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January 2008

Technical Report: Geotechnical Data for a Geologic Repository at Yucca Mountain, Nevada

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CHANGE HISTORY

Revision Number	Interim Change No.	Date	Description of Change
00		January 2008	Initial issue. To clarify the programmatic responsibilities for this report, the USGS/USBR contribution is generally contained in Sections 6.2.2 through 6.2.4 and Attachments I to III. The scope includes the compilation and interpretation of geologic data from boreholes, including thickness of alluvium; geotechnical laboratory static testing of physical properties of alluvium in core from sonic boreholes; and geologic and geotechnical data from mapping, logging, and testing of test pits in alluvium.

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The following individuals contributed to this report as co-originators: Dr. Kenneth Stokoe, Dr. Yin-Cheng Lin, Seong Yeol Jeon, Won Kyoung Choi, and Zane Walton.

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CONTENTS

CONTENTS (Continued)

FIGURES

FIGURES (Continued)

FIGURES (Continued)

FIGURES (Continued)

FIGURES (Continued)

FIGURES (Continued)

FIGURES (Continued)

FIGURES (Continued)

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ACRONYMS, ABBREVIATIONS, AND SYMBOLS

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
bgs	below ground surface
Calicobt	Calico Hills Formation bedded tuff
cm	centimeter, centimeters
CRWMS	Civilian Radioactive Waste Management System
Dev.	Devitrified
DTN	data tracking number
ECRB	Enhanced Characterization of the Repository Block
ESF	Exploratory Studies Facility
f	frequency in Hertz (cycles per sec)
ft	foot, feet (unit of measurement)
ft/s	feet per second
ft/sec	feet per second
FFT	Fast Fourier Transform
g	gram, grams
g/cm^3	grams per cubic centimeter
GFM	Geologic Framework Model
GM	silty gravel or silty gravel with sand
G_{max}	low-strain (maximum) shear modulus
GP	poorly graded gravel or poorly graded gravel with sand
GP-GM	poorly graded gravel with silt or poorly graded gravel with silt and sand
GR	gamma ray
GW	well-graded gravel or well-graded gravel with sand
GW-GM	well-graded gravel with silt or well-graded gravel with silt and sand
Hz	Hertz
in	inch
ITS	important-to-safety
kPa	kilopascals (i.e., thousand newtons per square meter, or about 20.886 lbs/ft^2)
ksf	kips-force per square foot
lbs	pounds (either pounds-force or pounds-mass)
lbs/ft^2	pounds-force per square foot
lbf/ft^3	pounds-force per cubic foot
lbm/ft^3	pounds-mass per cubic foot
lbs/ft^3	pounds per cubic foot (either pounds-force or pounds-mass)

ACRONYMS, ABBREVIATIONS AND SYMBOLS (Continued)

MPa	megapascal (i.e., million newtons per square meter, or about 20,886 lbs/ft^2)
ms	millisecond
msec	millisecond
Pah	Pah Canyon Tuff (Tpp)
pcf	pounds per cubic foot (either pounds-force or pounds-mass)
pp	pages
Prowuv	Prow Pass Tuff upper vitric nonwelded zone
Prowmd	Prow Pass Tuff moderately densely welded zone
Prowlv	Prow Pass Tuff lower vitric nonwelded zone
psi	pounds-force per square inch
“Q”	“quality”
QA	quality assurance
Qal	Quaternary alluvium
QAP	Quality Administrative Procedure
QTac	undifferentiated Quaternary/Tertiary alluvium and colluvium
RC	relative compaction
RC	resonant column
RCTS	resonant column and torsional shear
Rev	revision
RHHtop	Repository Host Horizon top
RQD	Rock Quality Designator or Rock Quality Designation
s	second
SASW	spectral analysis of surface waves
sec	second
SM	silty sand or silty sand with gravel
SMF	Sample Management Facility
SP	poorly graded sand or poorly graded sand with gravel
SP-SM	poorly graded sand with silt or poorly graded sand with silt and gravel
SW	well-graded sand or well-graded sand with gravel
SW-SM	well-graded sand with silt or well-graded sand with silt and gravel
SSD	saturated surface dry
Tac	Calico Hills Formation
TAD	Transporation, Aging, and Disposal
Tcb	Bullfrog Tuff
Tcbbt	pre-Bullfrog Tuff bedded tuff
Tcp	Prow Pass Tuff
Tcpbt	pre-Prow Pass Tuff bedded tuff
Tct	Tram Tuff
TIC	Technical Information Center
TDMS	Technical Data Management System

ACRONYMS, ABBREVIATIONS AND SYMBOLS (Continued)

Tmbt1	pre-Rainier Mesa Tuff bedded tuff
Tmr	Rainer Mesa Tuff of the Timber Mountain Group
Tpc	Tiva Canyon Tuff
TpcLD	Tiva Canyon Tuff: crystal-poor member, lower nonlithophysal zone, columnar subzone, low density zone
Tpp	Pah Canyon Tuff
Tpbt1	pre-Topopah Spring Tuff bedded tuff
Tpbt2	pre-Pah Canyon Tuff bedded tuff
Tpbt3	pre-Yucca Mountain Tuff bedded tuff
Tpbt3_dc	pre-Yucca Mountain Tuff bedded tuff – Delirium Canyon
Tpbt4	pre-Tiva Canyon Tuff bedded tuff
Tpbt5	pre-Tuff unit “x” bedded tuffs (also known as post-Tiva Canyon Tuff bedded tuff)
Tpcp	Tiva Canyon Tuff
Tpcpll	Tiva Canyon Tuff: crystal-poor member, lower lithophysal zone
Tpcpln	Tiva Canyon Tuff: crystal-poor member, lower nonlithophysal zone
Tpcpmn	Tiva Canyon Tuff: crystal-poor member, middle nonlithophysal zone
Tpcpul	Tiva Canyon Tuff: crystal-poor member, upper lithophysal zone
Tpcpun	Tiva Canyon Tuff: crystal-poor member, upper non-lithophysal zone
Tpcpv	Tiva Canyon Tuff: crystal-poor member, vitric zone
Tpcpv1	Tiva Canyon Tuff: crystal-poor member, vitric zone, nonwelded to partially welded subzone
Tpcpv2	Tiva Canyon Tuff: crystal- poor member, vitric zone, moderately welded subzone
Tpcpv3	Tiva Canyon Tuff: crystal- poor member, vitric zone, densely welded subzone
Tpcr	Tiva Canyon Tuff: crystal-rich member
Tpcrl	Tiva Canyon Tuff: crystal-rich member, lithophysal zone
Tpcrn	Tiva Canyon Tuff: crystal-rich member, nonlithophysal zone
Tpcrv	Tiva Canyon Tuff: crystal-rich member, vitric zone
Tpcrv1	Tiva Canyon Tuff: crystal-rich member, vitric zone, vitrophyre subzone
Tpcrv2	Tiva Canyon Tuff: crystal-rich member, vitric zone, moderately welded subzone
Tpcrv3	Tiva Canyon Tuff: crystal-rich member, vitric zone, non to partially welded subzone
Tpcy	Pinyon Pass Tuff
Tpki	Tuff unit “x”
Tpp	Pah Canyon Tuff
Tptf	Topopah Spring Tuff: crystal-poor member, lithic-rich zone
Tptrl	Topopah Spring Tuff: crystal-rich member, lithophysal zone
Tptrn	Topopah Spring Tuff: crystal-rich member, nonlithophysal zone
Tptpf/Tptrf	Topopah Spring Tuff: crystal-poor member, lithic-rich zone
Tptpll	Topopah Spring Tuff: crystal-poor member, lower lithophysal zone
Tptpln	Topopah Spring Tuff: crystal-poor member, lower nonlithophysal zone
Tptpmn	Topopah Spring Tuff: crystal-poor member, middle nonlithophysal zone
Tptpul	Topopah Spring Tuff: crystal-poor member, upper lithophysal zone

ACRONYMS, ABBREVIATIONS AND SYMBOLS (Continued)

Tptpv	Topopah Spring Tuff: crystal-poor member, vitric zone
Tptpv1	Topopah Spring Tuff: crystal-poor member, vitric zone, moderately welded subzone
Tptpv2	Topopah Spring Tuff: crystal-poor member, vitric zone, nonwelded subzone
Tptpv3	Topopah Spring Tuff: crystal-poor member, vitric zone, densely welded subzone
Tptrv3	Topopah Spring Tuff: crystal-rich member, vitric zone, nonwelded subzone
Tpy	Yucca Mountain Tuff
TS	torsional shear
TWP	technical work plan
URC	unconfined resonant column
USBR	U.S. Bureau of Reclamation
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
UTA	University of Texas at Austin
UTACED	University of Texas at Austin, Civil Engineering Department
Vit.	Vitric
VSP	vertical seismic profiling
V_C	unconstrained compression wave velocity
V_P	constrained compression wave velocity
V_R	Raleigh-wave phase velocity
V_S	shear wave seismic velocity
WHB	Waste Handling Building
YMP	Yucca Mountain Project

1. PURPOSE

The purpose of this report is to compile and provide basic interpretation of data acquired from 2004 through 2007 during geotechnical investigations in the vicinity of Yucca Mountain, Nevada. These data were collected for use in evaluating seismic ground motions for a geologic repository at Yucca Mountain and in designing foundations for important to safety (ITS) repository surface facilities. The data described in this report augment those previously documented in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829]).

Planning for the 2004 through 2007 work was originally documented in *Technical Work Plan for: Development of Seismic Inputs, Preparation of Seismic Topical Reports, and Evaluation of Disruptive Events Features, Events, and Processes* (Quittmeyer 2004 [DIRS 167793]; BSC 2004 [DIRS 169886]; BSC 2004 [DIRS 171850]). Planning was updated in *Technical Work Plan for: Seismic Studies* (BSC 2005 [DIRS 174637]) and *Seismic Studies* (BSC 2006 [DIRS 178322]). In June 2007, *Technical Work Plan for: Geotechnical Investigations for Repository Facilities* (SNL 2007 [DIRS 183286]) was issued to plan the continuing geotechnical investigations and their documentation in two reports. The first report was planned to summarize the acquisition and basic interpretation of additional geological, geophysical, and geotechnical data for use in analyses and modeling supporting a license application. This task is accomplished in this report by compiling and describing the relevant data from 2004 through 2007, compiling other relevant data from previous investigations, and performing some basic comparisons of the data.

The combined geotechnical data described in this report and in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829]) provide an adequate basis for analyses and modeling that support the license application. Available data are used along with an understanding of geologic processes to characterize parameters required for seismic ground motion studies and foundation design. Using this approach, interpolation and extrapolation allow parameter values to be provided for locations of interest. Characterization also includes an evaluation of uncertainty and variability in parameter values. The uncertainty and variability are incorporated in analyses and modeling activities such as the studies to develop ground motions for design and safety assessments (BSC 2004 [DIRS 170027], Section 6.2; BSC 2007 [DIRS 183776], Section 6.4).

Laboratory and field geotechnical investigations have continued through 2007 and are planned for completion in 2008. Results of these additional investigations are planned to enhance the characterization of geotechnical properties at Yucca Mountain and to strengthen their technical basis. With the exception of alluvium borehole depths from 22 boreholes drilled in 2007, results of the 2007–2008 testing will not be covered in this report but will be contained in a subsequent geotechnical testing report. At the conclusion of the 2007–2008 testing and following development of a second report, all work planned by *Technical Work Plan for: Geotechnical Investigations for Repository Facilities* (SNL 2007 [DIRS 183286]) will be complete.

The scope of this report is limited to a description of the acquisition of the geotechnical data, presentation and basic interpretations of the data, and comparisons to previous data. Analyses of the data to develop inputs for ground motion site-response modeling are contained in *Supplemental Earthquake Ground Motion Input for a Geologic Repository at Yucca Mountain, NV* (BSC 2007 [DIRS 183776]).

2. QUALITY ASSURANCE

Testing activities described in this report were initiated in 2004 and have continued into 2007. For the period 2004 to 2006, testing was carried out under the auspices of Bechtel SAIC Company (BSC). Work was controlled by the appropriate BSC procedures. On October 1, 2006, responsibility for testing activities was transferred to the Yucca Mountain Project (YMP) Lead Laboratory. From that point on, testing was controlled by the appropriate Lead Laboratory procedures and, for work carried out for the Lead Laboratory by the U.S. Geological Survey (USGS) or the U.S. Bureau of Reclamation (USBR), by appropriate USGS/USBR procedures. Thus, in the following discussion it is necessary to identify multiple procedures and implementing documents for the same functions.

The current technical work plan (TWP) (SNL 2007 [DIRS 183286]) for activities documented in this technical report was prepared in accordance with TST-PRO-006, *Testing Work Implementation and Control*. The TWP (SNL 2007 [DIRS 183286], Section 8.1) determined that testing tasks are subject to *Quality Assurance Requirements and Description* (QARD) (DOE 2007 [DIRS 182051]). This evaluation confirmed the one originally made in *Technical Work Plan for: Development of Seismic Inputs, Preparation of Seismic Topical Reports, and Evaluation of Disruptive Events Features, Events, and Processes*) (Quittmeyer 2004 [DIRS 167793], Section 8.1). The original plan was prepared in accordance with AP-2.27Q (*Planning for Science Activities*) and revised in accordance with LP-2.29Q-BSC (*Planning for Science Activities*). Preparation of this report is governed by LS-PRO-001, *Technical Reports*.

When testing started in 2004, *Technical Work Plan for: Development of Seismic Inputs, Preparation of Seismic Topical Reports, and Evaluation of Disruptive Events Features, Events, and Processes* (Quittmeyer 2004 [DIRS 167793]) was the applicable planning and implementing document for this testing program. Over the years, this TWP has been updated and revised (BSC 2004 [DIRS 169886]; BSC 2004 [DIRS 171850]; BSC 2005 [DIRS 174637]; BSC 2006 [DIRS 178322]). Currently, *Technical Work Plan for: Geotechnical Investigations for Repository Facilities* (SNL 2007 [DIRS 183286]) controls the work. Regardless of which TWP was active at the time of testing, the testing discussed in this report did not deviate from the methods described in the applicable TWP. Although the methods did not change, there were changes in the testing scope. Most changes in the testing program scope were implemented to address changes in the layout of ITS surface facilities. Such changes were made as the repository operations approach was refined.

Field and laboratory systems were necessary to perform the testing activities described in this report. Use of measuring and test equipment (M&TE), including calibration, was controlled in accordance with LP-12.1Q-BSC, *Control of Measuring and Test Equipment*, before October 1, 2006, and in accordance with TST-PRO-002, *Control of Measuring and Test Equipment*, after that date. USGS/USBR use of measuring and test equipment after October 1, 2006, including calibration, was controlled in accordance with YMPB-USGS-QMP-12.01. Field instruments used for testing were generally calibrated by the owning organization using transfer standards calibrated by a YMP-qualified supplier. For the majority of this work, the qualified supplier was the Bechtel Nevada/NSTec calibration facility, located in Las Vegas, NV.

Scientific Notebooks were used to document the majority of the testing activities. Prior to October 1, 2006, use of scientific notebooks was controlled by LP-SIII.11Q-BSC, *Scientific Notebooks*. After October 1, 2006, use of scientific notebooks were controlled by TST-PRO-003, *Scientific Notebooks*, or for the USGS/USBR work, by YMPB-USGS-QMP-SIII.01, *Scientific Notebooks.* Use of scientific notebooks included documentation of the calibration of measuring and test equipment. These notebooks have been submitted to the YMP records center.

The only testing activities not implemented using scientific notebooks were the Fixed-Free and Free-Free laboratory testing performed at the University of Texas at Austin, Civil Engineering Department (UTACED) laboratory. This testing, prior to October 1, 2006, was implemented using either technical procedure PA-PRO-0309, *Laboratory Geotechnical Testing of Soil, Rock and Aggregate Samples*, or PA-PRO-0310, *Laboratory Dynamic Rock/Soil Testing*. After October 1, 2006, this laboratory testing was performed using either TST-PRO-T-002, *Laboratory Geotechnical Testing of Soil, Rock and Aggregate Samples*, or TST-PRO-T-003*, Laboratory Dynamic Rock/Soil Testing*. The results from this laboratory testing were recorded in a scientific notebook and submitted to the YMP records center.

Because testing involved electronic data, evaluations were conducted in accordance with LP-SV.1Q-BSC, IT-PRO-009, or IM-PRO-002, *Control of the Electronic Management of Information,* as appropriate to develop and implement planned controls. To provide assurance of the integrity of transferred data, controls for transfer of electronic information consisted of check sums, parity checks, and file-size comparisons performed by computer operating systems during data transfer and storage. In addition, “zipping” data files prior to transfer to ensure that data integrity is maintained was carried out in cases in which data were transferred from one physical location to another. Security and integrity of the electronic information developed during the work activities was maintained by storing the information on network drives and on hard drives of password-protected personal computers. Network drives and hard drives were periodically backed up, as appropriate, and the backups labeled and stored.

3. USE OF SOFTWARE

The computer programs used in developing the parameter values in this technical report are listed in Table 3.1-1:

Table 3.1-1. Computer Software Used for This Technical Report

Software Name	Software Tracking No.	Computer Type
Microsoft Word, versions 2000 and 2003	610236-2000-00 610236-2000SR1-00 610236-2000SR2-00 610236-2000SR3-00 610236-2003-00 610236-2003SP1SP2-00	IBM PC-compatible
Microsoft Excel, versions 2000 and 2003	610236-2000-00 610236-2000SR1-00 610236-2000SR2-00 610236-2000SR3-00 610236-2003-00 610236-2003SP1SP2-00	IBM PC-compatible
AutoCAD 2004	609860-2004-00	IBM PC-compatible
CorelDraw version 12	Used solely for graphic representation Exempted by Section 2.0 of IM-PRO-003*	IBM PC-compatible
Adobe Acrobat versions 7 and 8	600919-7.0-00 600919-8.0-00	IBM PC-compatible
EarthVision version 5.1	10174-5.1-00 [DIRS 167994]	SGI IRIX 6.5
gINT, version 4.16	Used solely for graphic representation Exempted by Section 2.0 of IM-PRO-003*	IBM PC-compatible
Grapher versions 2.02 and 3.02	Used solely for graphic representation Exempted by Section 2.0 of IM-PRO-003*	IBM PC-compatible
WinSASW, version 1.23	10588-1.23-00 [DIRS 159433]	IBM PC-compatible
RCTEST, version 2.1	Integral to testing equipment/not modified	IBM PC-compatible
TSTEST, version 3.1	Integral to testing equipment/not modified	IBM PC-compatible

* IM-PRO-003, *Software Management*.

In accordance with Section 2.0 of IM-PRO-003, *Software Management*, Microsoft Word versions 2000 and 2003 and Microsoft Excel versions 2000 and 2003 are exempt from the requirement that software be qualified and documented prior to use in quality-affecting work. In accordance with Section 2.0 of IM-PRO-003, AutoCAD version 2004, CorelDraw version 12, and Adobe Acrobat versions 7 and 8 are also exempted software products. Microsoft Word was used to prepare this report. Microsoft Excel was used to display tabular data and perform calculations using the standard spreadsheet functions during data development. Calculations performed during data development using Microsoft Excel were governed through scientific notebook procedure TST-PRO-003. Note that statistical analyses of data presented in this report using Microsoft Excel were carried out solely for illustrative purposes and are not quality-affecting work. AutoCAD and CorelDraw were used for display purposes only. Adobe Acrobat was used to view report text and data files.

WinSASW version 1.23 was used in accordance with IM-PRO-003. The program was obtained from Software Configuration Management, was appropriate for its intended use, and was used only within its range of validation. The program was run on a Dell Dimension Desktop or a Dell Latitude Laptop Computer with a Windows 98 operating system. The computers are located at the University of Texas at Austin (UTA). Inputs were collected with a *.dat* extension and produced files with *.exd*, *.prf*, and *.thd* extensions (experimental dispersion curves, final shear wave velocity profile records, and theoretical dispersion curves). An electronic copy of all data is included in scientific notebook SN-M&O-SCI-047-V2 (Stokoe 2007 [DIRS 183327]). The outputs are shown in Attachments IV, V, and VI.

RCTEST version 2.1 and TSTEST version 3.1, referred to in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829], Section 6.2.10.2), are integral to the measuring and test equipment and are verified in accordance with TST-PRO-002, *Control of Measuring & Test Equipment*.

4. INPUTS

The geotechnical data used as inputs for this technical report are listed in this section and discussed in section 6. Inputs supporting the conclusions presented in Section 7 are direct inputs. Inputs providing additional information, but not used to support the conclusions are indirect inputs. The direct inputs include the following:

Free-Free Dynamic Laboratory Test Data

- DTN: MO0707FREEFREE.006, Unconfined, Free-Free Resonant Column (URC) Data from Tuff Samples for the Period of December 11, 2004 through May 7, 2006 [DIRS 183287].

Fixed-Free Dynamic Laboratory Test Data for 31 Specimens

- DTN: MO0707FIXEFREE.005, Fixed-Free Resonant Column and Torsional Shear (RCTS) Data from Tuff Samples for the Period of August 17, 2004 through May 20, 2006 [DIRS 183329].

Surface SASW Developed Test Data

- DTN: MO0609SASWSEDC.001, Surface Spectral Analysis of Surface Waves (SASW) Experimental Dispersion Curves for FY04 and FY05 for YMP [DIRS 183293]

- DTN: MO0609SASWSTDC.003, Surface Spectral Analysis of Surface Waves (SASW) Theoretical Dispersion Curves and V_S Profiles for FY04 and FY05 for YMP [DIRS 182125].

Underground SASW Developed Test Data

- DTN: MO0609SASWUEDC.002, Underground Spectral Analysis of Surface Waves (SASW) Experimental Dispersion Curves for FY05 for YMP [DIRS 183294]

- DTN: MO0609SASWUTDC.004, Underground Spectral Analysis of Surface Waves (SASW) Theoretical Dispersion Curves and V_S Profiles for FY05 for YMP [DIRS 183295].

2000–2001 Surface and ESF SASW Test Data

- DTN: MO0206SASWROCK.000, SASW Velocity Data from Rock Sites on the Crest of Yucca Mountain and in the ESF [DIRS 159081]

- DTN: MO0110SASWVDYM.000, SASW Velocity Data from the Top of Yucca Mountain [DIRS 158076].

USGS Borehole Logs for 2005 Drilling

- DTN: GS070683114233.005, Geotechnical Borehole Logs of 18 Repository Facilities Geotechnical Investigations Boreholes for the Yucca Mountain Waste Handling Building, 05/18/2007 – 06/20/2007 [DIRS 182109].

USGS Test Pit Data

- DTN: GS030783114233.001, Geotechnical Logs for the Waste Handling Building, Yucca Mountain Project, Nevada Test Site, Nevada, Version 07/16/2003 [DIRS 164561]

- DTN: GS070583114233.003, Geologic Descriptive Logs and Photomosaic Maps of Three Test Pits (TP-WHB-5, TP-WHB-6, AND TP-WHB-7) for the Yucca Mountain Waste Handling Building, 10/10/2006 – 11/07/2006 [DIRS 183296].

USGS Soil Properties Data

- DTN: GS070683114233.004, Index Properties and In Place Unit Weight Test Results From Soils from Nine Ring Density Excavations Performed at Yucca Mountain Project, 8/3/2006 to 9/27/2006 [DIRS 183297]

- DTN: GS080183114233.001, Index Properties of Alluvium Soils from Two Sonic Drill Core Holes Obtained at Yucca Mountain Project, 07/20/2006 to 09/28/2006 [DIRS 184671].

USGS Alluvium Thickness Contour Map

- DTN: GS070983114233.006, Alluvium Thickness Contour Map of Midway Valley, NV; 07/23/2007 – 08/10/2007 [DIRS 183649].

Survey Results for SASW Locations

- DTN: MO0701ABSRFLL2.000, SASW Investigations for Repository Facilities, As-Built SASW RF Line Locations-2 [DIRS 182483].

ESF/ECRB SASW Survey Data

- DTN: MO0706SASWPHII.000, SASW Investigations for Repository Facilities – Phase II [DIRS 183299] [DIRS 183299].

Test Pit Survey Data

- DTN: MO0706ABRTP567.000, As-Built Proposed Repository Facility Test Pits 5, 6 & 7 [DIRS 183301].

2005 Survey Data for 19 Boreholes

- DTN: GS070583114233.002, Geologic Descriptive Logs of Fill and Quaternary Alluvium Material in 19 Repository Facilities Geotechnical Investigations Boreholes for the Yucca Mountain Waste Handling Building, 04/12/2005 – 09/12/2005 [DIRS 183302].

26 New Borehole Survey Data

- DTN: MO0707RFGNPMV1.000, Repository Facility (RF) Geotechnical Investigations North Portal & Midway Valley – Part 1 [DIRS 183189].

SMF Borehole Logs

- DTN: MO0708SMFGLGIB.000, Sample Management Facility Geologic Logs for the Repository Facilities Geotechnical Investigations Boreholes, Geologic Logs for Boreholes UE-25 RF #30, #31, #33 through #39, #41, #57, #63, #75, #76, #78 through #80, #83, #95, #97, #104 through #107 and RF #112 [DIRS 183304]

- DTN: MO0612SMFGLGIB.000, Sample Management Facility Geologic Logs for the Repository Facilities Geotechnical Investigations Boreholes, Geologic Log for Borehole UE-25 RF #64 [DIRS 183648].

Pre-2005 USGS Borehole Logs

- DTN: GS931008314211.036, Graphical Lithologic Log of Borehole RF-3 (UE-25 RF #3), Version 1.0 [DIRS 150006].

Data used as indirect inputs consist of:

- DTN: MO0709FREEFRUQ.007, Unconfined, Free-Free Resonant Column (URC) Unqualified Data from Tuff Samples for the Period of August 17, 2004 through December 1, 2004 [DIRS 183292].

These data were collected during a scoping study and are unqualified. They are included here for completeness.

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5. ASSUMPTIONS

Assumptions used in acquiring and reducing data are described in appropriate scientific notebooks documenting data collection and are summarized in appropriate subsections of Section 6.

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6. TEST DISCUSSION AND DATA COMPILATION

6.1. OVERVIEW

Section 6 presents data that were acquired and parameters that were developed for use in geotechnical analyses for the North Portal Facilities (NPF) Area and in ground motion analyses for the ITS structures and the repository. Field data were acquired for three distinct geographic areas: the NPF Area which includes the Waste Handling Building (WHB) area that was previously characterized in 2000–2001 and the Aging Pad Area; the underground areas, which include the Exploratory Studies Facility (ESF) drifts and Enhanced Characterization of the Repository Block (ECRB) cross-drift; and the crest of Yucca Mountain and specific geologic features near Yucca Mountain. In addition to the field testing, samples collected throughout the YMP area have been tested in the laboratory to develop dynamic and static material properties for the various geologic units that encompass the planned repository and underlie the ITS facilities area.

Data acquired starting in 2004 and continuing through 2007 in the area of the NPF are provided in Section 6.2 and consist of:

- Geologic data, including depth of alluvium, from 19 boreholes drilled during 2005. The boreholes are designated RF#42 through RF#56, RF#58 through RF#60, and RF#64[1,2,3]
- Depth of alluvium data from 23 additional boreholes drilled in 2006 and the first half of 2007. The boreholes are designated RF#31, RF#33 through RF#39, RF#41, RF#57, RF#75, RF#76, RF#78, RF#79, RF#80, RF#83, RF#95, RF#97, RF#104 through RF#107, and RF#112. The complete geologic borehole logs for these boreholes are not included in this report, but are planned for inclusion in a subsequent report.
- Standard physical properties data obtained from static geotechnical laboratory testing performed on sonic core from boreholes RF#47 and RF#52.
- Geologic data, photographs, and in-place density measurements in the alluvium encountered in test pits TP-WHB-5 to TP-WHB-7.
- Maximum density, minimum density, specific gravity, particle-size distribution, in-place density, natural water content, and relative density data corresponding to in-place density tests that were performed in test pits.

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[1] These boreholes have a designator of "UE-25": that is, underground exploratory boreholes drilled in Area 25 of the Nevada Test Site. For brevity, the UE-25 preface will be omitted in this report.

[2] This drilling was completed in sufficient time to include only the depth of alluvium for RF#57 in this report. Thus, when reference is made in this report to the borehole logs for RF#42 through RF#60, the reader should recall that there is no log associated with RF#57. But the depths of alluvium for 22 boreholes drilled in FY07 (including RF#57) were utilized to develop alluvium depths as displayed in Figure 6.2-4 and listed in Table 6.2-2.

[3] Boreholes RF#61, RF#62, RF#63, and RF#64 were either drilled or planned for drilling at an aging pad location to the northwest of Exile Hill. This aging pad was subsequently relocated, and data from RF#61-RF#63 are not included in this report and are not planned for inclusion in the second report. Data from RF#64 were used in the development of the alluvium thickness map (see Section 6.2).

- Shear wave velocity profile data from 18 spectral analysis of surface waves (SASW) surveys for the NPF Area.
- Shear wave velocity profile data from six SASW surveys for the Aging Pad originally located to the northwest of Exile Hill. Although the borehole data in the aging pad are not included in this report, the SASW data are presented to provide additional data for use in evaluating the relationship between geology and shear wave velocity.

Data that were acquired in 2004 through 2006 at or near the crest of Yucca Mountain are summarized in Section 6.3 and consist of:

- Shear wave velocity profile data from 24 SASW surveys for the Yucca Mountain area and key geologic features near Yucca Mountain.

Data that were acquired in 2004 and 2005 along the Main Drift of the ESF and ECRB cross-drift are summarized in Section 6.4 and consist of:

- Shear wave velocity profile data from 45 SASW surveys in the underground facilities.

Geotechnical laboratory data that were acquired in 2004 through 2006 on samples selected from various boreholes distributed throughout the Yucca Mountain area are summarized in Section 6.5 and consist of:

- Resonant column and torsional shear (RCTS) test results for 31 samples of tuff and alluvium. Test results include density, water content, shear wave velocity, and shear modulus and material damping ratio as a function of shear strain and confining pressure.
- Free-Free testing of 135 tuff samples starting with the non-welded tuff units Tmr/Tmbt1 extending through to the Tram unit. Approximately four to eight samples were selected and tested from each major geologic unit. Data include shear wave velocity, small strain shear modulus, density, and material damping ratio.

6.2. DATA ACQUIRED AT THE NORTH PORTAL FACILITIES AREA

6.2.1. Overview

Section 6.2 summarizes the results of geotechnical testing activities performed from 2004 through 2007 in the NPF and Aging Pad Areas where ITS facilities will be located. The NPF Area is a larger area than the Waste Handling Building (WHB) sub-area whose characterization was described in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829]).

The expansion of the area where ITS facilities will be sited reflects the evolution and refinement of the operational approach for repository waste handling. The type of test and the section where the results are presented are as follows:

> Section 6.2.2 – Repository Facilities Drilling Program, boreholes drilled pre-2005, 2005, and 2006–2007.
>
> Section 6.2.3 – Standard static geotechnical laboratory testing of sonic core from boreholes RF#47 and RF#52
>
> Section 6.2.4 – Test pits TP-WHB-5 through TP-WHB-7
>
> Section 6.2.5 – SASW surveys NPF-1 through NPF-18 and AP-1, AP-3, and AP-5 through AP-8.

6.2.2. Repository Facilities Drilling Program

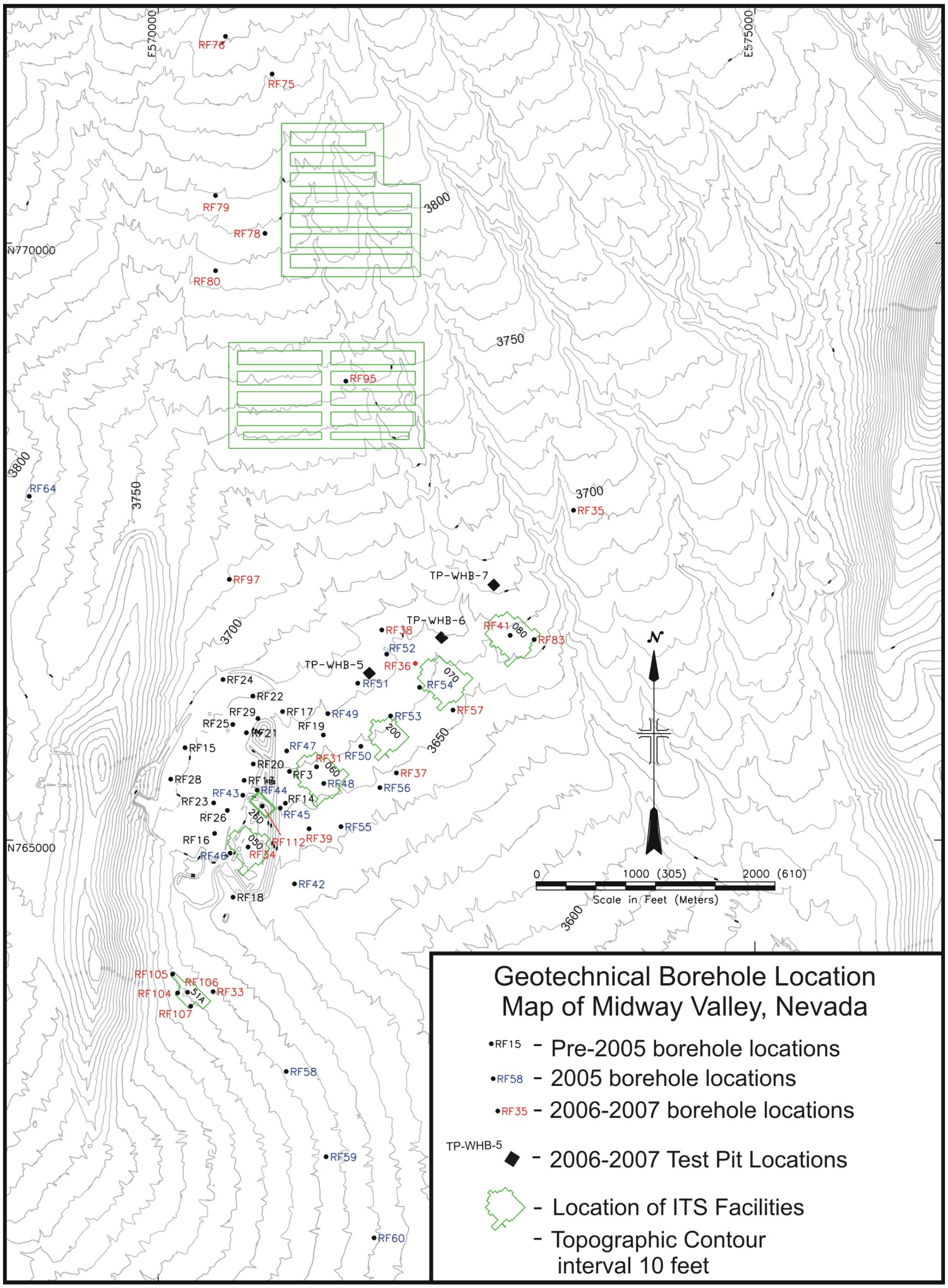
Exploratory drilling has been performed in the NPF Area since the mid-1980s. The earliest boreholes were drilled to collect data on potential sites for repository surface facilities. Beginning in 1998, additional boreholes were drilled to gather geotechnical information supporting foundation design of surface facilities and development of inputs for seismic ground motion analyses. Boreholes drilled through 2000 focused on an area in the immediate vicinity of the North Portal of the ESF. Following approval of the Site Recommendation (SR), the surface facilities layout evolved into an area that extended to the northeast, away from the North Portal. Consequently, a new phase of drilling was initiated in 2005 to collect relevant geotechnical information on the materials underlying the new layout. With plans for a transportation, aging, and disposal (TAD) canister system for packaging of commercial spent nuclear fuel, a further evolution of the layout of repository surface facilities ensued. In response, a new program of drilling was initiated to collect additional geotechnical data for confirmation of inputs used in analyses and modeling supporting a license application. This drilling program began in 2006, and continued through the fall of 2007. This section describes boreholes drilled in 2005 to mid-2007. Information on boreholes drilled in earlier years is found in *Preliminary Geotechnical Investigation for Waste Handling Building, Yucca Mountain Site Characterization Project* (CRWMS M&O 1999 [DIRS 109209]) and *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analyses for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829]).

Alluvium includes all unconsolidated material above bedrock, except where surface fill from drilling pads was identified. The bedrock underlying the area is Miocene-age tuffs of the Timber Mountain Group and the Paintbrush Group.

6.2.2.1. Boreholes

The 2005 program of exploratory drilling in the NPF Area began in March 2005 and concluded in July 2005 at the locations labeled in blue in Figure 6.2-1. The drilling program was developed to gain an understanding of subsurface geologic conditions. Twenty new boreholes were drilled (Figure 6.2-1, Table 6.2-1), but borehole RF#63 is not included in this report, due to a subsequent change of the surface facilities area layout that no longer includes the area northwest of Exile Hill. Borehole RF#64 is also located in the area northwest of Exile Hill, but it is included because it had already been logged prior to the change in facilities layout. The boreholes were drilled deep enough to penetrate the top of bedrock and determine the thickness of the alluvium.

Seventeen of the 19 boreholes were drilled with a 6-in coring system (6.163-in rotosonic carbide button bit), while 8-in-diameter casing was advanced with a reaming bit to the total depth. In two of the boreholes, RF#56 and RF#60, the upper parts of the boreholes were drilled with the 6.163-in bit, while 8-in-diameter casing was advanced with a reaming bit. The lower parts of these two boreholes were drilled with a 4-in coring system (4.56-in rotosonic carbide button bit), while 6-in-diameter casing was advanced with a reaming bit to the total depth. Geologic data acquired from the cores of the boreholes included depth of lithostratigraphic unit contacts (determined by Sample Management Facility (SMF) personnel; Table 6.2-1), welding, and percent core recovery. Detailed geologic borehole logs developed by the USBR are included in Attachment I.



Source: DTNs: GS030783114233.001 [DIRS 164561], GS070683114233.005 [DIRS 182109], GS931008314211.036 [DIRS 150006], MO0707RFGNPMV1.000 [DIRS 183189], MO0706ABRTP567.000 [DIRS 183301], MO0612SMFGLGIB.000 [DIRS 183648] for boreholes, test pits; BSC 2007 [DIRS 183259] and BSC 2007 [DIRS 180072] for ITS facilities.

Figure 6.2-1. Location Map Showing Geotechnical Boreholes from pre-2005, 2005, and 2006 to 2007 Drilling Programs, Midway Valley, Nevada

Table 6.2-1. Locations, Geologic Contacts, and Total Depth for Boreholes Drilled in 2005 in the NPF Area, Yucca Mountain, Nevada

Borehole ID: RF#	Northing[a] (ft)	Easting[a] (ft)	Ground Elevation (ft, NGVD29)	Depth to Top of Lithostratigraphic Unit[b] (ft)							Total Depth (ft)	Drilling Method
				Fill	Qal	Tmr	Tmbt1	Tpki	Tpbt5	Tpc		
RF#42	764633.0	571142.0	3634.9		0.0		84.0			113.6	118.9	sonic/core
RF#43	765375.5	570709.3	3669.9	0.0	19.4			90.5			110.1	sonic/core
RF#44	765418.8	570828.5	3676.3	0.0	26.8			108.0	121.4	122.4	143.5	sonic/core
RF#45	765268.1	571022.0	3650.0		0.0			93.0			125.5	sonic/core
RF#46	764889.9	570602.7	3669.2	0.0	27.2			84.2			103.5	sonic/core
RF#47	765746.7	571076.6	3663.9		0.0		97.0				122.3	sonic/core
RF#48	765474.3	571387.0	3653.6		0.0		113.3				159.3	sonic/core
RF#49	766058.8	571421.1	3668.8		0.0		112.9				142.9	sonic/core
RF#50	765785.0	571698.0	3656.3		0.0		123.2				155.5	sonic/core
RF#51	766313.7	571672.1	3672.0		0.0		128.4				156.7	sonic/core
RF#52	766557.0	571914.7	3672.4		0.0		164.7				184.7	sonic/core
RF#53	766039.7	571947.9	3661.3		0.0	138.0					160.6	sonic/core
RF#54	766278.9	572190.1	3661.6		0.0	183.0					196.7	sonic/core
RF#55	765112.3	571531.3	3642.2		0.0		110.2[d]	144.4			154.2	sonic/core
RF#56	765439.4	571857.2	3646.8		0.0	129.7	149.0	249.2	392.7	408.7	416.9	sonic/core
RF#58	763061.4	571072.6	3667.7		0.0				134.2	139.8	150.7	sonic/core
RF#59	762347.3	571406.7	3664.6		0.0				155.3[e]	156.3	179	sonic/core
RF#60	761667.3	571808.8	3650.1		0.0			144.5	176.1		195.6	sonic/core
RF#64	767879.6	568919.3	3787.6		0.0					69.5	105.0	sonic/core

[a] Nevada State Plane Coordinates, central zone, NAD 27.

[b] Lithostratigraphic unit designations are from Buesch et al. (1996 [DIRS 100106]). Abbreviations are: Qal, Quaternary alluvium; Tmr, Rainer Mesa Tuff of the Timber Mountain Group; Tmbt1, pre-Rainier Mesa Tuff bedded tuff; Tpki, Tuff unit "x"; Tpbt5, pre-Tuff unit "x" bedded tuffs (also known as post-Tiva Canyon Tuff bedded tuff); Tpc, Tiva Canyon Tuff.

[c] The log of RF#42 shows that Tmbt1 and "may be fill" for 75.4 to 84.0 feet; see Attachment I.

[d] The log of RF#55 shows reworked caliche-cemented material for 110.2 to 113.0 feet, so that is considered alluvium.

[e] The log of RF#59 shows no Tpbt5; the 155.3 ft for Tpbt5 is Tuff of Pinyon Pass (Tpcy), which usually is included in Tpbt5.

NOTE: See Attachment I for detailed borehole logs, except for RF#64 (MO0612SMFGLGIB.000 [DIRS 183648]). Gray cell = unit was not encountered.

Figure 6.2-2. Typical Sonic Core Rig Operation

Given the difficulty of collecting useful information regarding geotechnical properties in alluvial material with substantial gravel-, cobble-, and boulder-size material, the sonic coring method was used. Figure 6.2-2 is a photograph of the sonic rig used to drill the 2005 boreholes. This method provided improved recovery of alluvial materials over other drilling methods. The sonic coring method, as in other methods of sample recovery, recovers a disturbed sample. When coring through cobble- or boulder-size particles, this method may produce a rock flour, which can increase the apparent fines content (passing a No. 200 sieve) in the sample recovered. Also, drilling processes can break down oversize material (+3 in) and increase the apparent percentage of gravel-size material. As a result, classifications of the alluvial materials may not reflect in situ geologic conditions due to mechanical degradation of the sample. However, use of the Unified Soil Classification System (USCS) visual method provides consistent material classifications. For example, a material that may have an undisturbed classification of "poorly sorted gravel with sand (GP)s" will have the same classification from sonic core with slightly elevated fines and decreased gravel size. It does not appear that the sonic method affects the material to the point that major changes in the gradation occur. Figure 6.2-3 represents a typical sample management setup at the drill pad for the processing of the core.

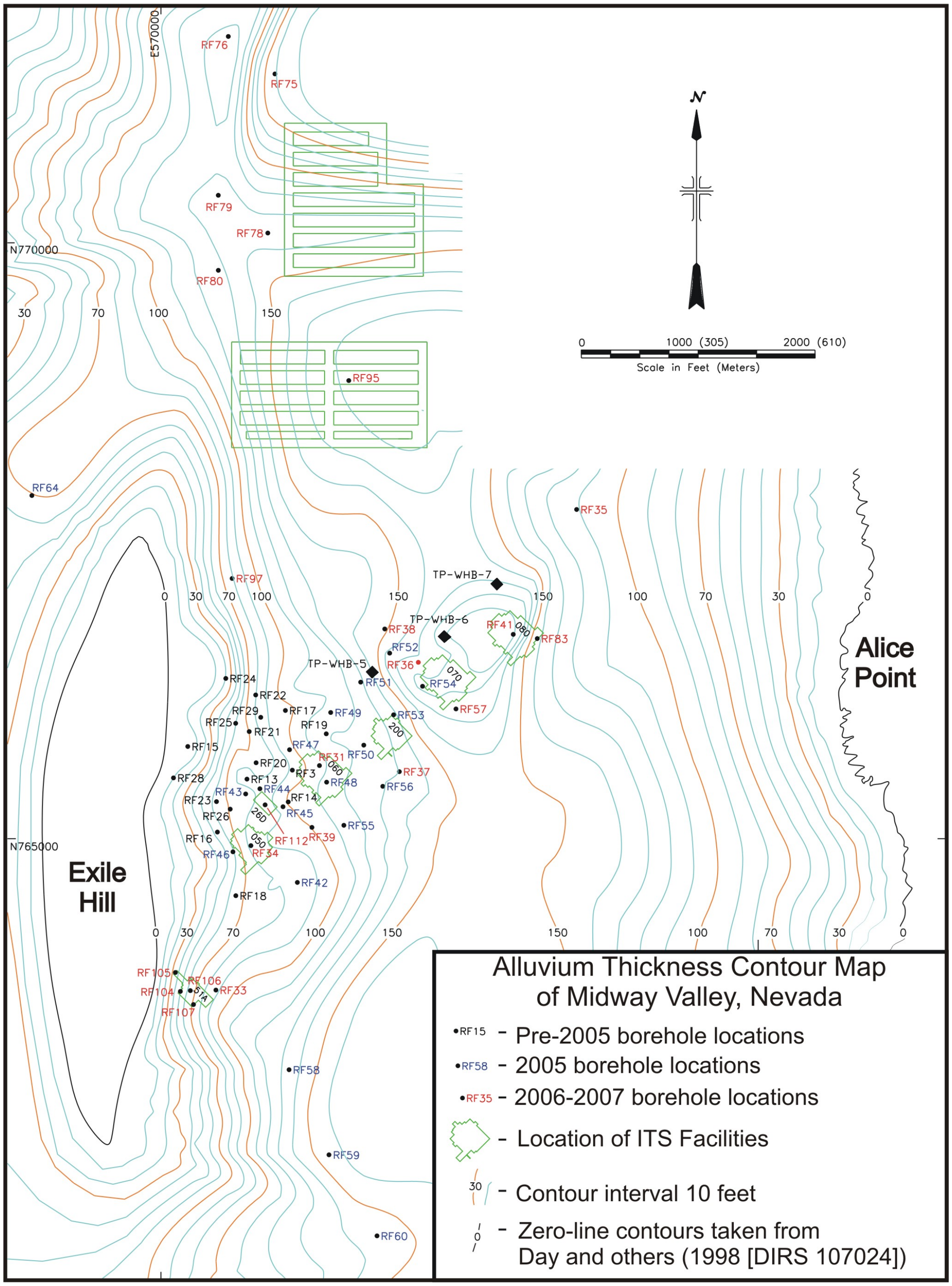
Boreholes drilled as part of the 2006 to 2007 program are shown in red in Figure 6.2-1. Only the locations and depth of the alluvium are available from these boreholes at the writing of this report.

Figure 6.2-3. Sample Management Facilities Staff Processing of Alluvium Core for RF#36

6.2.2.2. Thickness of Alluvium Beneath Repository Surface Facilities

A thickness of alluvium contour map (DTN: GS070983114233.006 [DIRS 183649]) was developed (Figure 6.2-4) using data from boreholes from pre-2005 drilling, 2005 drilling, and 2006–2007 drilling (Table 6.2-2). Development of the data is described in the supporting material for DTN: GS070983114233.006 [DIRS 183649]. Although the contour lines are depicted as solid, they represent an approximation of alluvium thickness and are not meant to depict an exact thickness at any given location. Orange contour lines (30-, 70-, 100-, and 150-ft) represent depths that were considered for site response modeling.

In the report titled *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829]), several detailed geologic cross sections were developed based on drilling results through 2000. These cross sections show the base of the alluvium in Midway Valley as relatively flat in each section. Results from the 2005 and 2006 to 2007 drilling program not only confirm this, but extend the interpretation of a smooth, relatively flat top of bedrock contact across two-thirds of Midway Valley from west to east (Figure 6.2-4). Alluvium thickness is zero at the base of Exile Hill (contact from Day et al. 1998 [DIRS 101557], Figure 2) and increases to about half way across the valley. Alluvium reaches a maximum thickness of almost 200 ft, and then begins to thin east towards Alice Point.



Source: DTN: GS070983114233.006 [DIRS 183649].

Figure 6.2-4. Alluvium Thickness Contour Map of Midway Valley, Nevada

Table 6.2-2. Borehole Locations and Alluvium Thickness for Boreholes Used in Figure 6.2-4

Borehole ID: RF#	Northing[a] (ft)	Easting [a] (ft)	Ground Elevation (ft, NGVD 29)	Fill Thickness (ft)	Depth to Bedrock (ft)	Alluvium Thickness (ft)
3	765575.0	571100.0	3657.7	0.0	91.0	91.0
13	765500.0	570720.1	3671.1	12.5	98.0	85.5
14	765308.6	571065.5	3651.4	0.0	101.8	101.8
15	765773.7	570224.7	3680.8	5.0	6.5	1.5
16	765055.5	570472.6	3672.0	22.4	75.7	53.3
17	766075.9	571041.9	3673.4	0.0	96.1	96.1
18	764521.6	570626.9	3640.3	0.0	65.0	65.0
19	765880.0	571383.8	3661.6	0.0	120.0	120.0
20	765637.2	570796.5	3671.1	28	98.0	70.0
21	765898.8	570739.0	3672.9	0.0	115.0	115.0
22	766206.1	570793.2	3680.3	0.0	80.0	80.0
23	765311.1	570465.0	3673.9	12.0	76.0	64.0
24	766344.6	570542.9	3685.8	10.0	30.0	20.0
25	765968.1	570626.5	3676.4	10.0	70.0	60.0
26	765248.0	570579.7	3670.8	14.0	85.0	71.0
28	765510.3	570104.9	3680.2	5.0	15.0	10.0
29	766018.4	570835.6	3672.6	0.0	85.0	85.0
31	765613.6	571326.9	3657.1	0.0	105.5	105.5
33	763729.9	570460.0	3671.3	0.0	87.6	87.6
34	764941.8	570753.0	3684.1	33.6	115.4	81.8
35	767762.5	573480.1	3693.8	0.0	110.7	110.7
36	766479.7	572154.6	3664.6	0.0	171.8	171.8
37	765562.4	571995.8	3647.6	0.0	130.1	130.1
38	766759.7	571873.8	3673.5	0.0	148.7	148.7
39	765094.7	571264.0	3644.6	0.0	100.4	100.4
41	766714.5	572949.5	3666.1	0.0	192.4	192.4
42	764633.0	571142.0	3634.9	0.0	84.0	84.0
43	765375.5	570709.3	3669.9	19.4	90.5	71.1
44	765418.8	570828.5	3676.3	26.8	108.0	81.2
45	765268.1	571022.0	3650.0	0.0	93.0	93.0
46	764889.9	570602.7	3669.2	27.2	84.2	57.0
47	765746.7	571076.6	3663.9	0.0	97.0	97.0
48	765474.3	571387.0	3653.6	0.0	113.3	113.3
49	766058.8	571421.1	3668.8	0.0	112.9	112.9
50	765785.0	571698.0	3656.3	0.0	123.2	123.2
51	766313.7	571672.1	3672.0	0.0	128.4	128.4
52	766557.0	571914.7	3672.4	0.0	164.7	164.7
53	766039.7	571947.9	3661.3	0.0	138.0	138.0
54	766278.9	572190.1	3661.6	0.0	183.1	183.1
55	765112.3	571531.3	3642.2	0.0	113.0	113.0

Table 6.2-2. Borehole Locations and Alluvium Thickness for Boreholes used in Figure 6.2-4 (Continued)

Borehole ID: RF#	Northing[a] (ft)	Easting [a] (ft)	Ground Elevation (ft, NGVD 29)	Fill Thickness (ft)	Depth to Bedrock (ft)	Alluvium Thickness (ft)
56	765439.4	571857.2	3646.8	0.0	129.7	129.7
57	766088.8	572470.1	3651.9	0.0	173.6	173.6
58	763061.4	571072.6	3667.7	0.0	134.2	134.2
59	762347.3	571406.7	3664.6	0.0	155.3	155.3
60	761667.3	571808.8	3650.1	0.0	144.5	144.5
64	767879.6	568919.3	3787.6	0.0	69.5	69.5
75	771417.1	570954.2	3851.4	0.0	60.4	60.4
76	771731.7	570563.8	3870.9	0.0	132.0	132.0
78	770082.2	570894.6	3806	0.0	135.5	135.5
79	770398.8	570480.1	3818.2	0.0	132.3	132.3
80	769769.3	570480.4	3796.1	0.0	127.9	127.9
83	766679.3	573150.5	3662.8	0.0	142.2	142.2
95	768844.1	571572.5	3753.0	0.0	182.1	182.1
97	767183.7	570595.9	3711.0	0.0	79.1	79.1
104	763718.9	570162.5	3682.6	0.0	50.3	50.3
105	763877.4	570120.9	3679.5	0.0	35.4	35.4
106	763725.1	570245.9	3677.6	0.0	62.6	62.6
107	763608.2	570272.1	3681.0	0.0	72.2	72.2
112	765283.9	570871.9	3688.8	34.8	121.0	86.2

Source: DTNs: GS030783114211.001 [DIRS 164561], GS070683114233.005 [DIRS 182109], MO0612SMFGLGIB.000 [DIRS 183648], MO0707RFGNPMV1.000 [DIRS 183189], GS931008314211.036 [DIRS 150006], MO0708SMFGLGIB.000 [DIRS 183304], GS070583114233.002 [DIRS 183302]

[a] Nevada State Plane Coordinates, central zone, NAD 27.

