Geotechnical Study

Ridge View/ High Ridge Channel – Sedimentation Basin
El Paso Texas

Prepared for:

Parkhill, Smith & Cooper, Inc.
1700 West Wall, Suite 100, Midland, TX 79701

December 18, 2018

wood.

Wood Environment & Infrastructure Solutions, Inc.
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December 18, 2018
Wood Project No. 1837192029

Parkhill, Smith & Cooper, Inc.
1700 West Wall, Suite 100
Midland, Texas 79701

Attn: Ms. Rene Franks, P.E., CFM

RE: Geotechnical Study
Ridge View/High Ridge Channel - Sedimentation Basin
El Paso, Texas

Dear Ms. Franks:

Wood Environment & Infrastructure Solutions, Inc. (Wood) submits this Geotechnical Report for the above referenced project. The report includes the results of site investigation and presents recommendations for the proposed improvements at the Ridge View and High Ridge Channel.

Should any questions arise concerning this report, we would be pleased to discuss them with you.

Respectfully submitted,
Wood Environment & Infrastructure Solutions, Inc.
Texas Registered Engineering Firm F-0012
Texas Registered Geoscience Firm 50184

STATE OF TEXAS
Mark J. Breitnauer
83085
LICENSED
PROFESSIONAL ENGINEER
12-18-2018

Mark J. Breitnauer, P.E.
Senior Engineer

Reviewed by:

David A. Varela, P.E
Senior Engineer

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REPORT **Page**

1.0 INTRODUCTION

This report is submitted pursuant to a geotechnical engineering study made by this firm for the proposed improvements planned at the Ridge View/High Ridge Channel located east of the intersection of Bear Ridge Drive and Franklin Hills Street in west El Paso, Texas. The objective of this study was to evaluate the physical properties of the soils underlying the site.

2.0 PROPOSED CONSTRUCTION

Details of the project were provided to Wood by Ms. Rene Franks, P.E., CFM and Wade Barnes, Ph.D., PE, CFM with Parkhill, Smith & Cooper, Inc.

It is our understanding that several storm water controls are currently being considered along an existing arroyo drainage area east of Franklin Hills Street in west El Paso, Texas. The proposed improvements will consist of the placement of a series of shallow step pools within the arroyo. At each pool location, a gabion wall structure and weir will be constructed in order to reduce the water and debris flow. In addition, gabion mattresses or rock rip rap will be used to line the slopes of the arroyo for erosion control. We also understand that a gravel maintenance road and walking trail will be constructed along the western perimeter of the arroyo.

Should final design details vary significantly from those outlined above, this firm should be notified for review and possible modification of recommendations.

3.0 SOIL STUDY

3.1 SUBSURFACE EXPLORATION

Our field exploration program consisted of performing a total of seven (7) test pits along the existing arroyo to depths ranging from 5 and 10 feet below existing grades ***(Figure 1)***. Excavator refusal on gravels and cobbles, and bedrock was encountered at the site that prevented further advancement to the planned depth of 15 feet.

The test pits were completed using a Volvo EC220D Excavator. During the field study, the soils encountered were examined, visually classified and logged. The locations of the test pits are graphically depicted on the Test Pit Location Plan as shown in ***Appendix A***; they were located by measuring wheel from existing site features and should be considered accurate only to the extent implied by the limitation of the depiction. Results of the field study are presented in ***Appendix A***, which includes test pit location plan and logs of the test pits.

The test pit logs and related information included in this report are indicators of subsurface conditions only at the specific locations and times noted. subsurface conditions, including groundwater levels, at other locations on the subject site may differ significantly from conditions, which exist at the sampling locations.

The soil encountered during the field study was classified in general accordance with the Unified Soil Classification System. The soil classification symbols appear on the boring logs and are briefly described in ***Appendix A***.

3.2 SURFACE REFRACTION SEISMIC & REFRACTION MICRO-TREMOR (REMI) SURVEY

In addition to the test pits, four surface refraction and refraction micro-tremor (REMI) surveys were completed on the Project Site to further evaluate the soil and bedrock conditions along the existing arroyo. The survey consisted of the placement of a 120-foot long seismic refraction and REMI survey near the center of the Site. The results of the survey are discussed further in Section 5.5.

4.0 SITE CONDITIONS & GEOTECHNICAL PROFILE

4.1 SITE CONDITIONS

The project site is an approximately 5.5-acre tract of land owned by the El Paso Water Utilities Public Service Board located east of the intersection of Bear Ridge Drive and Franklin Hills Street in west El Paso, Texas. The existing arroyo has a well-defined channel extend northeast-southwest then westward through the project site and flanked by steep topography on the southeast and southern side.

4.2 GEOTECHNICAL PROFILE

The general subsurface conditions encountered during the field investigation conducted October 31, 2018, are shown on the test pit logs presented in ***Appendix A***. The lines of stratification shown on the logs are based upon examination of the recovered soil samples and interpretation of the field logs and represent the approximate boundaries between the soil types; the actual transitions may be gradual.

As the exploratory logs indicate, the soils encountered at the project site generally consist of sands and gravels in a silt-clay matrix with cobble- and boulder-sized material throughout the depths explored. A silica and calcareous cementation is also present within the soil profile. All test pits terminated with excavator refusal at depths between 5 and 10 feet on bedrock. Surface limestone bedrock exposures were also observed near test pit 4 and seismic line 4 and may be encountered at depths shallower than 5 feet.

The soil classification symbols shown above and elsewhere herein are derived from ASTM D2487, *Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)* and D2488, *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).*

4.3 SOIL MOISTURE AND GROUNDWATER CONDITION

At the time of our field study, groundwater was not encountered, or should it be expected to occur naturally at this locale at an elevation that would impact the planned construction. Based on our experience within the project area, we understand that perched groundwater may be present at about 100 feet below the ground surface.

5.0 DISCUSSION AND RECOMMENDATIONS

5.1 GABION WALL STRUCTURES

We understand that gabion structures will be used in the project. Stone used for the gabion structures should consist of clean, durable materials with a maximum nominal diameter of 4 to 8 inches. The gabions should be carefully filled with rock by machine or hand methods to avoid any bulges and to provide a compact mass minimizing any voids. Stone obtained from the project site may be used for gabion structures as long as the aggregate is properly screened to meet size, hardness and manufacturer requirements. Additional recommendations provided by the manufacturer should be followed during construction.

Typical embedment of the gabions is 2 to 3 feet. If embedment depths cannot be achieved, alternate fastening methods will need to be discussed with the manufacturer. A net allowable soil bearing pressure of 2,500 pounds per square foot is recommended for the design of the gabion structures supported on 8 inches of compacted structural fill.

A desilting basin is proposed for construction upstream of the planned improvements. Due to the erosive nature of the existing soils, it is recommended that the slope faces of the desilting basin and channel be protected with a gabion mattress, rock rip rap or an equivalent slope protection material.

5.3 PERMANENT SLOPES

Unprotected permanent slopes should not be steeper than 3:1 (horizontal to vertical) for the project. The total slope height and horizontal width including benches can be used in calculating the overall steepness of the slope. Slopes steeper than 3:1 should be protected against erosion.

Revetment should be placed at the base of permanent slopes that are subject to stream erosion. The revetment should be consistent with the stream flow depths and velocity. Revetments should be embedded below the depth of potential scour.

5.4 SEISMIC REFRACTION SURVEY

A seismic refraction survey was conducted to evaluate the shear wave velocity for determination of the Soil Profile Type utilized for seismic structural design. The field investigation involved the placement of four seismic lines and included both seismic refraction for compression wave (p-wave) analyses and Refraction Microtremor (ReMi) for shear wave (s-wave) analyses. A Geometrics S-24 Smartseis signal enhancement seismograph with 120-foot geophone cable and 4.5 Hz vertical geophones was used in the work. P-wave energy for refraction seismic work utilizing the 120-ft geophone cable was generated using a 10-pound sledgehammer impacting a metal target plate on the ground surface. Ambient noise was utilized for ReMi analysis for a one-dimensional vertical s-wave profile at each 120-ft seismic line. Results of the testing are presented in ***Appendix B.***

The refraction seismic method assumes that the subsurface is organized into geo-material layers or horizons of increasing p-wave velocity with depth. P-wave velocity is a function of geo-material mass modulus, except that p-wave velocity can be strongly influenced (increased) if a high porosity geo-material mass is fluid-saturated. A 24-geophone array is capable of interpreting up to three, or sometimes four, horizons of increasing p-wave velocity. Interpreted subsurface material p-wave velocities from the seismic lines are average values obtained over lateral (or dipping geologic material interface) distances of at least 10, or more reliably, 20 feet. Discrete zones of geo-material could have slower or faster p-wave velocities, and therefore, be weaker or stronger than indicated by the average velocities interpreted from the refraction seismic data. However, velocity reversals, where softer, lower-velocity materials could underlie moderate- to higher-velocity materials, would not be detected using the p-wave seismic refraction technique. These conditions are common in strongly cemented soils and caliche environments.

Significant, relatively large-scale velocity reversals may be detected in vertical s-wave profiles obtained using the ReMi technique. ReMi results are derived using data from 12 or more geophones, and interpreted ReMi profiles are a vertical (one-dimensional) weighted average of the vertical s-wave profile underlying those geophones. Where lateral p-wave velocity profiles vary significantly across a seismic line, such as at Line 4, the 1-D s-wave results cannot effectively show a similar lateral variation. However, the combination of a higher s-wave velocity horizon, overlying a lower s-wave velocity horizon, can capture the presence of lateral change in s-wave velocity. These indirect interpretations of lateral s-wave velocity changes are noted on the seismic profiles as green arrows directing the interpreted velocity to the appropriate lateral portion of the profile.

Where p-wave results are not available to relevant depths, due to a groundwater table, shallow depth of investigation, the presence of velocity reversals, or very low subsurface velocities similar to velocities of sound in air, s-wave results with deeper depth of investigation can be used to estimate corresponding deeper p-wave velocities. Given a typical soil Poisson's ratio of 0.33, a p-wave velocity can be estimated by doubling the corresponding s-wave velocity. Also, in subsurface profiles where the s-wave velocity is considerably less than one-half of the corresponding p-wave velocity, relatively thin horizontal-oriented cementation or the presence of a water table, a velocity reversal or other anomalous condition may be indicated.

5.4.1 Excavation Conditions

In general, excavation criteria for rock or rock-like materials have been developed for mass excavation methods such as ripping using bulldozers of specific size and power. Although these criteria address mass excavation conditions such as access road construction, they do not specifically address excavation conditions for trench excavation. The following discussion is thus informative of general geo-material excavation behaviors; these behaviors are intended to provide general information to assist in the engineering assessment of specific (and possibly proprietary) trench excavation methodologies.

As indicated by the refraction seismic information and approximate excavation capabilities of various heavy equipment presented in **Table B-2** in **Appendix B**, mass excavation at the seismic lines can be effectively accomplished using appropriate equipment as listed for the geologic materials, primarily caliche in this geo-environment, as otherwise characterized from geologic mapping, reconnaissance, and geotechnical drilling. Using the criteria of Stacy and Noble (1975) summarized in **Figure B-2** in **Appendix B** (Rucker and Fergason, 2006, 2009), it is anticipated that mass excavation and trench excavation using backhoe-type equipment could proceed without significant difficulty in materials with p-wave velocities less than about 3,000 f/s. As indicated in **Table B-2** and **Figure B-1** in **Appendix B**, rock zones (or caliche zones) may need sufficiently heavy equipment. Mechanical methods such as hoe-ramming may be effective, or at least practical. Rock that may be excavatable using heavy equipment in mass excavation may not be excavatable in deep trenching or shaft excavation without specialized equipment and methods. Excavation, earthmoving and hauling techniques and equipment used on the project may have to contend with cobbles or boulders. Effective excavation of individual boulders or isolated zones of very strongly cemented material or rock may require blasting or other mechanical means of reducing the material.

5.5 GRAVEL MAINTENANCE ROAD

Gravels and sands in a silt and clay matrix soils were encountered along the proposed alignment. The recommended subgrade treatment consists of scarifying the native soils to a depth of 8 inches. Any gravel and cobbles greater than 3-inches in any dimension should be removed. The scarified soils should then be brought to within plus or minus 2 percent of optimum moisture content. Compaction of the soil should be accomplished by mechanical means to obtain a density of not less than 95 percent of maximum dry density. Optimum moisture content and maximum dry density should be determined in accordance with ASTM D1557.

In order to provide additional stability within the road area, it is recommended a geogrid, such as a Tensar TriAx-Tx160 or equivalent product, be placed on the compacted subgrade prior to the placement of the aggregate base course. Aggregate base course should conform with the requirements of Type A, Grade 1 or 2 of Item 247 of the Texas Department of Highways and Public Transportation Standard Specifications for Construction of Highways, Streets, and Bridges. An aggregate base course layer consisting of 8 inches is recommended for construction. It should be noted that periodic maintenance of the aggregate base material driving areas will be required.

It is recommended that the grading design for the project make provisions for the rapid drainage of the road with no ponding. In addition, the road should be graded with a crown in order to shed water immediately to designated areas to prolong the life of the gravel placed.

5.6 CONSTRUCTION OBSERVATION AND TESTING

The recommendations presented in this report are based upon a limited number of subsurface samples obtained from seven sampling locations and the four seismic survey lines at the site. The samples may not fully indicate the nature and extent of the variations that actually exist between sampling locations. For that reason, among others, we recommend that Wood be retained to observe earthwork construction. It should be noted if variations or other latent conditions become evident during earthwork construction, it will be necessary for us to review these conditions and modify its recommendations.

APPENDIX A

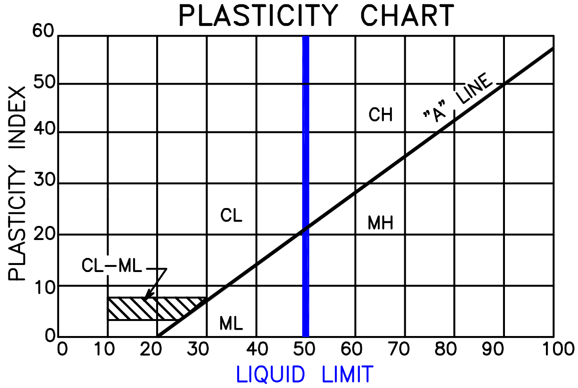
UNIFIED SOIL CLASSIFICATION SYSTEM

Soils are visually classified by the Unified Soil Classification System on the boring logs presented in this report. Grain–size analysis and Atterberg Limits Tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, see "The Unified Soil Classification System", Corp of Engineers, US Army Technical Memorandum No. 3–357 (Revised April 1960) or ASTM Designation: D2487–93T.

