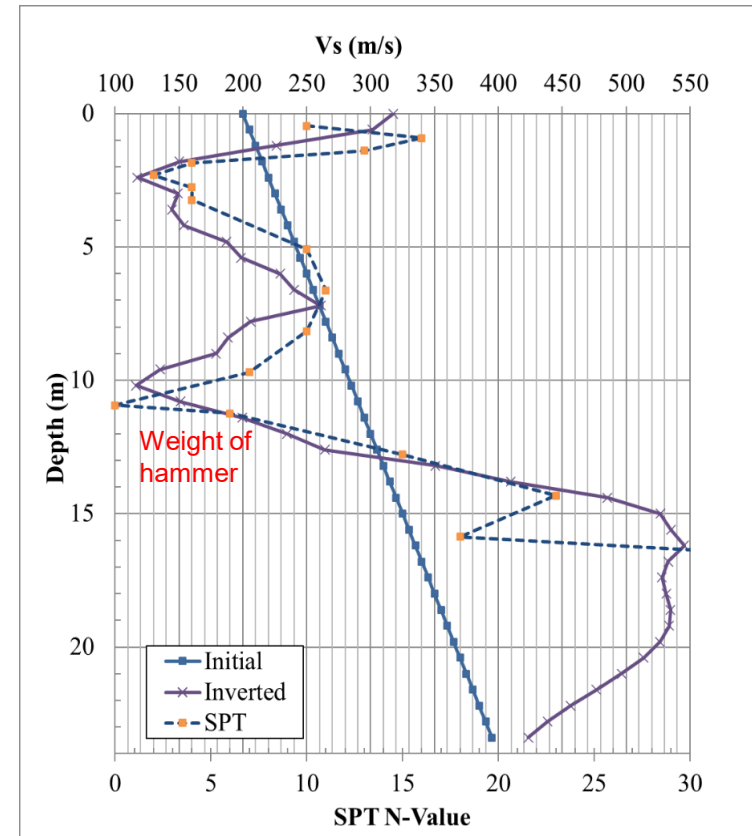
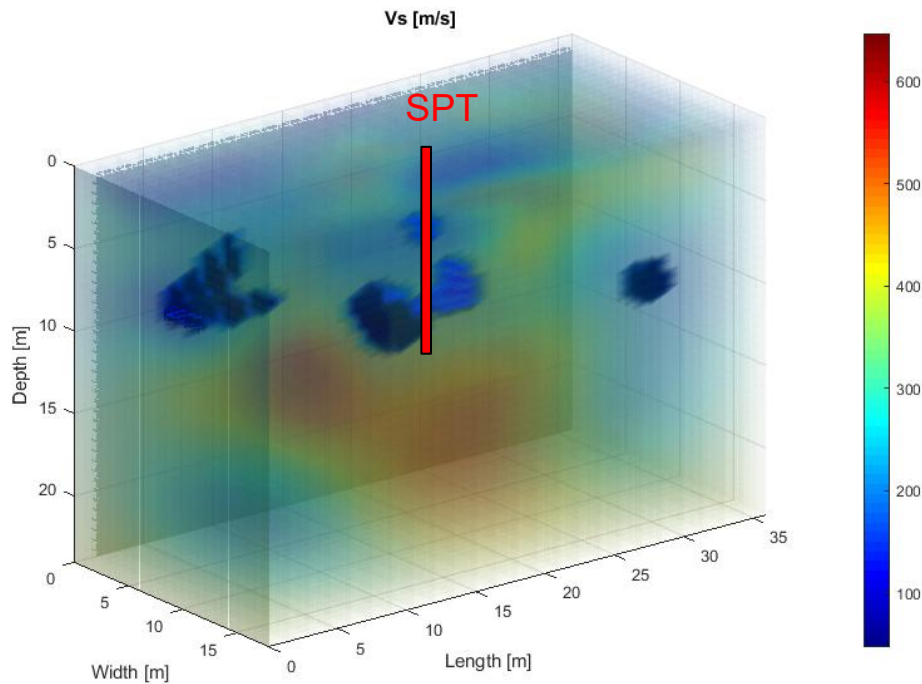


