ARKANSAS DEPARTMENT OF TRANSPORTATION

SUBSURFACE INVESTIGATION

STATE JOB NO. 040885

FEDERAL AID PROJECT NO. STPF-0017(52)

HWY. 59 REALIGNMENT (CRAWFORD CO.) (S)

STATE HIGHWAY 59 **SECTION** 5

IN CRAWFORD **COUNTY**

The information contained herein was obtained by the Department for design and estimating purposes only. It is being furnished with the express understanding that said information does not constitute a part of the Proposal or Contract and represents only the best knowledge of the Department as to the location, character and depth of the materials encountered. The information is only included and made available so that bidders may have access to subsurface information obtained by the Department and is not intended to be a substitute for personal investigation, interpretation and judgment of the bidder. The bidder should be cognizant of the possibility that conditions affecting the cost and/or quantities of work to be performed may differ from those indicated herein.

ARKANSAS DEPARTMENT OF TRANSPORTATION
ArDOT.gov | IDriveArkansas.com | Lorie H. Tudor, P.E., Director
MATERIALS DIVISION
11301 West Baseline Road | P.O. Box 2261 | Little Rock, AR 72203-2261 | Phone: 501.569.2185 | Fax: 501.569.2368

September 19, 2023

TO: Mr. Trinity Smith, Engineer of Roadway Design

SUBJECT: Job No. 040885
Hwy. 59 Realignment (Crawford Co.) (S)
Route 59, Section 5
Crawford County

Introduction

Submitted herein are results of geotechnical investigations and geotechnical recommendations and conclusions developed for rock excavation for the Highway 59 realignment project in Crawford County. It is understood that the Trail of Tears is located adjacent to the project alignment, causing environmental constraints. Evaluation of suitable rock excavation configuration was requested by Roadway Division and Environmental Division on August 28, 2023. Recommendations for a conceptual cross section were provided on August 31, 2023. These recommendations are confirmed in this memo. Design cross sections developed utilizing the conceptual cross section have been reviewed by Materials Division.

Geotechnical Investigations

Potential rock excavation is anticipated in the project realignment. A geophysical study using seismic refraction survey method was performed in June 2023 and subsequent verification borings were performed in August 2023. The purpose of the geotechnical investigations was to determine rock rippability and to develop suitable rock cut slope configurations.

The results of the verification borings are presented in Attachment A. These include a Plan of Borings showing the boring locations, boring logs, a legend interpreting the boring logs, and rock core pictures. The laboratory test results of uniaxial compressive tests on rock cores are also presented in Attachment A. Geological Strength Index (GSI) and Rock Mass Rating (RMR) of the rock cores, as evaluated by a licensed Professional Geologist, are included in Attachment A as well.

The results of the geophysical study are included in Attachment B. The geophysical study was performed utilizing a seismic refraction survey method at seven (7) selected locations. The geophysical study estimates the depth to bedrock / bedrock elevation at these locations and bedrock rippability as determined utilizing P-wave velocity measurements.

Analyses, Conclusions, and Recommendations

Cut Slope Configuration. Based on the boring results, the geophysical study, and the local geology, a conceptual cut slope configuration was developed utilizing the cross section at Sta. 110+00. The conceptual cross section is provided in Attachment C.

A complex cut slope configuration comprised of a 0.5H:1V lower slope and a 0.5H:1V upper slope with a 20-foot-wide maintenance bench is recommended. The maximum height of the lower 0.5H:1V slope should be limited to 15 feet while the upper 0.5H:1V slope varies in height. 3H:1V slope is recommended for the top 10 feet of surface overburden soils. To facilitate drainage and to prevent erosion, a 2% slope is recommended for the maintenance bench.

Bedrock Rippability and Classes of Excavation. The subsurface material labelled as "Soil" on the geophysical study cross sections is expected to be rippable. Removal of this material should be classified as "Common Excavation" or "Unclassified Excavation", as defined in ArDOT Standard Specifications Subsection 210.05(a) or Subsection 210.05(c), respectively.

Removal of the bedrock of any depth should be considered as "Rock Excavation" or "Unclassified Excavation", as defined in Subsection 210.05(b) or Subsection 210.05(c), respectively. The results of the borings reveal the sandstone bedrock is generally well cemented and resistant. It is the Materials Division's conclusion that the bedrock will be generally not rippable or at least not efficiently rippable. It should be anticipated that rock excavation methods other than ripping, such as blasting, be required for removal of the bedrock. While the geophysical study provides a reasonable estimate of overburden soil thickness, it is recommended the conclusions regarding bedrock rippability be utilized for information only.

Attachments

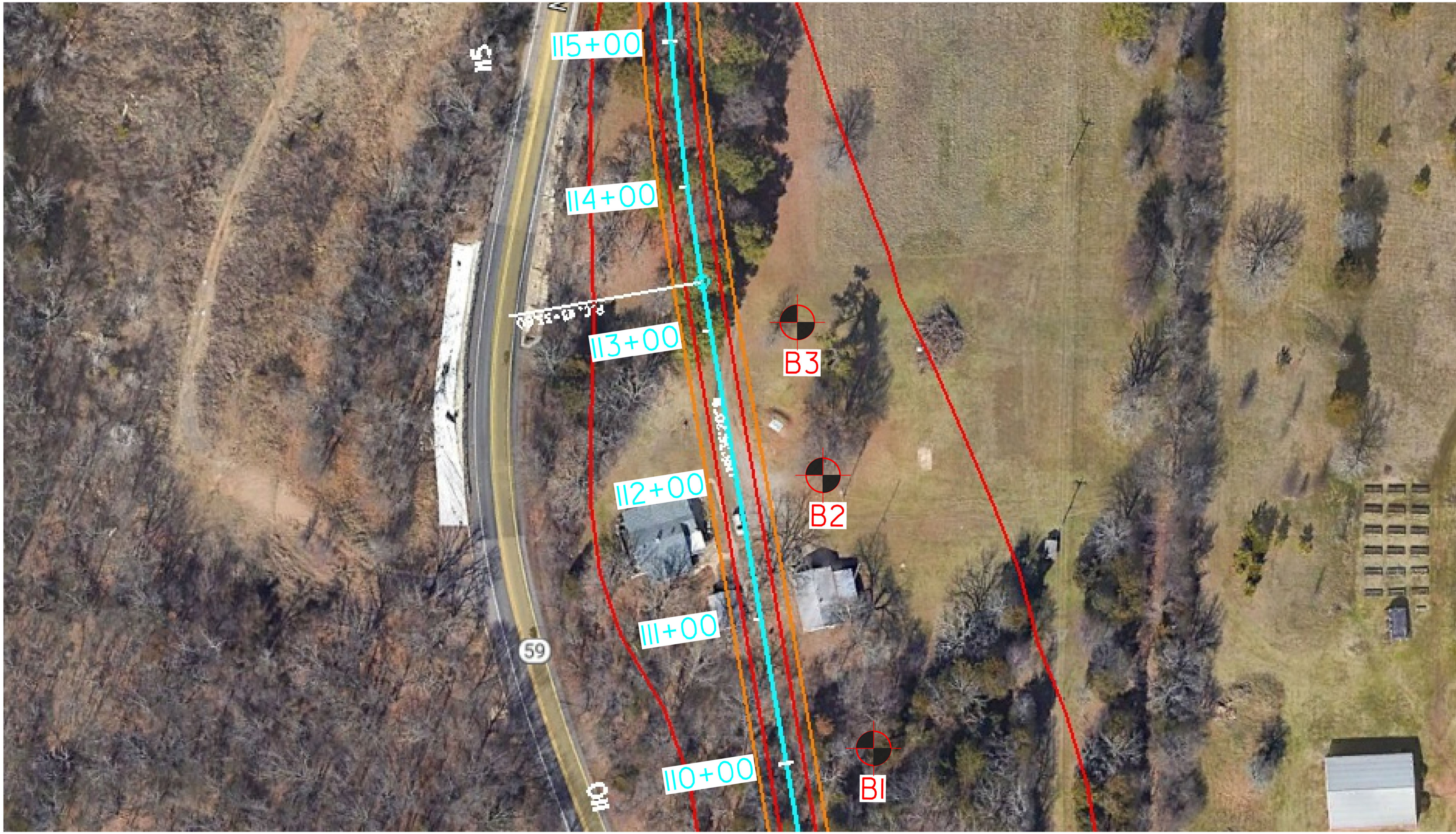
The following attachments are included in this submittal:

- Attachment A – Boring Results
- Attachment B – Results of Geophysical Study
- Attachment C – Conceptual Rock Cut Slope Configuration

Paul Tinsley
Materials Engineer

RPT:yz:mlg:pjt:mbb:pwc
cc: State Construction Engineer
District 4 Engineer
Program Management
Environmental

Attachment A



PLAN OF BORINGS	
HWY. 59 REALIGNMENT (CRAWFORD CO.) (S) ROUTE 59, SECTION 5 CRAWFORD COUNTY	
JOB NO. 040885	SHEET 1/1
NTS	

ARKANSAS DEPARTMENT OF TRANSPORTATION MATERIALS DIVISION - GEOTECHNICAL SEC.	BORING NO. 1 PAGE 1 OF 2
JOB NO. 040885 Crawford County JOB NAME: Hwy 59 Realignment, Section 5, Logmile 23.25 STATION: 110+00 LOCATION: 60' Right of Construction Centerline LOGGED BY: Guy King	DATE: August 23, 2023 TYPE OF DRILLING: Hollow Stem Auger - Diamond Core EQUIPMENT: Acker 1 HAMMER CORRECTION FACTOR: 1.54

COMPLETION DEPTH: 44.1

DEPTH FT.	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL SURFACE ELEVATION: 725.6	SOIL GROUP	MOISTURE CONTENT (%) ● PL — LL (10 20 30 40 50 60 70)	PERCENT PASSING NO. 200 SIEVE	NO. OF BLOWS PER 6-IN.	% TCR	% RQD
0–3			Brown Sand						
3–5.6			Moist, Very Dense, Brown Sand with Gravel (Sandstone Rock Fragments)				60 (4") 58 32 (1")		
5.6–14			SANDSTONE - Weathered with Highly Weathered Layers, Well Cemented with Poorly Cemented Layers, Frequent Vertical Fractures, Gray					45 92	12 34
14–19			SANDSTONE WITH FREQUENT SHALE PARTINGS - Slightly Weathered with Weathered Layers, Cemented, Frequent Vertical Fractures, Gray					88	34
19–35			SANDSTONE WITH FREQUENT SHALE PARTINGS - Slightly Weathered, Well Cemented, Frequent Vertical Fractures, Gray					98 96 94	52 64 70

REMARKS: 21 hour water level reading was approximately 24.5 feet below ground level.

ARKANSAS DEPARTMENT OF TRANSPORTATION
MATERIALS DIVISION - GEOTECHNICAL SEC.

BORING NO. 1
PAGE 2 OF 2

JOB NO. 040885 Crawford County
JOB NAME: Hwy 59 Realignment, Section 5, Logmile 23.25
STATION: 110+00
LOCATION: 60' Right of Construction Centerline
LOGGED BY: Guy King

DATE: August 23, 2023
TYPE OF DRILLING: Hollow Stem Auger - Diamond Core
EQUIPMENT: Acker 1
HAMMER CORRECTION FACTOR: 1.54

COMPLETION DEPTH: 44.1

DEPTH FT.	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL (SURFACE ELEVATION: 725.6)	SOIL GROUP	MOISTURE CONTENT (%) • PL ⊢⊣ LL (10 20 30 40 50 60 70)	PERCENT PASSING NO. 200 SIEVE	NO. OF BLOWS PER 6-IN.	% TCR	% RQD
								98	56
40			SHALE WITH OCCASIONAL SANDSTONE PARTINGS - Unweathered, Medium Hard, Gray					96	74
45			Boring Terminated						
50									
55									
60									
65									
70									

REMARKS: 21 hour water level reading was approximately 24.5 feet below ground level.

ARKANSAS DEPARTMENT OF TRANSPORTATION
MATERIALS DIVISION - GEOTECHNICAL SEC.

BORING NO. 2
PAGE 1 OF 1

JOB NO. 040885 Crawford County
JOB NAME: Hwy 59 Realignment, Section 5, Logmile 23.25
STATION: 112+00
LOCATION: 60' Right of Construction Centerline
LOGGED BY: Guy King

DATE: August 22, 2023
TYPE OF DRILLING: Hollow Stem Auger - Diamond Core
EQUIPMENT: Acker 1
HAMMER CORRECTION FACTOR: 1.54

COMPLETION DEPTH: 24.1

DEPTH FT.	DESCRIPTION OF MATERIAL (SURFACE ELEVATION: 724.1)	SOIL GROUP	MOISTURE CONTENT (%) (PL / LL; 10 20 30 40 50 60 70)	PERCENT PASSING NO. 200 SIEVE	NO. OF BLOWS PER 6-IN.	% TCR	% RQD
0–6.7	Moist, Very Dense, Brown Sand with Gravel (Sandstone Rock Fragments)				27 / 67-17 (7"); 60 / 21 (1")		
6.7–10.6	SANDSTONE - Slightly Weathered with Weathered Layers, Well Cemented with Poorly Cemented Layers, Frequent Vertical Fractures, Gray					79	27
10.6–14	SANDSTONE WITH FREQUENT SHALE PARTINGS - Weathered, Well Cemented, Frequent Vertical Fractures, Gray					92	48
14–19	SANDSTONE WITH FREQUENT SHALE PARTINGS - Slightly Weathered, Well Cemented, Frequent Vertical Fractures, Light Gray					98	62
19–24.1	SANDSTONE - Unweathered, Well Cemented, Light Gray					98	52
	Boring Terminated						

REMARKS:

ARKANSAS DEPARTMENT OF TRANSPORTATION
MATERIALS DIVISION - GEOTECHNICAL SEC.

BORING NO. 3
PAGE 1 OF 1

JOB NO. 040885 Crawford County
JOB NAME: Hwy 59 Realignment, Section 5, Logmile 23.25
STATION: 113+00
LOCATION: 60' Right of Construction Centerline
LOGGED BY: Guy King

DATE: August 22, 2023
TYPE OF DRILLING: Hollow Stem Auger - Diamond Core
EQUIPMENT: Acker 1
HAMMER CORRECTION FACTOR: 1.54

COMPLETION DEPTH: 23.3

DEPTH FT.	SYMBOL	SAMPLES	DESCRIPTION OF MATERIAL SURFACE ELEVATION: 727.1	SOIL GROUP	MOISTURE CONTENT (%) ● PL ⊢⊣ LL (10 20 30 40 50 60 70)	PERCENT PASSING NO. 200 SIEVE	NO. OF BLOWS PER 6-IN.	% TCR	% RQD
0–3.3			SANDSTONE - Weathered, Well Cemented, Frequent Vertical Fractures, Brown					78	48
3.3–10.7			SANDSTONE - Slightly Weathered with Weathered Layers, Well Cemented, Frequent Vertical Fractures, Brown					64	32
								92	50
10.7–18.3			SANDSTONE WITH FREQUENT SHALE PARTINGS - Slightly Weathered, Well Cemented, Frequent Vertical Fractures, Brown					88	0
18.3–23.3			SANDSTONE WITH FREQUENT SHALE PARTINGS - Unweathered, Well Cemented, Occasional Vertical Fractures, Brown					100	88
			Boring Terminated						

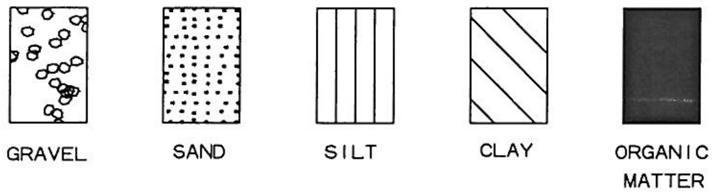
Depth scale: 5, 10, 15, 20, 25, 30, 35

REMARKS:

LEGEND

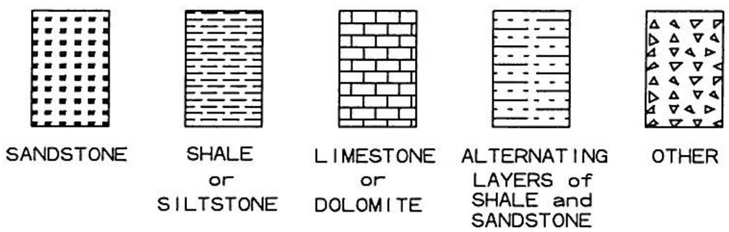
SOIL TYPES

(SHOWN IN SYMBOL COLUMN)
(PREDOMINANT TYPE SHOWN HEAVY)



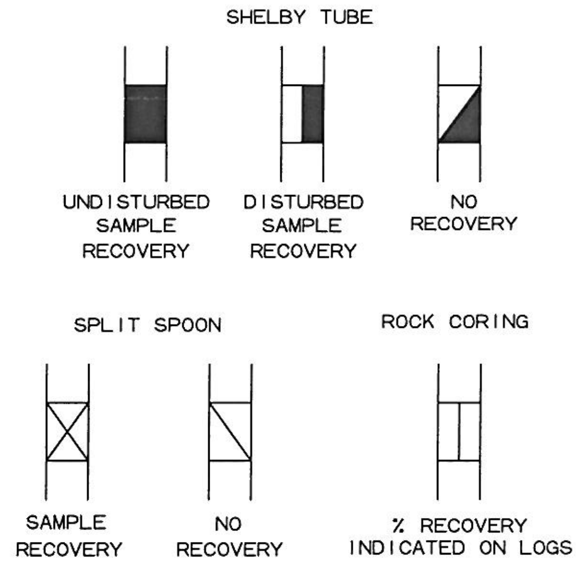
ROCK TYPES

(SHOWN IN SYMBOL COLUMN)



SAMPLER TYPES

(SHOWN IN SAMPLE COLUMN)



TERMS DESCRIBING CONSISTENCY OR CONDITION

GRANULAR SOIL		CLAY		CLAY-SHALE		SHALE	
'N' Value	Density	'N' Value	Consistency	'N' Value	Consistency	'N' Value	Consistency
0-4	Very Loose	0-1	Very Soft	0-1	Very Soft		
5-10	Loose	2-4	Soft	2-4	Soft	31-60	Soft
11-30	Medium Dense	5-8	Medium Stiff	5-8	Medium Stiff	Over 60	
31-50	Dense	9-15	Stiff	9-15	Stiff	More than 2"	
Over 50	Very Dense	16-30	Very Stiff	16-30	Very Stiff	Penetration	
		31-60	Hard	31-60	Hard	in 60 Blows:	Medium Hard
		Over 60	Very Hard	Over 60	Very Hard	Less than 2"	
						Penetration	
						in 60 Blows:	Hard

1. Ground water elevations indicated on boring logs represent ground water elevations at date or time shown on boring log. Absence of water surface implies that no ground water data is available but does not necessarily mean that ground water will not be encountered at locations or within the vertical reaches of these borings.
2. Borings represent subsurface conditions at their respective locations for their respective depths. Variations in conditions between or adjacent to boring locations may be encountered.
3. Terms used for describing soils according to their texture or grain size distribution are in accordance with the Unified Soil Classification System.

Standard Penetration Test – Driving a 2.0" O.D., 1-3/8" I.D. sampler a distance of 1.0 foot into undisturbed soil with a 140 pound hammer free falling a distance of 30 inches. It is customary to drive the spoon 6.0 inches to seat into undisturbed soil, then perform the test. The number of hammer blows for seating the spoon and performing the test are recorded for each 6 inches of penetration on the drill log. The field "N" Value (N_f) can be obtained by adding the bottom two numbers for example: $\frac{6}{8-9} \Rightarrow 8+9=17 blows/ft$. The "N" Value corrected to 60% efficiency (N_{60}) can be obtained by multiplying N_f by the hammer correction factor published on the boring log.

ROCK CORE PHOTO

Job No.: 040885
Job Name: Hwy 59 Realignment

ROCK CORE PHOTO

Job No.: 040885
Job Name: Hwy 59 Realignment

ROCK CORE PHOTO

Job No.: 040885
Job Name: Hwy 59 Realignment

040885
Sta: 110+00, 60' RT
Depth: 24.1 - 34.1

ROCK CORE PHOTO

Job No.: 040885
Job Name: Hwy 59 Realignment

040885
Sta: 110+00, 60' RT
Depth: 34.1 - 44.1

ROCK CORE PHOTO

Job No.: 040885
Job Name: Hwy 59 Realignment

040885
Sta: 112+00, 60' RT
Depth: 6.7 - 14.1

ROCK CORE PHOTO

Job No.: 040885
Job Name: Hwy 59 Realignment

ROCK CORE PHOTO

Job No.: 040885
Job Name: Hwy 59 Realignment

040885
Sta: 113+00, 60' RT
Depth: 1.0 - 13.3

ROCK CORE PHOTO

Job No.: 040885
Job Name: Hwy 59 Realignment

Summary of Rock Core Uniaxial Compression Test Results, Geological Strength Index (GSI) and Rock Mass Rating (RMR)

Project Number: 040885
Project Name: Hwy 59 Realignment
Date Tested: 9/1/2023

GSI: 80

Uniaxial Compressive Strength											RMR								
Station	Location	Depth (ft.)	Diameter (in.)	Height (in.)	Weight (g)	Unit Weight (pcf)	Total Load (lbs.)	Correction Factor	Stress (psi)	Rock Type	Uniaxial Compressive Strength Rating	RQD Rating	Spacing of Joints	Condition of Joints	Groundwater Condition	Sum	Class Number	Description	Notes
110+00	60' RT	12.9	1.76	4.00	404.70	159	23,700	1.00	9,742	Sandstone	7	3	8	12	7	37	IV	POOR ROCK	
110+00	60' RT	24.9	1.76	4.16	424.34	160	44,080	1.00	18,119	Sandstone	12	13	20	20	7	72	II	GOOD ROCK	
110+00	60' RT	43.7								Shale									Sample broke during prep.
112+00	60' RT	7.2	1.75	4.86	489.16	160	30,010	1.00	12,477	Sandstone	7	8	10	20	7	52	III	FAIR ROCK	
113+00	60' RT	1.3	1.76	5.04	504.31	157	56,320	1.00	23,150	Sandstone	12	8	10	20	7	57	III	FAIR ROCK	
113+00	60' RT	22.0	1.75	4.05	412.99	161	39,560	1.00	16,447	Sandstone	12	17	25	20	7	81	I	VERY GOOD ROCK	

Attachment B

September 18, 2023
Project No. 23-043

Arkansas Department of Transportation
Materials Division
11301 West Baseline Road
P.O. Box 2261
Little Rock, Arkansas 72203-2261

Attn: Mr. Paul Tinsley, P.E.