6.2.3. Static Geotechnical Laboratory Testing of Sonic Core

At the completion of the 2005 drilling program, alluvium samples from two boreholes were selected for static geotechnical laboratory testing. The testing consisted of standard physical properties tests on the alluvium from boreholes RF#47 and RF#52. The sonic core alluvium samples recovered from these boreholes were sent to the U.S. Bureau of Reclamation Soils Laboratory in Denver, Colorado.

The alluvium samples were separated based on the field classifications (Unified Soil Classification System [USCS] Visual Method) completed on site using procedures YMP-USGS-GP-57 R0 [DIRS 183647] and YMPB-USGS-GP-57 R0 [DIRS 183646], *Determining Unified Soil Classification (Visual Method)*. The samples were analyzed in the laboratory using procedures in scientific notebook SN-USGS-SCI-144-V1 (Strauss 2007 [DIRS 183281]). USCS group classifications determined in the laboratory also used USBR 5000-86 [DIRS 158737], *Procedure for Determining Unified Soil Classification (Laboratory Method)*. A summary of the laboratory USCS classifications, gradation test results (particle size distribution), specific gravity, and average absorption percent is given in Table 6.2-3. Detailed laboratory test results and gradation curve plots for the sonic cores are given in Attachment III.

Table 6.2-3. Summary of Laboratory Physical Properties Testing of Alluvium from Boreholes RF#47 and RF#52

Borehole ID: RF#	Depth Range (ft)	USCS Group Symbol	Percent Plus 3-in	Percent Gravel	Percent Sand	Percent Fines	Minus No. 4 Specific Gravity	Absorption Percent
47	4.5 to 8.8	GP-GM	0.0	46.7	41.9	11.4	2.51	5.5
47	8.8 to 13.5	SM	4.0	39.5	43.3	13.2	2.49	6.4
47	13.5 to 15.7	SM	0.0	24.4	56.5	19.1	2.52	6.4
47	15.7 to 18.2	SP-SM	9.7	39.4	40.1	10.8	2.52	5.1
47	18.2 to 20.5	SM	0.0	33.9	48.3	17.8	2.5	5.7
47	20.7 to 21.7	GW-GM	0.0	57.2	34.7	8.1	2.53	5.8
47	21.7 to 26.2	SM	0.0	31.4	51.8	16.8	2.51	6.1
47	26.2 to 28.6	SP-SM	4.0	40.6	44.1	11.3	2.53	6.3
47	28.6 to 31.6	SM	0.0	24.7	53.8	21.5	2.51	6.3
47	31.6 to 34.8	SM	3.6	39.0	43.3	14.1	2.51	6.1
47	34.8 to 36.5	SM	0.0	33.1	47.3	19.6	2.52	6.3
47	36.5 to 40.9	SM	5.6	35.9	44.3	14.2	2.5	5.0
47	40.9 to 43.8	GM	8.3	41.1	38.1	12.5	2.52	5.4
47	43.8 to 51.0	GM	0.0	43.3	42	14.7	2.49	5.1
47	51.9 to 52.7	SP-SM	0.0	35.2	53.9	10.9	2.51	5.6
47	54.1 to 56.8	SM	0.0	36.9	45.4	17.7	2.51	5.3
47	56.8 to 58.2	SM	0.0	21.8	53.1	25.1	2.48	5.3
47	59.0 to 68.6	GM	2.1	43.2	41.0	13.7	2.52	5.8
47	70.0 to 87.5	SM	2.6	37.0	46.6	13.8	2.49	4.9
47	87.5 to 88.9	SM	0.0	31.1	41.3	27.6	2.54	6.7
52	0.0 to 2.9	GM	9.7	38.0	37.0	15.3	2.54	5.9
52	2.9 to 5.4	SP-SM	0.0	40.1	51.5	8.4	2.54	5.6
52	5.4 to 11.0	GW-GM	1.1	48.4	40.3	10.2	2.52	4.8
52	11.0 to 24.2	SM	1.2	36.6	49.4	12.8	2.5	6.1
52	24.2 to 30.7	SM	0.0	15.9	68.0	16.1	2.43	6.9
52	30.7 to 35.2	SP-SM	0.0	43.8	45.4	10.8	2.5	5.1
52	35.2 to 40.3	SM	0.0	37.4	46.8	15.8	2.51	6.0
52	40.3 to 44.5	GW-GM	3.5	46.7	40.2	9.6	2.52	6.5
52	44.5 to 50.3	SM	0.0	34.7	51.5	13.8	2.51	5.8
52	50.3 to 61.8	GM	1.7	44.2	40.6	13.5	2.51	5.4
52	61.8 to 68.4	SM	2.0	35.8	48.4	13.8	2.51	6.0
52	68.4 to 104.5	SM	1.9	41.8	41.8	14.5	2.53	5.9
52	104.5 to 107.9	GM	14.0	36.0	34.1	15.9	2.52	3.7
52	109.5 to 148.2	GM	8.6	42.9	35.7	12.8	2.52	15.8
52	149.8 to 152.5	SM	0.0	38.3	44.5	17.2	2.53	6.7
52	152.5 to 155.8	GM	16.9	35.7	35.1	12.3	2.54	5.0
52	157.8 to 160.7	GM	5.9	44.5	36.6	13.0	2.53	4.7

Source: DTN: GS080183114233.001 [DIRS 184671].

NOTE: See Attachment III for detailed laboratory test results and laboratory gradation curve plots.

6.2.4. Testing in Test Pits

In 2000, four test pits were excavated and the alluvium was tested. Complete details of this exploration are documented in *Geotechnical Data for a Potential Waste Handling Building and Ground Motion Analyses for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829]). In this report, results are presented from an additional three test pits that were excavated and tested in 2006–2007.

6.2.4.1. Mapping and Logging of Three Test Pits

Beginning in August 2006, three test pits were excavated to analyze engineering properties of the alluvium in the NPF Area. The test pits, designated TP-WHB-5 through -7, were surveyed and located as shown in Figure 6.2-1. The test pits were excavated to approximately 19 ft below ground surface, with side slopes formed by a series of five horizontal benches with vertical sides (approximately 4-ft depth to each level), yielding an overall average slope of about 2:1 (horizontal to vertical) for slope stability. The pits were square, approximately 75 ft on a side (at ground surface), with one of the four side slopes excavated to provide a ramp to the bottom of the pit. Figure 6.2-5 shows Test Pit #6, which is representative of the other two test pits. The limits of the test pits were surveyed (DTN: MO0706ABRTP567.000 [DIRS 183301]). All test pits were sprayed with water during excavation to control dust; as a result, the measured water contents may not be representative of in situ conditions.

There is minor variation in the materials encountered in the test pits. The field classifications indicate that all the material is coarse-grained, mainly poorly graded gravel (GP) or poorly graded sand (SP) with varying percentages of cobbles and boulders. At the top of test pit TP-WHB-5, the percentage of fines was estimated visually at 10%, and a dual classification was given (i.e., SP-SC), also with gravel and cobbles.

Three soil units were mapped and field-classified within test pit TP-WHB-5, down the approximate center of the east wall of the pit (included in the log and shown on the photographs in Attachment II). The soil units are continuous to the other walls of the pit. The USCS group classifications for the mapped units are poorly graded sand with clay and cobbles (SP-SC)c, poorly graded sand with gravel and cobbles (SP)gc, and poorly graded gravel with sand and cobbles (GP)sc. The lowest measured dry density value, from 6-ft-diameter ring density tests at 19-ft depth, expressed as mass per unit volume, was 109.2 lbm/ft^3 (pounds-mass per cubic foot), and the highest measured dry density value, at the 4-ft depth, was 114.3 lbm/ft^3.

Five soil units were mapped and field-classified within test pit TP-WHB-6, down the approximate center of the East wall of the pit and included in the log of this test pit (Attachment II). Similar soil units with minor variations in percentages of gravel, sand, and cobbles were identified elsewhere on pit walls, but are not included in the log. All of the soil units in this test pit were classified as poorly graded sand (SP), with varying amounts of gravel and cobbles, or poorly graded gravel (GP) with varying amounts of sand and cobbles. The lowest measured dry density value, from 6-ft-diameter ring density tests at 12-ft depth, was 105.1 lbm/ft^3, and the highest measured dry density value, at the 4-ft depth, was 111.8 lbm/ft^3.

Seven soil units were mapped and field-classified within test pit TP-WHB-7, down the approximate center of the east wall of the pit and included in the log of this test pit (see

Attachment II). Similar soil units with minor variations in percentages of gravel, sand, and cobbles were identified elsewhere on pit walls, but are not included in the log. All of the soil units in this test pit were classified as poorly graded sand (SP), with varying amounts of gravel and cobbles, or poorly graded gravel (GP) with varying amounts of sand, cobbles, and boulders. One soil unit received a group symbol of (GP/SP)c, because the gravel and sand components were about equal. The lowest measured dry density value, from 6-ft-diameter ring density tests at 4-ft depth, was 108.2 lbm/ft^3, and the highest measured dry density value, at the 12-ft depth, was 114.8 lbm/ft^3.

The alluvium in the three exposed walls of each test pit was mapped and logged according to the Unified Soil Classification System (USCS) using YMP-USGS-GP-57 R0 [DIRS 183647] and YMPB-USGS-GP-57 R0 [DIRS 183646]. The results of mapping are shown on the test pit logs and on the photo mosaic test pit maps in Attachment II.

Figure 6.2-5. Test Pit #6 in the North Portal Facilities Area

6.2.4.2. Water Replacement Ring Density Tests

Nine 6-ft-diameter water replacement ring density tests were performed within the test pits, where greater than 20% of the particles (on a weight basis) were retained on the 1.5-inch (37.5-mm) sieve. The water replacement ring density tests were performed using scientific notebook SN-USGS-SCI-145-V1 (Lung 2007 [DIRS 183626]), and ASTM D 5030-04 [DIRS 183650], *Density of Soil and Rock in Place by the Water Replacement Method.* Samples of alluvium were collected and sent to the U.S. Bureau of Reclamation Soils Laboratory in Denver, Colorado, for physical properties testing and laboratory classification (USCS) using procedures in scientific notebook SN-USGS-SCI-144-V1 (Strauss 2007 [DIRS 183281]) and USBR 5000-86.

The results of the in-place density tests, including moisture content and relative density, are summarized in Table 6.2-4. USCS group classifications indicated in Table 6.2-4 are based on laboratory classifications performed using scientific notebook SN-USGS-SCI-144-V1 (Strauss 2007 [DIRS 183281]) and USBR 5000-86 [DIRS 158737], and not on the field classifications discussed in the previous section. For detailed testing results and the laboratory gradation curve plots for each sample, refer to Attachment II.

Figure 6.2-6. Ring Density Test Being Performed in a Test Pit

Table 6.2-4. Summary of In-Place Soil Density Tests and Relative Density

Test Pit No. TP-WHB-	**Sample Depth (feet)**	**Sample Management Facility Sample No. 01041**	**USCS Group Symbol[a]**	**Volume of Test Hole (ft^3)**	**Total Mass of Test Material (lbs)**	**Moisture Content (%)**	**In-Place Wet Density[b] (lbm/ft^3)**	**In-Place Dry Density(b) (lbm/ft^3)**	**Relative Density (%)**
5	4	600	GP-GM	16.07	1963.55	6.9	122.20	114.3	102
5	12	602	GW	20.0	2293.30	4.8	114.70	109.4	102
5	19	603	GP	14.36	1640.05	4.6	114.21	109.2	72
6	4	601	SP-SM	21.24	2486.80	4.7	117.10	111.8	81
6	12	700	SP-SM	20.96	2319.65	5.3	110.67	105.1	61
6	19	604	SP-SM	15.72	1735.40	3.7	110.39	106.5	60
7	4	605	GW-GM	15.14	1712.00	4.5	113.08	108.2	74
7	12	606	SP	12.77	1537.30	4.9	120.38	114.8	100
7	19	607	SP-SM	14.34	1691.35	3.8	117.95	113.6	68

Source: DTN: GS070683114233.004 [DIRS 183297]; Strauss 2007 [DIRS 183281].

[a] For explanation of USCS soil group symbols, see USBR 5000-86 [DIRS 158737] or Attachment II.
[b] Density is expressed as mass per unit volume, in pounds-mass per cubic foot (lbm/ft^3).

NOTE: See Attachment II for detailed laboratory test results and laboratory gradation curve plots.

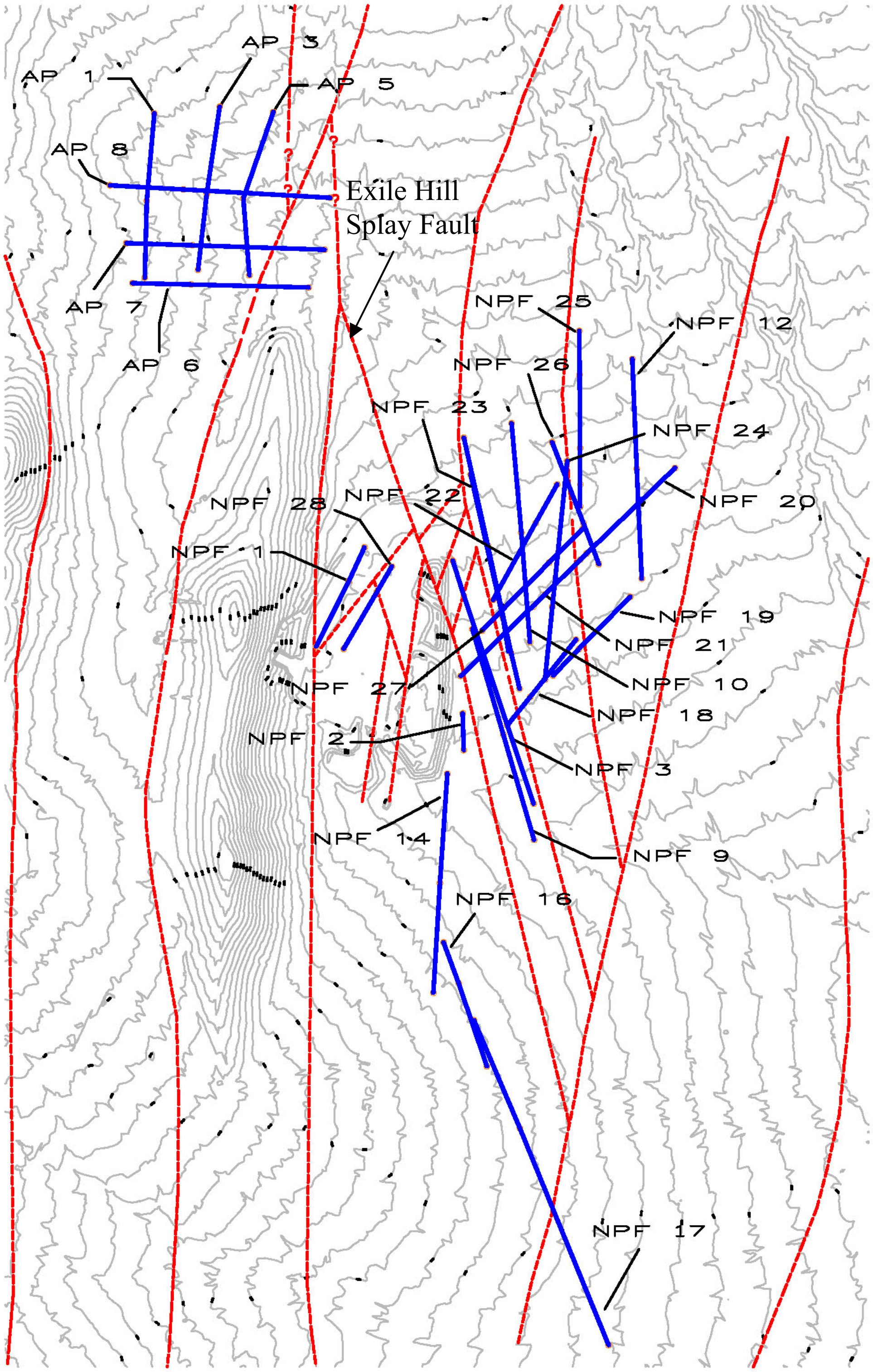
6.2.5. SASW Surveys from NPF Area Sites (18 Surveys)

In 2004 and 2005, 18 SASW surveys were performed in the North Portal Facilities (NPF) area and 6 SASW surveys in an Aging Pad (AP) location. These surveys augment the 35 SASW surveys performed in 2000 and 2001 to characterize the WHB Area. The previous SASW testing is documented in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829], Section 6.2.7). Figure 6.2-7 displays the SASW surveys that were performed in the NPF Area and in the previously planned Aging Pad Area in 2004 and 2005.

6.2.5.1. Approach

The SASW method has several attributes that make it a valuable complement to other seismic field methods in evaluating shear wave velocity profiles. First, the SASW method is both nondestructive and nonintrusive, and can therefore be performed without greatly affecting the surrounding environment. Second, because the SASW method does not require a borehole for the test to be performed, it can be conducted relatively quickly (about 2 sites to V_S profile depths around 500 to 800 ft per 10-hour day) and an extensive amount of ground can be investigated. This coverage is a significant advantage over borehole methods which investigate localized areas in and around the borehole. The SASW method is a useful tool to supplement the information from borehole methods and to characterize V_S properties between boreholes. Third, the SASW method is global in nature, measuring soil and rock properties over large lateral extents approximately equal to the depth of the V_S profile. Fourth, the SASW method operates using wavelengths that are within the range of wavelengths excited by earthquakes (although they are considerably shorter than the longest wavelength excited by earthquakes). Therefore, for earthquake applications, the SASW method provides soil and rock stiffness over a range in wavelengths that is appropriate for earthquake analysis.

In 2000 and 2001, the SASW surveys were performed by personnel from UTA led by Dr. Kenneth H. Stokoe. During that campaign, a bulldozer or a vibroseis was used as the energy source, allowing shear wave velocity to be determined to a depth of approximately 200 ft in the NPF Area. In 2004 and 2005, additional SASW testing was performed to provide coverage over a larger area, consistent with the evolution of the layout of ITS surface facilities, and to determine velocities to a greater depth by using a more energetic source. This testing consisted of 20 SASW surveys resulting in 18 shear wave velocity profiles as displayed in Figure 6.2-7 and detailed in Table 6.2-5. This testing was also performed by the UTA. In this campaign a new vibroseis truck called the "Liquidator", was used that was capable of generating more energy at low frequencies that allowed profiling to depths greater than 1,000 ft. Figure 6.2-8 depicts the vibroseis truck referred to as "Liquidator."



Source: DTN: MO0701ABSRFLL2.000 [DIRS 182483]; BSC 2004 [DIRS 170029].

NOTE: Red: mapped and inferred faults and fault splays; blue: SASW lines.

Figure 6.2-7. North Portal Facilities Area SASW Testing in 2004 and 2005

Figure 6.2-8. Vibroseis Truck Referred to as “Liquidator,” Provided by UTA

Table 6.2-5. Eighteen SASW Tests Performed at the NPF Area during 2004 and 2005

No.	Site Name	Profile Depth (ft)	Test Date
1	NPF 1	40	16-Jul-04
			23-Jul-04
2	NPF2 and NPF14	1,426	16-Jul-04
3	NPF3 and NPF9	1,472	17-Jul-04
			21-Jul-04
4	NPF10	1,404	23-Aug-04
5	NPF12	1,434	21-Aug-04
			23-Aug-04
6	NPF16	533	23-Jul-04
			24-Jul-04
7	NPF17	1,409	23-Jul-04
			24-Jul-04
			10-Aug-04
8	NPF18	487	24-May-05
9	NPF19	751	24-May-05
10	NPF20	815	25-May-05
11	NPF21	743	25-May-05
12	NPF22	572	26-May-05
13	NPF23	1,340	26-May-05
14	NPF24	949	27-May-05
15	NPF25	1,345	28-May-05
16	NPF26	552	28-May-05
17	NPF27	635	28-May-05
18	NPF28	424	11-June-05

Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTES: NPF5 through NPF8 and NPF11 test designations were never used for identifying surveys in the NPF Area. Field personnel inadvertently missed utilizing these designations.

NPF2 and NPF14 were combined into a single shear wave velocity as testing was initially performed at a shallow depth with survey NPF2 and to a deeper depth for the NPF14 survey.

NPF3 and NPF9 were combined into a single shear wave velocity as testing was initially performed at a shallow depth with survey NPF3 and to a deeper depth for the NPF9 survey.

For the 2004 and 2005 SASW surveys, both a Hewlett-Packard (HP) and an Agilent 35670A Dynamic Signal Analyzer were used at various times as the recording device for SASW testing. Both instruments are four-channel analyzers that can record the signals detected by the sensors (geophones or accelerometers) and perform Fast Fourier Transform (FFT) calculations to generate the phase plots of paired sensors. These phase plots allowed the field test team the opportunity to judge if further tests utilizing additional spacings were warranted. Because four channels were available, the 2004–2005 SASW test arrangement was modified to measure a total of three receivers; the 2000–2001 testing, which utilized a two-channel analyzer, only record the data from two receivers. By doing so, data from two receiver spacings were collected from one test array at a time. The additional sensor spacing saved about 50% of the testing time for the same number of test spacings compared to the setup using only two receivers.

For NPF sites, Mark Products Model L-4C and L-10 geophones, which have natural frequencies of 1 and 4.5 Hz, respectively, were used in the SASW tests. These geophones have excellent performance in the low-frequency range. For example, the Mark Products Model L-4C geophones perform well in the frequency range from 1 to 300 Hz, which facilitates collection of data in the 1- to 4-Hz range, providing crucial information for determining the velocity of deeper layers.

Calibration of the geophones identified that their performance could be impacted by temperatures above 95°F. During the summer months, when most of the SASW testing was performed, temperatures at Yucca Mountain reached as high as 110°F. The procedure for using the geophones was modified to minimize the affects of the high surface temperatures by insulating them with cooling wraps, and their temperatures were monitored using an off-the-shelf temperature device with an accuracy of +/- 2° F throughout testing to ensure that the geophones were not affected by the high temperatures.

The basic sensor spacings at the surface sites are similar to those used in 2000 and 2001 but because of the larger energy and lower operating frequency provided by the “Liquidator.” vibroseis truck, the spacings were expanded, which resulted in longer SASW surveys. This increase in spacing provided ability to achieve the deeper profile depths. The nominal test spacings used were 750, 1,000, or 1,600 ft at different surface sites. Specifics regarding the measurement and analysis that converts the measurement of the Rayleigh waves into velocity profiles are detailed in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829], Section 6.2.7.1).

All of the NPF SASW sites were surveyed and the results were submitted to the TDMS as part of DTN: MO0701ABSRFLL2.000 [DIRS 182483]. The surveys were not performed at each receiver spacing, but they were performed at the center point and the largest receiver spacing for a specific test location. The survey coordinates are identified as –C, –F or –N to designate the Center, Far, and Near receiver relative to the energy source. All shorter spacing lines are contained within the survey line represented by the largest receiver spacing.

For these tests, the energy source was either an 8-lb. sledge hammer for sensor spacings less than 50 ft or a vibroseis truck for receiver spacings greater than or equal to 50 ft. The SASW surveys performed with the vibroseis truck used a swept-sine mode in which the truck source signal was swept over the frequency of interest. A built-in source output of the analyzer is utilized to control the vibroseis trucks to perform a stepped-sine vibration (vibrating at each frequency for several seconds from high-to-low frequencies) or other sine wave vibrations.

The SASW measurements were performed using a sequence of increasing spacings. Distances between receivers generally started at 6 ft and progressed to 12, 25, 50, 100, 200, 400, 800, and 1,600 ft. (These distances represent a typical receiver spacing, but variations in the spacings would occur in the field to accommodate specific site conditions or the target profile depth.) Actual sensor spacings used in performing the measurements are recorded in the scientific notebook SN-M&O-SCI-047-V1 (Stokoe 2007 [DIRS 183272]). For each sensor spacing, five measurements were typically averaged for each survey when a hammer was used as the source. For the vibroseis truck the spectral functions were determined one frequency at a time in a swept-sine fashion. Successful implementation of the SASW method requires that multiple receiver spacings are used at one site. Multiple spacings are not used in creating the theoretical dispersion curve that matches the experimental dispersion curve. Rather, the theoretical dispersion curve is calculated assuming that the receivers are located 2λ and 4λ (λ is wavelength) from the source.

The test configurations for a specific site, the resulting phase plots, and experimental and theoretical dispersion curves are contained in scientific notebook SN-M&O-SCI-047-V2 (Stokoe 2007 [DIRS 183327]). The final acquired and developed data for these sites, which also consists of the experimental and theoretical dispersion curves and the final velocity profiles, are contained in DTNs: MO0609SASWSEDC.001 [DIRS 183293] and MO0609SASWSTDC.003 [DIRS 182125].

6.2.5.2. Assumptions, Parameters, and Statistical Analysis of SASW Data

There are several assumptions made in analyzing the SASW field data. They are: (1) Poisson's ratio, (2) unit weight (or mass density), and (3) location of ground water table. The assumed values of Poisson's ratio and unit weight depend on the inferred shear wave velocity (V_S) profile. In most cases, except Sites YM1 through YM 4 on the ridge of Yucca Mountain, if the resulting V_S is less than 2,000 fps at a depth, the assumed Poisson's ratio and unit weight are 0.33 and 120 pcf at the same depth, respectively. If the resulting V_S is between 2,000 fps and 5,000 fps, the assumed Poisson's ratio and unit weight are 0.25 and 130 pcf. If the resulting V_S is more than 5,000 fps, the assumed Poisson's ratio and unit weight are 0.20 and 135 pcf. The relationships between the resulting V_S, and Poisson's ratio and unit weight are shown in Figures 6.2-9 and 6.2-10, respectively. The developed V_S profile is insensitive to the assumed values of Poisson's ratio and unit weight for ranges typical of geotechnical materials (Brown 1998 [DIRS 157230; Stokoe et al. 1994 [DIRS 157265]).

As the wavelength used in SASW testing increases, and hence the depth of penetration increases, the surface wave propagates through a greater soil/rock volume. The resolution of the SASW method (ability to detect changes in velocity and thickness at depth) decreases as wavelength increases because larger volumes of soil are being sampled as wavelength increases. Therefore, the SASW resolution is best near the surface and decreases at greater depths in the profile. For these analyses, the shear wave velocity profiles are presented to a maximum depth of approximately 0.5 times the longest wavelength recorded in the field. The maximum profile depth is based on the fact that most of the surface wave particle motion is occurring at depths less than 0.5 times the longest wavelength.

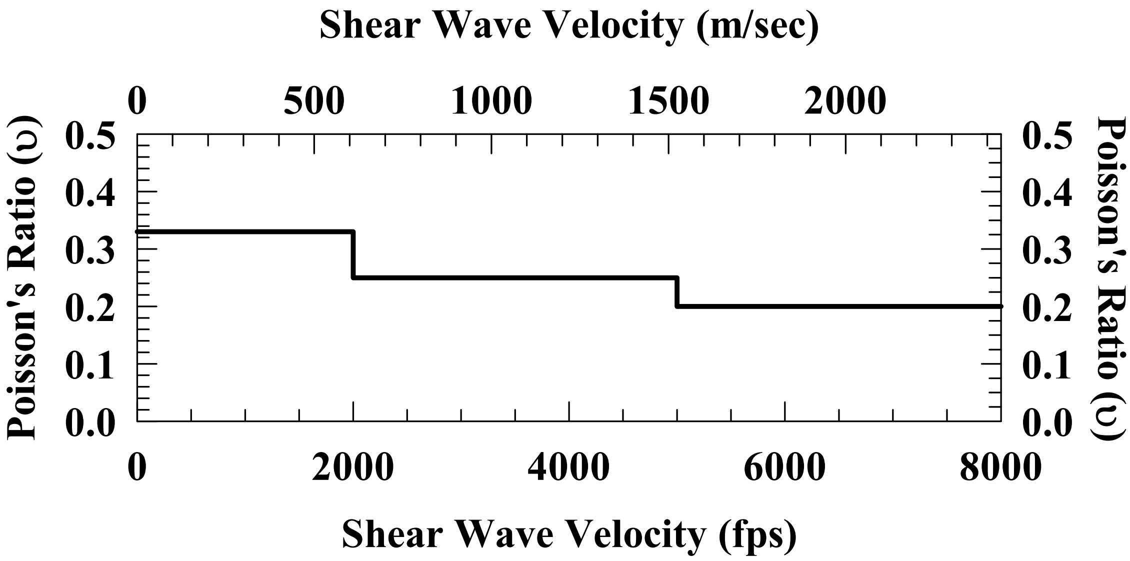


Figure 6.2-9. Assumed Relationship between Assumed υ and Resulting V_S

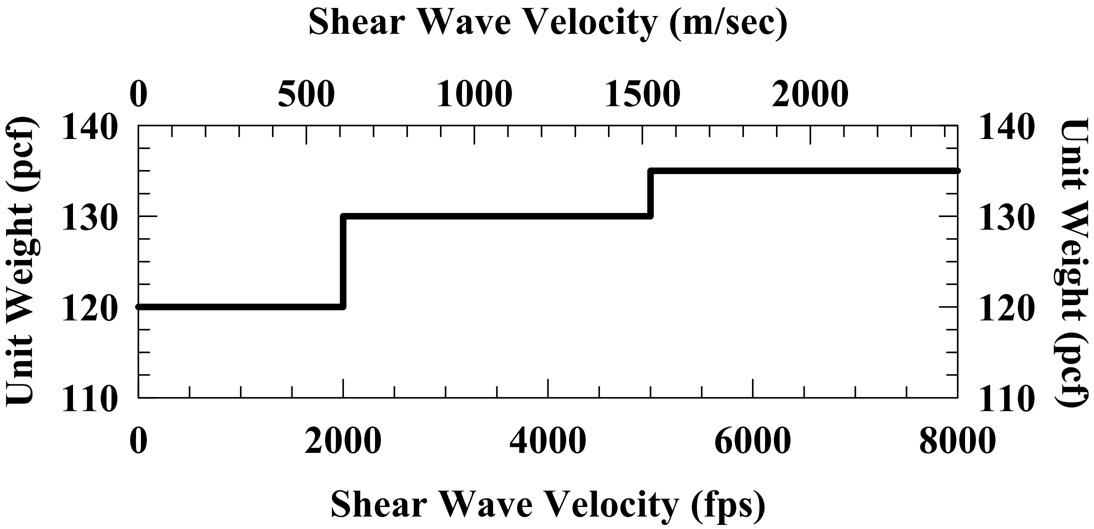
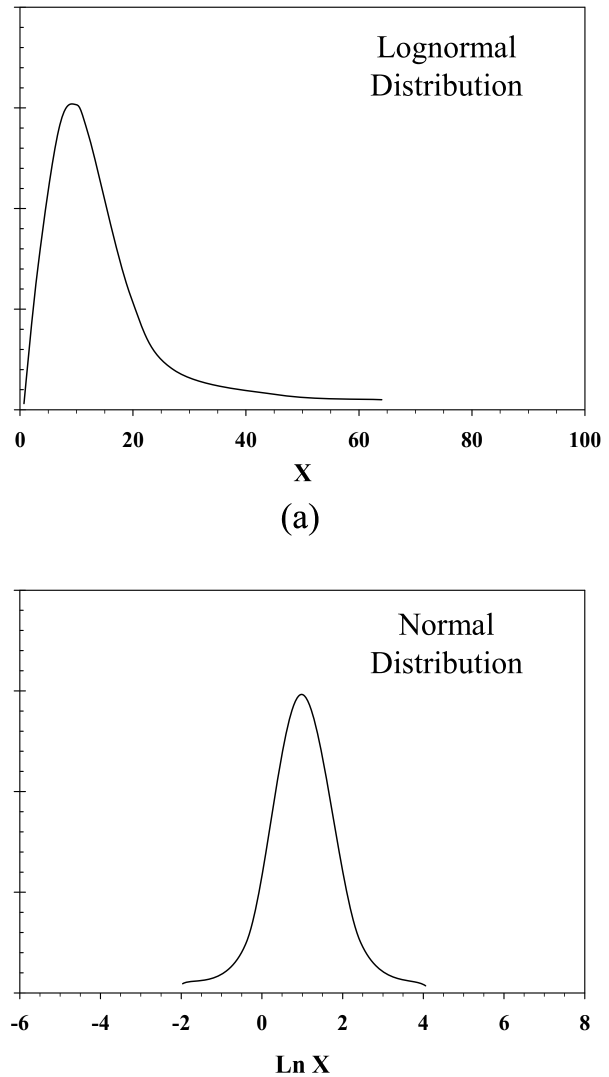


Figure 6.2-10. Assumed Relationship between Assumed Unit Weight and Resulting V_S

The distribution of V_S profiles in this report is assumed to be a log-normal distribution. In addition, the median and corresponding 16th and 84th percentile boundaries are three important "indices" used as a standard to evaluate the representative V_S profiles acquired at this area. Also, the coefficient of variation (COV), the ratio of one standard deviation to the mean, of a test site is investigated. The COV may be able to be used as an index of the uniformity of a site. One thing that needs to be mentioned here is that the calculations of the four parameters cited above only apply to three or more V_S profiles at the same area. It is preferable to have five or more profiles whenever possible. Also, before conducting the statistical analysis, if there is more than one profile at the same site, these profiles are averaged to calculate the representative profile of this site. By doing so, one avoids putting too much statistical weight on the same site where multiple profiles have been acquired.

The statistical analysis performed in this report is based on the assumption that the distribution of V_S values at a given depth in a given population of V_S profiles is log normally distributed. A random variable X has a lognormal distribution as shown in Figure 6.2-11(a) if the natural logarithm of X is normally distributed as shown in Figure 6.2-11(b).



(a)

(b)

Figure 6.2-11. Example of a Log-normally Distributed Variable X

More detailed definition of lognormal distribution can be found in several textbooks such as *Probability Concepts in Engineering Planning and Design, Volume 1- Basic Principles* (Ang and Tang 1975 [DIRS 160321]). In addition, in this report, each V_S profile was divided into 1-ft depth intervals to calculate the needed data. To obtain the median and 16th and 84th percentile of the V_S profiles based on the assumption of a lognormal distribution, the sample mean (μ) and sample standard deviation (σ) of the measured V_S values at the depth in the profiles was calculated using the following equations:

$$\mu = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \text{(Eq. 6.2-1)}$$

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \mu)^2} \qquad \text{(Eq. 6.2-2)}$$

where x_i is the V_S value in each profile at the same depth.

Now, let Y = Ln X, which is normally distributed with a mean (λ) and a standard deviation (ζ). The equations used to calculate λ and ζ are:

$$\lambda = \ln(\mu) - \frac{\zeta^2}{2} \qquad \text{(Eq. 6.2-3)}$$

$$\zeta = \sqrt{\ln\left(1 + \left(\frac{\sigma}{\mu}\right)^2\right)} \qquad \text{(Eq. 6.2-4)}$$

The median (x_m) of the lognormal distribution can be calculated based on the λ and ζ by:

$$\frac{\ln(x_m) - \lambda}{\zeta} = \Phi^{-1}(0.5) = 0 \quad \text{or} \quad x_m = e^{\lambda} \qquad \text{(Eq. 6.2-5)}$$

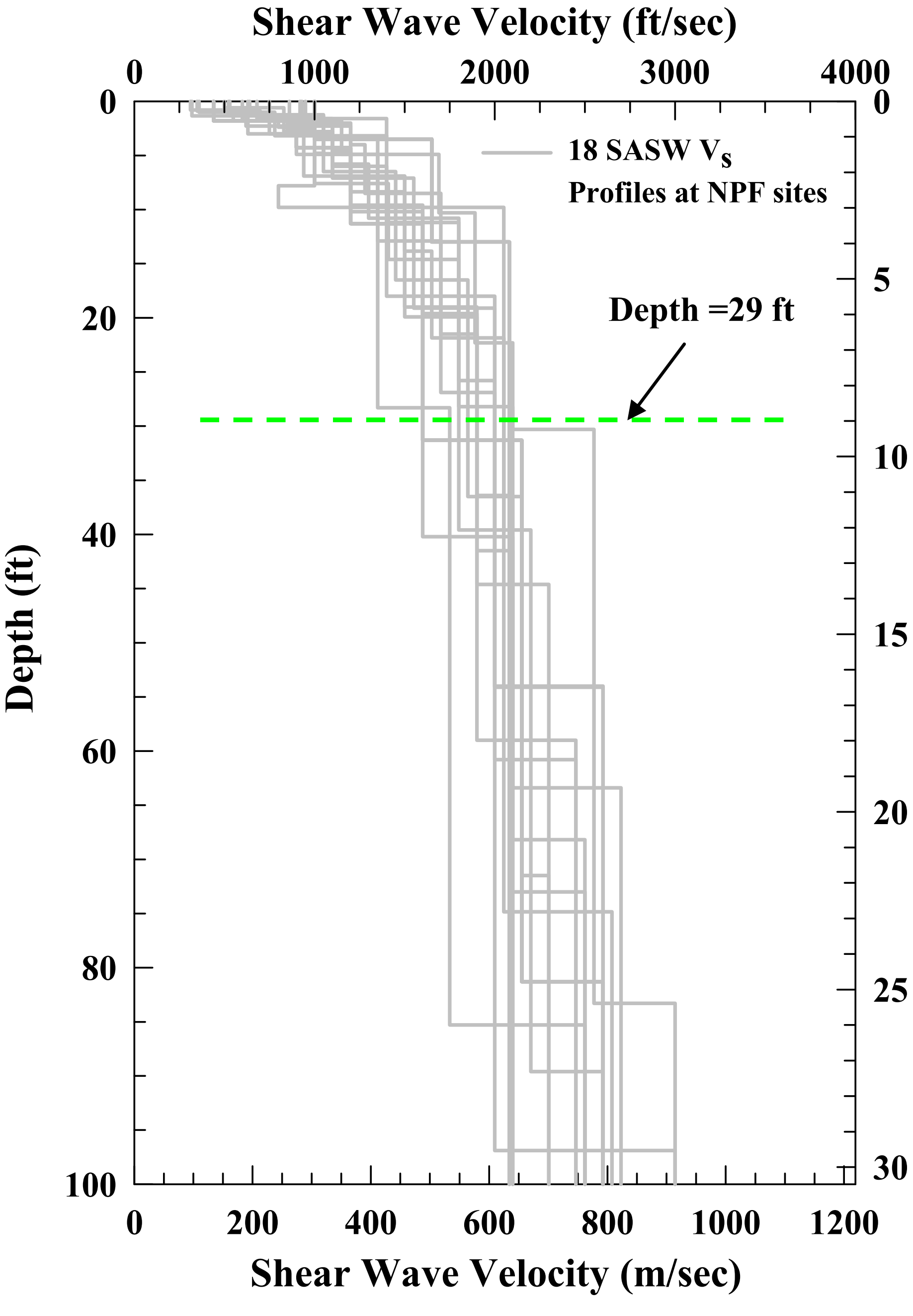
where Φ is the standard normal function.

The values of 16th and 84th percentiles are equal to the means minus or plus one standard deviation, respectively, and they can be calculated by Equations 6.2-6 and 6.2-7.

$$\frac{\ln(x_{16^{th}}) - \lambda}{\zeta} = \Phi^{-1}(0.16) = -1 \ \text{or} \ x_{16^{th}} = e^{\lambda-\zeta} \qquad \text{(Eq. 6.2-6)}$$

$$\frac{\ln(x_{84^{th}}) - \lambda}{\zeta} = \Phi^{-1}(0.84) = 1 \ \text{or} \ x_{84^{th}} = e^{\lambda+\zeta} \qquad \text{(Eq. 6.2-7)}$$

Statistical analysis demonstrated in this discussion starts with the V_S profiles displayed in Figure 6.2-12, which only represents the profiles for the top 100 ft. The V_S values at a 29-ft depth from the 18 profiles are listed in Table 6.2-6 and will be used in this discussion on statistical analysis.



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

Figure 6.2-12. Individual SASW V_S Profiles from 18 NPF Sites

Table 6.2-6. Table of V $_S$ Values at a Depth of 29 ft from 18 NPF Sites and Their Sample Mean and Standard Deviation

No.	Site Name	V_S at 29 ft., fps	Mean (μ), fps	Standard Deviation (σ), fps
1	NPF 1	2,050	1,921	154
2	NPF 2 and 14	2,080*		
3	NPF 3 and 9	2,050		
4	NPF 10	1,850		
5	NPF 12	2,000		
6	NPF 16	1,900		
7	NPF 17	2,100		
8	NPF 18	2,000		
9	NPF 19	2,000		
10	NPF 20	2,000		
11	NPF 21	1,900		
12	NPF 22	2,100		
13	NPF 23	1,900		
14	NPF 24	1,800		
15	NPF 25	1,750		
16	NPF 26	1,600		
17	NPF 27	1,900		
18	NPF 28	1,600*		

Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

* Average V_S of three possible profiles at the same depth.

Based on Equations 6.2-1 and 6.2-2, the sample mean and standard deviation are calculated which are 1,921 and 154 fps, respectively. Table 6.2-7, presents the data used in the frequency plot shown in Figure 6.2-13. It was found convenient to divide the V_S data into 100-fps bins (increments) in developing the frequency plot. The frequency plot of real data and the assumed lognormal distribution are compared in Figure 6.2-13. The mean (Equation 6.2-1), median (Equation 6.2-5) and mode are shown in Figure 6.2-13. The mode is the most likely value of V_S at a depth 29 ft.

Table 6.2-7. Frequency Plot Data for V_S Values at 29 ft at 18 NPF Sites

V_S Interval		Number of Occurrences	Frequency of Occurrences (%)
Lower Bound (fps)	**Upper Bound (fps)**		
(a)	**(b)**	**(c)**	**(d)**
1,400	1,500	0	0
1,500	1,600	2	11
1,600	1,700	0	0
1,700	1,800	2	11
1,800	1,900	5	28
1,900	2,000	4	22
2,000	2,100	5	28
2,100	2,200	0	0
2,200	2,300	0	0
$\sum$		18	100

(d) = (c) / Σ (c).

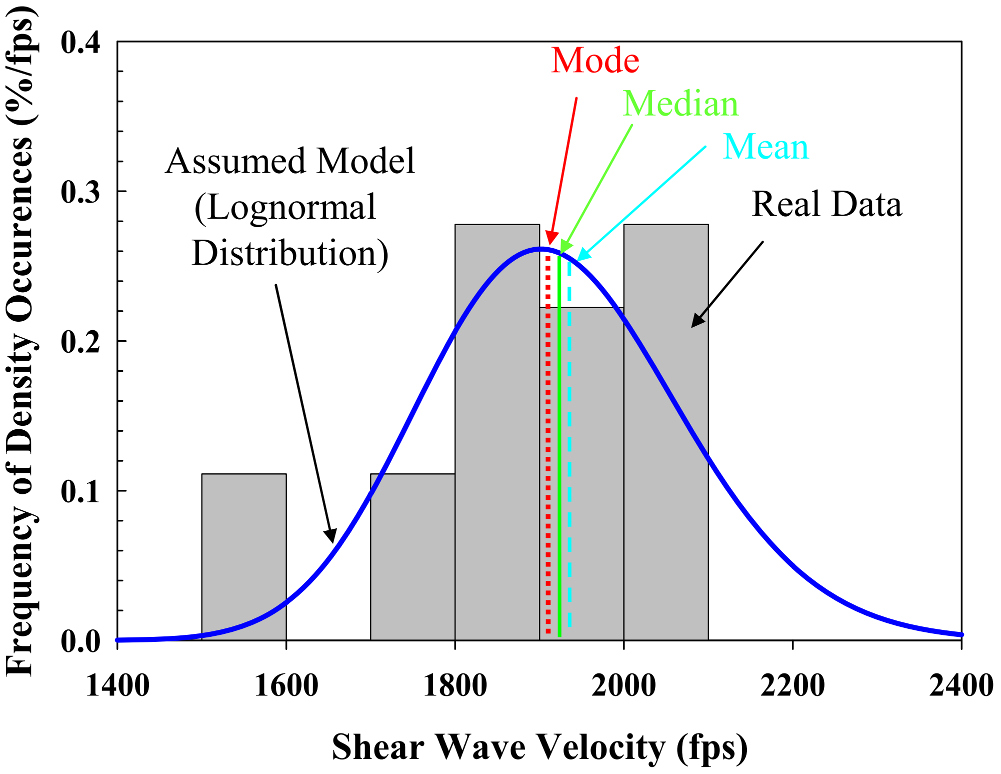


Figure 6.2-13. Frequency Plot of V_S Values at a Depth of 29 ft at 18 NPF Sites

By using Equations 6.2-3 through 6.2-7, the λ, ζ, x_m, x_{16th}, and x_{84th} can be obtained based on the calculated μ and σ. Their values are presented in Table 6.2-8. The μ, x_m, x_{16th}, and x_{84th} are shown in Figure 6.2-14.

The coefficient of variation (COV) is also presented in Table 6.2-8. The COV is determined by:

$$COV = \frac{\sigma}{\mu} \qquad \text{(Eq. 6.2-8)}$$

After the calculation is performed for each depth (foot by foot), the statistical information is presented as shown in Figure 6.2-15, which is identical to the Figure 6.2-16 in Section 6.2.5.3.

Table 6.2-8. Statistical Data of V_S Profiles at 29 ft from 18 NPF Sites

Data	Depth (ft)	Profile No.	μ (fps)	σ (fps)	λ	ζ	x_m (fps)	x_{16th} (fps)	x_{84th} (fps)	COV
Equation	N/A	N/A	6.2-1	6.2-2	6.2-3	6.2-4	6.2-5	6.2-6	6.2-7	6.2-8
Value	29	18	1,921	154	7.557	0.080	1,915	1,768	2,074	0.080

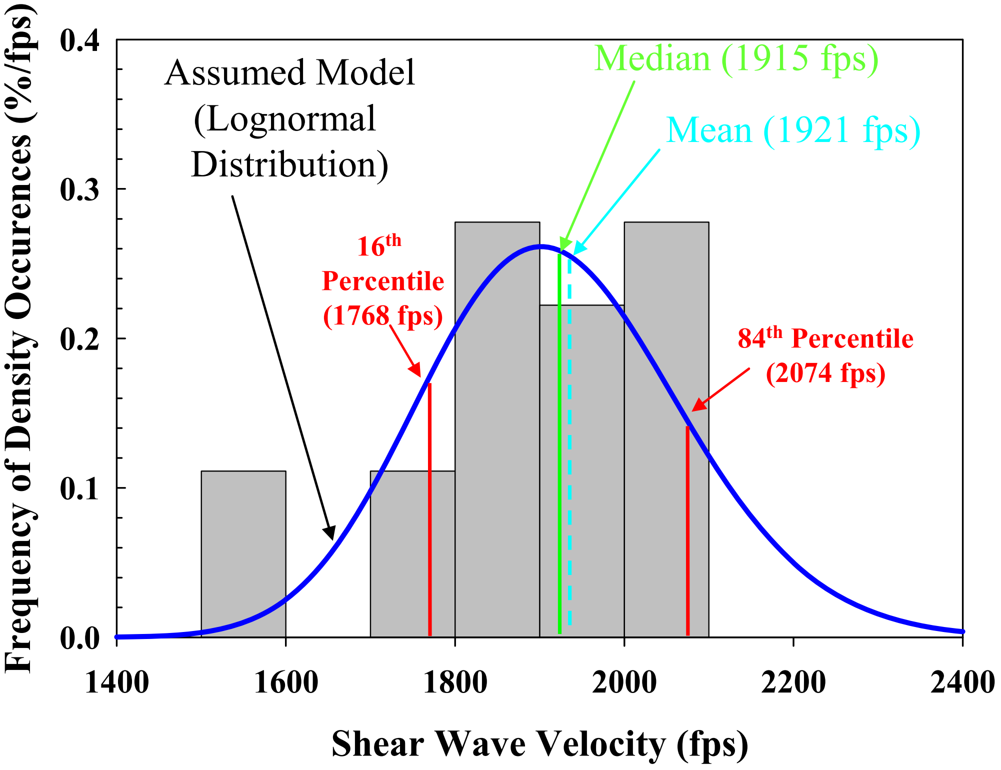
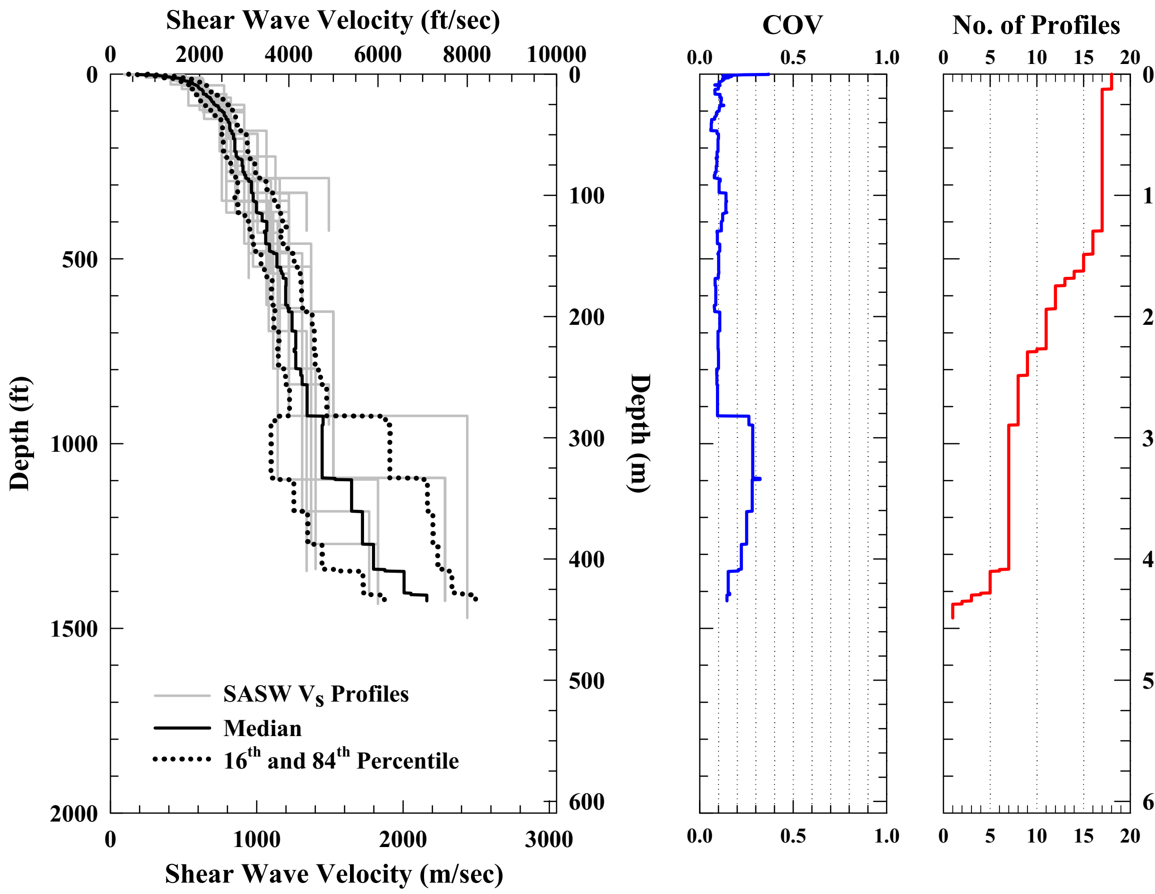


Figure 6.2-14. Frequency Plot of V_S Values at a Depth of 29 ft at 18 NPF Sites



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.2-15. Individual Profiles and Statistical Analysis of 18 SASW Tests Performed at NPF Area

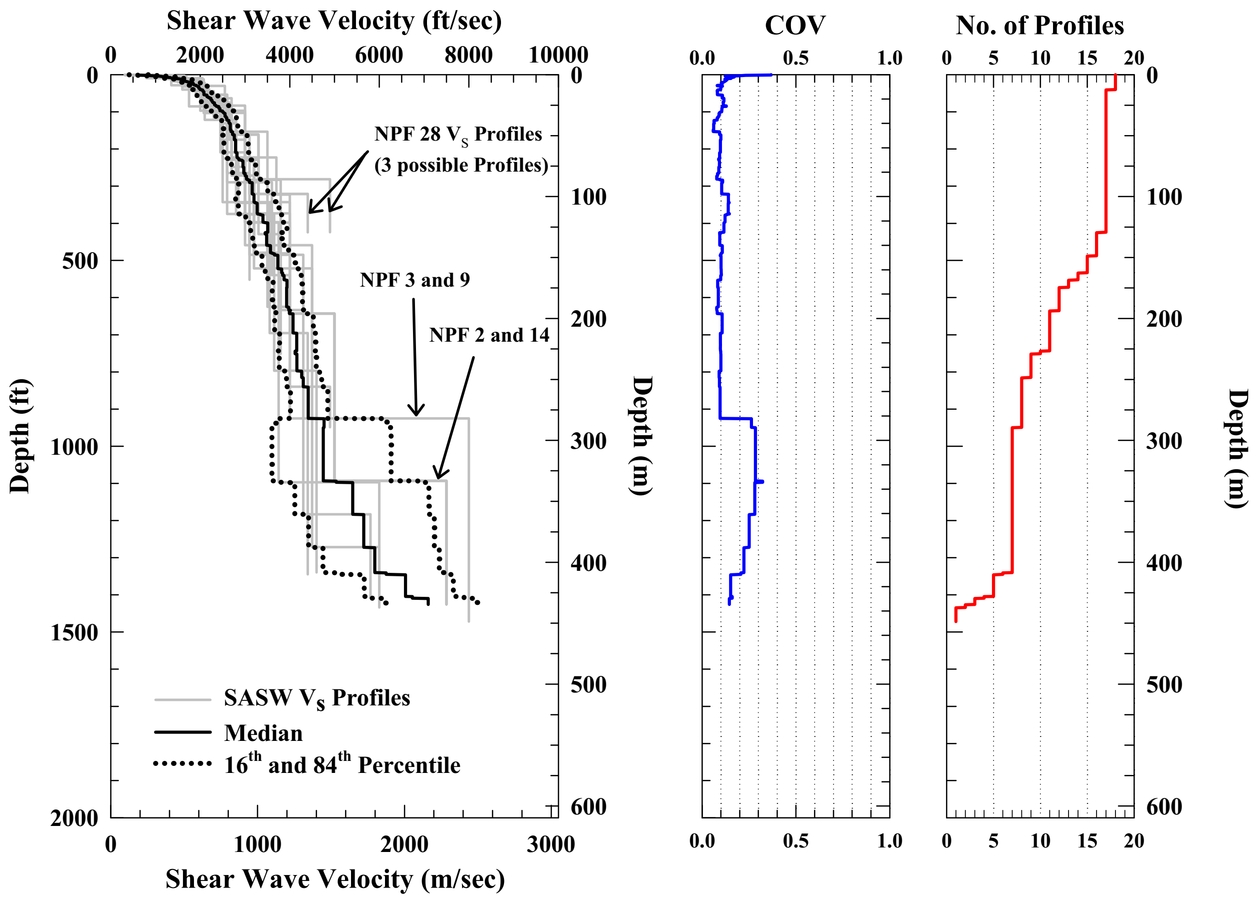
6.2.5.3. Results

The individual experimental and theoretical dispersions curves and the resulting shear wave velocity profiles for the NPF Area are contained in Attachment IV. Among the 18 NPF Area V_S profiles, the shortest profile was acquired at Site NPF 1. Data from NPF 1 suggest that a large lateral variation in shear wave velocity exists at this site. The variation between the three alternative V_S profiles at NPF 1, is more than 50% which can not be accounted for in the data reduction so only the consistent portion of the V_S profiles at the shallow depths for Site NPF 1 are displayed. Since these three profiles are only consistent in the top 40 ft. the final profile only extends to a depth of 40 ft in Table 6.2-5. Alternatively, at NPF 28, the differences/variation of the three V_S profiles are less than 15%. This variation is assumed to result from some lateral variability which is not large for engineering analyses so all three V_S profiles for Site NPF 28 are displayed. The deepest SASW V_S profile obtained in the NPF Area is 1,472 ft at Site NPF 3 and 9. In general, the depths of profiles range from 500 to 1,450 ft.