Site 5: Kanapaha site

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

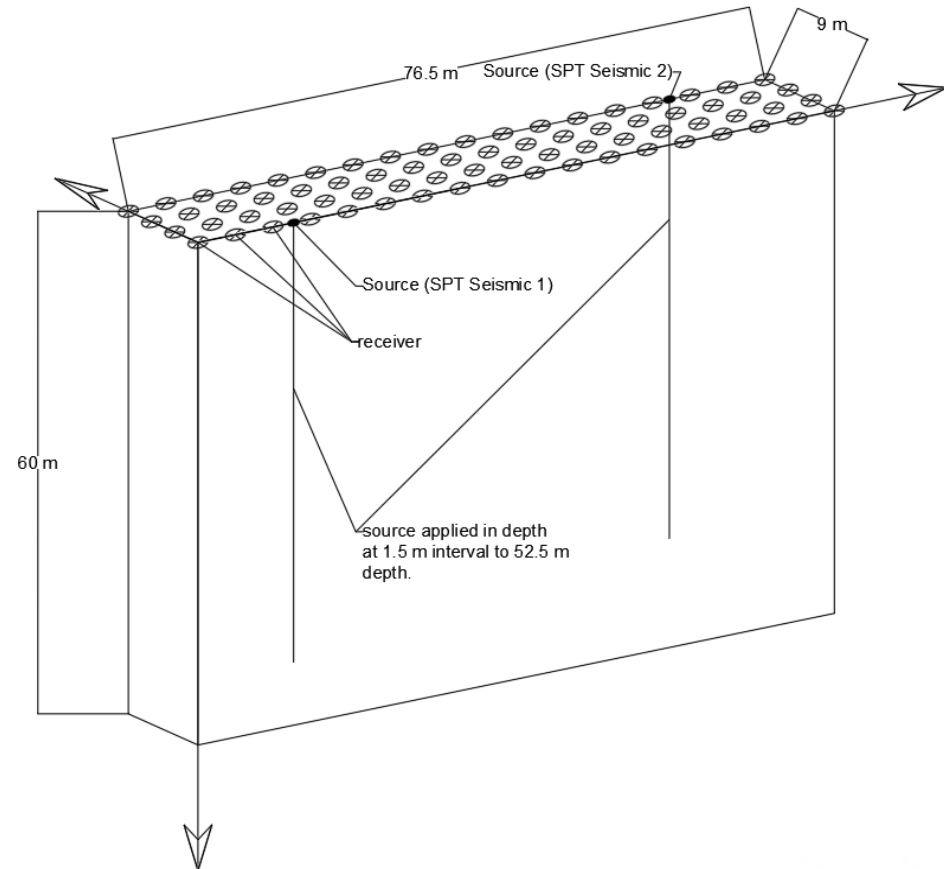


Kanapaha site result

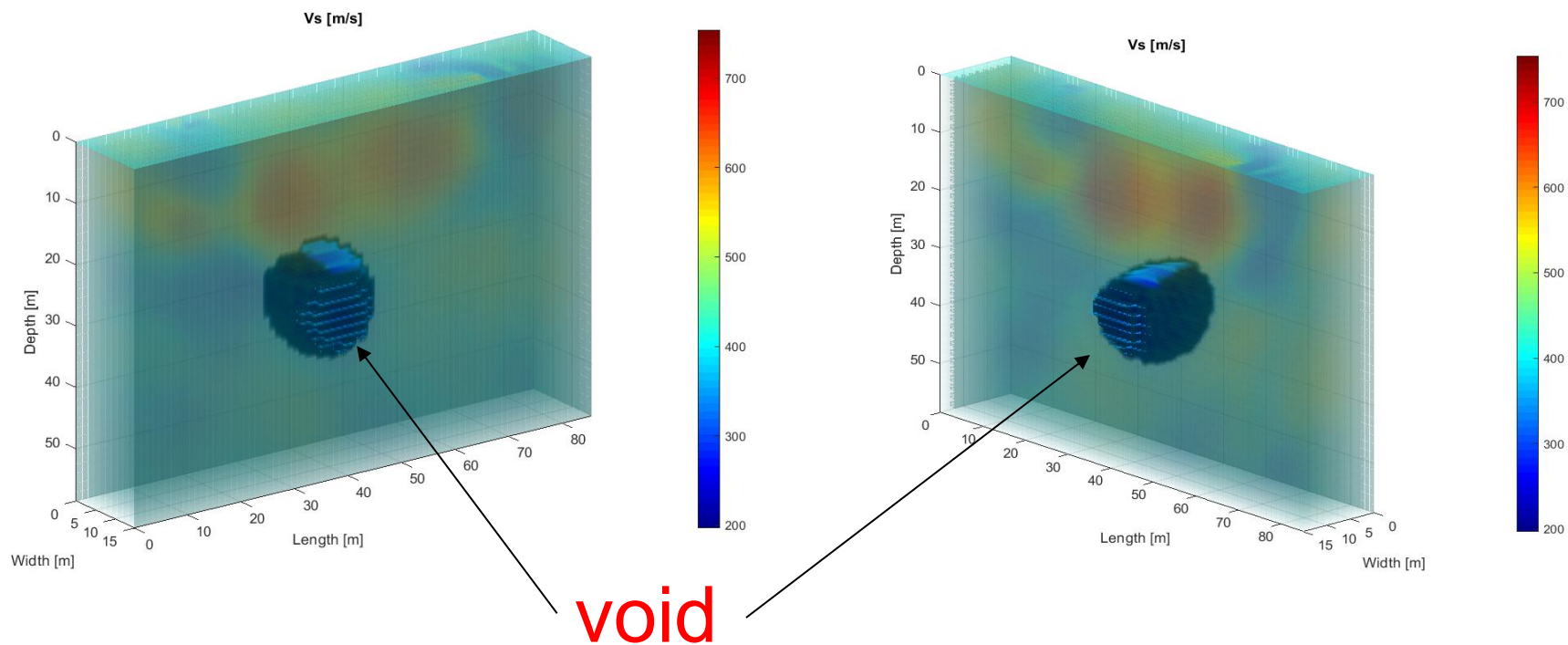