MAJOR DIVISIONS				GRAPHIC SYMBOL	GROUP SYMBOL	TYPICAL NAMES
COARSE–GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (50% or less of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)			GW	Well graded gravels, gravel–sand mixtures, or sand–gravel–cobble mixtures.
					GP	Poorly graded gravels, gravel–sand mixtures or sand–gravel–cobble mixtures
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line or hatched zone on plasticity chart		GM	Silty gravels, gravel–sand–silt mixtures
			Limits plot above "A" line & hatched zone on plasticity chart		GC	Clayey gravels, gravel–sand–clay mixtures
	SANDS (More than 50% of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 seive)			SW	Well graded sands, gravelly sands
					SP	Poorly graded sands, gravelly sands
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line or hatched zone on plasticity chart		SM	Silty sands, sand–silt mixtures
			Limits plot above "A" line & hatched zone on plasticity chart		SC	Clayey sands, sand–clay mixtures
FINE–GRAINED SOILS (50% or more passes No. 200 sieve)	SILTS Limits plot below "A" line or hatched zone on plasticity chart	SILTS OF LOW PLASTICITY (Liquid Limit Less Than 50%)			ML	Inorganic silts, clayey silts with slight plasticity
		SILTS OF HIGH PLASTICITY (Liquid Limit More Than 50%)			MH	Inorganic silts, micaceous or diatomaceous silty soils, elastic silts
	CLAYS Limits plot above "A" line & hatched zone on plasticity chart	CLAYS OF LOW PLASTICITY (Liquid Limit Less Than 50%)			CL	Inorganic clays of low to medium plasticity; gravelly clays, sandy clays, silty clays, lean clays
		CLAYS OF HIGH PLASTICITY (Liquid Limit More Than 50%)			CH	Inorganic clays of high plasticity, fat clays, sandy clays of high plasticity

NOTE: **Coarse grained soils with between 5% & 12% passing the No. 200 sieve and fine grained soils with limits plotting in the hatched zone on the plasticity chart to have double symbol.**

PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
COBBLES	Above 3 inches
GRAVEL	3 inches to No. 4 sieve
Coarse Gravel	3 inches to 3/4 inch
Fine Gravel	3/4 inch to No. 4 sieve
SAND	No. 4 sieve to No. 200
Coarse	No. 4 sieve to No. 10
Medium	No. 10 sieve to No. 40
Fine	No 40 sieve to No. 200
FINES (SILT or CLAY)	Below No. 200 sieve

SOIL MOISTURE CLASSIFICATION

MOISTURE CONDITION	FIELD IDENTIFICATION	ESTIMATED RANGE OF MOISTURE	
		Group A (%)	Group B (%)
Dry	Absence of moisture, dusty. Dry to the touch.	0-4	0-8
Damp	Grains appear slightly darkened, but no visible water. Silt/clay may clump. Sand will not bulk. Soils are below plastic limits.	4-8	8-16
Moist	Grains appear darkened, but no visible water. Silt/clay will clump. Sand will bulk. Soils are often at or near plastic limits.	8-16	16-30
Wet	Visible water on larger grain surfaces. Sand and cohesionless silt exhibit dilatancy. Cohesive silt/clay can be readily remolded. "Wet" indicates that the soil is much wetter than the optimum moisture content and above the plastic limit (APL).	>16	>30
Water Bearing	A water-producing formation.	N/A	N/A

Group A - Coarse Grained Soils, nonplastic to plasticity index <7.
Includes: SM, SP-SM, SP, SW, GM, GP, and GW.

Group B - Fine Grained Soils to clayey sands & gravels with a plasticity index >7.
Includes: GC, SC, ML, MH, CL, and CH.

CLIENT:

PSC **Parkhill, Smith & Cooper, Inc.**
Engineers ▪ Architects ▪ Planners

wood.

E & I S, INC.
125 MONTOYA ROAD
EL PASO, TX 39932

LEGEND

- Test Pit Approximate Location
- Percolation Test Approximate Location
- Seismic Line Approximate Location

DRAWN BY: MJB

CHK'D BY: DAV

PROJECTION:

SCALE: AS SHOWN

PROJECT:

Ridge View / High Ridge Channel – Sedimentation Basin
El Paso, El Paso County, Texas

SITE PLAN

REV NO. 0

DATE 12/11/2018

PROJECT NO. **1837192029**

FIGURE NO. **1**

PROJECT Ridge View-High Ridge Channel - Sedimentation Basin
El Paso, El Paso County, Texas

wood.
Environment & Infrastructure Solutions, Inc.
125 Montoya Road
El Paso, TX 79932
Telephone: 915-585-2472

JOB NO. 1837192029 **DATE** 10/31/18

BACKHOE TYPE Volvo EC220D Excavator
LOCATION See Test Pit Location Plan
SURFACE ELEV. Existing Ground Surface
DATUM Existing Ground Surface

GROUNDWATER

	DEPTH	HOUR	DATE
▽	NE		10/31/2018
▼			

Depth in Feet	Graphical Log	Sample	Sample Type	Moisture Content Percent of Dry Weight	Unified Soil Classification or Rock Unit	REMARKS	SOIL DESCRIPTION
0			G		GM	Loose to Dense	Silty Gravel with Sand - Brown GRAVEL, angular to subangular, some sand, little silt, nonplastic fine, dry. Cobble- and boulder-sized material observed in the excavation.
5			G		SM	Hard dig	Silty Sand with Gravel - Light brown medium and fine SAND, little silt, nonplastic fines, little gravel, subangular to subrounded, dry. Cobble- and boulder-sized material observed in the excavation.
10							Refusal at 6 feet. NE - Not Encountered
15							
20							

SAMPLE TYPE
B - Undisturbed Bulk Sample
D - Disturbed Bulk Sample
U - 3" O.D. 2.42" I.D. tube sample
A - Drill Cuttings
G - Grab sample

LOG OF TEST PIT NO. TP-1

wood.
Environment & Infrastructure Solutions, Inc.
125 Montoya Road
El Paso, TX 79932
Telephone: 915-585-2472

PROJECT Ridge View-High Ridge Channel - Sedimentation Basin
El Paso, El Paso County, Texas

JOB NO. 1837192029 **DATE** 10/31/18

BACKHOE TYPE Volvo EC220D Excavator
LOCATION See Test Pit Location Plan
SURFACE ELEV. Existing Ground Surface
DATUM Existing Ground Surface

GROUNDWATER

	DEPTH	HOUR	DATE
▽	NE		10/31/2018
▼			

Depth in Feet	Graphical Log	Sample	Sample Type	Moisture Content Percent of Dry Weight	Unified Soil Classification or Rock Unit	REMARKS	SOIL DESCRIPTION
0			G		GM		Silty Gravel with Sand - Brown GRAVEL, angular to subangular, some sand, little silt, nonplastic fine, dry. Cobble- and boulder-sized material observed in the excavation.
						Dense layer of cobble-sized material	Dense cobble-sized fraction observed between 2 and 4 feet.
5							
							Terminated at 8 feet. NE - Not Encountered
10							
15							
20							

SAMPLE TYPE
B - Undisturbed Bulk Sample
D - Disturbed Bulk Sample
U - 3" O.D. 2.42" I.D. tube sample
A - Drill Cuttings
G - Grab sample

LOG OF TEST PIT NO. TP-2

PROJECT	Ridge View-High Ridge Channel - Sedimentation Basin El Paso, El Paso County, Texas
JOB NO.	1837192029
DATE	10/31/18

Environment & Infrastructure Solutions, Inc.
125 Montoya Road
El Paso, TX 79932
Telephone: 915-585-2472

GROUNDWATER

	DEPTH	HOUR	DATE
▽	NE		10/31/2018
▼			

BACKHOE TYPE	Volvo EC220D Excavator
LOCATION	See Test Pit Location Plan
SURFACE ELEV.	Existing Ground Surface
DATUM	Existing Ground Surface

Depth in Feet	Graphical Log	Sample	Sample Type	Moisture Content Percent of Dry Weight	Unified Soil Classification or Rock Unit	REMARKS	SOIL DESCRIPTION
0			G		GM		Silty Gravel with Sand - Brown GRAVEL, angular to subangular, some sand, little silt, nonplastic fine, dry. Cobble- and boulder-sized material observed in the excavation.
			G				
						interbedded sand layers	
			G				
5			G				
							Terminated at 6 feet. NE - Not Encountered
10							
15							
20							

SAMPLE TYPE
B - Undisturbed Bulk Sample
D - Disturbed Bulk Sample
U - 3" O.D. 2.42" I.D. tube sample
A - Drill Cuttings
G - Grab sample

LOG OF TEST PIT NO. TP-3

Environment & Infrastructure Solutions, Inc.
125 Montoya Road
El Paso, TX 79932
Telephone: 915-585-2472

PROJECT Ridge View-High Ridge Channel - Sedimentation Basin
El Paso, El Paso County, Texas

JOB NO. 1837192029 **DATE** 10/31/18

BACKHOE TYPE Volvo EC220D Excavator
LOCATION See Test Pit Location Plan
SURFACE ELEV. Existing Ground Surface
DATUM Existing Ground Surface

GROUNDWATER

	DEPTH	HOUR	DATE
▽	NE		10/31/2018
▼			

Depth in Feet	Graphical Log	Sample	Sample Type	Moisture Content Percent of Dry Weight	Unified Soil Classification or Rock Unit	REMARKS	SOIL DESCRIPTION
0			G		GM		Silty Sand with Gravel - Light brown medium and fine SAND, little silt, nonplastic fines, little gravel, subangular to subrounded, dry. Cobble- and boulder-sized material observed in the excavation.
			G		SM		Silty Sand with Gravel - Light brown medium and fine SAND, little silt, nonplastic fines, little gravel, subangular to subrounded, dry. Cobble- and boulder-sized material observed in the excavation.
5						Loose soils at 5 feet.	
10							Terminated at 10 feet.. NE - Not Encountered
15							
20							

SAMPLE TYPE
B - Undisturbed Bulk Sample
D - Disturbed Bulk Sample
U - 3" O.D. 2.42" I.D. tube sample
A - Drill Cuttings
G - Grab sample

LOG OF TEST PIT NO. TP-4

Environment & Infrastructure Solutions, Inc.
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El Paso, TX 79932
Telephone: 915-585-2472

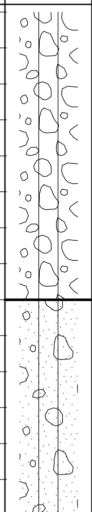
PROJECT Ridge View-High Ridge Channel - Sedimentation Basin
El Paso, El Paso County, Texas

JOB NO. 1837192029 **DATE** 10/31/18

BACKHOE TYPE Volvo EC220D Excavator
LOCATION See Test Pit Location Plan
SURFACE ELEV. Existing Ground Surface
DATUM Existing Ground Surface

GROUNDWATER

	DEPTH	HOUR	DATE
▽	NE		10/31/2018
▼			



Depth in Feet	Sample Type	Unified Soil Classification or Rock Unit	REMARKS	SOIL DESCRIPTION
0	G, G, G, G	GM		Silty Gravel with Sand - Brown GRAVEL, angular to subangular, some sand, little silt, nonplastic fine, dry. Cobble- and boulder-sized material observed in the excavation.
5	G	SM		Silty Sand with Gravel - Light brown medium and fine SAND, little silt, nonplastic fines, little gravel, subangular to subrounded, dry. Cobble- and boulder-sized material observed in the excavation.
10, 15, 20				Refusal at 6 feet. NE - Not Encountered

SAMPLE TYPE
B - Undisturbed Bulk Sample
D - Disturbed Bulk Sample
U - 3" O.D. 2.42" I.D. tube sample
A - Drill Cuttings
G - Grab sample

LOG OF TEST PIT NO. TP-5

Environment & Infrastructure Solutions, Inc.
125 Montoya Road
El Paso, TX 79932
Telephone: 915-585-2472

PROJECT Ridge View-High Ridge Channel - Sedimentation Basin
El Paso, El Paso County, Texas

JOB NO. 1837192029 **DATE** 10/31/18

BACKHOE TYPE Volvo EC220D Excavator
LOCATION See Test Pit Location Plan
SURFACE ELEV. Existing Ground Surface
DATUM Existing Ground Surface

GROUNDWATER

	DEPTH	HOUR	DATE
∇	NE		10/31/2018
▼			

Depth in Feet	Graphical Log	Sample	Sample Type	Moisture Content Percent of Dry Weight	Unified Soil Classification or Rock Unit	REMARKS	SOIL DESCRIPTION
0			G		GM		Silty Gravel with Sand - Brown GRAVEL, angular to subangular, some sand, little silt, nonplastic fine, dry.
			G				
			G				
5			G				
6							Refusal at 6 feet. NE - Not Encountered
10							
15							
20							

SAMPLE TYPE
B - Undisturbed Bulk Sample
D - Disturbed Bulk Sample
U - 3" O.D. 2.42" I.D. tube sample
A - Drill Cuttings
G - Grab sample

LOG OF TEST PIT NO. TP-6

PROJECT Ridge View-High Ridge Channel - Sedimentation Basin
El Paso, El Paso County, Texas

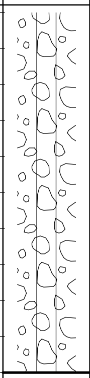
wood.
Environment & Infrastructure Solutions, Inc.
125 Montoya Road
El Paso, TX 79932
Telephone: 915-585-2472

JOB NO. 1837192029 **DATE** 10/31/18

BACKHOE TYPE Volvo EC220D Excavator
LOCATION See Test Pit Location Plan
SURFACE ELEV. Existing Ground Surface
DATUM Existing Ground Surface

GROUNDWATER

	DEPTH	HOUR	DATE
▽	NE		10/31/2018
▼			

Depth in Feet	Graphical Log	Sample	Sample Type	Moisture Content Percent of Dry Weight	Unified Soil Classification or Rock Unit	REMARKS	SOIL DESCRIPTION
0					GM		Silty Gravel with Sand - Brown GRAVEL, angular to subangular, some sand, little silt, nonplastic fine, dry. Cobble- and boulder-sized material observed in the excavation.
5							Refusal at 5 feet. NE - Not Encountered
10							
15							
20							

SAMPLE TYPE
B - Undisturbed Bulk Sample
D - Disturbed Bulk Sample
U - 3" O.D. 2.42" I.D. tube sample
A - Drill Cuttings
G - Grab sample

LOG OF TEST PIT NO. TP-7

APPENDIX B

REFRACTION SEISMIC EQUIPMENT AND PROCEDURES

Refraction seismic surveys are performed in general conformance with the guidelines presented in ASTM D5777-95 Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation for refraction surveys using compression waves (p-waves). ASTM D5777 does not address shear wave (s-wave) surveys; standard practice is followed for refraction surveys using s-waves. In some investigations, such as seeking and tracing earth fissures or other significant discontinuities (Rucker and Keaton, 1998), non-standard procedures and analyses, such as signal amplitude analysis, are used as part of the investigation process.