RE: RESULTS of SEISMIC REFRACTION SURVEY
JOB No. 040885, TASK ORDER G007
HWY. 59 REALIGNMENT (CRAWFORD CO.)(S) ROUTE 59, SECTION 5
CRAWFORD COUNTY, ARKANSAS

Mr. Tinsley,

Submitted herewith is the final report of the Seismic Refraction Survey performed for the selected alignment of Job 040885 between Sta 108+00 and 114+00. The survey was performed by The University of Arkansas Department of Civil Engineering in general accordance with the scope outlined in the memorandum to the ARDOT Consultant Coordinator of April 17, 2023 and subsequently discussed with the Department. A draft report was previously submitted on June 8, 2023.

Please let us know any questions or comments on this draft report. We appreciate the opportunity to be of continued service to ARDOT.

Sincerely,

GRUBBS, HOSKYN,
BARTON & WYATT, LLC

Mark E. Wyatt, P.E.
President

MEW:jw

Attachment: Draft Results of Seismic Refraction Survey

Copies Submitted: ARDOT Materials
Attn: Mr. Paul Tinsley, P.E. (1-email)

ARDOT Consultant Coordinator
Attn: Ms. Jessica Jackson, P.E. (1-email)

Seismic Refraction Survey for ARDOT Job# 040885 Highway 59 Van Buren, Arkansas

for:

Grubbs, Hoskyn, Barton, & Wyatt, INC
C/O: Mark Wyatt, PE
1 Trigon Place
Little Rock, Arkansas 72209, US
Phone: 501-455-2536

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and

Graduate Research Assistants Mohammadyar Rahimi

July 2023

Table of Contents

1.0 Introduction

Seismic refraction was conducted to map subsurface conditions and bedrock depth for the Highway 59 realignment (ARDOT Job# 040885) in Van Buren, AR. Testing was conducted on May 22 and 23, 2023. The goal of the testing was to estimate the depth to bedrock, bedrock rippability, and other subsurface conditions along the proposed highway realignment. Background on the proposed testing methods is provided in Section 2. Section 3 discusses testing techniques and locations, Section 4 includes data processing, Section 5 includes interpretation and results, Section 6 is the summary, and Section 7 includes references.

2.0 Background on Testing Techniques

This section provides a brief background on geophysical method used on the project.

Seismic Refraction: The seismic refraction method (Redpath 1973, ASTM D5777) is a body wave method which consists of measuring (at known points along the surface) the travel times of compression (P-waves) or shear (S-waves) waves generated by an impulsive energy source at the surface. See Figure 1 for a diagram of the seismic refraction method. The body wave energy source is typically a sledgehammer for P-wave seismic refraction where vertical blows are used. P-waves are detected by a linear array of receivers (geophones) placed along the ground surface and recorded via a seismograph. The velocity of the P-waves is dependent upon the elastic properties of the material in which they travel from source to receiver. When P-waves are generated at the surface the P-waves travel along the surface (direct arrival), but also travel into the earth. When the P-wave hits an interface where the velocity changes significantly, a portion of the wave energy is reflected, and a portion is transmitted into the layer. When the velocity of the deeper layer is greater than the shallower layer, a portion of the wave energy is critically refracted along the layer interface. This critically refracted wave travels along the interface at the velocity of the deeper layer and continually produces head waves that travel back to the surface. For testing, the instant of the source pulse (e.g., the sledgehammer hitting the ground), "zero time" is recorded by the seismograph and the time to first wave arrival at each geophone is identified. The raw data is then displayed in a plot as the first arrival time at each receiver (first wave arrival) versus receiver distance from the source. For receivers near the source, the direct wave is the first arrival, but at larger source distances, the critically refracted wave arrives first due to traveling faster along the deeper layer boundary. The slopes of the arrival times at each geophone are used to determine the velocity of subsurface layers (the inverse of the slope of the arrival times in Figure 1), while an application of Snell's law of refraction of waves is used to determine the depth-to-layer interfaces.

The analysis of the seismic refraction data to determined depth to various layers can be undertaken using several techniques depending on the complexity of the subsurface. The simplest method is the time intercept method (Redpath 1973) and is applicable for sites with generally planar layer interfaces. This method requires at a minimum shots off each end of the array and can be used to resolve multiple layer boundaries and sloping layers. For more complex subsurface conditions (i.e., rapidly changing bedrock elevations or undulating layers), a more complex analysis such as the generalized reciprocal method (Redpath 1973) may be used. For the most complex sites, tomographic inversions can be performed which model the subsurface as velocity cells and account for rapid changes in velocity and layer thickness. This method requires more shot points within the array to be effective.

In general, seismic refraction is often used for mapping strong velocity contrasts such as soil over bedrock. Although the method is effective at mapping large velocity contrasts below the surface, it suffers from potential errors at some sites. The most serious drawback is the method requires that all layers below the ground surface must increase in velocity with increasing depth. Although this is typically a valid assumption, this is not always true and significant errors can result if velocity reversals exist in the subsurface. Moreover, thin layers with minimum velocity contrast with the above layers maybe hidden in the analysis which may lead to some errors in the depths to layer interfaces.

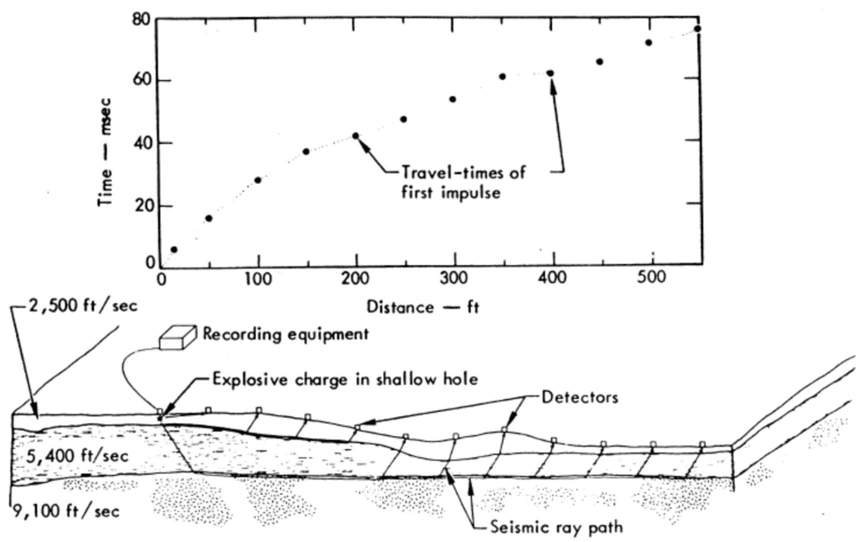


Figure 1 Refraction example field setup and travel time vs distance graph (Redpath 1973).

3.0 Testing Method and Locations

The geophysical testing for the proposed highway realignment was conducted using the seismic refraction method utilizing P-waves. A total of seven lines were surveyed for the study. These lines (from STA 108+04 to STA 114+04) are shown in Figure 2 and aligned perpendicular to the proposed highway centerline. Each survey line was placed near an even station for the proposed highway realignment. However, in some cases due to natural obstacles, such as trees or buildings, the survey line orientation and position was adjusted in order to perform the work. While the position of the array may vary from an even station, for comparison purposes, we compare the results of the survey to the nearest even station.

P-wave seismic refraction was conducted for each line using a linear array of 36-42 (depending on the length of array), 4.5 Hz vertical geophones with a uniform spacing between geophones of 6.5 ft. P-waves were generated using a 12 lb sledgehammer at multiple source locations along the array generally off each end and 5 shots within each array. The waveforms were recorded using two 24 channel Geometrics Geode seismographs. A picture of the seismic refraction equipment is shown in Figure 3. Survey lines for the project consisted of 36 geophones (230 ft array length) or 42 geophones (270 ft array length). For the 36 geophone arrays (STA 108+04, STA 108+86, STA 112+98, and STA 114+04), shots were made at the -3.28 ft, 36 ft, 75 ft, 115 ft, 154 ft, 194 ft, and 233 ft locations along the line. For the 42 geophone arrays (STA 109+91, STA 110+79 and STA 112+06), shots were made at the -3.28 ft, 36 ft, 75 ft, 115 ft, 154 ft, 194 ft, 233 ft and 272 ft locations along the line. At each shot location, 5 hits were stacked in order to increase the signal-to-noise ratio. The location of each shot point and array were established using a Trimble Geo 7x centimeter accuracy GPS. The relative location of each geophone was surveyed with Moasure inertial measurement unit. For the refraction analysis, the elevation of each geophone was estimated based on the relative elevation recorded by Moasure adjusted with GPS elevation for each shot point in the array.

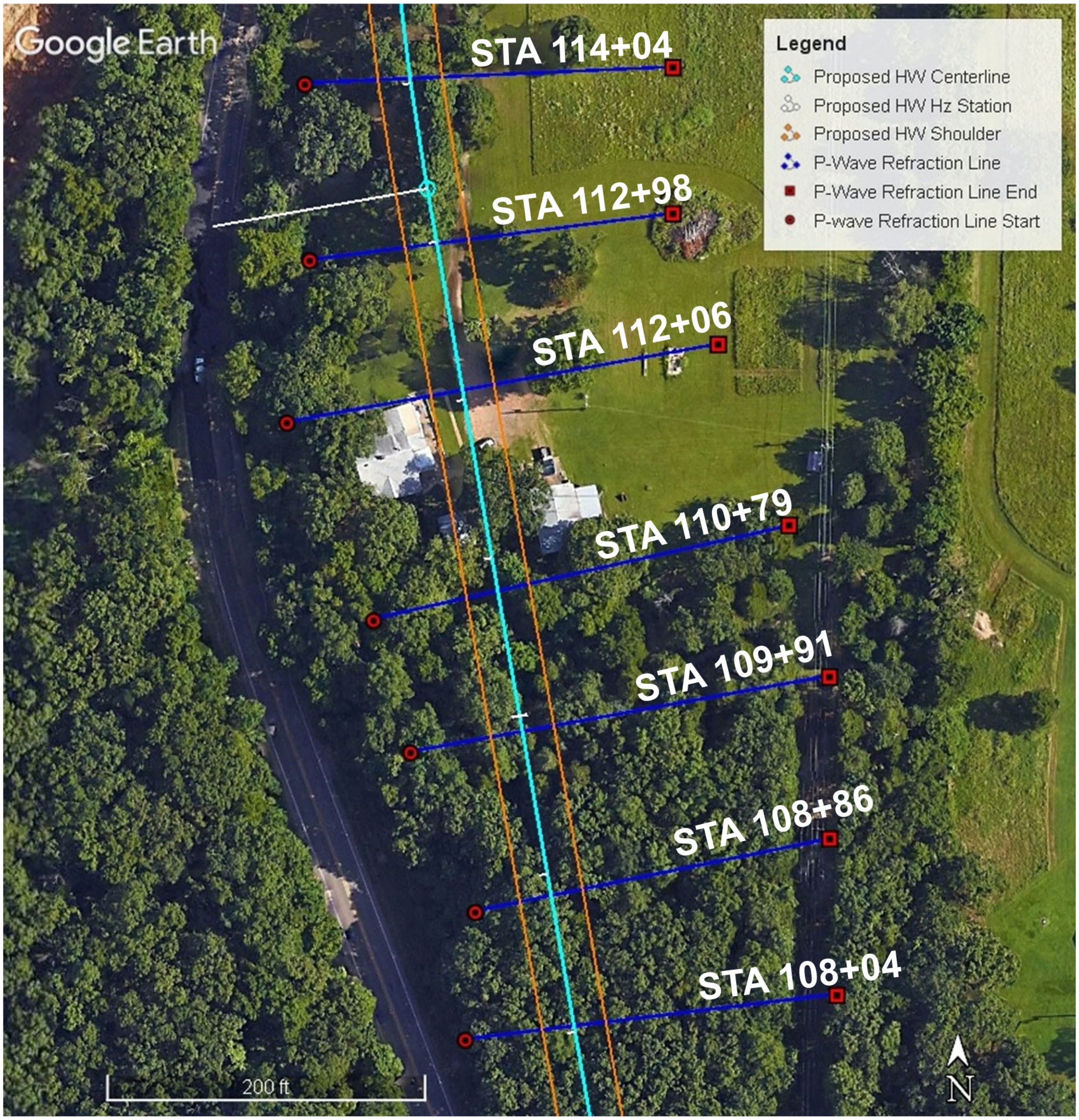


Figure 2 Site map of the seismic refraction survey conducted for the Highway 59 Realignment.

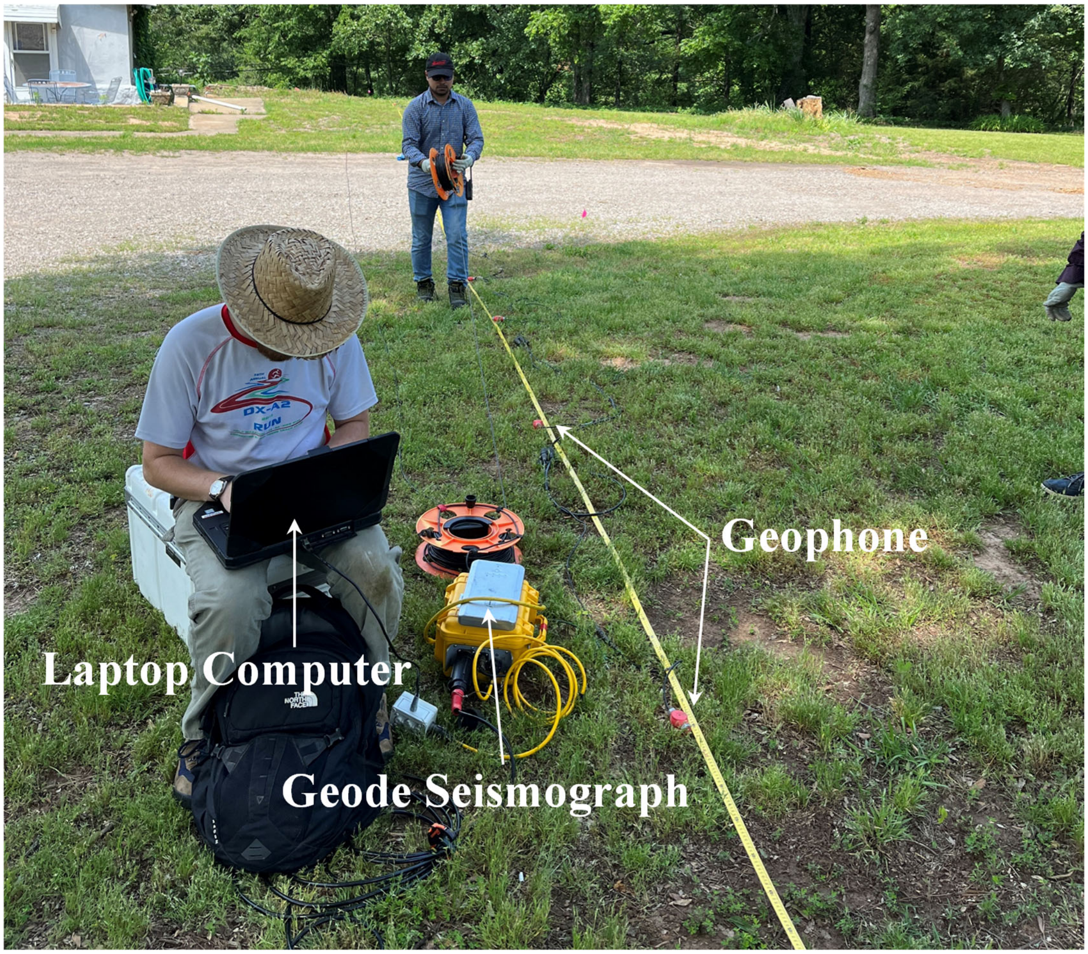


Figure 3 Picture of seismic refraction equipment used at STA 112+06.

4.0 Data Processing

The P-wave seismic refraction data was processed using the Geometrics software package SeisImager in general accordance with ASTM D5777. The P-wave arrivals were picked using the SeisImager Pickwin module, which allowed the P-wave first arrival to be picked manually for each geophone and shot (the picks for STA 108+91 is shown Figure 4). The number of layers is determined based on the variations in the slope of the lines fit through the P-wave arrival times, as shown in Figure 4. The first arrivals for each line were saved in Pickwin and exported to Plotrefraction for further processing. It is expected that the arrival times at each geophone were generally picked within 0.5 ms accuracy with some picks being as high a 1.0 ms. In general, the recorded waveforms were of high quality and allowed clear identification of the first P-wave arrival.

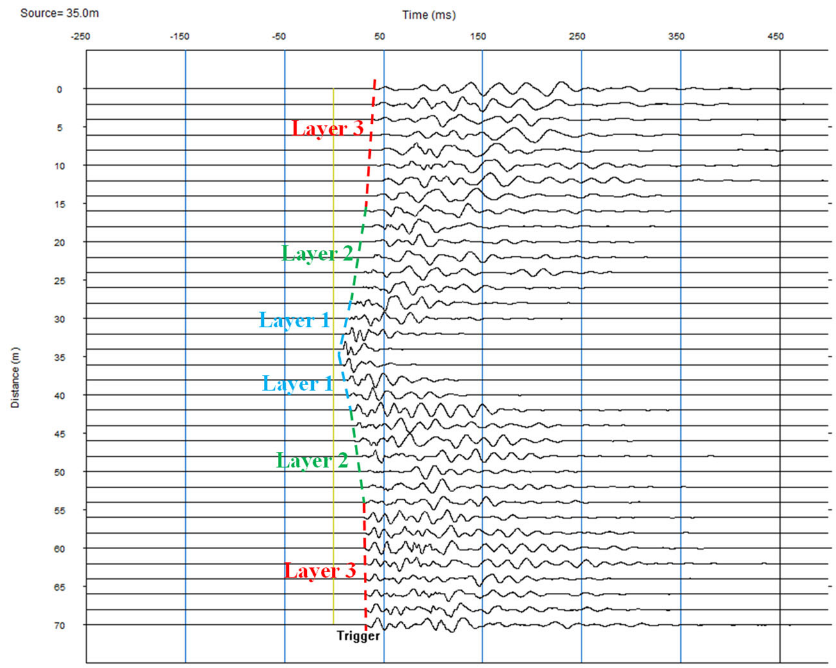


Figure 4 An example plot of P-wave arrival picking using Pickwin along with the estimated subsurface layers.

After picking the P-wave first arrival times, the picks were imported into the SeisImager software. Each arrival time included shot location, geophone location along the line, first arrival time, and geophone elevation. First analyses were conducted using the time interval method (TIM) and generalized reciprocal method (GRM). Each pick was assigned an appropriate layer from which they refracted based on the slope of the P-wave arrival times. Typically, 3-5 layers could be identified from the arrivals. Following the TIM and GRM modeling, the data was modeled using the tomographic analysis method in SeisImager. A minimum of 50 iterations of the non-linear raypath inversion were implemented to improve the fit to the arrival times. The goodness of the fit between the experimental (observed) and the inverted model (calculated) was judged based on visual inspection and the magnitude of the root-mean-square (rms) error (see Figure 5). The final inversions were exported to Surfer for presentation.

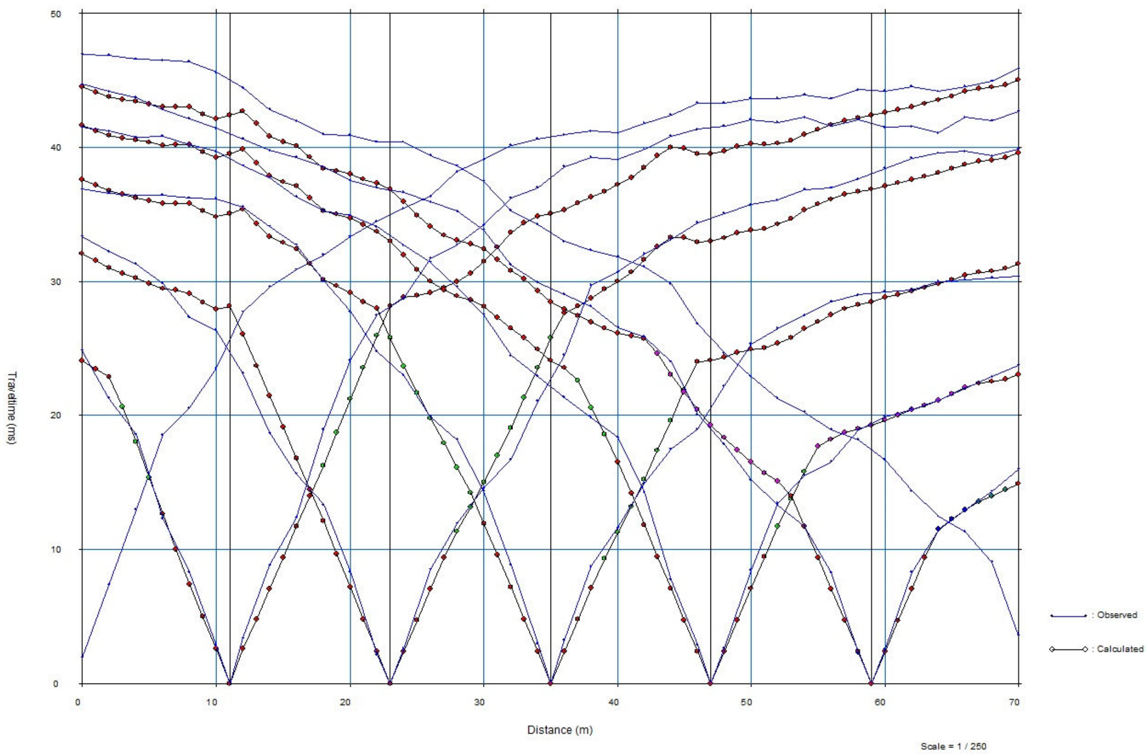


Figure 5 Observed (experimental) versus calculated (inverted) travel time arrivals.