Site 6: Miami site

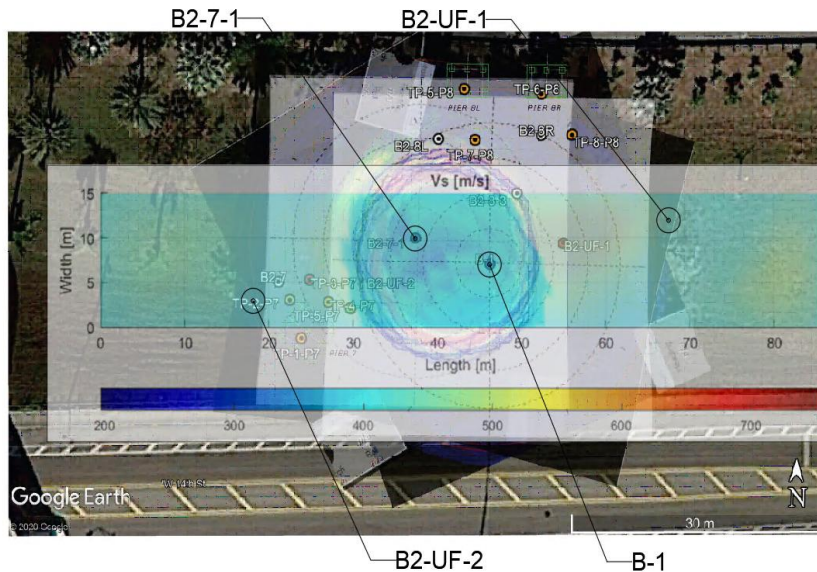
- 2 SPTs to 175 ft depth, 150 ft apart
- 72 geophones located in 18 x 4 grid at 15'x10' spacing