When computing statistics on the suite of profiles at the NPF Area, all profiles at a given depth are used. As shown in Figure 6.2-16, as depth increases, the number of profiles decreases. Although its recognized that a statistical analysis on a small population (less than 10) is not ideal, the analysis was still performed for consistency in illustrating the data from the larger population.

In Figure 6.2-16, the 18 NPF Area V_S profiles and the statistical analysis results are shown. As seen, the COV profile is quite constant (about 0.10) from 30 to 930 ft. However, below 930 ft the COV value becomes three times larger because of the significant variability in the velocities in the lower parts of the V_S profiles, especially the higher velocities at Sites NPF 2 and 14, and NPF 3 and 9. Some greater variability in profiles can be observed in the depth range of 280 to 430 ft. These profiles are alternative interpretations from Site NPF 28, which is located near Exile Hill. Site NPF 28 has minimal overlying alluvium which directly overlies Tiva Canyon Tuff without any intervening non-welded units, which are found on the other (northeast) side of the Exile Hill Fault Splay. It is likely, therefore, at these depths (280 to 430 ft) for Sites NPF 2, NPF 14, and NPF 28, that the velocities represent those associated with the welded Tiva Canyon Tuff, whereas for the other sites surveyed in 2004 and 2005 these depths are associated with the non-welded units below the alluvium. The welded and non-welded units have distinctly different velocity characteristics. At the bottom of the V_S profiles for Sites NPF 2 and 14, and NPF 3 and 9, the V_S values increase abruptly. Based on results from the 2001 drilling (BSC 2002 [DIRS 157829]) these SASW surveys where performed almost directly on or near the Exile Hill Splay fault and they may even cross the fault at the southern end of the survey line. This created a complex shear wave velocity measurement. Therefore, to avoid the uncertainty associated with the lack of lateral uniformity in the tuff at the bottom of these V_S profiles, the V_S data were removed at deeper depths in computing profile statistics.

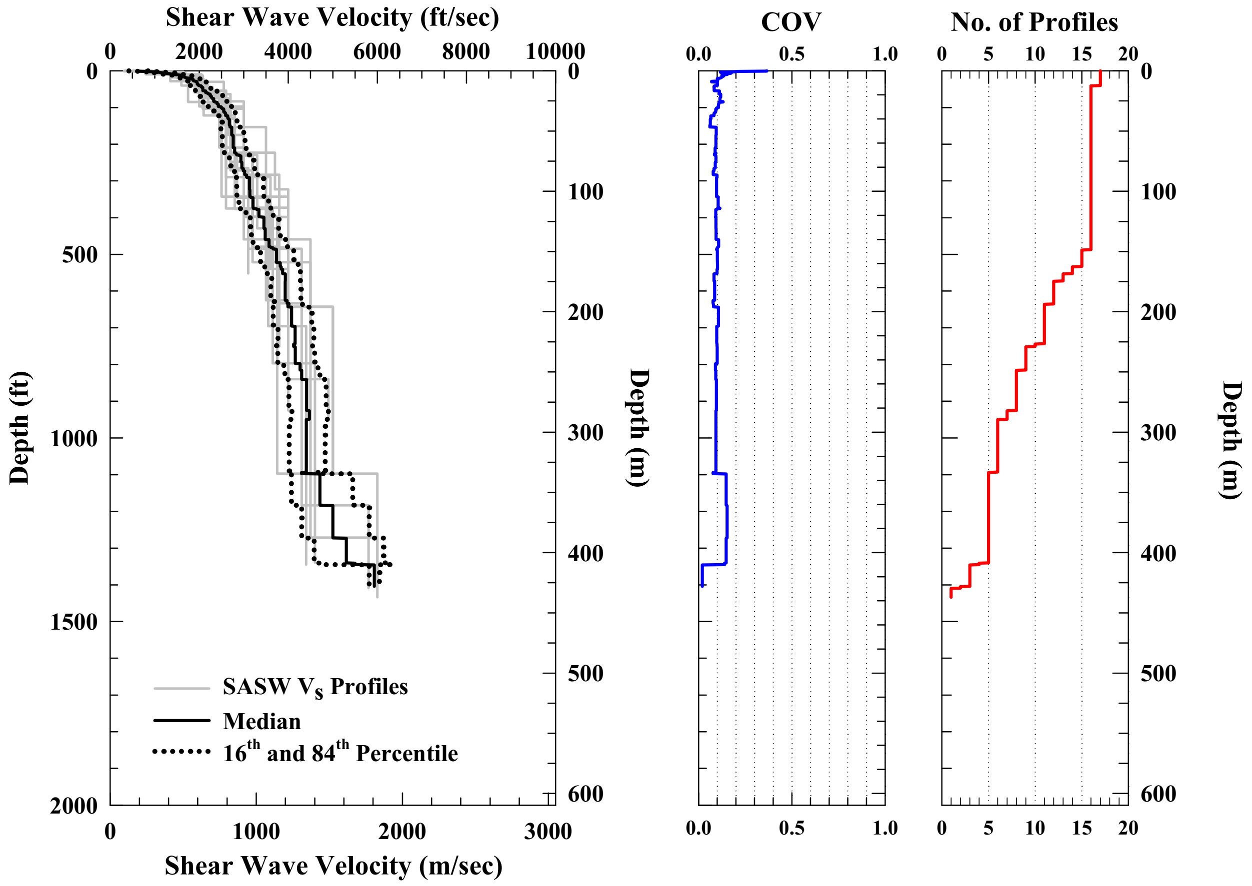
Results that exclude the V_S profiles at the bottom of Sites NPF 2 and NPF 14, NPF 3 and NPF 9, and NPF 28 is presented in Figure 6.2-17. As seen, the COV profile has a constant value of 0.10 from about 30 to 1,100 ft and smaller COV values below 1,100 ft than shown in Figure 6.2-16. In the final data submittal, SASW surveys NPF 2 and NPF 14 were combined into a single velocity profile, as were NPF 3 and NPF 9. These surveys were combined as they represented the same physical location in the North Portal Area. NPF 2 and NPF 3 were performed in early summer of 2004; following modifications to the vibroseis truck, which improved the signal source quality at low frequencies, the surveys were repeated later that summer as NPF 14 and NPF 9 to achieve deeper profile depths.



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.2-16. Individual Profiles and Statistical Analysis of 18 SASW Tests Performed at NPF Area



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.2-17. Individual Profiles and Statistical Analysis of 17 SASW Tests Performed at NPF Area without Site NPF 28 and Bottom V_S Profiles below 900 ft of Sites NPF 2 and 14 and NPF 3 and 9

6.2.5.4. Aging Pad Results

In 2004, the North Portal Facilities design had an aging pad located to the northwest of Exile Hill as displayed in Figure 6.2-7. SASW surveys covering this preliminary location were identified with an "AP" in their site name. Subsequent to carrying out those surveys, this aging pad was eliminated from the design and aging pads were located to the northeast of Exile Hill (Figure 6.2-1). Even though these surveys no longer address a specific facility, they still provide velocity data for the area and are included in this report. The individual experimental and theoretical dispersions curves and the resulting shear wave velocity profiles are contained in Attachment IV.

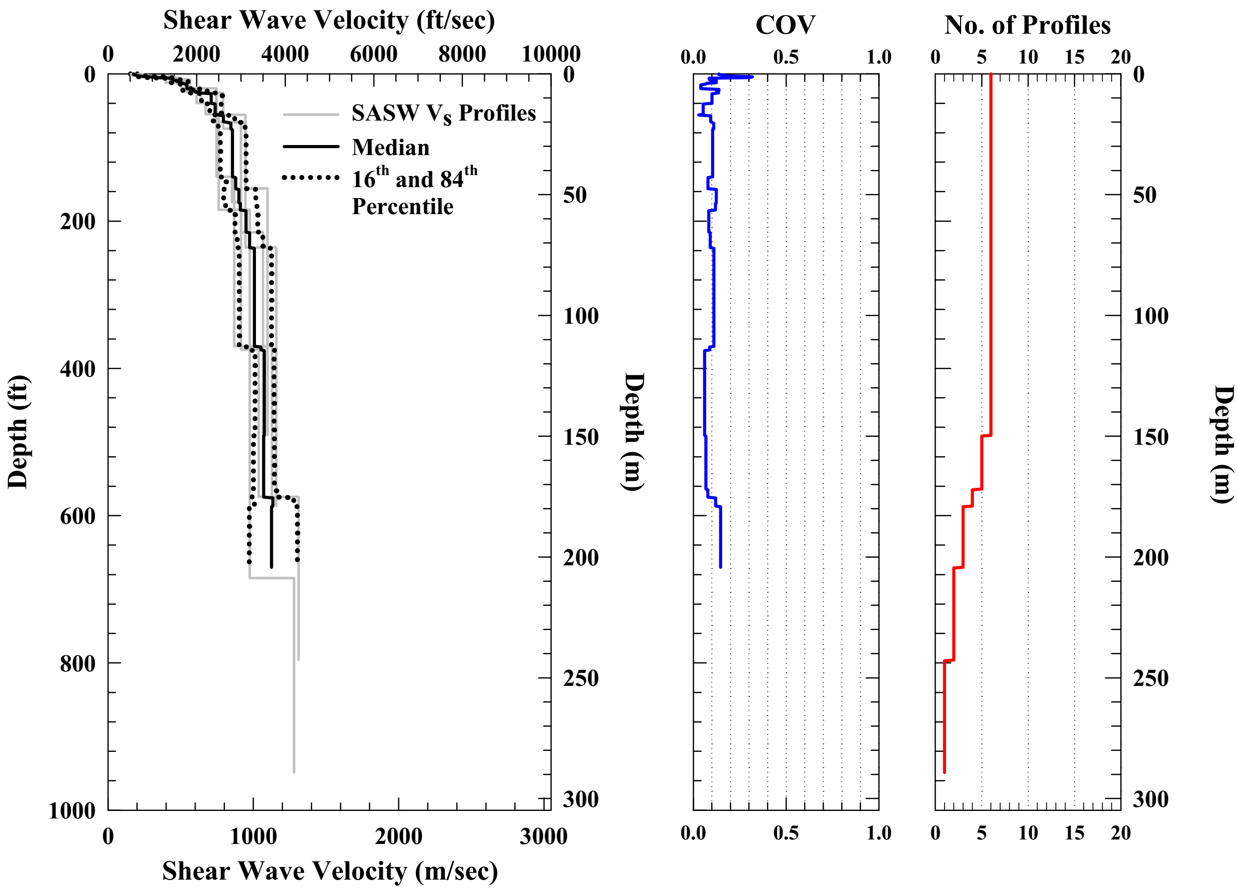
At the former aging pad area, six SASW tests were carried out in 2004 and 2005. The area (Figure 6.2-7) that was covered by the SASW testing is about 800 by 1,000 ft. Information about these six SASW surveys is presented in Table 6.2-9. For the Aging Pad Area, the deepest V_S profile is about 950 ft at Site AP 8. The shallowest one is about 490 ft at Site AP 5. On average, the profiling depth is about 670 ft for these six sites. The six SASW V_S profiles are plotted in Figure 6.2-18 with their statistical information. As seen in the COV profile, on average, this area has a very low COV value, about 0.1, from surface to the depth of about 600 ft. This low value shows that the velocity of the geologic deposit is very uniform in this area. This uniformity is attributed to the greater thickness of the alluvium and bedded tuffs.

Table 6.2-9. Six SASW Tests Performed at the Aging Pad Area

No.	Site Name	Profile Depth (ft)	Test Date
1	AP 1	587	25-Aug-04
2	AP 3	564	25-Aug-04
3	AP 5	491	25-Aug-04
4	AP 6	670	31-May-05
5	AP 7	796	31-May-05
6	AP 8	949	31-May-05

Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: The initial naming convention for the Aging Pad SASW surveys intended to use odd number designations for the north-south surveys and even numbers for the east-west surveys. Test personnel changed between the 2004 and 2005 surveys. New personnel failed to follow the initial naming convention; therefore AP 2 and AP 4 were never used in designating an SASW survey.



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.2-18. Individual Profiles and Statistical Analysis of the Six SASW V_S Profiles in the AP Area

6.3. DATA ACQUIRED AT AREAS OUTSIDE NORTH PORTAL FACILITIES AREA

6.3.1. Overview

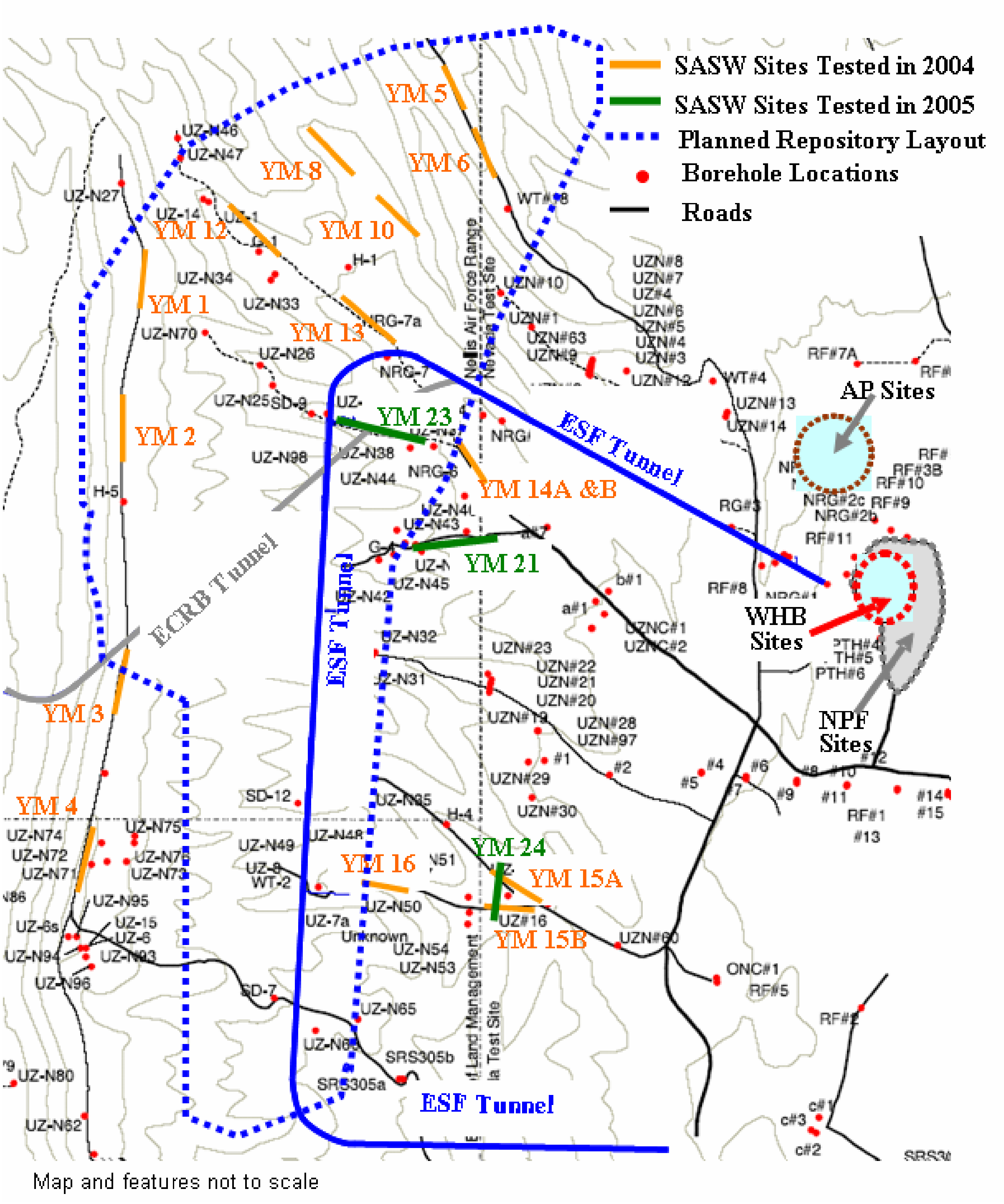
In 2004 and 2005, a total of 24 SASW surveys were performed on the surface outside the NPF Area. The SASW surveys performed in 2004 and 2005 augment the 33 sites that were surveyed from 2000 to 2001. The location and the details regarding the 2000 to 2001 work is contained in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829], Section 6.4.2.1).

The data for the 24 SASW surveys performed in 2004 are identified with a "YM." Eighteen of these surveys were performed in areas that were near the waste emplacement area. Figure 6.3-1 represents the 18 SASW surveys that were performed for the purposes of obtaining velocities over or near the waste emplacement areas.

Six of the SASW survey sites in the vicinity of Yucca Mountain were tested because these locations represent areas where a specific geologic unit, such as the Calico Hills Formation, would be at a depth such that its velocity could be characterized using the SASW method. This testing at these six locations allowed measurements of the velocity of geologic units that occur below the waste emplacement area but that are too deep to be reached by SASW surveys within the repository subsurface footprint. All of the surface SASW surveys performed in 2004 and 2005 that were outside the North Portal Facilities Area are listed in Table 6.3-1, but due to the scale of the map, they could not be displayed in figure 6.3-1.

The locations of all of the SASW sites (with the exception YM 18 and YM 24) were surveyed and the results were submitted to the TDMS as part of DTN: MO0701ABSRFLL2.000 [DIRS 182483]. The location surveys were not performed at each receiver location, but they were performed at the center point and at the largest receiver spacing for a specific test location. Each receiver location is identified as –C, –F or –N to designate the center, far, and near receiver relative to the energy source. All shorter spacing lines are contained within the survey line representing the largest spacing. Section 6.2.5 contains the description of the receiver configuration and the discussion of the energy sources used in performing these SASW surveys.

The test configuration for a specific site, the resulting phase plots and experimental and theoretical dispersion curves are contained in scientific notebook SN-M&O-SCI-047-V2 (Stokoe 2007 [DIRS 183327]). The final acquired and developed data for these sites, which also consist of the experimental and theoretical dispersion curves and the final velocity profiles, are contained in DTNs: MO0609SASWSEDC.001 [DIRS 183293] and MO0609SASWSTDC.003 [DIRS 182125].



Map and features not to scale

Source: DTN: MO0701ABSRFLL2.000 [DIRS 182483] and BSC 2007 [DIRS 180072] for ITS facilities.

NOTE: Sites YM 17, YM 19, YM 20, YM 22, YM 25, and YM 26 are outside the area of this map and are not included.

Figure 6.3-1. Approximate Locations of the Yucca Mountain Sites above the Proposed Repository Area and the Areas of the NPF and AP Sites

Table 6.3-1. Information about the 24 SASW Tests Performed in the Yucca Mountain Area during 2004 and 2005

No.	Site Name	Profile Depth (ft)	Test Date
1	YM 1	1,467	13-Jul-04
			18-Aug-04
2	YM 2	1,314	9-Jul-04
			17-Aug-04
3	YM 3	1,121	10-Jul-04
			17-Aug-04
4	YM 4	970	9-Jul-04
5	YM 5	1,496	15Jul-04
			19-Aug-04
6	YM 6	456	19-Jul-04
			19-Aug-04
7	YM 8	833	21-Jul-04
8	YM 10	976	22-Jul-04
			20-Aug-04
9	YM 12	743	7-Jul-04
10	YM 13	734	5-Jul-04
			14-Aug-04
11	YM 14A	982	2-Jul-04
			13-Aug-04
12	YM 14B	982	3-Jul-04
			13-Aug-04
13	YM 15A	1,276	29-Jun-04
			30-Jun-04
			9-Aug-04
14	YM 15B	1,139	30-Jun-04
			16-Aug-04
15	YM 16	1,149	1-Jul-04
			10-Aug-04
			16-Aug-04
16	YM 17	1,492	14-Jul-04
			19-Aug-04
17	YM 19	678	2-Jun-05
18	YM 20	965	3-Jun-05
19	YM 21	995	7-Jun-05
20	YM 22	945	8-Jun-05
21	YM 23	1,031	10-Jun-05

Table 6.3-1. Information about the 24 SASW Tests Performed in the Yucca Mountain Area during 2004 and 2005 (Continued)

No.	Site Name	Profile Depth (ft)	Test Date
22	YM 24	451	10-Jun-05
23	YM 25	790	11-Jun-05
24	YM 26	1,243	13-Jun-05

Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: YM 7, YM 9, and YM 11 test designations were not used during this test program. YM 18 designation used on a test that was performed to evaluate the SASW method with other testing methods and not intended for use in characterizing the site velocity properties; therefore, YM 18 will not be included in this report.

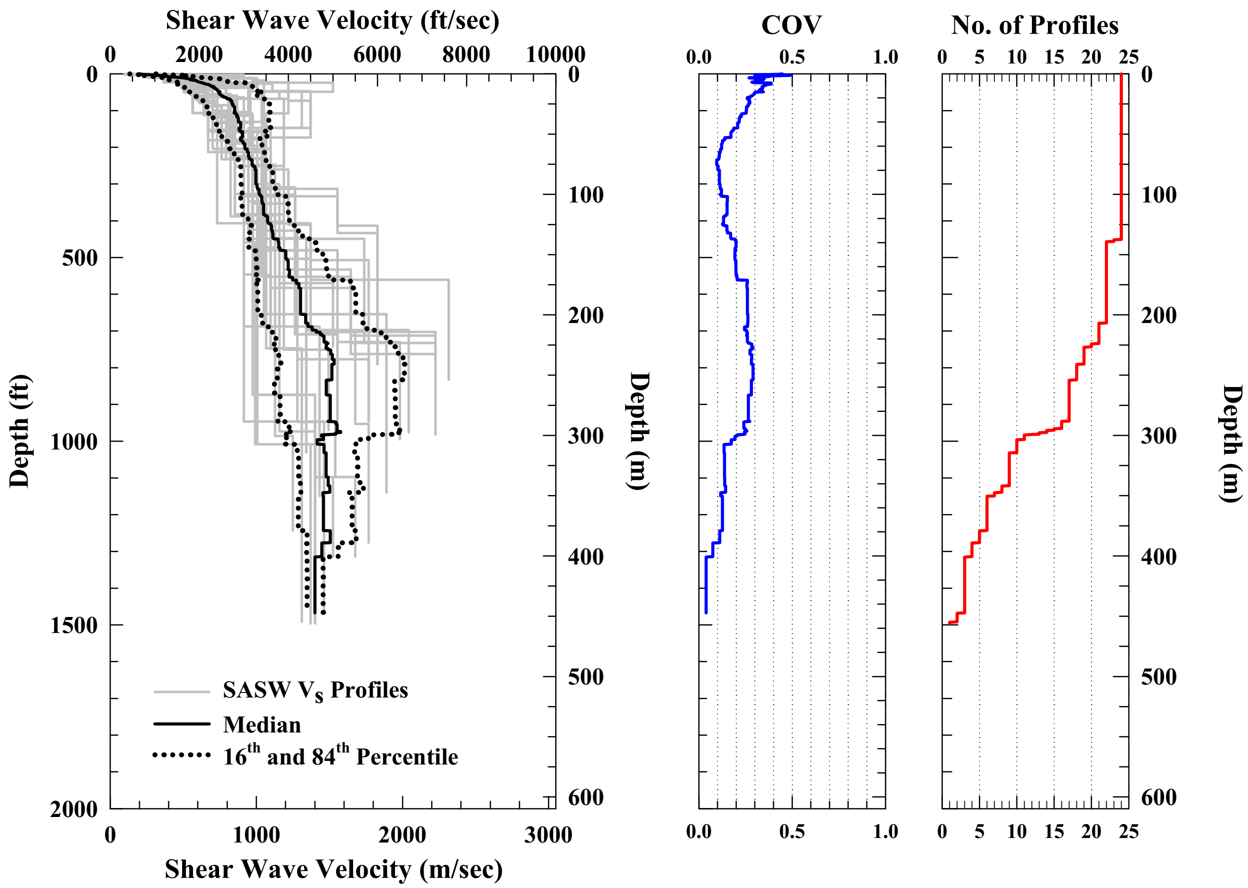
6.3.2. Results of SASW Surveys outside the North Portal Facilities Area

The individual experimental and theoretical dispersions curves and the resulting shear wave velocity profiles are contained in Attachment V. Figures 6.3-2 through 6.3-8 consist of various compilations of the shear wave velocity profiles as well as a statistical analysis of the profiles.

The method for performing the statistical analysis of the SASW measurements is contained in Section 6.2.5.2.

Figure 6.3-2 shows the 24 V_S profiles of YM sites and their statistical analysis. Among the 24 YM sites, the shallowest SASW V_S profile is 451 ft at Site YM 24. In contrast, the deepest one, 1,496 ft, is at Site YM 5. The maximum depth is almost twice the maximum profiling depth obtained in the 2000 and 2001 SASW test at this area. Moreover, most of the 24 SASW V_S profiles are over 750 ft. As observed in Figure 6.3-2, some profiles are stiffer, V_S values larger than 5,800 fps at the bottom of the profiles or softer, V_S values that never exceed 5,800 fps in the profile. Possible causes of this variability include variability in the geology related to the distribution of fractures, consolidation of the material, and the deposition mechanisms in the area tested. These factors would affect the transfer of seismic energy through the tested area. As a result of the velocity variability, the COV profile has a wide range of values from 0.05 to 0.35 at various depths below about 25 ft.

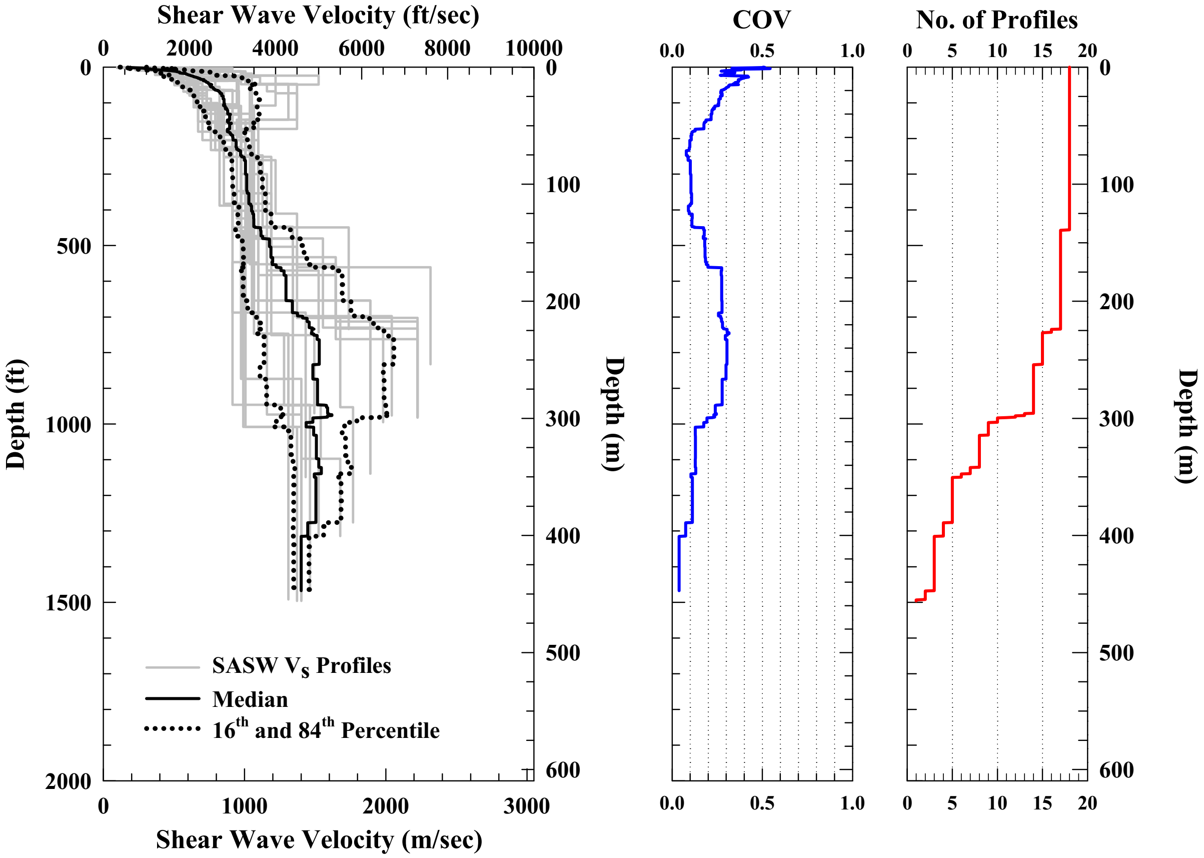
Figure 6.3-3 presents the 18 V_S profiles of the YM sites that either are over or near the repository waste emplacement area (see Figure 6.3-1 to locate the repository footprint). It should be noted that there is not much difference between the results in Figures 6.3-2 and 6.3-3. In addition, it seems that the velocity profiles can be separated into several velocity groups below 600 ft in Figure 6.3-2. This grouping is not observed in the 2000 and 2001 SASW tests because the depths of the SASW profiles were not deep enough to see it.



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.3-2. Individual Profiles and Statistical Analysis of 24 SASW Tests Performed around the Yucca Mountain Area



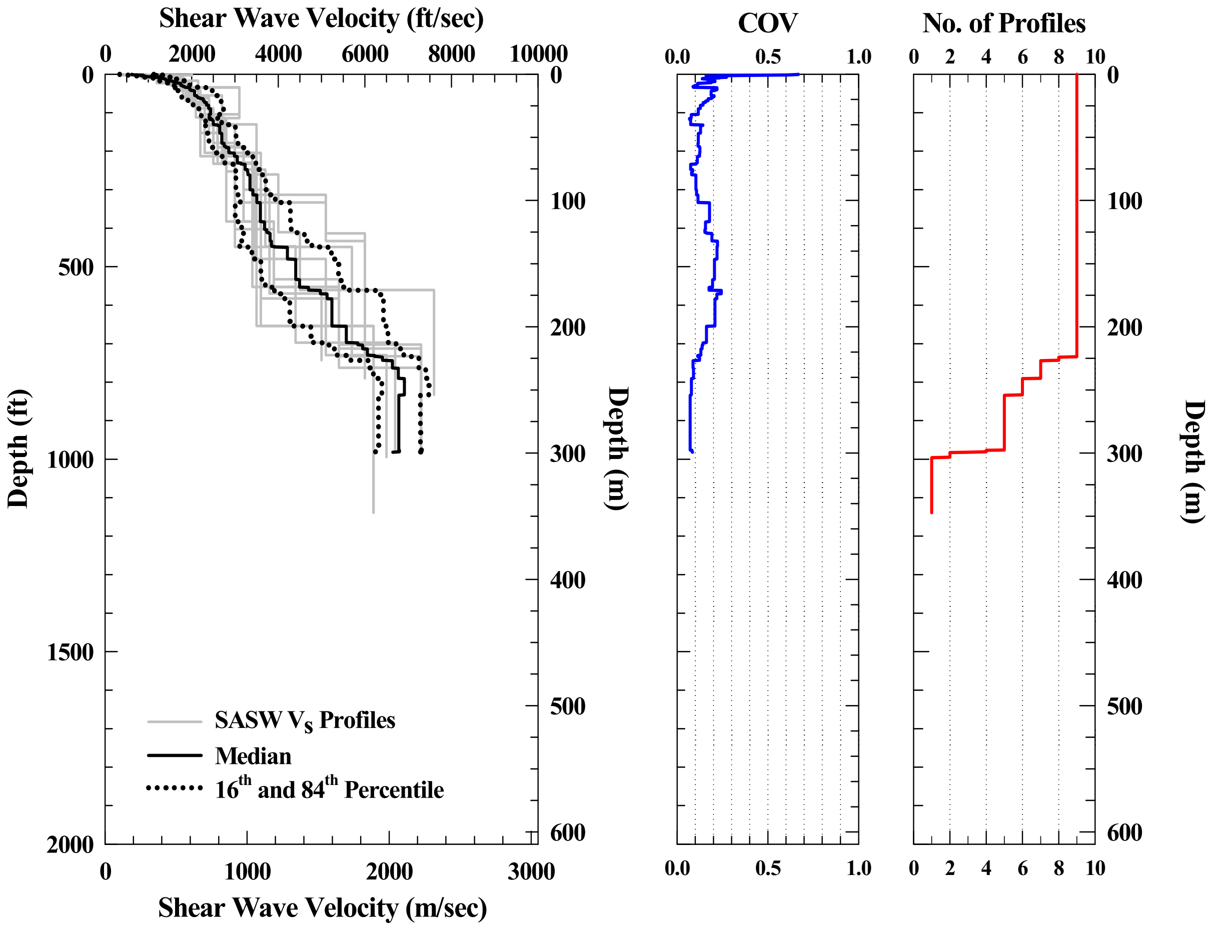
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: These sites are near the repository area. Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.3-3. Individual Profiles and Statistical Analysis of 18 SASW Tests Performed within or near the Repository Waste Emplacement Area Footprint

Because of the large variation in the V_S profiles determined at the YM sites, the 24 sites are divided into three generalized groups based on their V_S profiles. The first group is “stiffer” sites. This group exhibits V_S values higher than 5,800 fps at the bottom of the profiles. The sites are YM 8, YM 10, YM 12, YM 13, YM 14A, YM 14B, YM 15B, YM 21, and YM 25. These nine sites are around the planned repository area, except for Site YM 25, which is located along the southern tip of Fran Ridge, to the southeast of the repository footprint. The V_S profiles and corresponding statistical analysis of the stiffer sites are shown in Figure 6.3-4. The second group is “softer” sites. This group exhibits V_S values that never exceed 5,800 fps in the profile. The sites are YM 1, YM 2, YM 3, YM 4, YM 5, YM 6, YM 16, YM 17, YM 23, and YM 26. Site YM 26, which is located on the road to the Yucca Mountain Crest near Rainer Ridge and WT#17, is the only site not around the planned repository footprint area. The V_S profiles and statistical analysis of the softer sites are shown in Figure 6.3-5. The remaining five sites, YM 15A, YM 19, YM 20, YM 22, and YM 24, are “neutral” sites whose V_S profiles in the 750 ft to 1000 ft range do not extend to a sufficient depth >1,200 ft to allow them to be grouped into “stiffer” or “softer” categories, or they have V_S profiles that are distributed between the first two groups. These “neutral” sites are shown in Figure 6.3-6.

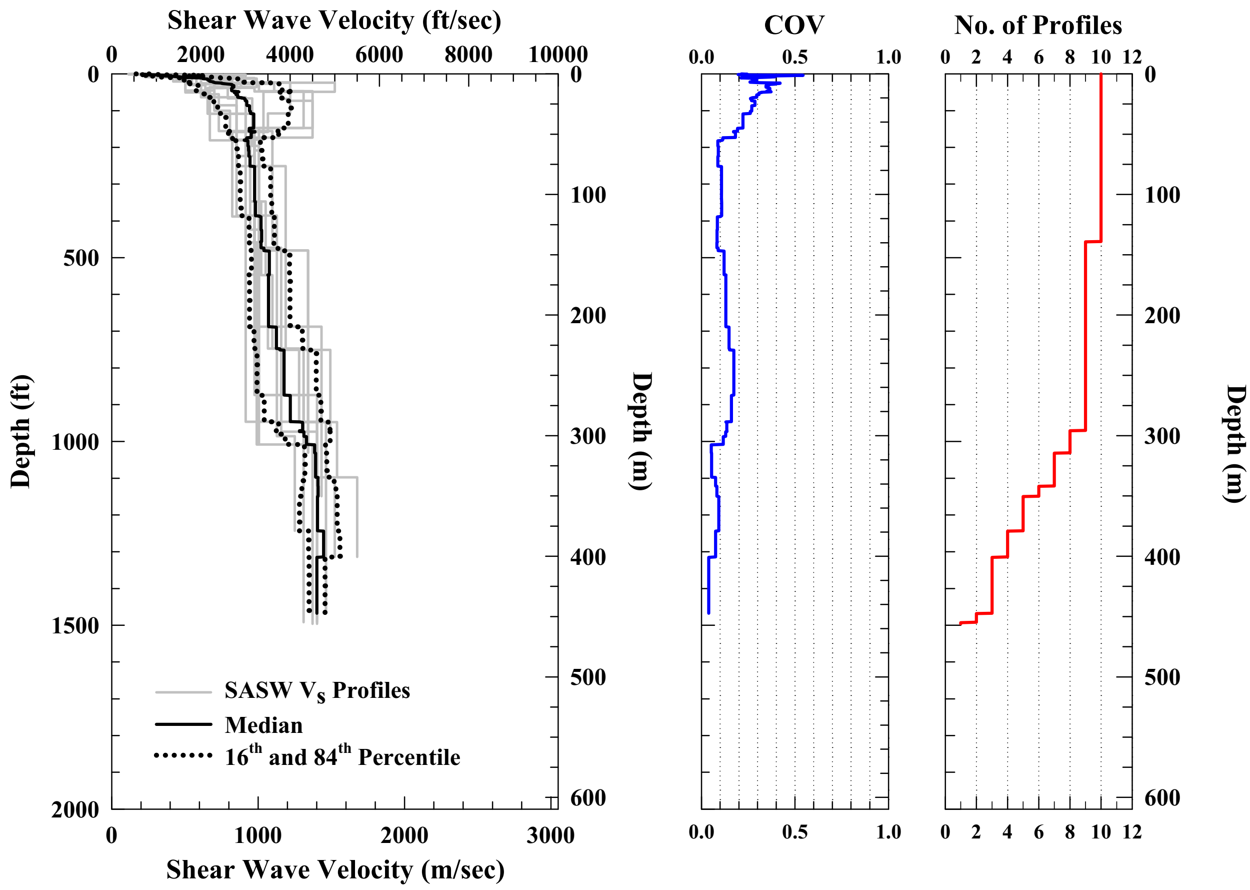
If only the sites around the planned repository area are considered, Figures 6.3-4 and 6.3-5 can be re-plotted as Figures 6.3-7 and 6.3-8, respectively. As seen, there is not much difference between Figures 6.3-4 and 6.3-7 and Figures 6.3-5 and 6.3-8 in terms of their median V_S profile, the 16th and 84th percentile boundaries, and the COV profiles. This comparison is true even in Figures 6.3-2 or 6.3-3, where the COV values are larger in the top 180 ft and at the depths from 450 ft to 1000 ft. The reason for the lager variation in the top 180 ft is the velocity inversions in the shallow V_S profiles. The reason for the larger COV values at the depths from 450 ft to 1,000 ft could be geologic variability and localized fracturing in some areas. As observed, the COV values in Figures 6.3-4 through 6.3-8 are smaller than the COV values in Figure 6.3-2 (or 6.3-3). This is because similar profiles are grouped to make the statistical analyses in Figures 6.3-4 through 6.3-8.



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

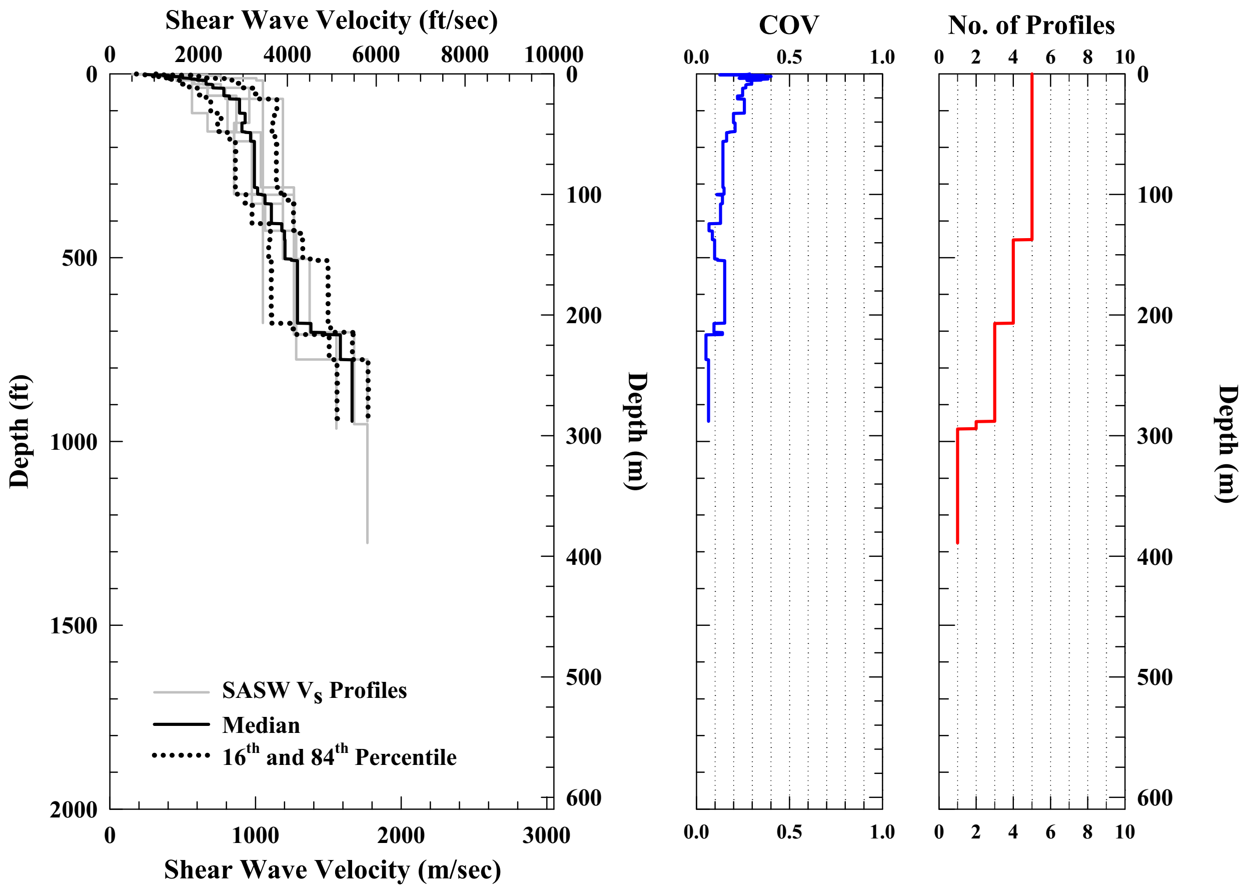
Figure 6.3-4. Individual Profiles and Statistical Analysis of the Nine “Stiffer” SASW V_S Profiles around the Yucca Mountain Area



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

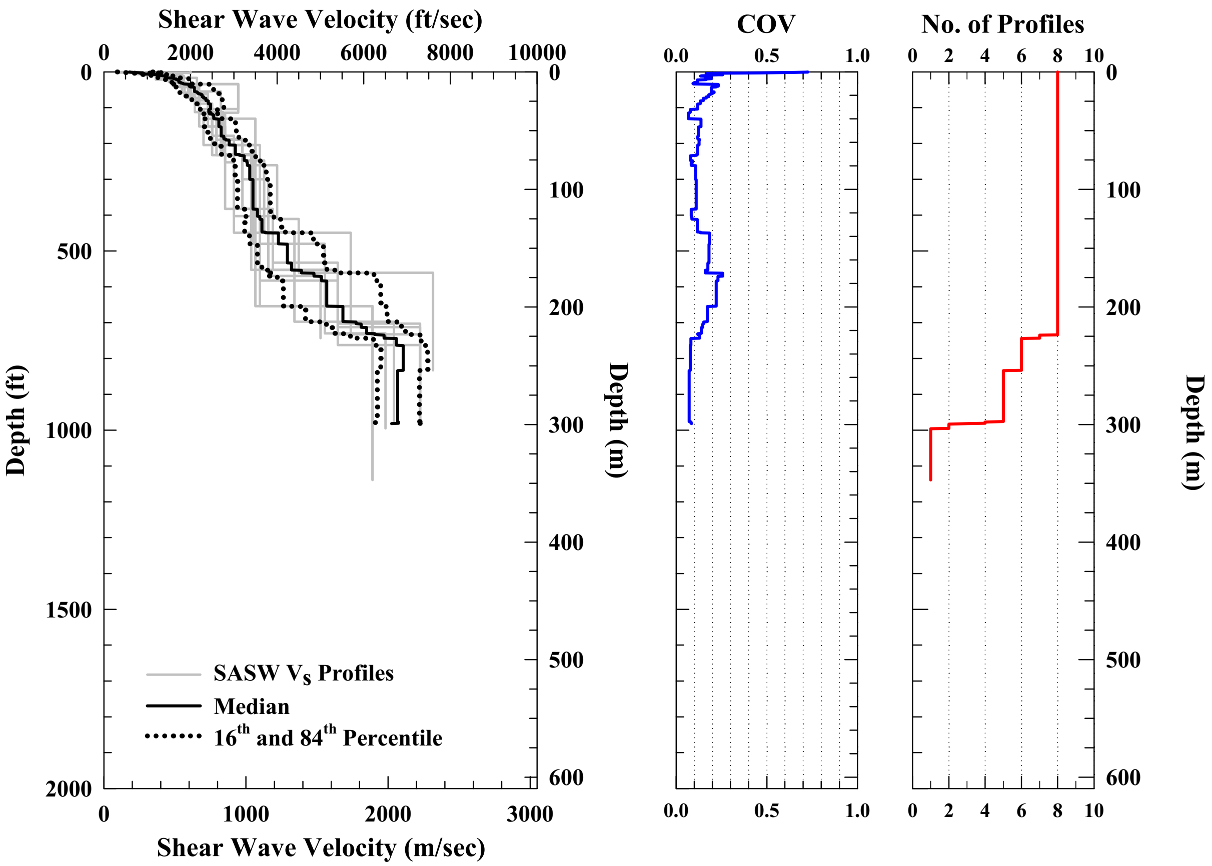
Figure 6.3-5. Individual Profiles and Statistical Analysis of the Ten “Softer” SASW V_S Profiles around the Yucca Mountain Area



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

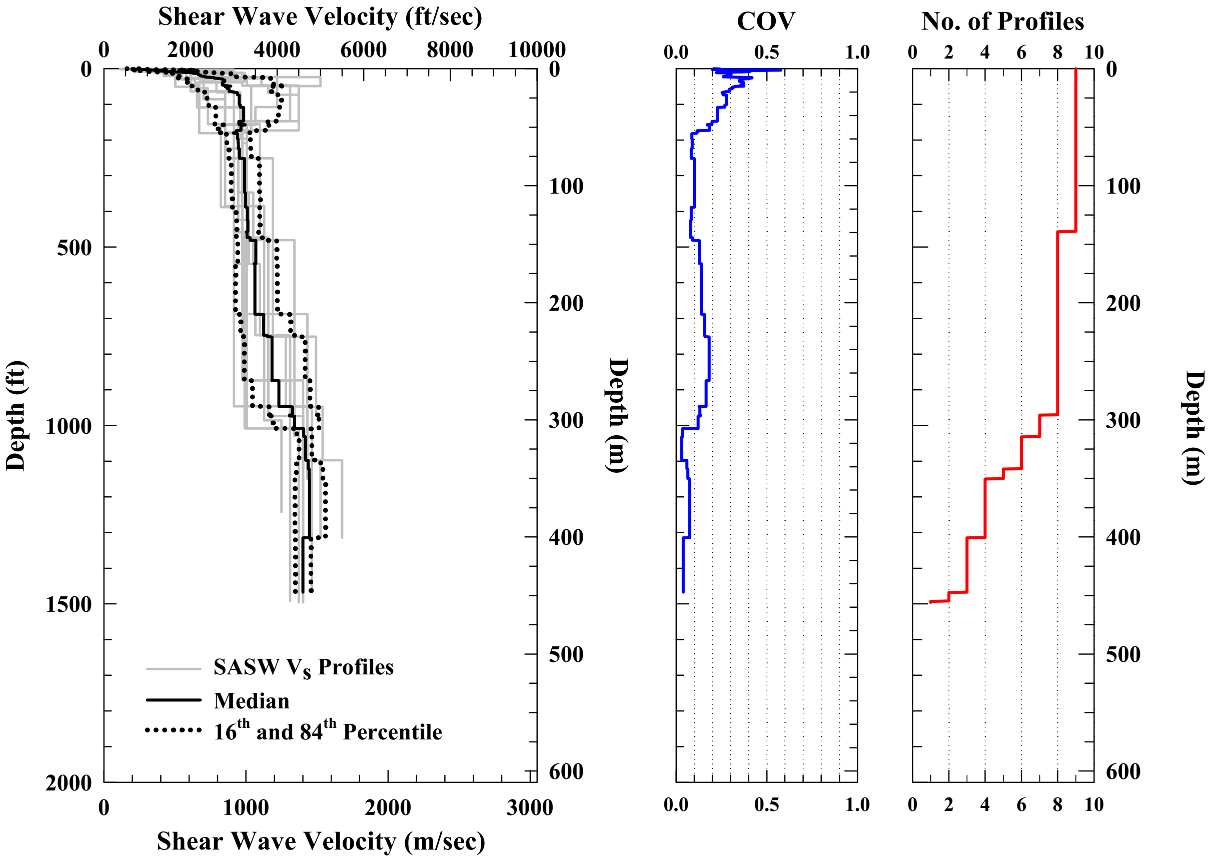
Figure 6.3-6. Individual Profiles and Statistical Analysis of the Five “Neutral” SASW V_S Profiles around the Yucca Mountain Area



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.3-7. Individual Profiles and Statistical Analysis of the Eight “Stiffer” SASW V_S Profiles That Were Measured around the Yucca Mountain Area and over the Waste Emplacement Area



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125].