In order to determine the rippability of rock units using the Vp results from seismic refraction, the Caterpillar Handbook on Ripping (2000) was used. This handbook provides the industry standard for rock rippability for different types of dozer/ripper combinations (D8, D9, D10, and D11 with multi or single shanks) based on the P-wave velocity of the rock materials. In the handbook, geologic rock type is divided into three groups (rippable, marginal rippable, and non-rippable rock units) based on their P-wave velocities. The chart provided for a D8R Caterpillar Dozer (see Figure 6) was used as a guide to determine the ranges of P-wave velocity (Vp) associated with the soil (V_p<3000 ft/s), rippable (3000 ft/s <V_p< 6500 ft/s), marginal rippable (6500 ft/s <V_p< 8500 ft/s), and non-rippable (V_p> 8500 ft/s) rock materials. In general, the values listed for sedimentary sandstone rock in Figure 6 was used to determine the appropriate ranges. While P-wave velocity gives a guide to rippability of rock, the fracture orientation, number of refractions, and other parameters should be considered when determining rippability.

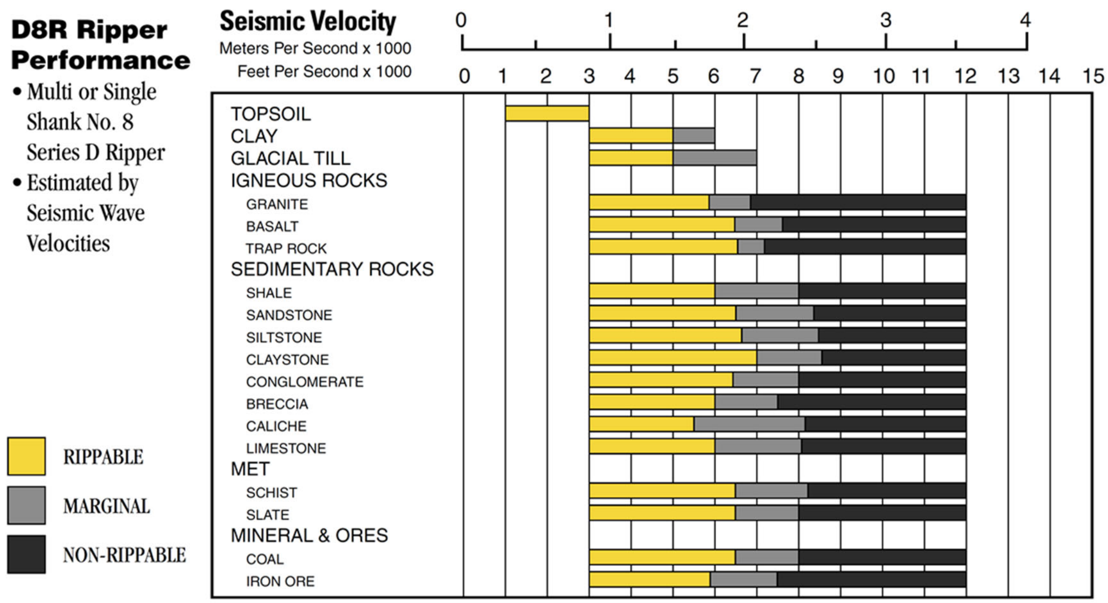


Figure 6 Rippability of rock materials based on the P-wave velocity for D8R ripper (Caterpillar Handbook on Ripping 2000).

5.0 Interpretation and Results

The results of the seismic refraction measurements that included 7 different 2D Vp cross sections are presented in this section. Please refer to Figure 2 for the location and orientation of each cross section.

5.1 Survey Line STA 108+04

Shown in Figure 7 is the 2D Vp cross section generated using the seismic refraction measurements for STA 108+04 along with the approximate ground surface and excavation profile at STA 108+00 provided by ARDOT. It should be noted that the estimated ground surface elevation provided by ARDOT is approximately 5 ft lower in elevation than elevations measured in the field for the survey line. This difference could be caused by differences in line location/orientation and errors in both elevation measurements and should be considered when interpretating the results. The estimated depths to rippable, marginal rippable, and non-rippable rock materials are separated using solid black contour lines. Based on the rippability chart provided in the Caterpillar Handbook on Ripping (2000), V_p values less than 3000 ft/s are considered as soil materials, V_p values ranging from 3000-6500 ft/s are considered as rippable rock materials, V_p values ranging from 6500-8500 ft/s are considered as marginal rippable rock materials, and V_p values approximately greater than 8500 ft/s are considered as non-rippable rock materials.

From Figure 7, the subsurface layering of this survey line can be divided into three layers. This includes a relatively thick soil layer at the ground surface with thickness ranging from 7.5-17.5 ft (shown with blue), underlain by a rippable rock layer with a thickness ranging from 2.5-20 ft (shown with green and yellow). The rest of the section is composed of a marginally rippable rock down to the bottom of the section (shown with orange). It should be noted that the resolution and accuracy of the seismic refraction results decrease as depth increases.

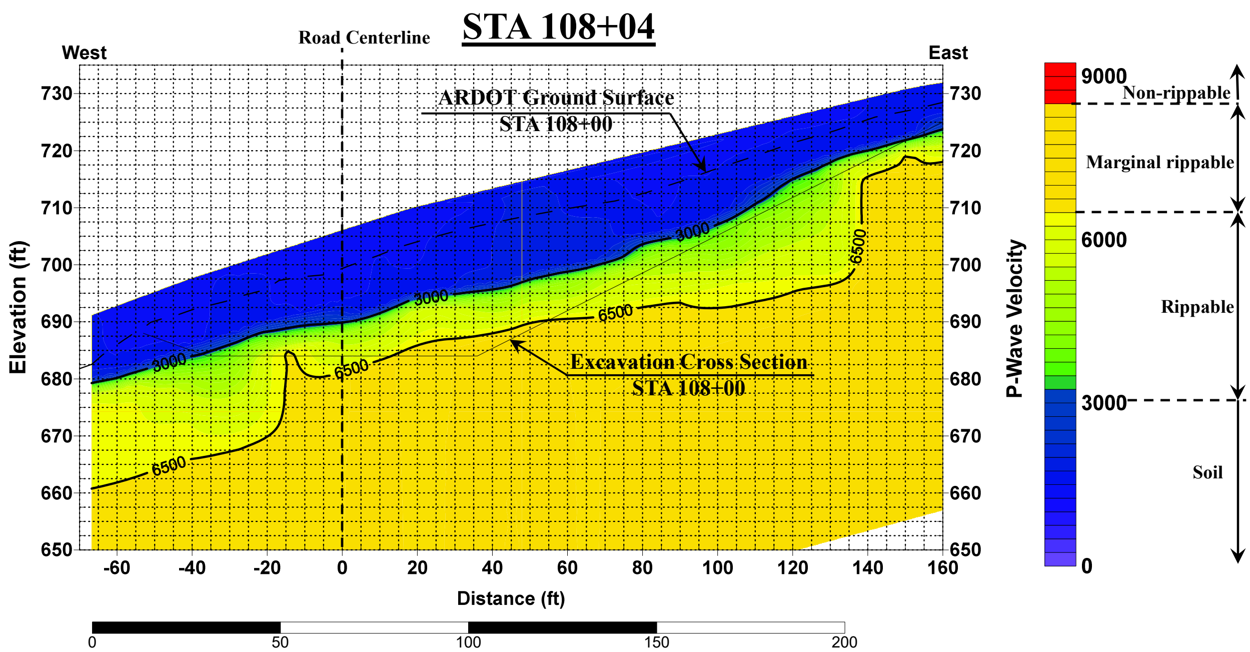


Figure 7 2D V_p cross section for STA 108+04.

5.2 Survey Line STA 108+86

Presented in Figure 8 is the 2D V_p cross section generated using the seismic refraction measurements for STA 108+86 along with the approximate ground surface and excavation profile at STA 109+00 provided by ARDOT. Similar to the previous line, the estimated ground surface elevation provided by ARDOT is approximately 2.5-5 ft lower in elevation than elevations measured in the field for the survey line. This difference could be caused by differences in line location/orientation and errors in both elevation measurements and should be considered when interpretating the results. The estimated depths to rippable, and marginal rippable rock materials are also shown in this figure. Similar to the STA 108+04 cross section, a relatively thick soil layer is observed at the ground surface with thickness varying from 2.5-17.5 ft. This layer is followed by a rippable rock layer with a thickness ranging from 10-20 ft. The rest of the section consisted of a marginally rippable rock.

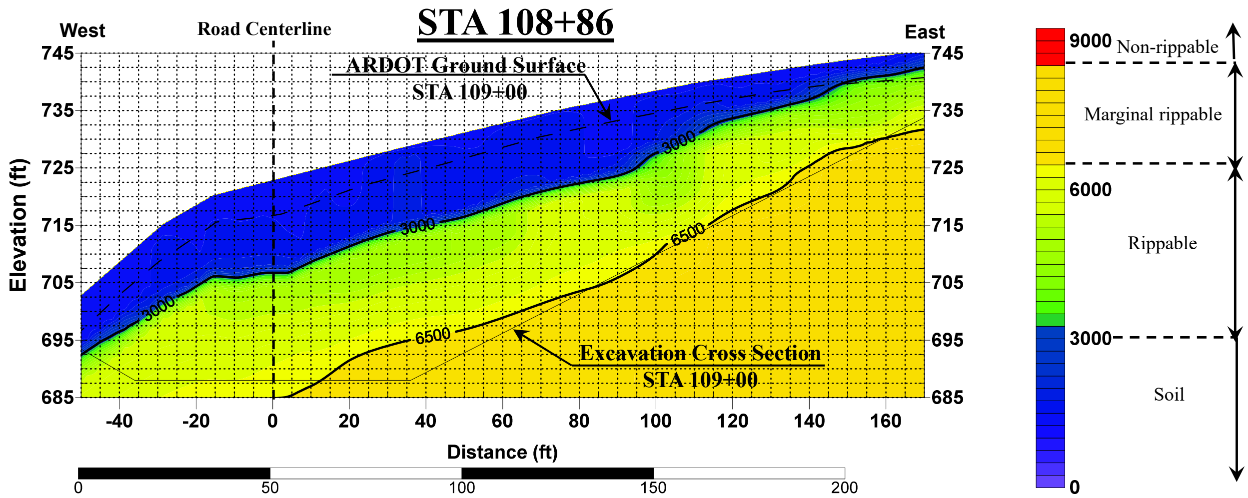


Figure 8 2D V_p cross section for STA 108+86.

5.3 Survey Line STA 109+91

The result of the seismic refraction measurements for STA 109+91 is shown in Figure 9 along with the approximate ground surface and excavation profile at STA 110+00 provided by ARDOT. For this cross section, the estimated ground surface elevation provided by ARDOT is very similar to the surface elevation measured in the field. The contour lines associated with rippable, and marginally rippable rock materials are shown as well. From Figure 9, the subsurface layers from this survey line include three layers. Similar to previous lines there is a soil layer at the ground surface with thickness varying from 2.5-15 ft, a rippable rock layer from the bottom of the soil layer with a thickness varying from 2.5-17.5 ft, followed by a marginally rippable rock layer up to depth ranging down to the bottom of the section.

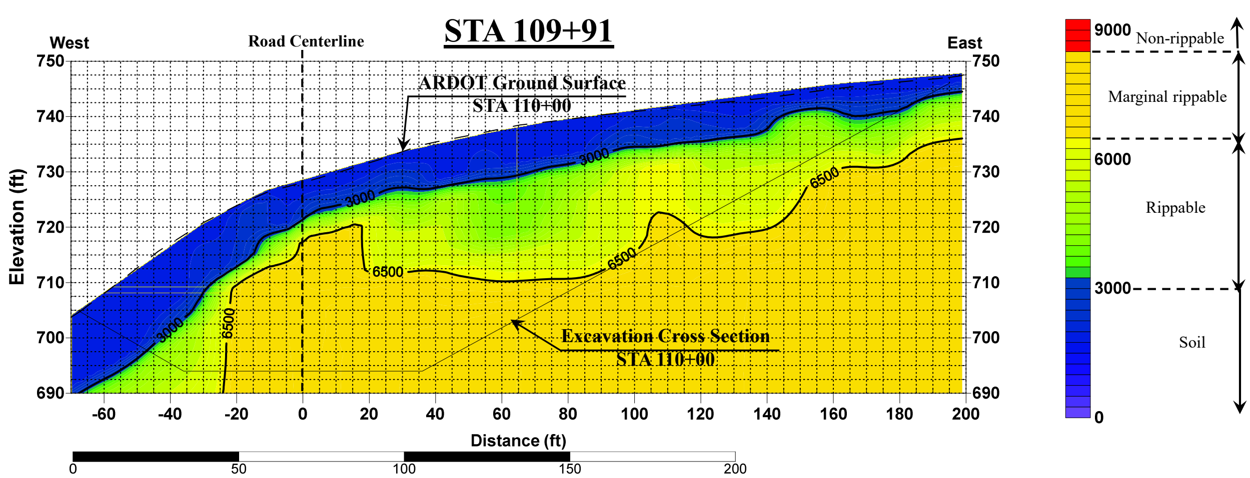


Figure 9 2D V_p cross section for STA 109+91.

5.4 Survey Line STA 110+79

Shown in Figure 10 is the 2D V_p cross section for STA 110+79 along with the approximate ground surface and excavation profile at STA 111+00 provided by ARDOT. For this cross section, the estimated ground surface elevation provided by ARDOT is approximately 2.5 ft lower than the surface elevation provided in the field. The contour lines associated with the rippable, and marginally rippable rock materials are shown as well. Three layers make up the subsurface layering of this survey line. It consists of a relatively thin soil layer compared to previous lines with thickness ranging from 2.5-7.5 ft. The top soil layer is followed by a rippable rock layer to a thickness ranging from 2.5-12.5 ft. This is followed by a marginally rippable rock layer down to the bottom of the section.

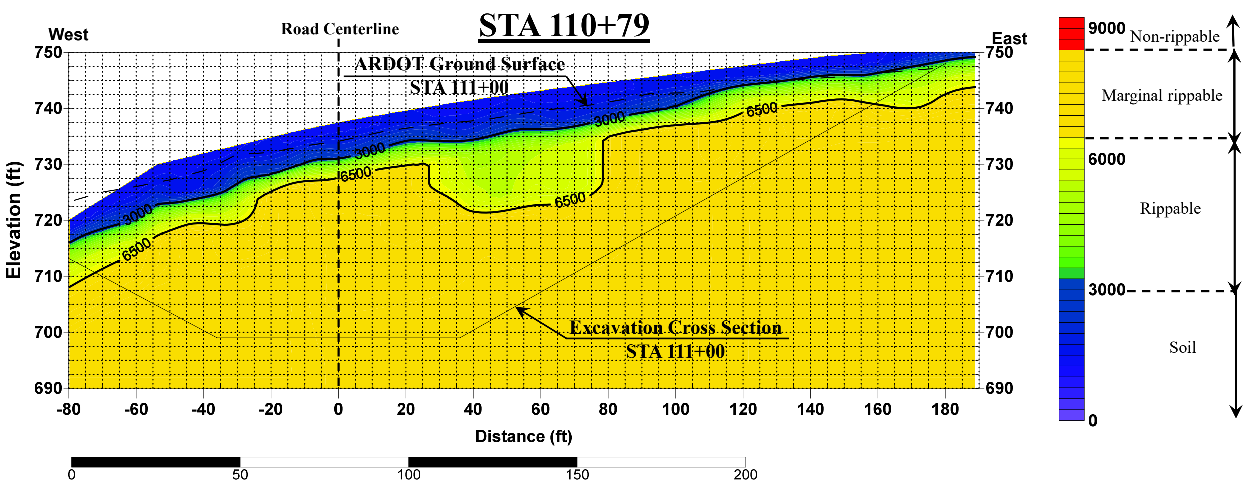


Figure 10 2D V_p cross section for STA 110+79.

5.5 Survey Line STA 112+06

The 2D V_p cross section for STA 112+06 is shown in Figure 11 along with the approximate ground surface and excavation profile at STA 112+00 provided by ARDOT. For this cross section, the estimated ground surface elevation provided by ARDOT is approximately 0-2.5 ft higher than the surface elevation provided in the field. The contour lines related to the rippable, and marginally rippable rock units are also shown. The subsurface layering of this line includes four layers with a soil layer at the ground surface thicker on the left side and getting shallower in the right side of section with thickness ranging from 0-10 ft. Underlying the soil layer is a rippable rock layer with a thickness ranging from 2.5-17.5 ft. Finally, there is a marginally rippable rock layer extending to the bottom of the section.

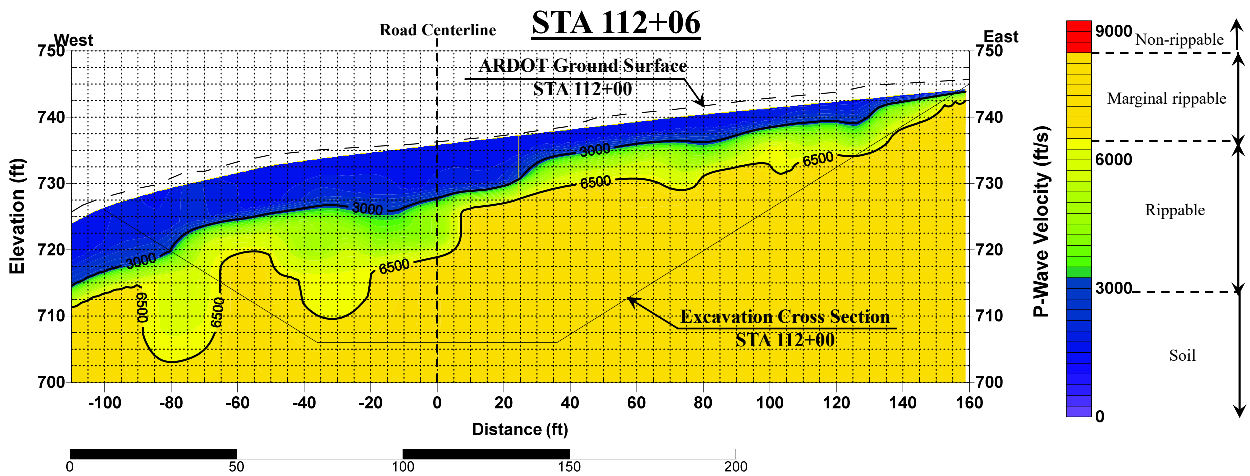


Figure 11 2D Vp cross section for STA 112+06.

5.6 Survey Line STA 112+98

Shown in Figure 12 is the 2D V_p cross section for STA 112+98 along with the approximate ground surface and excavation profile at STA 113+00 provided by ARDOT. For this cross section, the estimated ground surface elevation provided by ARDOT is very similar to surface elevation measured in the field. The contour lines that separate rocks with different rippability degrees are also shown. A soil layer exists at the ground surface with thickness varying from 2.5-7.5 ft. This layer is underlain by a thin rippable rock layer that has a thickness ranging from 2.5-5 ft. This is followed by a very thin marginally rippable rock layer up to a thickness varying from 2.5-7.5 ft. The rest of the section is composed of a non-rippable rock down to the bottom of the section.

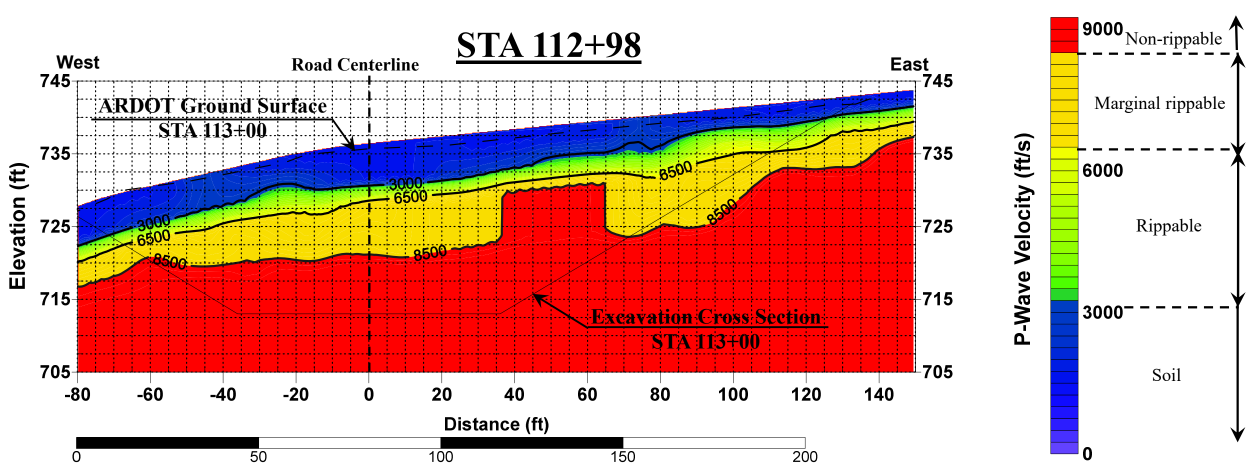


Figure 12 2D Vp cross section for STA 112+98.

5.7 Survey Line STA 114+04

Shown in Figure 12 is the 2D V_p cross section for STA 114+04 along with the approximate ground surface and excavation profile at STA 114+00 provided by ARDOT. For this cross section, the estimated ground surface elevation provided by ARDOT is very similar to surface elevation measured in the field. The contour lines that separate rocks with different rippability degree are also shown. A soil layer exists at the ground surface with thickness varying from 2.5-7.5 ft. Similar to STA 112+98, this layer is underlain by a thin rippable rock layer with a thickness ranging from 2.5-5 ft. This is followed by a thin marginally rippable rock layer up to a thickness varying from 5-7.5 ft. The rest of the section is composed of a non-rippable rock to the bottom of the section.