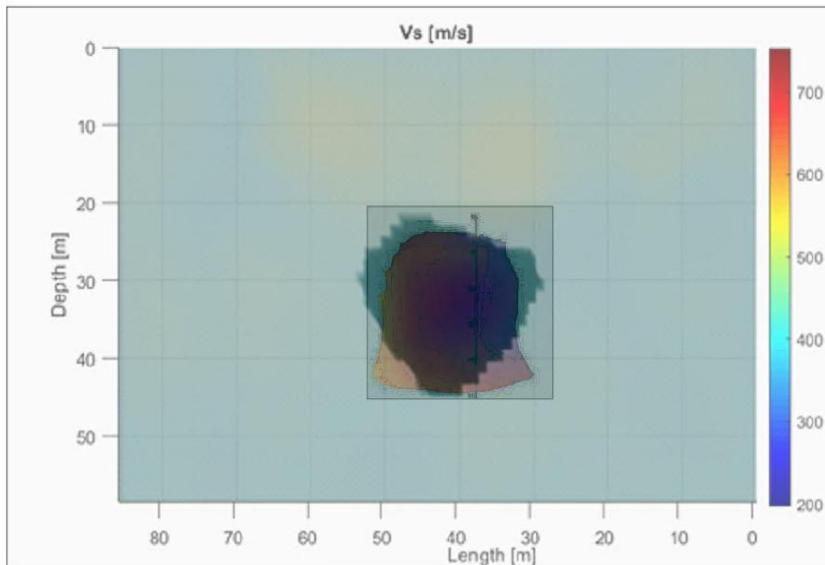
Miami site results



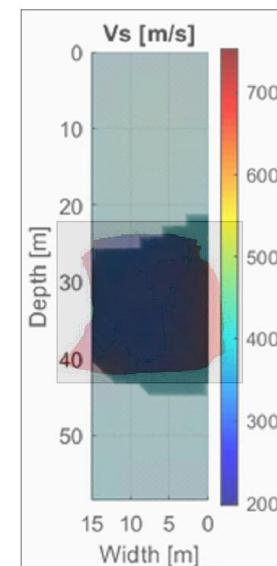
Miami site: SPT-seismic vs Sonar



Top-down overlay



North-south overlay



East-west overlay

3D SPT-Seismic Software

➤ Define Required Parameters for Data Analysis Including 3D Visualizations

MATLAB App

File Settings View

Medium

X-Start

X-Finish

dx

Y-Start

Y-Finish

dy

Z-Start

Z-Finish

dz

Show

Receiver Location

X-Start

X-Finish

dx

Y-Start

Y-Finish

dy

Delay Time

T0 (s)

Show

Source Location

X

Y

Z Range

Select

Show/Hide Table

Add SPT source

Show

Material

Nu

Vs Max

Vs Min

Density

Time

dt (s)

Unit

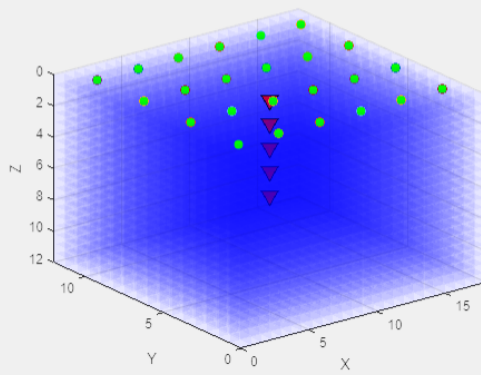
SI (m)

English (Ft)

Import

Refresh

Source #	Sx	Sy	Depth (m)	Node #
1.0000	9.0000	6.0000	0.9754	3.0000
2.0000	9.0000	6.0000	2.4994	5.0000
3.0000	9.0000	6.0000	4.0234	8.0000
4.0000	9.0000	6.0000	4.0234	8.0000
5.0000	9.0000	6.0000	4.0234	8.0000
6.0000	9.0000	6.0000	4.0234	8.0000
7.0000	9.0000	6.0000	5.5474	10.0000
8.0000	9.0000	6.0000	5.5474	10.0000
9.0000	9.0000	6.0000	5.5474	10.0000
10.0000	9.0000	6.0000	5.5474	10.0000
11.0000	9.0000	6.0000	5.5474	10.0000
12.0000	9.0000	6.0000	5.5474	10.0000
13.0000	9.0000	6.0000	5.5474	10.0000
14.0000	9.0000	6.0000	5.5474	10.0000
15.0000	9.0000	6.0000	5.5474	10.0000
16.0000	9.0000	6.0000	5.5474	10.0000
17.0000	9.0000	6.0000	5.5474	10.0000
18.0000	9.0000	6.0000	5.5474	10.0000
19.0000	9.0000	6.0000	5.5474	10.0000
20.0000	9.0000	6.0000	5.5474	10.0000
21.0000	9.0000	6.0000	5.5474	10.0000
22.0000	9.0000	6.0000	7.0714	13.0000



Message

Input medium successfully.

