Geo^{3}T^2

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Geophysical Studies to Support Roadway Investigations

Ned Billington, PG

and Paul Weaver, PG

ESP Associates, P.A.

Topics

- NCDOT Standard Approach to Roadway Investigations
- Geophysical Methods
  - Seismic Refraction
  - Surface Wave Seismic
  - Terrain Conductivity
- Example Project

NCDOT Investigation for Roadways

Purpose: Characterize subsurface conditions, such as soil type and thickness, depth to water, and depth to rock.

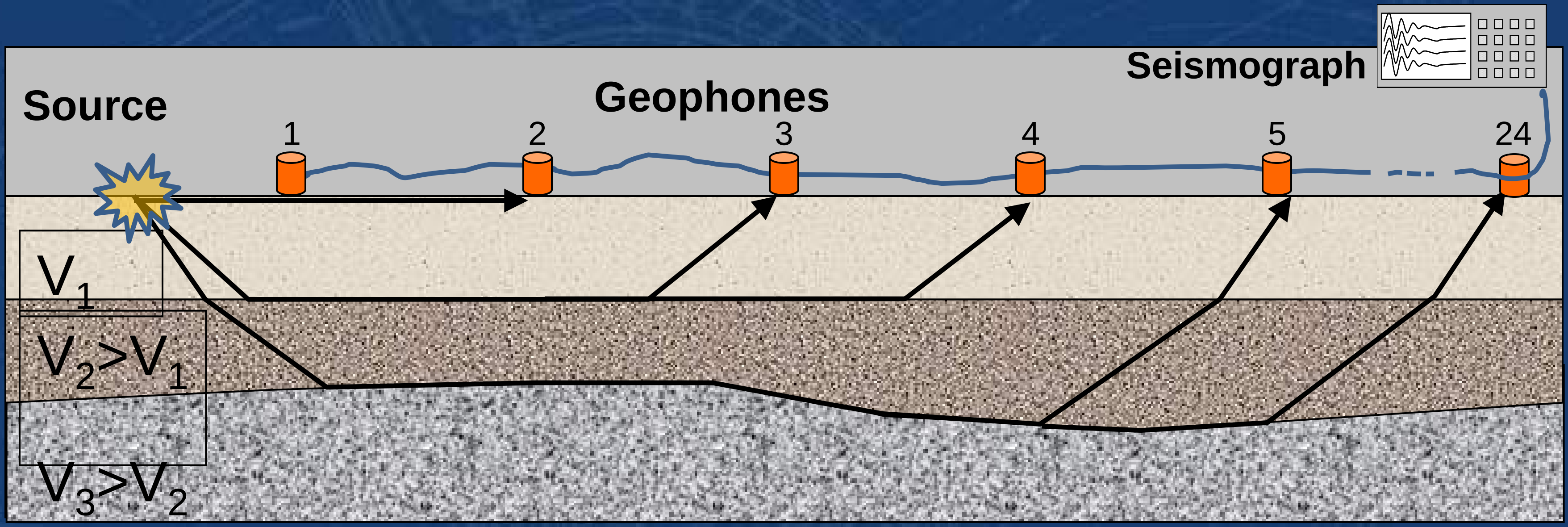
- Borings every 200 feet along centerline
- Drill 10 feet below proposed grade in cut areas
- Drill 1.5 time height of embankment in fill areas (min. 10 feet)
- Drill to SPT/auger refusal
- Typically no rock coring
- Drill offset borings if rock encountered above proposed grade

Geophysical Methods

- Seismic Refraction
  - Compressional Wave Velocity Models
- Surface Wave Seismic
  - Shear Wave Velocity Models
- Terrain Conductivity
  - Average electrical conductivity of subsurface volume

Seismic Refraction

- Obtain first arrivals of energy that travel along the interfaces between successively faster "layers"



Seismic Refraction

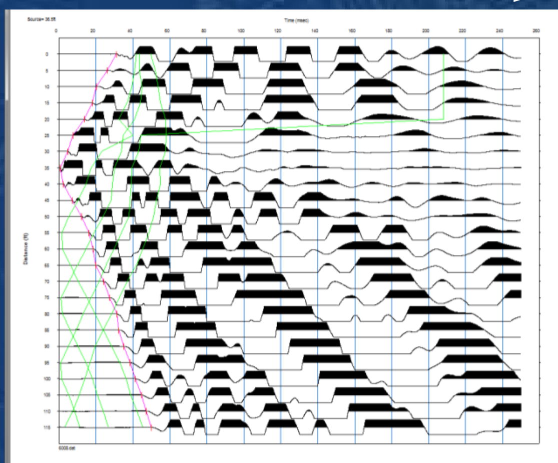
- Seismic data obtained with fixed geophones and an active source (sledgehammer, Seisgun, AWD, etc.)

Refraction Data Analysis

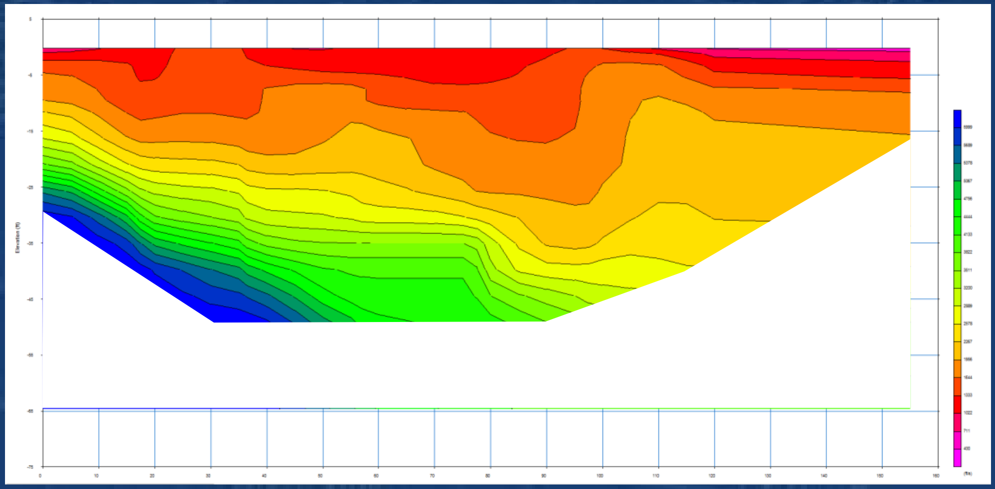
Pick First Arrivals

Time

Distance



Assign Geometry and Model Velocity

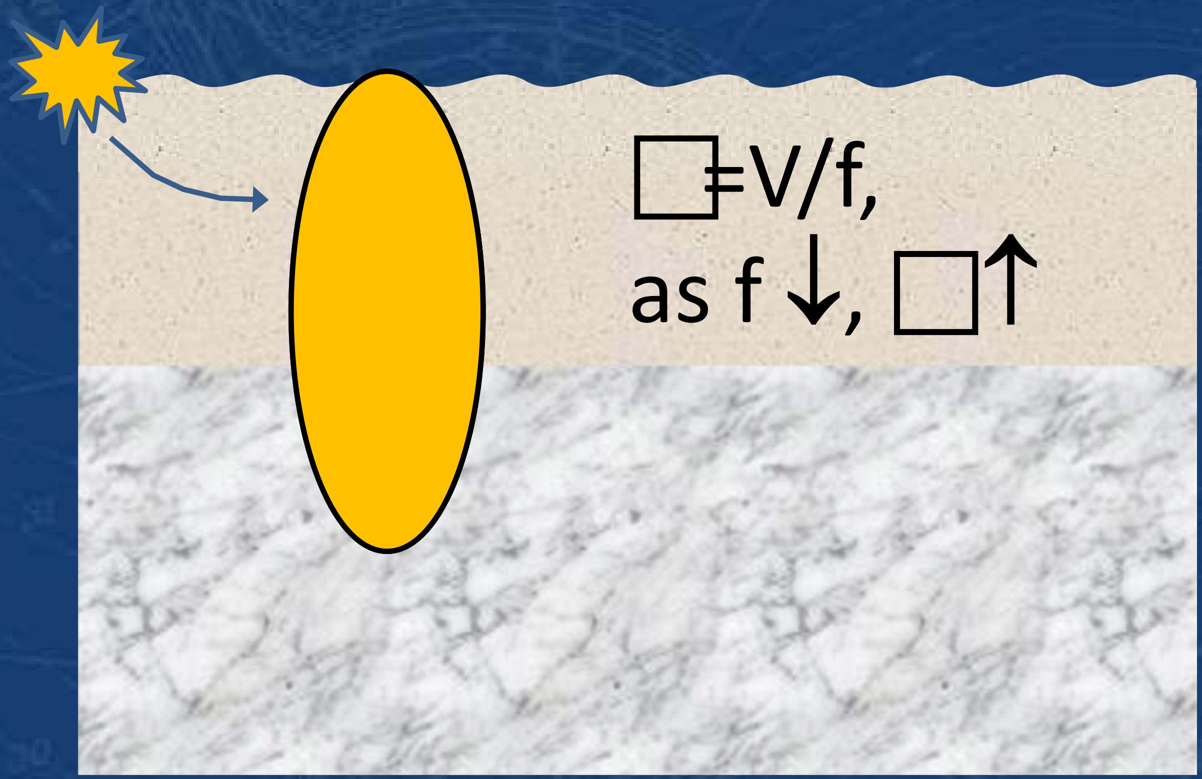


Seismic Refraction

- Provides compressional wave velocity model
- Can indicate approximate depth to rock
- Can incorporate topography
- Can access locations where drill rigs cannot
- Challenges:
  - Thin "layers"
  - Velocity reversals
  - Out-of plane refractions
  - Saturated soils