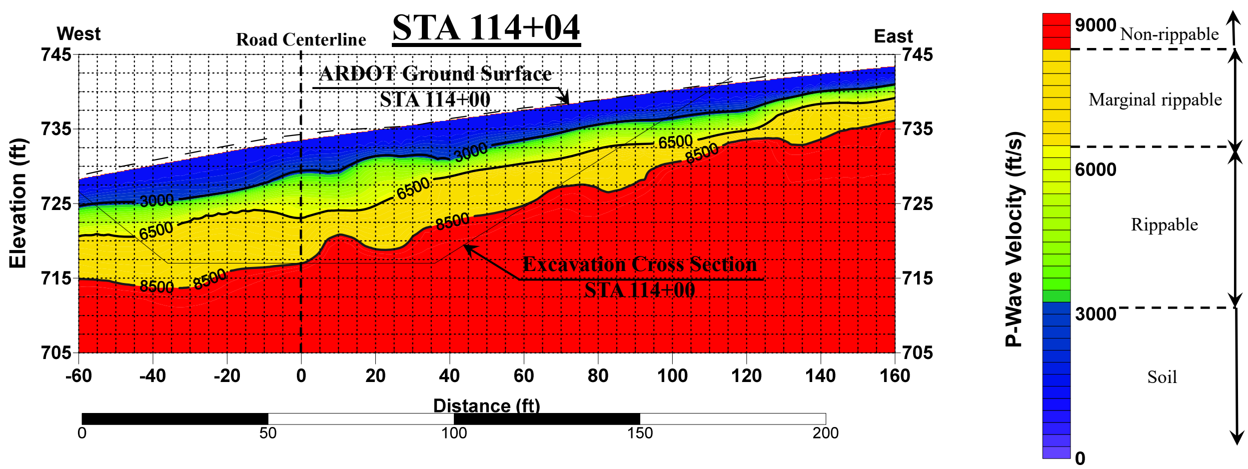


Figure 12 2D Vp cross section for STA 114+04.

6.0 Summary

Seismic refraction measurements were conducted along 7 different survey lines to identify the subsurface layering and bedrock rippability along the proposed realignment of Highway 59. According to the geophysical testing results, STA 108+04 and 108+86 have a thicker soil layer than other lines and generally a softer rock formation underlying the soil. For stations further up the hill (along the alignment), the thickness of the soil layer is expected to be shallower ranging from 2.5-10 ft along different survey lines. This layer is underlain by a rippable rock layer that extends to a depth varying from 5-20 ft. This layer is followed by a marginally rippable rock layer up to depth ranging from 8-35 ft. In general, the rock becomes stiffer near the top of the hill compared to the base of the hill.

7.0 References

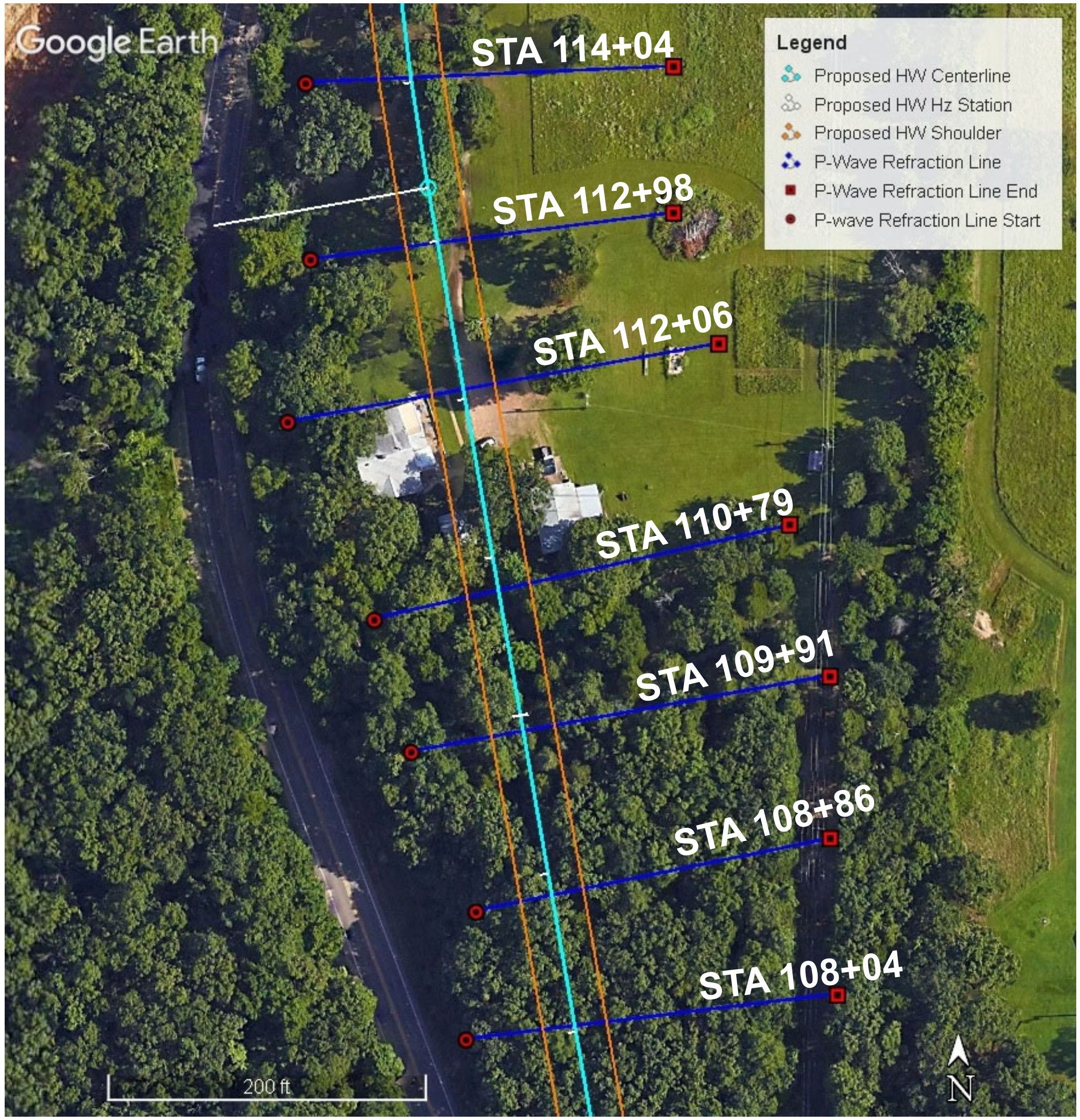
ASTM D5777. Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation. DOI: 10.1520/D5777-00R11e1.

Caterpillar Inc (2000). Handbook of Ripping 12th edition. http://www.dot.ca.gov/hq/esc/geotech/references/Rock_Cut_Slope_References/31_Handbook_of_Ripping_Caterpiller.pdf

Redpath, B. B., 1973, Seismic refraction exploration for engineering site investigations: U. S. Army Engineer Waterway Experiment Station Explosive Excavation Research Laboratory, Livermore, California, Technical Report E-73-4, 51 p.

Highway 59 Realignment
(ARDOT Job# 040885)
Van Buren, AR

Seismic Refraction Survey Results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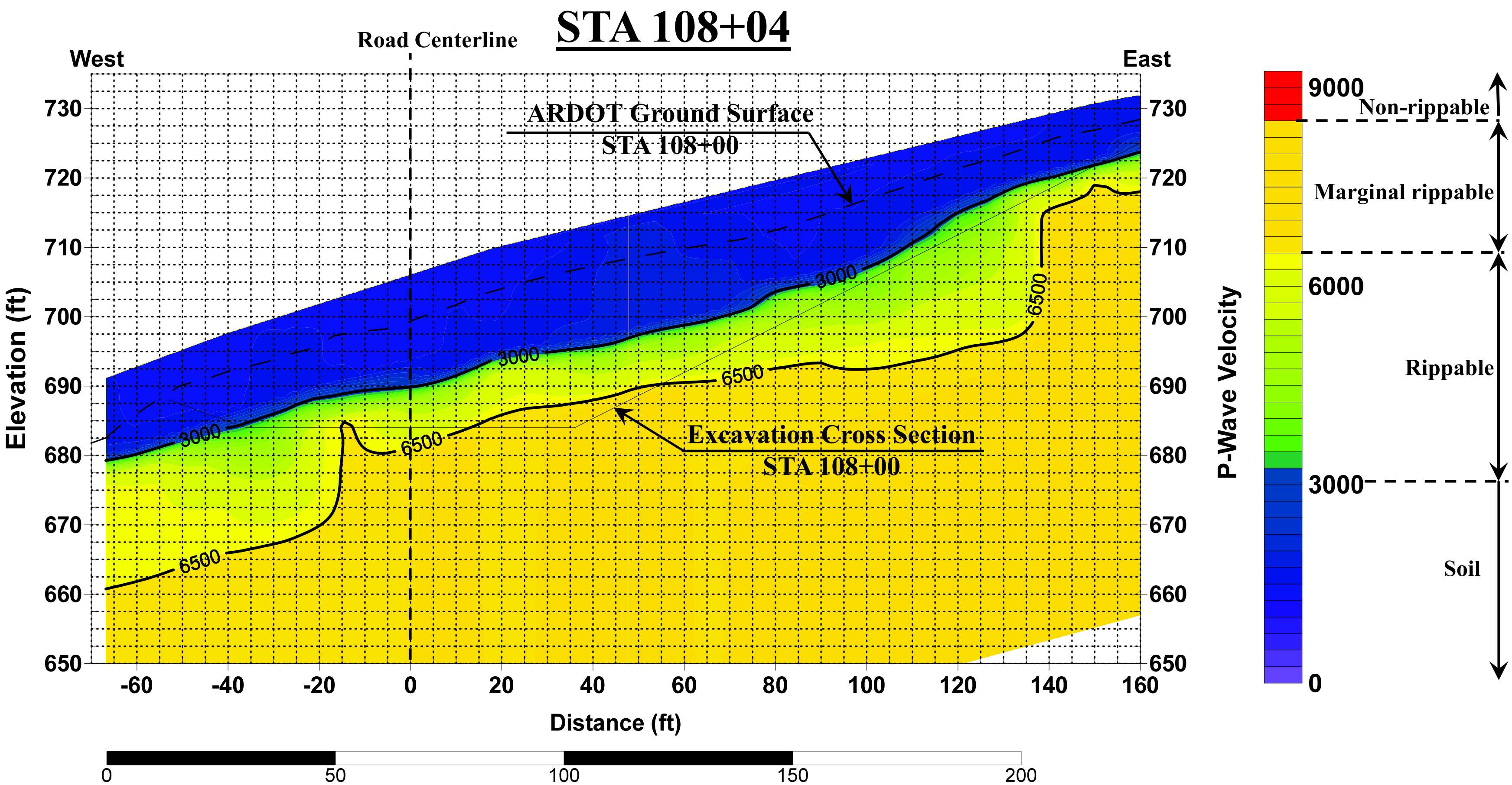
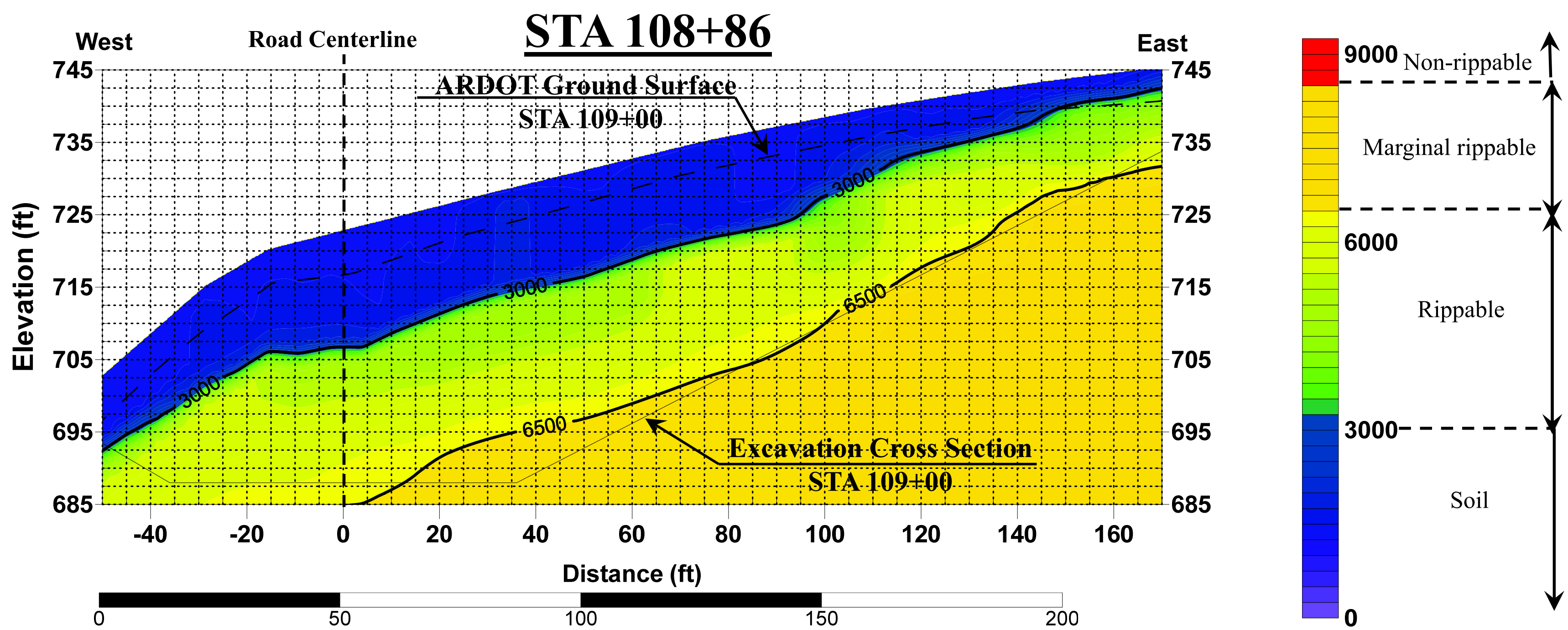
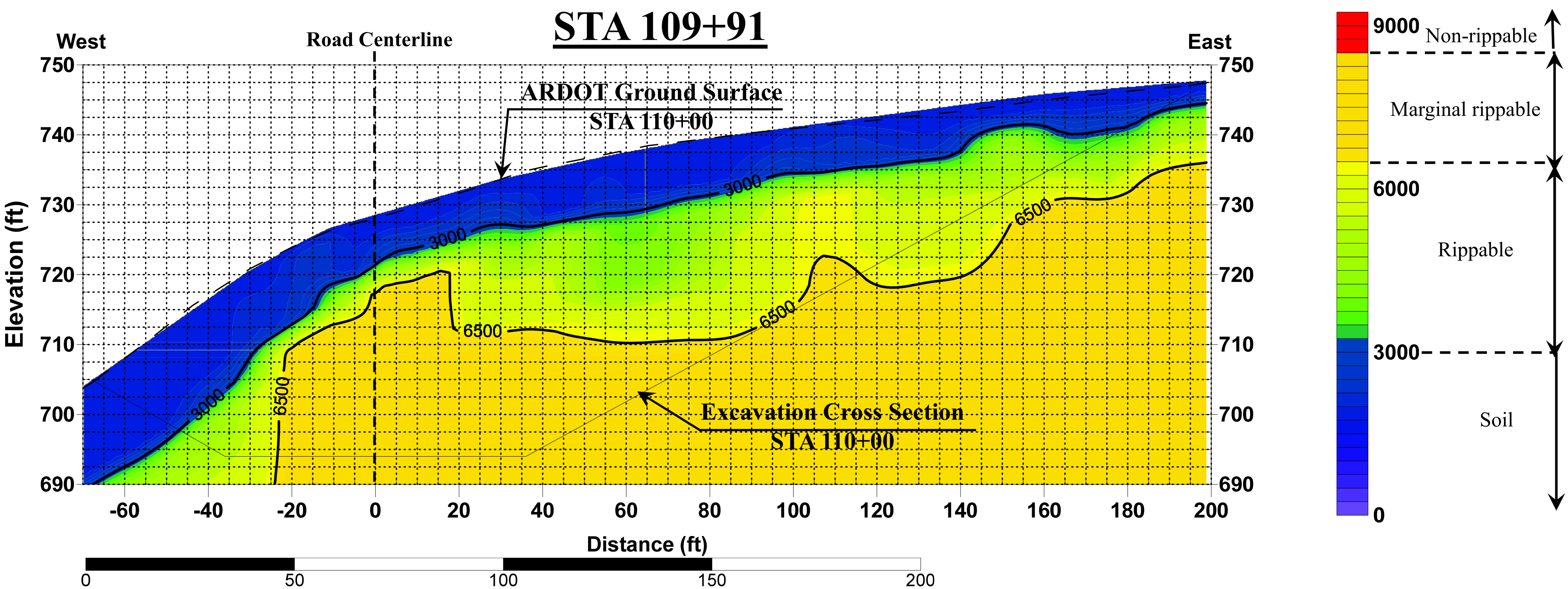
STA 114+04
STA 112+98
STA 112+06
STA 110+79
STA 109+91
STA 108+86
STA 108+04
Legend
Proposed HW Centerline
Proposed HW Hz Station
Proposed HW Shoulder
P-Wave Refraction Line
P-Wave Refraction Line End
P-wave Refraction Line Start
200 ft
N

St. 108

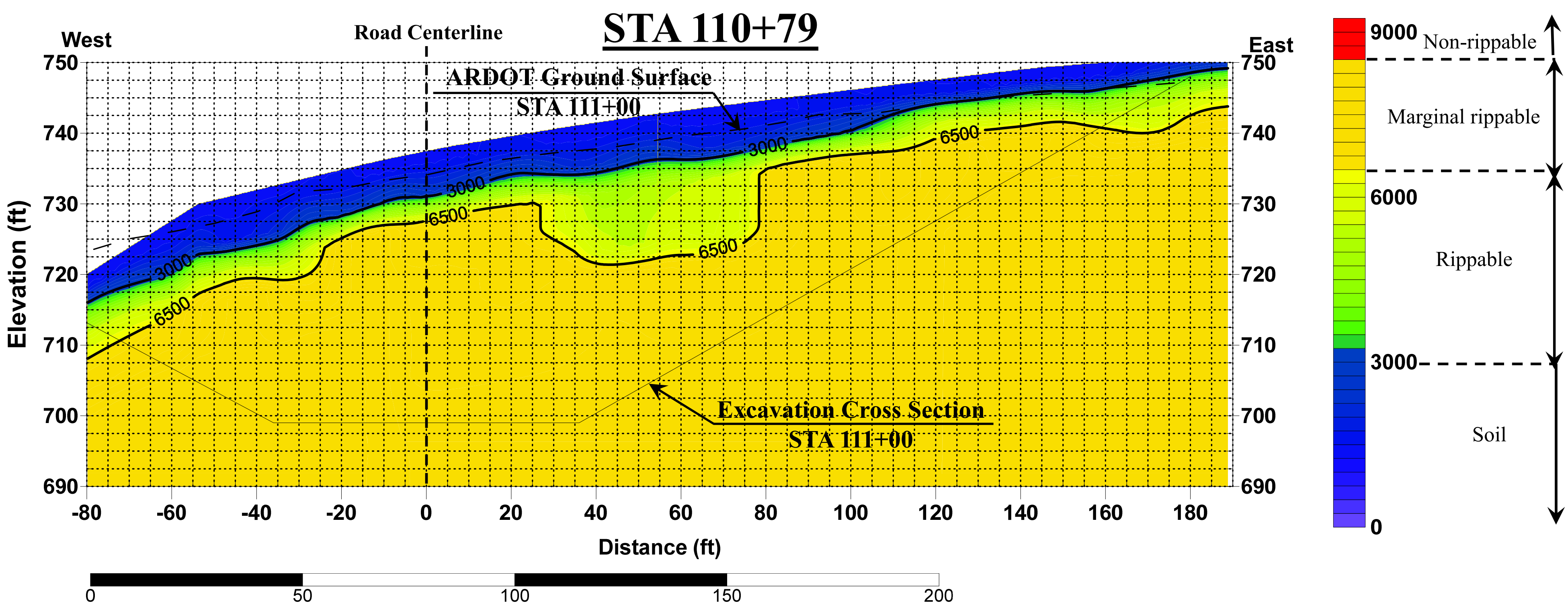


STA 108+04
Road Centerline
West
East
ARDOT Ground Surface
STA 108+00
Excavation Cross Section
STA 108+00
3000
6500
730
720
710
700
690
680
670
660
650
-60
-40
-20
0
20
40
60
80
100
120
140
160
Elevation (ft)
Distance (ft)
0
50
100
150
200
P-Wave Velocity
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil

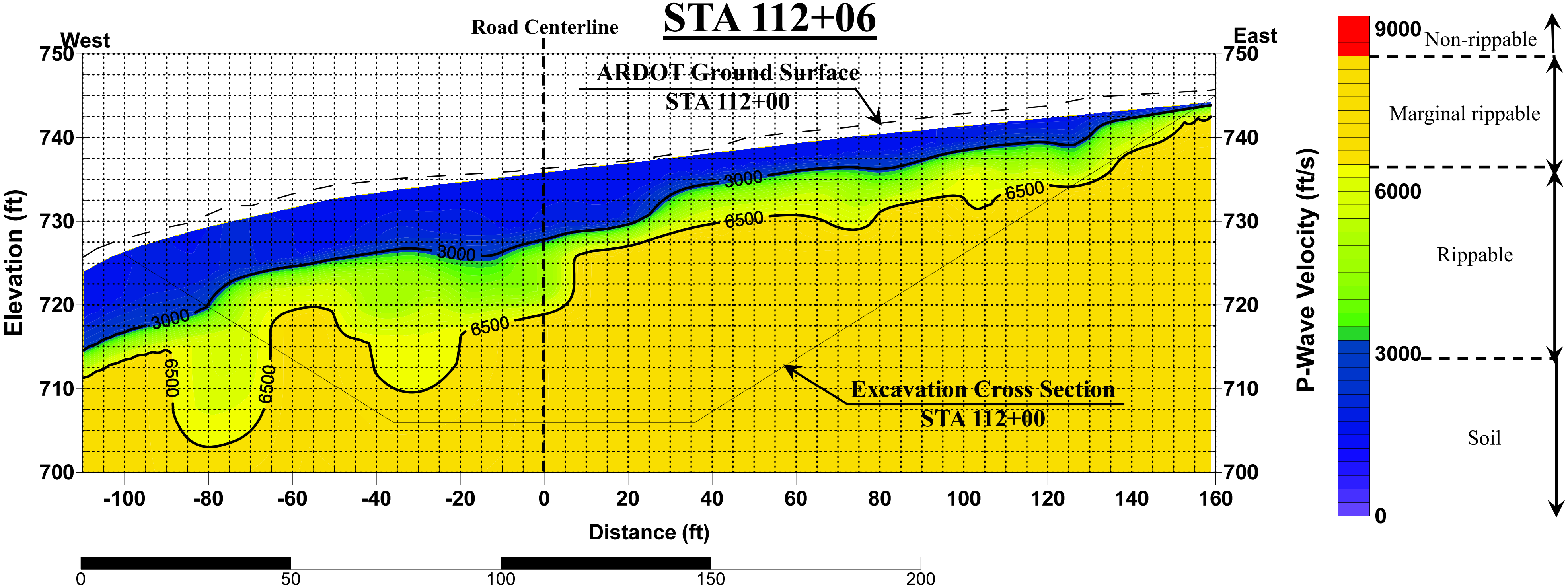

STA 108+86
West
Road Centerline
East
ARDOT Ground Surface
STA 109+00
Excavation Cross Section
STA 109+00
3000
6500
Elevation (ft)
745
735
725
715
705
695
685
-40
-20
0
20
40
60
80
100
120
140
160
Distance (ft)
0
50
100
150
200
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil

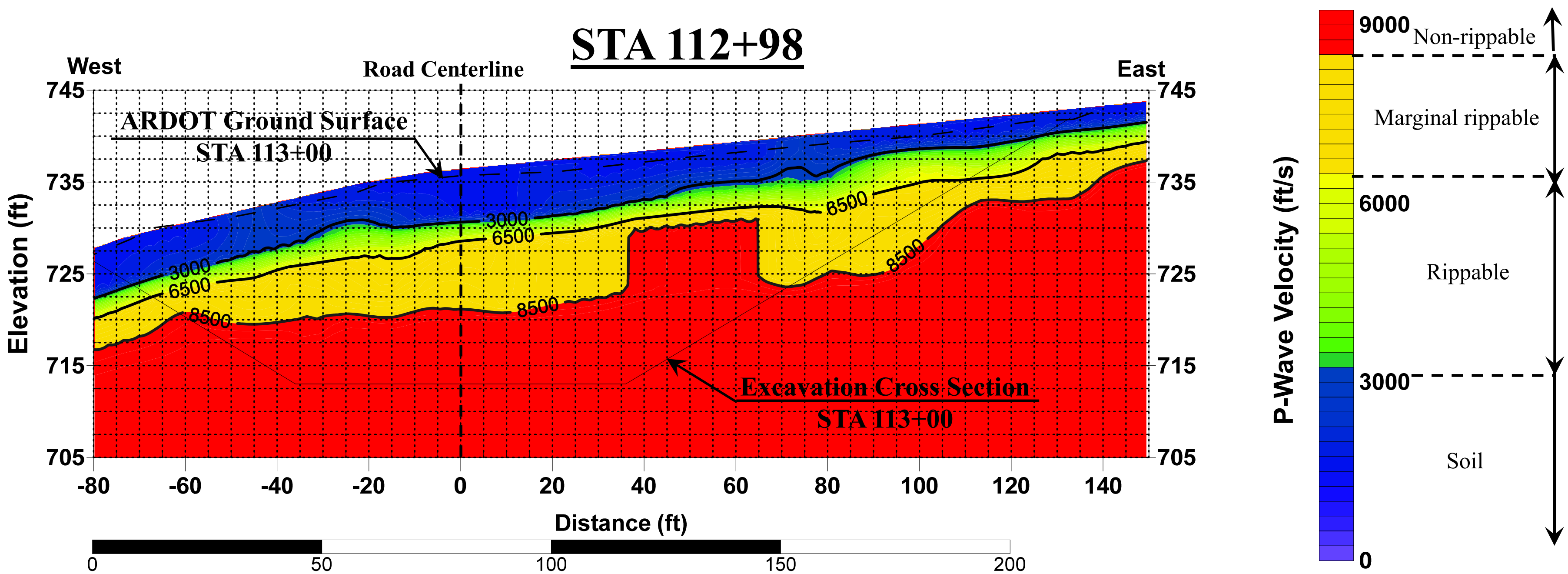


STA 109+91
West
Road Centerline
East
ARDOT Ground Surface
STA 110+00
Excavation Cross Section
STA 110+00
3000
6500
Elevation (ft)
Distance (ft)
750
740
730
720
710
700
690
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
200
0
50
100
150
200
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil

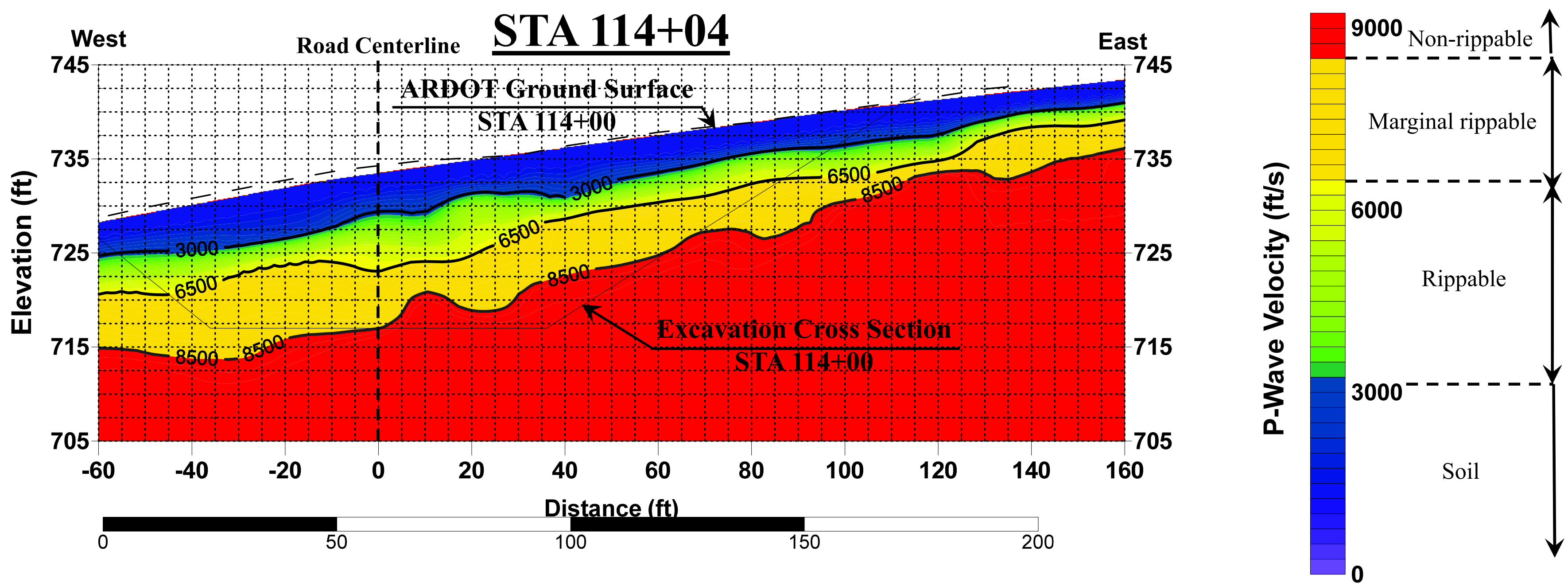

STA 110+79
West
East
Road Centerline
ARDOT Ground Surface
STA 111+00
Excavation Cross Section
STA 111+00
3000
6500
Elevation (ft)
Distance (ft)
750
740
730
720
710
700
690
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
0
50
100
150
200
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil

STA 112+06


Road Centerline
West
East
ARDOT Ground Surface
STA 112+00
Excavation Cross Section
STA 112+00
3000
6500
Elevation (ft)
Distance (ft)
750
740
730
720
710
700
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
0
50
100
150
200
P-Wave Velocity (ft/s)
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil



STA 112+98
West
Road Centerline
East
ARDOT Ground Surface
STA 113+00
Excavation Cross Section
STA 113+00
Elevation (ft)
745
735
725
715
705
3000
6500
8500
-80
-60
-40
-20
0
20
40
60
80
100
120
140
Distance (ft)
0
50
100
150
200
P-Wave Velocity (ft/s)
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil


STA 114+04
West
Road Centerline
East
ARDOT Ground Surface
STA 114+00
Excavation Cross Section
STA 114+00
Elevation (ft)
745
735
725
715
705
3000
6500
8500
-60
-40
-20
0
20
40
60
80
100
120
140
160
Distance (ft)
0
50
100
150
200
P-Wave Velocity (ft/s)
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil

Attachment C

DATE REVISED	DATE REVISED	FED.RD. DIST.NO.	STATE	JOB NO.	SHEET NO.	TOTAL SHEETS
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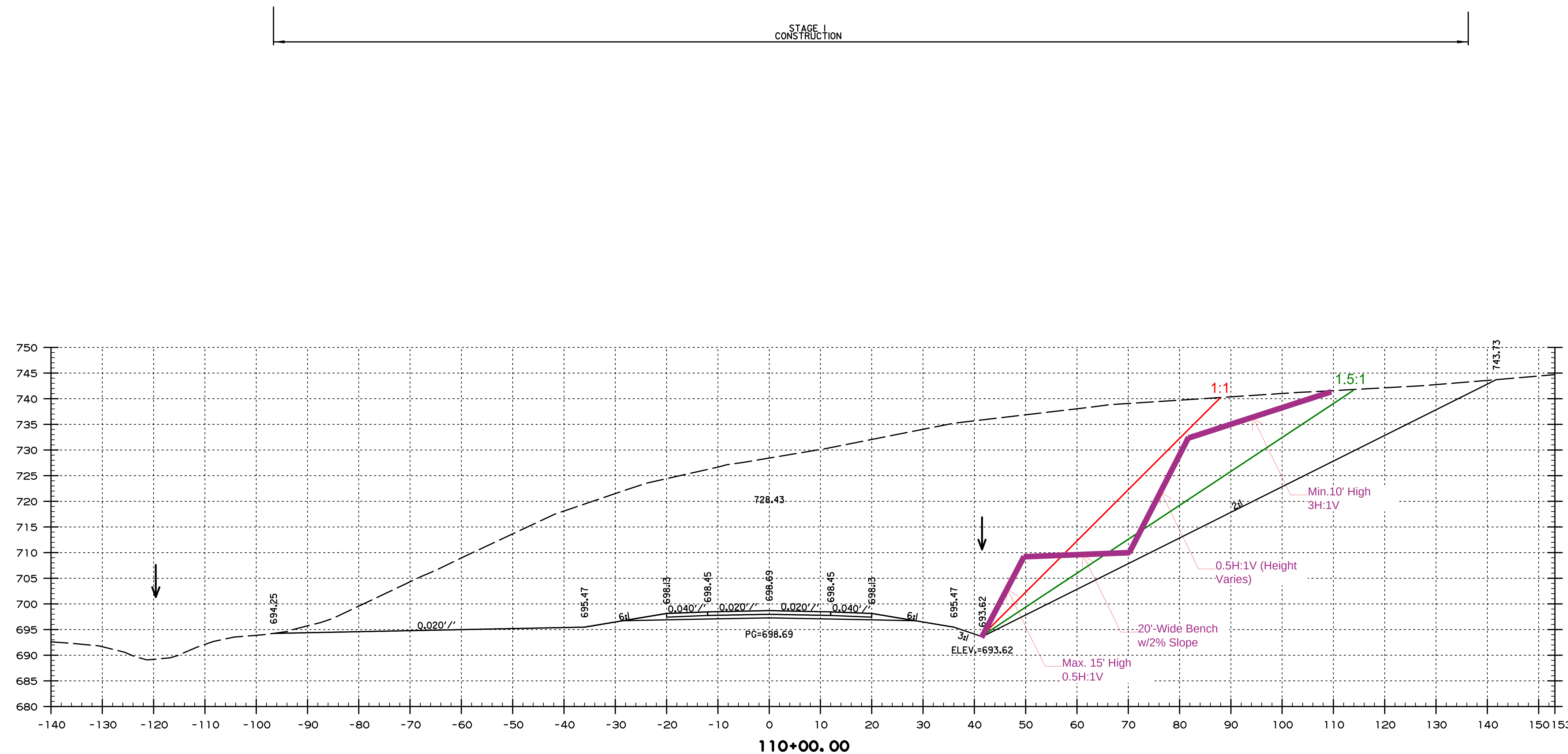
		CROSS SECTIONS				



STA. 110+00 TO STA. 110+00

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SCALE: 1:20

September 18, 2023
Project No. 23-043

Arkansas Department of Transportation
Materials Division
11301 West Baseline Road
P.O. Box 2261
Little Rock, Arkansas 72203-2261

Attn: Mr. Paul Tinsley, P.E.

RE: RESULTS of SEISMIC REFRACTION SURVEY
JOB No. 040885, TASK ORDER G007
HWY. 59 REALIGNMENT (CRAWFORD CO.)(S) ROUTE 59, SECTION 5
CRAWFORD COUNTY, ARKANSAS

Mr. Tinsley,

Submitted herewith is the final report of the Seismic Refraction Survey performed for the selected alignment of Job 040885 between Sta 108+00 and 114+00. The survey was performed by The University of Arkansas Department of Civil Engineering in general accordance with the scope outlined in the memorandum to the ARDOT Consultant Coordinator of April 17, 2023 and subsequently discussed with the Department. A draft report was previously submitted on June 8, 2023.

Please let us know any questions or comments on this draft report. We appreciate the opportunity to be of continued service to ARDOT.

Sincerely,

GRUBBS, HOSKYN,
BARTON & WYATT, LLC

Mark E. Wyatt, P.E.
President

MEW:jw

Attachment: Draft Results of Seismic Refraction Survey

Copies Submitted: ARDOT Materials
Attn: Mr. Paul Tinsley, P.E. (1-email)

ARDOT Consultant Coordinator
Attn: Ms. Jessica Jackson, P.E. (1-email)

Seismic Refraction Survey for ARDOT Job# 040885 Highway 59 Van Buren, Arkansas

for:

Grubbs, Hoskyn, Barton, & Wyatt, INC
C/O: Mark Wyatt, PE
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Little Rock, Arkansas 72209, US
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and

Graduate Research Assistants Mohammadyar Rahimi

July 2023

Table of Contents

1.0 Introduction

Seismic refraction was conducted to map subsurface conditions and bedrock depth for the Highway 59 realignment (ARDOT Job# 040885) in Van Buren, AR. Testing was conducted on May 22 and 23, 2023. The goal of the testing was to estimate the depth to bedrock, bedrock rippability, and other subsurface conditions along the proposed highway realignment. Background on the proposed testing methods is provided in Section 2. Section 3 discusses testing techniques and locations, Section 4 includes data processing, Section 5 includes interpretation and results, Section 6 is the summary, and Section 7 includes references.

2.0 Background on Testing Techniques

This section provides a brief background on geophysical method used on the project.

Seismic Refraction: The seismic refraction method (Redpath 1973, ASTM D5777) is a body wave method which consists of measuring (at known points along the surface) the travel times of compression (P-waves) or shear (S-waves) waves generated by an impulsive energy source at the surface. See Figure 1 for a diagram of the seismic refraction method. The body wave energy source is typically a sledgehammer for P-wave seismic refraction where vertical blows are used. P-waves are detected by a linear array of receivers (geophones) placed along the ground surface and recorded via a seismograph. The velocity of the P-waves is dependent upon the elastic properties of the material in which they travel from source to receiver. When P-waves are generated at the surface the P-waves travel along the surface (direct arrival), but also travel into the earth. When the P-wave hits an interface where the velocity changes significantly, a portion of the wave energy is reflected, and a portion is transmitted into the layer. When the velocity of the deeper layer is greater than the shallower layer, a portion of the wave energy is critically refracted along the layer interface. This critically refracted wave travels along the interface at the velocity of the deeper layer and continually produces head waves that travel back to the surface. For testing, the instant of the source pulse (e.g., the sledgehammer hitting the ground), "zero time" is recorded by the seismograph and the time to first wave arrival at each geophone is identified. The raw data is then displayed in a plot as the first arrival time at each receiver (first wave arrival) versus receiver distance from the source. For receivers near the source, the direct wave is the first arrival, but at larger source distances, the critically refracted wave arrives first due to traveling faster along the deeper layer boundary. The slopes of the arrival times at each geophone are used to determine the velocity of subsurface layers (the inverse of the slope of the arrival times in Figure 1), while an application of Snell's law of refraction of waves is used to determine the depth-to-layer interfaces.

The analysis of the seismic refraction data to determined depth to various layers can be undertaken using several techniques depending on the complexity of the subsurface. The simplest method is the time intercept method (Redpath 1973) and is applicable for sites with generally planar layer interfaces. This method requires at a minimum shots off each end of the array and can be used to resolve multiple layer boundaries and sloping layers. For more complex subsurface conditions (i.e., rapidly changing bedrock elevations or undulating layers), a more complex analysis such as the generalized reciprocal method (Redpath 1973) may be used. For the most complex sites, tomographic inversions can be performed which model the subsurface as velocity cells and account for rapid changes in velocity and layer thickness. This method requires more shot points within the array to be effective.

In general, seismic refraction is often used for mapping strong velocity contrasts such as soil over bedrock. Although the method is effective at mapping large velocity contrasts below the surface, it suffers from potential errors at some sites. The most serious drawback is the method requires that all layers below the ground surface must increase in velocity with increasing depth. Although this is typically a valid assumption, this is not always true and significant errors can result if velocity reversals exist in the subsurface. Moreover, thin layers with minimum velocity contrast with the above layers maybe hidden in the analysis which may lead to some errors in the depths to layer interfaces.

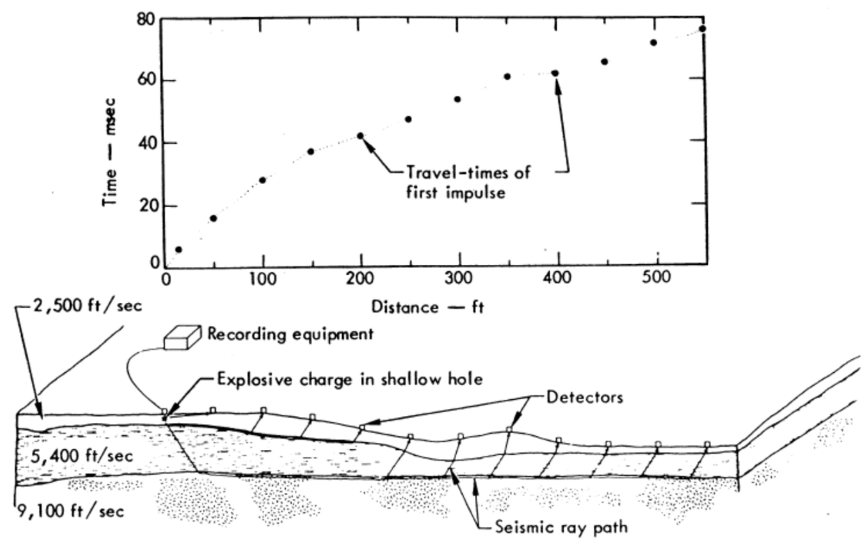


Figure 1 Refraction example field setup and travel time vs distance graph (Redpath 1973).

3.0 Testing Method and Locations

The geophysical testing for the proposed highway realignment was conducted using the seismic refraction method utilizing P-waves. A total of seven lines were surveyed for the study. These lines (from STA 108+04 to STA 114+04) are shown in Figure 2 and aligned perpendicular to the proposed highway centerline. Each survey line was placed near an even station for the proposed highway realignment. However, in some cases due to natural obstacles, such as trees or buildings, the survey line orientation and position was adjusted in order to perform the work. While the position of the array may vary from an even station, for comparison purposes, we compare the results of the survey to the nearest even station.

P-wave seismic refraction was conducted for each line using a linear array of 36-42 (depending on the length of array), 4.5 Hz vertical geophones with a uniform spacing between geophones of 6.5 ft. P-waves were generated using a 12 lb sledgehammer at multiple source locations along the array generally off each end and 5 shots within each array. The waveforms were recorded using two 24 channel Geometrics Geode seismographs. A picture of the seismic refraction equipment is shown in Figure 3. Survey lines for the project consisted of 36 geophones (230 ft array length) or 42 geophones (270 ft array length). For the 36 geophone arrays (STA 108+04, STA 108+86, STA 112+98, and STA 114+04), shots were made at the -3.28 ft, 36 ft, 75 ft, 115 ft, 154 ft, 194 ft, and 233 ft locations along the line. For the 42 geophone arrays (STA 109+91, STA 110+79 and STA 112+06), shots were made at the -3.28 ft, 36 ft, 75 ft, 115 ft, 154 ft, 194 ft, 233 ft and 272 ft locations along the line. At each shot location, 5 hits were stacked in order to increase the signal-to-noise ratio. The location of each shot point and array were established using a Trimble Geo 7x centimeter accuracy GPS. The relative location of each geophone was surveyed with Moasure inertial measurement unit. For the refraction analysis, the elevation of each geophone was estimated based on the relative elevation recorded by Moasure adjusted with GPS elevation for each shot point in the array.