Seismic Equipment - Refraction seismic surveys are performed using a Geometrics SE-24 24-channel signal signal enhancement seismograph. This instrument has the capability to simultaneously record 12 or 24 channels of geophone data. Signal enhancement capability permits the use of a sledgehammer as the seismic energy source. A timing sensor is attached to the hammer, and for p-waves, a metal plate is set securely on the ground surface and struck. Generating horizontally polarized s-waves typically involves jumping on the ground or dropping a 10-pound sledgehammer at the end of the line for a 12-channel system or in the center for a 24-channel system.

Because of the signal enhancement capability, signals from several or many strikes can be added together to increase the total signal available relative to noise to obtain the seismic record. Although explosives can also be used as a p-wave seismic energy source, a sledgehammer does not require licenses or permits, or involve special limitations, regulations and liabilities. Explosive energy sources may be needed for long geophone arrays. Geophone cables with 12 geophone takeouts at 10-foot, 25-foot or 20-meter spacings are presently used. Vertical geophones are used to obtain p-wave data and horizontal geophones are used to obtain s-wave data. The seismograph system is extremely portable. In areas where vehicular access is not possible, the equipment can be mobilized by various means, including backpacking, packhorse, helicopter and canoe.

Field Procedures - The field operations are directed by our experienced engineer or geologist, who operates the equipment, prepares the records and examines the data in the field. Refraction seismic lines are generally laid out using the standard spacings on the geophone cables. A maximum depth of investigation of about 75 to 100 feet may be possible using a 300-foot array. For shorter lines with improved near-surface resolution, 10-foot spacings between geophones with a 120-foot array have a maximum depth of investigation of about 30 to 40 feet, and with a 240-foot array have a maximum depth of investigation of about 60 to 80 feet. Other geophone spacings can also be used. To improve the resolution of near-surface interfaces, energy source positions generally are set at 12.5 feet from the ends of a 25-foot spacing geophone array or at 5 feet from the ends of a 10-foot geophone spacing array. Several shots locations are utilized along the length of an array. When three shots are obtained, there is a foreshot and a backshot at the array ends and a midshot at the array center. The midshot is usually placed midway between the two centermost geophones. When five shots are obtained, the additional shotpoints are located midway between the foreshot-midshot and the midshot-backshot. For 240-foot 24-channel arrays, shotpoints are arrayed at 30-foot intervals along the array. These multiple shot points permit interpretation of near-surface interfaces at various locations along the array as well as near the endpoints for variable subsurface profiles, and permits more refined overall interpretations of shallow and mid-depth subsurface velocities and interfaces. In cases when both enhanced depth of investigation and improved shallow resolution are needed, multiple geophone arrays are completed end to end and combined into longer composite geophone arrays with greater depths of investigation. Additional energy shotpoints are then, at a minimum, performed at the midpoint and far endpoint of each adjacent geophone array to provide seismic energy travel path coverage over the extended array.

Surface wave data is also typically collected for each seismic line setup and interpreted for vertical shear wave profiles using the Refraction Microtremor method. This procedure is described separately. To facilitate the collection of low frequency surface wave data, 4.5 Hz geophones are typically used for surface seismic work.

REFRACTION SEISMIC EQUIPMENT AND PROCEDURES (Cont.)

P-wave data are recorded for general exploration work. S-wave data are also recorded when dynamic subsurface material properties are desired. An s-wave arrival is verified by obtained two sets of horizontal data that are 180 degrees out of phase. The phase reversal is obtained by either reversing the horizontal geophone orientation or reversing the hammer impact direction. Hard copy printouts of all field data are made and inspected as the information is collected. Field notes, including line number and orientation, topographic variations and other notes as appropriate are made on the hard copy printout. Locations and other notes are made on site maps and in notebooks as appropriate. Initial first arrival picks are made in the field and array endpoint arrival times are checked for immediate data adequacy verification as part of the quality control process.

Interpretation - Although preliminary or quality control initial refraction seismic data interpretations may sometimes be performed in the field, full interpretations are completed in the office. At the present time, two interpretation methods are being used; the intercept time method (ITM) and an optimization software routine based on finite difference optimization software. ITM breaks an interpretation into several distinct layers. It is simple, can be performed with a calculator, and can provide excellent interpretations of near surface layer depths and velocities. Optimization provides a continuously variable velocity interpretation through a discrete grid. Interpretations using optimization also indicate zones where interpretation has occurred, thus providing quality control on the depths to which the interpretation can be relied upon. However, the discrete grid used by optimization results in a low resolution near surface interpretation. The combination of both ITM and, when appropriate, optimization methods provides two separate interpretations with complimentary strengths and cross-checking capability. These interpretation methods are applied as appropriate to a particular project.

Refraction seismic data interpretation using the intercept time method is detailed by Mooney (1973). A personal computer spreadsheet is used to perform the necessary calculations to obtain depths and layer velocities, and print out time-distance plots and depth interpretations. This method is used for interpretations of up to three layers. It is considered that more than three layers cannot be effectively interpreted using twelve geophone data points. Interpretations are then completed manually to produce a final interpreted geologic profile and layer depths.

Refraction seismic data interpretation using optimization is performed using the SeisOpt2D (presently Version 4.0) software package by Optim, L.L.C., 1999-2016, of Reno, Nevada. Energy source and geophone receiver locations and elevations, and first arrival times are entered into the software package, and first arrival travel times are optimized through a process of repeated (typically 10,000 to 100,000) iterations. Multiple seismic lines combined end to end into a longer composite line can be effectively interpreted using this software. Model grid dimensions and element sizes are selected, with larger grids containing smaller elements providing greater potential resolution. However, very large grids containing small elements may become unstable, and several runs may need to be made to obtain stable, robust interpretations. Once a robust interpretation has been obtained, the resulting seismic velocity profile is printed out with varying colors indicating the interpreted velocities.

References:

Mooney, H.M., 1973, Engineering Seismology Using Refraction Methods, Bison Instruments, Inc., Minneapolis, Minnesota.

Rucker, M.L. and Keaton, J.R., 1998, Tracing an Earth Fissure Using Seismic-Refraction Methods with Physical Verification, in Land Subsidence Case Studies and Current Research: Proceedings of the Dr. Joseph F. Poland Symposium on Land Subsidence, Edited by Borchers, J.W., Special Publication No. 8, Association of Engineering Geologists, Star Publishing Company, Belmont, California, p. 207-216.

REFRACTION MICROTREMOR (ReMi) SHEAR WAVE EQUIPMENT AND PROCEDURES

Refraction microtemor or ReMi surveys are performed in general accordance with the method described by Louie (2001) to develop vertical one-dimensional shear wave (s-wave) velocity profiles. The same equipment used for ReMi is also used for refraction seismic. When appropriate, both p-wave and s-wave data can be collected with the same physical seismic line setup.

ReMi Seismic Equipment - ReMi surveys are performed using a Geometrics SE-12 or SE-24 Smartseis signal enhancement seismograph. These instruments have the capability to digitally record and store up to 12 or 24 channels of geophone data in SEG2 format. Up to 16,384 samples can be acquired for each geophone channel at sample intervals as long as 0.25, 0.5, 1 and 2 milliseconds. Sampling events to collect ReMi field data may typically last 6, 12 or 24 seconds. Geophone cables with 12 geophone takeouts at 10-foot or 20-meter spacings are presently used. Vertical geophones with resonant frequencies of 28 Hz and 4.5 Hz are used to obtain surface wave data for s-wave vertical profile analysis. High frequency geophones are used for shorter arrays with shallower depths of investigation, and low frequency geophones are used for longer arrays with greater depths of investigation. Broad band ambient site noise may be used as a surface wave energy source. Controlled surface wave energy sources include jogging alongside shorter geophone arrays and driving a field vehicle alongside longer geophone arrays. The seismograph system is extremely portable. In areas where vehicular access is not possible, the equipment can be mobilized by various means, including backpacking, packhorse, helicopter and canoe.

ReMi Field Procedures - The field operations are directed by our experienced engineer or geologist, who operates the equipment, prepares the records and examines the data in the field. ReMi seismic lines are generally laid out using the standard spacings on the geophone cables. A depth of investigation of about 100 meters or more may be possible using a 240 meter array. For shorter lines with improved near-surface resolution, 10-foot array spacings between geophones have a shallowr depth of investigation. Other geophone spacings can also be used.

Data collection consists of the system sampling the ambient or generated surface waves (a sampling event) at the geophone array for several to many seconds. Typical sampling times and intervals for a sampling event may be 6 seconds at 0.5 milliseconds, 12 seconds at 1 millisecond and 24 seconds at 2 milliseconds for array lengths of 60 feet, 120 to 240 feet, and 240 meters, respectively. Several sampling events are collected at each ReMi setup. For shorter arrays where ReMi with surface wave energy generated by jogging is conducted in concert with seismic refraction data collection, four sampling events may typically be recorded. For longer arrays where urban ambient noise or a field vehicle generates the surface wave energy, six to ten sampling events may be recorded. Field notes, including line number and orientation, topographic variations, locations and other notes as appropriate are made in a logbook. Sample data files are saved and stored on a field laptop computer connected to the Geode seismograph and preliminary interpretations made for immediate data adequacy verification as part of the quality control process.

Interpretation - Although preliminary or quality control initial ReMi seismic data interpretations may sometimes be performed in the field, full interpretations are completed in the office. Data files, typically about 580kb each in size, are transferred from the seismograph to the laptop computer using 3.5-inch floppy disks. Interpretation is performed using the SeisOpt ReMi Version 6.0 (2010) software package by Optim, L.L.C., of Reno, Nevada. The software consists of two modules. The ReMi VsSpect module is used to convert the SEG2 files into a spectral energy shear wave frequency versus shear wave velocity presentation for a ReMi seismic setup. The interpreter then selects a dispersion curve consisting of the lower bound of the spectral energy shear wave velocity versus frequency trend, and that dispersion curve is saved to disk. Tracing the lower bound (slowest) of the shear wave velocity at each frequency selects the ambient energy propagating parallel to the geophone array, since energy propagating incident to the array will appear to have a faster propagating velocity. The second module, ReMi Disper, is then invoked. The interpreter models a dispersion curve with multiple layers and s-wave velocities to match the selected dispersion curve from the field data. An interpreted vertical s-wave profile is obtained through this process. It must be understood that this type of interpretation may not result in a unique solution.

Louie, J.L., 2001, Faster, Better: Shear-wave velocity to 100 meters depth from refraction microtremor arrays, Bulletin of the Seismological Society of America, Vol. 91, 347-364.

TABLE B-1
Approximate Erodability & Excavatability of Materials
Limestone & Cemented Soils (caliche)

Seismic Velocity f/s (m/s) (Rucker and Fergason, 2006)	Trackhoe / Dozer Type & Power (Cat, 1984, 1993)	Erodability / Excavatability Index (Kirsten 1982; NRCS, 2001)	Erosion Threshold Stream Power, KW/m^2 (Annandale, 1995)
s-wave < 750 f/s (230 m/s) p-wave < 1,500 f/s (460 m/s)	Hand spade	< 0.01	Very erodible
s-wave 750 – 1,500 (230 – 460) p-wave 1,500 – 3,000 (460 – 910)	Hand pick & spade	0.01 – 0.099	Very erodible – 0.2
s-wave 1,500 - ~1,800 (460 – 550) p-wave 3,000 - ~3,500 (910 – 1,070)	Cat 325BL 168 hp 125 KW Cat D6D 136 hp 101 KW	0.1 – 0.99	0.2 – 1.0
s-wave ~1,800 – 2,000 (550 – 610) p-wave ~3,500 – 4,000 (1,070 – 1,220)	Cat 330BL 222 hp 165 KW Cat D7G 200 hp 149 KW	1.0 – 9.99	1.0 – 5.0
s-wave ~2,100 – 3,000 (640 – 910) p-wave ~4,200 – 5,900 (1,280 – 1,800)	Cat 345BL 321 hp 239 KW Cat D8L 335 hp 249 KW	10 – 99	5.0 – 30
s-wave 3,000 – 3,600 (910 – 1,100) p-wave 5,900 – 7,200 (1,800 – 2,200)	Cat 375 428 hp 319 KW Cat D9L 460 hp 342 KW	100 – 999	30 – 200

Note: Bulldozer and backhoe power ranges are presented by Kirsten (1982, 1988) as a measure of equivalent performance for excavation. All velocities are approximate and represent a typical range. S-wave velocities are assumed to be about half of p-wave velocities consistent with a Poisson's ratio of 0.33. Seismic velocity ranges for backhoes and trackhoes in cemented soils with typical p-wave velocity less than 6,000 f/s (1,830 m/s) are from Rucker and Fergason (2006). See the Caterpillar Performance Handbook (Caterpillar, 1984, 1993 or current edition) for details on use of seismic information for rippability. Different model configurations include variations in weight and horsepower.