Surface Wave Seismic

- MASW, ReMi, SASW methods
- Dispersion – Change in velocity with frequency/wavelength

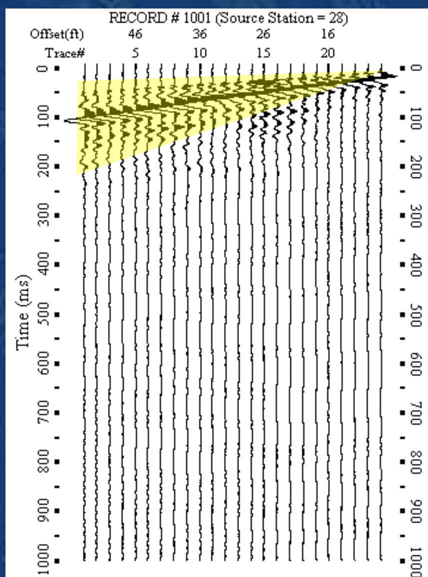


MASW Data Acquisition

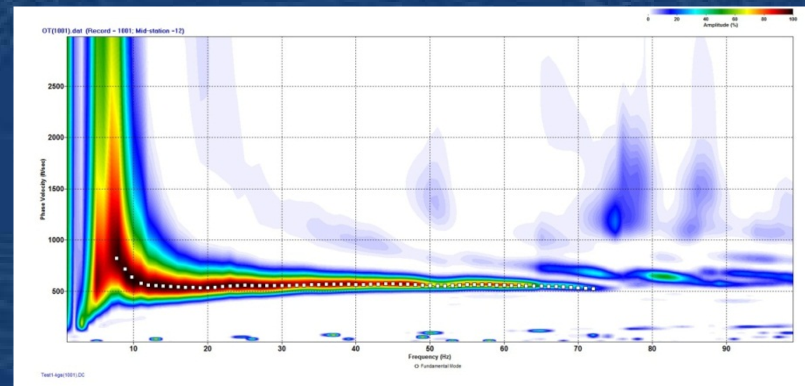
- Fixed geophone array (like seismic refraction)
- Or with a towed land streamer

1D MASW

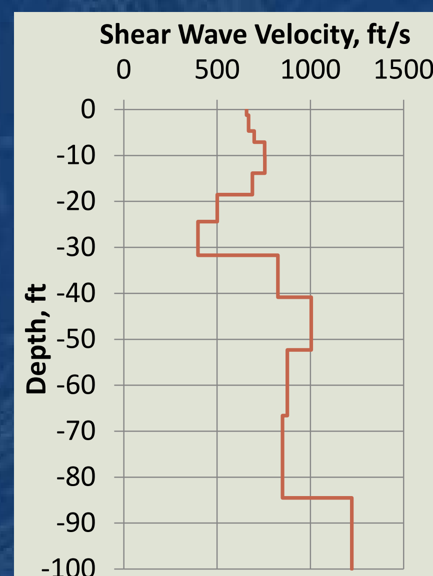
Recognize Surface Wave Energy



Convert to frequency-velocity domain

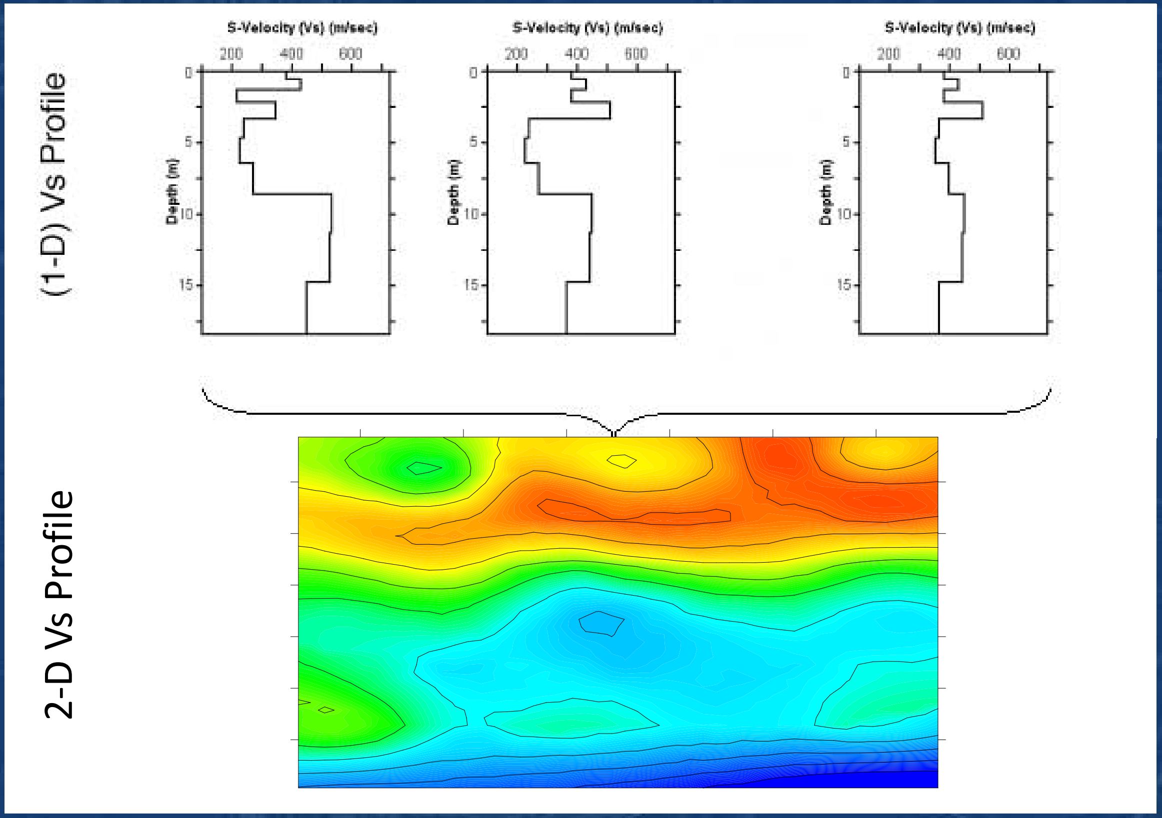


Produce 1D Inversion Model



2D MASW

- For multiple array locations, generate and combine 1D models into 2D cross-section



Surface Wave Seismic

- Provides shear wave velocity model
- Can indicate approximate depth to rock
- Can show velocity reversals
- Can be collected at same time as refraction data
- Challenges:
  - Very shallow bedrock
  - Topography

Electromagnetic Induction

- EM instruments provide:
  - Terrain Conductivity (Quadrature) and
  - Metal Detection (In-Phase)
- Depth of response depends on coil spacing, frequency, dipole orientation, and other factors
- More conductive soil = higher conductivity
  More resistive = lower conductivity response

EM Terrain Conductivity Tools

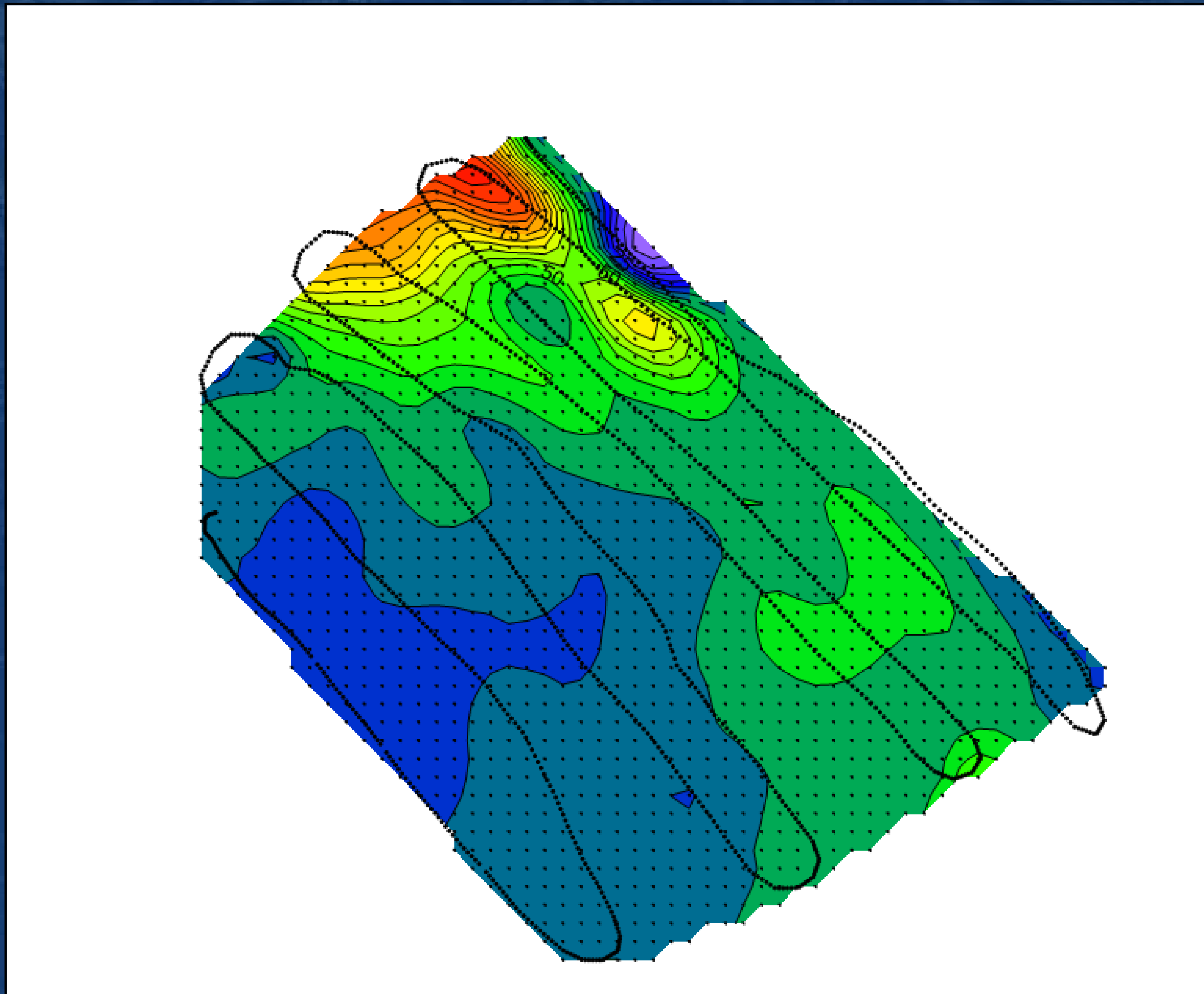
- Fixed Coil Spacing, Single Frequency
  - Geonics EM31