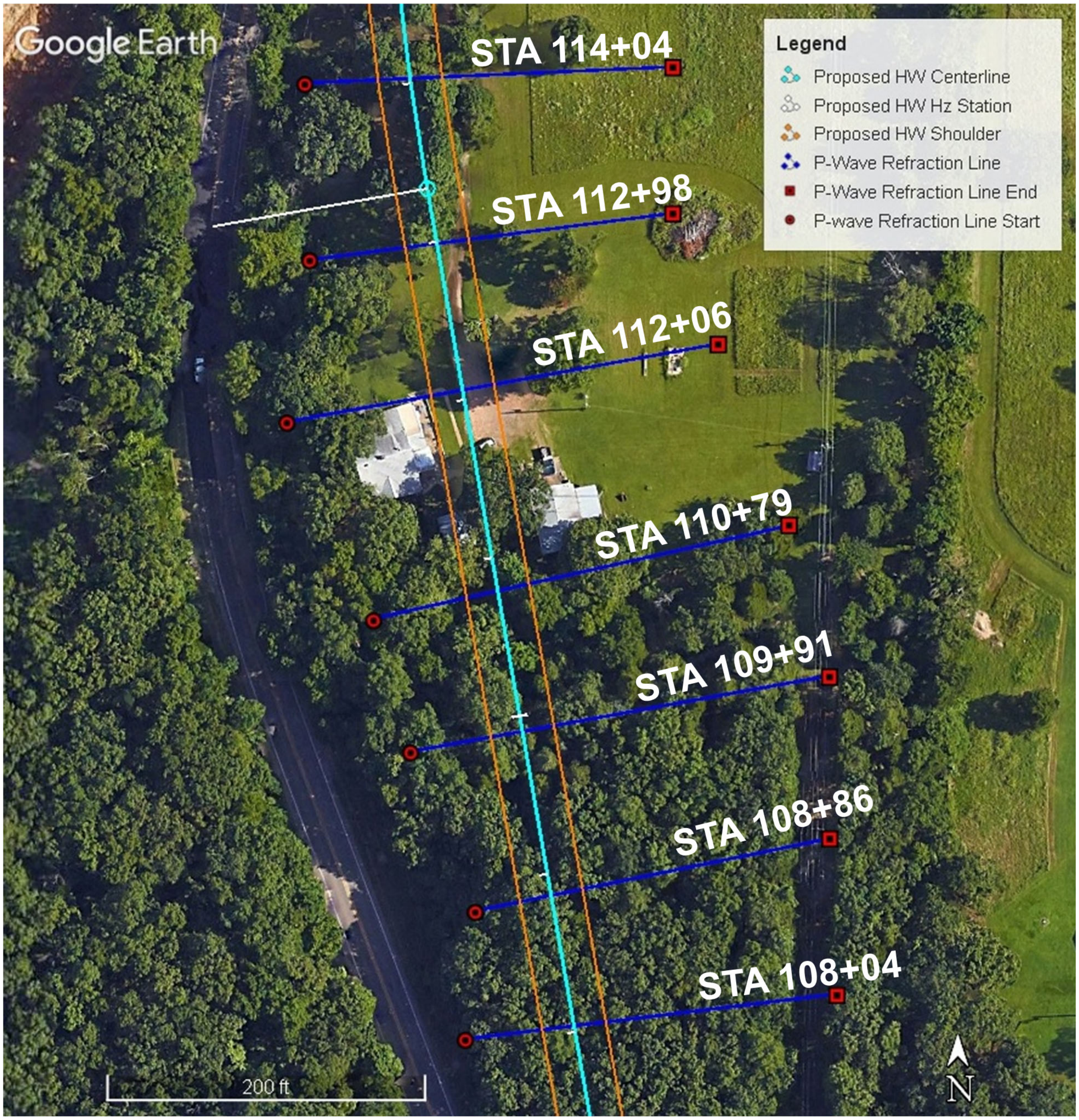


Figure 2 Site map of the seismic refraction survey conducted for the Highway 59 Realignment.

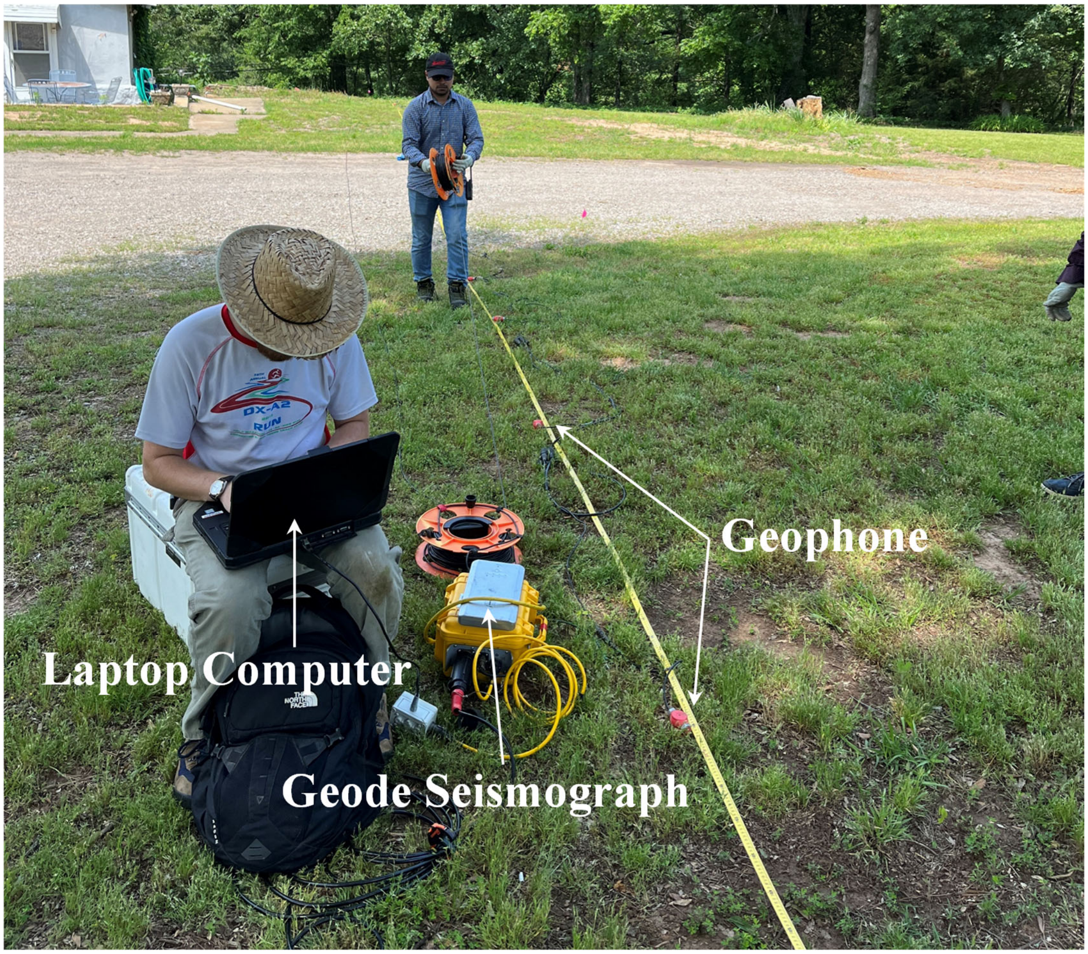


Figure 3 Picture of seismic refraction equipment used at STA 112+06.

4.0 Data Processing

The P-wave seismic refraction data was processed using the Geometrics software package SeisImager in general accordance with ASTM D5777. The P-wave arrivals were picked using the SeisImager Pickwin module, which allowed the P-wave first arrival to be picked manually for each geophone and shot (the picks for STA 108+91 is shown Figure 4). The number of layers is determined based on the variations in the slope of the lines fit through the P-wave arrival times, as shown in Figure 4. The first arrivals for each line were saved in Pickwin and exported to Plotrefraction for further processing. It is expected that the arrival times at each geophone were generally picked within 0.5 ms accuracy with some picks being as high a 1.0 ms. In general, the recorded waveforms were of high quality and allowed clear identification of the first P-wave arrival.

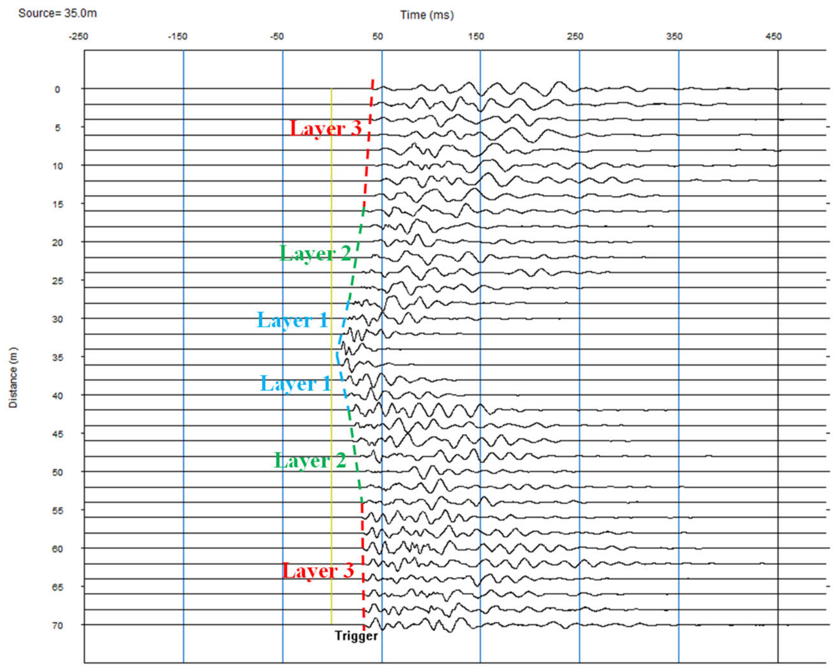


Figure 4 An example plot of P-wave arrival picking using Pickwin along with the estimated subsurface layers.

After picking the P-wave first arrival times, the picks were imported into the SeisImager software. Each arrival time included shot location, geophone location along the line, first arrival time, and geophone elevation. First analyses were conducted using the time interval method (TIM) and generalized reciprocal method (GRM). Each pick was assigned an appropriate layer from which they refracted based on the slope of the P-wave arrival times. Typically, 3-5 layers could be identified from the arrivals. Following the TIM and GRM modeling, the data was modeled using the tomographic analysis method in SeisImager. A minimum of 50 iterations of the non-linear raypath inversion were implemented to improve the fit to the arrival times. The goodness of the fit between the experimental (observed) and the inverted model (calculated) was judged based on visual inspection and the magnitude of the root-mean-square (rms) error (see Figure 5). The final inversions were exported to Surfer for presentation.

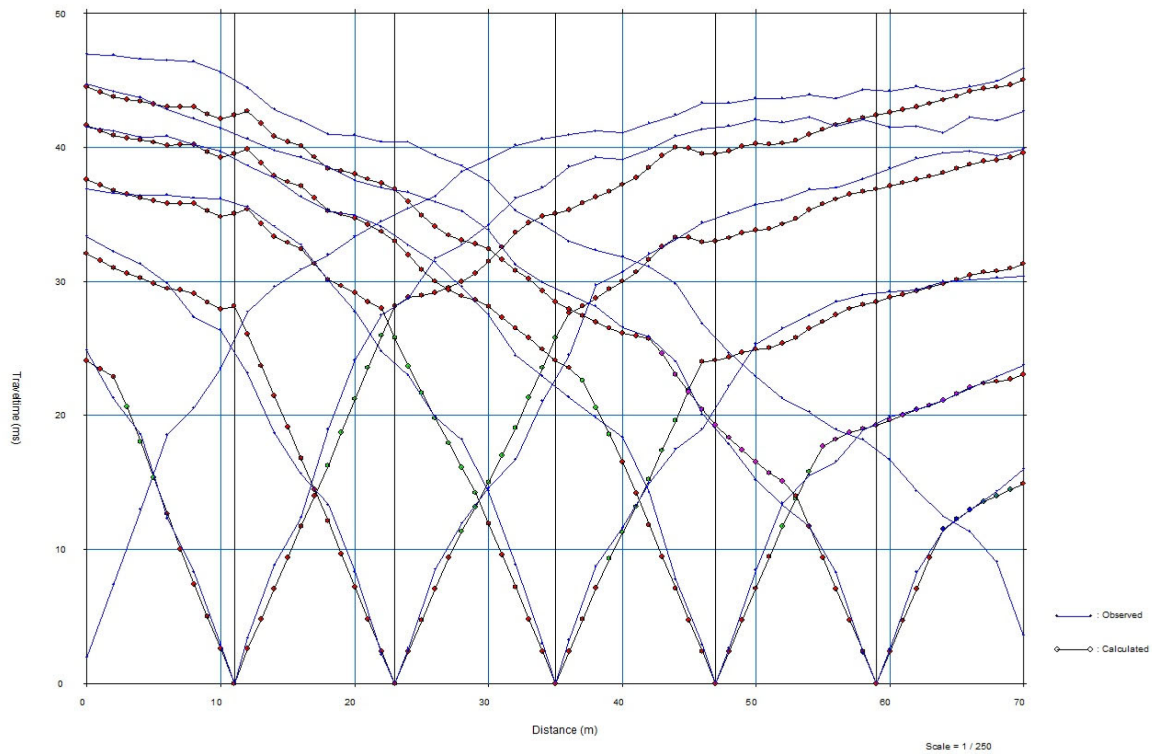


Figure 5 Observed (experimental) versus calculated (inverted) travel time arrivals.

In order to determine the rippability of rock units using the Vp results from seismic refraction, the Caterpillar Handbook on Ripping (2000) was used. This handbook provides the industry standard for rock rippability for different types of dozer/ripper combinations (D8, D9, D10, and D11 with multi or single shanks) based on the P-wave velocity of the rock materials. In the handbook, geologic rock type is divided into three groups (rippable, marginal rippable, and non-rippable rock units) based on their P-wave velocities. The chart provided for a D8R Caterpillar Dozer (see Figure 6) was used as a guide to determine the ranges of P-wave velocity (Vp) associated with the soil (V_p<3000 ft/s), rippable (3000 ft/s <V_p< 6500 ft/s), marginal rippable (6500 ft/s <V_p< 8500 ft/s), and non-rippable (V_p> 8500 ft/s) rock materials. In general, the values listed for sedimentary sandstone rock in Figure 6 was used to determine the appropriate ranges. While P-wave velocity gives a guide to rippability of rock, the fracture orientation, number of refractions, and other parameters should be considered when determining rippability.

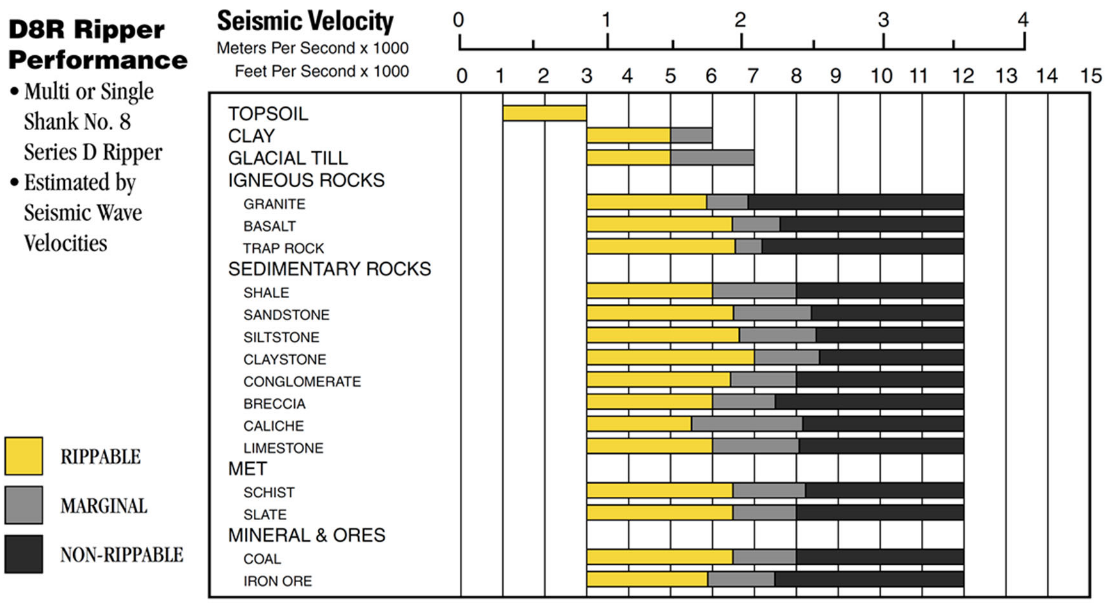


Figure 6 Rippability of rock materials based on the P-wave velocity for D8R ripper (Caterpillar Handbook on Ripping 2000).

5.0 Interpretation and Results

The results of the seismic refraction measurements that included 7 different 2D Vp cross sections are presented in this section. Please refer to Figure 2 for the location and orientation of each cross section.

5.1 Survey Line STA 108+04

Shown in Figure 7 is the 2D Vp cross section generated using the seismic refraction measurements for STA 108+04 along with the approximate ground surface and excavation profile at STA 108+00 provided by ARDOT. It should be noted that the estimated ground surface elevation provided by ARDOT is approximately 5 ft lower in elevation than elevations measured in the field for the survey line. This difference could be caused by differences in line location/orientation and errors in both elevation measurements and should be considered when interpretating the results. The estimated depths to rippable, marginal rippable, and non-rippable rock materials are separated using solid black contour lines. Based on the rippability chart provided in the Caterpillar Handbook on Ripping (2000), V_p values less than 3000 ft/s are considered as soil materials, V_p values ranging from 3000-6500 ft/s are considered as rippable rock materials, V_p values ranging from 6500-8500 ft/s are considered as marginal rippable rock materials, and V_p values approximately greater than 8500 ft/s are considered as non-rippable rock materials.

From Figure 7, the subsurface layering of this survey line can be divided into three layers. This includes a relatively thick soil layer at the ground surface with thickness ranging from 7.5-17.5 ft (shown with blue), underlain by a rippable rock layer with a thickness ranging from 2.5-20 ft (shown with green and yellow). The rest of the section is composed of a marginally rippable rock down to the bottom of the section (shown with orange). It should be noted that the resolution and accuracy of the seismic refraction results decrease as depth increases.

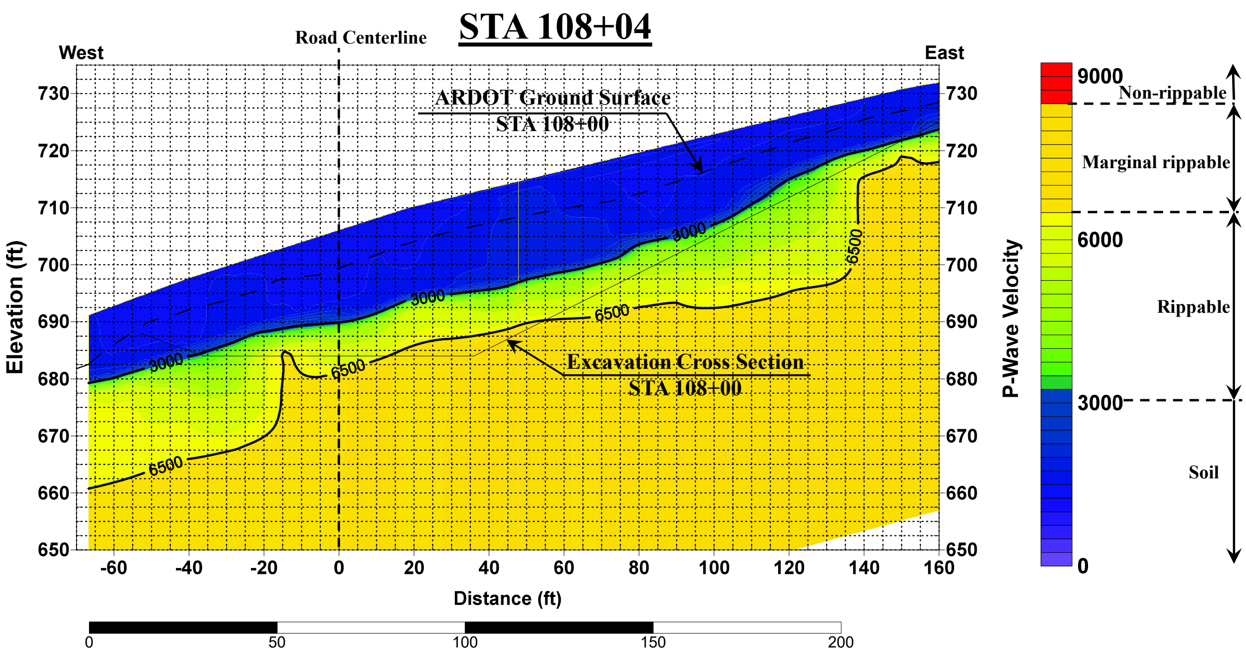


Figure 7 2D V_P cross section for STA 108+04.

5.2 Survey Line STA 108+86

Presented in Figure 8 is the 2D V_P cross section generated using the seismic refraction measurements for STA 108+86 along with the approximate ground surface and excavation profile at STA 109+00 provided by ARDOT. Similar to the previous line, the estimated ground surface elevation provided by ARDOT is approximately 2.5-5 ft lower in elevation than elevations measured in the field for the survey line. This difference could be caused by differences in line location/orientation and errors in both elevation measurements and should be considered when interpretating the results. The estimated depths to rippable, and marginal rippable rock materials are also shown in this figure. Similar to the STA 108+04 cross section, a relatively thick soil layer is observed at the ground surface with thickness varying from 2.5-17.5 ft. This layer is followed by a rippable rock layer with a thickness ranging from 10-20 ft. The rest of the section consisted of a marginally rippable rock.