TABLE B-2

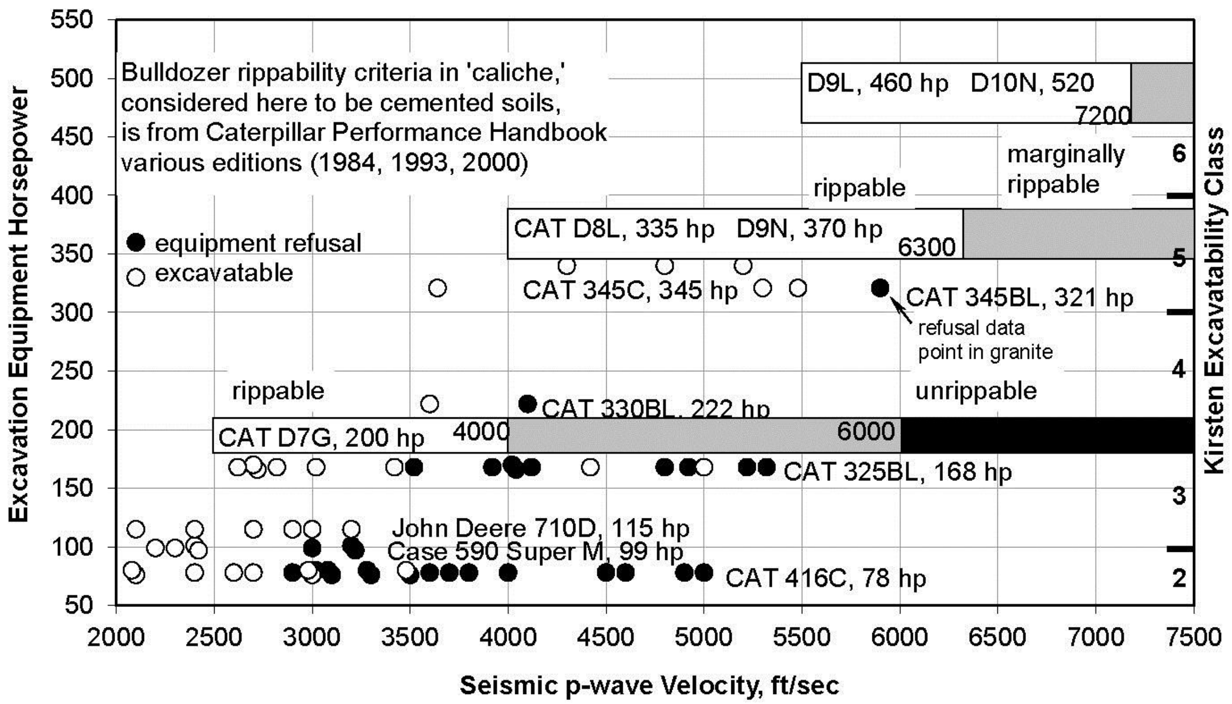
Approximate Excavatability of Materials
Using Various Ripping & Trenching Equipment

Material & Range of Marginal Rippability by Seismic Velocity (Cat, 1984; 1993; 2012)	Typical Bulldozer Used as Ripper for mass excavation (Cat, 1984; 1993; 2012)	Equivalent Backhoe for trenching excavation (Kirsten, 1982; 1988)
"Caliche"		
4,000 – 6,000 fps	D7G, 200 HP	235
5,500 – 7,700 fps	D8R/T, 305-310 HP	-
6,300 – 8,600 fps	D8L, 335 HP	245
6,300 – 8,600 fps	D9R/T, 405-410 HP	-
6,300 – 8,700 fps	D9N, 370 HP	-
7,200 – 10,300 fps	D9L, 460 HP	RH 40
7,200 – 10,300 fps	D10T, 580 HP	-
7,200 – 10,300 fps	D10N, 520 HP	-
7,400 – 10,600 fps	D10, 700 HP	-
7,500 – 11,000 fps	D11T, 850 HP	-
7,600 – 11,000 fps	D11N, 770 HP	
Sandstone		
5,500 – 6,300 fps	D7G, 200 HP	235
7,400 – 9,600 fps	D8L, 335 HP	245
7,300 – 9,600 fps	D9N, 370 HP	-
8,600 – 10,800 fps	D9L, 460 HP	RH 40
8,600 – 10,900 fps	D10N, 520 HP	-
9,400 – 11,400 fps	D10, 700 HP	-
9,800 – 12,000 fps	D11N, 770 HP	-
Limestone		
4,300 – 5,700 fps	D7G, 200 HP	235
7,700 – 9,200 fps	D8L, 335 HP	245
7,700 – 9,200 fps	D9N, 370 HP	-
8,600 – 11,000 fps	D9L, 460 HP	RH 40
8,600 – 11,000 fps	D10N, 520 HP	-
9,600 – 12,000 fps	D10, 700 HP	-
9,900 – 12,400 fps	D11N, 770 HP	-

Note: Bulldozer and backhoe power are presented by Kirsten (1982, 1988) as a measure of equivalent performance for excavation. The Caterpillar D6D bulldozer and 225 backhoe and D4E/D5B bulldozer and 215 backhoe are considered equivalent. Seismic velocities below marginal indicate that the material is rippable. Seismic velocities above marginal indicate that the material is non-rippable. All velocities are approximate and represent a typical range. See the Caterpillar Performance Handbook (Caterpillar, 1984, 1993, 2012 or current edition) for details on use of this information. Different model configurations include variations in weight and horsepower.

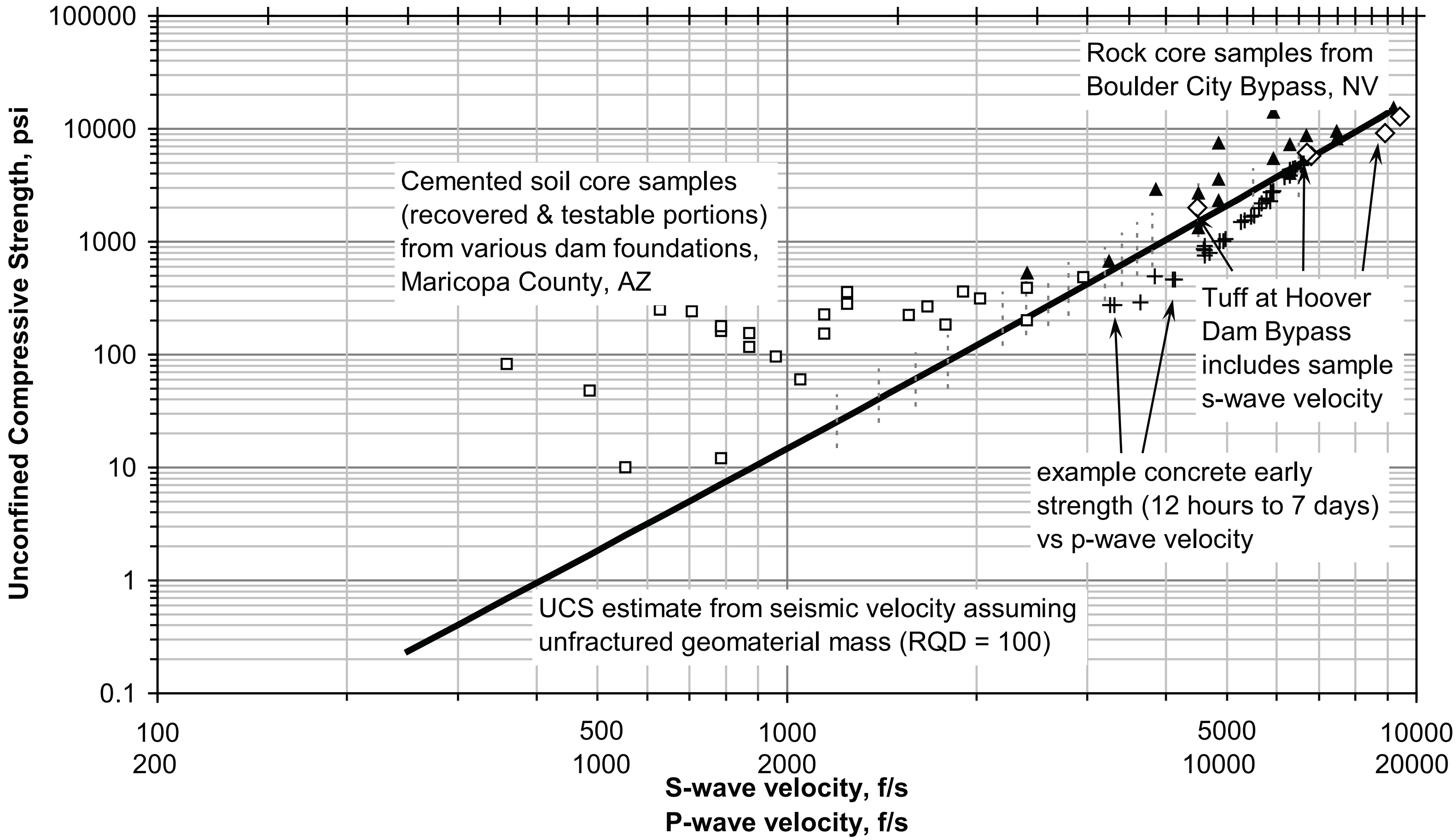
FIGURE C-1

Typical Excavatability Performance in Cemented Soils for Various Equipment Completing Test Pits in Salt River Valley Area

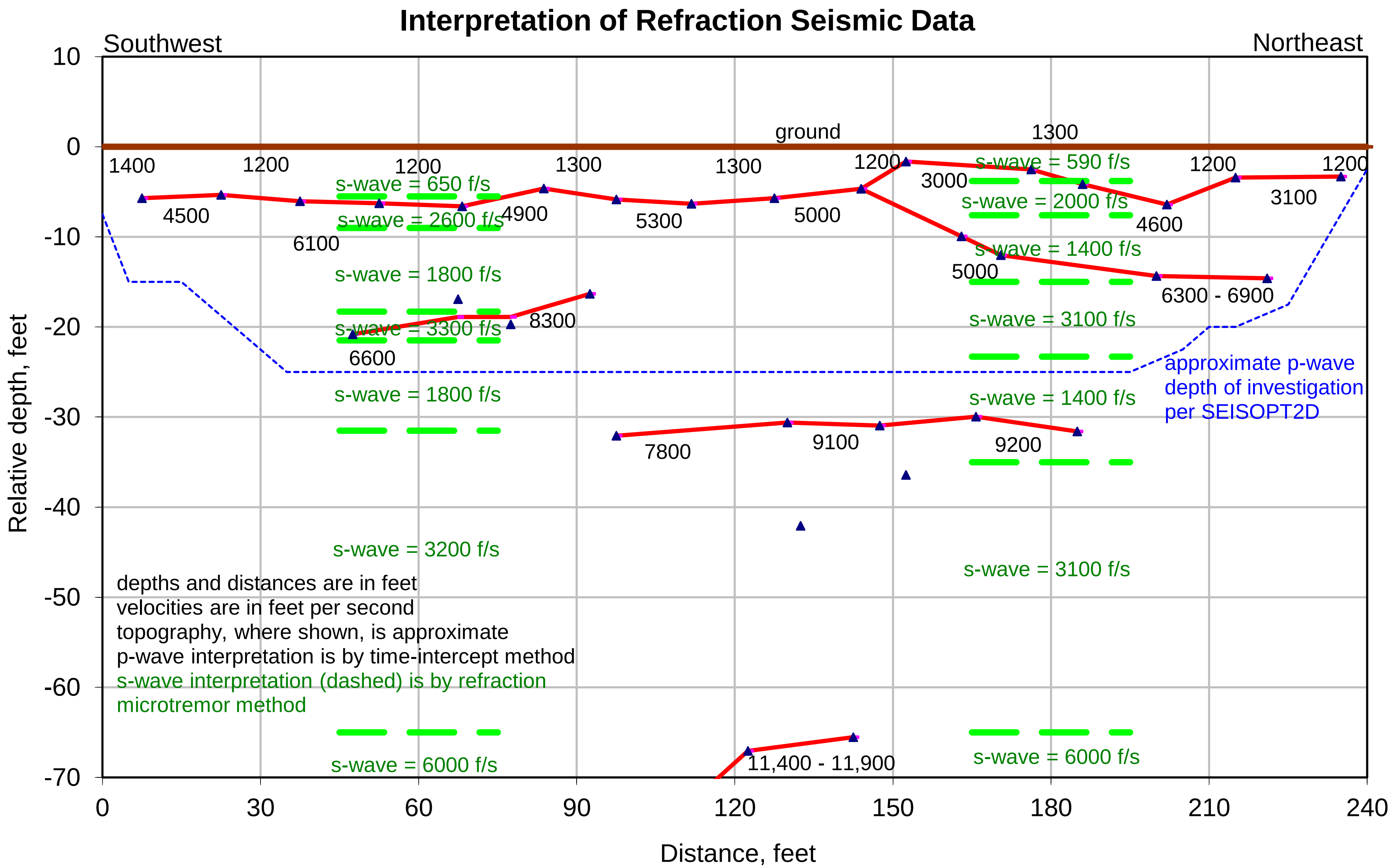


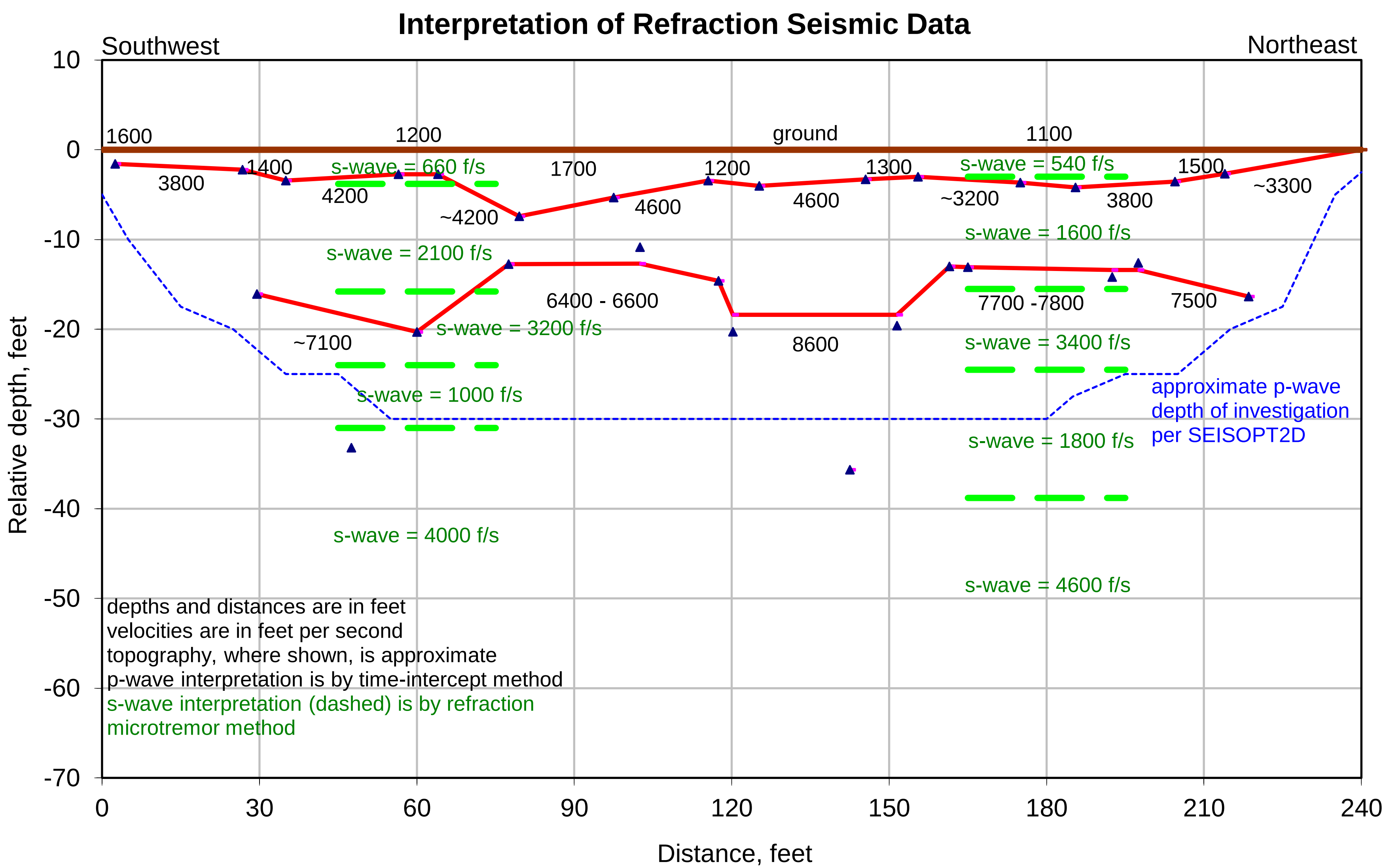
Note: From Rucker and Fergason, (2006; 2009). This chart documents typical backhoe and trackhoe excavation performance at lower seismic p-wave velocities than are presented in the Caterpillar Rippability Charts (CAT 1981, 1993, 2000). These correlations were developed in cemented materials as a function of subsurface material p-wave seismic velocity and equipment horsepower using data from test pits with overlapping seismic lines in the Salt River Valley, Arizona area. Although there are anticipated to be differences between cemented soils and highly weathered to decomposed granites, this chart shows a general trend of increasing p-wave velocities indicating more power required for excavation.