- Fixed Coil Spacing, Multi-Frequency
  - Geophex GEM-2
  - GSSI Profiler

Collecting EM Data

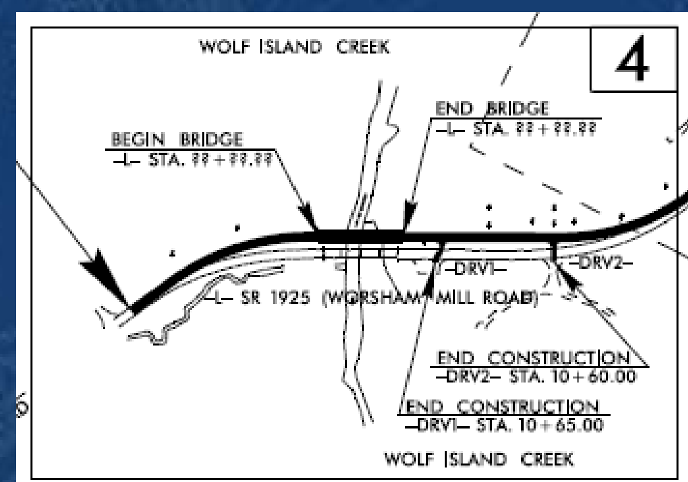
- One person walking along "parallel" lines
- GPS positioning or fixed stationing
- Data recorded at fixed time interval (1 sec, e.g.)
- Line spacing determines lateral resolution

Processing EM Data



Example Project

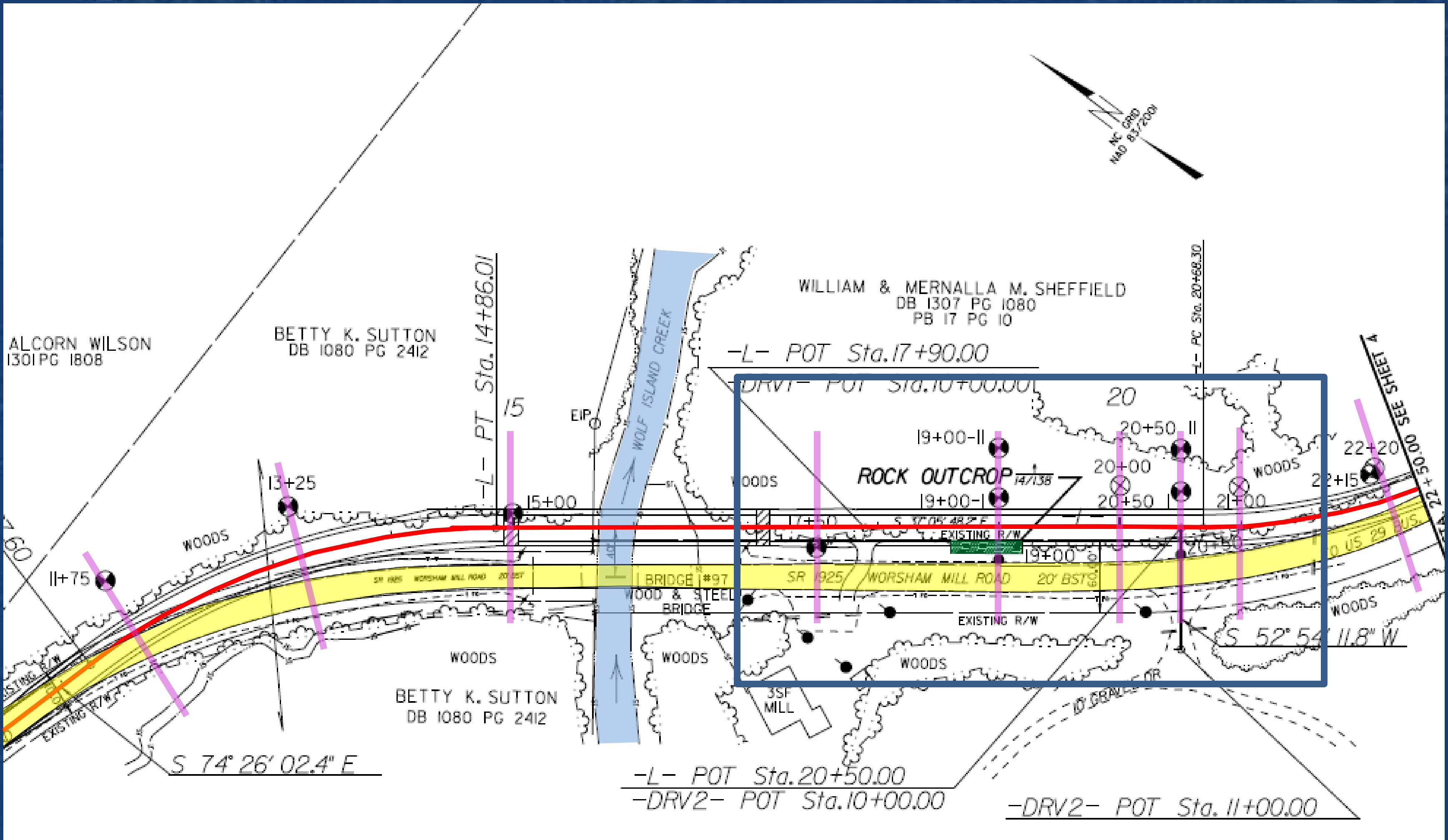
- Bridge No. 97 on SR 1925 (Worsham Mill Road) over Wolf Island Creek in Rockingham County, B-4803
  - 2-Lane Road, severe curve and narrow bridge
  - Historic mill on one corner of bridge
  - Centerline of proposed roadway on steep slope



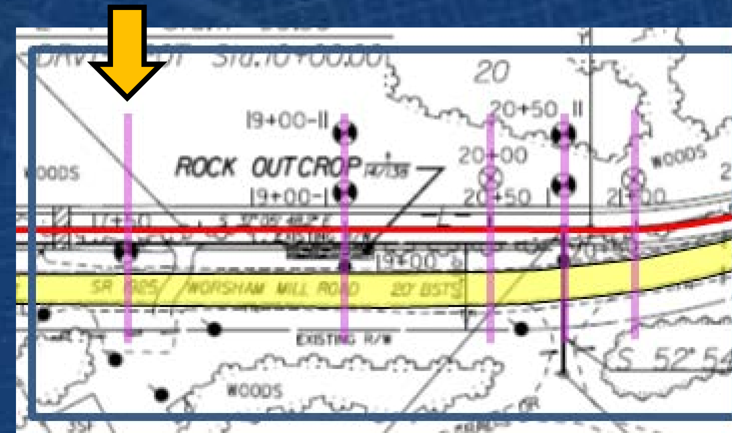
Geotechnical Investigation

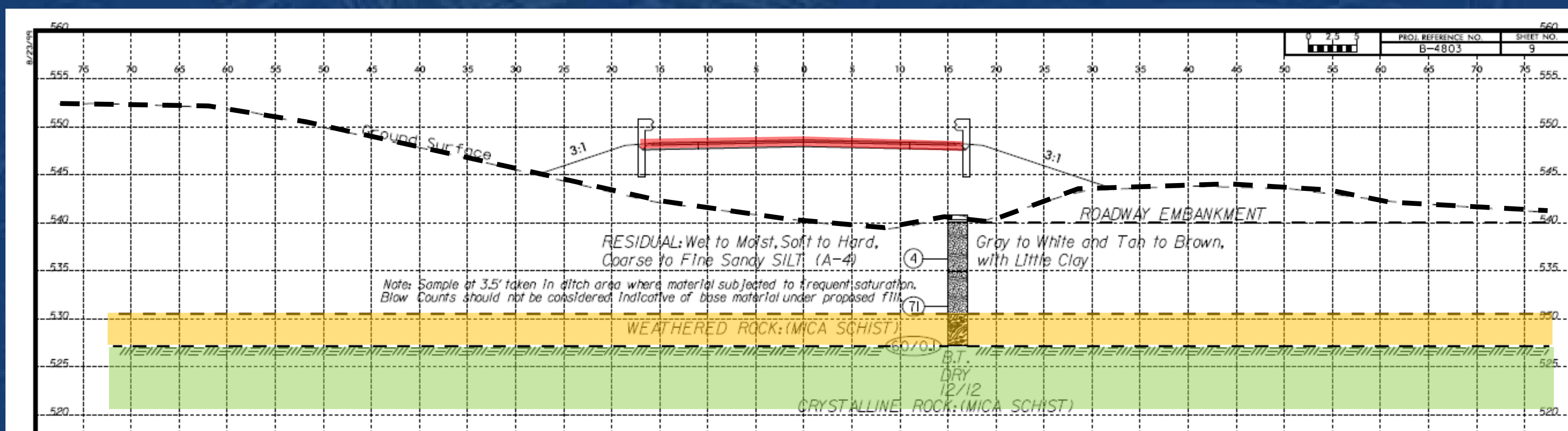
- Approx. 150-foot boring spacing
- Could only drill at top of slope along most of alignment
- Drilled several offset borings due to encountering auger/SPT refusal (“rock”) above proposed grade
- Bridge rod drives at toe of slope to get rock depth