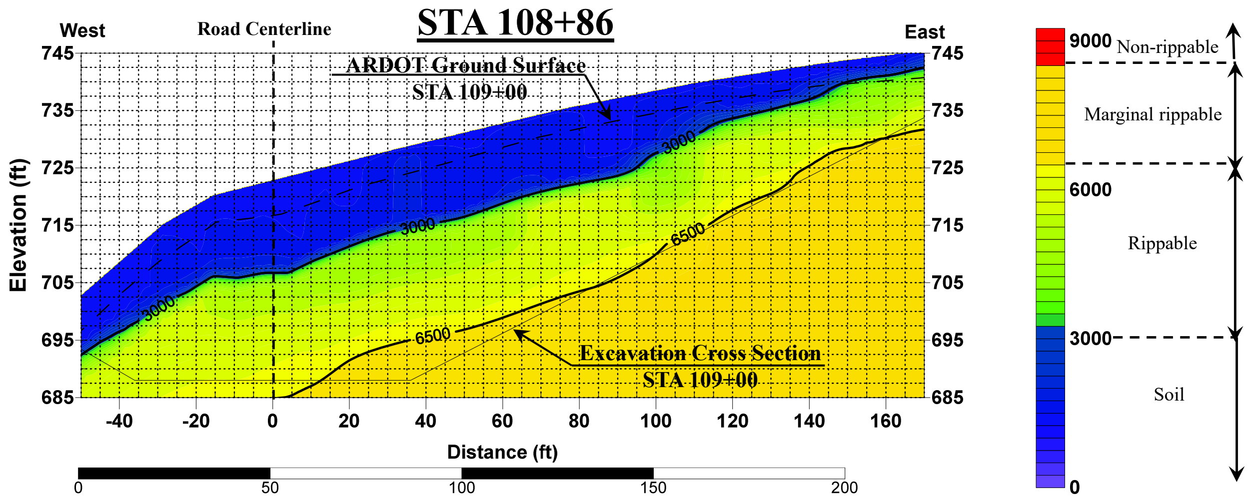


Figure 8 2D V_p cross section for STA 108+86.

5.3 Survey Line STA 109+91

The result of the seismic refraction measurements for STA 109+91 is shown in Figure 9 along with the approximate ground surface and excavation profile at STA 110+00 provided by ARDOT. For this cross section, the estimated ground surface elevation provided by ARDOT is very similar to the surface elevation measured in the field. The contour lines associated with rippable, and marginally rippable rock materials are shown as well. From Figure 9, the subsurface layers from this survey line include three layers. Similar to previous lines there is a soil layer at the ground surface with thickness varying from 2.5-15 ft, a rippable rock layer from the bottom of the soil layer with a thickness varying from 2.5-17.5 ft, followed by a marginally rippable rock layer up to depth ranging down to the bottom of the section.

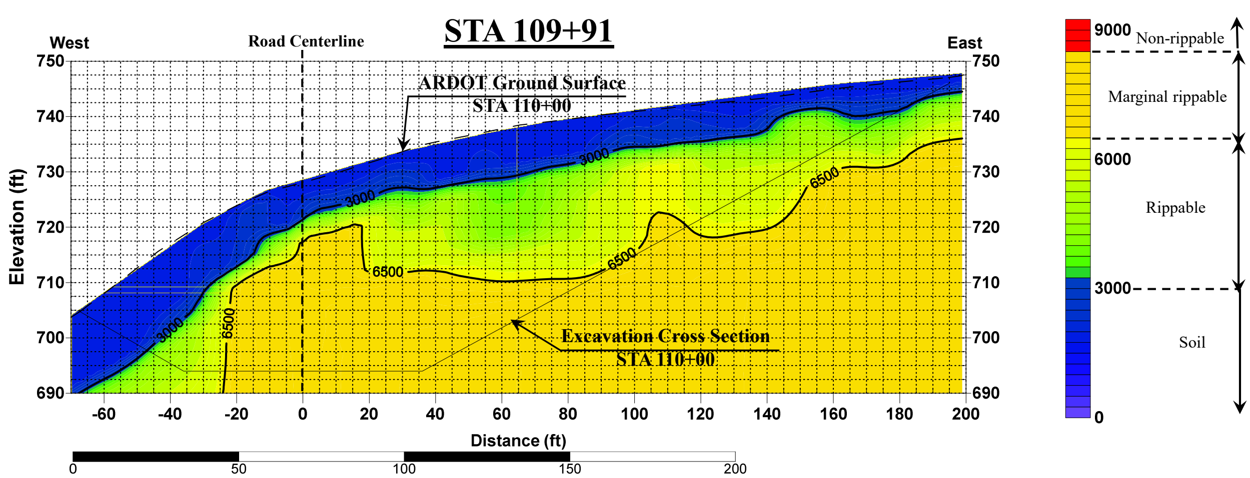


Figure 9 2D V_p cross section for STA 109+91.

5.4 Survey Line STA 110+79

Shown in Figure 10 is the 2D V_p cross section for STA 110+79 along with the approximate ground surface and excavation profile at STA 111+00 provided by ARDOT. For this cross section, the estimated ground surface elevation provided by ARDOT is approximately 2.5 ft lower than the surface elevation provided in the field. The contour lines associated with the rippable, and marginally rippable rock materials are shown as well. Three layers make up the subsurface layering of this survey line. It consists of a relatively thin soil layer compared to previous lines with thickness ranging from 2.5-7.5 ft. The top soil layer is followed by a rippable rock layer to a thickness ranging from 2.5-12.5 ft. This is followed by a marginally rippable rock layer down to the bottom of the section.

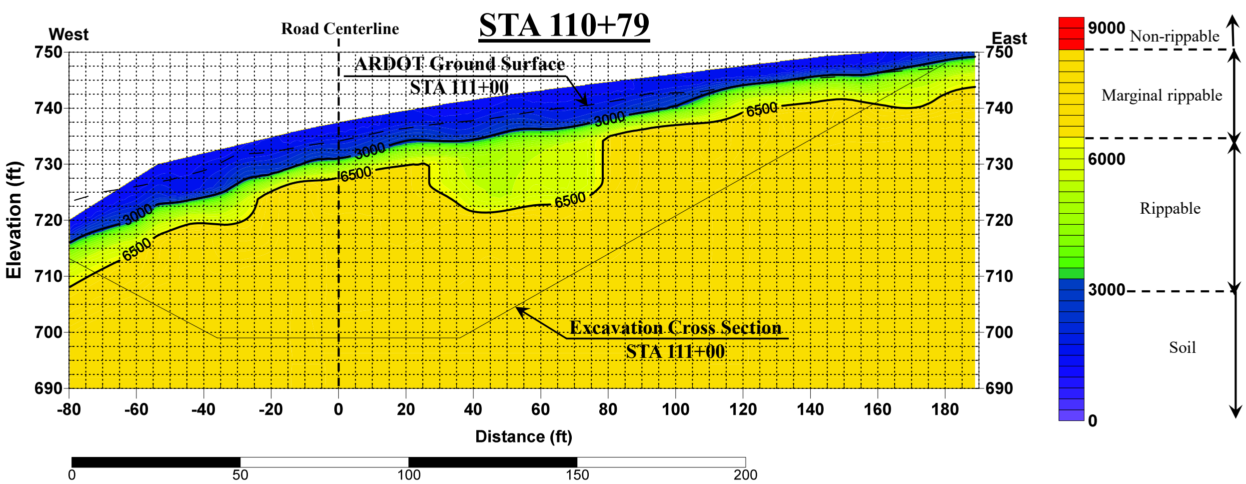


Figure 10 2D V_p cross section for STA 110+79.

5.5 Survey Line STA 112+06

The 2D V_p cross section for STA 112+06 is shown in Figure 11 along with the approximate ground surface and excavation profile at STA 112+00 provided by ARDOT. For this cross section, the estimated ground surface elevation provided by ARDOT is approximately 0-2.5 ft higher than the surface elevation provided in the field. The contour lines related to the rippable, and marginally rippable rock units are also shown. The subsurface layering of this line includes four layers with a soil layer at the ground surface thicker on the left side and getting shallower in the right side of section with thickness ranging from 0-10 ft. Underlying the soil layer is a rippable rock layer with a thickness ranging from 2.5-17.5 ft. Finally, there is a marginally rippable rock layer extending to the bottom of the section.

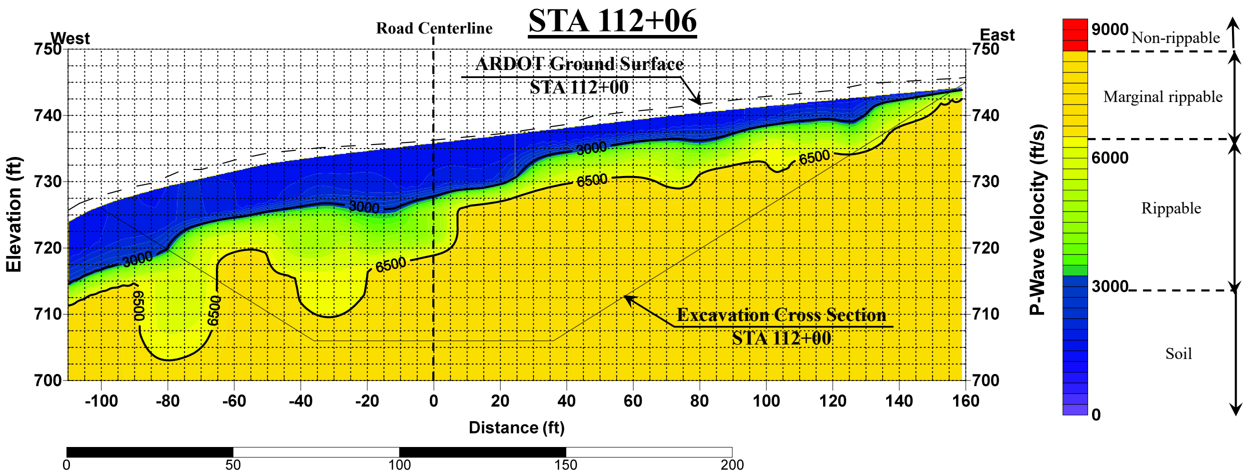


Figure 11 2D Vp cross section for STA 112+06.

5.6 Survey Line STA 112+98

Shown in Figure 12 is the 2D V_p cross section for STA 112+98 along with the approximate ground surface and excavation profile at STA 113+00 provided by ARDOT. For this cross section, the estimated ground surface elevation provided by ARDOT is very similar to surface elevation measured in the field. The contour lines that separate rocks with different rippability degrees are also shown. A soil layer exists at the ground surface with thickness varying from 2.5-7.5 ft. This layer is underlain by a thin rippable rock layer that has a thickness ranging from 2.5-5 ft. This is followed by a very thin marginally rippable rock layer up to a thickness varying from 2.5-7.5 ft. The rest of the section is composed of a non-rippable rock down to the bottom of the section.

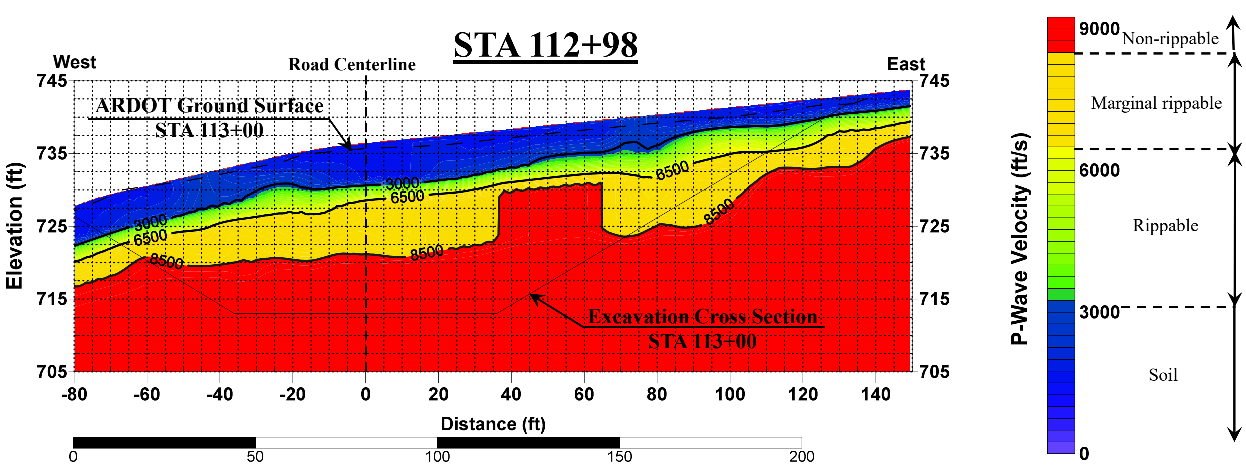


Figure 12 2D Vp cross section for STA 112+98.

5.7 Survey Line STA 114+04

Shown in Figure 12 is the 2D V_p cross section for STA 114+04 along with the approximate ground surface and excavation profile at STA 114+00 provided by ARDOT. For this cross section, the estimated ground surface elevation provided by ARDOT is very similar to surface elevation measured in the field. The contour lines that separate rocks with different rippability degree are also shown. A soil layer exists at the ground surface with thickness varying from 2.5-7.5 ft. Similar to STA 112+98, this layer is underlain by a thin rippable rock layer with a thickness ranging from 2.5-5 ft. This is followed by a thin marginally rippable rock layer up to a thickness varying from 5-7.5 ft. The rest of the section is composed of a non-rippable rock to the bottom of the section.

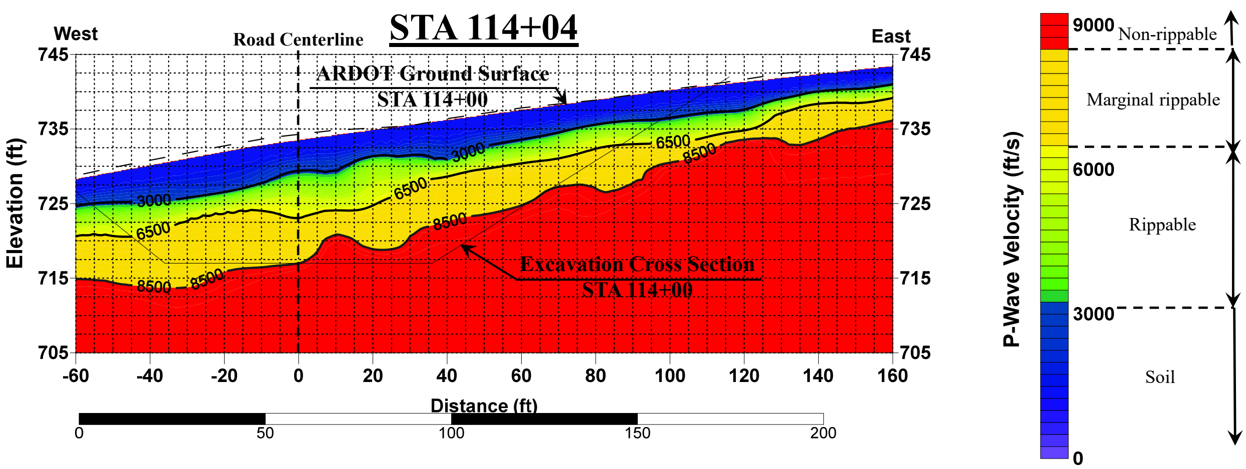


Figure 12 2D Vp cross section for STA 114+04.

6.0 Summary

Seismic refraction measurements were conducted along 7 different survey lines to identify the subsurface layering and bedrock rippability along the proposed realignment of Highway 59. According to the geophysical testing results, STA 108+04 and 108+86 have a thicker soil layer than other lines and generally a softer rock formation underlying the soil. For stations further up the hill (along the alignment), the thickness of the soil layer is expected to be shallower ranging from 2.5-10 ft along different survey lines. This layer is underlain by a rippable rock layer that extends to a depth varying from 5-20 ft. This layer is followed by a marginally rippable rock layer up to depth ranging from 8-35 ft. In general, the rock becomes stiffer near the top of the hill compared to the base of the hill.

7.0 References

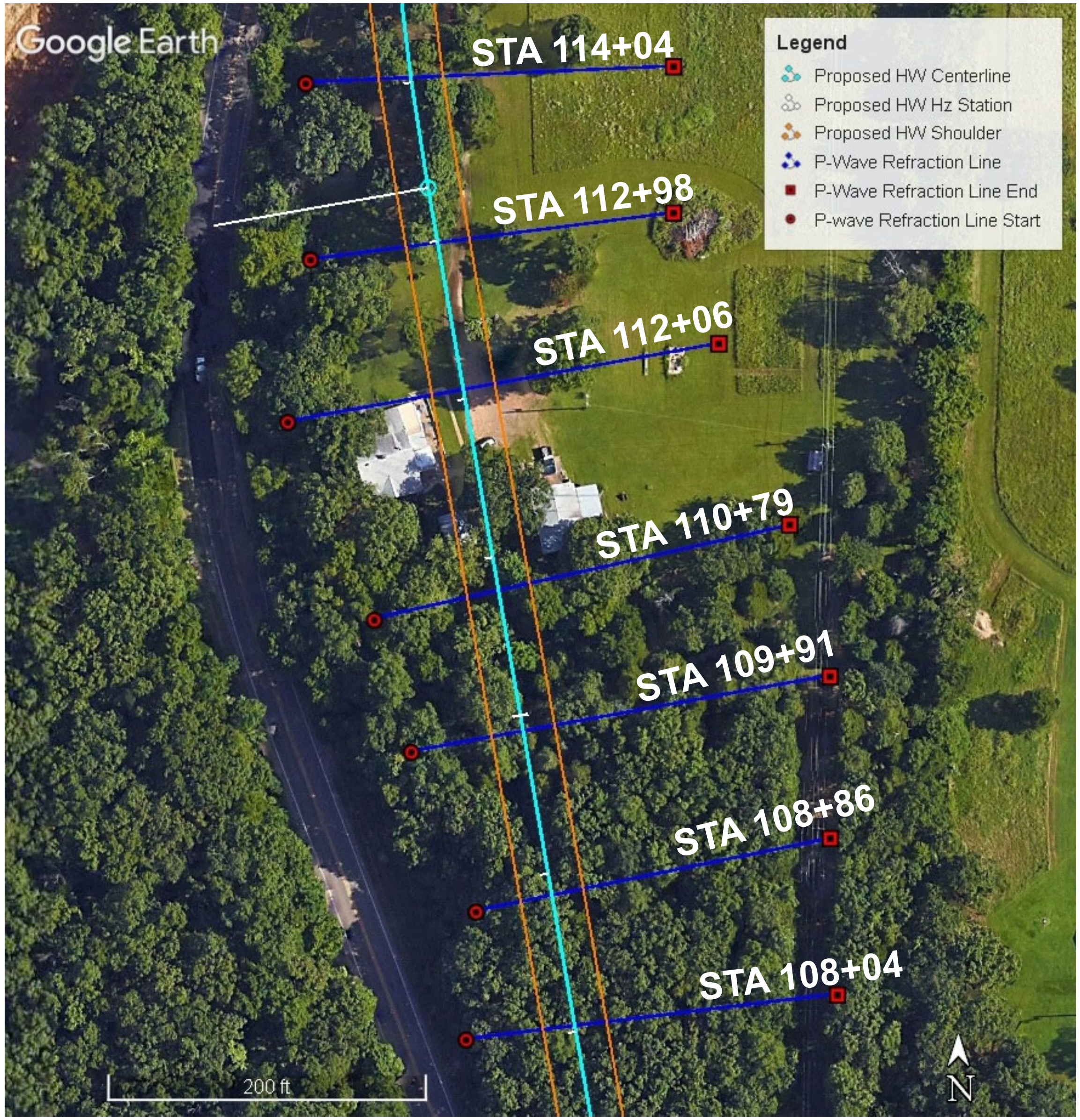
ASTM D5777. Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation. DOI: 10.1520/D5777-00R11e1.

Caterpillar Inc (2000). Handbook of Ripping 12th edition. http://www.dot.ca.gov/hq/esc/geotech/references/Rock_Cut_Slope_References/31_Handbook_of_Ripping_Caterpiller.pdf

Redpath, B. B., 1973, Seismic refraction exploration for engineering site investigations: U. S. Army Engineer Waterway Experiment Station Explosive Excavation Research Laboratory, Livermore, California, Technical Report E-73-4, 51 p.