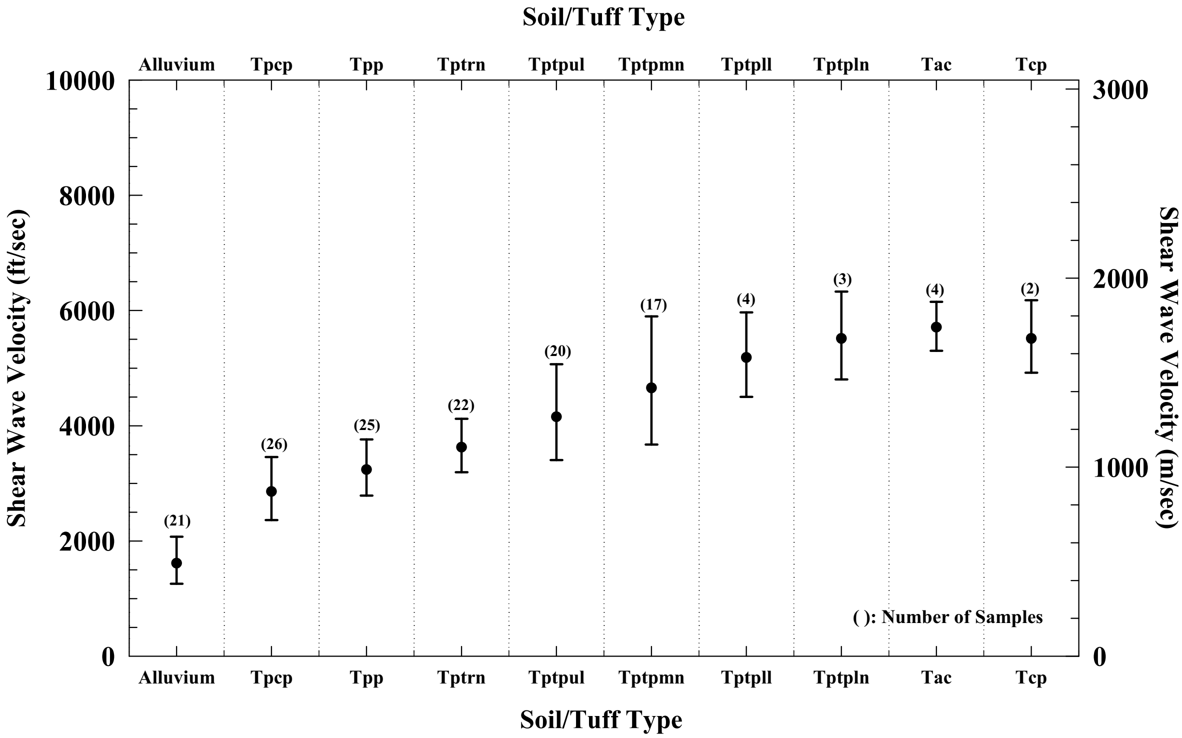
NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.3-8. Individual Profiles and Statistical Analysis of the Nine "Softer" SASW V_S Profiles Measured around the Yucca Mountain Area and over the Waste Emplacement Area

6.3.3. Statistical Analyses Based on Geologic Unit

Based on geologic profile information from the geologic framework model (GFM) (BSC 2004 [DIRS 170029]), shear wave velocities from surface SASW measurements were compiled and compared for the various alluvium and tuff units underlying Yucca Mountain. Because the depths and thicknesses of layers vary, the same units were compared regardless of their depths. However, the thickness of each layer had to be at least 10% of the layer depth to be utilized.

The general criteria used in selecting which sites to include in this analysis was based on having geologic profiles available in the GFM (not all areas tested were covered by the GFM) for the areas where SASW was performed. For sites used in this analysis, SASW surveys extended to at least 200 ft and accurate survey information exists. The 26 surveys from the 2004 campaign (16 YM, 7 NPF, and 3 AP sites) and 7 surveys from the 2001 campaign (7 D) meet these criteria and were selected for this analysis. The comparisons are presented in Figure 6.3-9. As seen, the alluvium has the lowest median V_S value at about 1,600 fps. In contrast, the Tptpln has the highest median V_S value at around 5,500 fps. In addition, the Tptpmn has the largest variation in the V_S value, which could be attributed to variation in density or fracturing of the unit.



Source: DTNs: MO0609SASWSTDC.003 [DIRS 182125] and MO0110SASWVDYM.000 [DIRS 158076].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.3-9. Distribution of V_S Velocities from SASW Testing by Geologic Unit

6.4. DATA ACQUIRED IN THE ESF AND THE ECRB CROSS-DRIFT

6.4.1. Overview

This section discusses the SASW surveys that were performed in the underground in December 2004 and June 2005. The surveys were performed in both the ESF main drift tunnel and the ECRB tunnel. When the data are presented, the five SASW surveys performed in 2001 are included in the summary plots for completeness. The details of the 2001 testing in the tunnel are described in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829], Section 6.3.2).

6.4.2. Approach

A total of 45 SASW surveys were performed in the ESF main drift tunnel and the ECRB auxiliary tunnel during 2004 and 2005 and are discussed in Section 6.4.4 and 6.4.5. The number is nine times as many tests as performed in the ESF tunnel in 2001. The locations were selected to represent a range of the exposed geologic units that comprise both the waste emplacement area as well as the geologic units above the waste emplacement area. When performing SASW surveys in the tunnel, it was preferred that a test location not be within 20 ft of the transition between tuff units. In several test locations, 20 ft of clearance from a transition between tuff units was not possible. When testing units near the transition between two tuff units, the measurement could be biased by the effects that result when a surface wave laterally samples two materials with different shear wave velocities. For example Site 03+15 was setup to test the Tpki unit but it was near the boundary with the Tpcrn2 unit. The resulting shear wave velocities were actually consistent with those of the Tpcrn2 unit, as determined at other locations, as opposed to the Tpki that was being tested. This bias is sometimes referred to as the 'boundary effect' during the reporting of these data.

Figure 6.4-2 displays the SASW test locations performed in 2004, and Figure 6.4-3 displays the 2005 test locations. Statistically, a large percentage of testing was concentrated on measuring the Tptpll and Tptpmn units, as these two units represent the majority of the waste emplacement horizon. In the underground, these two units are predominately available in the ECRB cross-drift.

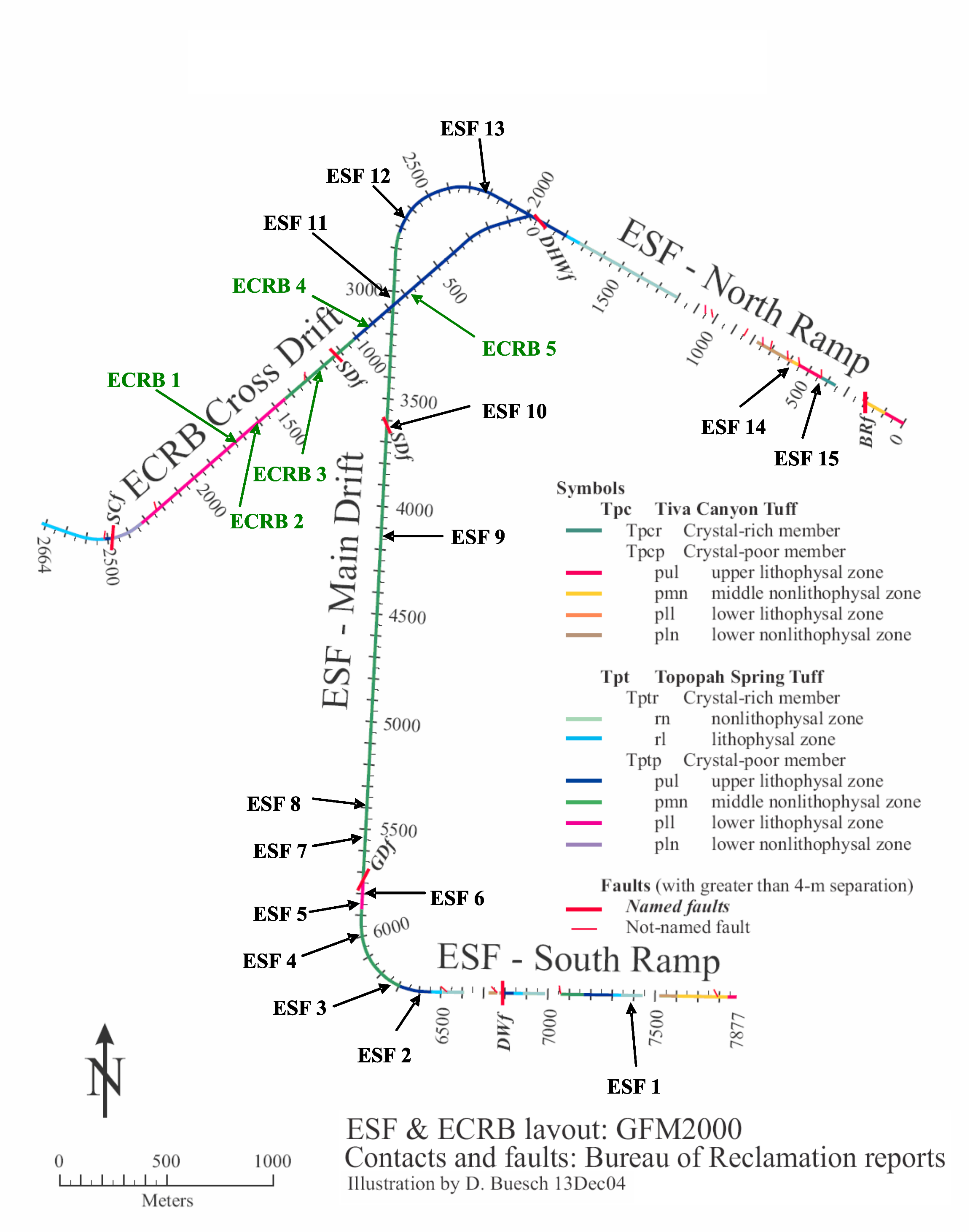
For the testing performed in 2004 and 2005, Wilcoxon Model 736 accelerometers matched with signal amplifiers were used as receivers. They were coupled to the rock using magnets to affix them to nails that had been driven into holes drilled into the tunnel surface. For the ESF, the surveys were performed at a height of roughly 3 to 6 ft from the bottom of the tunnel invert, but none of them reached the spring line height of the tunnel. The majority of the ESF surveys were performed on the wall that was on the outside of the ESF tunnel. In looking in from the North Portal, this would be the right-hand side of the tunnel, and from the South Portal this would be the left-hand side of the tunnel. For the ECRB cross-drift, the surveys were performed at approximately the spring line (center) of the tunnel wall. When looking into the ECRB cross-drift from the ESF tunnel, the SASW surveys were performed on the left-hand rib of the tunnel, with the exception of the ECRB 16 + 41 test location, which was located on the right-hand rib at a break in the conveyor belt assembly.

The center point of 29 sites representing a portion of both the 2004 and 2005 test locations were surveyed and their coordinates are listed in DTN: MO0706SASWPHII.000 [DIRS 183299]. The remaining 16 sites were not surveyed prior to suspension of operations in the tunnel in March 2007. The locations of these sites were developed by using a tape measure to record the distance to the nearest tunnel survey marker. Table 6.4-1 lists all sites tested, their specific tunnel location, and the geologic unit tested. The geologic unit identification was derived from *Geologic Framework Model (GFM2000)* (BSC2004 [DIRS 170029]).

For the underground SASW surveys, receiver spacings of 2, 4, 8, 16, and 32 ft were generally used. The 6 in and 1 ft spacings used in the 2001 testing were removed from the testing procedure. Testing at these shorter spacings resulted in highly variable and noisy data that were affected by the fractures and lithophysal cavities that exist near the tunnel wall, many of which extend 0.5 to 1 ft in diameter. Two impact hammers of 1 and 8 lbs. were used to excite the surface wave energy along the tunnel wall. Figure 6.4-1 displays a typical accelerometer attached to the drift wall and the 1lb hammer used as a signal source.

SASW surveys performed underground were documented in scientific notebook SN-M&O-SCI-047-V1 (Stokoe 2007 [DIRS 183272]). The final data submittals consisting of the experimental and theoretical dispersion curves, as well as the resulting shear wave velocity profile, are contained in DTNs: MO0609SASWUEDC.002 [DIRS 183294] and MO0609SASWUTDC.004 [DIRS 183295].

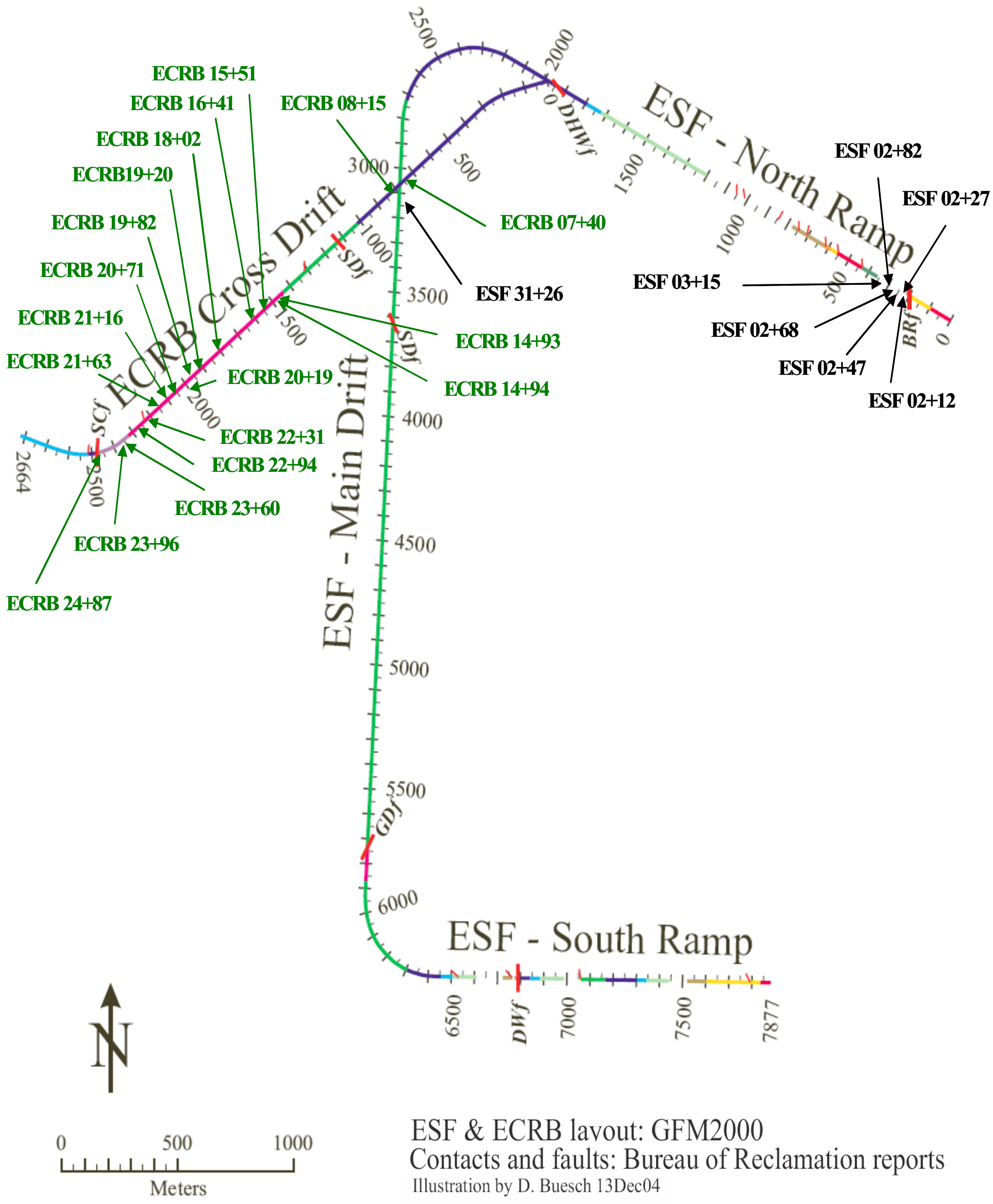
Figure 6.4-1. Typical Accelerometer Installation and Signal Source Hammer



Source: Lin 2007 [DIRS 182739]; BSC 2004 [DIRS 170029].

NOTE: *BRf* = Bow Ridge Fault, *DHWf* = Drill Hole Wash Fault, *SDf* = Sundance Fault, *DWf* = Dune Wash Fault , *SCf* = Solitaro Canyon , *GDf* = Ghost Dance Fault.

Figure 6.4-2. Approximate Locations of the SASW Tests Performed in the ESF and ECRB Tunnels in 2004



Source: Lin 2007 [DIRS 182739]; BSC 2004 [DIRS 170029].

NOTES: *BRf* = Bow Ridge Fault, *DHWf*= Drill Hole Wash Fault, *SDf* = Sundance Fault, *DWf* = Dune Wash Fault, *SCf* = Solitaro Canyon Fault, *GDf* = Ghost Dance Fault.

Legend for tunnel units can be found in figure 6.4-2.

Figure 6.4-3. Approximate Locations of the SASW Tests Performed in the ESF and ECRB Tunnels in 2005

Table 6.4-1. Forty-Five SASW Tests Performed in the ESF and ECRB Tunnels

No.	Site Name	Geologic Unit	No. of Samples	Tunnel	Location	Profile Depth (ft)	Test Date
1	ESF 1	Tptrn	1	ESF	74 + 00	12.6	13-Dec-04
2	ESF 14	Tpcpmn-Tpcpll*	1	ESF	05 + 80	7.6, 14.6	15-Dec-04
3	ESF 15	Tpcrn2	1	ESF	04 + 18	15.2	15-Dec-04
4	ESF 02 + 47	Tmbt1a	3	ESF	02 + 47	15.1	09-June-05
5	ESF 02 + 12	Tmbt1b		ESF	02 + 12	7.5, 14.5	09-June-05
6	ESF 02 + 27	Tmbt1b		ESF	02 + 27	14.7	09-June-05
7	ESF 02 + 68	Tpki	3	ESF	02 + 68	15.2	09-June-05
8	ESF 02 + 82	Tpki		ESF	02 + 82	13.9	09-June-05
9	ESF 03 + 15	Tpki		ESF	03 + 15	10.0	09-June-05
10	ESF 2	Tptpul	7	ESF	64 + 05	13.9	13-Dec-04
11	ESF 12	Tptpul		ESF	26 + 66	11.8	14-Dec-04
12	ESF 13	Tptpul		ESF	22 + 06	13.8	14-Dec-04
13	ECRB 4	Tptpul		ECRB	09 + 10	13.4	15-Dec-04
14	ECRB 5	Tptpul		ECRB	06 + 59	15.8	15-Dec-04
15	ECRB 07 + 40	Tptpul		ECRB	07 + 40	11.0	08-June-05
16	ECRB 08 + 15	Tptpul		ECRB	08 + 15	15.7	08-June-05
17	ESF 3	Tptpmn	9	ESF	62 + 61	15.5	13-Dec-04
18	ESF 4	Tptpmn		ESF	59 + 80	15.9	13-Dec-04
19	ESF 7	Tptpmn		ESF	55 + 32	15.2	14-Dec-04
20	ESF 8	Tptpmn		ESF	53 + 81	15.9	14-Dec-04
21	ESF 9	Tptpmn		ESF	41 + 21	15.3	14-Dec-04
22	ESF 10	Tptpmn		ESF	36 + 22	15.6	14-Dec-04
23	ESF 11	Tptpmn		ESF	30 + 06	15.8	14-Dec-04
24	ESF 31+26	Tptpmn		ESF	31 + 26	14.8	09June-05
25	ECRB 3	Tptpmn		ECRB	12 + 20	15.5, 15.0	15-Dec-04
26	ESF 5	Tptpll	17	ESF	58 + 46	15.0	13-Dec-04
27	ESF 6	Tptpll		ESF	57 + 96	15.9	13-Dec-04
28	ECRB 1	Tptpll		ECRB	17 + 29	14.8	14-Dec-04
29	ECRB 2	Tptpll		ECRB	16 + 07	15.4	14-Dec-04
30	ECRB 14 + 93	Tptpll		ECRB	14 + 93	16.9	08-June-05
31	ECRB 14 + 94	Tptpll		ECRB	14 + 94	14.3	08-June-05
32	ECRB 15 + 51	Tptpll		ECRB	15 + 51	14.9	08-June-05
33	ECRB 16 + 41	Tptpll		ECRB	16 + 41	14.8	08-June-05
34	ECRB 18+02	Tptpll		ECRB	18 + 02	15.2	08-June-05
35	ECRB 19+20	Tptpll		ECRB	19 + 20	14.5	08-June-05
36	ECRB 19 + 82	Tptpll		ECRB	19 + 82	11.3, 12.3	07-June-05
37	ECRB 20 + 19	Tptpll		ECRB	20 + 19	15.7	07-June-05
38	ECRB 20 + 71	Tptpll		ECRB	20 + 71	13.8	07-June-05
39	ECRB 21 + 16	Tptpll		ECRB	21 + 16	10.1	07-June-05
40	ECRB 21 + 63	Tptpll		ECRB	21 + 63	15.0	07-June-05
41	ECRB 22 + 31	Tptpll		ECRB	22 + 31	15.6	07-June-05
42	ECRB 22 + 94	Tptpll		ECRB	22 + 94	14.9	07-June-05

Table 6.4-1. Forty-Five SASW Tests Performed in the ESF and ECRB Tunnels (Continued)

No.	Site Name	Geologic Unit	No. of Samples	Tunnel	Location	Profile Depth (ft.)	Test Date
43	ECRB 23 + 60	Tptpln	3	ECRB	23 + 60	15.9	06-June-05
44	ECRB 23 + 96	Tptpln		ECRB	23 + 96	14.7	06-June-05
45	ECRB 24 + 87	Tptpln		ECRB	24 + 87	12.7	06-June-05

Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; BSC 2004 [DIRS 170029].
* This SASW survey crossed two geologic units.

6.4.3. Results of SASW Surveys in the ESF and ECRB Tunnels

Based on the geologic information of the ESF and ECRB tunnels developed from GFM2000 (BSC 2004 [DIRS 170029]), there were nine tuff units tested by the SASW method. The tuff units are listed in Table 6.4-1 (Geologic Unit). The shear wave velocity at depths of 10 to 15 ft behind the tunnel face in each V_S profile should represent the V_S of the tuff without the influence of stress release due to the tunnel excavation, and profiles not reaching a depth of 10 ft or more were not included in the statistical analysis. Therefore, the median and 16th and 84th percentile boundaries are based on the bottom portion of the profiles for the SASW measurements in each tuff unit. The SASW V_S profiles are divided into seven groups as discussed below. The individual experimental and theoretical dispersions curves and the resulting shear wave velocity profiles are contained in Attachment VI. Table 6.4-2 provides a list of the profiles included in the statistical analysis along with the depths of the sample points and the corresponding V_S values.

For each of the following tuff units—Tpcpmn-Tpcpll (SASW survey transected the contact between the Tpcpmn and Tpcpll), Tpcrn2 (Tiva Canyon Tuff: crystal-rich mixed-pumice subzone), and Tptrn (Topopah Spring Tuff: crystal-rich nonlithophysal zone)—V_S profiles were only obtained from a single site. The results from these tuff units are presented in Figure 6.4-4. Even though these tuffs represent three different types of tuffs, Site ESF 14 and ESF 15, which are next to each other, have similar velocities, about 2,800 fps, at the bottom of the shear wave velocity profiles.

For the Tmbt1 tuff (pre-Rainier Mesa Tuff bedded tuffs), all V_S profiles agree closely except profile 1 of ESF 02 + 12 below 12 ft deep (Figure 6.4-5). The ESF 02 + 12 site is close to the contact between two different tuff units, Tmbt1 and Tpcpmn, which could explain the difference, especially when you compare the V_S profiles of ESF 02 + 12 with that developed for ESF 14 (Tpcpmn-Tpcpll).

Table 6.4-2. SASW Profiles Used to Calculate the Median and 16th and 84th Percentile Boundaries

Tuff Type	Site Name	Sample Depth	V_S Value	Notes
Tmbt1	ESF 02+47	15.1	**2100**	
	ESF 02+12	14.5	**4000**	
	ESF 02+27	14.7	**1620**	
Tpki	ESF 02+68	15.2	4500	Three possible profiles and average value was used in statistic analysis
		15.2	4500	
		15.2	4500	
	Average	15.2	**4500**	
	ESF 02+82	13.9	**4500**	
	ESF 03+15	10.0	**2700**	
Tptpul	ESF 2	13.9	**3900**	
	ESF 12	11.8	**4900**	
	ESF 13	13.8	**4900**	
	ECRB 4	13.4	**4500**	
	ECRB 5	15.8	**4000**	
	ECRB 07+40	11.0	**4500**	
	ECRB 08+15	15.7	**5300**	
Tptpmn	T1	20.0	4000	Three possible profiles and average value was used in statistic analysis
		20.0	3500	
		20.0	2900	
	Average	20.0	**3467**	
	T2	20.0	**7000**	
	T3	20.0	**6250**	
	T4	20.0	**6000**	
	T5	20.0	**6000**	
	ESF 3	15.5	4300	Two possible profiles and smaller V_S value was used in statistic analysis
		15.5	5100	
	Smaller V_S of the Two	15.5	**4300**	
	ESF 4	15.9	4100	Two possible profiles and average value was used in statistic analysis
		15.9	5000	
	Average	15.9	**4550**	
	ESF 7	15.2	**4300**	
	ESF 8	15.9	4500	Two possible profiles and average value was used in statistic analysis
		15.9	4500	
	Average	15.9	**4500**	
	ESF 9	15.3	5300	Two possible profiles and average value was used in statistic analysis
		15.3	5300	
	Average	15.3	**5300**	

Table 6.4-2. SASW Profiles Used to Calculate the Median and 16th and 84th Percentile Boundaries (Continued)

Tuff Type	Site Name	Sample Depth	V_S Value	Notes
Tptpmn (cont.)	ESF 10	15.6	**5300**	
	ESF 11	15.8	**7800**	
	ECRB 3	15.5	7800	Two possible profiles and smaller V_S value was used in statistic analysis
		15.0	7300	
	Smaller V_S of the Two	15.0	**7300**	
	ESF 31+26	14.8	**4750**	
Tptpll	ESF 5	15.0	**6000**	
	ESF 6	15.9	**3500**	
	ECRB 1	14.8	**5400**	
	ECRB 2	15.4	**4400**	
	ECRB 14+93	16.9	5400	Two possible profiles and average value was used in statistic analysis
		16.9	4000	
	Average	16.9	**4700**	
	ECRB 14+94	14.3	**4900**	
	ECRB 15+51	14.9	**4500**	
	ECRB 16+41	14.8	4300	Two possible profiles and average value was used in statistic analysis
		14.8	3850	
	Average	14.8	**4075**	
	ECRB 18+02	15.2	**5500**	
	ECRB 19+20	14.5	4000	Two possible profiles and average value was used in statistic analysis
		14.5	3800	
	Average	14.5	**3900**	
	ECRB 19+82	11.3	4800	Two possible profiles and smaller V_S value was used in statistic analysis
		12.3	4000	
	Smaller V_S of the Two	12.3	**4000**	
	ECRB 20+19	15.7	**3800**	
	ECRB 20+71	13.8	**4900**	
	ECRB 21+16	10.1	**2800**	
	ECRB 21+63	15.0	**2100**	
	ECRB 22+31	15.6	**5500**	
	ECRB 22+94	14.9	**6500**	
Tptpln	ECRB 23+60	15.9	**6000**	
	ECRB 23+96	14.7	**5700**	
	ECRB 24+87	12.7	**5100**	

Source: DTNs: MO0609SASWUTDC.004 [DIRS 183295] and MO0206SASWROCK.000 [DIRS 159081].

As seen in Figure 6.4-6, the V_S profiles of the Tpki (Tuff unit "X") tuff are consistent, except for Site ESF 03 + 15. Site ESF 03 + 15 is near the boundary between Tpki and Tpcr tuffs, and the latter seems stiffer than the former based on the comparison of V_S profiles of Tpki and Tpcrn2 (ESF 15) tuffs. So, the "boundary effect" may be the reason for the inconsistency.

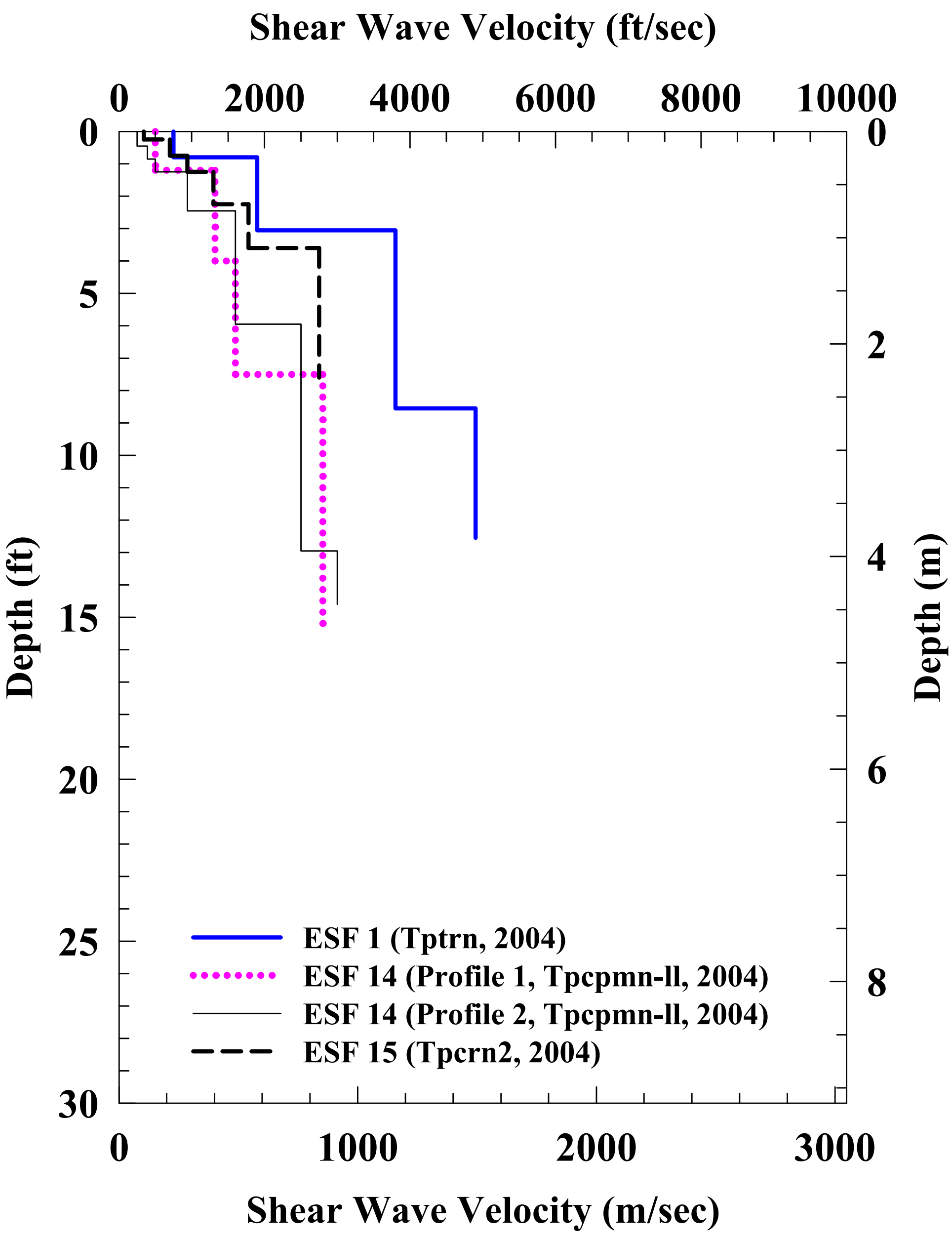
When comparing the Tptpul (Topopah Spring Tuff: crystal-poor upper lithophysal zone) tuff V_S profiles (Figure 6.4-7), these profiles are inconsistent above the top 12 ft, but they reach similar V_S values below that depth. In general, the deeper V_S values agree with each other, ranging from about 4,000 to 5,000 fps.

In Figure 6.4-8, there is a large variation in the SASW V_S profiles of the Tptpmn (Topopah Spring Tuff: crystal-poor middle nonlithophysal zone) tuff. This same variability is as observed in the 2001 SASW tunnel tests. By combining the SASW measurements on the Tptpmn tuff from 2001 and 2005, further studies were conducted.

By taking the SASW tests performed in the ESF Tunnel in 2001 into account, there are 14 SASW V_S profiles (Figure 6.4-9) for Tptpmn tuff. Based on the V_S values in the deepest parts of these 14 profiles, the median and 16th and 84th percentile boundaries were obtained. Although there is a large variation in the 14 SASW profiles, it seems that they can be divided into two groups based on their deeper (bottom) V_S profiles. This division is a V_S value of 5,800 fps, which separates the "stiffer" and "softer" velocity groups in the mountain area. The two velocity groups as well as their median and 16th and 84th percentile boundaries are shown in Figures 6.4-10 and 6.4-11. These high and low velocity ranges are used to compare with the deep V_S profiles at the mountain area in Section 6.4.5 of this report.

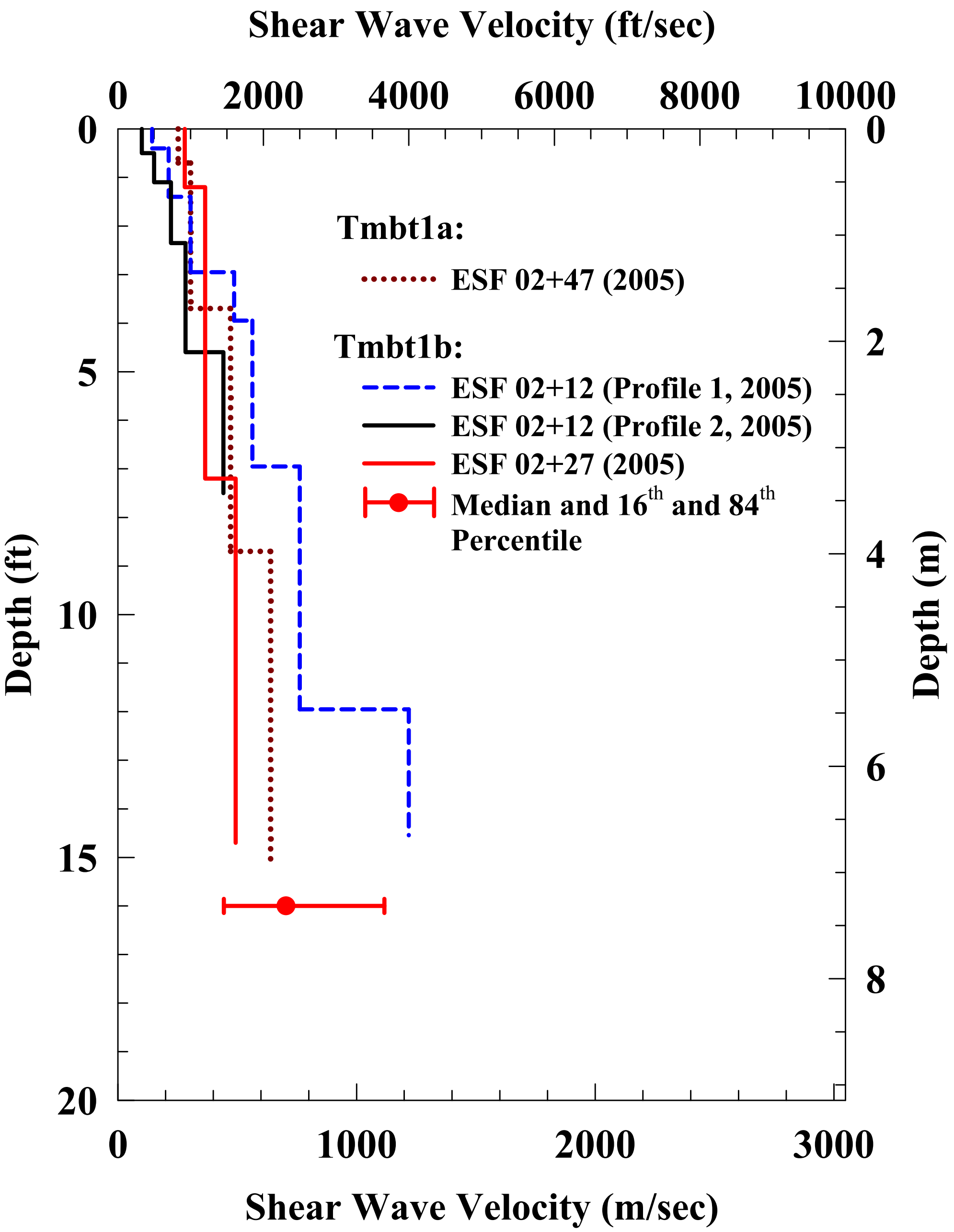
Regarding the Tptpll (Topopah Spring Tuff: crystal-poor lower lithophysal zone) tuff, the largest tuff group sampled, most V_S profiles come reasonably close together below 13 ft, except for Sites ECRB 21 + 63 and ECRB 22 + 94 (Figure 6.4-12). Since locations 22+94 is near the transition of the Tptpll tuff unit, a possible explanation for the differences, is the "boundary effect" discussed in Section 6.4.2. However, the decrease in the V_S profile of Site ECRB 21 + 63 could result from the existence of other geologic features in the tuff or the higher lithophysae content at this location.

The last type of tuff compared is Tptpln (Topopah Spring Tuff: crystal-poor lower nonlithophysal zone) tuff and all V_S profiles converge to the range of 5,000 to 6,000 fps below about 10 ft as shown in Figure 6.4-13.



Source: DTN: MO0609SASWUTDC.004 [DIRS 183295].

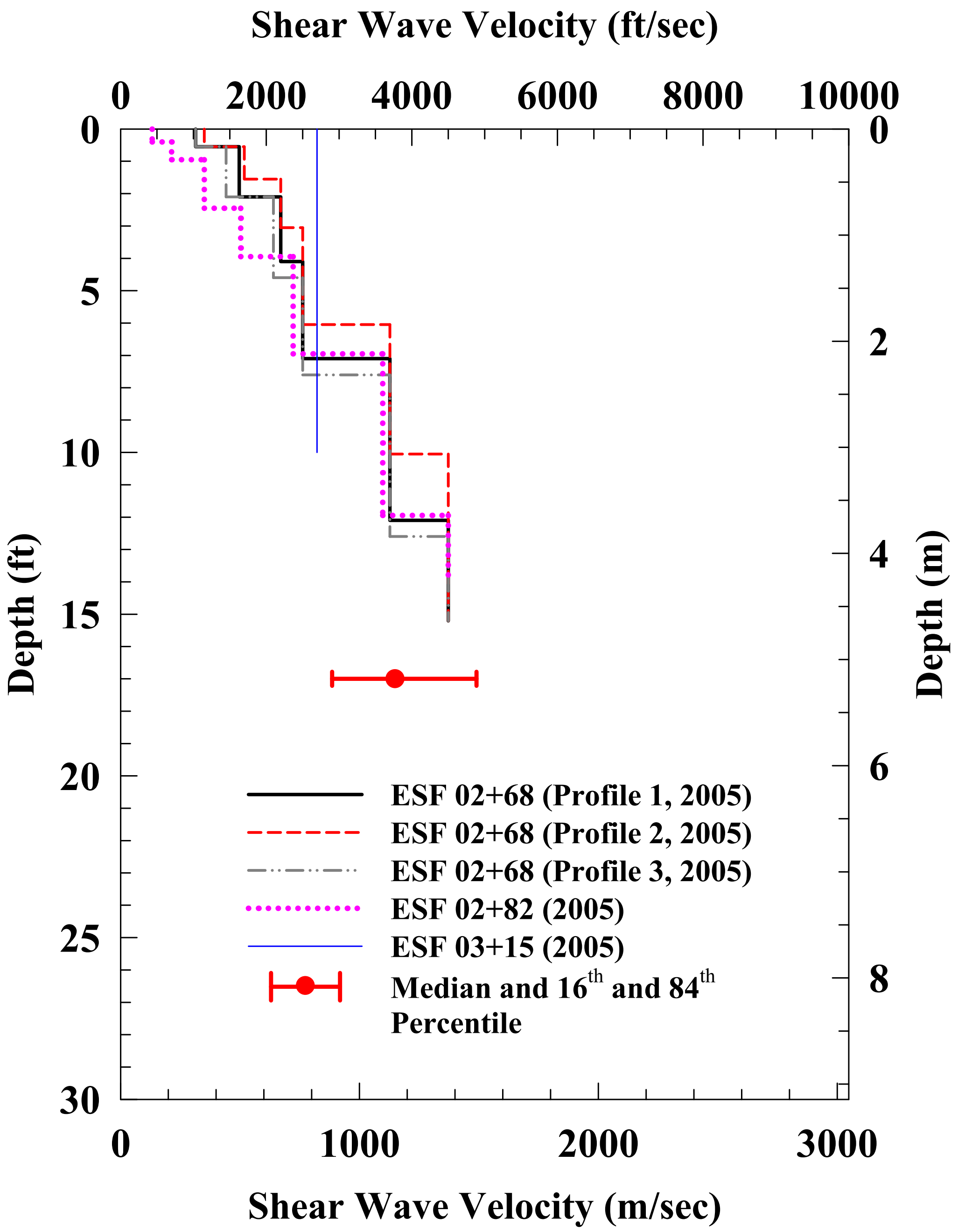
Figure 6.4-4. SASW V_S Profiles of Single Sample Tuffs



Source: DTN: MO0609SASWUTDC.004 [DIRS 183295].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

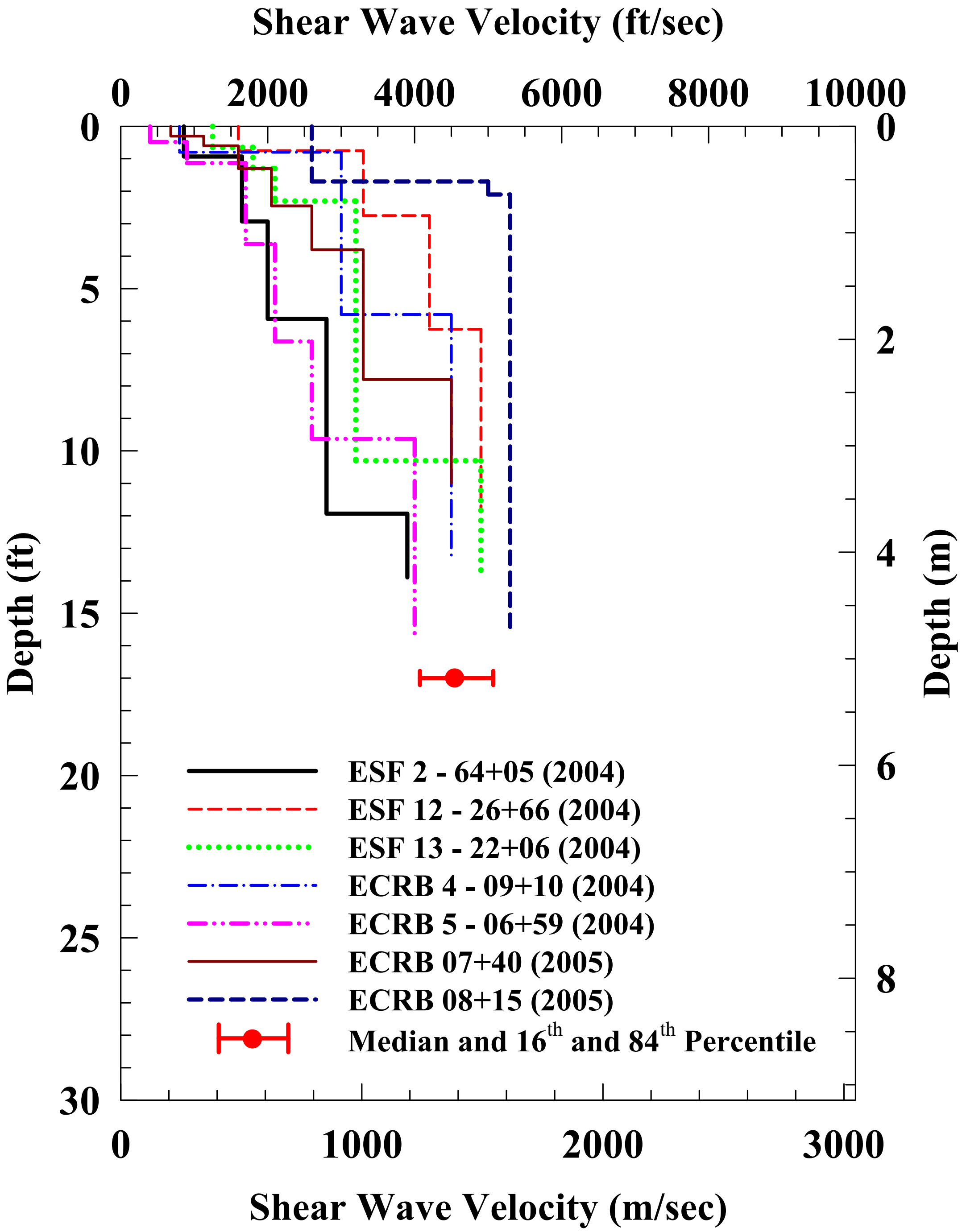
Figure 6.4-5. SASW V_S Profiles of Tmbt1 Tuff



Source: DTN: MO0609SASWUTDC.004 [DIRS 183295].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

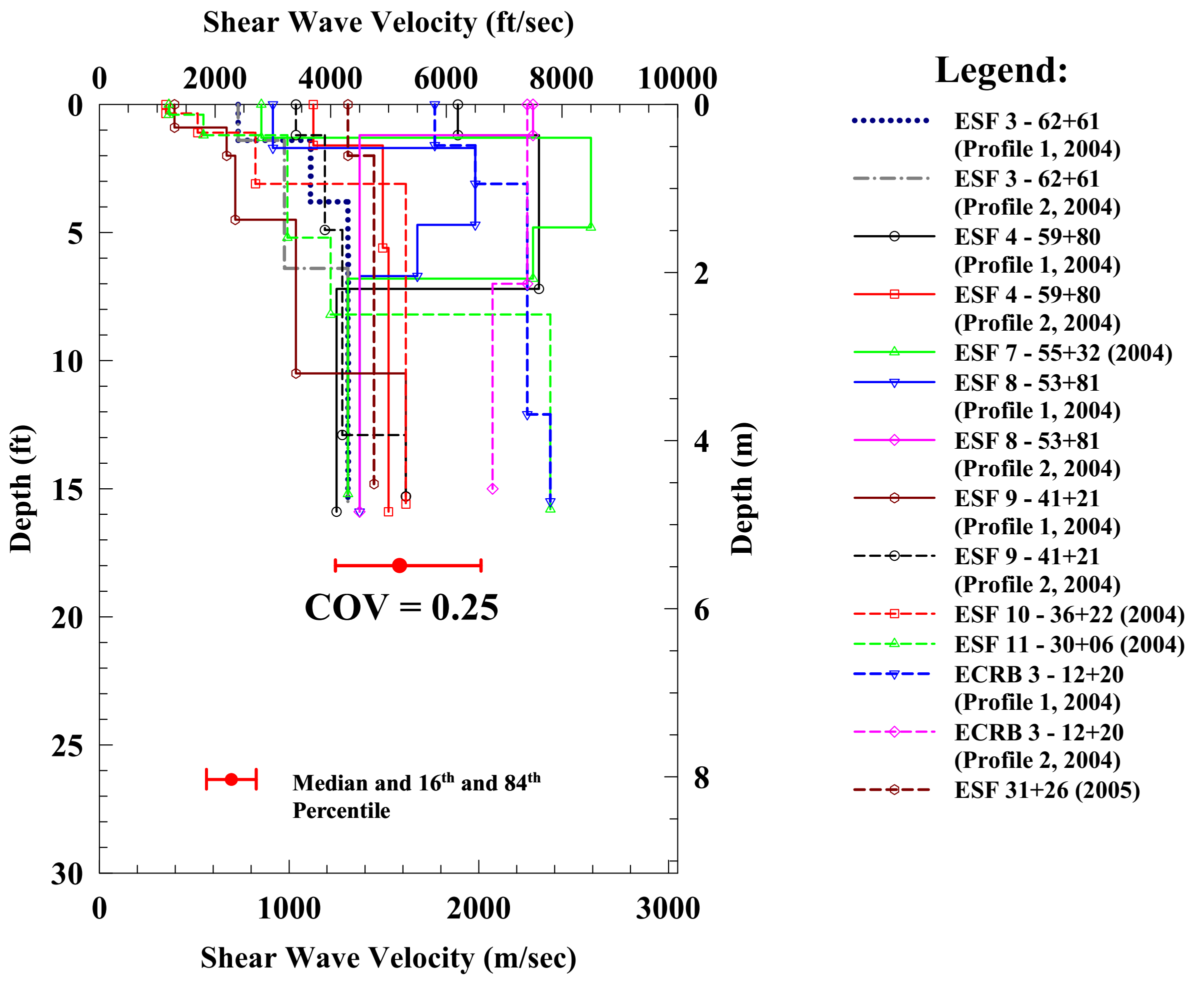
Figure 6.4-6. SASW V_S Profiles of Tpki Tuff



Source: DTN: MO0609SASWUTDC.004 [DIRS 183295].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

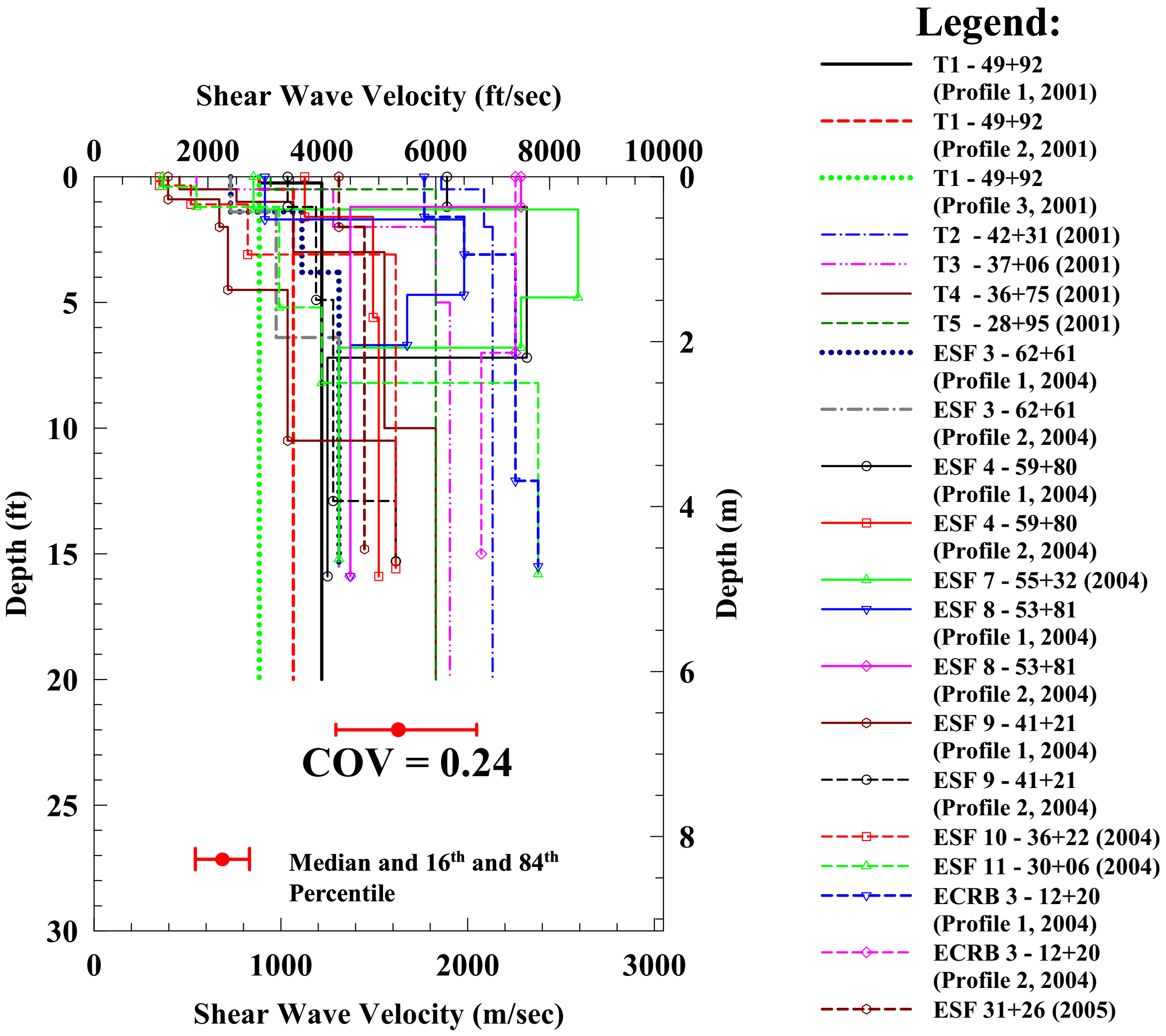
Figure 6.4-7. SASW V_S Profiles of Tptpul Tuff



Source: DTN: MO0609SASWUTDC.004 [DIRS 183295].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.4-8. SASW V_S Profiles of Tptpmn Tuff

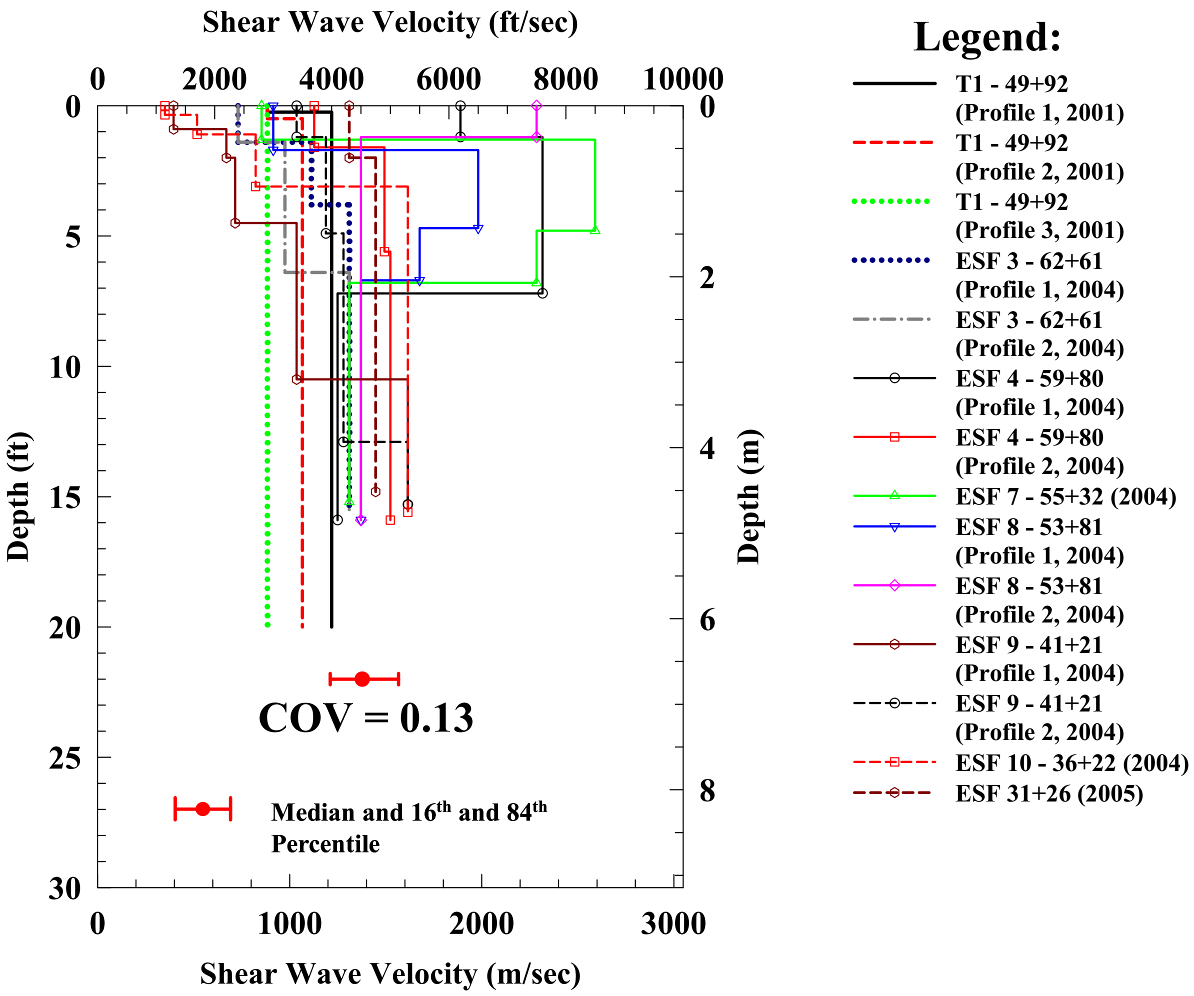


Source: DTNs: MO0609SASWUTDC.004 [DIRS 183295] and MO0206SASWROCK.000 [DIRS 159081].