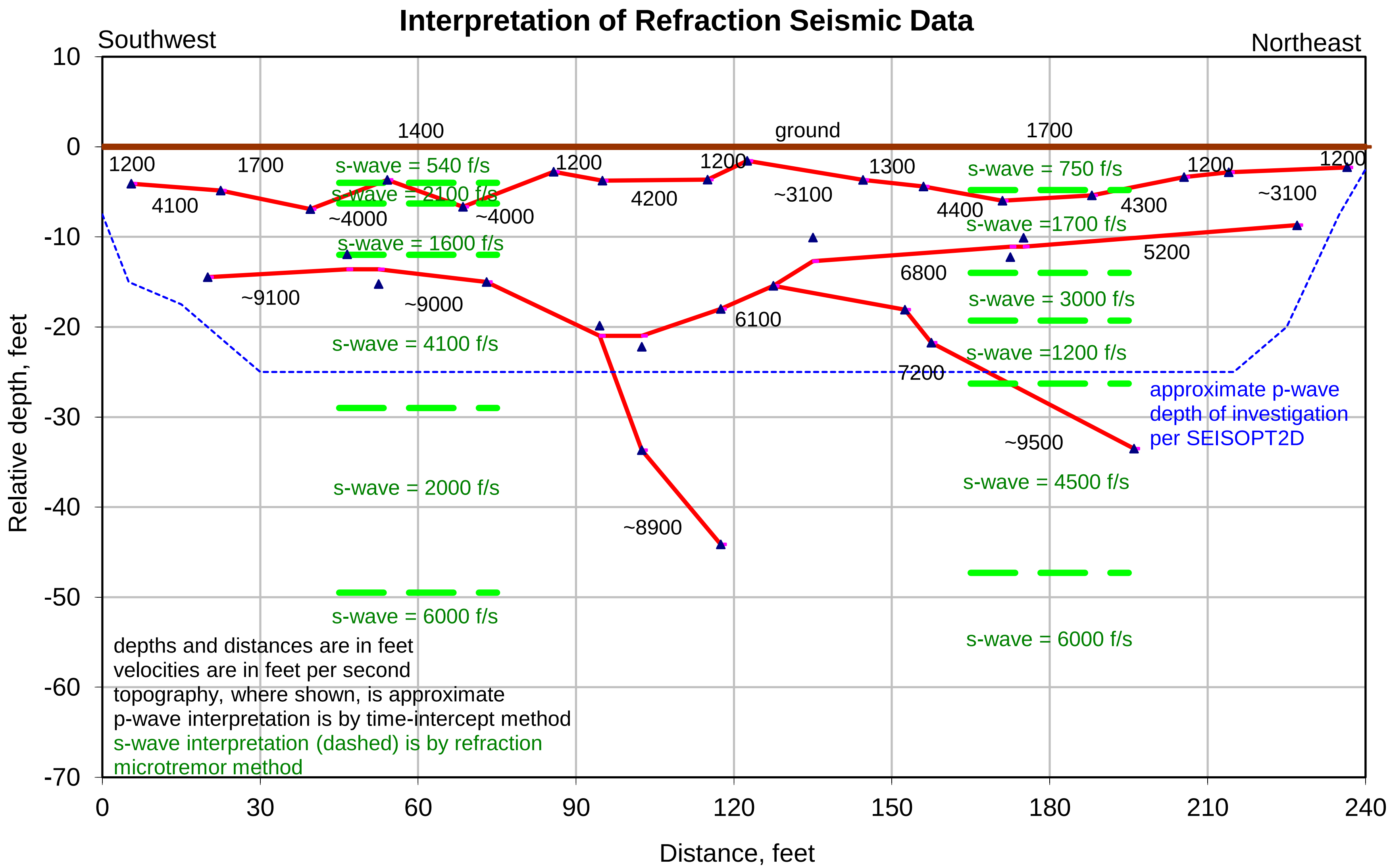
Chart B-1



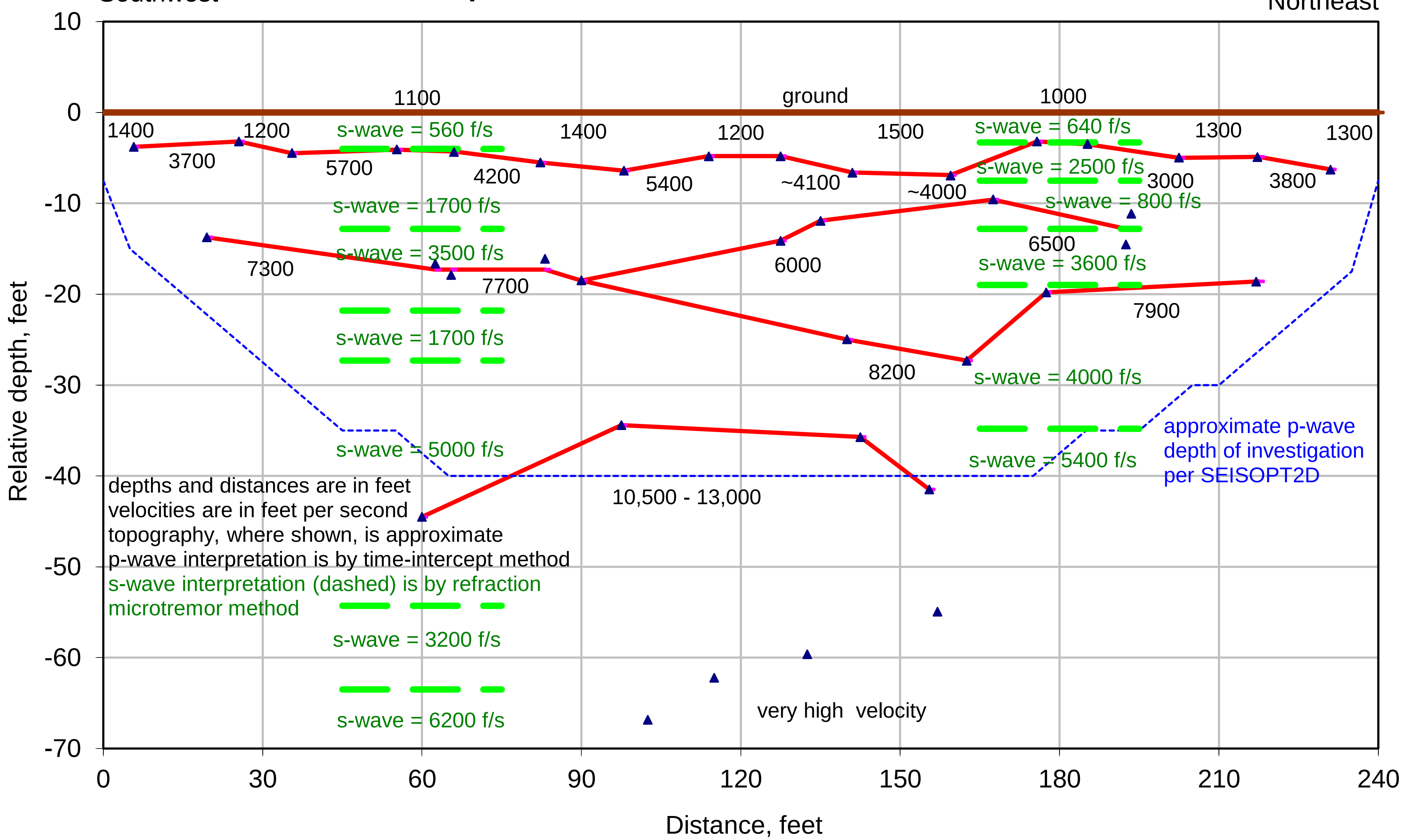
Note that this method assumes an unfractured geo-material mass (RQD = 100). Since fracturing tends to reduce seismic velocity, this method should typically underestimate UCS in fractured rock masses.


Interpretation of Refraction Seismic Data
Southwest
Northeast
ground
Relative depth, feet
Distance, feet
1400
1200
1200
1300
1300
1200
1300
1200
1200
4500
6100
4900
5300
5000
3000
3100
4600
5000
6300 - 6900
8300
6600
7800
9100
9200
11,400 - 11,900
s-wave = 650 f/s
s-wave = 2600 f/s
s-wave = 1800 f/s
s-wave = 3300 f/s
s-wave = 1800 f/s
s-wave = 3200 f/s
s-wave = 6000 f/s
s-wave = 590 f/s
s-wave = 2000 f/s
s-wave = 1400 f/s
s-wave = 3100 f/s
s-wave = 1400 f/s
s-wave = 3100 f/s
s-wave = 6000 f/s
approximate p-wave depth of investigation per SEISOPT2D
depths and distances are in feet
velocities are in feet per second
topography, where shown, is approximate
p-wave interpretation is by time-intercept method
s-wave interpretation (dashed) is by refraction microtremor method

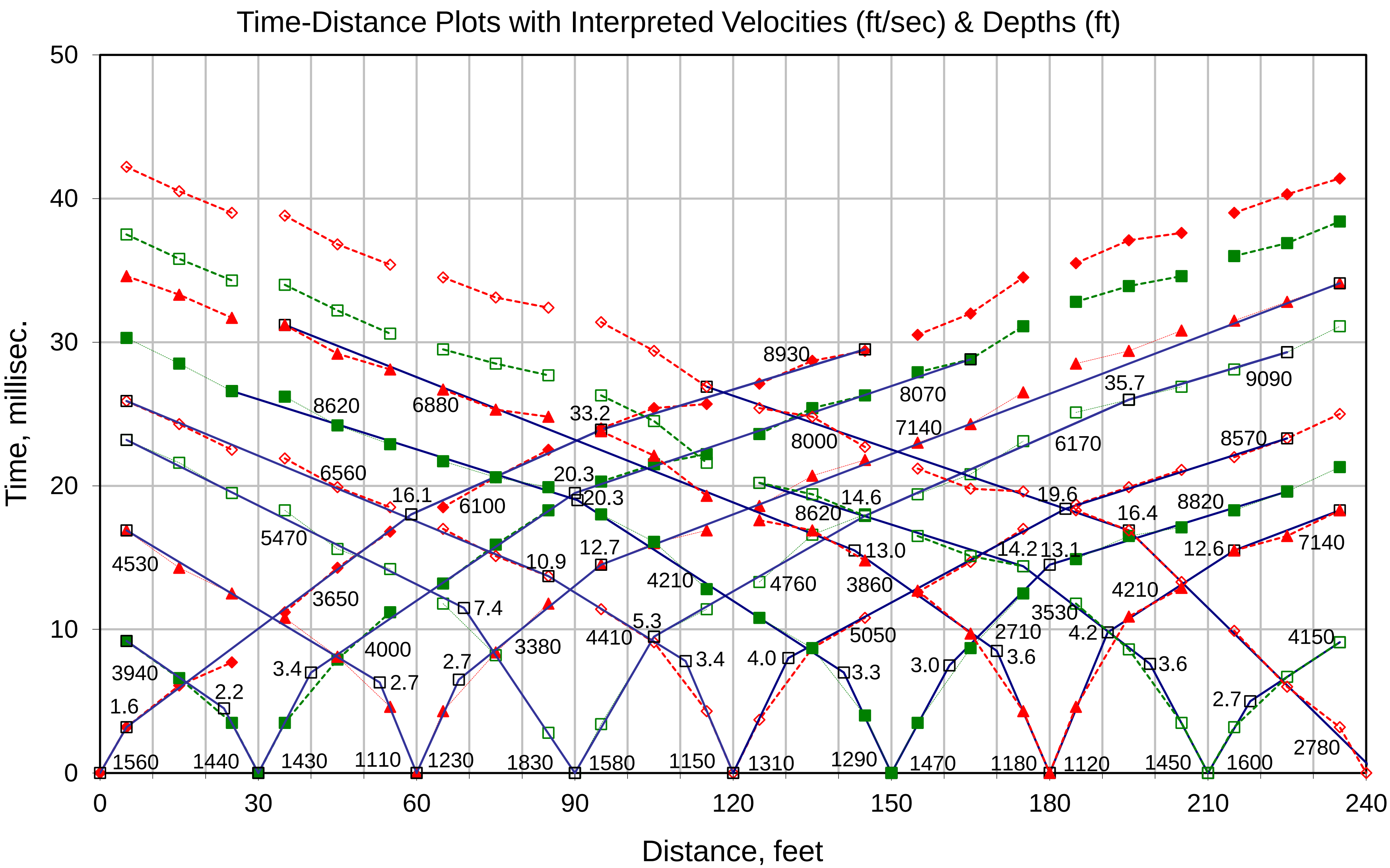

Interpretation of Refraction Seismic Data
Southwest
Northeast
1600
1200
ground
1100
1400
s-wave = 660 f/s
1700
1200
1300
s-wave = 540 f/s
1500
3800
4200
~4200
4600
4600
~3200
3800
~3300
s-wave = 1600 f/s
s-wave = 2100 f/s
6400 - 6600
7700 -7800
7500
s-wave = 3200 f/s
~7100
8600
s-wave = 3400 f/s
s-wave = 1000 f/s
approximate p-wave
depth of investigation
per SEISOPT2D
s-wave = 1800 f/s
s-wave = 4000 f/s
s-wave = 4600 f/s
depths and distances are in feet
velocities are in feet per second
topography, where shown, is approximate
p-wave interpretation is by time-intercept method
s-wave interpretation (dashed) is by refraction
microtremor method
Relative depth, feet
Distance, feet
10
0
-10
-20
-30
-40
-50
-60
-70
0
30
60
90
120
150
180
210
240