Next

Status ●

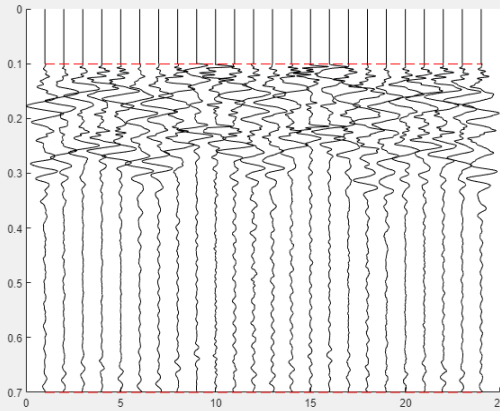
Step1 Step2 Step3 Step4 Step5 Step6

Data conditioning

MATLAB App

File Settings View

Open



Num. Data Files 22

File Number 1

Time Domain

Frequency Domain

Duration 0 0.07 0.14 0.21 0.28 0.35 0.42 0.49 0.56 0.63 0.7

Message

Previous Data for all of SPT sources have been loaded.

Status ●

Step1 Step2 Step3 Step4 Step5 Step6

MATLAB App

File Settings View

Data Conditioning

Filter Settings

f1 5 f2 10 f3 40 f4 50

Time_max 0.6

Automatic Rearrange

Flip Compile Geophone Array Rearrange

Show/Hide Processed Data Table

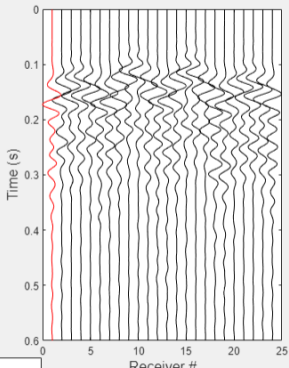
Show/Hide Original Data Table

Shot #	Z-Coord	Node #
1.0000	0.9754	3.0000
2.0000	2.4994	5.0000
3.0000	4.0234	8.0000
4.0000	4.0234	8.0000
5.0000	4.0234	8.0000
6.0000	4.0234	8.0000
7.0000	5.5474	10.0000

Source Spinner 5

Current Source Node 8

Channel Spinner 1



Time (s)

Receiver #

Message

Previous Filtering: Done. Next

Status ●

MATLAB App

File Settings View

Data Conditioning

Filter Settings

f1 5 f2 10 f3 40 f4 50

Time_max 0.6

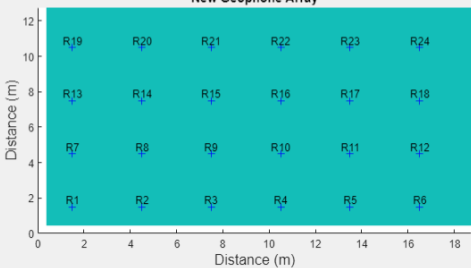
Automatic Rearrange

Flip Compile Geophone Array Rearrange

Show/Hide Processed Data Table

Show/Hide Original Data Table

New Geophone Array



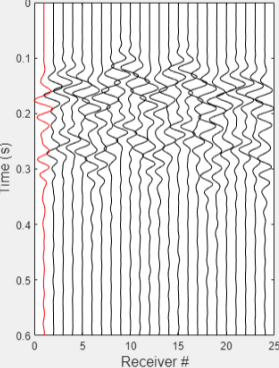
Distance (m)

Distance (m)

Source Spinner 1

Current Source Node 3

Channel Spinner 1



Time (s)