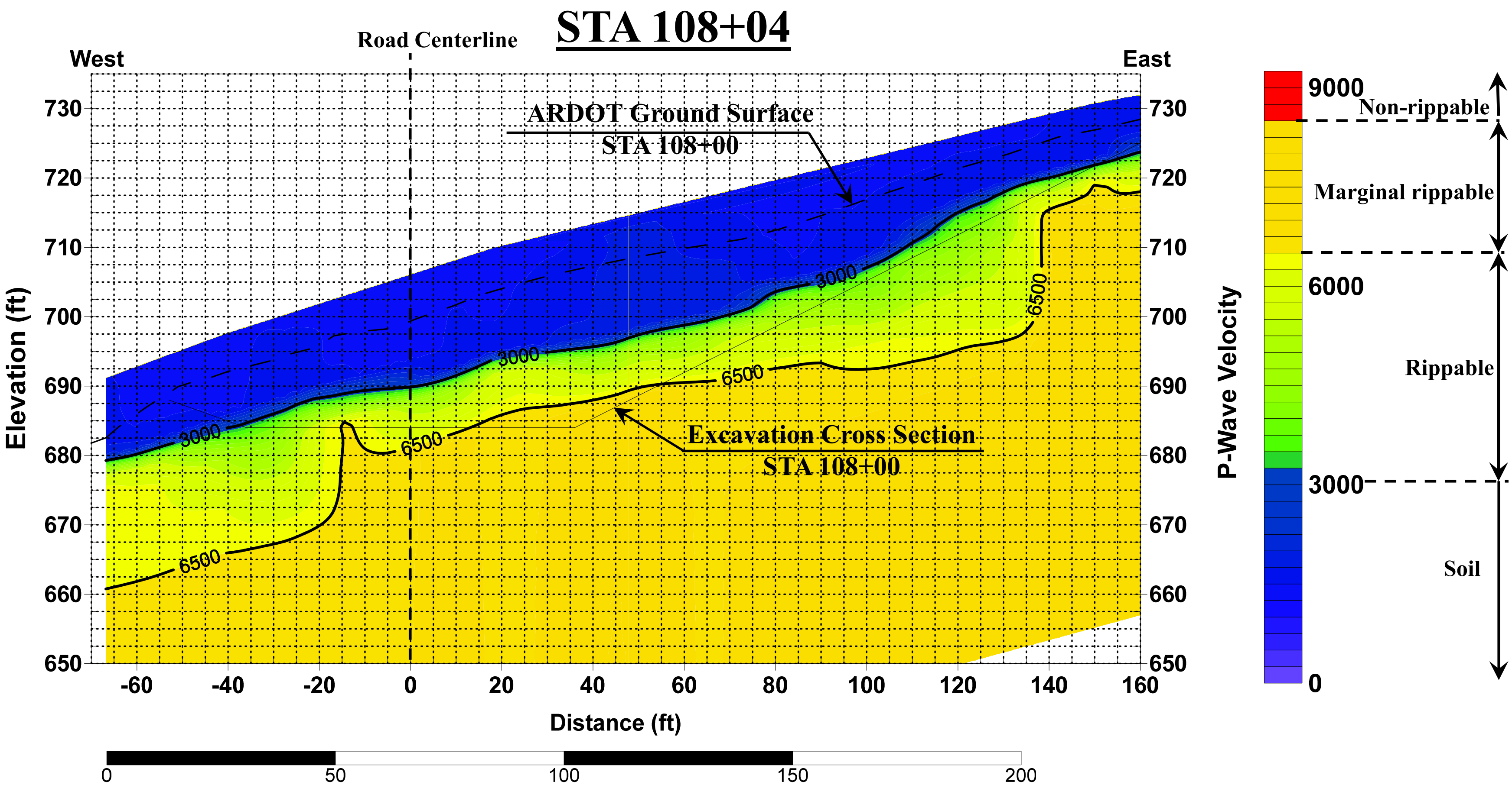
Highway 59 Realignment
(ARDOT Job# 040885)
Van Buren, AR

Seismic Refraction Survey Results

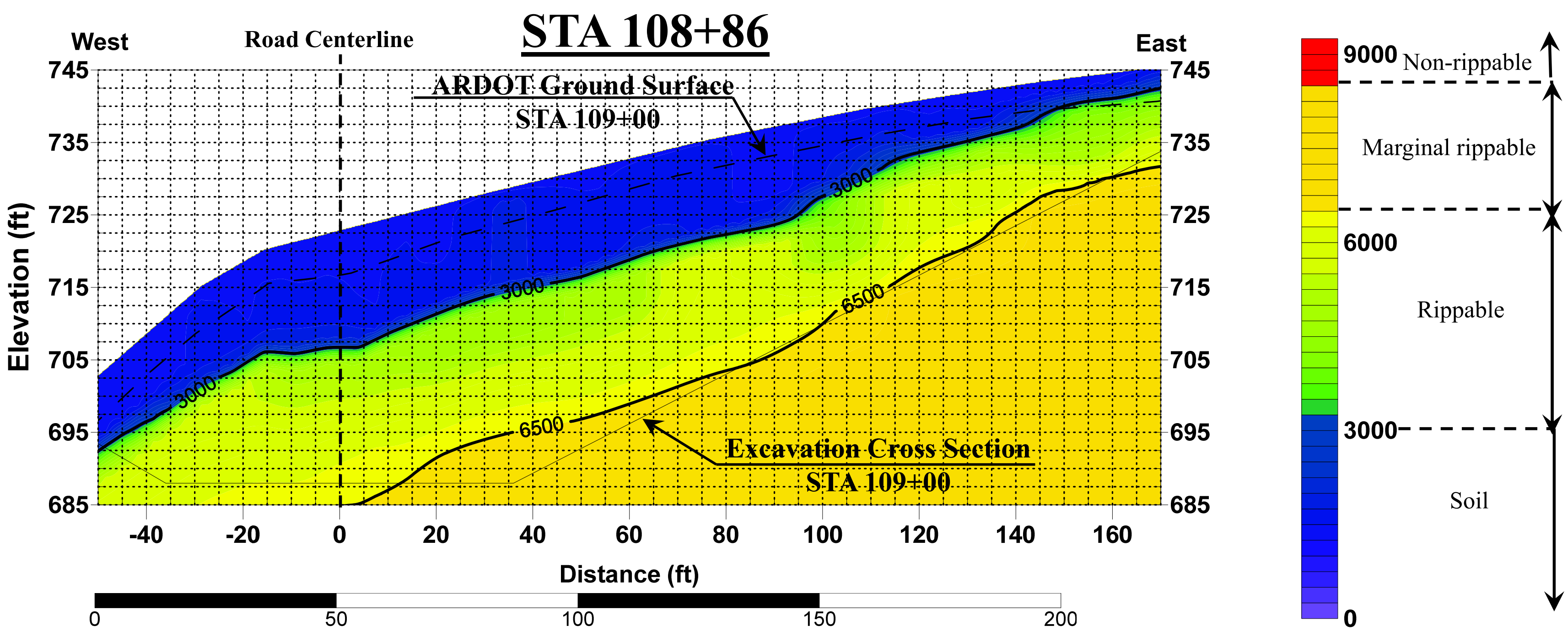


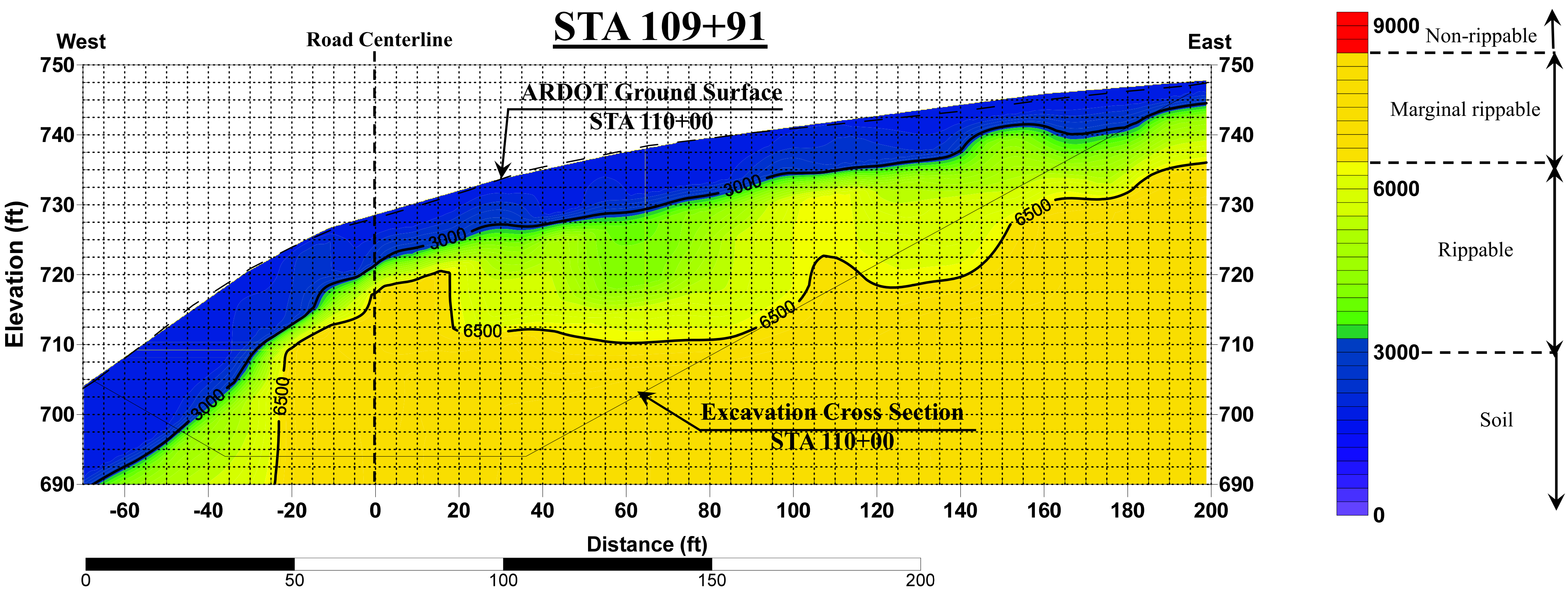
Google Earth
STA 114+04
STA 112+98
STA 112+06
STA 110+79
STA 109+91
STA 108+86
STA 108+04
Legend
Proposed HW Centerline
Proposed HW Hz Station
Proposed HW Shoulder
P-Wave Refraction Line
P-Wave Refraction Line End
P-wave Refraction Line Start
200 ft
N

St. 108

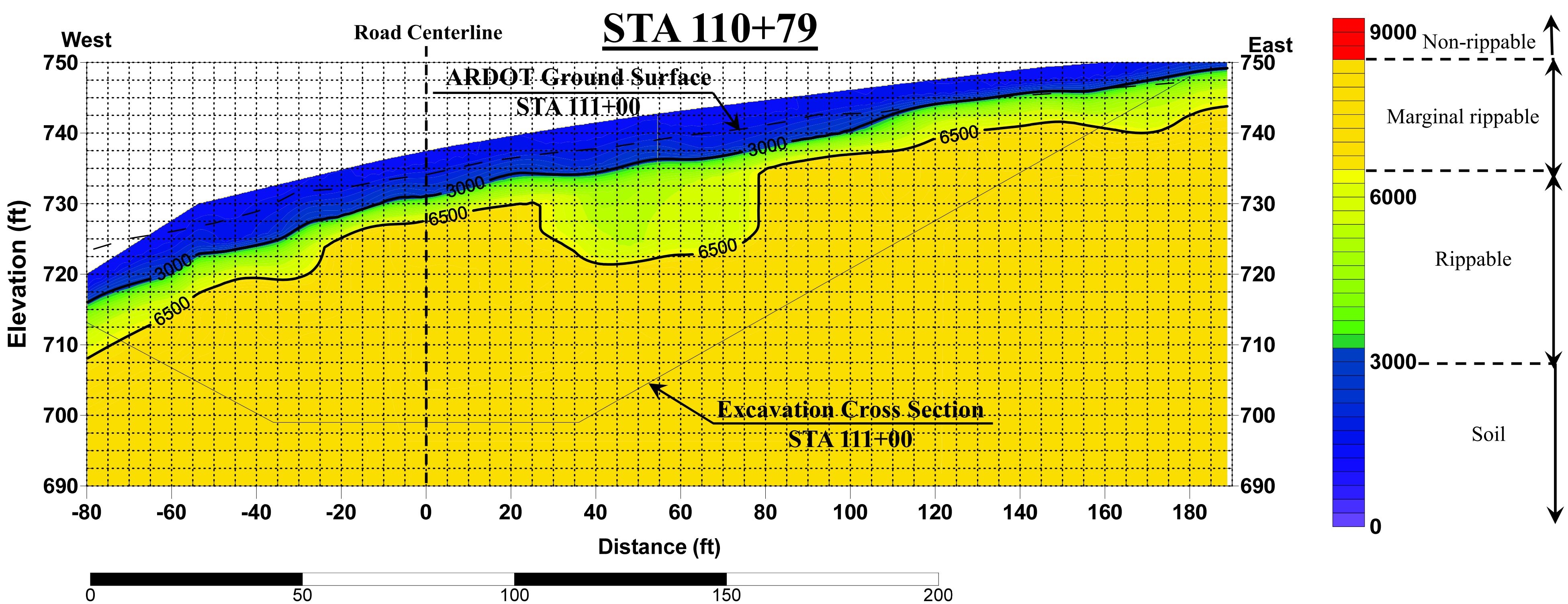


STA 108+04
Road Centerline
West
East
ARDOT Ground Surface
STA 108+00
Excavation Cross Section
STA 108+00
3000
6500
Elevation (ft)
Distance (ft)
730
720
710
700
690
680
670
660
650
-60
-40
-20
0
20
40
60
80
100
120
140
160
0
50
100
150
200
P-Wave Velocity
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil

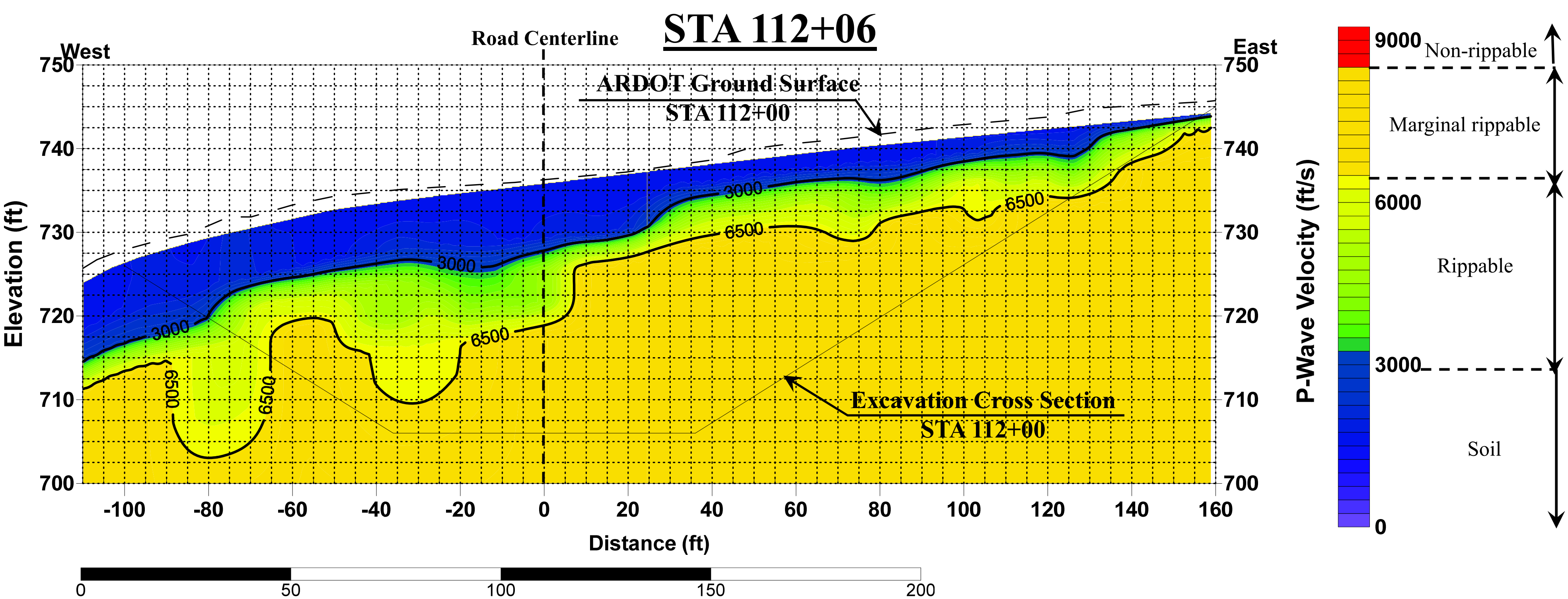

STA 108+86
West
Road Centerline
East
ARDOT Ground Surface
STA 109+00
Excavation Cross Section
STA 109+00
3000
3000
3000
6500
6500
Elevation (ft)
745
735
725
715
705
695
685
-40
-20
0
20
40
60
80
100
120
140
160
Distance (ft)
0
50
100
150
200
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil

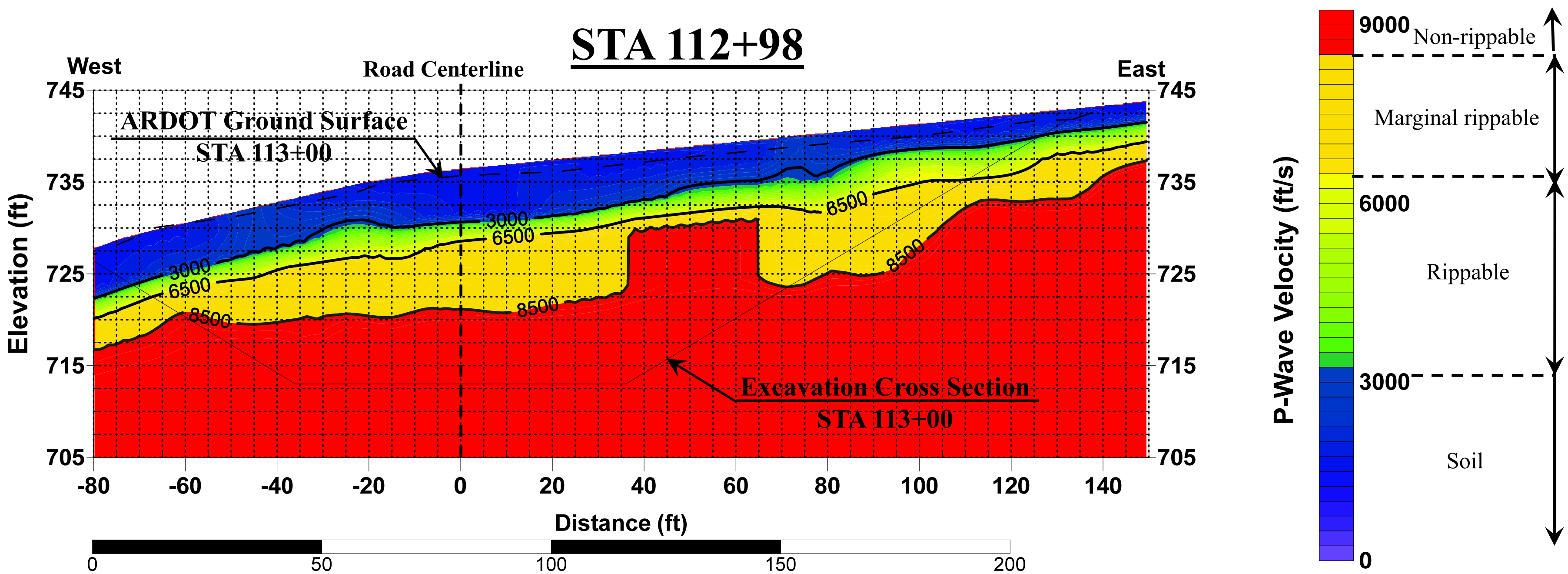


STA 109+91
West
Road Centerline
East
ARDOT Ground Surface
STA 110+00
Excavation Cross Section
STA 110+00
3000
6500
Elevation (ft)
750
740
730
720
710
700
690
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
200
Distance (ft)
0
50
100
150
200
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil

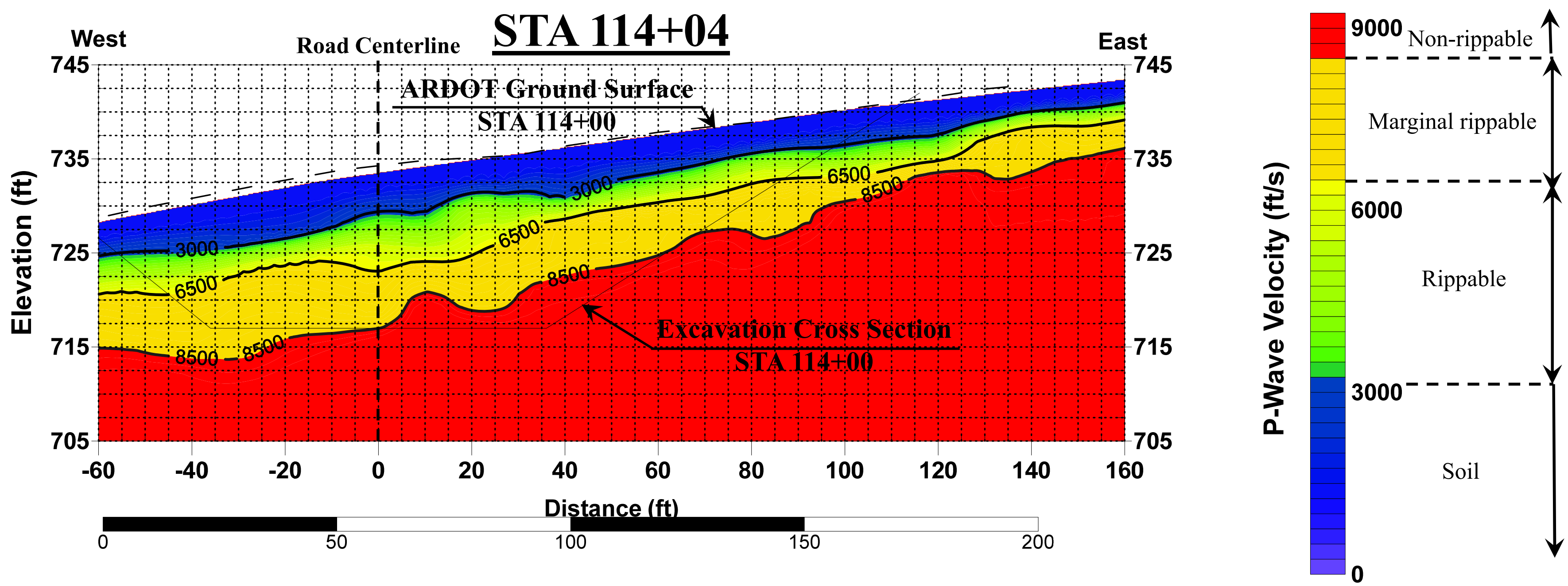


STA 110+79
West
Road Centerline
East
ARDOT Ground Surface
STA 111+00
Excavation Cross Section
STA 111+00
3000
6500
Elevation (ft)
750
740
730
720
710
700
690
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
Distance (ft)
0
50
100
150
200
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil


STA 112+06
West
East
Road Centerline
ARDOT Ground Surface
STA 112+00
Excavation Cross Section
STA 112+00
3000
6500
Elevation (ft)
Distance (ft)
750
740
730
720
710
700
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
0
50
100
150
200
P-Wave Velocity (ft/s)
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil



STA 112+98
West
Road Centerline
East
ARDOT Ground Surface
STA 113+00
Excavation Cross Section
STA 113+00
3000
6500
8500
Elevation (ft)
745
735
725
715
705
-80
-60
-40
-20
0
20
40
60
80
100
120
140
Distance (ft)
0
50
100
150
200
P-Wave Velocity (ft/s)
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil


STA 114+04
West
Road Centerline
East
ARDOT Ground Surface
STA 114+00
Excavation Cross Section
STA 114+00
3000
6500
8500
745
735
725
715
705
Elevation (ft)
-60
-40
-20
0
20
40
60
80
100
120
140
160
Distance (ft)
0
50
100
150
200
P-Wave Velocity (ft/s)
9000
6000
3000
0
Non-rippable
Marginal rippable
Rippable
Soil