Interpretation of Refraction Seismic Data
Southwest
Northeast
Relative depth, feet
Distance, feet
ground
1400
1700
1200
1700
1200
1200
1300
1200
1200
4100
~4000
~4000
4200
~3100
4400
4300
~3100
5200
6800
~9100
~9000
6100
7200
~9500
~8900
s-wave = 540 f/s
s-wave = 2100 f/s
s-wave = 1600 f/s
s-wave = 4100 f/s
s-wave = 2000 f/s
s-wave = 6000 f/s
s-wave = 750 f/s
s-wave =1700 f/s
s-wave = 3000 f/s
s-wave =1200 f/s
s-wave = 4500 f/s
s-wave = 6000 f/s
approximate p-wave depth of investigation per SEISOPT2D
depths and distances are in feet
velocities are in feet per second
topography, where shown, is approximate
p-wave interpretation is by time-intercept method
s-wave interpretation (dashed) is by refraction microtremor method

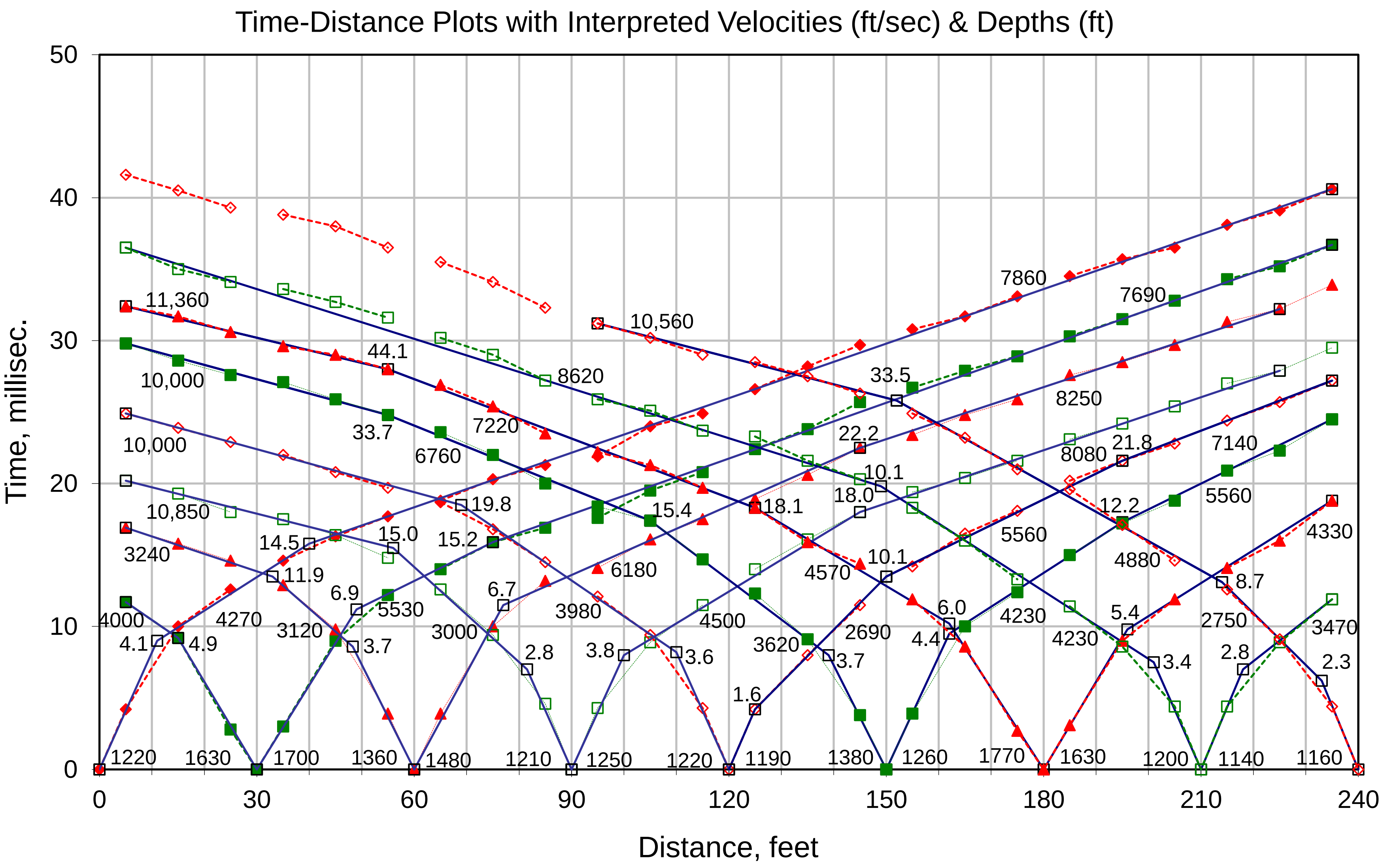
Interpretation of Refraction Seismic Data



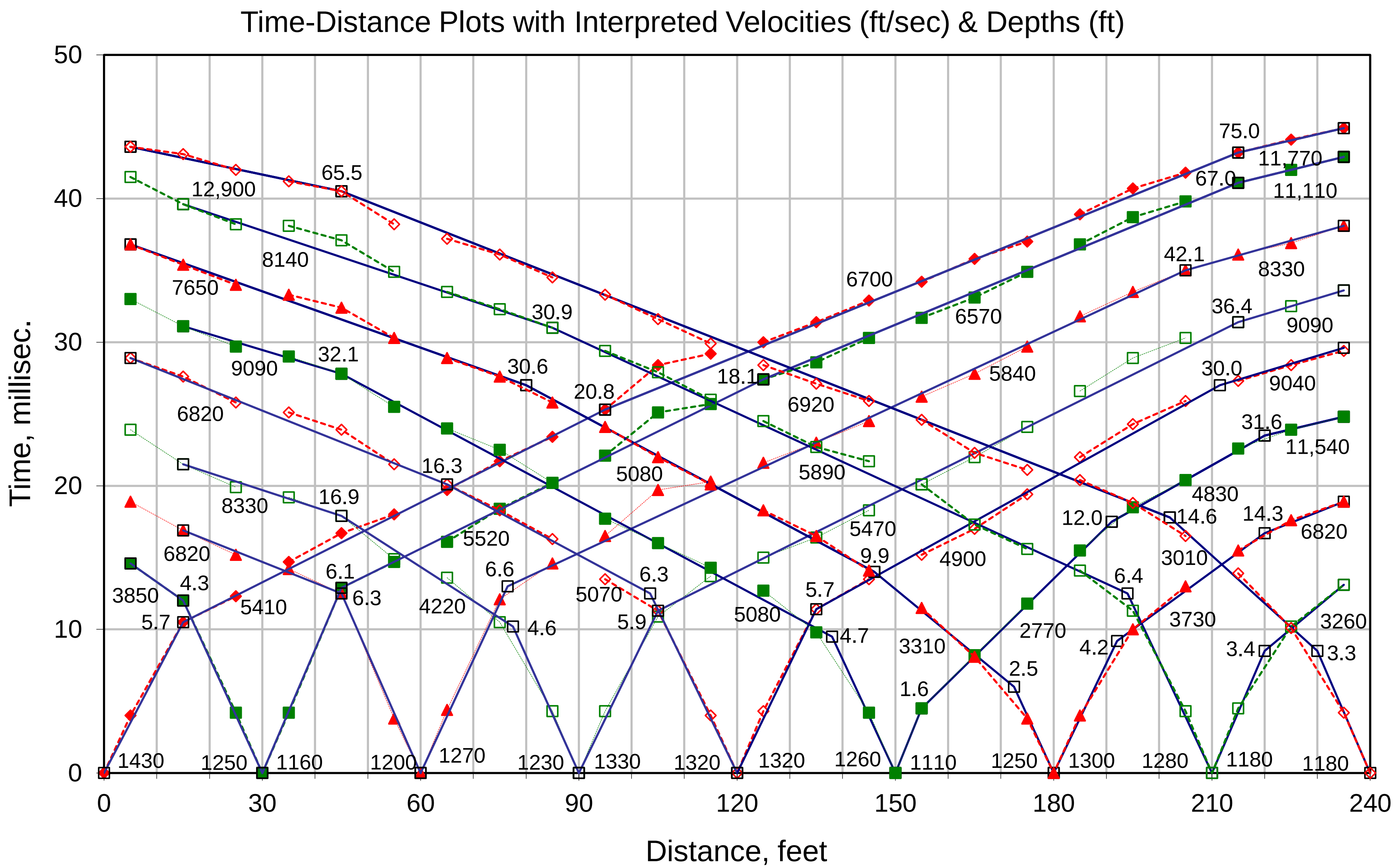
Line 2

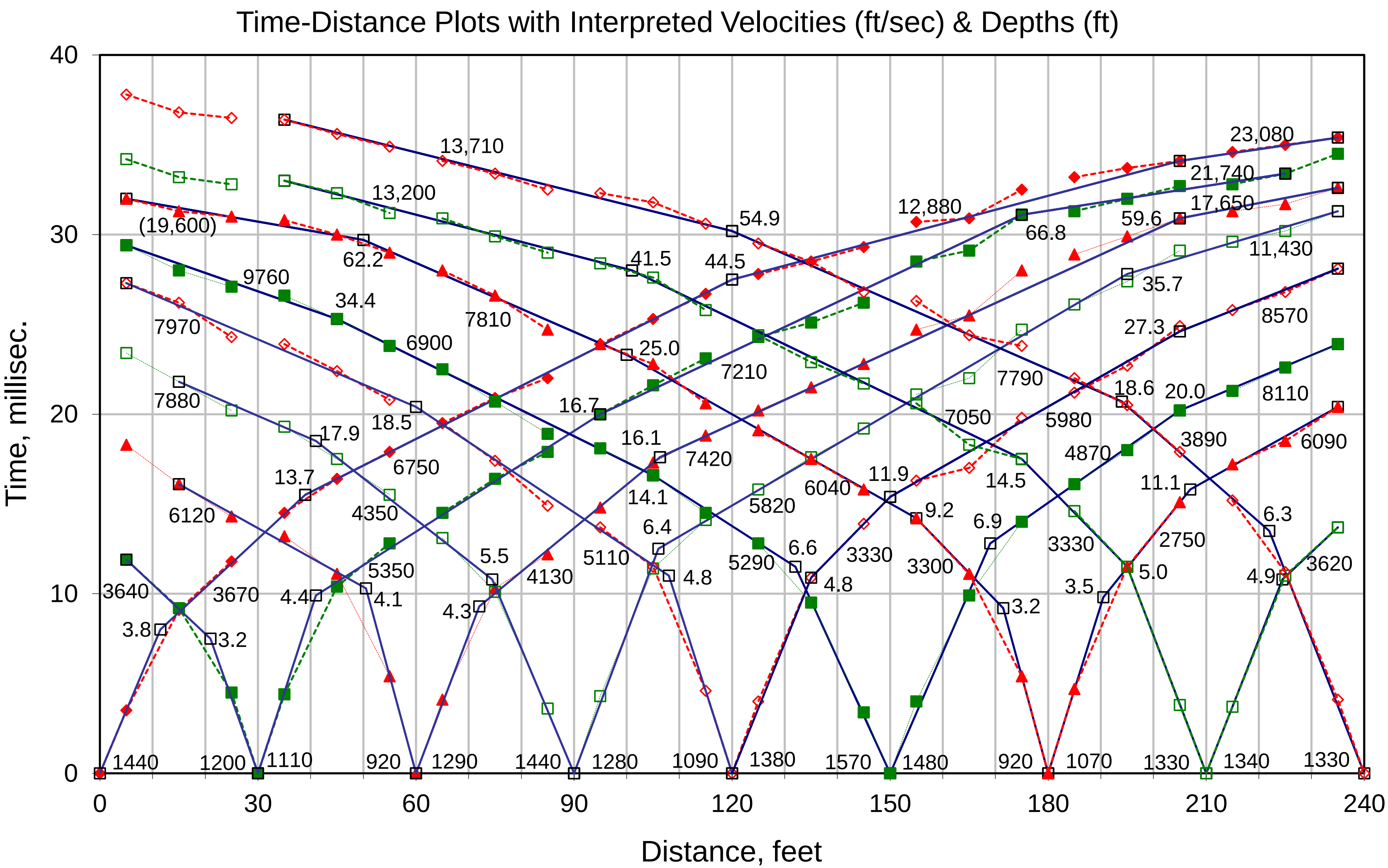

Time-Distance Plots with Interpreted Velocities (ft/sec) & Depths (ft)
Time, millisec.
Distance, feet
0
10
20
30
40
50
0
30
60
90
120
150
180
210
240
1560
1440
1430
1110
1230
1830
1580
1150
1310
1290
1470
1180
1120
1450
1600
2780
3940
4530
5470
3650
4000
3380
4410
4210
4760
3860
5050
2710
3530
4210
4150
8620
6880
6560
6100
8930
8070
8000
7140
8620
6170
8570
8820
9090
7140
1.6
2.2
3.4
2.7
2.7
7.4
16.1
10.9
20.3
20.3
12.7
33.2
5.3
3.4
4.0
3.3
14.6
13.0
3.0
3.6
14.2
13.1
19.6
16.4
35.7
4.2
3.6
2.7
12.6

Line 3


Time-Distance Plots with Interpreted Velocities (ft/sec) & Depths (ft)
Time, millisec.
Distance, feet
0
10
20
30
40
50
0
30
60
90
120
150
180
210
240
11,360
10,000
10,000
10,850
3240
4000
4.1
4.9
4270
3120
1220
1630
1700
1360
1480
1210
1250
1220
1190
1380
1260
1770
1630
1200
1140
1160
44.1
33.7
6760
7220
8620
10,560
14.5
11.9
6.9
5530
3.7
15.0
15.2
19.8
6.7
3000
2.8
3980
3.8
6180
15.4
3.6
4500
1.6
18.1
3620
4570
3.7
18.0
10.1
22.2
33.5
10.1
2690
4.4
6.0
7860
8250
8080
5560
4230
4230
21.8
12.2
5.4
3.4
7690
7140
5560
4880
8.7
2750
2.8
4330
3470
2.3