NOTES: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

In addition to data from 2004 and 2005, the plot also includes data from 2001.

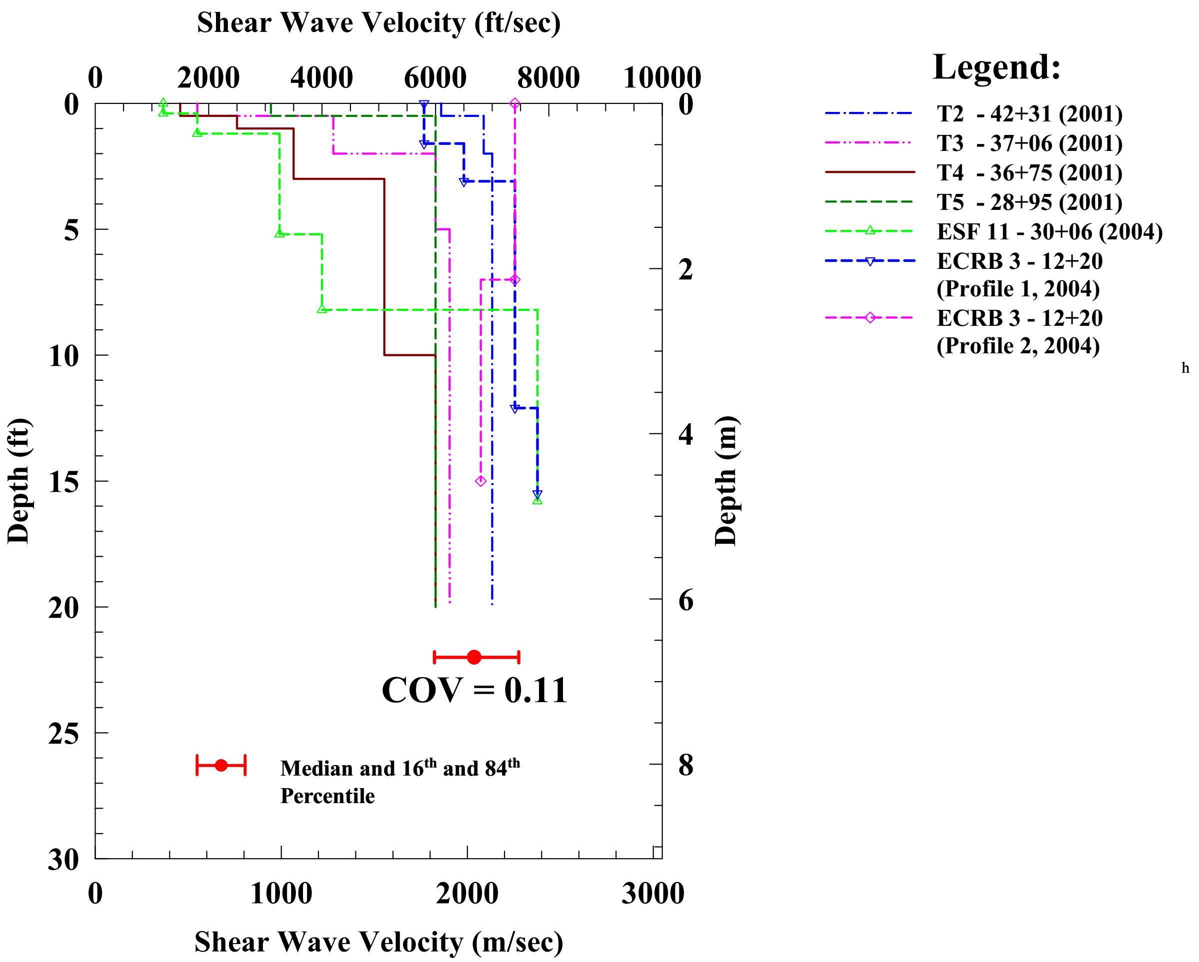
Figure 6.4-9. SASW V_S Profiles of Tptpmn Tuff



Source: DTNs: MO0609SASWUTDC.004 [DIRS 183295] and MO0206SASWROCK.000 [DIRS 159081].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

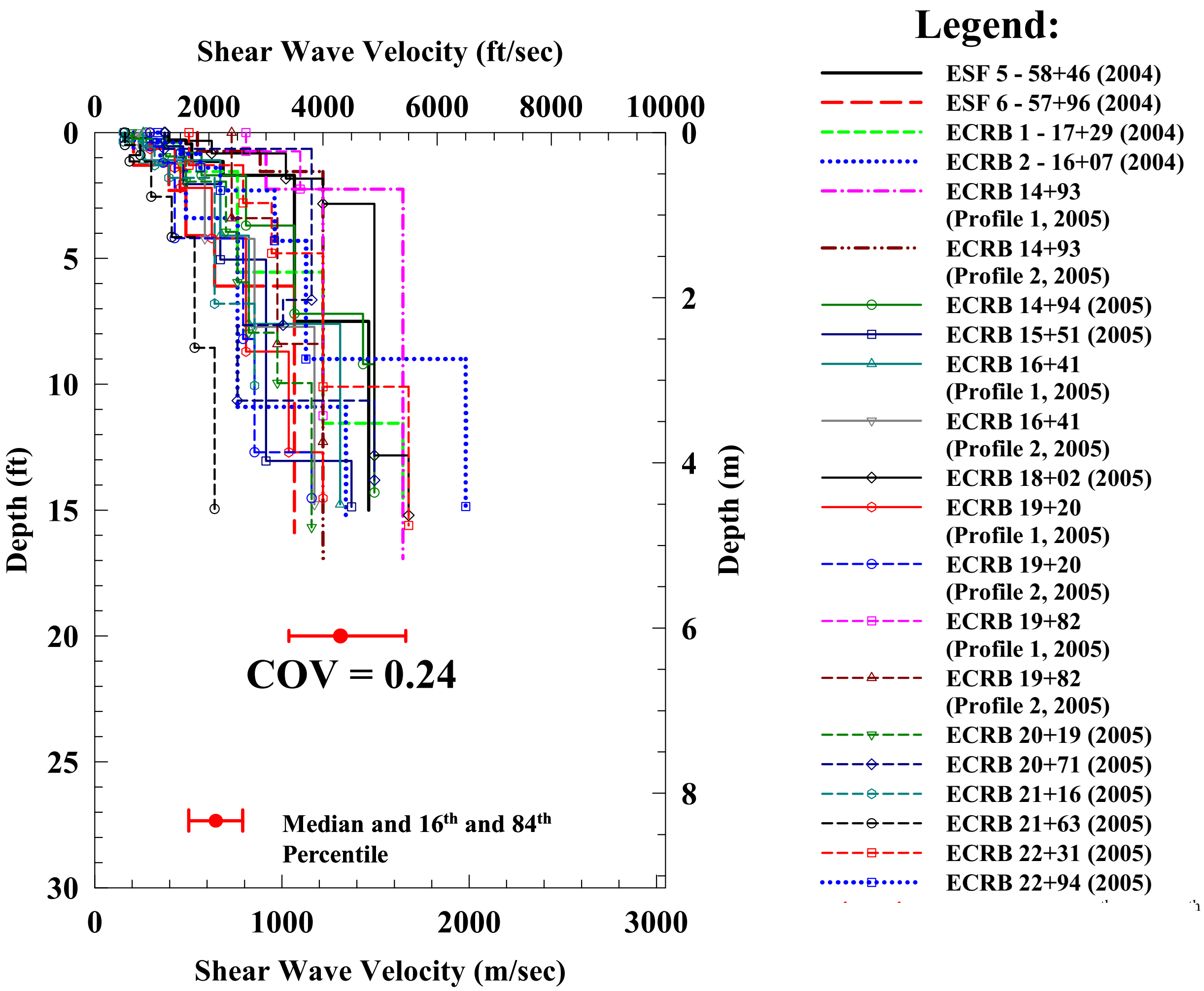
Figure 6.4-10. SASW V_S Profiles of Softer Tptpmn Tuff Sites



Source: DTNs: MO0609SASWUTDC.004 [DIRS 183295] and MO0206SASWROCK.000 [DIRS 159081].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

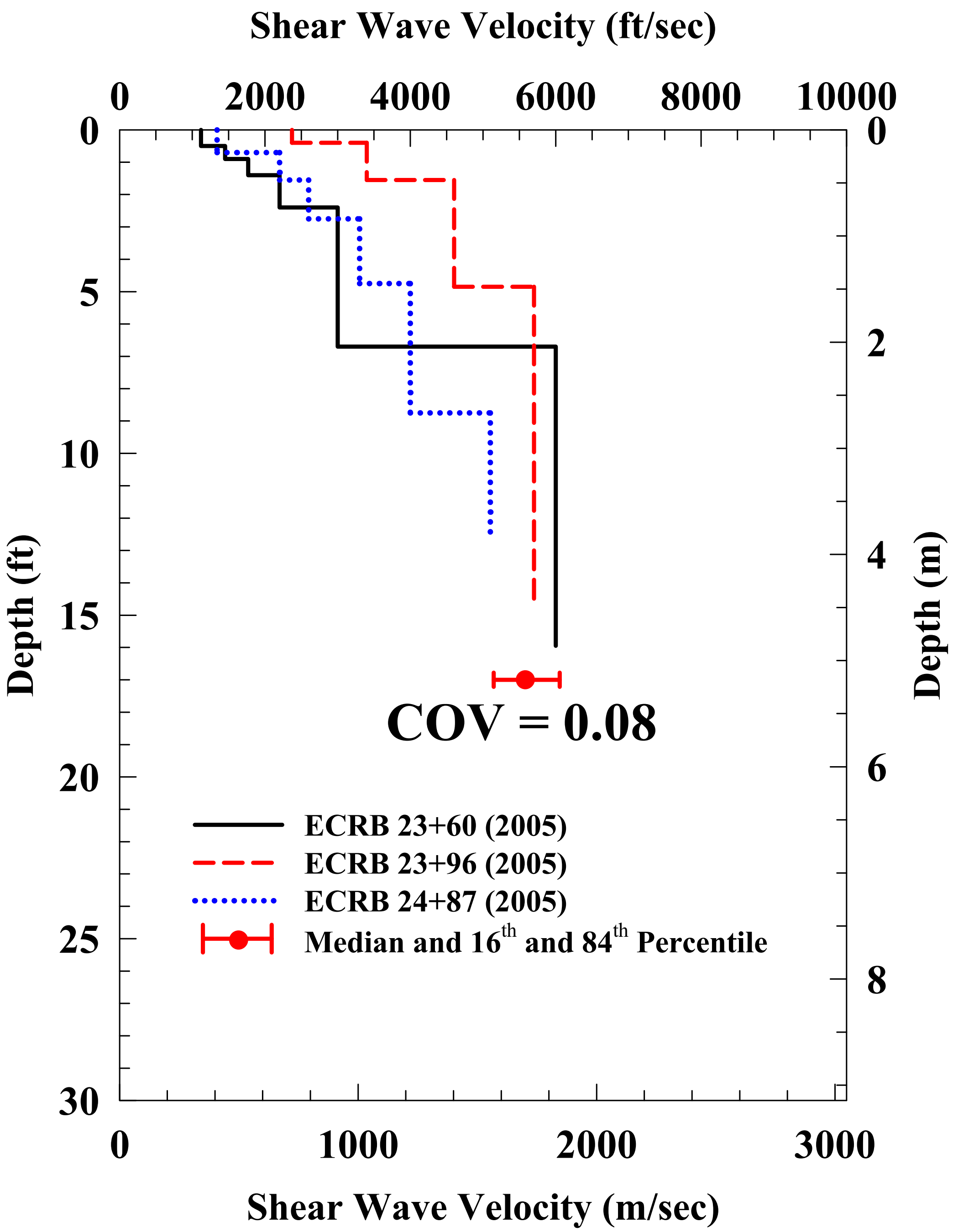
Figure 6.4-11. SASW V_S Profiles of Stiffer Tptpmn Tuff Sites



Source: DTN: MO0609SASWUTDC.004 [DIRS 183295].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.4-12. SASW V_S Profiles of Tptpll Tuff

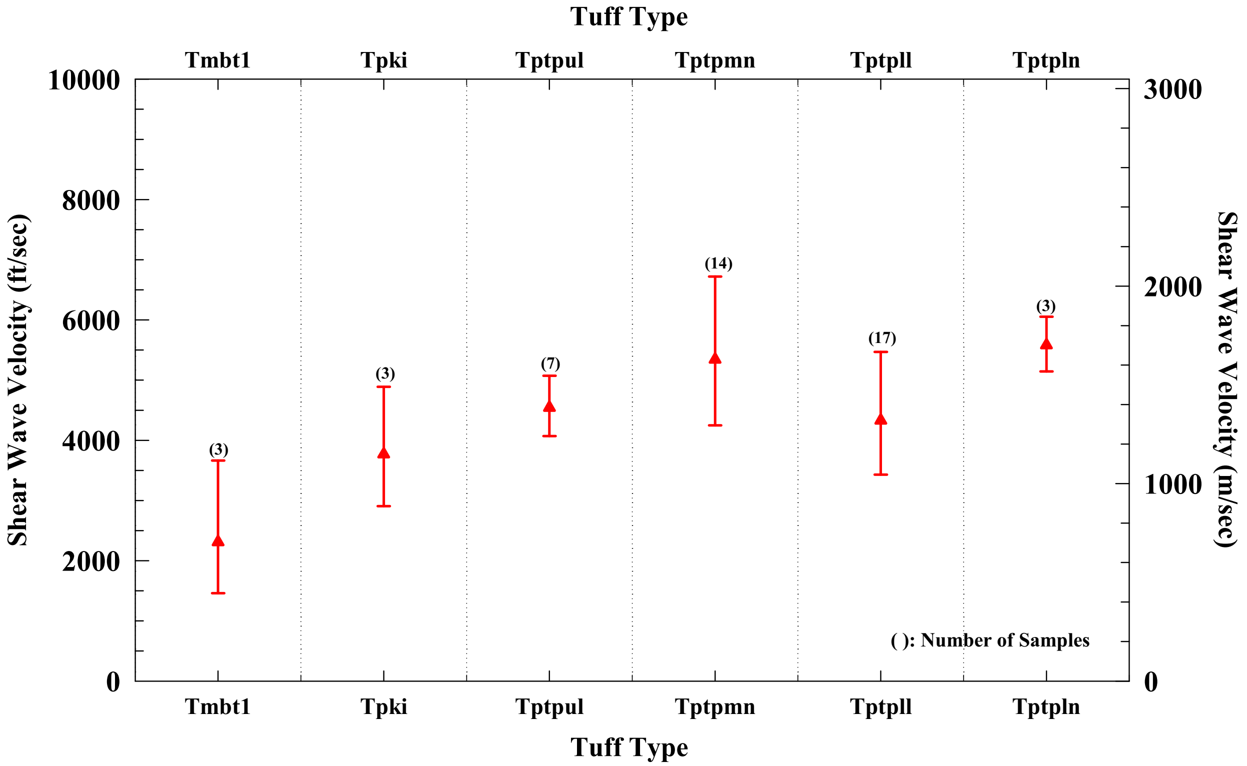


Source: DTN: MO0609SASWUTDC.004 [DIRS 183295].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2.

Figure 6.4-13. SASW V_S Profiles of Tptpln Tuff

Based on the geologic information in Table 6.4-1 and Figures 6.4-4 through 6.4-13, a comparison was conducted between six different tuffs in Figure 6.4-14. As seen, the Tmbt1 has the lowest median V_S value, which is about 2,300 fps. In contrast, the Tptpln has the highest median V_S value, which is around 5,500 fps.

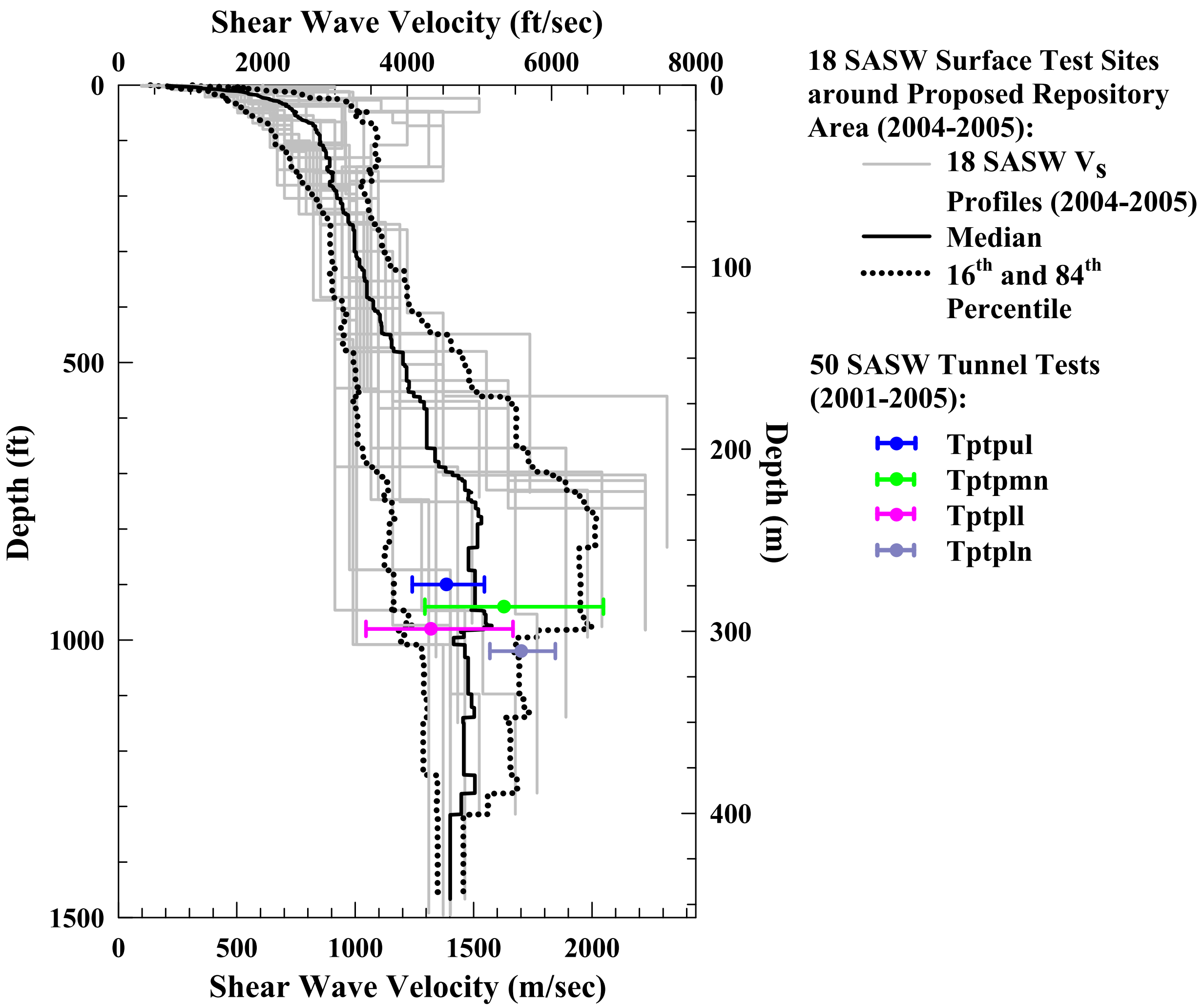


NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2 using data represented in Figures 6.4-4 through 6.4-13.

Figure 6.4-14. Distribution of SASW Velocities by Underground Geologic Units

6.4.4. Comparison of Crest SASW with Underground SASW Measurements

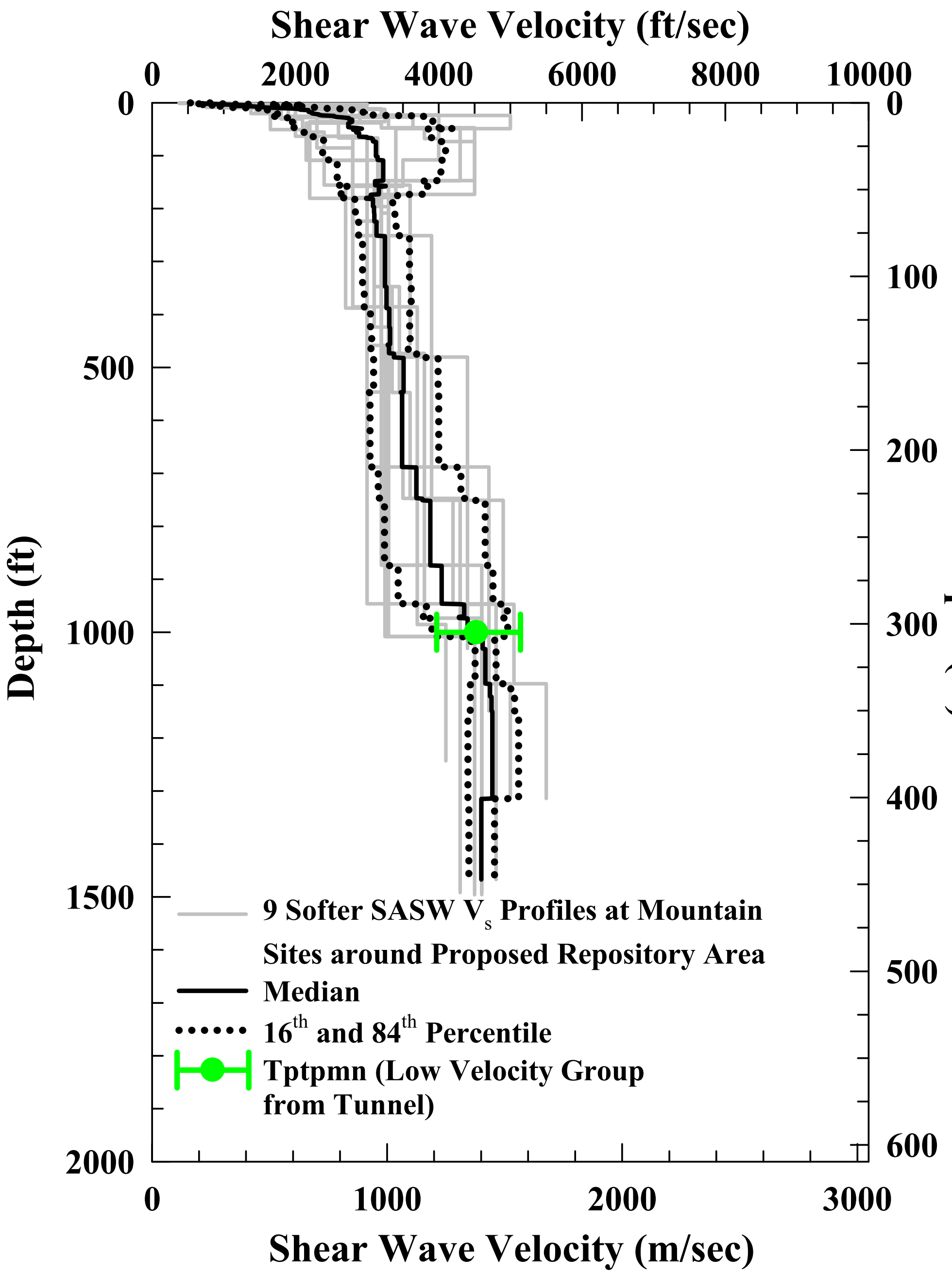
Because the SASW tests that were carried out in the Yucca Mountain area in 2004 and 2005 allowed V_S profiles to be determined to depths near 1,000 ft, a comparison can be made between the SASW V_S profiles at about 1,000 ft derived from surface-based surveys with V_S values measured in the tunnel by SASW testing. The SASW V_S profiles of 18 YM sites (reference Section 6.3.2, Figure 6.3-3) were chosen for comparison with all the tunnel SASW results. The comparison is presented in Figure 6.4-15, which shows very good consistency between these measurements. Furthermore, if the V_S ranges of the high and low velocity groups of the Tptpmn tuff are used instead of their overall V_S range, it can be seen that the high and low velocity groups at the mountain area match the high and low velocity groups of the Tptpmn tuff. These comparisons are shown in Figures 6.4-16 and 6.4-17. The comparison shows that tuffs of the same geologic unit may have large variations in stiffness due to geologic variations (e.g., fracturing and/or voids) in the tuff.



Source: DTNs: MO0609SASWSTDC.003 [DIRS 182125]; MO0609SASWUTDC.004 [DIRS 183295]; MO0206SASWROCK.000 [DIRS 159081].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2; 18 sites refer to those sites whose data are plotted in Figure 6.3-3

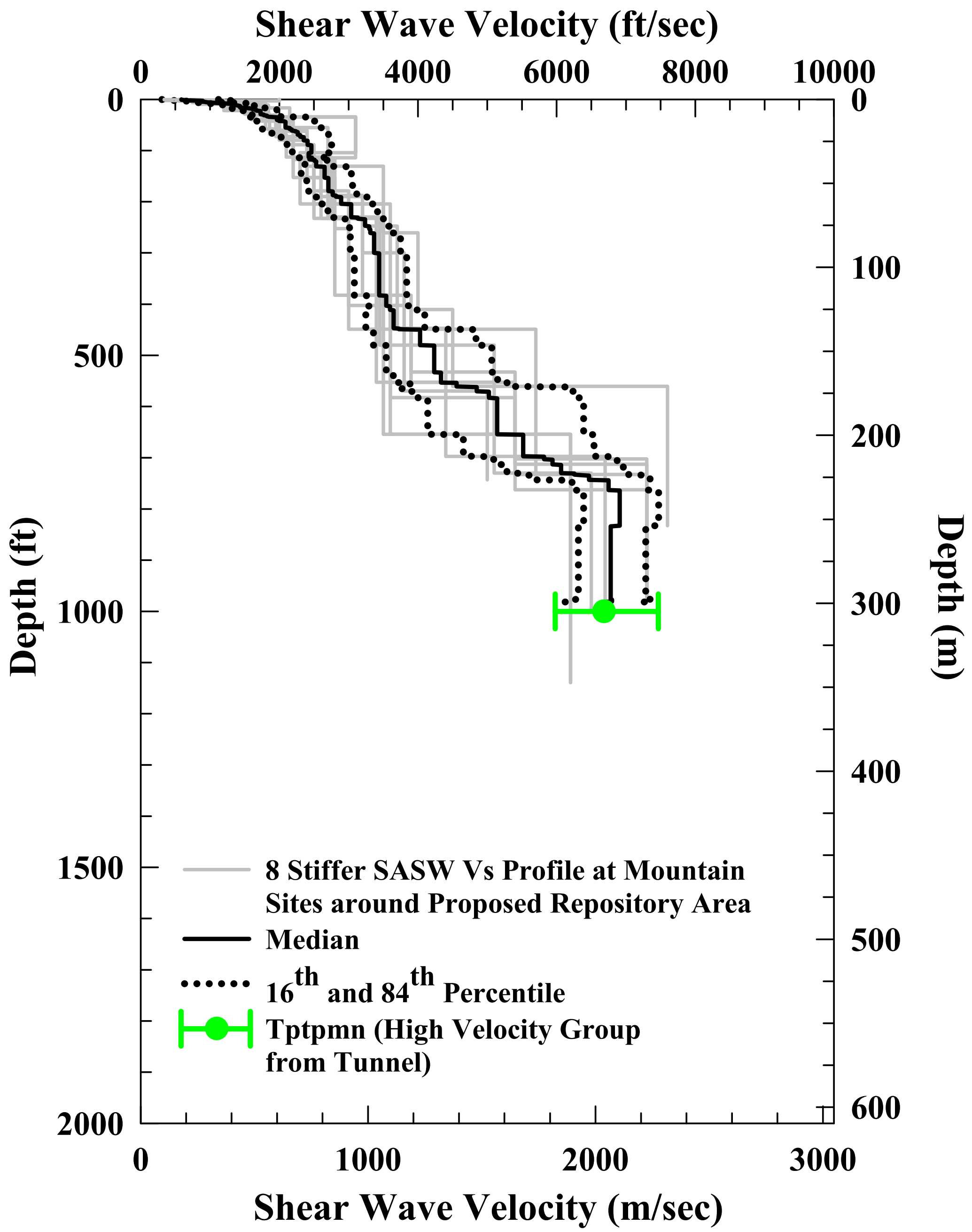
Figure 6.4-15. Comparisons of: (1) SASW Measurements in the Mountain Area around the Proposed Repository Area and (2) SASW Measurements in the ESF and ECRB Tunnels



Source: DTNs: MO0609SASWSTDC.003 [DIRS 182125]; MO0609SASWUTDC.004 [DIRS 183295]; MO0206SASWROCK.000 [DIRS 159081].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2; The nine softer sites refer to YM 1, YM 2, YM 3, YM 4, YM 5, YM 6, YM 16, YM 17, and YM 23.

Figure 6.4-16. Comparisons of the Low Velocity Groups of the SASW Measurements at Mountain Area above the Proposed Repository Area and V_S Values of the Tptpmn Tuff Measured in the ESF and ECRB Tunnels



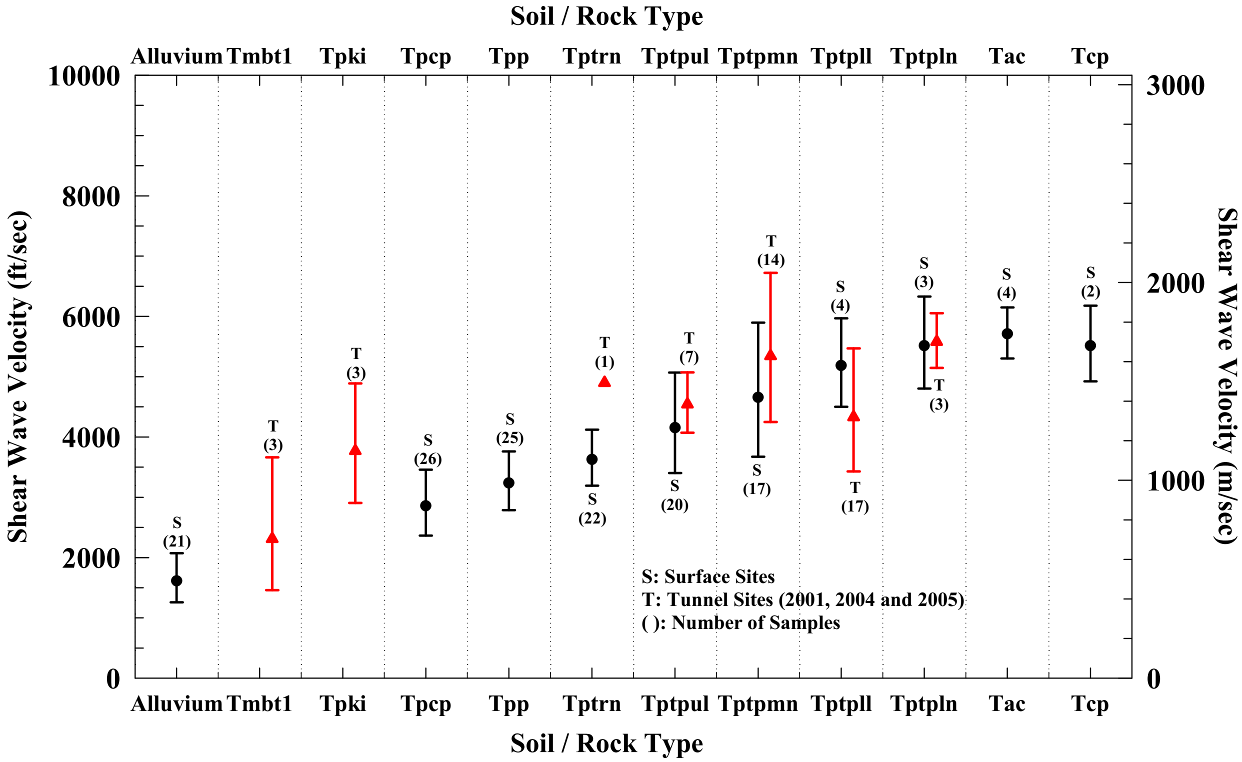
Source: DTNs: MO0609SASWSTDC.003 [DIRS 182125]; MO0609SASWUTDC.004 [DIRS 183295]; MO0206SASWROCK.000 [DIRS 159081].

NOTE: Statistical data have been calculated for illustrative purposes only as described in Section 6.2.5.2; the eight sites refer to YM 8, YM 10, YM 12, YM 13, YM 14, YM 15B, YM 21, and YM 25.

Figure 6.4-17. Comparisons of the High Velocity Groups of the SASW Measurements at Mountain Area above the Proposed Repository Area and V_S Values of the Tptpmn Tuff Measured in the ESF and ECRB Tunnels

According to Figures 6.3-9 and 6.4-14, a comparison based on the geologic material type between surface and tunnel SASW test results is shown in Figure 6.4-18. This comparison shows the same type of consistency and general overlap between the surface and tunnel SASW test results for Tptpul, Tptpmn, Tptpll, and Tptpln. In addition, both surface and tunnel results show the Tptpln has the highest median V_S value (over 5,500 fps) compared to the other types of tuff.

In general, the median V_S values obtained from the tunnel SASW tests are higher than from the surface SASW tests. This difference is probably impacted by the sample size, with the surface SASW tests sampling a much larger volume of material than the tunnel SASW test, combined with the fact that the poorest material in the tunnel could not be tested due to the large number and size of the "flaws." As a result, more cracks, lithophysae, fissures, etc., were sampled in the surface SASW tests, which likely resulted in the somewhat lower median shear wave velocities. The only exception is the Tptpll tuff. The reason or reasons for this difference are unknown at this time.



NOTE: Statistical data (median values) have been calculated for illustrative purposes only as described in Section 6.2.5.2 and based on the data presented in Figures 6.3-9 and 6.4-14.

Figure 6.4-18. Comparison of V_S Ranges between Surface and Tunnel SASW Test Sites Based on Geologic Material

6.5. DYNAMIC LABORATORY TESTING

6.5.1 Overview

Dynamic properties testing on a total of 168 specimens of tuff were performed by the UTACED laboratory. The specimens were supplied from the Sample Management Facility (SMF) at Yucca Mountain and they were selected to represent most of the major geologic units above, at, and below the waste emplacement level. This laboratory testing started in 2004 and consisted of 33 samples subjected to Fixed-Free testing using the Resonant Column and Torsional Shear (RCTS) system. The RCTS testing program is described in Section 6.5.2. This testing focused on specimens that originated from the geologic units underlying the Tiva Canyon Tuffs, as the 2000–2001 program generally tested the Tiva Canyon Tuffs as documented in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829]).

Attachment VII contains all Fixed-Free testing results from 2004 through 2006. The Fixed-Free results displayed in Attachment VII (Tables VII-3 through VII-7, VII-9, VII-11, VII-13, VII-15, VII-17, VII-19, VII-21, VII-23, VII-25, VII-27, VII-31, VII-33, VII-35, VII-36, VII-38, VII-40, VII-42, VII-44, VII-46, and VII-48) are not discussed or presented in any of the figures in this section. These tables represent test results that were developed when the parent sample was split or under-cored to produce a smaller sample. This sample was then tested with the objective of assessing sample size effects. At the time this report was developed, a thorough analysis of these results for sample size effects had not been performed; therefore, the results are not presented in this report. This analysis will be discussed in future geotechnical reports.

From 2004 through 2006, 135 specimens were also tested using the unconfined Resonant Column (Free-Free) method. The specimens were selected so that approximately six to eight could be tested from each major geologic unit above, at, and below the waste emplacement horizon. The Free-Free testing is detailed in Section 6.5.3. The dynamic laboratory testing described in this report augments the previous laboratory testing of tuff and alluvium documented in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829]).

Laboratory measurements of the dynamic properties of tuff specimens will be used to support the technical basis for ground motion site-response modeling and surface facilities foundation design. The dynamic properties that were measured are the shear modulus and material damping. Objectives of the laboratory measurements include:

- Measurement of shear modulus reduction and material damping increase as a function of increasing shear strain

- Investigation of the effect of confining pressure (isotropic stress state)

- Investigation of the effect of time of confinement at each isotropic stress state

- Investigation of the effect of number of loading cycles

- Investigation of the effect of excitation frequency.

A detailed description of all dynamic laboratory tests performed at the UTACED and covered in Sections 6.5.2 and 6.5.3 is contained in scientific notebook SCI-M&O-048-V1 (Wong and Stokoe 2007 [DIRS 183328]).

6.5.2 RCTS (Fixed-Free) Testing of Tuff Samples

6.5.2.1. Method of Testing

The laboratory measurements employed combined resonant column and torsional shear (RCTS) testing. The RCTS apparatus can be idealized as a Fixed-Free system as discussed in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829], Section 6.2.10.1). The bottom of the specimen is fixed against rotation at the base pedestal, and the top of the specimen is connected to the driving system. The driving system can rotate freely to excite the specimen in torsional motion. A photograph and schematic illustration of the device are shown in Figures 6.5-1(a) and 6.5-1(b), respectively.

The basic operational principle of the Fixed-Free resonant column (RC) test is to vibrate the cylindrical specimen in first-mode torsional motion. Harmonic torsional excitation is applied to the top of the specimen over a range in frequencies, and the variation of the acceleration amplitude of the specimen with frequency is obtained. Once first-mode resonance is established, measurements of the resonant frequency and amplitude of vibration are made. These measurements are then combined with equipment characteristics and specimen size to calculate shear wave velocity and shear modulus based on stress wave propagation. Material damping is determined either from the width of the frequency response curve or from the free-vibration decay curve. A full description of the test procedure and the method of analysis are provided in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829], Section 6.2.10).

The torsional shear (TS) test is another method of determining shear modulus and material damping using the same RCTS equipment, but operating it in a different manner. A cyclic torsional force with a given frequency, generally below 10 Hz, is applied at the top of the specimen. Instead of determining the resonant frequency, the stress-strain hysteresis loop is determined from measuring the torque-twist response of the specimen. Proximitors are used to measure the angle of twist while the voltage applied to the coil is calibrated to yield torque. Shear modulus is calculated from the slope of a line through the end points of the hysteresis loop, and material damping is obtained from the area of the hysteresis loop. A full description of the test method is provided in SN-M&O-SCI-048-V1, Supplement Volume 1 (Wong and Stokoe 2007 [DIRS 183328]).

The tuff specimens that were tested were collected from both existing and new boreholes from various locations around Yucca Mountain, near the North Portal Facility and surrounding area, in the ESF, and in the ECRB cross-drift. The surface boreholes and boreholes in the ESF and ECRB tunnels are shown in Figures 6.5-2 and 6.5-3, respectively. The boreholes circled in Figure 6.5-2 and those designated by arrows in Figure 6.5-3 are the boreholes where the original cores for the Fixed-Free RCTS tests were recovered. All the parent boreholes and locations are tabulated in Table 6.5-1, with the number of cores from each borehole noted.

Thirty-three tuff specimens were tested using the RCTS device. These specimens are listed in Table 6.5-2. Thirty-one specimens were cored from Yucca Mountain borehole samples. Two other specimens were cored from larger test specimens. In all cases, the dimensions were measured to determine the volume, and they were weighed to determine the specimen mass. The stratigraphic units, boreholes, and associated information for the 33 tuff specimens are listed in Table 6.5-3 and Table VII-1. The specimens were inspected for defects and a Free-Free resonant column test was performed on each specimen prior to RCTS testing.

The results of the Free-Free resonant column tests on the original specimens are documented in SN-M&O-SCI-048-V1, Supplement Volumes 6 and 7 (Wong and Stokoe 2007 [DIRS 183328]), and the data submittal to the TDMS was documented in SN-M&O-SCI-048-V1, Supplement Volume 9 (Wong and Stokoe 2007 [DIRS 183328]). The dimensions of the original cores changed through the re-coring, cutting and/or trimming processes. Free-Free resonant column tests were performed whenever these processes were done. The results of the Free-Free resonant column tests on the cored specimens are documented in SN-M&O-SCI-048-V1, Supplement Volumes 2 through 5 (Wong and Stokoe 2007 [DIRS 183328]), along with the results of the Fixed-Free resonant column and torsional shear tests on corresponding specimens. The Free-Free resonant column method is described in Section 6.5.3 of this report. The data submittal to the TDMS was documented in SN-M&O-SCI-048-V1, Supplement Volume 9 (Wong and Stokoe 2007 [DIRS 183328]).

Following preparation, the specimens were affixed in the RCTS device. Some specimens were tested under additional conditions with an exterior membrane or with an epoxy membrane. The epoxy membrane resulted in filling the lithophysae exposed on the specimen surface. The conditions of all specimens tested in the RCTS device are listed in the applicable data table for that sample located Attachment VII.

Dynamic testing of each specimen involved the evaluation of shear modulus (G) and material damping (D) over a range of isotropic confining pressures. Three or more isotropic confining pressures were used in a loading sequence, with the isotropic confining pressure, (σ_o), doubled upon completion of the required tests at the lower pressure. Low-amplitude resonant column testing was performed at each σ_o to determine the effects of magnitude of confinement and time of confinement on the small-strain shear modulus, G_{max}, and small-strain material damping ratio, $D_{S\ min}$. Low-amplitude dynamic tests are defined as those tests in which the resonant amplitude did not exceed 0.001% and was often below that level. Complete listings of the test pressures at which low-amplitude RC testing was performed are presented in the (a) portion of the applicable data Tables VII-2 through VII-59.

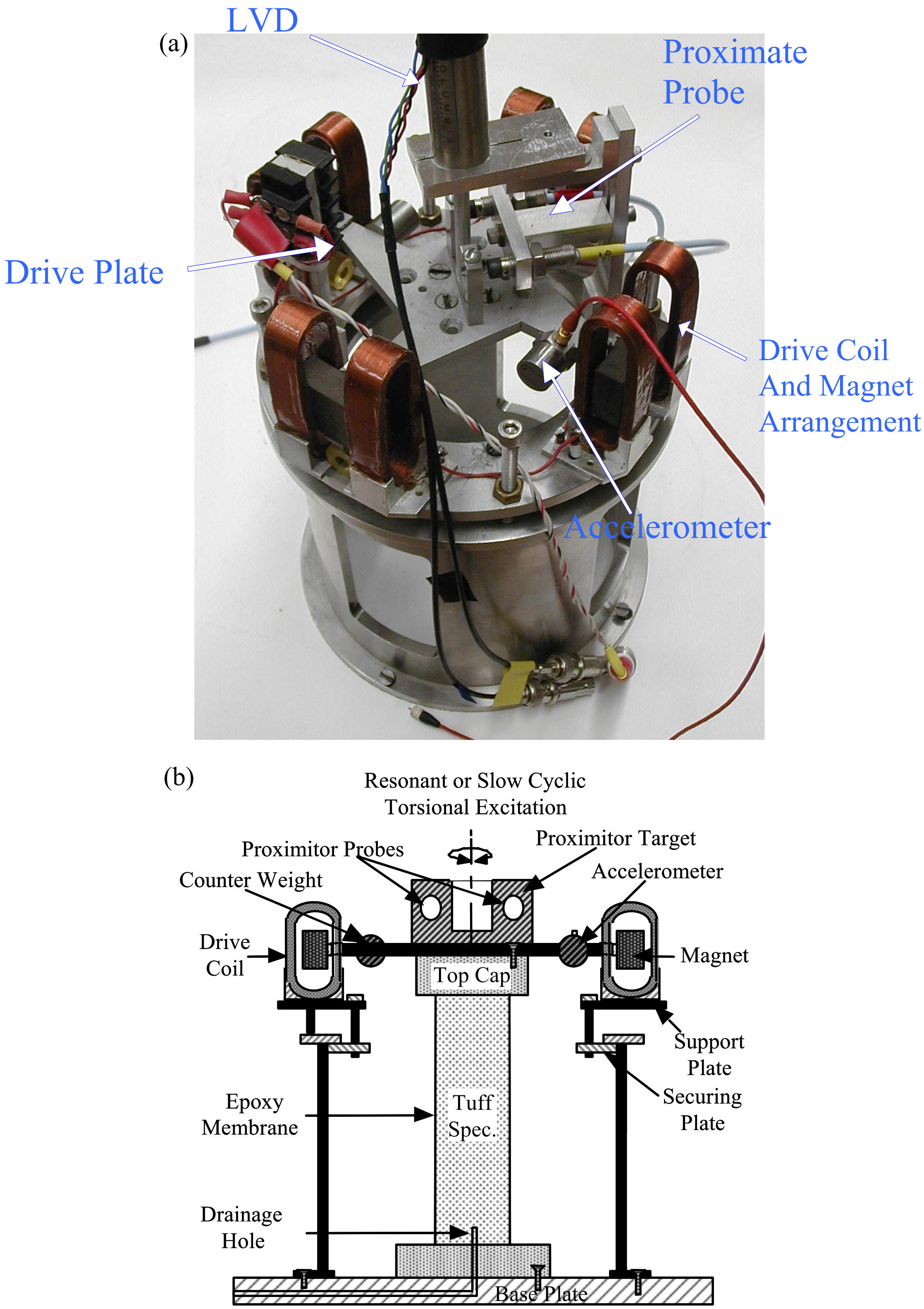
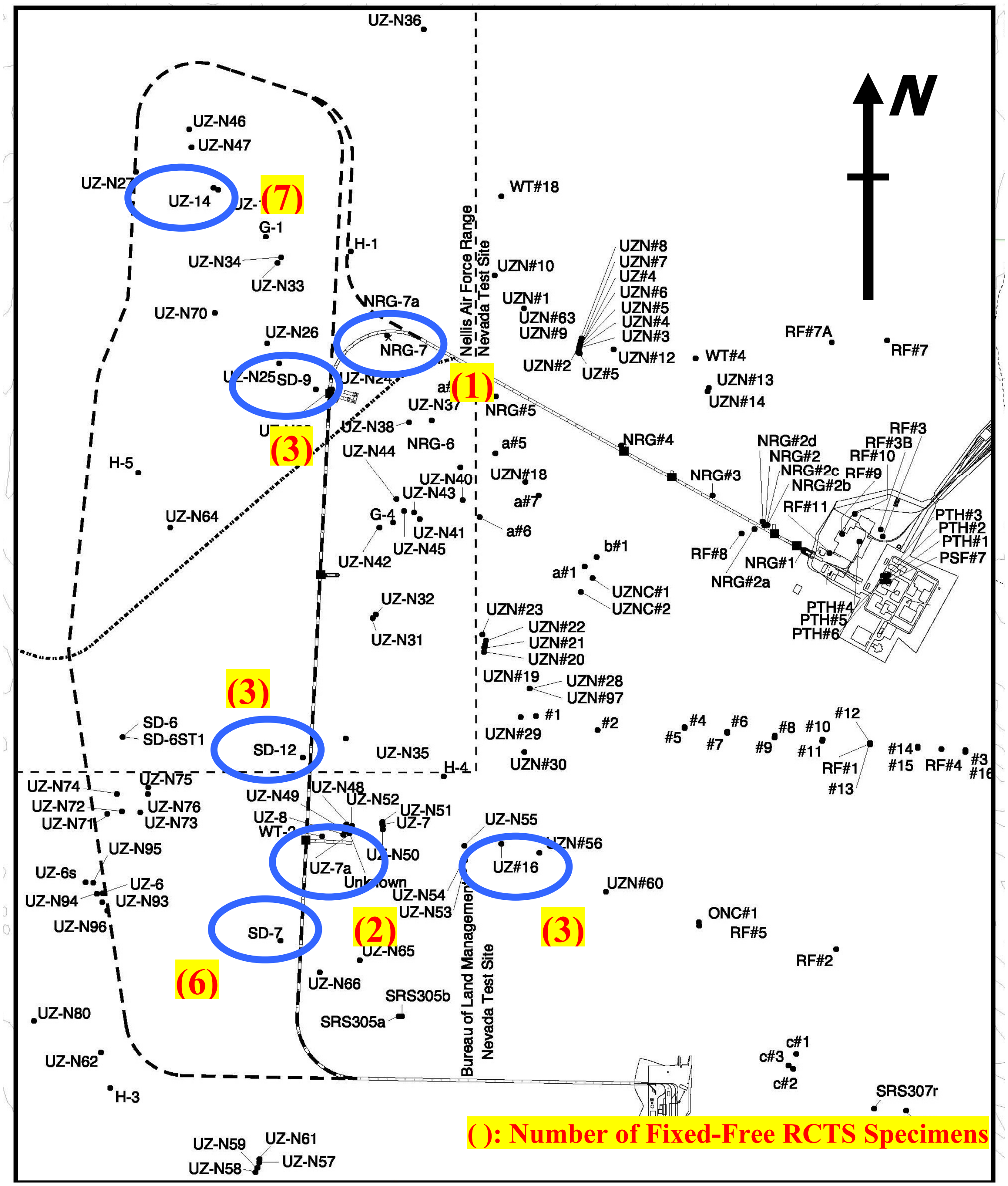


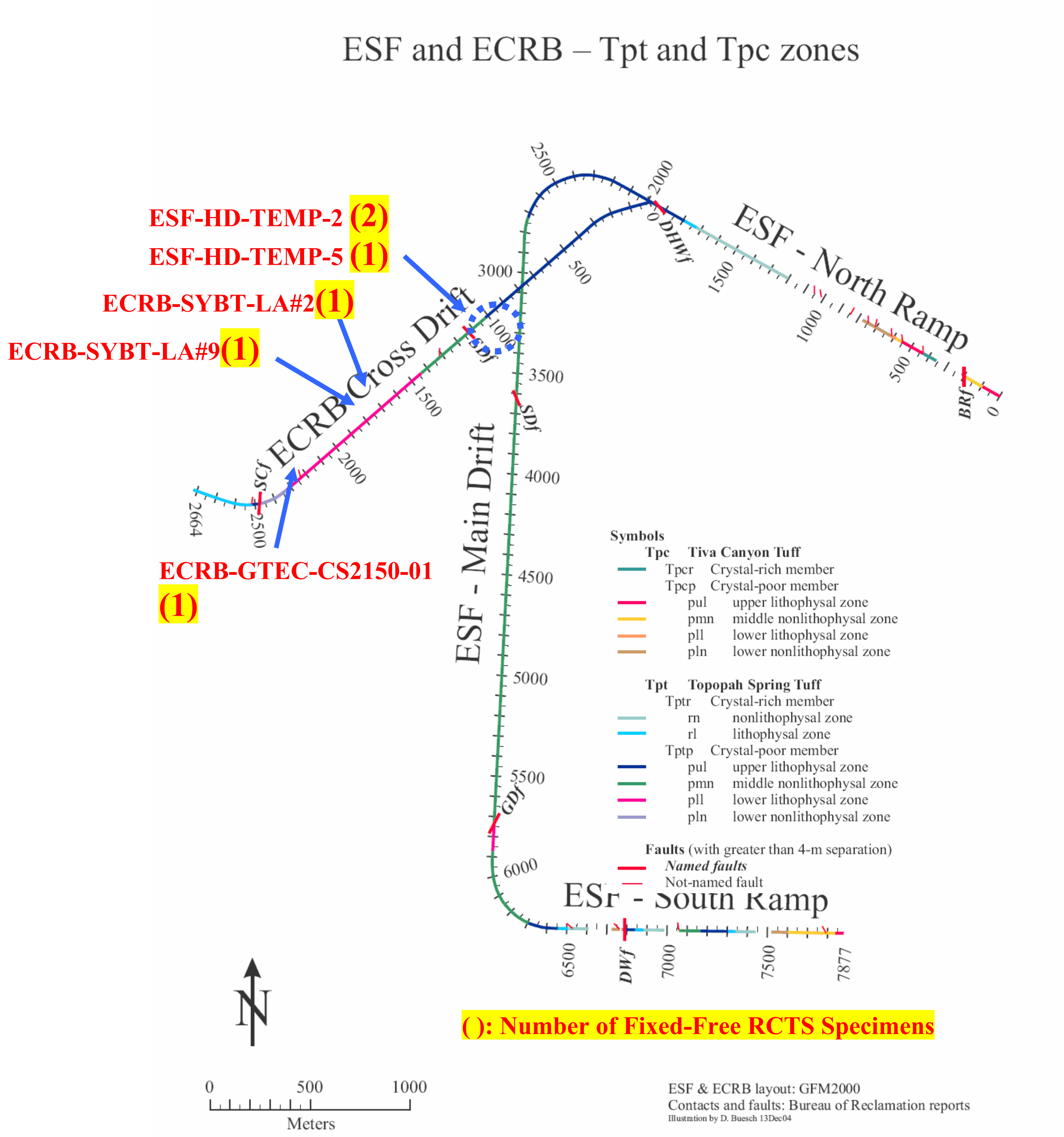
Figure 6.5-1. The Combined Resonant Column and Torsional Shear Device (Confining Chamber Not Shown): (a) Photograph of the Device without a Specimen and (b) Schematic Illustration of the Device



Source: Wong and Stokoe 2007 [DIRS 183328].