Geotechnical Investigation



Cross-Section 17+50





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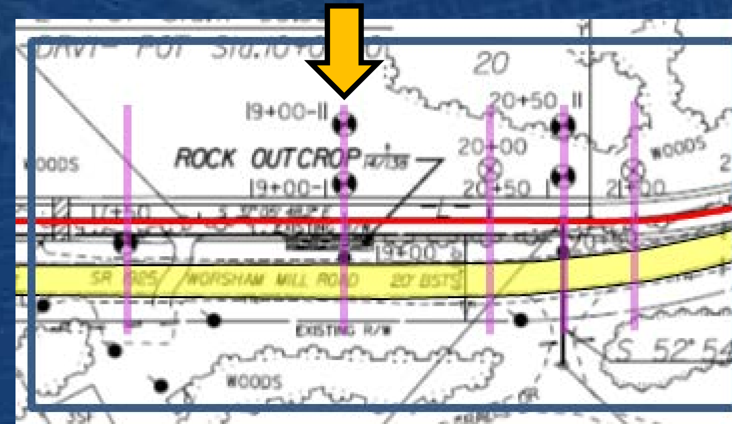
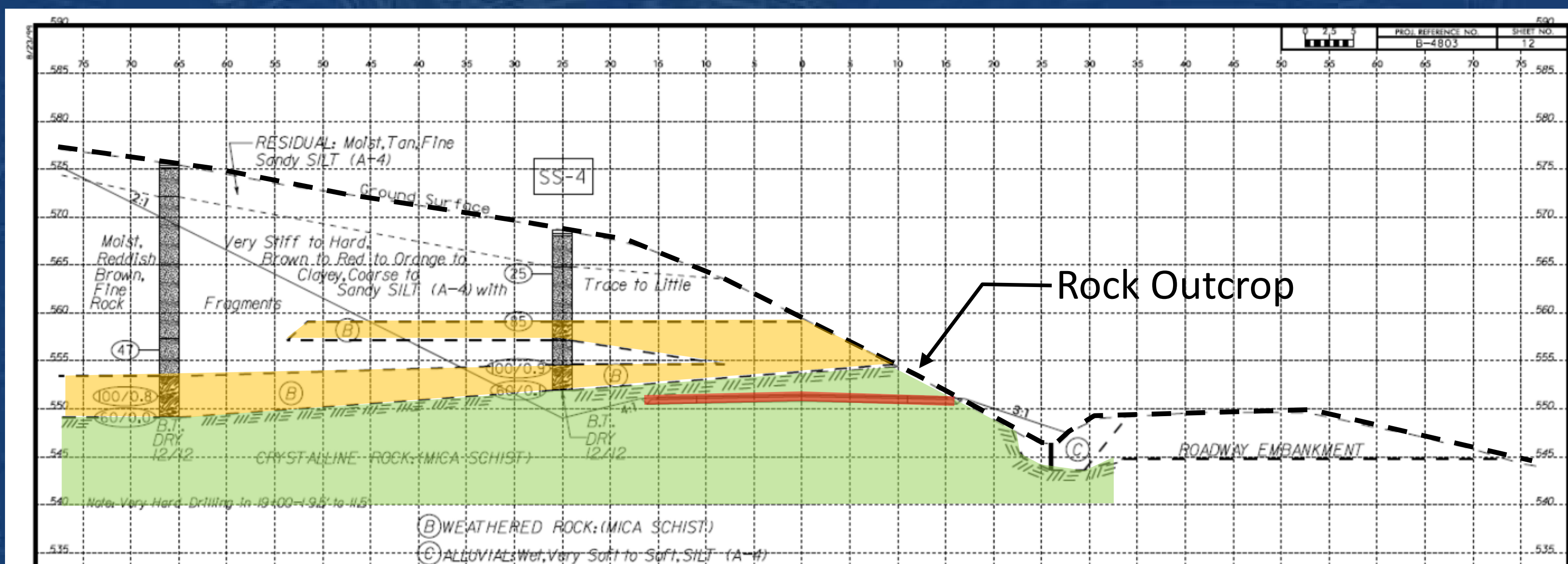
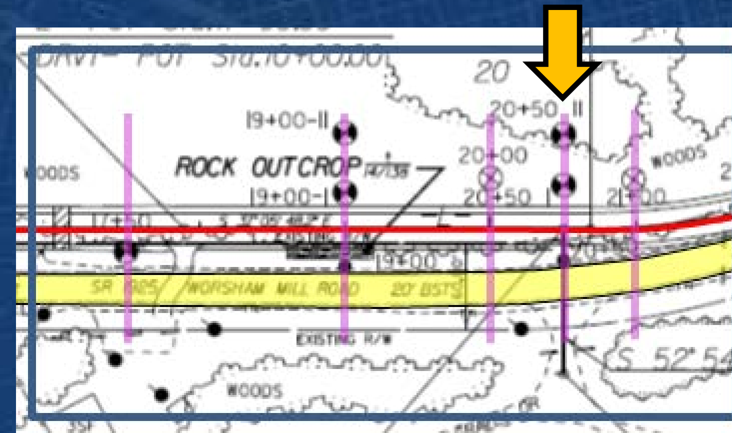
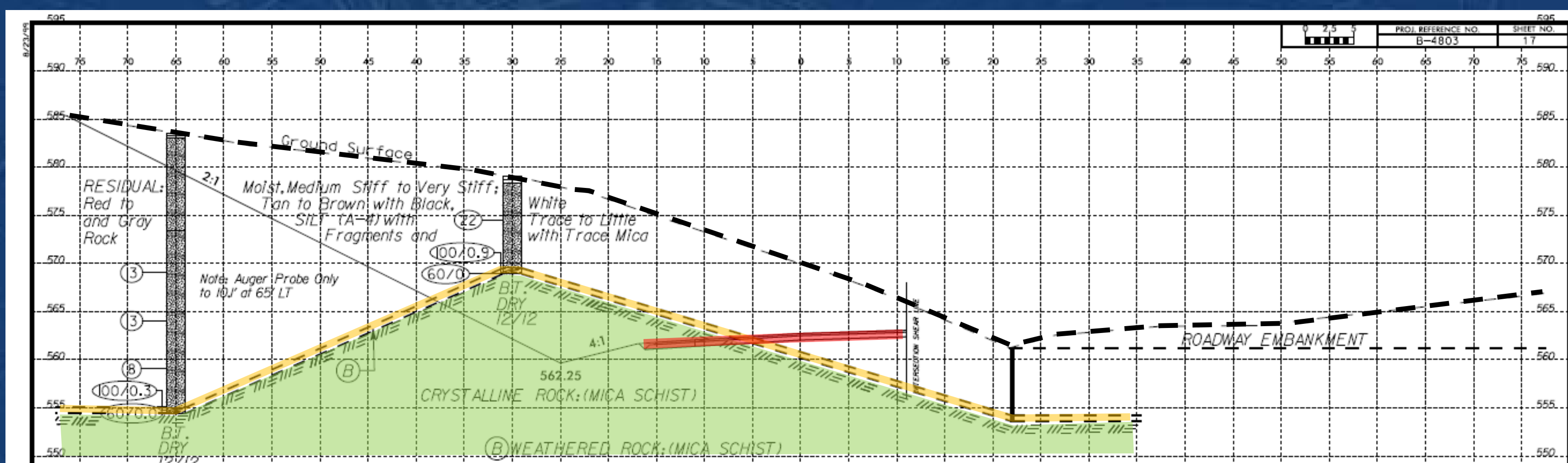
Cross-Section 19+00