Line 1

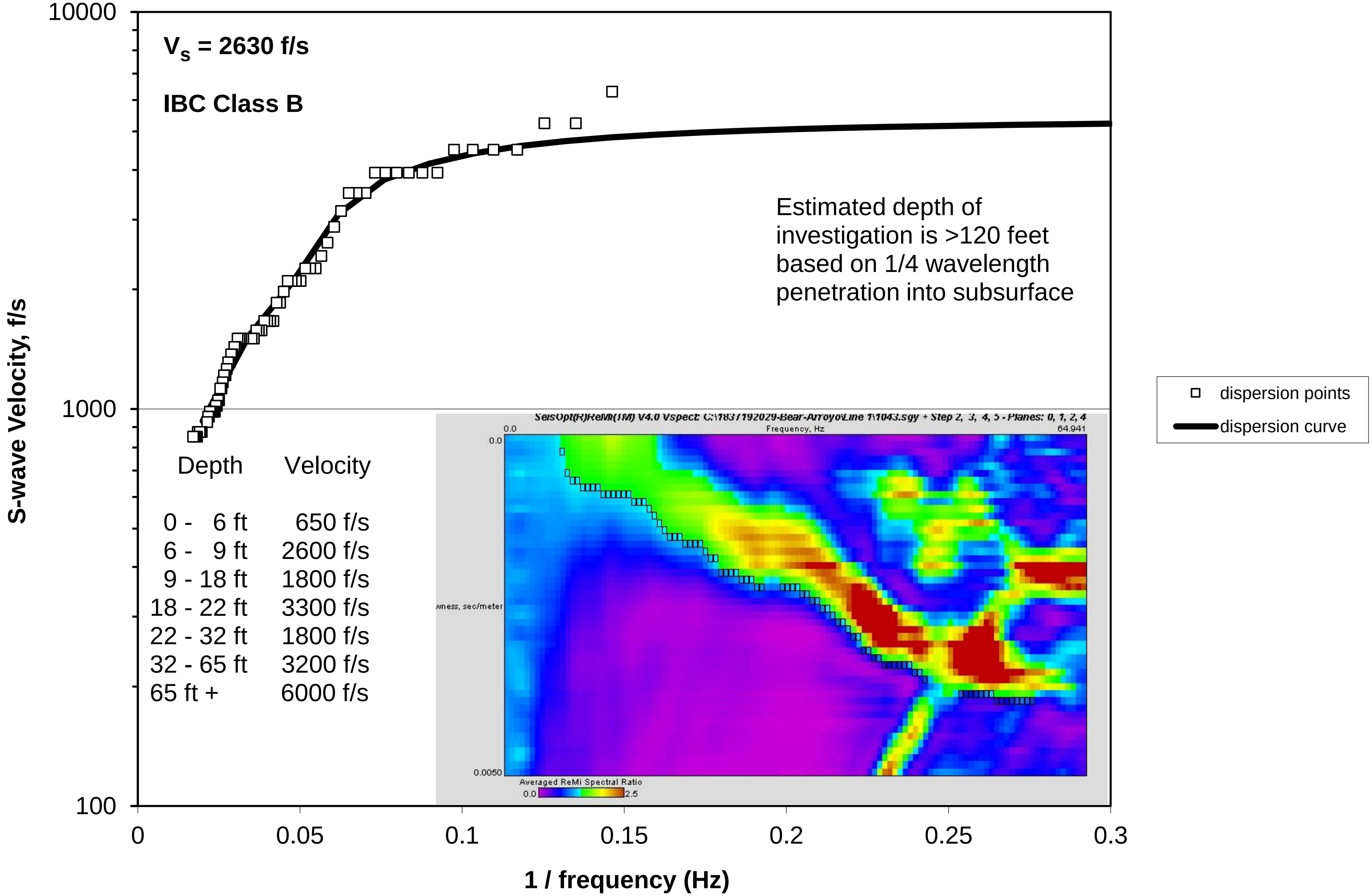

Time-Distance Plots with Interpreted Velocities (ft/sec) & Depths (ft)
Time, millisec.
Distance, feet
0
10
20
30
40
50
0
30
60
90
120
150
180
210
240
75.0
11,770
67.0
11,110
65.5
12,900
8140
7650
6700
6570
42.1
8330
36.4
9090
32.1
9090
30.9
30.6
20.8
18.1
6920
5840
30.0
9040
31.6
11,540
6820
16.3
5080
5890
4830
16.9
8330
12.0
14.6
14.3
6820
5520
5470
4900
3010
6820
6.1
6.3
6.6
6.3
9.9
6.4
4.3
3850
5.7
5410
4220
5070
5.9
5080
5.7
4.7
3310
2770
4.2
3730
3.4
3260
3.3
4.6
1.6
2.5
1430
1250
1160
1200
1270
1230
1330
1320
1320
1260
1110
1250
1300
1280
1180
1180


Time-Distance Plots with Interpreted Velocities (ft/sec) & Depths (ft)
Time, millisec.
Distance, feet
13,710
13,200
54.9
12,880
23,080
21,740
17,650
(19,600)
62.2
41.5
44.5
66.8
59.6
11,430
9760
34.4
7810
35.7
7970
6900
25.0
7210
27.3
8570
7880
16.7
7790
18.6
20.0
8110
17.9
18.5
16.1
7420
7050
5980
3890
6090
6750
4870
13.7
14.1
11.9
14.5
11.1
6120
4350
5820
6040
9.2
6.9
6.3
6.4
3330
3330
2750
5.5
5110
5290
6.6
3300
3620
5350
4130
4.8
4.8
3.5
5.0
4.9
3640
3670
4.4
4.1
4.3
3.2
3.8
3.2
1440
1200
1110
920
1290
1440
1280
1090
1380
1570
1480
920
1070
1330
1340
1330

Refraction Microtremor S-wave Interpretation

Line 1A
(0 - 120')

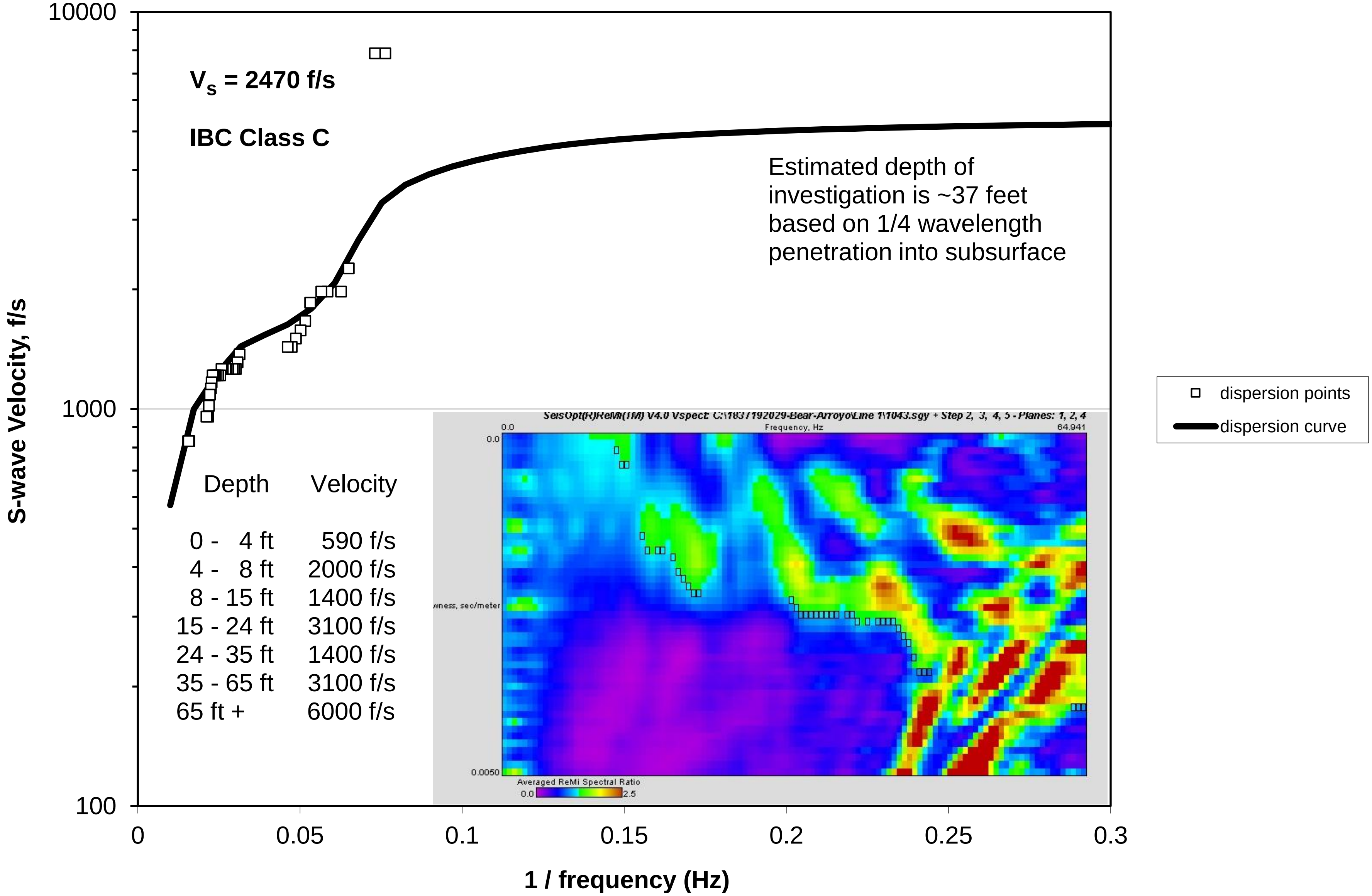
Wood Job No.18-3719-2029



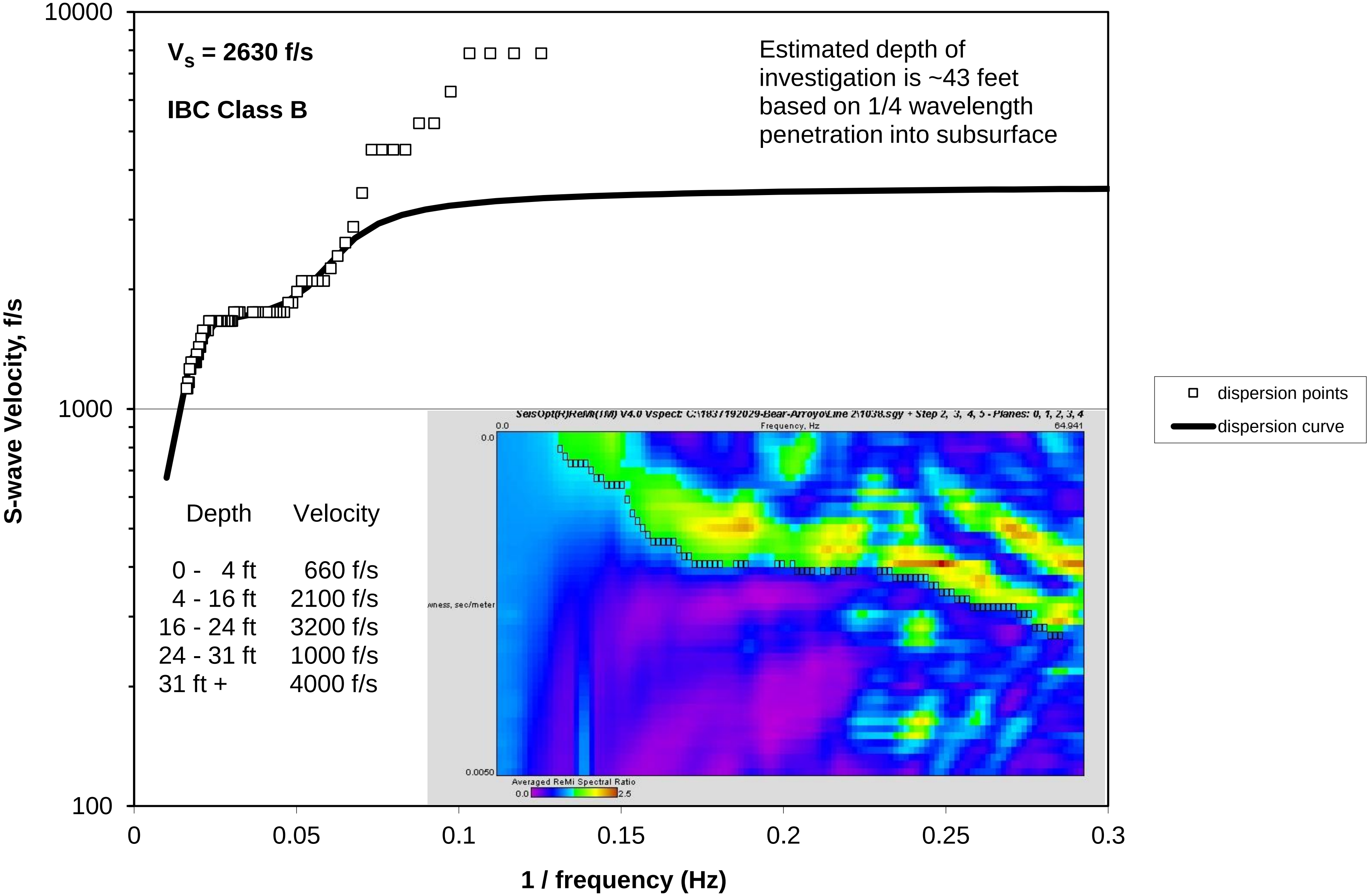
Refraction Microtremor S-wave Interpretation

Line 1B
(120 - 240')