Receiver #

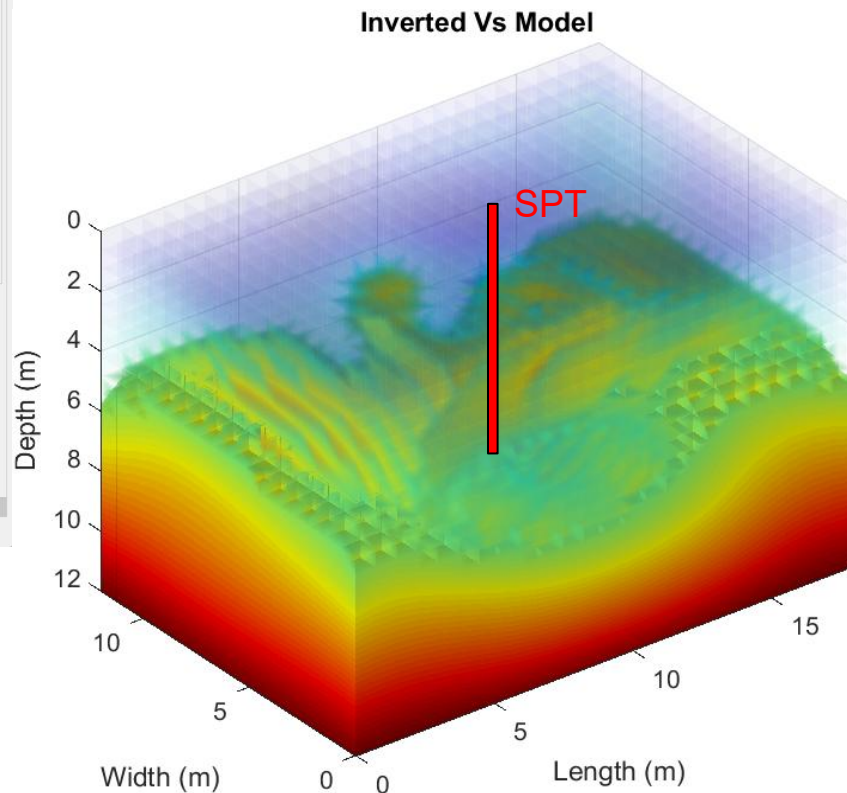
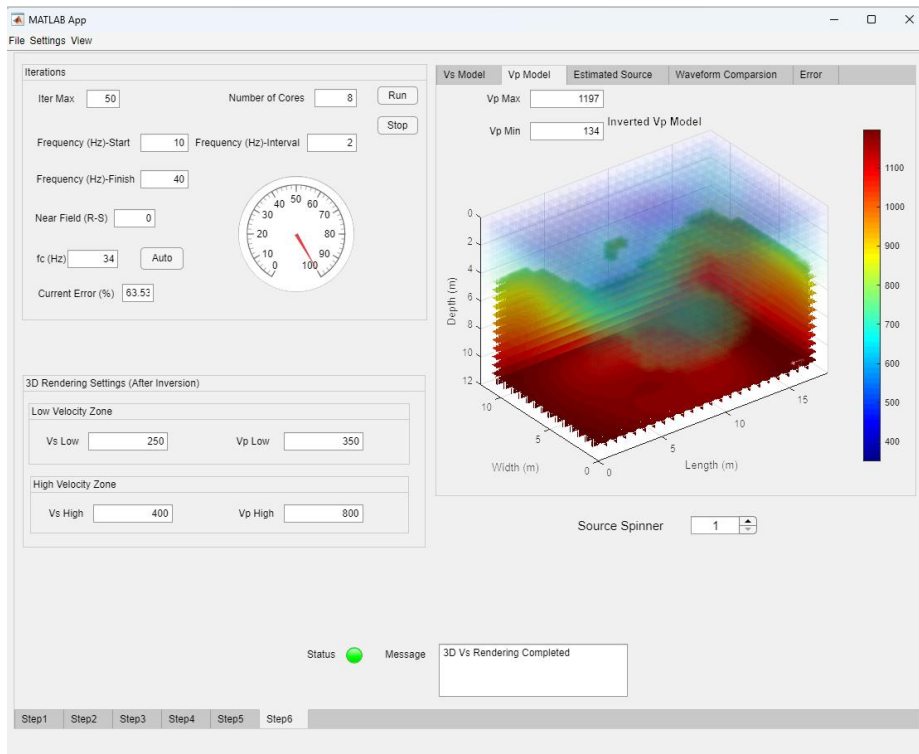
Message

Previous Filtering: Done. Next

Status ●

Step1 Step2 Step3 Step4 Step5 Step6

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.