NOTE: The blue ellipse is placed around the borehole from which the samples were collected.

Figure 6.5-2. Existing Boreholes in the Vicinity of Yucca Mountain from Which Tuff Cores Were Recovered



Source: Wong and Stokoe 2007 [DIRS 183328].

NOTE: *BRf* = Bow Ridge Fault, *DHWf* = Drill Hole Wash Fault, *SDf* = Sundance Fault, *DWf* = Dune Wash Fault, *SCf* = Solitaro Canyon , *GDf* = Ghost Dance Fault

Figure 6.5-3. Boreholes in the ESF and ECRB Tunnels from Which Tuff Cores Were Recovered

Table 6.5-1. Parent Boreholes or Tunnel Locations and Number of Original Cores; Fixed-Free Resonant Column and Torsional Shear Testing at UTA

Parent Borehole	No. of Original Cores	Locations
ECRB-GTEC-CS2150-01	1	ECRB 21 + 50
ECRB-SYBT-LA#2	1	ECRB 15 + 50
ECRB-SYBT-LA#9	1	ECRB 16 + 50
ESF-HD-TEMP-2	2	ESF Alcove 5
ESF-HD-TEMP-5	1	ESF Alcove 5
UE-25 UZ#16	3	Surface
USW NRG-7/7A	1	Surface
USW SD-12	3	Surface
USW SD-7	6	Surface
USW SD-9	3	Surface
USW UZ-14	7	Surface
USW UZ-7a	2	Surface
Total	31	

Table 6.5-2. Stratigraphic Units for Thirty-Three Specimens Dynamically Tested in the Combined Fixed-Free Resonant Column and Torsional Shear Device at UTA

Stratigraphic Unit	Unit Abbreviation	No. of Fixed-Free Specimens
RAINIER MESA	Tmr	—
Pre-Rainier Mesa	Tmbt1	—
TUFF UNIT X	Tpki	—
TIVA CANYON TUFF:		
Crystal-Rich Vitric	Tpcrv	—
Crystal-Rich Nonlithophysal	Tpcrn	—
Crystal-Rich Lithophysal	Tpcrl	—
Crystal-Poor Upper Lithophysal	Tpcpul	—
Crystal-Poor Middle Nonlithophysal	Tpcpmn	—
Crystal-Poor Lower Lithophysal	Tpcpll	—
Crystal-Poor Lower Nonlithophysal	Tpcpln	—
Crystal-Poor Vitric	Tpcpv	—
YUCCA MOUNTAIN TUFF	Tpy, Tpbt3	1, 1
PAH CANYON TUFF	Tpp, Tpbt2	1, 1
TOPOPAH SPRING TUFF:		
Crystal-Rich Vitric	Tptrv	—
Crystal-Rich Nonlithophysal	Tptrn	1
Crystal-Rich Lithophysal	Tptrl	1
Crystal-Poor Lithic-Rich	Tptpf / Tptrf	—
Crystal-Poor Upper Lithophysal	Tptpul	4
Crystal-Poor Middle Nonlithophysal	Tptpmn	4
Crystal-Poor Lower Lithophysal	Tptpll	5
Crystal-Poor Lower Nonlithophysal	Tptpln	1
Crystal-Poor Vitric	Tptpv	1
Pre-Topopah Spring Bedded Tuff	Tpbt1	—
CALICO HILLS	Tac	3
PROW PASS	Tcp	3
Pre-Prow Pass Bedded Tuff	Tcpbt	—
BULLFROG	Tcp	3
Pre-Bullfrog Bedded Tuff	Tcbbt	—
TRAM	Tct	3

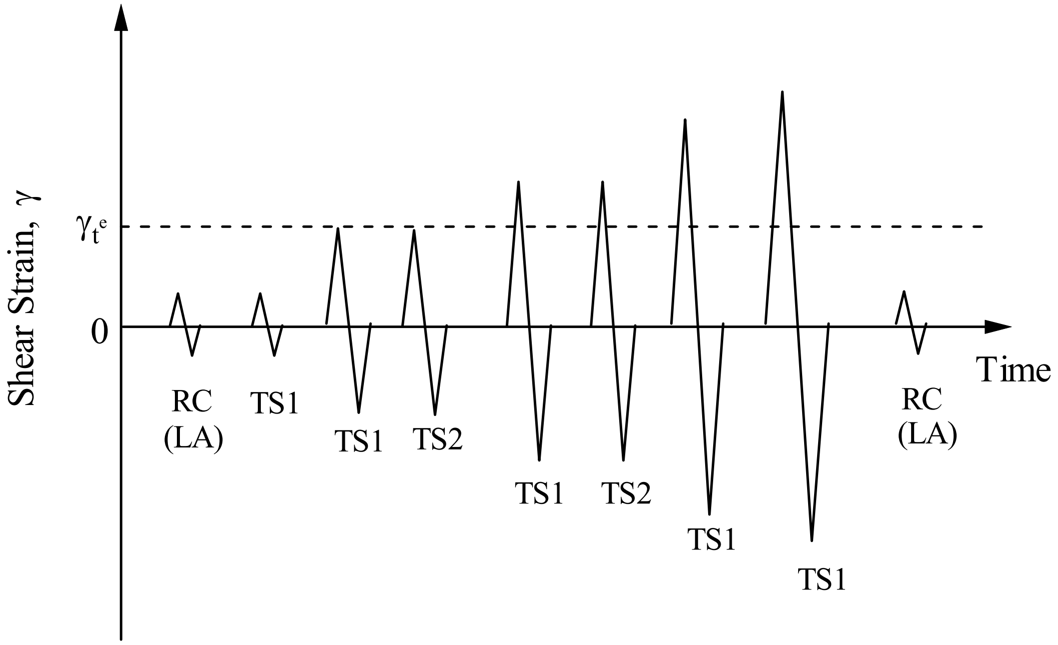
All specimens were tested at small strains at the different confining pressures in an increasing confining pressure sequence. High-amplitude resonant column and torsional shear tests were performed during this loading path at one or more pressures below or at the estimated in-situ mean effective stress, σ_m, and often at $4\sigma_m$. In cases where $4\sigma_m$ was greater than 400 psi, these tests were performed at 400 psi following tests at 100 psi or σ_m.

High-amplitude testing was composed of two series of tests. The first involved cyclic torsional shear testing as illustrated in Figure 6.5-4. A complete set of torsional shear tests required about two hours to perform at each confining pressure. Torsional shear tests were conducted with the drainage line opened at all times. The shearing strains, (γ), that were attained were those that could be generated within the limit of power applied in torsion. The majority of the measurements was performed at an excitation frequency of 0.5 Hz and are labeled as TS1 in Figure 6.5-4. However, TS tests at two or three different levels of γ were also conducted to evaluate the effect of excitation frequency on G and D at these strains. In these tests (denoted as TS2 in Figure 6.5-4), ten cycles of loading were applied at four different frequencies ranging from 0.1 to 5 Hz.

After the TS tests were completed, confinement of the specimen was continued at the given pressure. A series of high-amplitude resonant column (HARC) tests was performed following the TS tests. However, before the HARC tests commenced, small-strain RC tests were performed to determine if any changes in the coupling of the rock specimen with the top cap or base pedestal might have occurred from the TS tests. Significant changes are defined as a change of 5% in G_{max} and 10% in $D_{S\ min}$; however, no significant changes were measured in any of the tests immediately after the TS tests.

HARC testing was conducted to evaluate the influence of shear strain amplitude on G and D. This series of tests is illustrated in Figure 6.5-5. A complete set of resonant column tests took about two hours to perform and these tests were performed with the drainage line opened just as in the case of the TS tests. In these tests, about 1000 cycles of loading were applied at each strain amplitude.

Upon completion of the high-amplitude RC tests, low-amplitude RC tests were again performed to determine if any changes in the coupling of tuff core with the top cap or base pedestal occurred from the high-amplitude tests. If no significant changes were measured in G_{max} and $D_{S\ min}$ after a short rest period, the next stage of testing (low-amplitude tests at a higher confining pressure) was undertaken. In two cases (Specimens 7C-2 and 1G-1), testing was stopped after the first set of HARC tests at the lower confining pressure due to failure at the top-cap-specimen interface. Otherwise, no significant changes were measured due to the HARC tests.



Source: Wong and Stokoe 2007 [DIRS 183328].

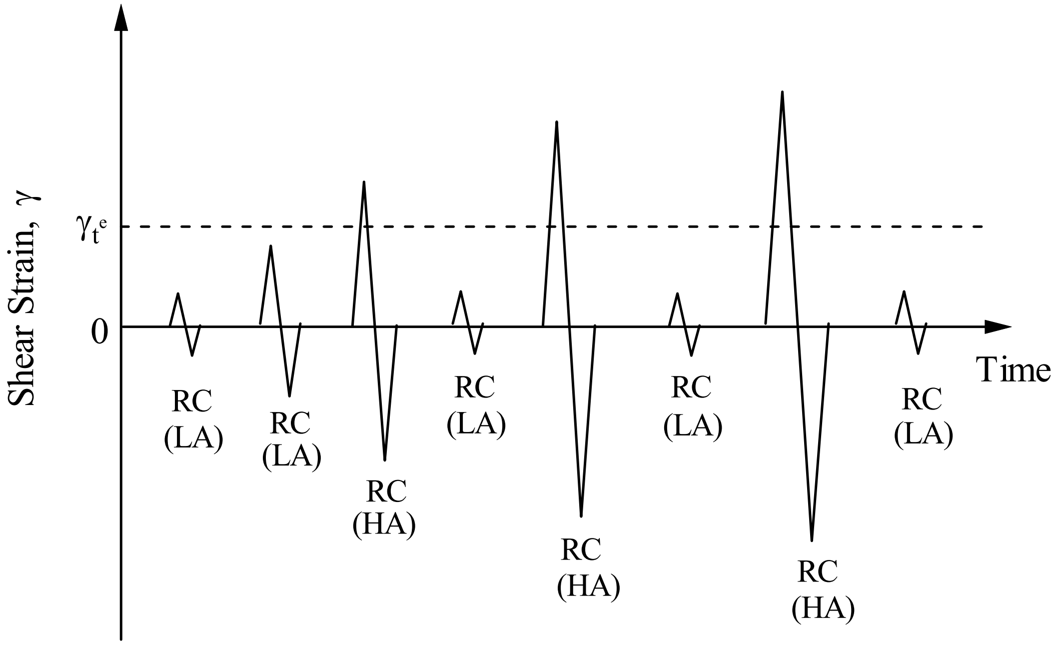
NOTES: γ_t^e = elastic threshold strain; below γ_t^e, G is constant and equal to G_{max}.

RC (LA) = resonant column test at low-amplitudes (strains < 0.001%).

TS1 = torsional shear test in which 10 cycles are applied at 0.5 Hz.

TS2 = torsional shear test in which 10 cycles are applied at each of four frequencies between 0.1 Hz to 5 Hz (0.1, 0.5, 1, and 5 Hz) for the test specimens.

Figure 6.5-4. Testing Procedure Used in the Torsional Shear Test to Investigate the Effects of Strain Amplitude, Number of Loading Cycles, and Excitation Frequency on G and D of the Test Specimens



Source: Wong and Stokoe 2007 [DIRS 183328].

NOTES: RC = resonant column test in which about 1,000 cycles of loading are applied during each measurement.

γ_t^e = elastic threshold strain; below γ_t^e, G is constant and equal to G_{max}.

RC (LA) = resonant column test at low-amplitudes (strains < 0.001%).

RC (HA) = resonant column test at amplitudes above γ_t^e.

Figure 6.5-5. Testing Procedure Used in the Resonant Column Test to Investigate the Effect of Strain Amplitude on G and D of the Test Specimens

6.5.2.2. Results of RCTS Tests

Dynamic Properties in the Small-Strain Range ($\gamma < 0.001\%$)

Tuff specimens were selected to represent a range of lithostratigraphic units below the Tiva Canyon Tuff. A total of 33 specimens were tested. The initial properties of the 33 specimens are presented in Table VII-1 and Table 6.5-3 The 33 specimens are divided into four groups based on their total unit weight (γ_t): Group 1 (very low density) – γ_t from 60 pcf to 92 pcf; Group 2 (low density) – γ_t from 93 pcf to 120 pcf; Group 3 (medium density) – γ_t from 121 pcf to 140 pcf; Group 4 (high density) – γ_t from 141 pcf to 150 pcf. This grouping was chosen because of the relationship between the small-strain shear wave velocity (V_S) and γ_t as shown in Figure 6.5-6.

Table 6.5-3. Fixed-Free Testing, General Specimen Size, Weight and Testing Matrix Table

Spec. No.	Spec. ID	Type	Initial Specimen Size		Total Unit Weight, lb/ft^3 (g/cm^3)	Isotropic Test		
			Height In. (cm)	Dia. In. (cm)		Low-Amplitude RC and TS Tests ksf (kPa)	High-Amplitude RC Tests ksf (kPa)	High-Amplitude TS Tests ksf (kPa)
Tuff1	UTA-42-A (1G-1)	Tptrl	1.81 (4.6)	0.83 (2.1)	136 (2.2)	0, 7.2, 15.8 (0,345,759)	15.8 (759)	15.8 (759)
Tuff2a	UTA-42-B (2B-3)	Tptpul	4.13 (10.5)	1.77 (4.5)	135 (2.2)	0, 1.4, 2.9, 5.8, 11.5, 23.0 (0, 69, 138, 276, 552, 1105)	5.8, 23.0 (276, 1105)	5.8, 23.0 (276, 1105)
Tuff2b	UTA-42-B (2C-2)	Tptpul	1.81 (4.6)	0.83 (2.1)	141 (2.3)	0, 1.4, 2.9, 5.8, 11.5, 23.0 (0, 69, 138, 276, 552, 1105)	5.8, 23.0 (276, 1105)	5.8, 23.0 (276, 1105)
Tuff3a	UTA-42-C (3C-2)	Tptpmn	4.02 (10.2)	1.57 (4.0)	144 (2.3)	0, 5.2, 10.4, 20.7, 41.5, 64.8 (0, 249, 497, 994, 1988, 3106)	20.7, 64.8 (994, 3106)	20.7, 64.8 (994, 3106)
Tuff3b	UTA-42-C (3K-2)**	Tptpmn	1.97 (5.0)	0.83 (2.1)	147 (2.4)	0, 5.2, 10.4, 20.7, 41.5, 64.8 (0, 249, 497, 994, 1988, 3106)	20.7, 64.8 (994, 3106)	20.7, 64.8 (994, 3106)
Tuff4	UTA-42-D (4C-2)	Tptrn	4.57 (11.6)	1.57 (4.0)	145 (2.3)	0, 13.8, 27.4, 54.4, 64.8 (0, 663, 1312, 2609, 3106)	0, 54.4, 64.8 (0, 2609, 3106)	0, 54.4, 64.8 (0, 2609, 3106)
Tuff5	UTA-42-E (5C-2)	Tptpll	3.35 (8.5)	1.57 (4.0)	138 (2.2)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)

Table 6.5-3. Fixed-Free Testing, General Specimen Size, Weight and Testing Matrix Table (Continued)

			Initial Specimen Size			**Isotropic Test**		
Spec. No.	**Spec. ID**	**Type**	**Height In. (cm)**	**Dia. In. (cm)**	**Total Unit Weight, lb/ft^3 (g/cm^3)**	**Low-Amplitude RC and TS Tests ksf (kPa)**	**High-Amplitude RC Tests ksf (kPa)**	**High-Amplitude TS Tests ksf (kPa)**
Tuff6	UTA-42-F (6C-2)	Tptpln	4.84 (12.3)	1.57 (4.0)	147 (2.4)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff7	UTA-42-G (7C-2)	Tac (Devitrified)	4.37 (11.1)	1.57 (4.0)	103 (1.7)	0, 3.6, 7.2, 14.4 (0, 173, 345, 690)	0, 14.4 (0, 690)	0, 14.4 (0, 690)
Tuff8	UTA-42-H (8C-2)	Tac (Vitric)	5.67 (14.4)	1.57 (4.0)	94 (1.5)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff9	UTA-42-I (9A-2)	Tptpll	5.24 (13.3)	1.77 (4.5)	136 (2.2)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff10	UTA-42-J (10A-2)	Tptpll	3.78 (9.6)	1.77 (4.5)	138 (2.2)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff11	UTA-42-K (11C-1) *	Tptpul	2.91 (7.4)	1.57 (4.0)	139 (2.2)	0	0	0
Tuff12	UTA-42-L (12C-1)	Tptpul	3.90 (9.9)	1.57 (4.0)	137 (2.2)	0	0	0
Tuff13	UTA-42-M (13C-2)	Tptpmn	5.98 (15.2)	1.57 (4.0)	144 (2.3)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff14	UTA-42-N (14C-2)	Tptpmn	4.72 (12.0)	1.57 (4.0)	145 (2.3)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff15	UTA-42-O (15C-3)	Tptpll	5.55 (14.1)	1.57 (4.0)	143 (2.3)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff16	UTA-42-P (16C-2)	Tptpll	4.13 (10.5)	1.57 (4.0)	138 (2.2)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)

Table 6.5-3. Fixed-Free Testing, General Specimen Size, Weight and Testing Matrix Table (Continued)

Spec. No.	Spec. ID	Type	Initial Specimen Size		Total Unit Weight, lb/ft^3 (g/cm^3)	Isotropic Test		
			Height In. (cm)	Dia. In. (cm)		Low-Amplitude RC and TS Tests ksf (kPa)	High-Amplitude RC Tests ksf (kPa)	High-Amplitude TS Tests ksf (kPa)
Tuff17	UTA-42-Q (17C-2)	Tcp	4.37 (11.1)	1.57 (4.0)	110 (1.8)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff18	UTA-42-R (18C-2)	Tcp	3.90 (9.9)	1.57 (4.0)	119 (1.9)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff19	UTA-42-S (19C-2)	Tcb	5.63 (14.3)	1.57 (4.0)	149 (2.4)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff20	UTA-42-T (20C-2)	Tct	5.20 (13.2)	1.57 (4.0)	111 (1.8)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff21	UTA-42-U (21C-2)	Tct	5.47 (13.9)	1.57 (4.0)	103 (1.7)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff23	UTA-42-W (23C)	Tpy	13.49 (5.3)	3.91 (1.5)	91 (1.5)	0, 3.0, 5.9, 11.8, 23.6, 47.2 (0,145, 283, 565, 1131, 2262)	0, 11.8, 47.2 (0, 565, 2262)	0, 11.8, 47.2 (0, 565, 2262)
Tuff24	UTA-42-X (24C)	Tpbt3	14.05 (5.5)	3.93 (1.5)	81 (1.3)	0, 4.6, 9.4, 18.7, 37.4, 57.6 (0, 221, 448, 896, 1793, 2761)	0, 18.7, 57.6 (0, 896, 2761)	0, 18.7, 57.6 (0, 896, 2761)
Tuff25	UTA-42-Y (25C)	Tpp	13.58 (5.3)	3.94 (1.6)	76 (1.2)	0, 4.6, 9.4, 18.7, 37.4, 57.6 (0, 221, 448, 896, 1793, 2761)	0, 18.7, 57.6 (0, 896, 2761)	0, 18.7, 57.6 (0, 896, 2761)
Tuff27	UTA-42-AA (27C)	Tptpv3	12.28 (4.8)	3.96 (1.6)	145 (2.3)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff28	UTA-42-AB (28E)	Tpbt2	13.68 (5.4)	3.92 (1.5)	63 (1.0)	0, 5.5, 10.8, 21.6, 43.2, 57.6 (0, 262, 517, 1034, 2068, 2761)	0, 21.6, 57.6 (0, 1034, 2761)	0, 21.6, 57.6 (0, 1034, 2761)

Table 6.5-3. Fixed-Free Testing, General Specimen Size, Weight and Testing Matrix Table (Continued)

Spec. No.	Spec. ID	Type	Initial Specimen Size		Total Unit Weight, lb/ft^3 (g/cm^3)	Isotropic Test		
			Height In. (cm)	Dia. In. (cm)		Low-Amplitude RC and TS Tests ksf (kPa)	High-Amplitude RC Tests ksf (kPa)	High-Amplitude TS Tests ksf (kPa)
Tuff29	UTA-42-AC (29C)	Tac (Dev.)	14.02 (5.5)	3.95 (1.6)	109 (1.7)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff30	UTA-42-AD (30A)	Tcp	13.81 (5.4)	3.96 (1.6)	143 (2.3)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff31	UTA-42-AE (31A)	Tcb	11.37 (4.5)	3.96 (1.6)	120 (1.9)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff32	UTA-42-AF (32A)	Tcb	11.37 (4.5)	3.96 (1.6)	105 (1.7)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)
Tuff33	UTA-42-AG (33A)	Tct	11.33 (4.5)	3.95 (1.6)	110 (1.8)	0, 3.6, 7.2, 14.4, 28.8, 57.6 (0, 173, 345, 690, 1381, 2761)	0, 14.4, 57.6 (0, 690, 2761)	0, 14.4, 57.6 (0, 690, 2761)

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329]; Wong and Stokoe 2007 [DIRS 183328].

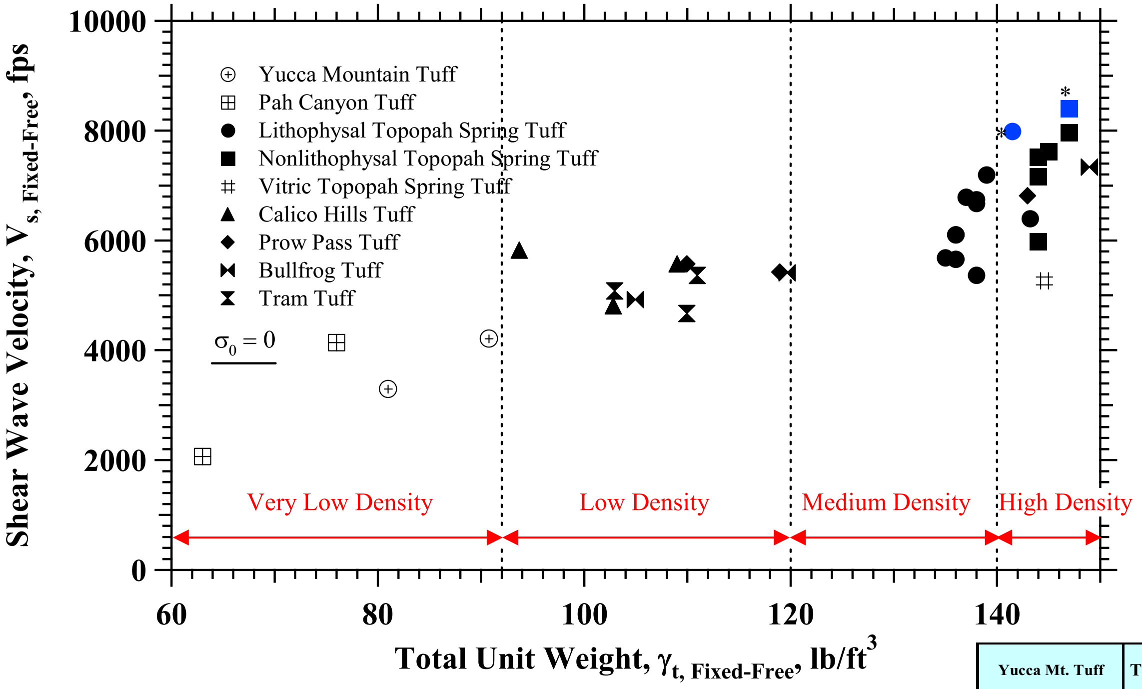
The shear wave velocities, shear moduli, and material damping values from the RCTS tests are presented in tabular form in Tables VII-2 through VII-59 of Attachment VII. In this section, the principal results from these measurements are presented in summary tables and graphs and are briefly discussed.

The variations in small-strain shear modulus, G_{max}, with isotropic confining pressure, σ_o, that were measured by resonant column testing are presented in Figures 6.5-7 through 6.5-10 for Groups 1 through 4, respectively. Specimens 11C-1 and 12C-1 were tested only at the unconfined state due to many large voids on their surfaces. As shown in the figures, half of the four tuff specimens in Group 1 (Figure 6.5-7) exhibit little to no increase in G_{max} with increasing σ_o. The two specimens that exhibit moderate pressure dependency on G_{max} are bedded tuffs: Pre-Yucca Mountain bedded tuff (Tpbt3) and Pre-Pah Canyon bedded tuff (Tpbt2). They have two of the three lowest γ_t values as well as the lowest G_{max} values throughout the entire test pressure range compared with the other specimens. Although no measurements of micro-cracks were made, one possible reason for the moderate pressure dependency of G_{max} exhibited by these two specimens is closing of micro-cracks as the pressure increased. It is thought that micro-cracks in these weak and porous specimens were closing as the pressure was increased because their volume change associated with the increase in pressure (estimated from the height change combined with the approximation of isotropic straining) was negligible.

None of the samples from Group 2 to Group 4 (Figures 6.5-8 to 6.5-10) exhibit any pressure dependency on $G_{max.}$

Two specimens were re-cored from larger cores: specimen 2C-2 was re-cored from 2B-2 and specimen 3K-2 was from the piece of core next to 3C-2. The re-cored specimens have an average diameter and height of 0.83 and 1.89 in., respectively. Based on visual inspection of Specimens 2B-3 and 2C-2, the smaller re-cored specimen (2C-2) had fewer surface lithophysae. In addition, the total unit weight of the re-cored specimen was 6 pcf larger. These two factors resulted in an increase in G_{max}, 94% higher than the G_{max} value of the larger parent specimen at the highest confining pressure as shown in Figure 6.5-9. For Specimens 3C-2 and 3K-2, Specimen 3K-2 was cored from the piece of core next to Specimen 3C-2. Specimen 3K-2 had a slightly higher γ_t than Specimen 3C-2 (higher by 3 pcf). The higher unit weight and the slightly different location resulted in an increase in G_{max} of 39 % for the smaller specimen (3K-2) at the highest confining pressure as shown in Figure 6.5-10.

The variations in small-strain material damping ratio, $D_{S\ min}$, with σ_o that were measured by resonant column testing are shown in Figures 6.5-11 through 6.5-14 for Groups 1 through 4, respectively. As with G_{max}, D_{min} shows only a small effect of σ_o for the specimens. The values of $D_{S\ min}$ range from about 0.2% to 1.4% at the highest confining pressures at which the specimens were tested. With the exception of the two bedded tuff samples discussed above, the γ_t values do not correlate with V_S (and hence G_{max}). The two re-cored small specimens exhibit lower $D_{S\ min}$ values (with $\Delta D_{S\ min}$ equal to 0.64% and 0.12%) compared with the larger specimens (Specimens 2B-3 and 3C-2, respectively) at their highest test pressures.



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTES: *Specimens cored from larger specimens and had fewer surface lithophysae.

Group 1: Very Low Density Specimens from Yucca Mountain Tuff (Tpy and Tpbt3) and Pah Canyon Tuff (Tpp and Tpbt2).

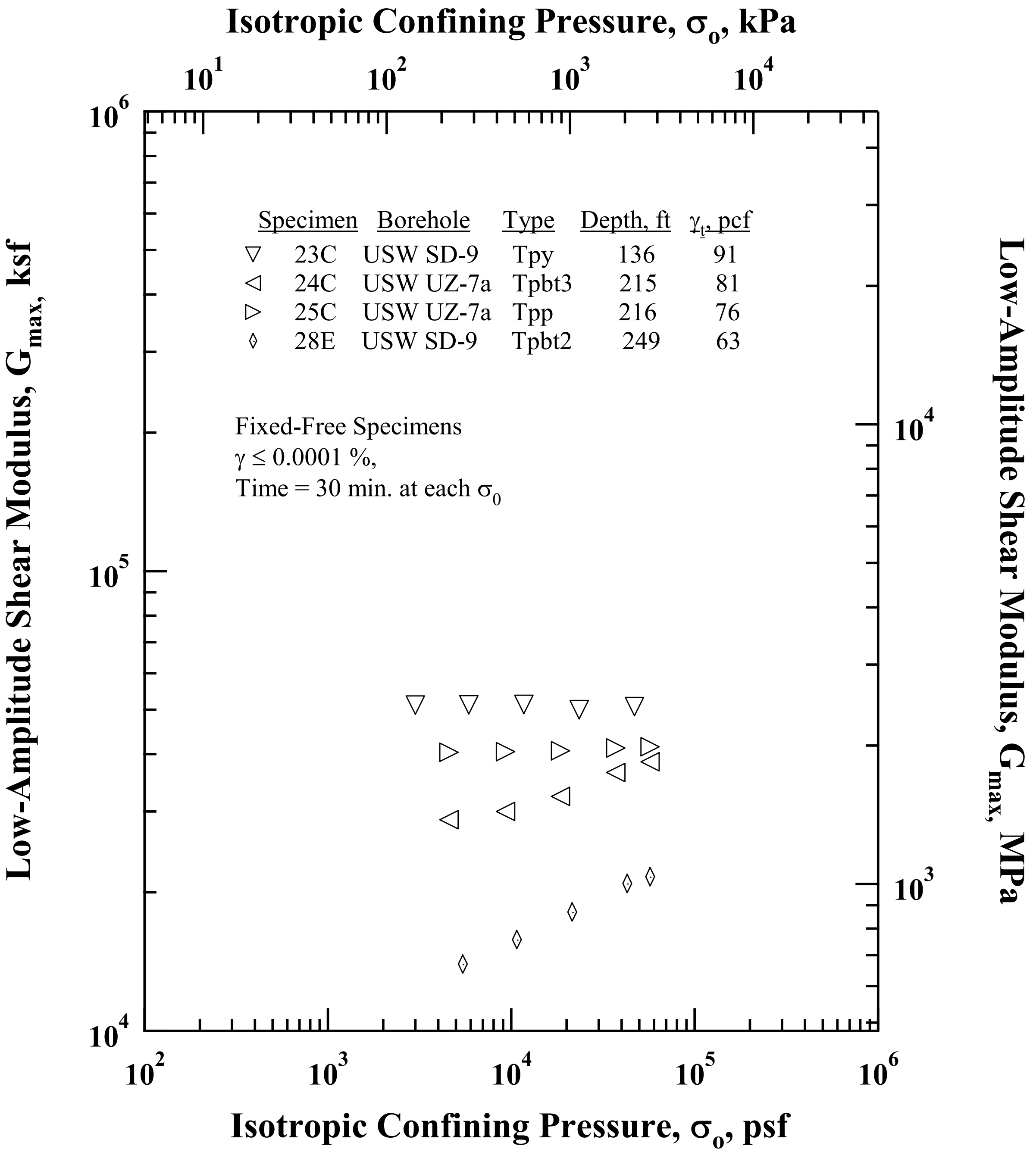
Group 2: Low Density Specimens from Calico Hills (Tac), Prow Pass (Tcp), Bullfrog (Tcb), and Tram (Tct).

Group 3: Medium Density Specimens from Topopah Spring Tuff, Crystal-Rich, Lithophysal (Tptrl); Topopah Spring Tuff, Crystal-Poor, Upper Lithophysal (Tptpul); and Topopah Spring Tuff, Crystal-Poor, Lower Lithophysal (Tptpll).

Group 4: High Density Specimens from Topopah Spring Tuff, Crystal-Rich, Nonlithophysal (Tptrn); Topopah Spring Tuff, Crystal-Poor, Middle Nonlithophysal (Tptpmn); Topopah Spring Tuff, Crystal-Poor, Lower Nonlithophysal (Tptpln); Topopah Spring Tuff, Crystal-Poor, Vitric (Tptpv); Prow Pass (Tcp); and Bullfrog (Tcb).

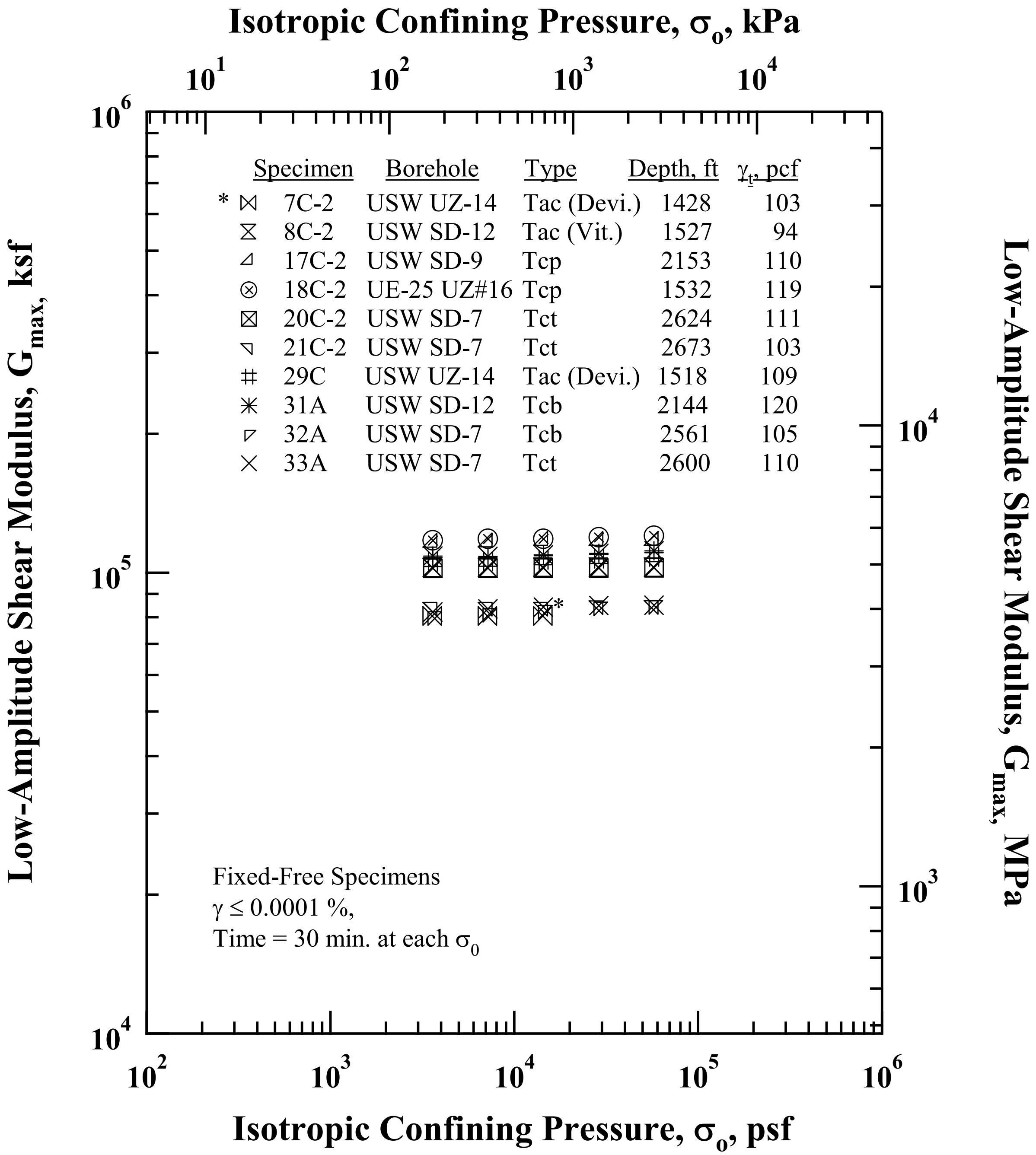
Yucca Mt. Tuff	**Tpy, Tpbt3**
Pah Canyon Tuff	**Tpp, Tpbt2**
Topopah Spring Tuff	**Tptrn**
	Tptrl
	Tptpul
	Tptpmn
	Tptpll
	Tptpln
	Tptpv
Calico Hills	**Tac**
Prow Pass	**Tcp**
Bullfrog	**Tcb**
Tram	**Tct**

Figure 6.5-6. Variation of Shear Wave Velocity with Total Unit Weight of the Thirty-Three Tuff Specimens from Stratigraphic Units below Tiva Canyon Tuff; V_S Measured at the Unconfined State in the Resonant Column Test



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

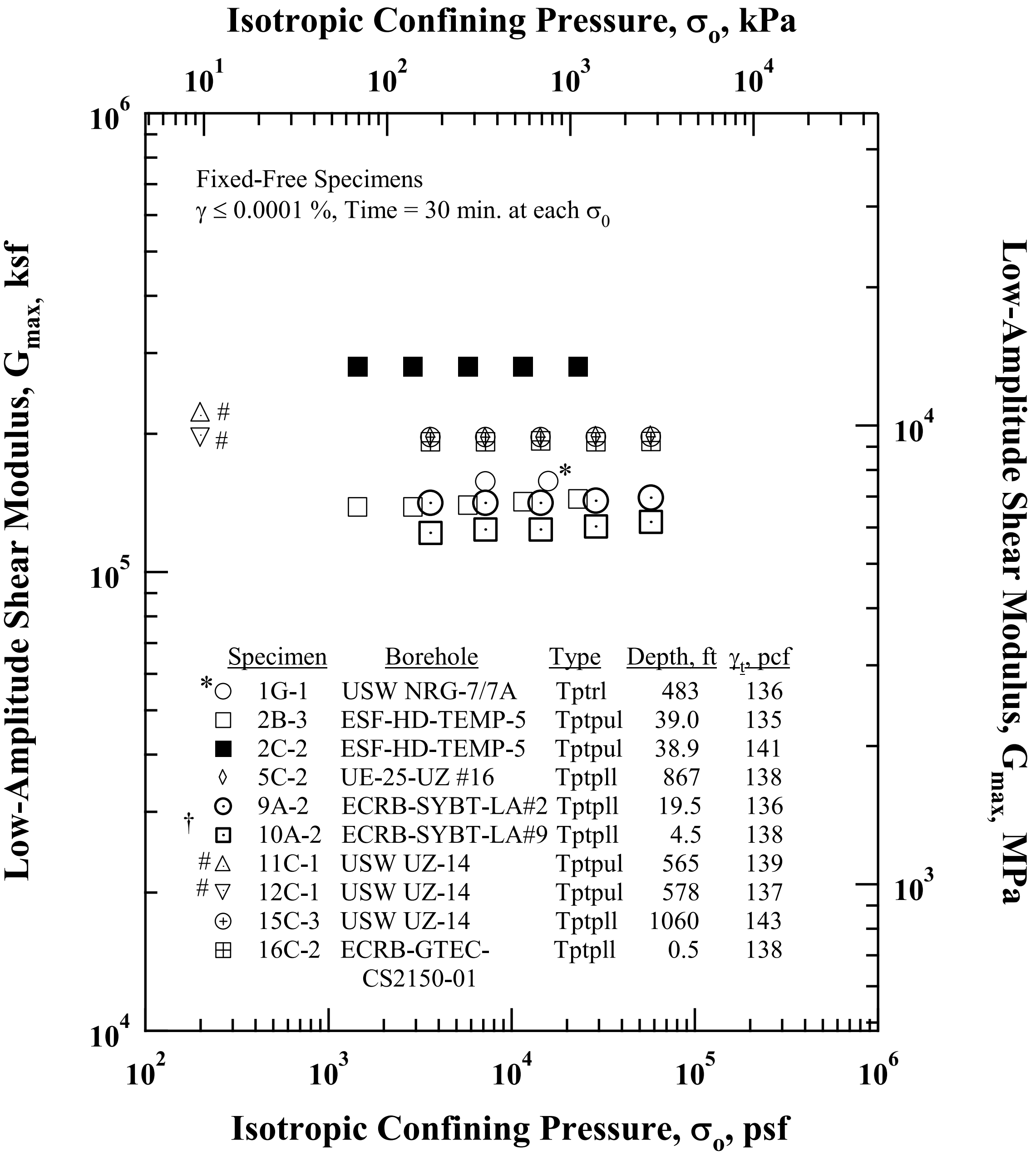
Figure 6.5-7. Variation in Low-Amplitude Shear Modulus with Isotropic Confining Pressure of Tuff Specimens with a Very Low Density (Group 1)



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTE: * Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

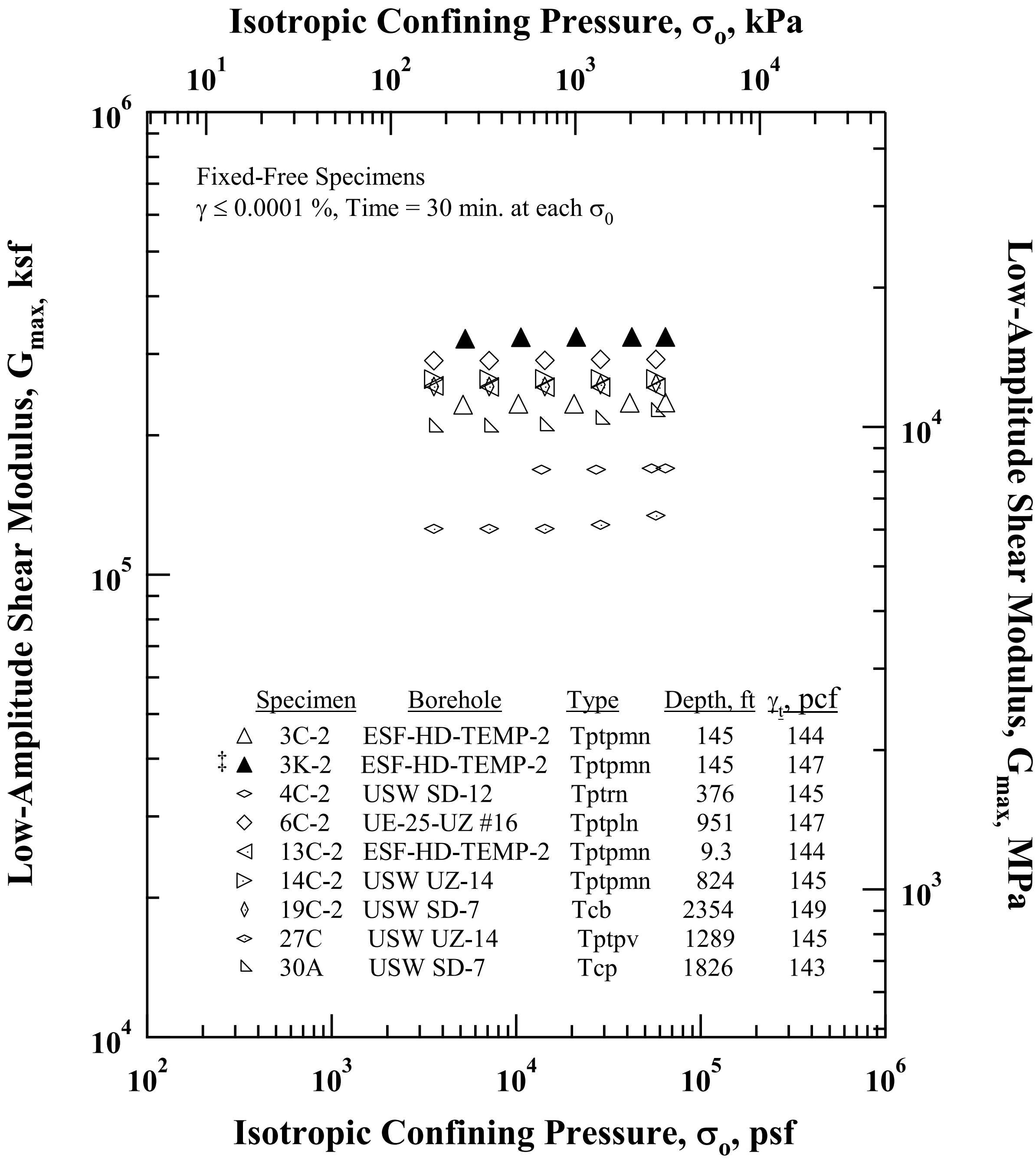
Figure 6.5-8. Variation in Low-Amplitude Shear Modulus with Isotropic Confining Pressure of Tuff Specimens with a Low Density (Group 2)



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTES: † Specimen 2C-2 was cored from Specimen 2B-3 and had fewer surface lithophysae.
Tests were performed only at unconfined state due to many large voids on specimen surface.
* Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

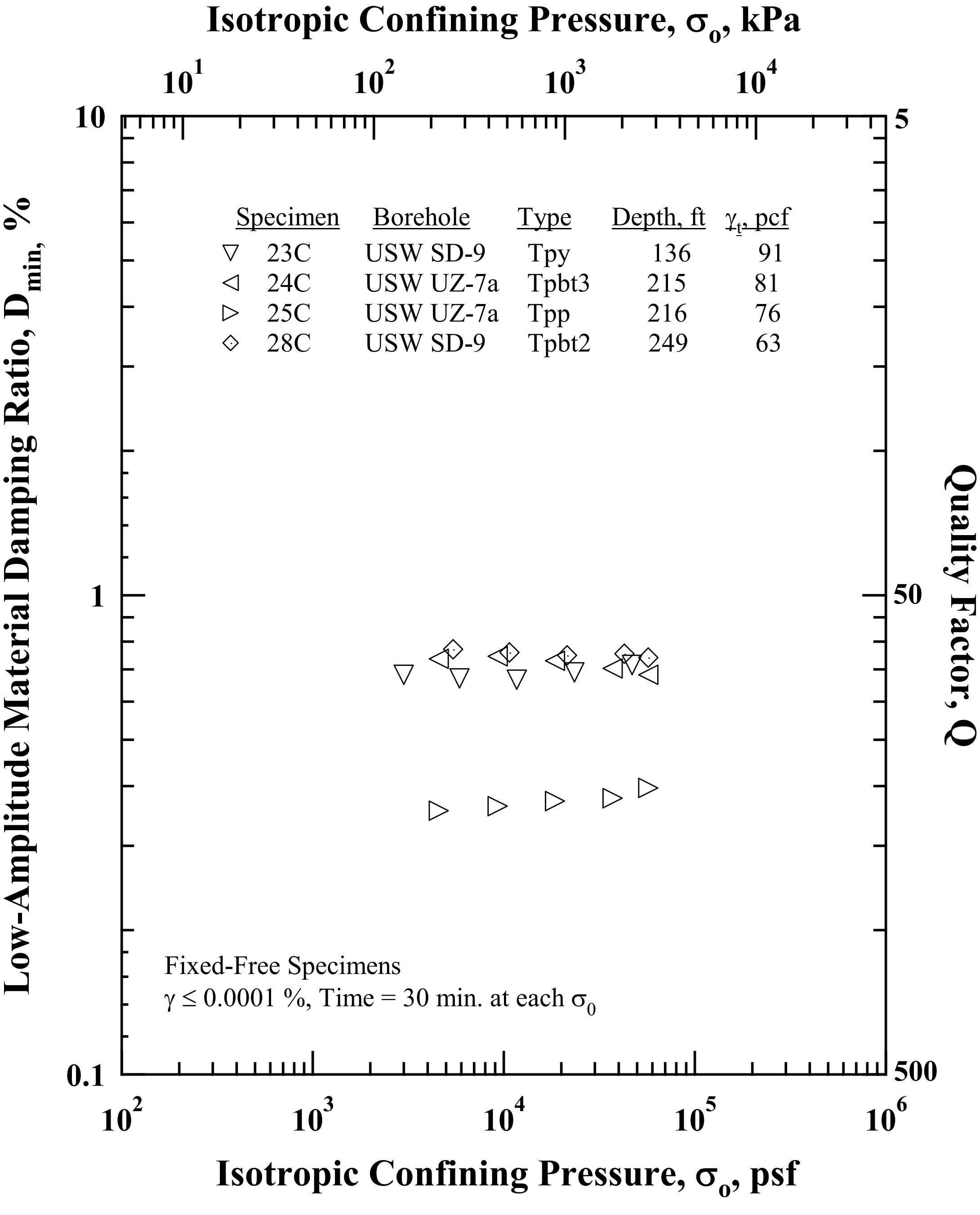
Figure 6.5-9. Variation in Low-Amplitude Shear Modulus with Isotropic Confining Pressure of Lithophysal Tuff Specimens with a Medium Density (Group 3)



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

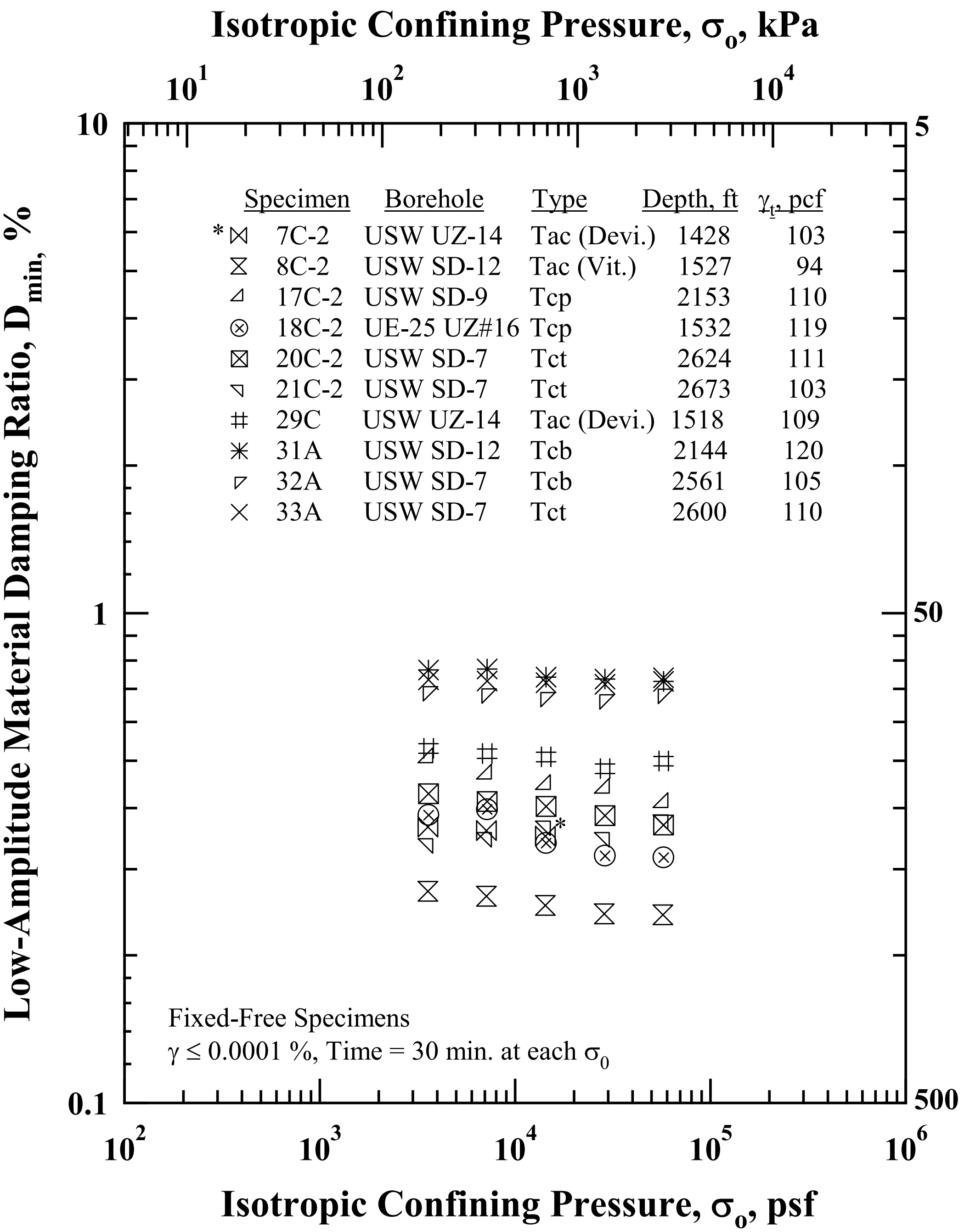
NOTE: ‡ Specimen 3K-2 was cored from Specimen 3D and had fewer surface lithophysae.