Cross-Section 20+50





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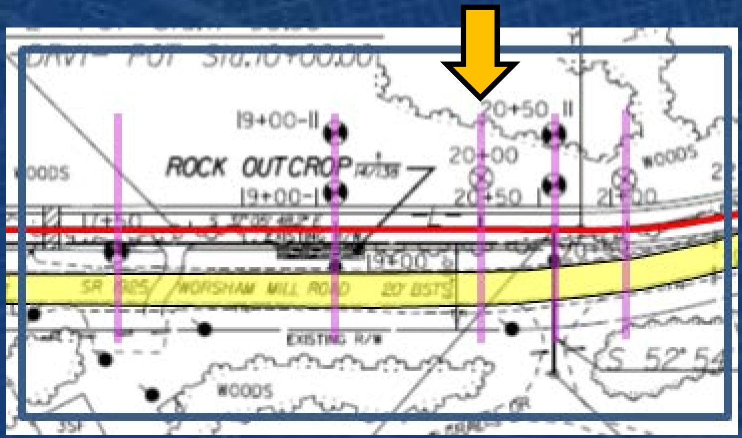
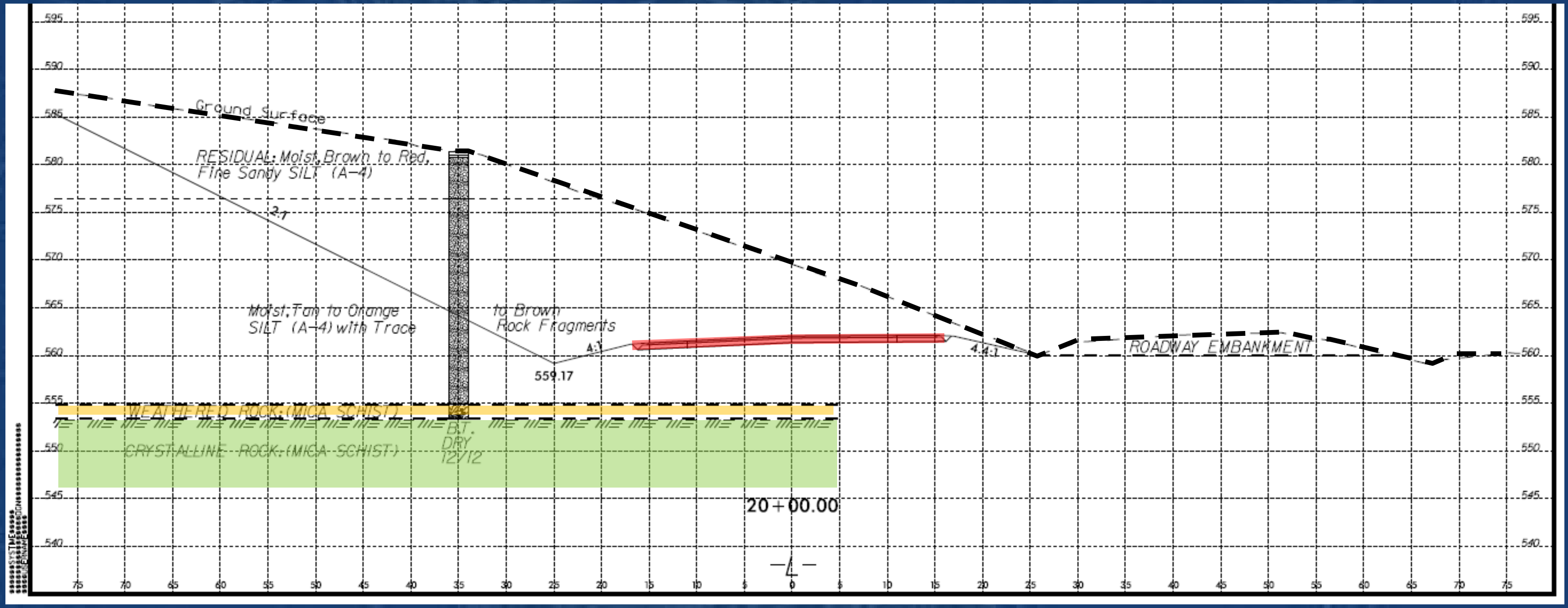
Cross-Section 20+00





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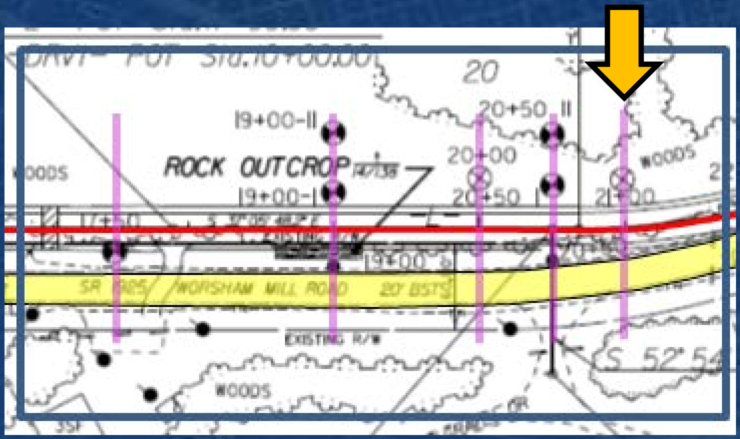
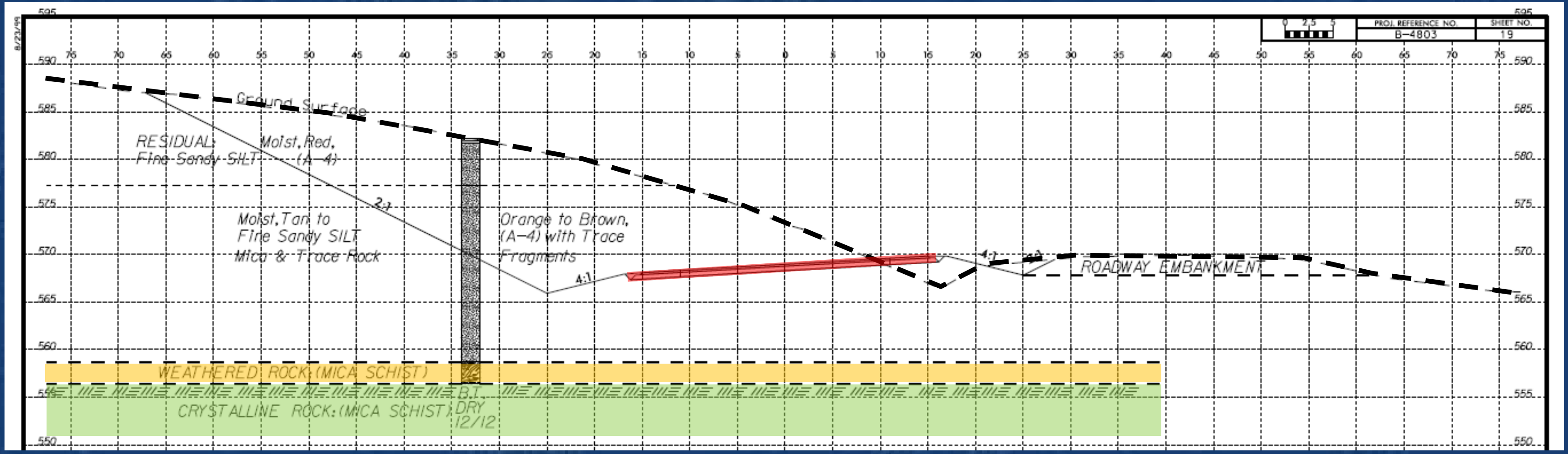
Cross-Section 21+00

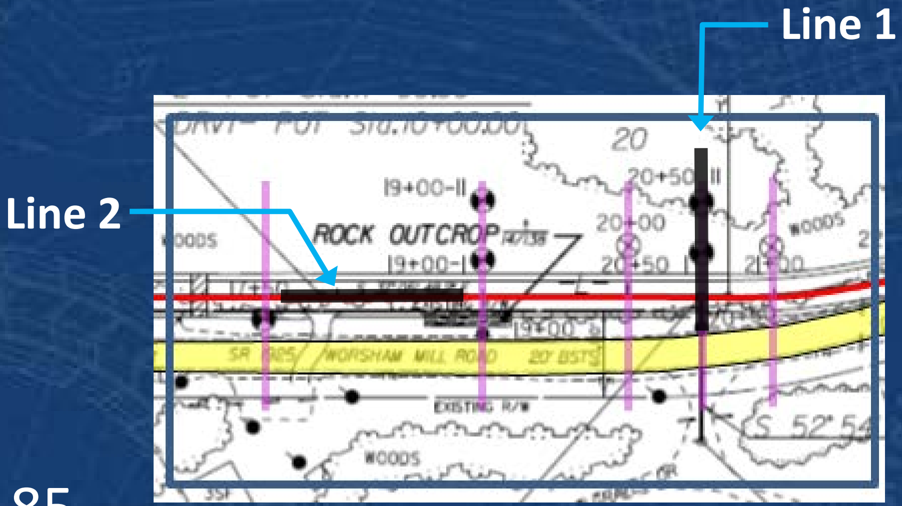




Geophysical Demonstration

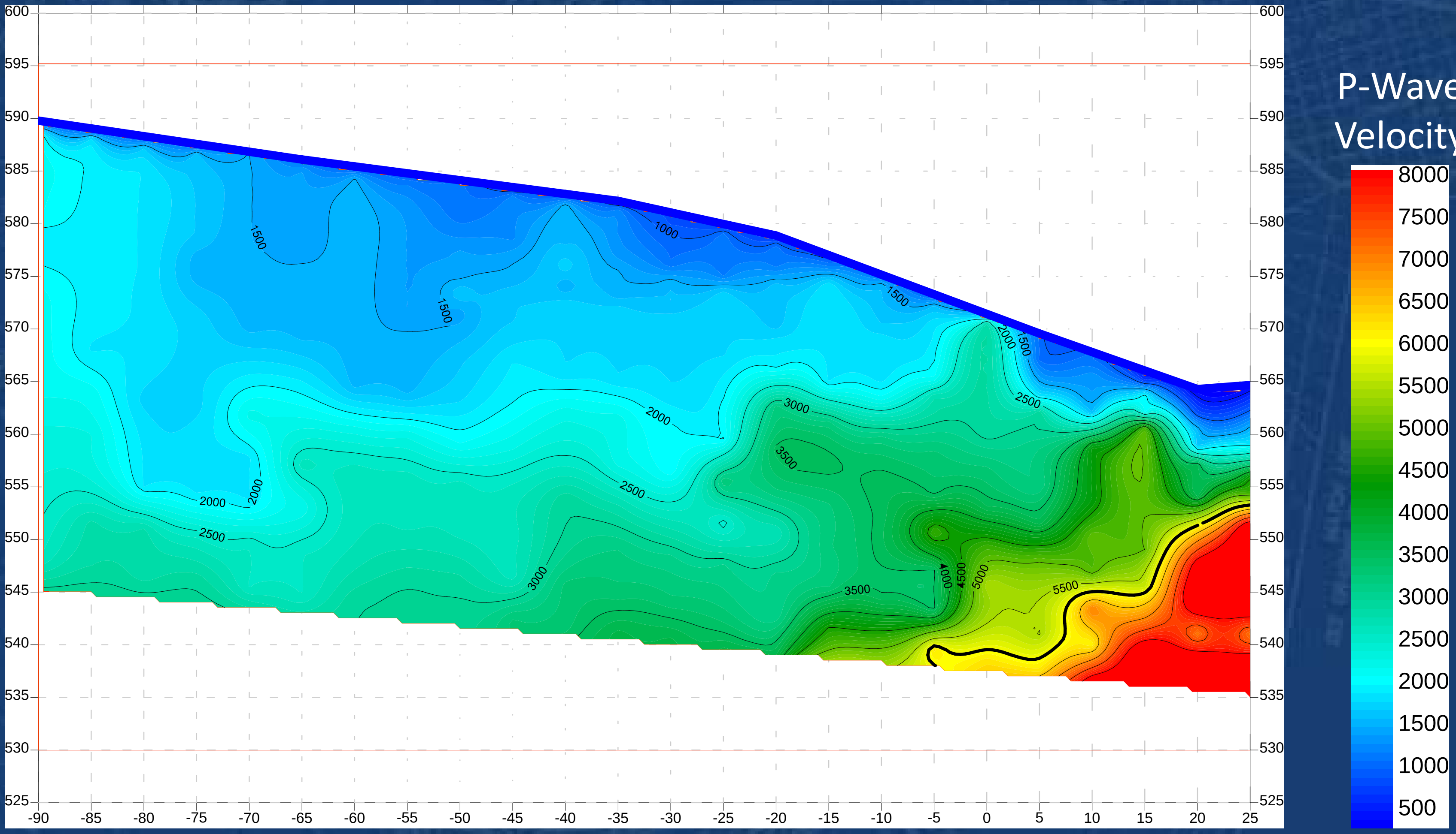
- Seismic Refraction
- Surface Wave Seismic
- EM Terrain Conductivity