Wood Job No.18-3719-2029



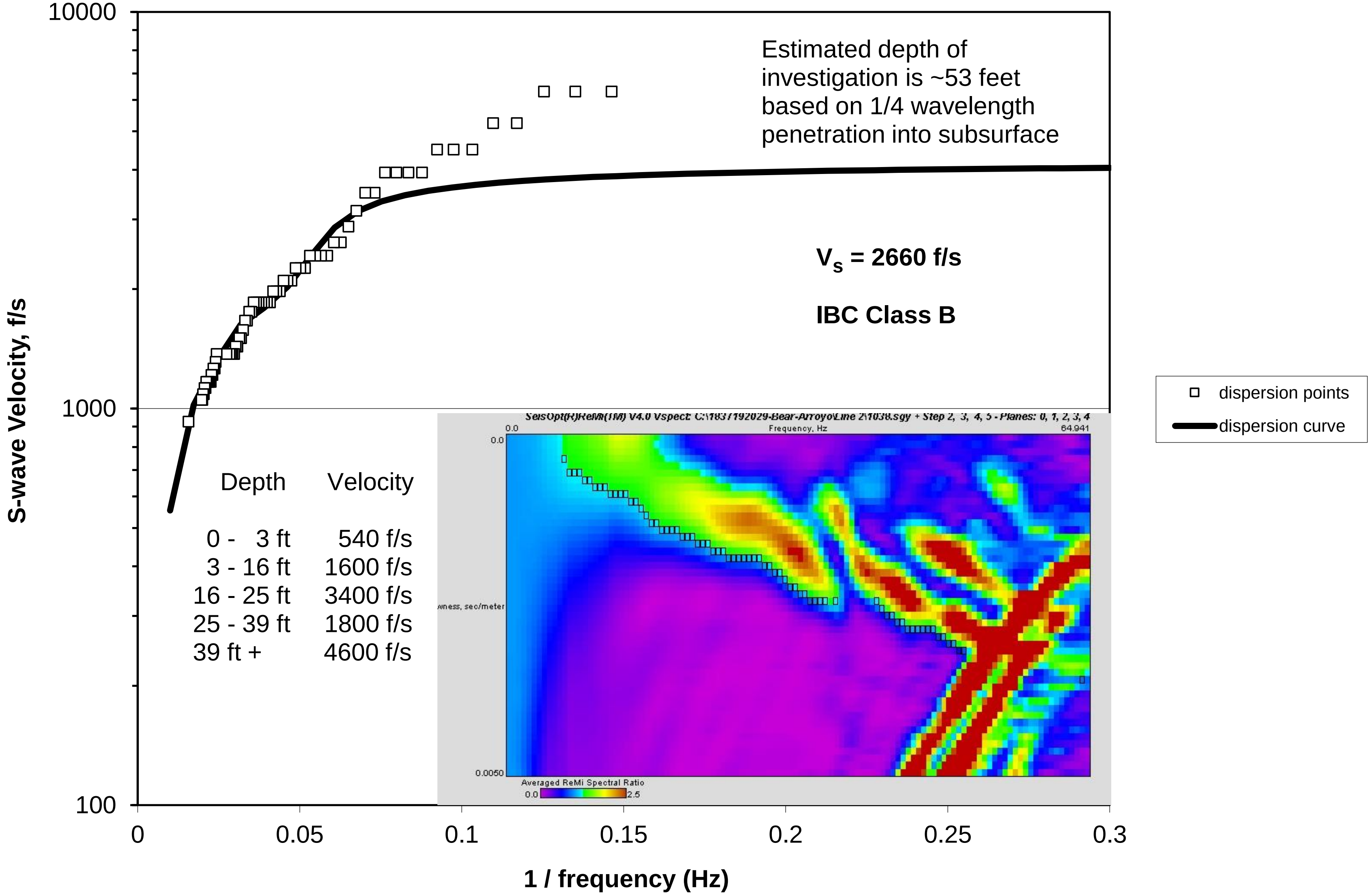
Line 2A
(0 - 120')


10000
1000
100
S-wave Velocity, f/s
0
0.05
0.1
0.15
0.2
0.25
0.3
1 / frequency (Hz)
Vs = 2630 f/s
IBC Class B
Estimated depth of investigation is ~43 feet based on 1/4 wavelength penetration into subsurface
Depth Velocity
0 - 4 ft 660 f/s
4 - 16 ft 2100 f/s
16 - 24 ft 3200 f/s
24 - 31 ft 1000 f/s
31 ft + 4000 f/s
Frequency, Hz
Averaged ReMi Spectral Ratio
dispersion points
dispersion curve

Refraction Microtremor S-wave Interpretation

Line 2B
(120 - 240')

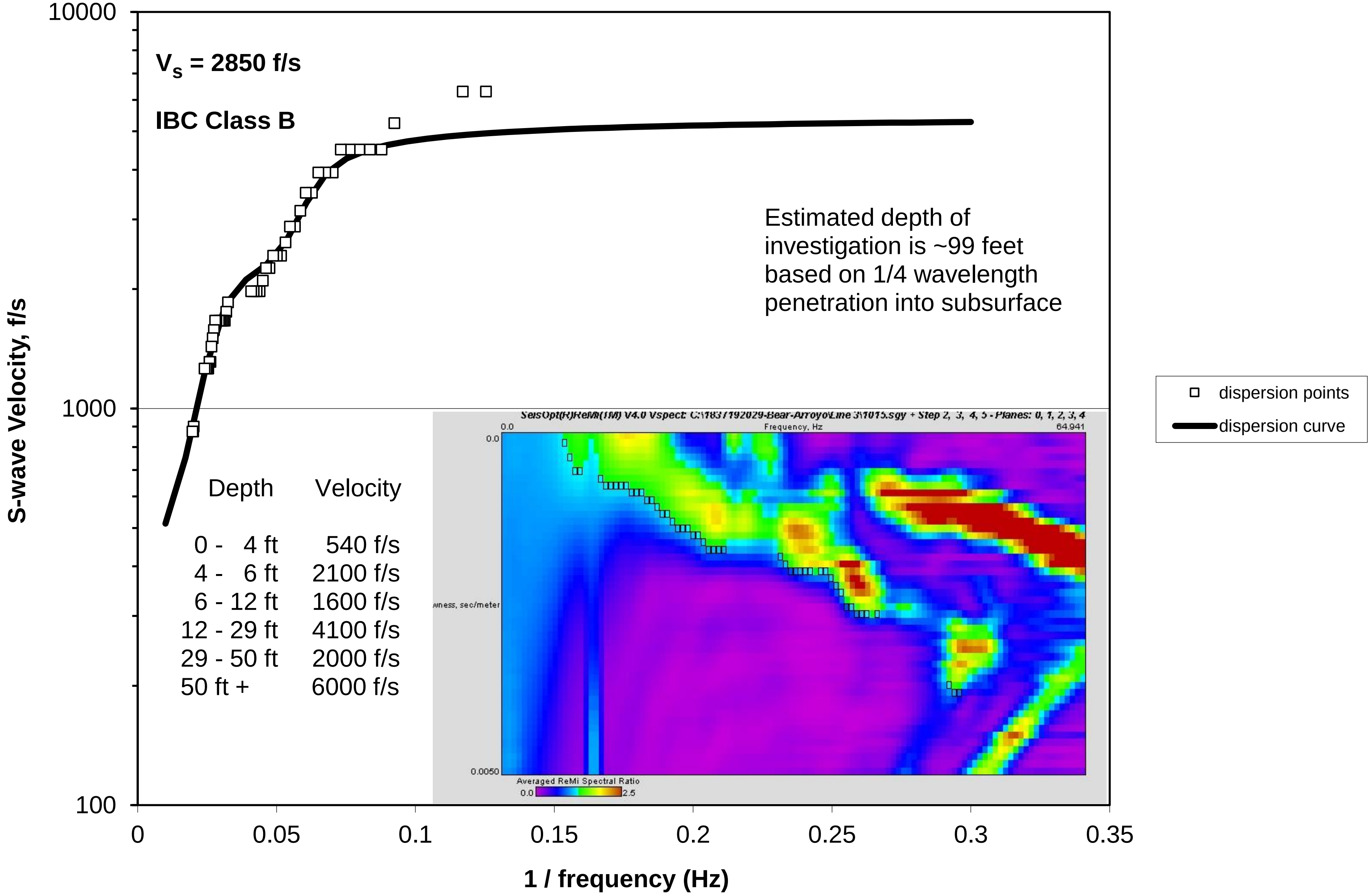
Wood Job No.18-3719-2029



Refraction Microtremor S-wave Interpretation

Line 3A
(0 - 120')

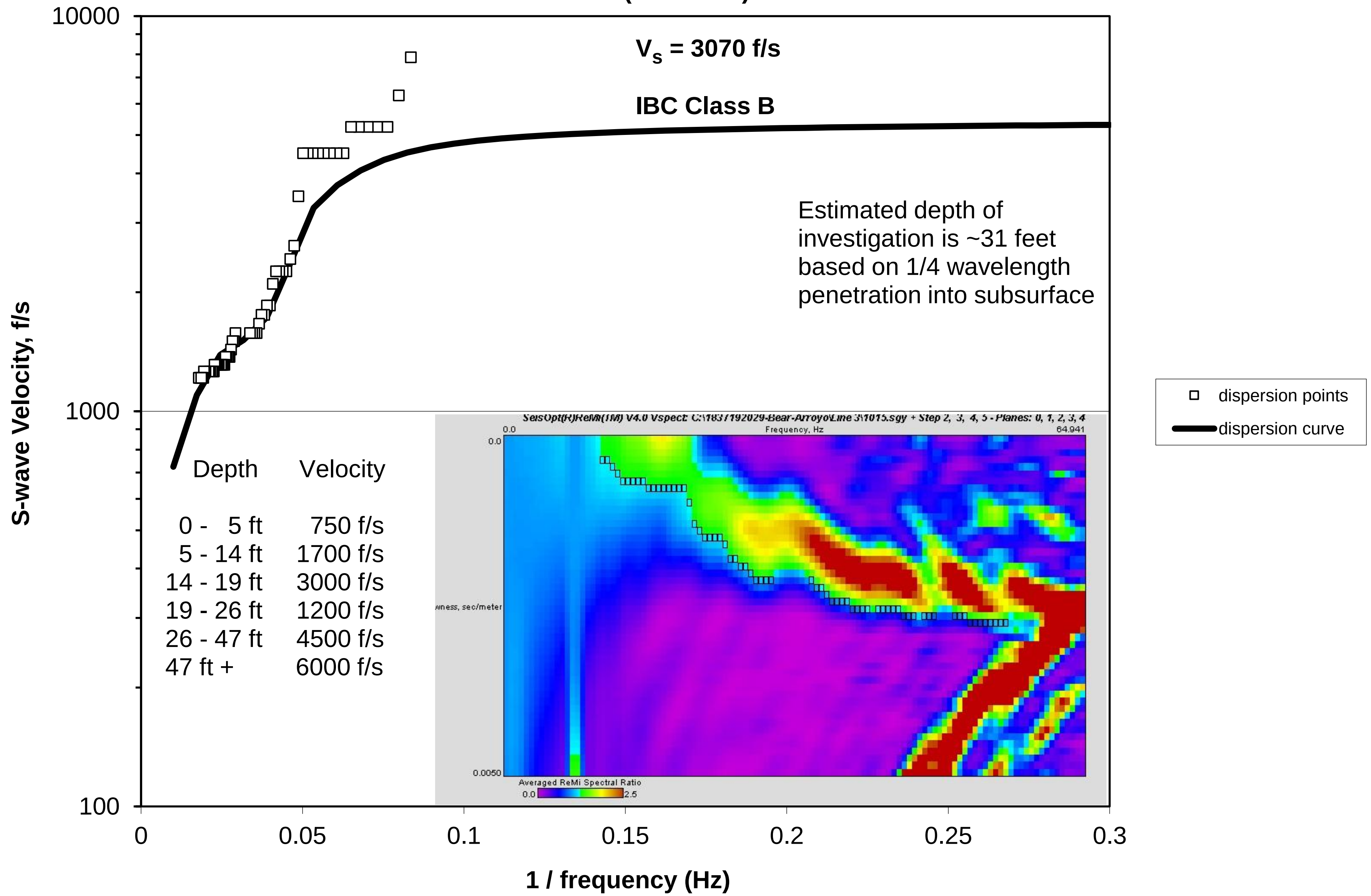
Wood Job No.18-3719-2029



Refraction Microtremor S-wave Interpretation

Line 3B
(120 - 240')

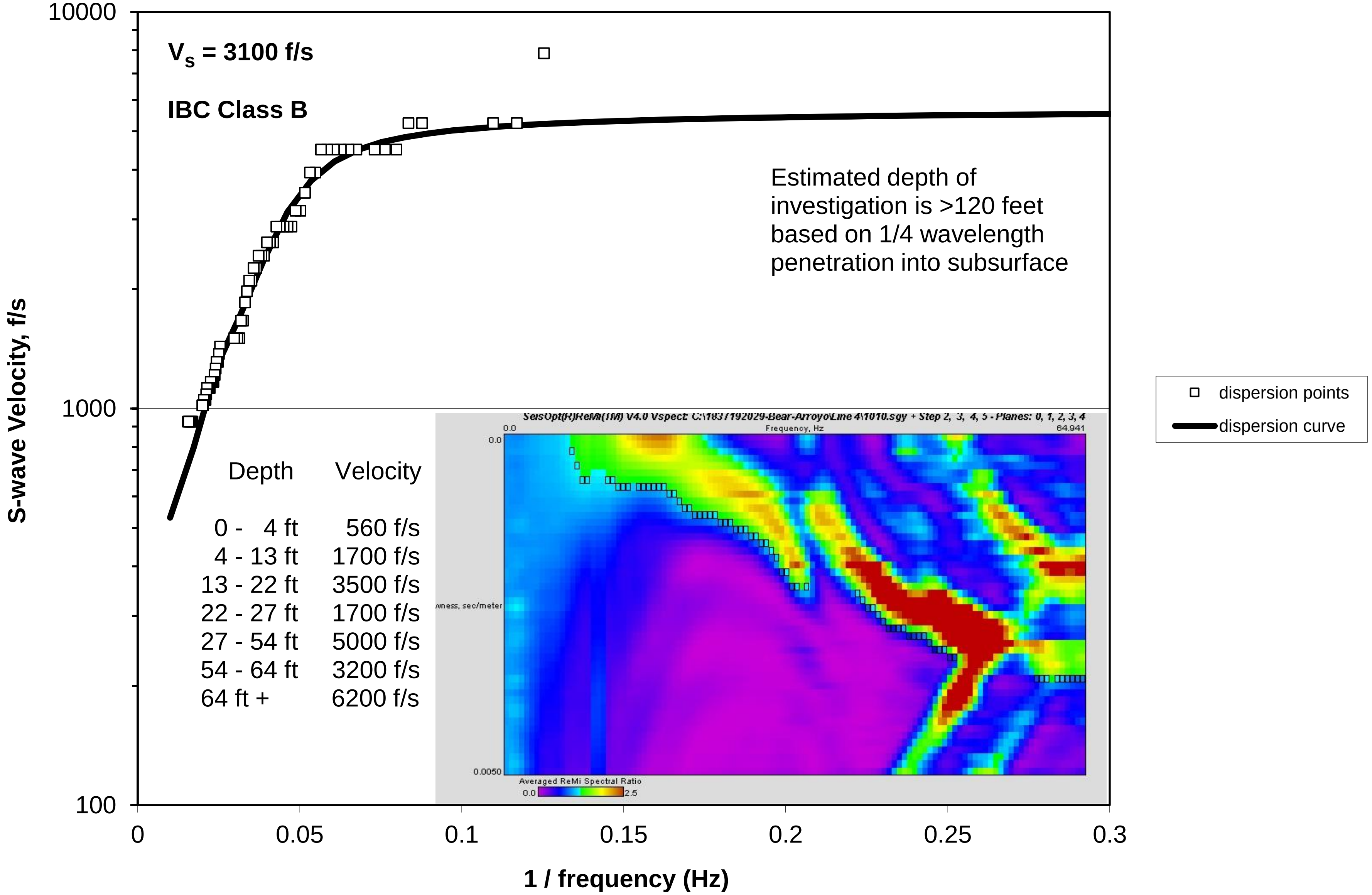
Wood Job No.18-3719-2029



Refraction Microtremor S-wave Interpretation

Line 4A
(0 - 120')

Wood Job No.18-3719-2029



Line 4B
(120 - 240')