Figure 6.5-10. Variation in Low-Amplitude Shear Modulus with Isotropic Confining Pressure of Tuff Specimens with a High Density (Group 4)



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

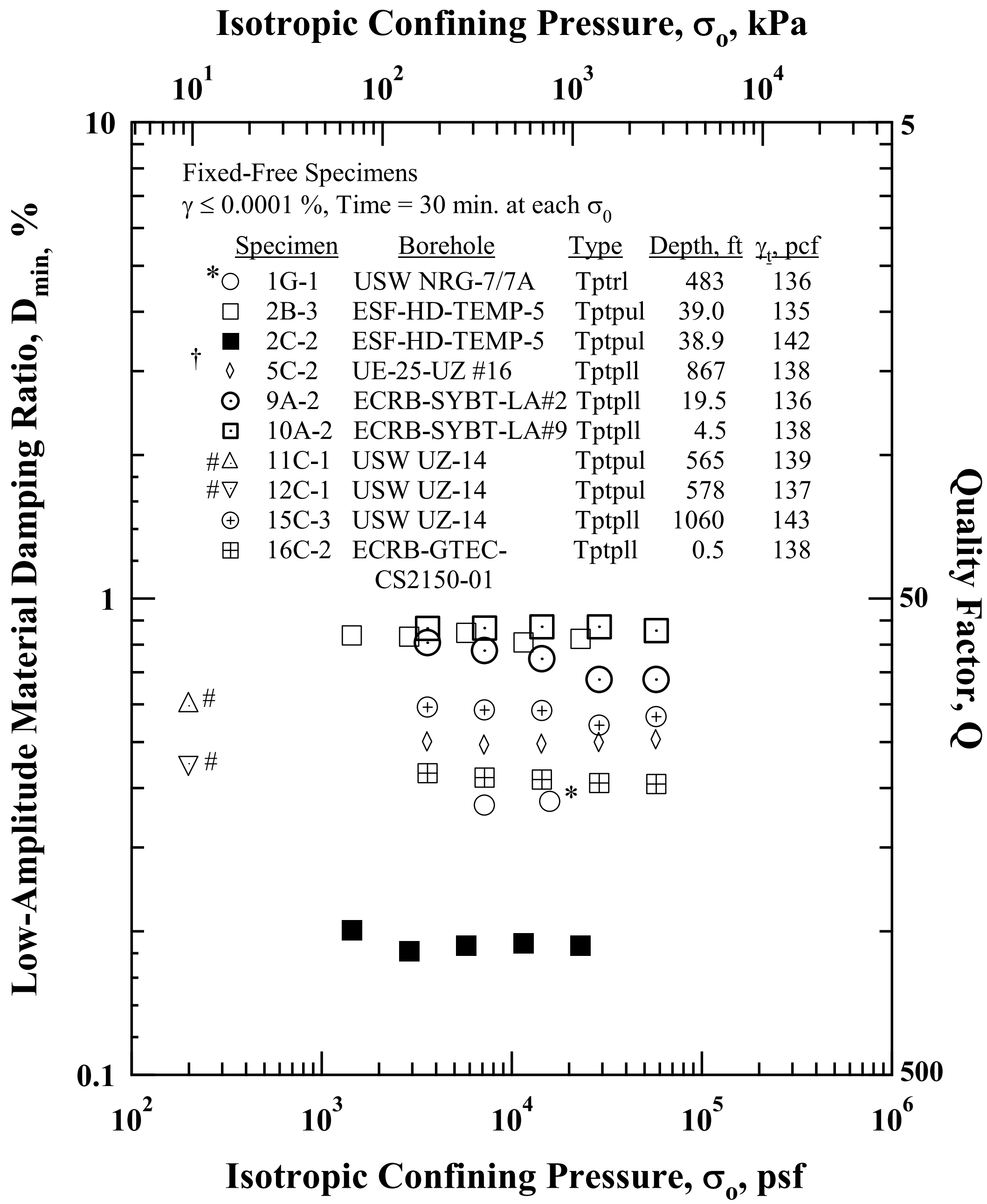
Figure 6.5-11. Variation in Low-Amplitude Material Damping Ratio with Isotropic Confining Pressure of Tuff Specimens with a Very Low Density (Group 1)



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTE: * Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

Figure 6.5-12. Variation in Low-Amplitude Material Damping Ratio with Isotropic Confining Pressure of Tuff Specimens with a Low Density (Group 2)



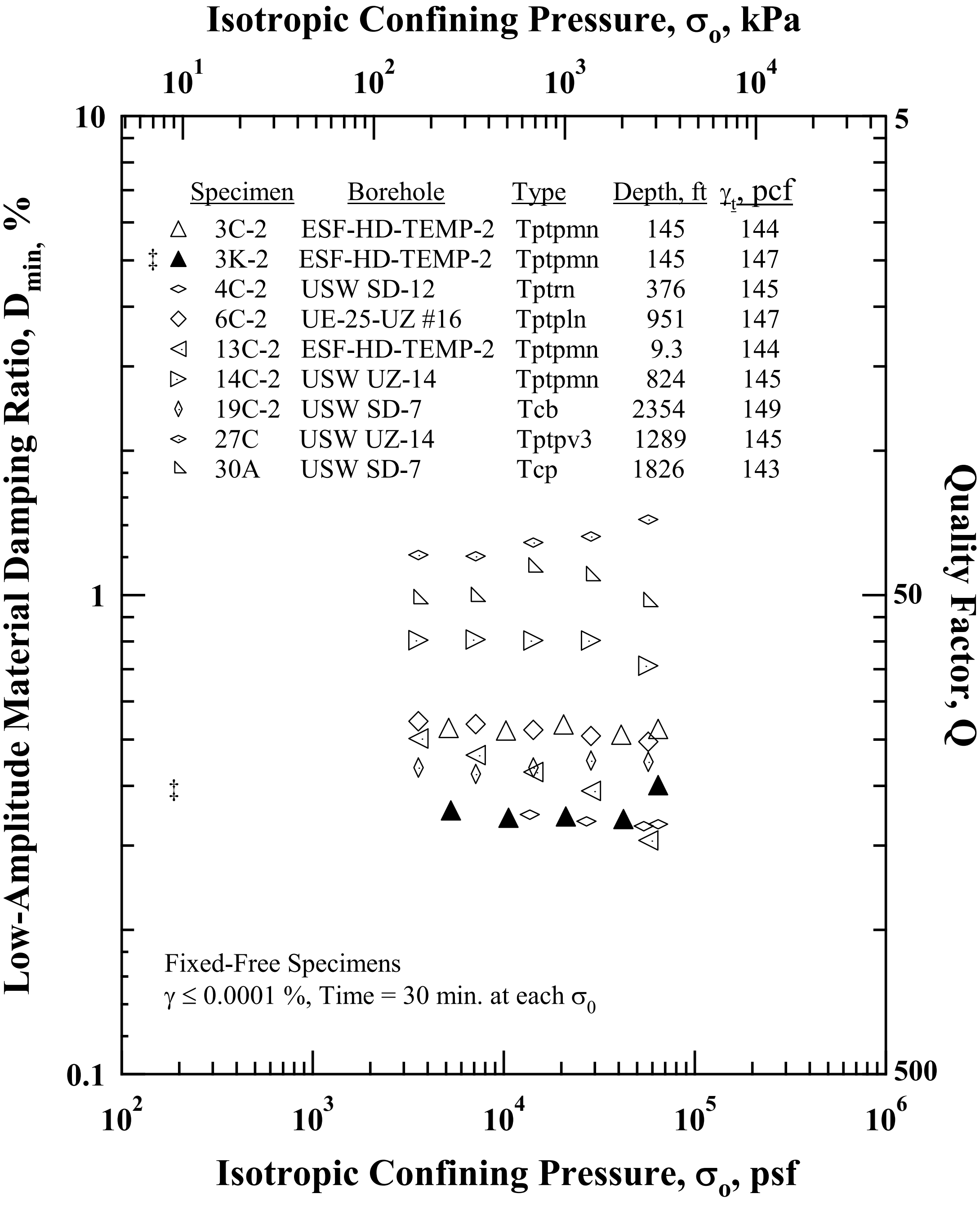
Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTES: † Specimen 2C-2 was cored from Specimen 2B-3 and had fewer surface lithophysae.

\# Tests were performed only at unconfined state due to many large voids on specimen surface.

* Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

Figure 6.5-13. Variation in Low-Amplitude Shear Modulus with Isotropic Confining Pressure of Lithophysal Tuff Specimens with a Medium Density (Group 3)

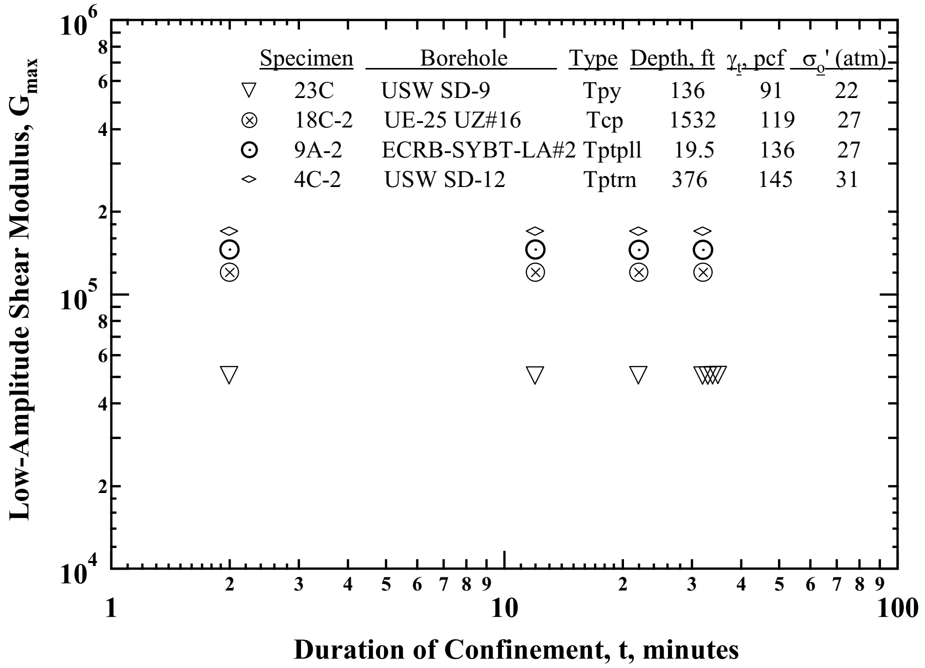


Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

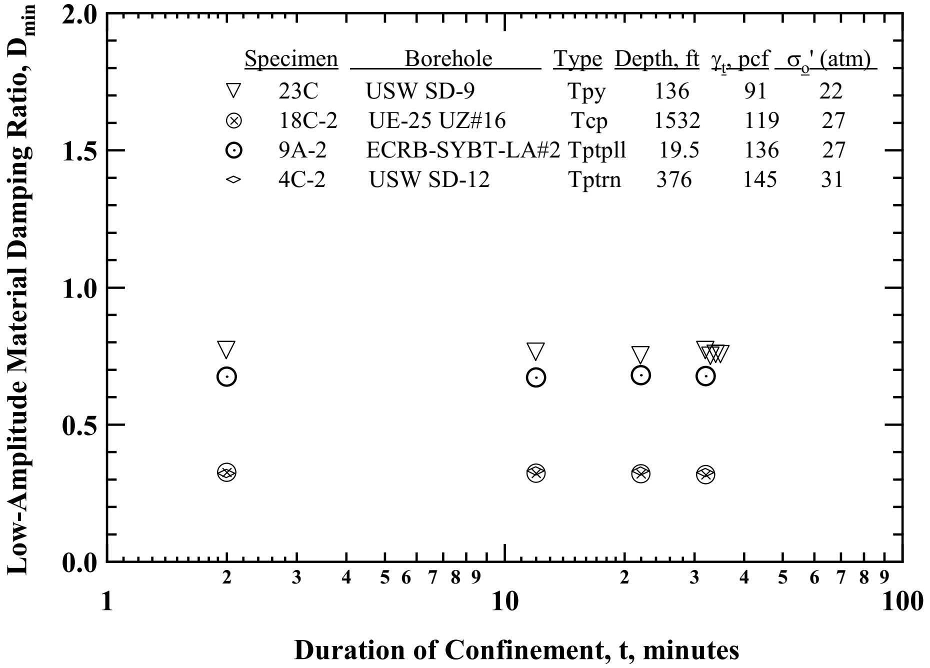
NOTE: ‡ Specimen 3K-2 was cored from Specimen 3D and had fewer surface lithophysae.

Figure 6.5-14. Variation in Low-Amplitude Shear Modulus with Isotropic Confining Pressure of Tuff Specimens with a High Density (Group 4)

The effects on G_{max} and D_{min} of the intact tuff specimens of two other parameters were also studied. These parameters are time of confinement at a constant isotropic stress state, *t*, and excitation frequency, *f*. The effect of *t* on G_{max} and D_{min} was negligible in these tests (less than a 1% change over the testing time that ranged from about 30 to 60 minutes at each σ_o). Examples of the negligible effect of t on G_{max} and D_{min} are shown in Figure 6.5-15 for specimens from Group 1 through 4. The effect of *f* was investigated by performing small-strain TS tests using 10 cycles of loading at four different frequencies ranging from 0.1 to 5 Hz as denoted by TS2 in Figure 6.5-4. Exciting slow-cyclic motion in pure torsion was more difficult than exciting resonance in torsion (RC testing) due to the impact of "flaws" (cracks, lithophysae, etc.) in the specimens. The flaws create non-uniformities within a specimen that result, to varying degrees, in bending and torsional motions occurring when torque is applied to the top of the specimen. When this complex motion occurs, it occurs together in slow-cyclic loading (TS testing). This motion distorts the values of G_{max} and $D_{S\ min}$ in TS testing, with a larger impact on $D_{S\ min}$. However, the two motions (bending and torsion) generally have different resonant frequencies that allow them to be separated and measurements in torsional resonance (RC testing) to be performed with little distortion. Therefore, one set of G_{max} measurements (Specimen 10A-2) in TS testing was discarded and about one-half of the $D_{S\ min}$ data in TS testing were also discarded due to complication caused by bending. (No values in the RC data set were discarded.) With the remaining data, example results of the effect of *f* on G_{max} are presented in Figures 6.5-15 and 6.5-16. As seen, the average change in G_{max} as excitation frequency changes from 1 to 400 Hz is less than 8%, with G_{max} decreasing slightly at the highest frequencies. The scatter in the $D_{S\ min}$ data is much more than in the G_{max} data, as seen in Figures 6.5-17 and 6.5-18. In these figures, values of normalized material damping ratio vary from about 1.65 to 0.5 times $D_{S\ min}$ at 1 Hz when the excitation frequency increases to about 400 Hz. The lack of consistent trends combined with the complexity of making TS measurements in specimens with varying flaws makes determining a correlation in G_{max} and $D_{S\ min}$ with frequency unclear so that a frequency independent approximation is suggested.



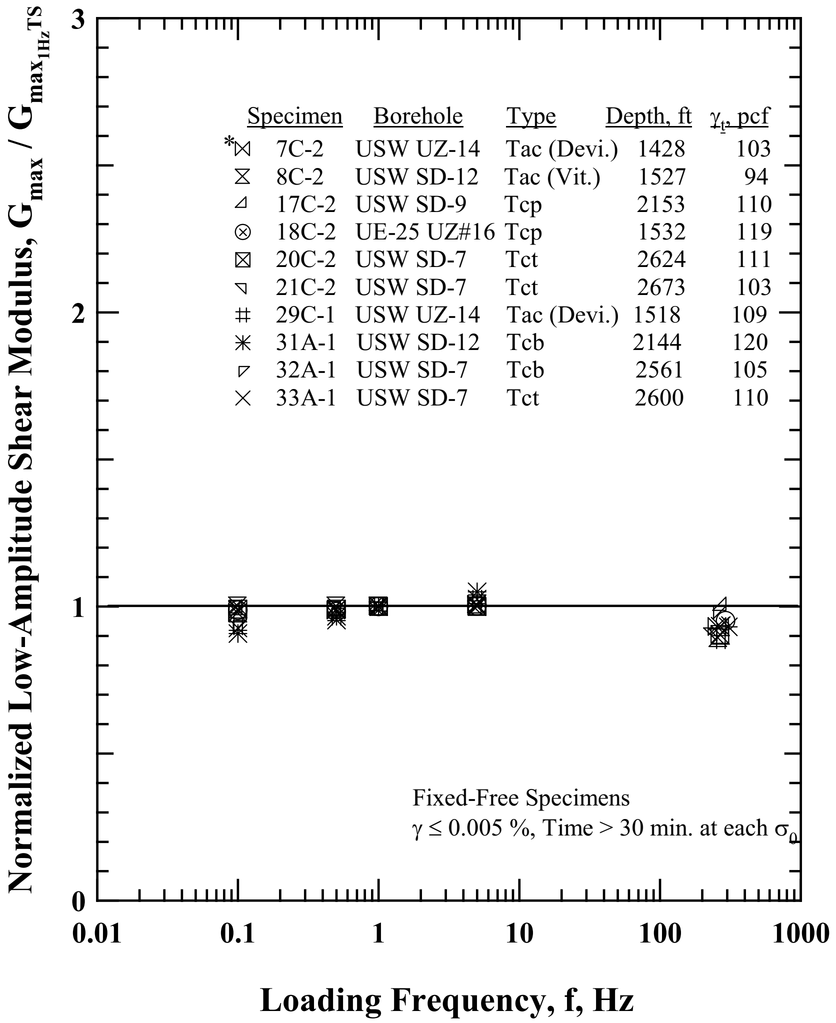
(a) Small-Strain Shear Modulus (G_{max}) vs. Duration of Confinement (t)



(b) Small-Strain Material Damping Ratio (D_{min}) vs. Duration of Confinement (t)

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

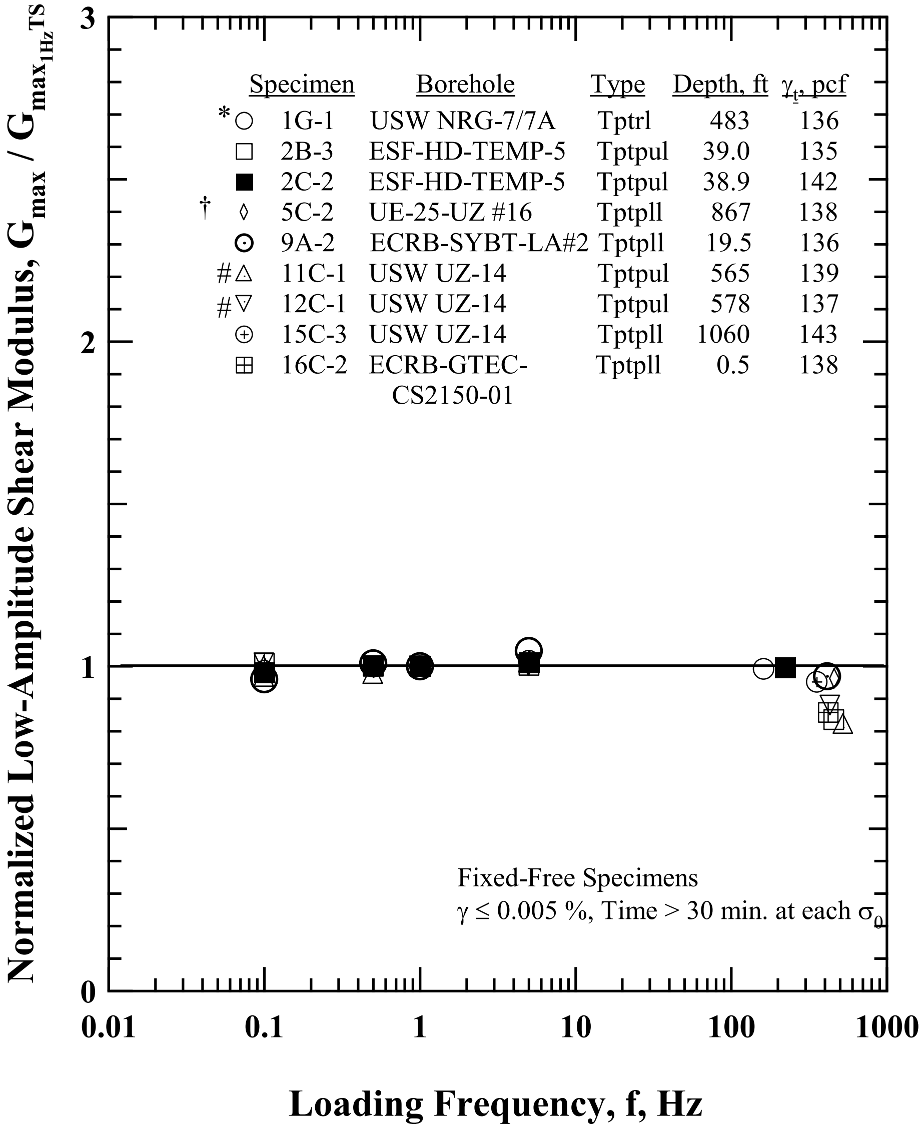
Figure 6.5-15. Variation of (a) Small-Strain Shear Modulus and (b) Small-Strain Material Damping Ratio with Duration of Isotropic Confining Pressure of Representative Tuff Specimens from Groups 1 through 4 as Determined from Resonant Column Tests



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTE: *Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

Figure 6.5-16. Variation in Normalized Low-Amplitude Shear Modulus with Loading Frequency of Tuff Specimens with a Low Density (Group 2) as Determined from Combined Resonant Column and Torsional Shear Tests



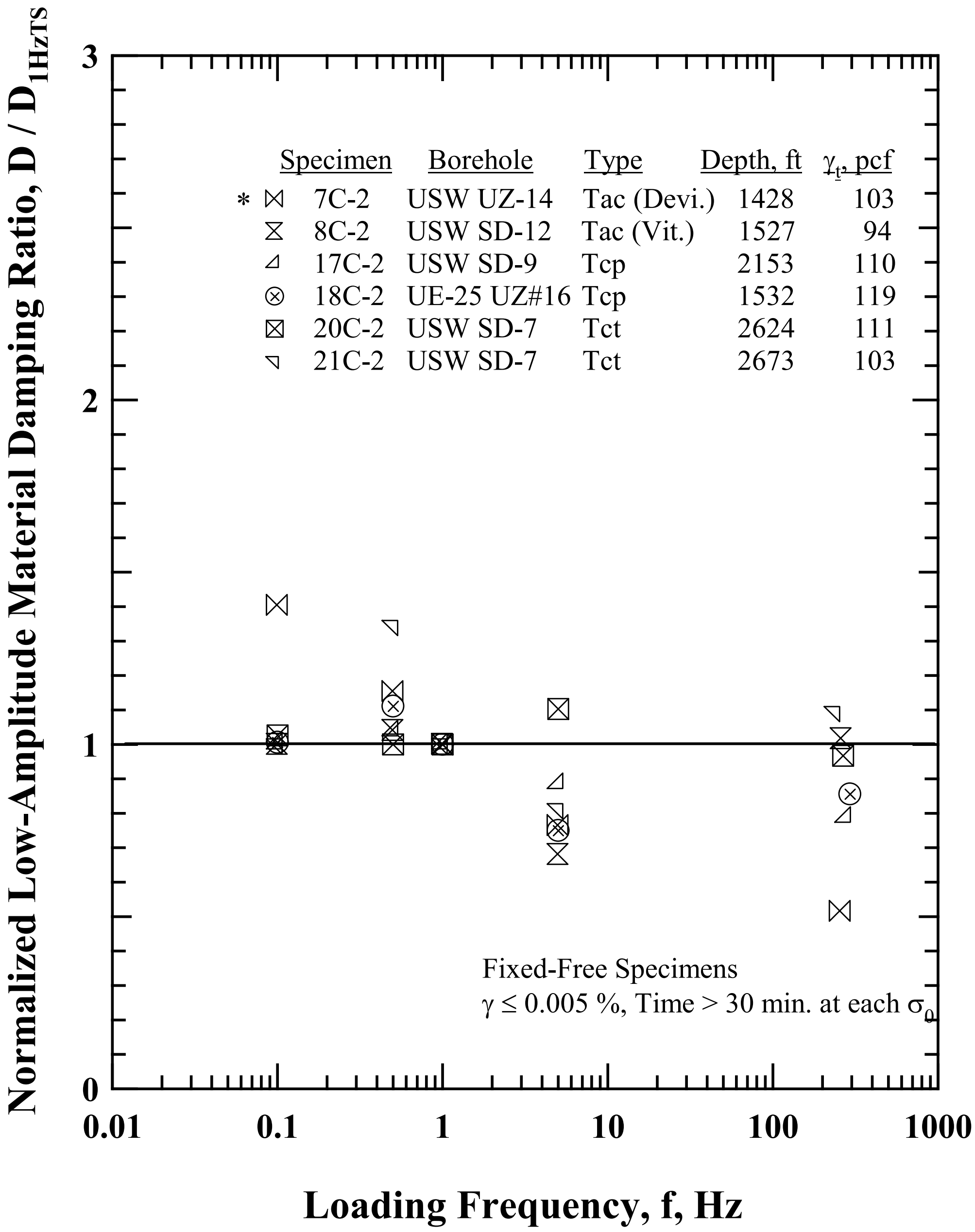
Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTES: † Specimen 2C-2 was cored from Specimen 2B-3 and had fewer surface lithophysae.

\# Tests were performed only at unconfined state due to many large voids on specimen surface.

* Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

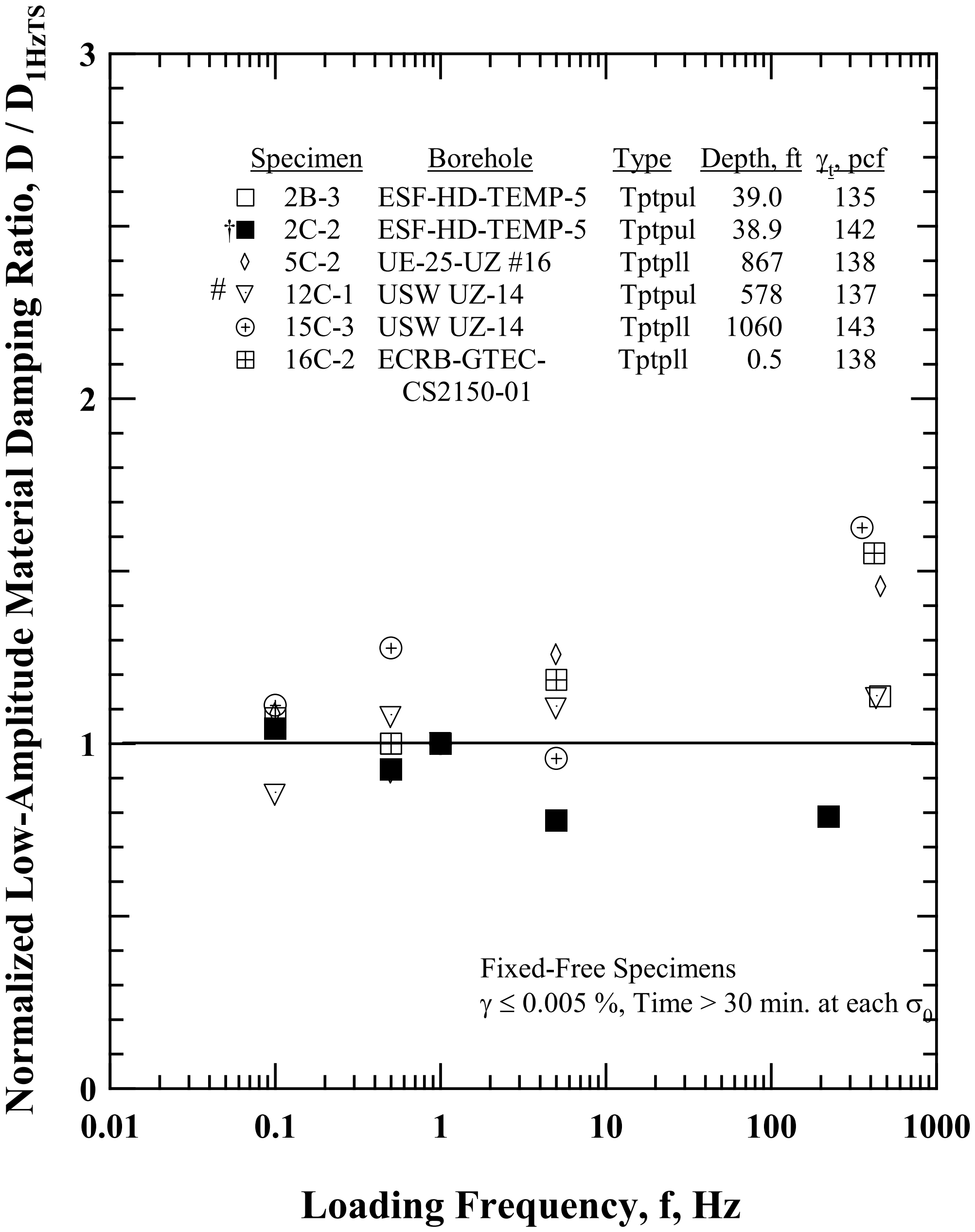
Figure 6.5-17. Variation in Normalized Low-Amplitude Shear Modulus with Loading Frequency of Lithophysal Tuff Specimens with a Medium Density (Group 3) as Determined from Combined Resonant Column and Torsional Shear Tests



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTE: *Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

Figure 6.5-18. Variation in Normalized Low-Amplitude Material Damping Ratio with Loading Frequency of Tuff Specimens with a Low Density (Group 2) as Determined from Combined Resonant Column and Torsional Shear Tests



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTES: † Specimen 2C-2 was cored from Specimen 2B-3 and had fewer surface lithophysae.

Tests were performed only at unconfined state due to many large voids on specimen surface.

Figure 6.5-19. Variation in Normalized Low-Amplitude Material Damping Ratio with Loading Frequency of Lithophysal Tuff Specimens with a Medium Density (Group 3) as Determined from Combined Resonant Column and Torsional Shear Tests

Dynamic Properties in the Large-Strain Range ($\gamma > 0.001\%$)

The influence of shearing strain, γ, on shear modulus (G), normalized shear modulus (G/G_{max}) and material damping ratio (D) as measured by resonant column testing is shown in Figures 6.5-20 through 6.5-22, respectively, for the 33 tuff specimens. Only values measured at the highest test pressure of each specimen are shown in the figures. As seen, both G and D exhibit linear ranges where they are constant and equal to G_{max} and $D_{S\,min}$, respectively. This linear range is followed by a nonlinear range where G decreases and D_S increases as γ increases. To illustrate this point further, the data for two specimens that are presented in Figures 6.5-21 and 6.5-22 are re-plotted by themselves in Figure 6.5-23. In Figure 6.5-23a, the $G/G_{max} - \log \gamma$ and $D - \log \gamma$ relationships for Specimen 25C are shown. For this specimen, the linear range extends to a strain of about 0.013%, after which G/G_{max} decreases and D increases. It is interesting to note that D is affected more in the nonlinear range than G. This behavior also occurs in soils (Darendeli 2001 [DIRS 183318]). In Figure 6.5-23b, the same relationships are shown for Specimen 5C-2. In this case, the linear range extends to a strain of about 0.0032% which is less than the range exhibited by Specimen 25C. However, for each specimen, the linear range for $G/G_{max} - \log \gamma$ and $D - \log \gamma$ is essentially the same.

Figures 6.5-24 through 6.5-27 show the relationships between G/G_{max} and $\log \gamma$ of the four density groups, respectively. Test results obtained at two different pressures for each specimen are plotted together, except for the four specimens that were tested at only one pressure (Specimens 7C-2 and 1G-1) or at the unconfined state only (Specimens 11C-1 and 12C-1). As with G_{max}, σ_o shows a small effect on the $G/G_{max} - \log \gamma$ relationships of most specimens. The material that shows the most effect, although a small effect, is the bedded tuff (Specimens 24C and 28E), which displays a slight increase in G/G_{max} values in the nonlinear range as σ_o increases. These trends maybe the result of the variability in the material.

The modified hyperbolic representation for the $G/G_{max} - \log \gamma$ relationship as proposed by Darendeli (2001 [DIRS 183318]) is added to each figure simply as a reference line so that comparisons of data between figures can be easily assessed. This representation is shown by the solid line in each figure. Darendeli's representation can be expressed as:

$$\frac{G}{G_{max}} = \frac{1}{1 + \left(\frac{\gamma}{\gamma_r}\right)^{a}} \qquad \text{(Eq. 6.5-1)}$$

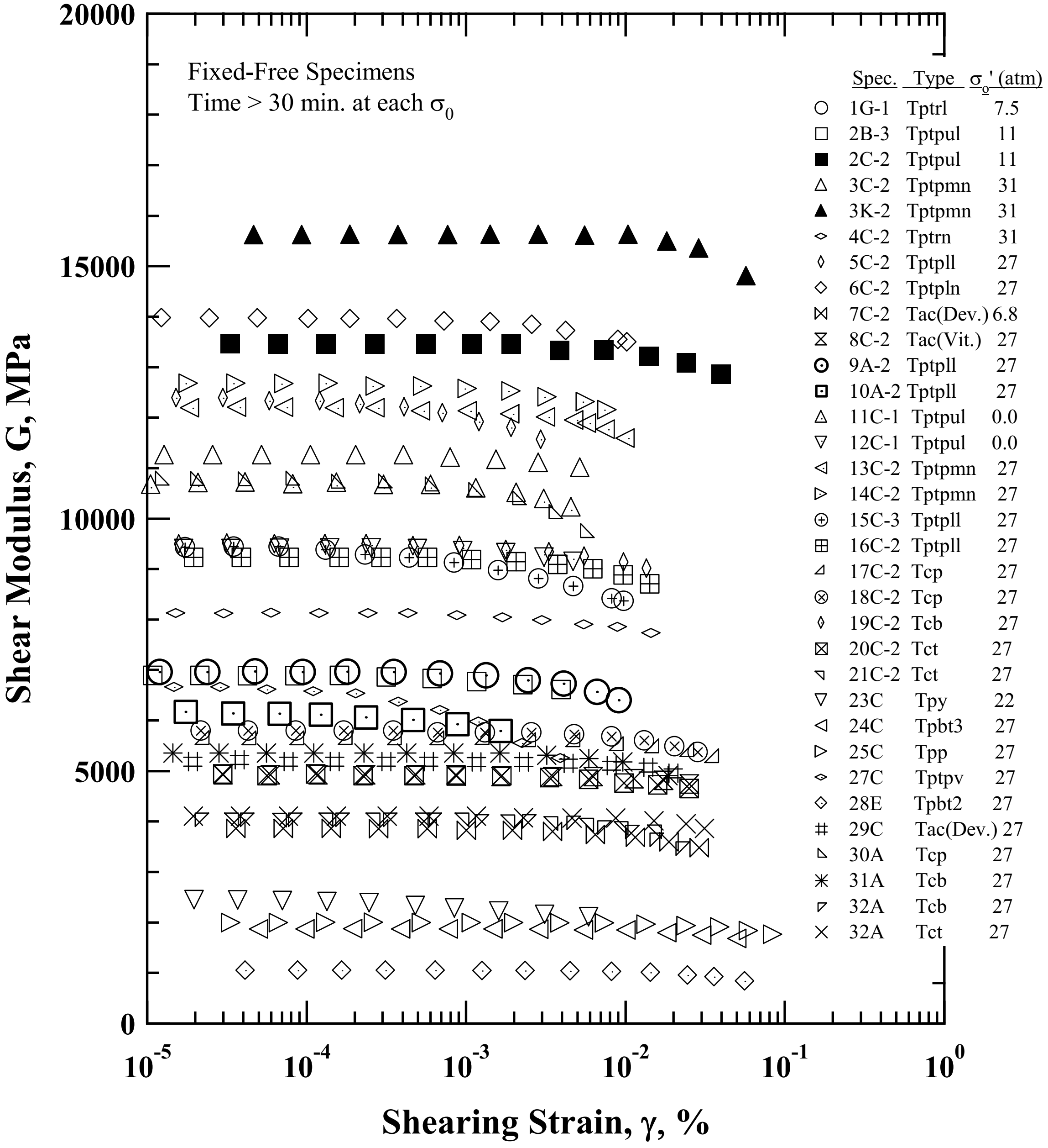
in which

γ_r = reference shear strain
a = curvature coefficient (dimensionless exponent).

The reference strain, γ_r, is defined as the value of γ equal to the shear strain at which G/G_{max} equals 0.5. The value of γ_r of 0.26 and an "a" value of 0.92 are used for the reference line shown in Figures 6.5-24 through 6.5-27. These values were selected so that the reference line would fall within the data and they have no further meaning.

In general, the $G/G_{max} - \log \gamma$ relationships of the 33 specimens follow the general trend in the reference line. There is some variability, which is likely due to natural material property scatter.

Figures 6.5-28 through 6.5-31 show the relationships between D and $\log \gamma$ of the four density groupings, respectively. The $D - \log \gamma$ relationships obtained at two different pressures for each specimen are plotted together, except for four specimens that were tested at only one pressure (Specimens 7C-2 and 1G-1) or at the unconfined state only (Specimens 11C-1 and 12C-1) . As with the $G/G_{max} - \log \gamma$ relationships, σ_o has only a minor effect on the $D - \log \gamma$ relationships of most specimens. The two bedded tuffs (Specimens 24C and 28E) exhibit slightly larger linear ranges when σ_o increases as shown in Figure 6.5-28.



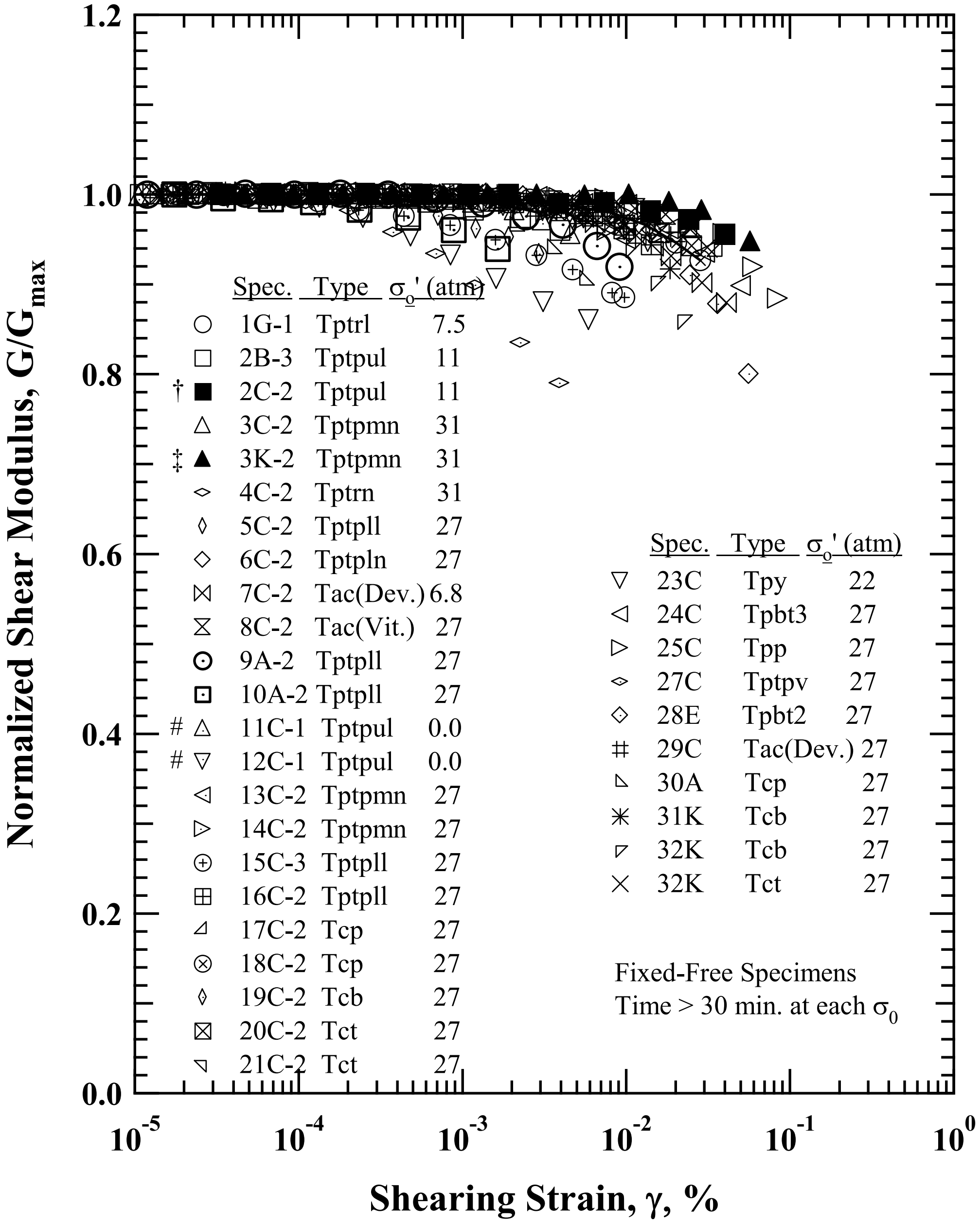
Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTES: † Specimen 2C-2 was cored from Specimen 2B-3 and had fewer surface lithophysae.

‡ Specimen 3K-2 was cored from Specimen 3D and had fewer surface lithophysae.

Tests were performed only at unconfined state due to many large voids on specimen surface.

Figure 6.5-20. Variation in Shear Modulus with Shearing Strain of the Thirty-Three Tuff Specimens from Stratigraphic Units below Tiva Canyon Tuff at Their Highest Test Pressures as Determined from Resonant Column Tests



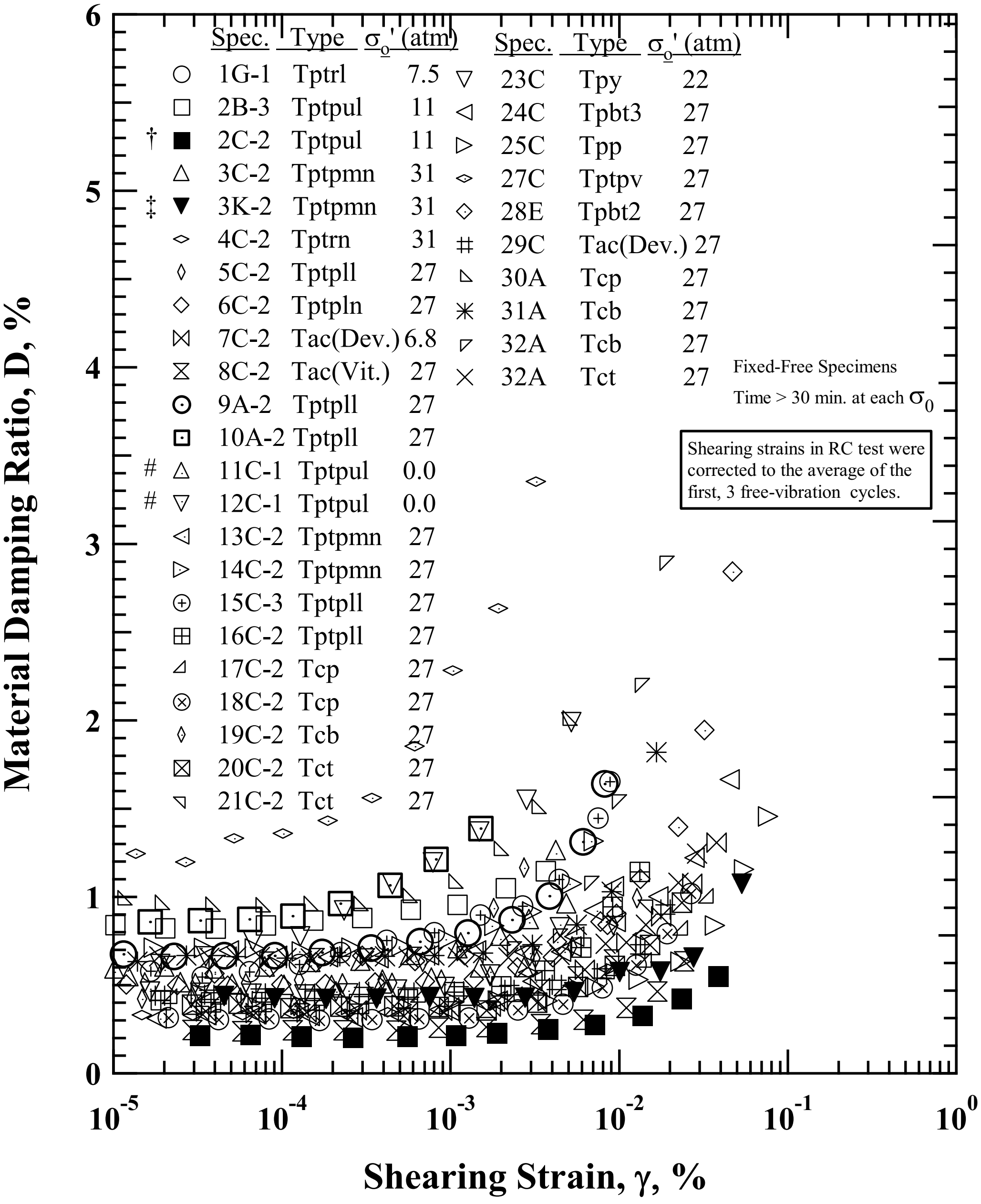
Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTES: † Specimen 2C-2 was cored from Specimen 2B-3 and had fewer surface lithophysae.

‡ Specimen 3K-2 was cored from Specimen 3D and had fewer surface lithophysae.

Tests were performed only at unconfined state due to many large voids on specimen surface.

Figure 6.5-21. Variation in Normalized Shear Modulus with Shearing Strain of the Thirty-Three Tuff Specimens from Stratigraphic Units below Tiva Canyon Tuff at Their Highest Test Pressures as Determined from Resonant Column Tests



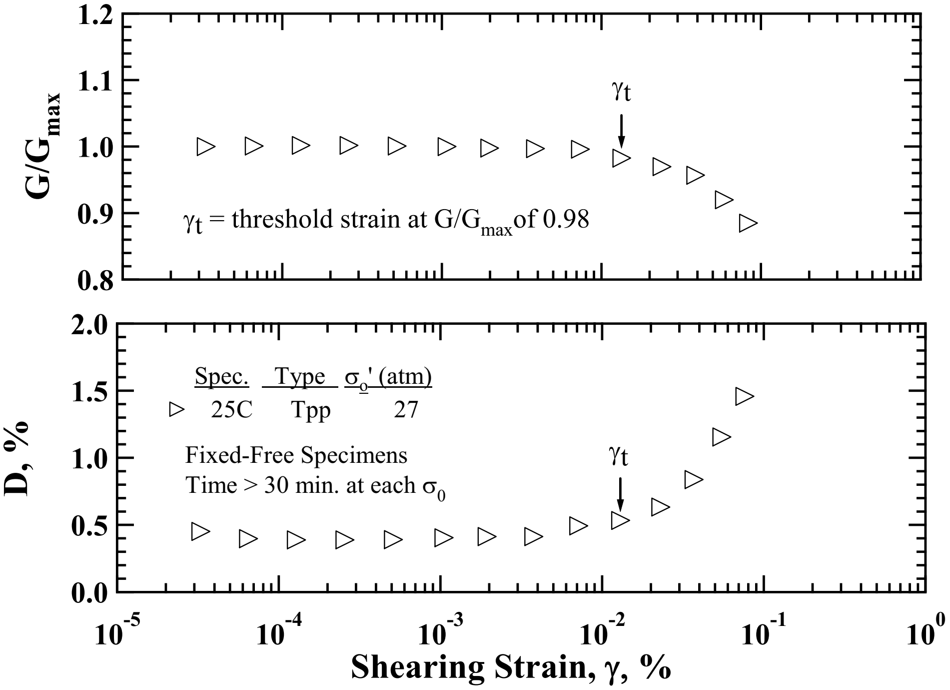
Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTES: † Specimen 2C-2 was cored from Specimen 2B-3 and had fewer surface lithophysae.

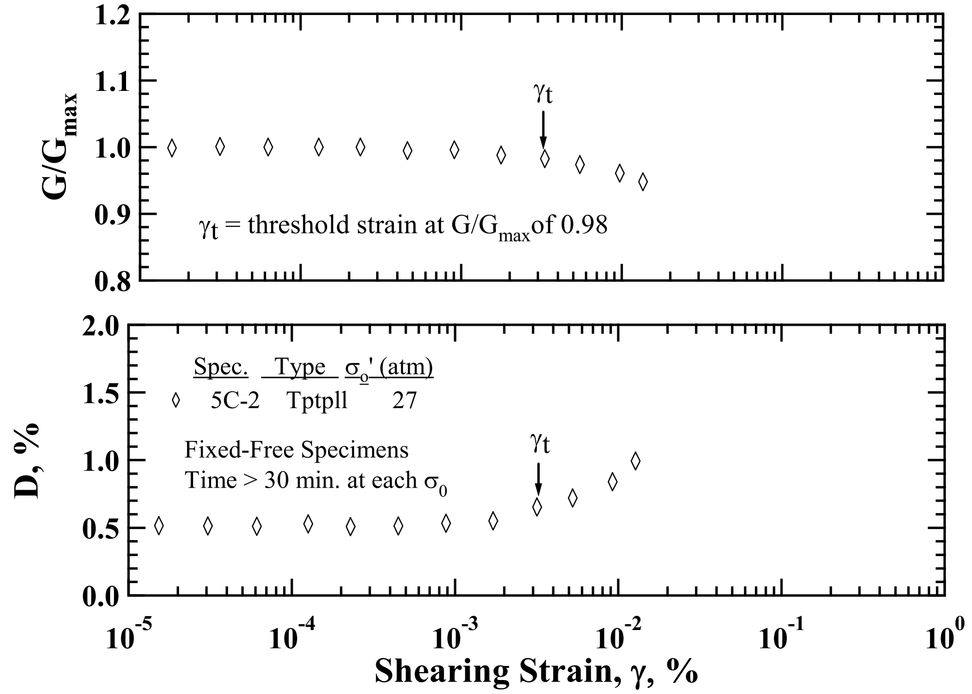
‡ Specimen 3K-2 was cored from Specimen 3D and had fewer surface lithophysae.

Tests were performed only at unconfined state due to many large voids on specimen surface.

Figure 6.5-22. Variation in Material Damping Ratio with Shearing Strain of the Thirty-Three Tuff Specimens from Stratigraphic Units below Tiva Canyon Tuff at Their Highest Test Pressures as Determined from Resonant Column Tests



(a) G/G$_{max}$ – log γ and D– log γ for Specimen 25C

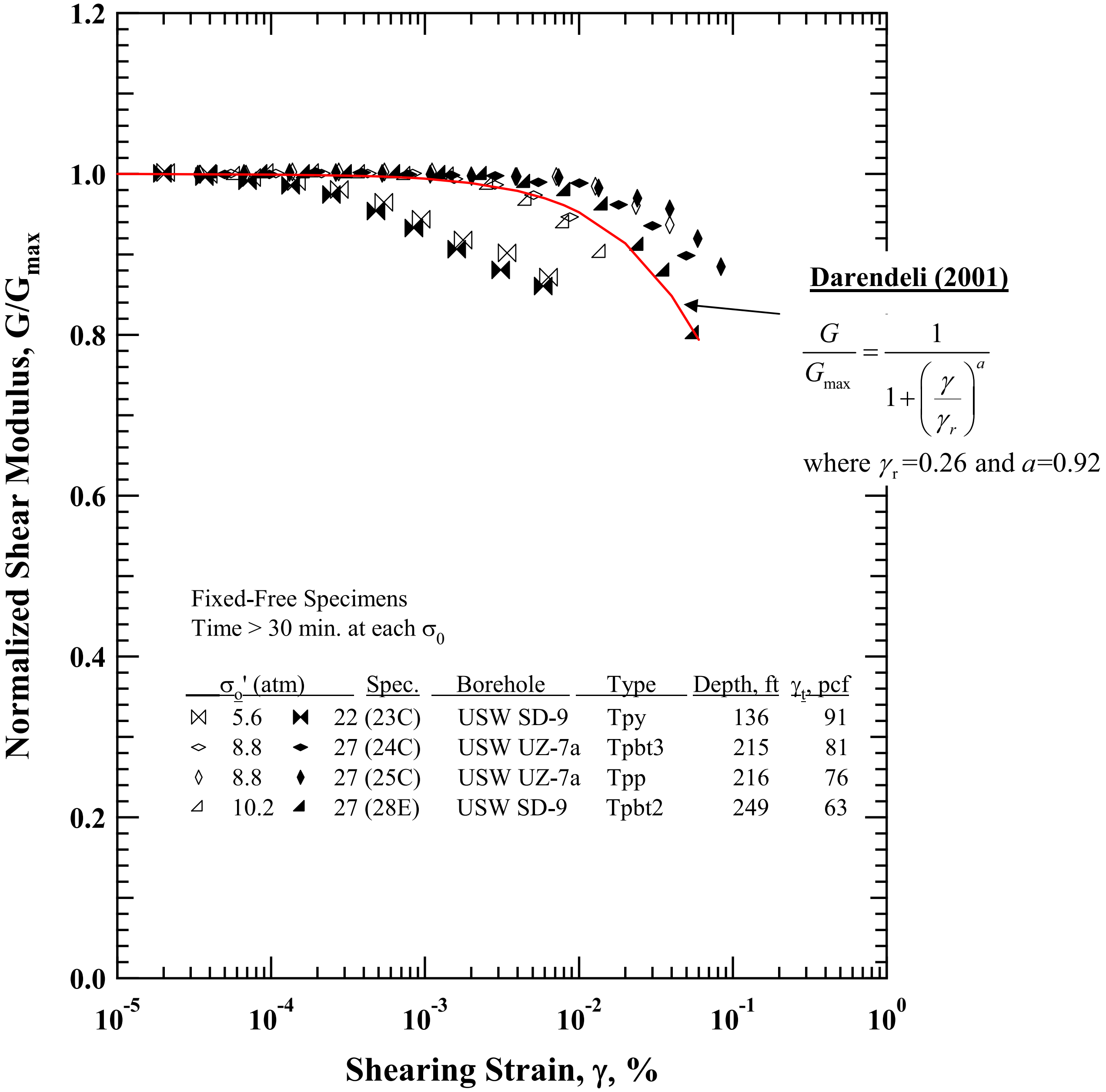


(b) G/G$_{max}$ – log γ and D– log γ for Specimen 5C-2

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTE: γ_t = point at which the shear modulus and material damping ratio with shear strain goes non-linear.