Seismic Refraction

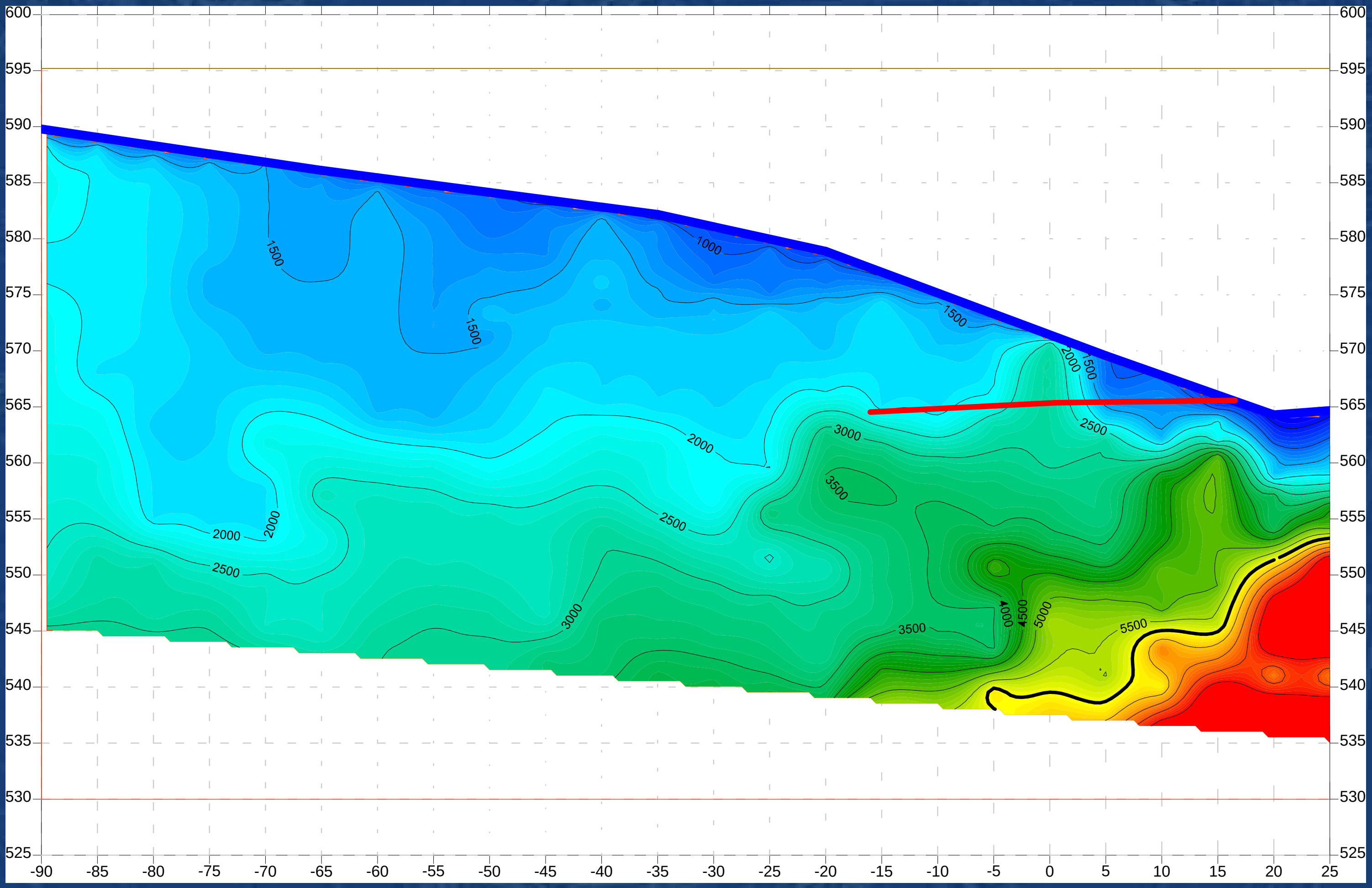


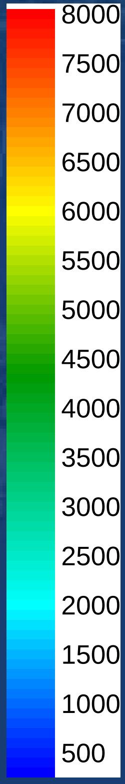
- Two Lines
  - Line 1: Section 20+50
  - Line 2: CL 17+70 to 18+85
- 24-channel Geode seismograph
- 8 Hz vertical Geophones
- 5-foot geophone spacing, 115-foot array
- 20-lb sledgehammer source

Refraction Line 1, 20+50

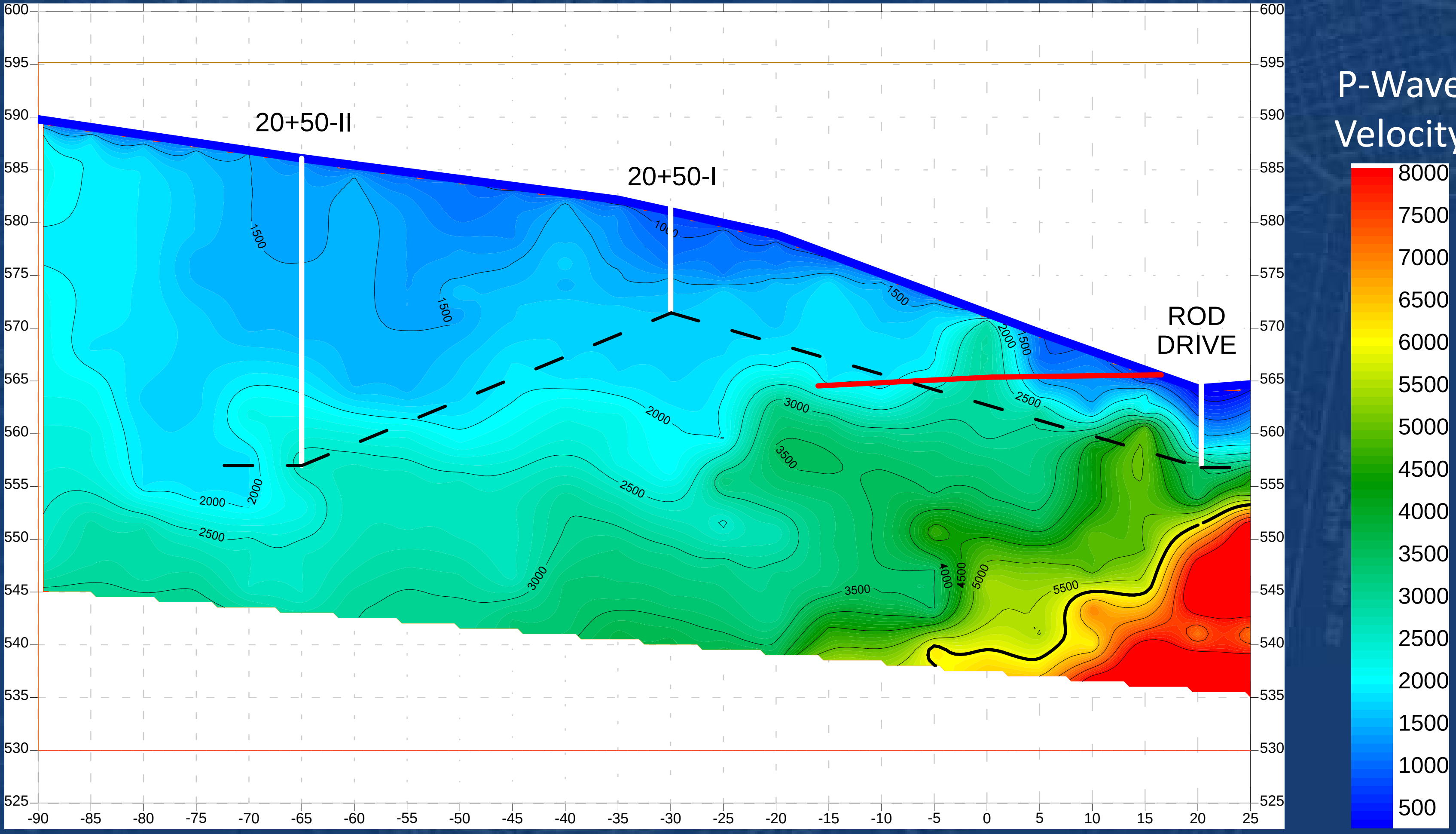


Refraction Line 1, 20+50

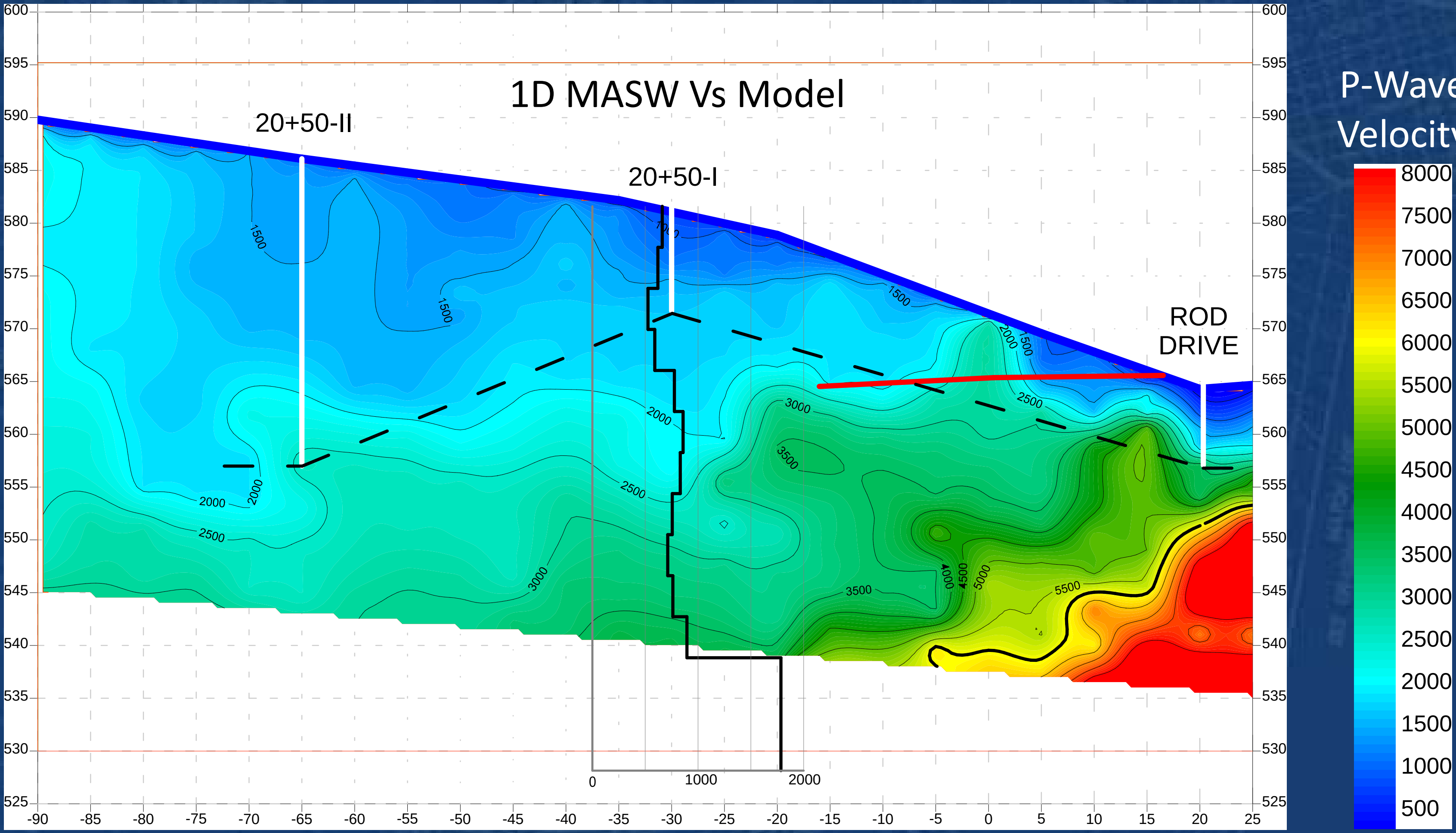




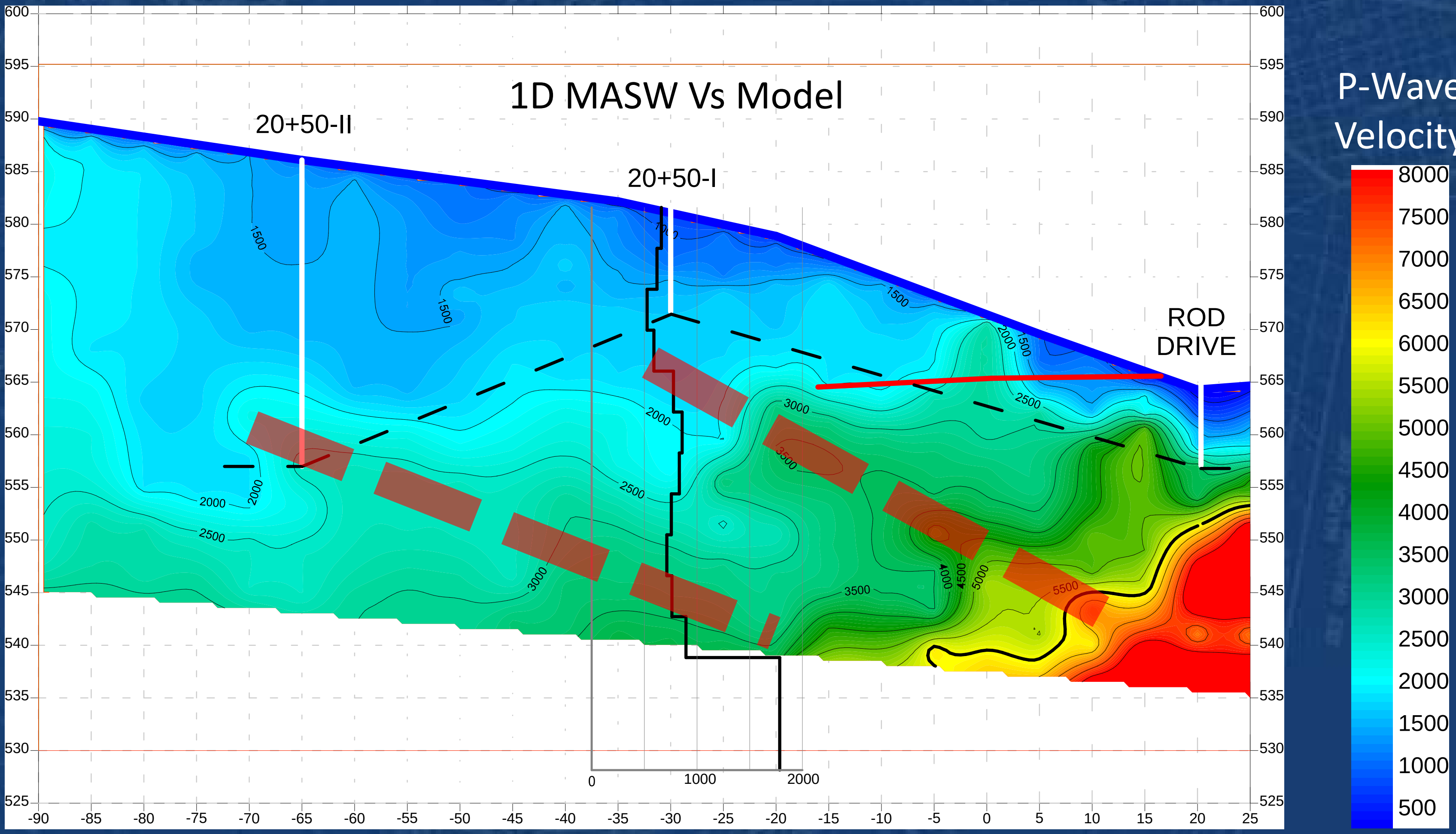
Refraction Line 1, 20+50



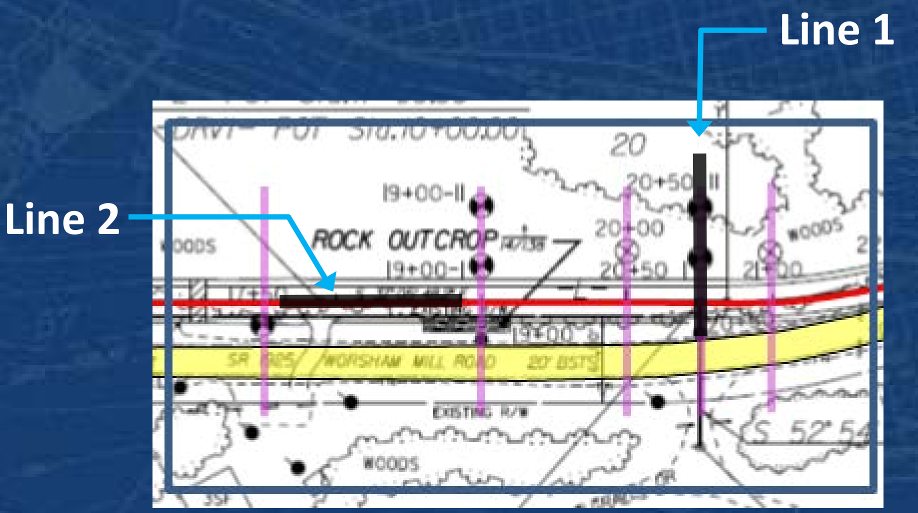
Refraction Line 1, 20+50

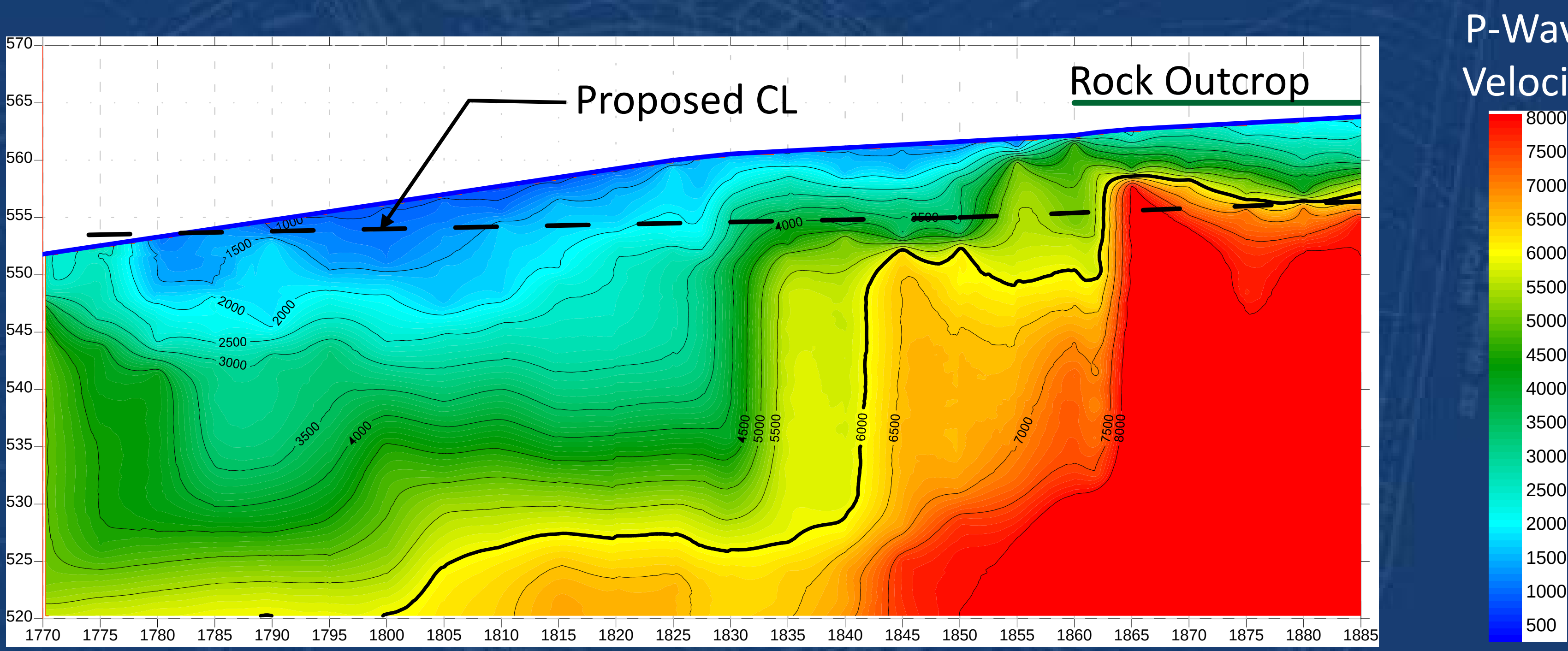


Refraction Line 1, 20+50



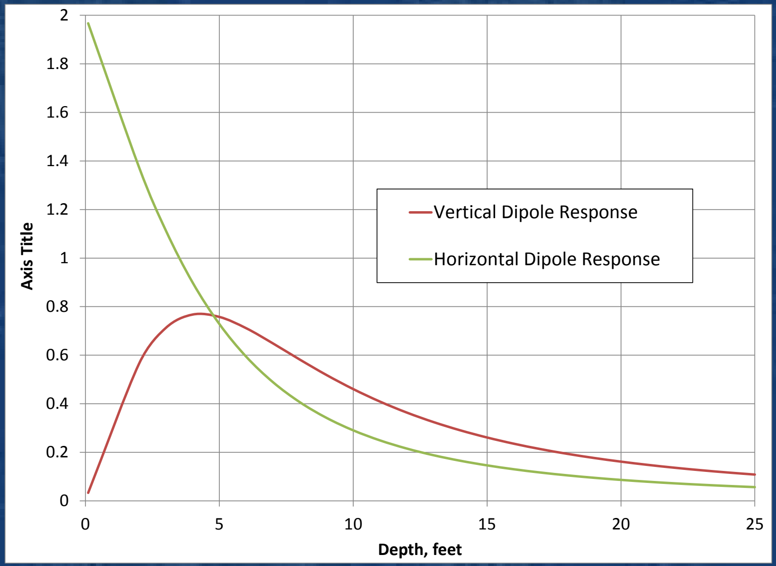
Refraction Line 2
CL 17+70 to 18+85



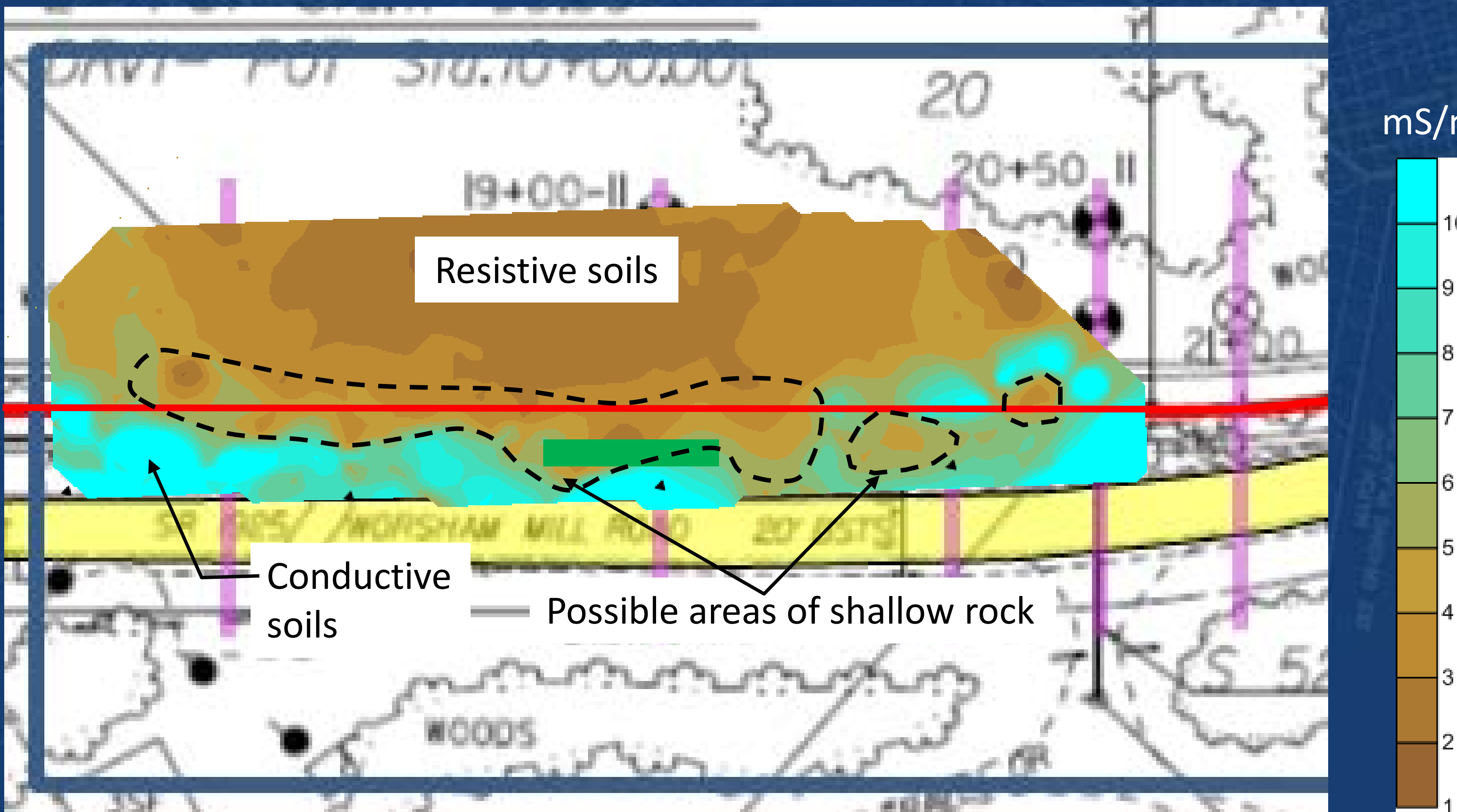


Terrain Conductivity Test

- Geonics EM31, Vertical dipole mode
  - 9.8 kHz, 12-ft coil spacing, ~20-ft depth
- Line spacing roughly 15 to 20 feet



Terrain Conductivity



Summary

- Boring data combined with seismic velocity models can provide a more comprehensive evaluation than either method alone
- 1D MASW shear wave velocity models can be generated from seismic refraction data to aid in evaluation
- 2D shear wave velocity models can be used to characterize subsurface stiffness and depth to rock
- Terrain conductivity could be performed as an initial study get possible locations of shallow rock

Recommendations

- Consider performing a geophysical study prior to selecting initial boring locations at sites where shallow rock is likely
- Consider using geophysics where access by conventional drilling equipment is limited
- Consider using geophysics to help resolve depth to rock issues identified by geotechnical investigations

Thank you!