Figure 6.5-23. Individual Plots of the Variation of Normalized Shear Modulus and Material Damping Ratio with Shearing Strain of Specimens (a) 25C and (b) 5C-2 at Their Highest Test Pressures as Determined from Resonant Column Tests

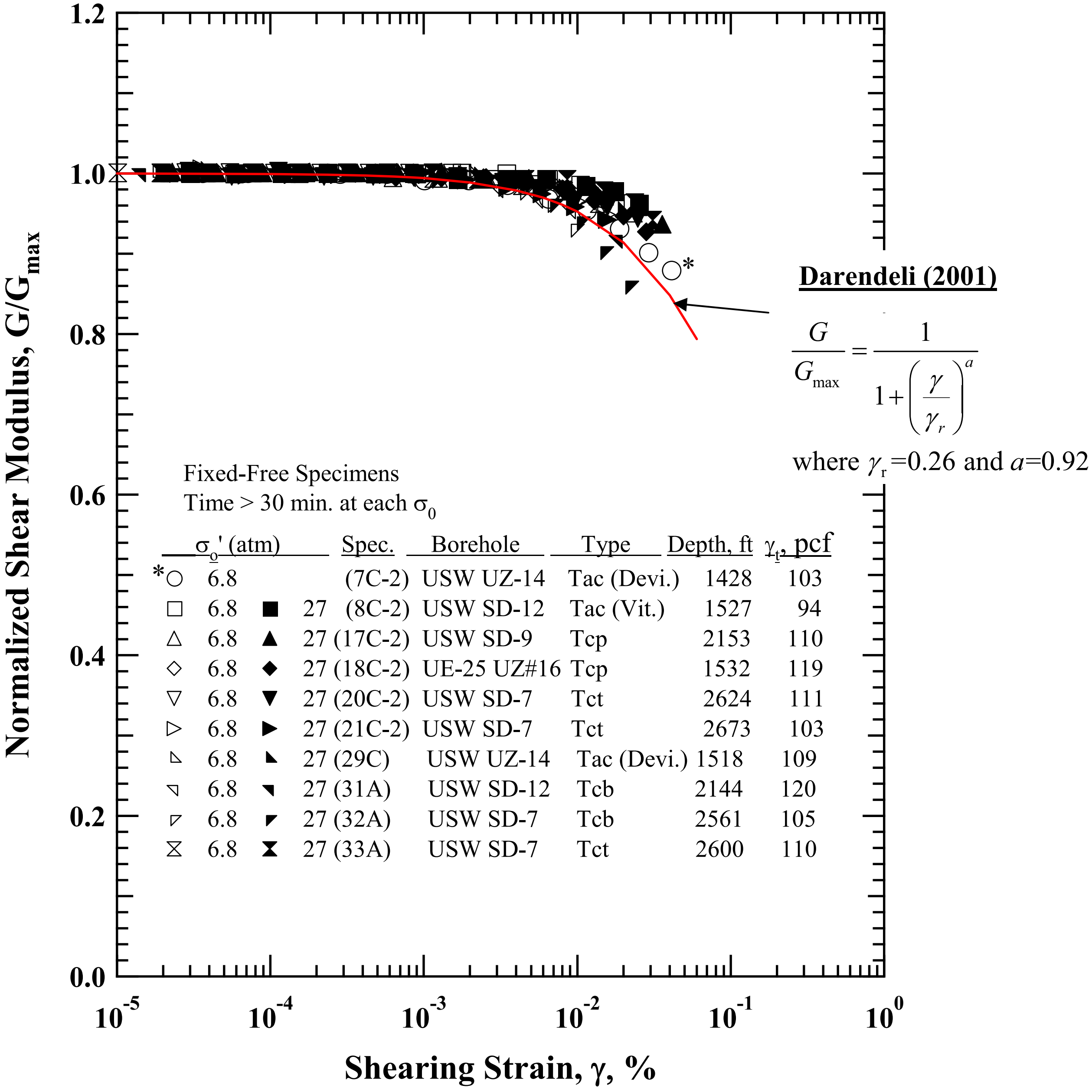


$$\frac{G}{G_{\max}} = \frac{1}{1+\left(\frac{\gamma}{\gamma_r}\right)^a}$$

where γ_r=0.26 and a=0.92

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

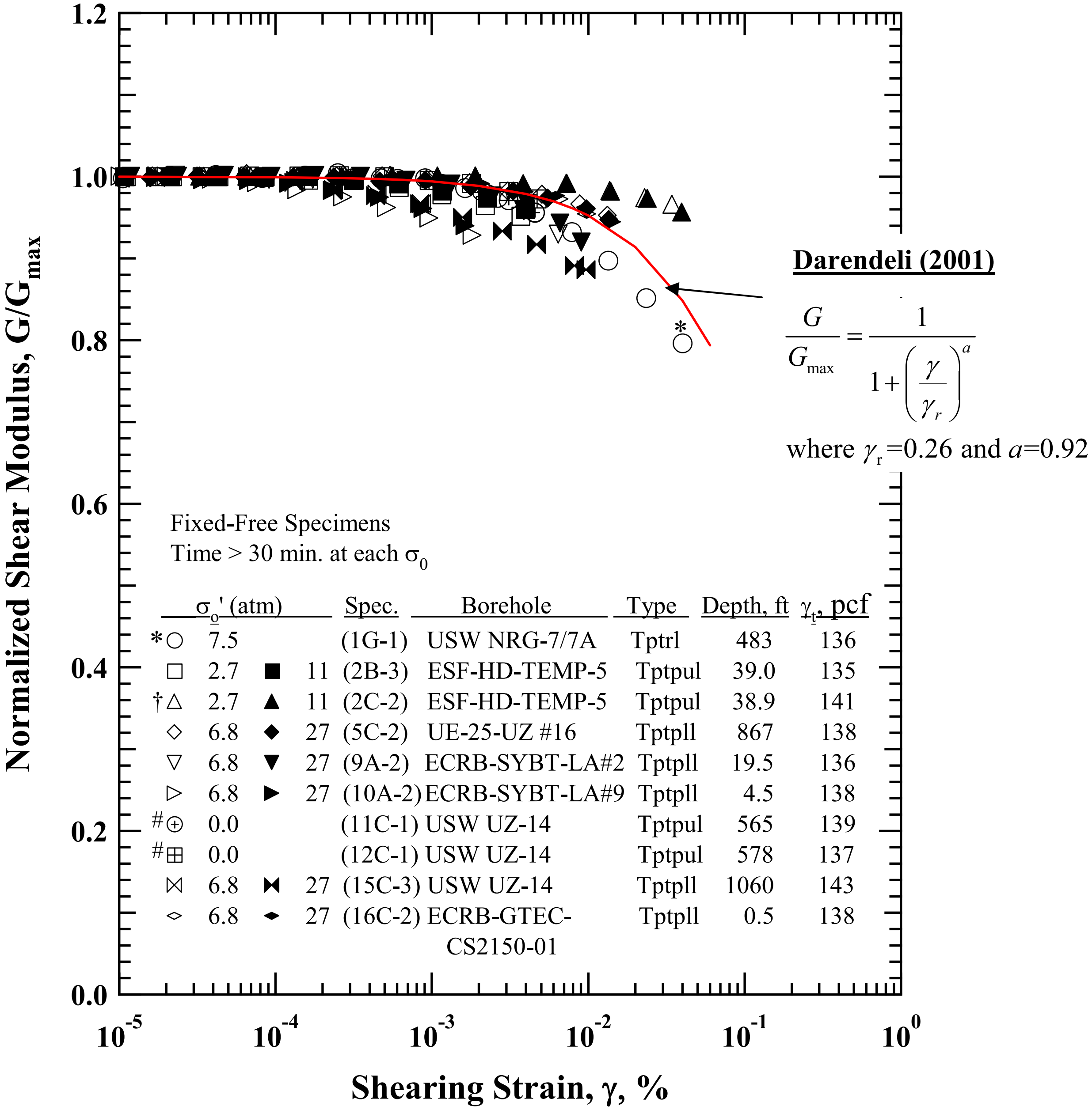
Figure 6.5-24. Variation in Normalized Shear Modulus with Shearing Strain and Confining Pressure of Tuff Specimens with a Very Low Density (Group 1)



Source: DTN:MO0707FIXEFREE.005 [DIRS 183329].

NOTE: *Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

Figure 6.5-25. Variation in Normalized Shear Modulus with Shearing Strain and Confining Pressure of Tuff Specimens with a Low Density (Group 2)



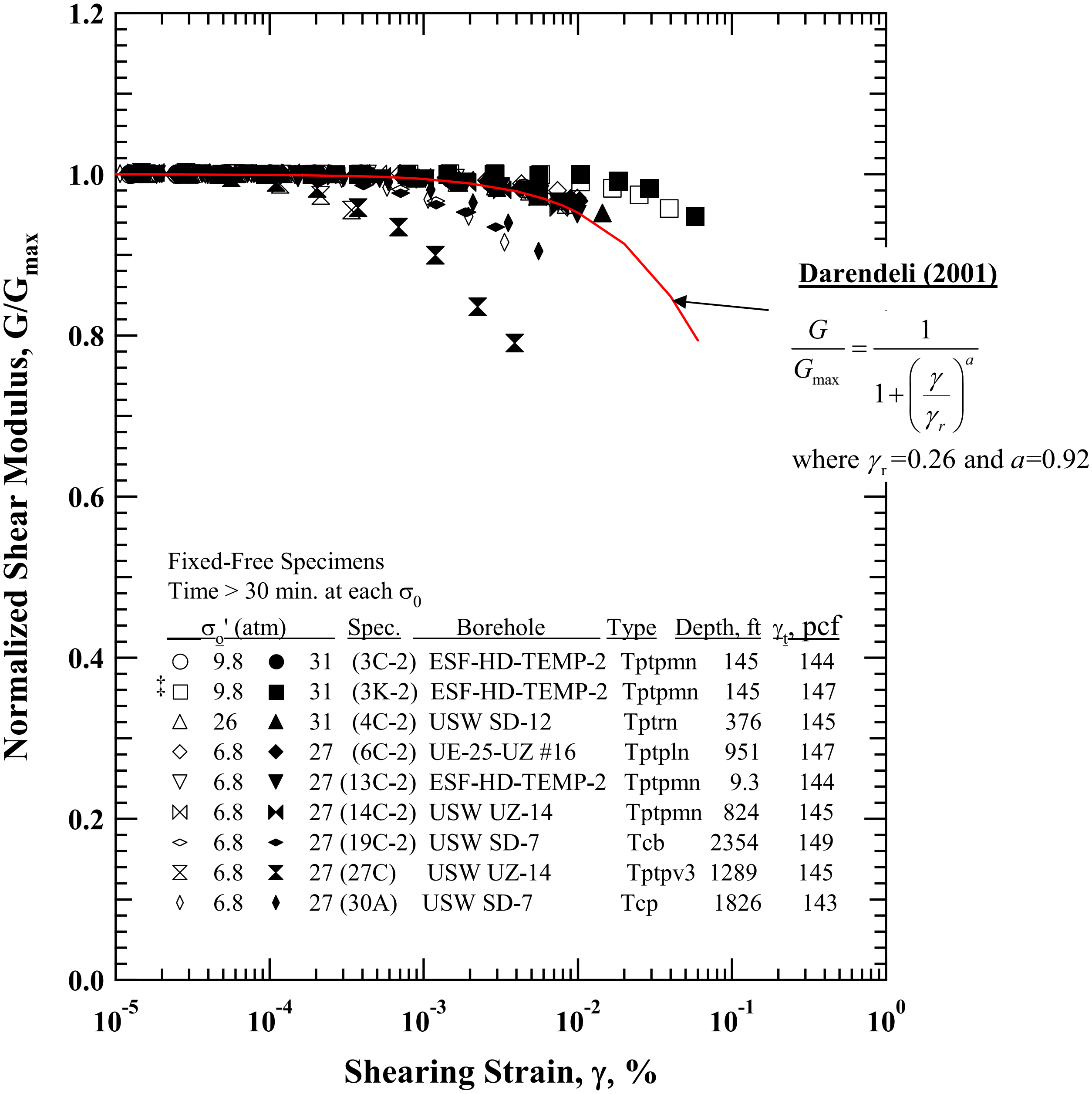
Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTES: † Specimen 2C-2 was cored from Specimen 2B-3 and had fewer surface lithophysae.

Tests were performed only at unconfined state due to many large voids on specimen surface.

* Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

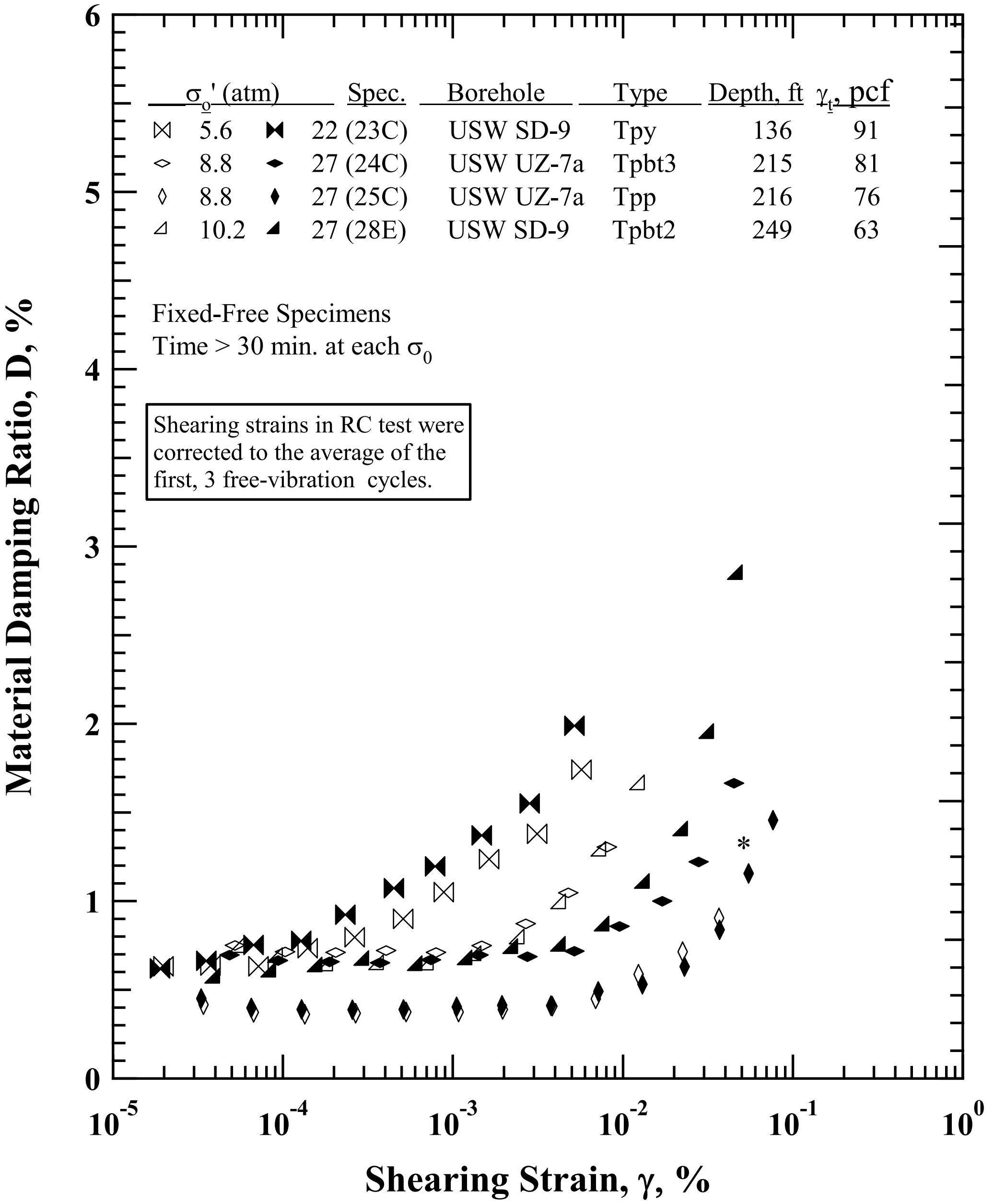
Figure 6.5-26. Variation in Normalized Shear Modulus with Shearing Strain and Confining Pressure of Lithophysal Tuff Specimens with a Medium Density (Group 3)



Source: DTN:MO0707FIXEFREE.005 [DIRS 183329].

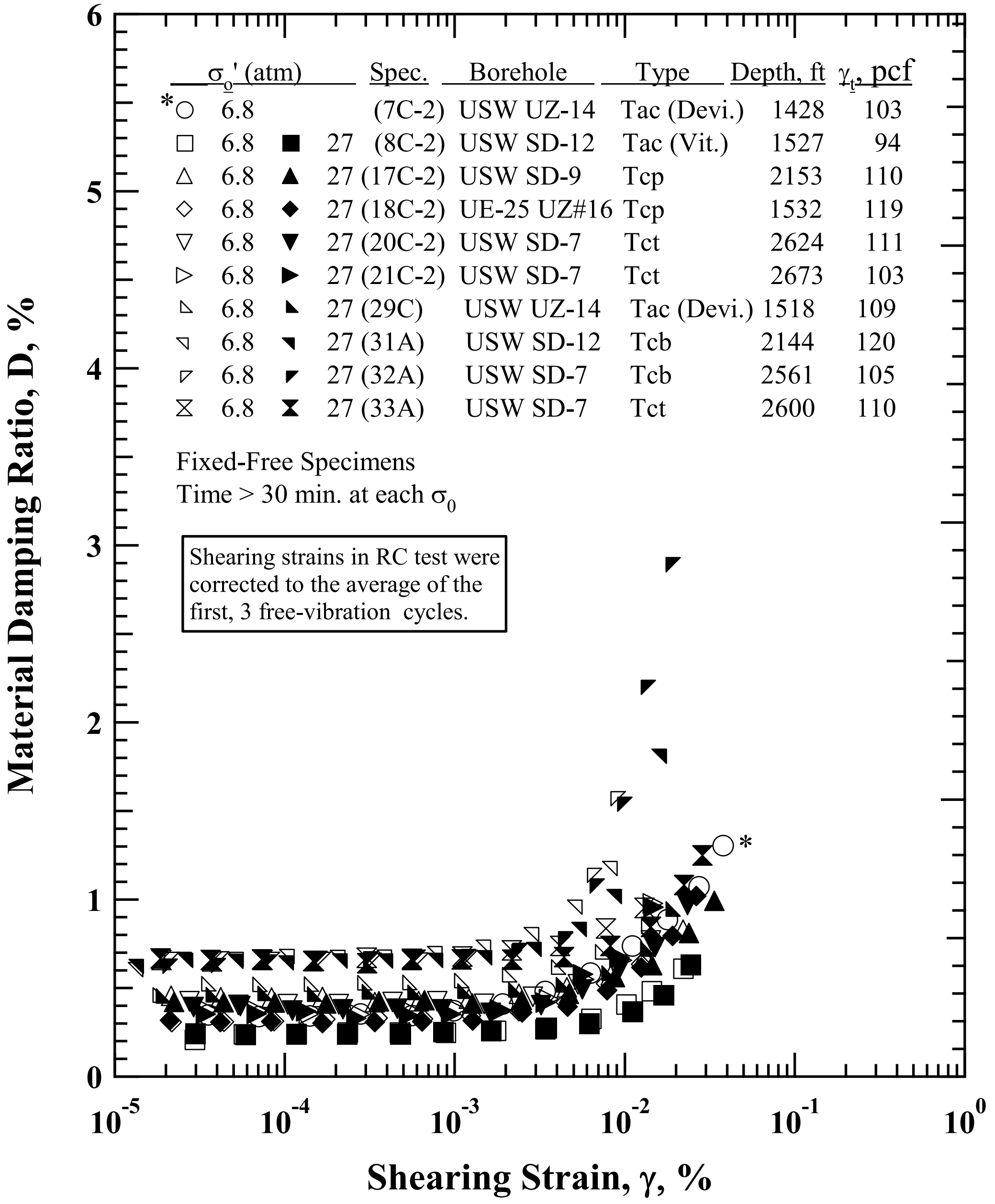
NOTE: ‡ Specimen 3K-2 was cored from Specimen 3D and had fewer surface lithophysae.

Figure 6.5-27. Variation in Normalized Shear Modulus with Shearing Strain and Confining Pressure of Tuff Specimens with a High Density (Group 4)



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

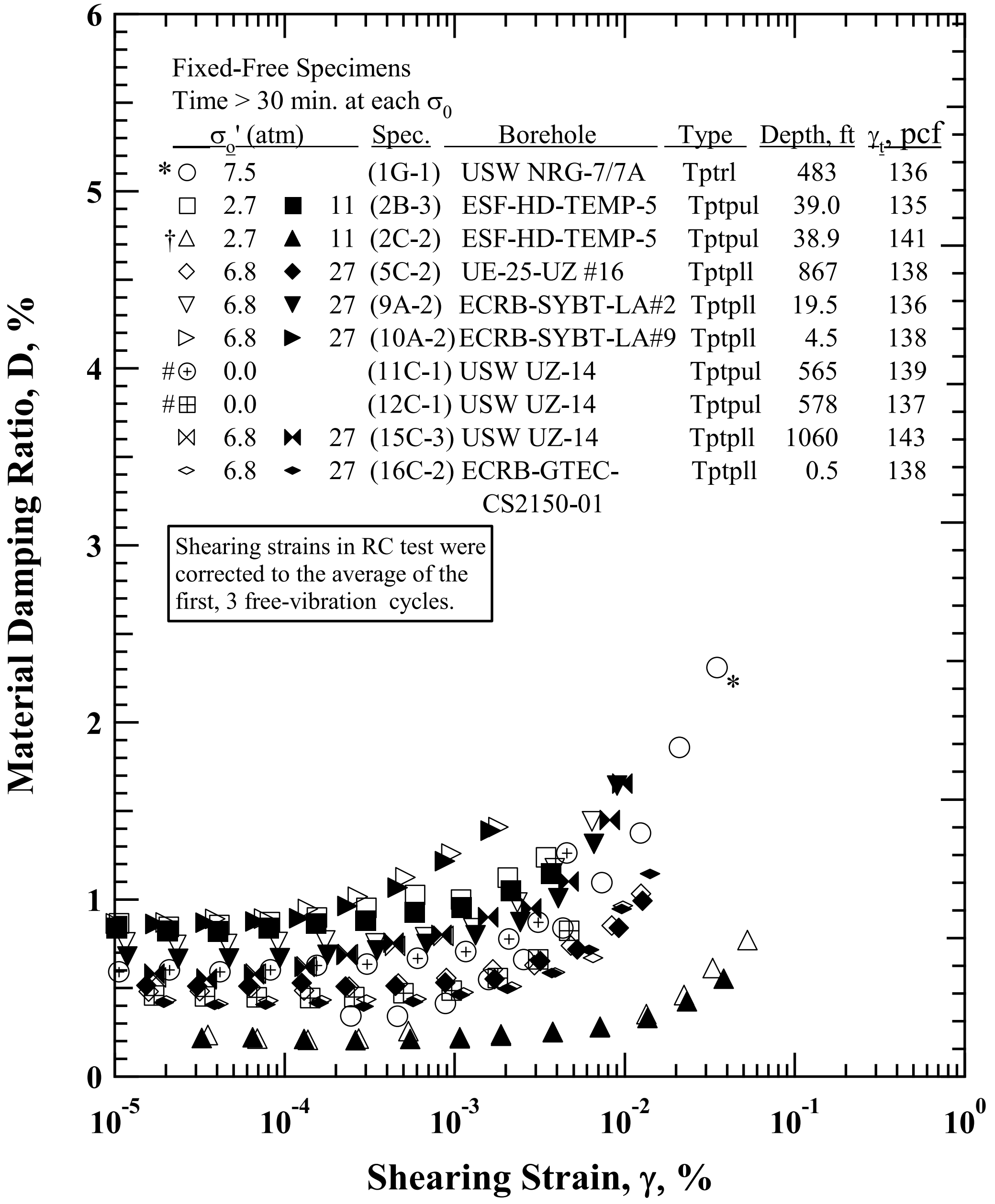
Figure 6.5-28. Variation in Material Damping Ratio with Shearing Strain and Confining Pressure of Tuff Specimens with a Very Low Density (Group 1)



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTE: *Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

Figure 6.5-29. Variation in Material Damping Ratio with Shearing Strain and Confining Pressure of Tuff Specimens with a Low Density (Group 2)



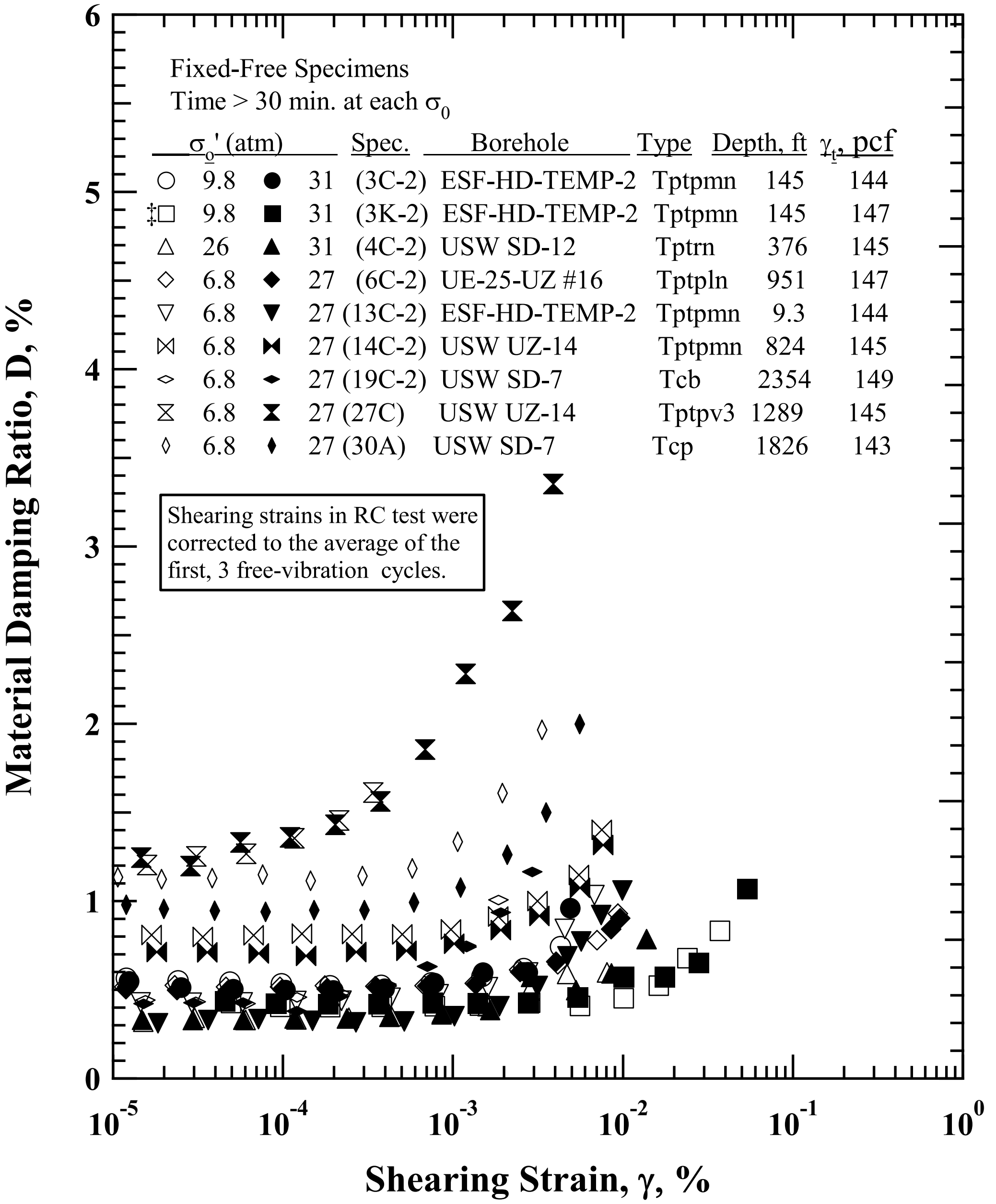
Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTES: † Specimen 2C-2 was cored from Specimen 2B-3 and had fewer surface lithophysae.

Tests were performed only at unconfined state due to many large voids on specimen surface.

* Test was stopped due to failure at the interface between specimen and top cap and/or base pedestal.

Figure 6.5-30. Variation in Material Damping Ratio with Shearing Strain and Confining Pressure of Lithophysal Tuff Specimens with a Medium Density (Group 3)



Source: DTN: MO0707FIXEFREE.005 [DIRS 183329].

NOTE: ‡ Specimen 3K-2 was cored from Specimen 3D and had fewer surface lithophysae.

Figure 6.5-31. Variation in Material Damping Ratio with Shearing Strain and Confining Pressure of Tuff Specimens with a High Density (Group 4)

6.5.3. Free-Free Laboratory Testing of Tuff Samples

Free-Free testing is a laboratory testing method that was incorporated into the geotechnical investigations starting in 2004. This Free-Free method involves an unconfined resonant column (URC) test set-up and is used to evaluate the stiffness and material damping ratios of soil and rock specimens at small strains. Measurements in both shear and compression can be performed on the same specimen, to provide comparisons with measurements from the laboratory combined Resonant Column and Torsional Shear (RCTS) tests and the field Spectral-Analysis-of-Surface-Waves (SASW), cross-hole, downhole, and compression and shear wave suspension logging tests. The simplicity of the URC set-up eliminates potential compliance problems such as fixity of the bottom platen in a Fixed-Free configuration and equipment-induced damping in the torsional electrical motor of the RCTS test (Stokoe et al. 1994 [DIRS 157264]). Because the URC laboratory testing method was not performed during 2000 and 2001, a detailed discussion on the test methodology is contained in Section 6.5.3.2.

6.5.3.1. Approach

The Free-Free laboratory testing of tuff samples covered in this report started in 2004 and completed in late 2006. Free-Free tests were performed on a total of 135 samples taken from the boreholes listed in Table 6.5-4. Table 6.5-5 lists the samples with their parent borehole and some additional description. Five of the samples were cored from boulders collected on the surface near Fran Ridge. These boulders were under-cored to provide approximately 4” diameter × 8” long specimens. For these samples, Table 6.5-5 identifies the specimens with the terminology “Surface Samples” in the “Parent Borehole” column. Because this testing was performed on samples that already existed in the SMF, the first step was to identify all available samples for a given geologic unit. In many cases there were only 4 to 8 samples of a particular unit available; therefore, all available specimens were tested regardless of the location of the parent borehole. For example, this is the case for the Tram geologic unit. Only five samples existed from a single borehole; therefore, all available specimens were tested. For those units that were well represented in the SMF inventory, the approach was to select samples from a variety of boreholes with an emphasis on selecting specimens from boreholes that were distributed in a north to south direction across the repository block. The intent was to assess the variability in a geologic unit across the footprint of the repository, relative to the manner in which the materials were deposited. In addition, if the unit had several sub-units, where possible, a representative number of samples were selected from each sub-unit; this especially applied to the Topopah Spring Tuff unit in which the repository is located. To increase the numbers of samples from the Topopah Spring Tuff, specimens were tested from several boreholes in the underground. Figure 6.5-34 displays the locations for the samples that were recovered from underground boreholes.

Finally, if specimens existed in the inventory from boreholes drilled in the NPF Area, they were included in the testing program (Figure 6.5-33). Laboratory testing of specimens from boreholes that had downhole seismic testing or surface SASW performed nearby provide additional insight into the velocity data collected by the various testing methods.

Table 6.5-4. Parent Boreholes and Number of Specimens

Parent Borehole	No. of Specimens	Location
ECRB-GTEC-CS1922-02	1	ECRB 19 + 22
ECRB-GTEC-CS1922-03	1	ECRB 19 + 22
ECRB-GTEC-CS2150-01	2	ECRB 21 + 50
ECRB-SYBT-LA#2	1	ECRB 15 + 50
ECRB-SYBT-LA#9	1	ECRB16 + 50
ESF-BRFA-HPF#2	1	ESF Alcove 2
ESF-HD-TEMP-13	1	ESF Alcove 5
ESF-HD-TEMP-2	3	ESF Alcove 5
ESF-HD-TEMP-5	2	ESF Alcove 5
ESF-HD-WH-49	1	ESF Alcove 5
ESF-NAD-F/M#3	1	ESF Alcove 6
UE-25 NRG#2	1	Surface
UE-25 NRG#2b	1	Surface
UE-25 NRG#4	1	Surface
UE-25 RF#14	3	Surface
UE-25 RF#15	5	Surface
UE-25 RF#16	1	Surface
UE-25 RF#17	2	Surface
UE-25 RF#22	2	Surface
UE-25 UZ#16	9	Surface
USW NRG-6	1	Surface
USW NRG-7/7A	3	Surface
USW SD-12	23	Surface
USW SD-7	26	Surface
USW SD-9	8	Surface
USW UZ-14	27	Surface
USW UZ-7a	2	Surface
Surface Samples	5	Cored from boulders

Table 6.5-5. Individual Specimens, Parent Boreholes and Descriptive Information

UT Spec. No.	SMF Spec. ID	Borehole	Strat. Unit	Depth (ft)		Spec. Length (in.)	Spec. Dia. (in.)	Weight (g)	Total Unit Weight, γ_t (pcf)	Porosity (n)
FR1	01025902	USW NRG-7/7A	Tptrl	482.5	483.1	7.15	3.22	2015.0	131.6	0.173
FR2	01025905	ESF-HD-TEMP-5	Tptpul	38.5	39.2	8.35	1.76	724.9	136.6	0.142
FR3	01025910	ESF-HD-TEMP-2	Tptpmn	144.7	145.4	8.76	2.40	1503.1	144.0	0.095
FR4	01025886	USW SD-12	Tptrn3	375.7	376.3	7.31	2.40	1216.2	139.5	0.123
FR5	01025914	UE-25-UZ#16	Tptpll	866.7	867.3	7.19	2.40	1123.9	131.5	0.173
FR6	01025915	UE-25-UZ#16	Tptpln	950.6	951.3	8.18	2.39	1398.8	145.0	0.089
FR7	01025881	USW UZ-14	Tac Dev.	1427.2	1428	9.12	2.41	1082.8	99.5	0.375
FR8	01025890	USW SD-12	Tac Vit.	1526.6	1527.4	9.18	2.39	984.9	90.8	0.429
FR9	01025864	USW UZ-14	Tptrn3	367.6	368.3	8.27	2.40	1244.7	126.7	0.204
FR10	01025863	USW UZ-14	Tptrn3	363.7	364.4	8.34	2.40	1275.3	128.6	0.192
FR11	01025897	USW SD-7	Tptrn4	402.1	402.9	9.97	3.26	2873.3	131.5	0.173
FR12	01025887	USW SD-12	Tptrn4	405.3	406.1	9.47	2.41	1547.1	136.1	0.145
FR13	01025895	USW NRG-6	Tptrn4	414.5	415.4	10.57	3.28	3228.0	137.5	0.136
FR14	01025862	USW UZ-14	Tptrn	341	341.7	8.44	2.41	1333.3	131.6	0.173
FR15	01025901	UE-25 NRG#4	Tptrl	666.1	666.8	8.55	3.25	2270.9	122.1	0.233
FR16	01025879	USW UZ-14	Tptpv3	1351.0	1351.7	8.51	2.41	1365.5	134.2	0.156
FR17	01025903	USW NRG-7/7A	Tptpv1	1476.0	1476.7	8.40	2.41	1192.8	118.7	0.254
FR18	01025877	USW UZ-14	Tptpv3	1288.7	1289.3	7.19	2.40	1209.5	141.5	0.111
FR19	01025889	USW SD-12	Tptpul	504.9	505.6	8.14	2.39	1043.9	108.6	0.318
FR20	01025888	USW SD-12	Tptpul	499.7	500.3	7.15	2.41	964.3	112.7	0.292
FR21	01025866	USW UZ-14	Tptpul	496.2	496.8	7.23	2.40	1009.6	117.7	0.261
FR22	01025865	USW UZ-14	Tptpul	495.2	495.9	8.16	2.40	1148.3	118.4	0.256
FR23	01025868	USW UZ-14	Tptpul	577	577.7	8.48	2.39	1332.7	133.9	0.158
FR24	01025904	ESF-HD-TEMP-13	Tptpul	38.3	39.2	10.38	1.77	901.8	135.1	0.151
FR25	01025867	USW UZ-14	Tptpul	564.1	564.9	9.12	2.38	1424.6	133.2	0.163
FR26	01025871	USW UZ-14	Tptpmn	823.0	823.8	9.99	2.41	1707.5	143.0	0.101
FR27	01025906	ESF-HD-TEMP-5	Tptpmn	12.2	13	9.39	1.76	839.6	140.6	0.116
FR28	01025907	ESF-HD-WH-49	Tptpmn	21.9	22.6	8.31	2.41	1392.2	139.8	0.121
FR29	01025908	ESF-HD-TEMP-2	Tptpmn	8.8	9.5	8.20	2.41	1391.0	141.8	0.109
FR30	01025869	USW UZ-14	Tptpmn	812.5	813.2	7.93	2.41	1351.0	142.4	0.105
FR31	01025909	ESF-HD-TEMP-2	Tptpmn	85.2	85.9	8.41	2.41	1437.3	142.6	0.104
FR32	01025938	ESF-NAD-F/M#3	Tptpmn	16.2	16.9	8.67	2.41	1481.5	142.8	0.102
FR33	01025912	ECRB-SYBT-LA#9	Tptpll	4.2	4.7	6.32	1.78	573.2	138.8	0.128
FR34	01025913	ECRB-SYBT-LA#2	Tptpll	19.2	19.7	6.17	1.78	536.0	133.4	0.161
FR35	01025923	ECRB-GTEC-CS1922-02	Tptpll	10.8	11.3	5.86	2.48	1003.2	135.1	0.151
FR36	01025872	USW UZ-14	Tptpll	1016.2	1016.9	8.33	2.39	1403.8	142.8	0.103
FR37	01025926	ECRB-GTEC-CS2150-01	Tptpll	6.3	7.1	10.06	3.77	3703.5	125.3	0.213
FR38	01025925	ECRB-GTEC-CS2150-01	Tptpll	0.2	0.8	7.10	2.50	1161.7	127.4	0.200
FR39	01025873	USW UZ-14	Tptpll	1059	1059.7	8.27	2.41	1385.7	139.5	0.123
FR40	01025876	USW UZ-14	Tptpln	1242.7	1243.4	7.95	2.41	1391.2	145.9	0.083

Table 6.5-5. Individual Specimens, Parent Boreholes and Descriptive Information (Continued)

UT Spec. No.	SMF Spec. ID	Borehole	Strat. Unit	Depth (ft)		Spec. Length (in.)	Spec. Dia. (in.)	Weight (g)	Total Unit Weight, γ_t (pcf)	Porosity (n)
FR41	01025874	USW UZ-14	Tptpln	1246	1246.7	7.82	2.40	1341.0	143.9	0.096
FR42	01025919	UE-25-UZ#16	Tptpln	1073.3	1073.9	7.24	2.40	1253.1	145.9	0.083
FR43	01025875	USW UZ-14	Tptpln	1248.9	1249.7	9.19	2.40	1583.8	145.4	0.086
FR44	01025918	UE-25-UZ#16	Tptpln	1045.1	1045.8	7.96	2.40	1371.0	144.8	0.090
FR45	01025917	UE-25-UZ#16	Tptpln	993.2	993.7	8.34	2.38	1398.5	143.5	0.098
FR46	01025916	UE-25-UZ#16	Tptpln	991.6	992.3	8.32	2.39	1405.9	144.0	0.095
FR47	01025977	UE-25- RF#15	Tpcpul	130.2	130.9	8.96	2.40	1378.4	130.0	0.183
FR48	01025983	UE-25- RF#17	Tpcpul	540.7	541.4	8.79	2.39	1354.5	131.1	0.176
FR49	01025978	UE-25- RF#15	Tpcpul	149.3	150.0	8.28	2.40	1301.0	132.5	0.167
FR50	01025929	USW SD-9	Tac Dev.	1569.9	1570.8	11.02	3.26	2432.9	100.7	0.367
FR51	01025882	USW UZ-14	Tac Dev.	1432.4	1433.2	9.17	2.38	1112.7	103.4	0.350
FR52	01025883	USW UZ-14	Tac Dev.	1443	1443.9	10.78	3.28	2335.8	97.7	0.386
FR53	01025884	USW UZ-14	Tac Dev.	1517.6	1518.5	10.86	3.28	2642.8	109.5	0.312
FR54	01025898	USW SD-7	Tac Vit.	1468.2	1468.9	8.22	3.22	1521.2	86.4	0.457
FR55	01025892	USW SD-12	Tac Vit.	1595	1595.7	8.73	2.31	843.7	87.5	0.450
FR56	01025935	USW SD-12	Tac Vit.	1497.8	1498.6	9.35	2.39	999.1	90.5	0.431
FR57	01025891	USW SD-12	Tac Vit.	1592.2	1592.9	8.65	2.36	879.3	88.4	0.444
FR58	01025900	USW SD-7	Tcp	1919.8	1920.5	8.49	2.39	1024.3	102.2	0.357
FR59	01025899	USW SD-7	Tcp	1707.7	1708.4	8.46	2.37	1091.7	111.5	0.299
FR60	01025893	USW SD-12	Tcp	1712.9	1713.5	6.99	2.37	851.2	105.4	0.337
FR61	01025932	USW SD-9	Tcp	2012.4	2013.1	8.98	2.40	1141.0	106.8	0.329
FR62	01025931	USW SD-9	Tcp	1903.9	1904.8	11.00	3.26	2687.7	111.1	0.302
FR63	01025885	USW UZ-14	Tcp	1879.7	1880.6	10.67	3.27	2663.3	113.3	0.288
FR64	01025894	USW SD-12	Tcp	2071.2	2071.9	8.43	2.40	1114.9	111.4	0.300
FR65	01025920	UE-25 UZ#16	Tcp	1531.6	1532.3	8.09	2.40	1141.8	118.3	0.257
FR66	01025933	USW SD-9	Tcp	2152.9	2153.6	8.63	2.40	1113.8	108.7	0.317
FR67	01025921	UE-25 UZ#16	Tcp	1656.8	1657.5	8.13	2.40	1176.9	122.2	0.232
FR68	01026007	USW UZ-14	Tcb	2127.5	2128.4	10.57	3.27	2373.7	101.8	0.360
FR69	01025988	USW SD-7	Tcb	2206.8	2207.5	8.52	2.38	1224.8	122.6	0.229
FR70	01025995	USW SD-7	Tcb	2458.3	2459.1	9.29	2.42	1524.9	136.3	0.143
FR71	01025993	USW SD-7	Tcb	2248.9	2249.7	9.48	2.40	1568.4	139.1	0.126
FR72	01025994	USW SD-7	Tcb	2352.8	2353.5	8.51	2.41	1498.8	147.6	0.073
FR73	01025990	USW SD-7	Tct	2646.9	2647.6	8.64	2.38	1070.2	105.7	0.336
FR74	01025991	USW SD-7	Tct	2654.0	2654.7	8.75	2.39	1026.5	99.9	0.372
FR75	01025992	USW SD-7	Tct	2672.2	2672.9	9.03	2.38	1079.3	102.3	0.357
FR76	01025989	USW SD-7	Tct	2623.7	2624.4	8.35	2.38	1071.0	109.7	0.311
FR77	01026043	UE-25 NRG#2b	Tmr	44.0	44.4	4.89	2.39	462.3	80.5	0.494
FR78	01026008	UE-25 NRG#2	Tmr	2.0	2.7	8.85	2.39	992.8	95.2	0.402
FR79	01025973	UE-25 RF#14	Tpki	131.0	131.7	8.43	2.39	868.9	87.4	0.451
FR80	01025974	UE-25 RF#14	Tpki	164.7	165.4	8.08	2.38	785.0	82.9	0.479

Table 6.5-5. Individual Specimens, Parent Boreholes and Descriptive Information (Continued)

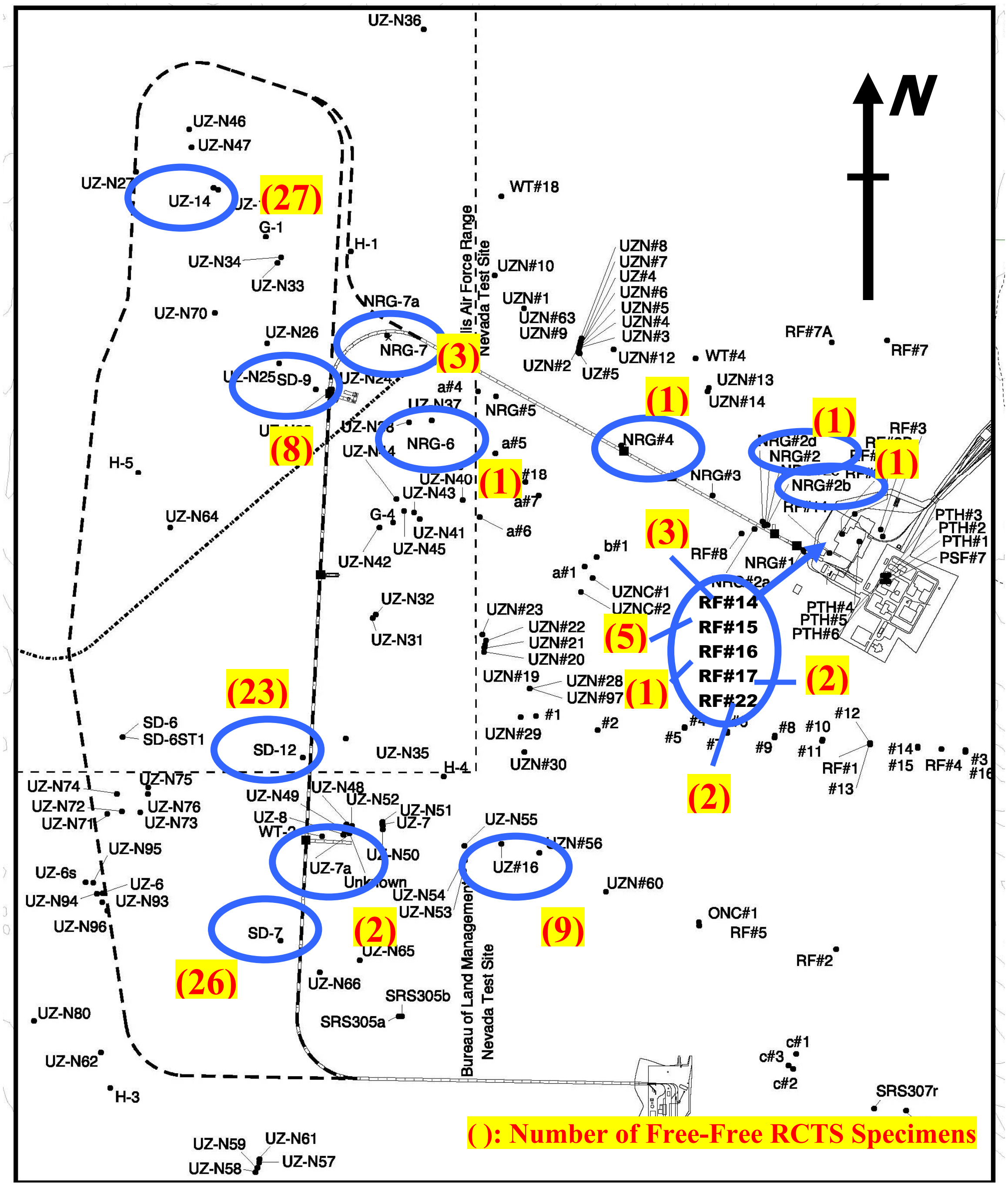
UT Spec. No.	SMF Spec. ID	Borehole	Strat. Unit	Depth (ft)		Spec. Length (in.)	Spec. Dia. (in.)	Weight (g)	Total Unit Weight, γ_t (pcf)	Porosity (n)
FR81	01025984	UE-25- RF#22	Tpcrn	514.3	514.9	7.09	2.47	968.5	108.7	0.317
FR82	01025975	UE-25- RF#14	Tpcrn	231.2	231.9	8.58	2.40	1151.1	112.7	0.292
FR83	01025976	UE-25- RF#15	Tpcrn	33.2	34.1	10.87	3.27	2832.6	118.3	0.257
FR84	01025985	UE-25- RF#22	Tpcrl	527.1	527.6	6.19	2.39	879.1	120.9	0.240
FR85	01025982	UE-25- RF#17	Tpcrl	470.7	471.2	5.82	2.39	869.6	126.9	0.203
FR86	01025986	ESF-BRFA-HPF#2	Tpcpmn	10.2	10.9	8.22	2.41	1416.8	144.2	0.094
FR87	01025979	UE-25- RF#15	Tpcpmn	226.0	226.7	8.37	2.41	1458.3	146.0	0.083
FR88	01025980	UE-25- RF#15	Tpcpll	247.8	248.6	9.49	2.40	1370.3	121.6	0.236
FR89	01025981	UE-25- RF#16	Tpcpll	412.8	413.5	8.47	2.39	1318.9	132.0	0.170
FR90	01025996	USW SD-12	Tpcpln	145.2	145.9	8.33	2.40	1435.3	145.5	0.086
FR91	01025987	USW SD-7	Tpcpln	136.3	137.2	11.06	3.26	3465.9	143.4	0.099
FR92	01025998	USW SD-12	Tpcpv	256.2	256.8	7.61	2.42	813.9	88.9	0.441
FR93	01026001	USW NRG-7/7A	Tpy	132.2	132.9	8.42	2.40	1034.0	103.1	0.352
FR94	01026002	USW SD-9	Tpy	135.9	136.8	10.41	3.21	1983.5	89.6	0.437
FR95	01025999	USW SD-12	Tpbt3	272.4	273.1	8.30	2.40	840.6	85.5	0.463
FR96	01026004	USW UZ-7a	Tpbt3	214.0	214.7	8.48	2.40	812.5	80.5	0.494
FR97	01025997	USW SD-12	Tpcpv	249.0	249.5	6.65	2.38	918.6	118.2	0.257
FR98	01026006	USW UZ-14	Tpp	134.1	134.8	8.56	2.37	684.4	69.2	0.565
FR99	01026005	USW UZ-7a	Tpp	216.2	216.9	8.73	2.40	757.6	72.9	0.542
FR100	01026003	USW SD-9	Tpbt2	248.0	249.0	11.66	3.20	1607.4	65.3	0.590
FR101	01026000	USW SD-12	Tpbt2	303.1	303.7	7.60	2.37	585.5	66.3	0.583
FR102	01025924	ECRB-GTEC-CS1922-03	Tptpll	7.2	7.9	8.92	3.76	3700.0	142.0	0.108
FR103	01026732	USW UZ-14	Tpy	69.8	70.1	2.77	2.39	309.4	94.8	0.404
FR104	01026733	USW UZ-14	Tpbt3	80.7	81.1	4.84	2.39	553.6	97.0	0.390
FR105	01026734	USW UZ-14	Tpbt3	88.2	88.6	5.09	2.36	464.6	79.1	0.503
FR106	01026735	USW UZ-14	Tpp	178.6	179.0	4.75	2.39	430.7	76.7	0.518
FR107	01026724	USW SD-12	Tptpv3	1284.6	1284.9	3.31	2.39	547.4	140.7	0.116
FR108	01026725	USW SD-12	Tptpv/v	1352.9	1353.4	5.97	2.39	666.7	95.0	0.403
FR109	01026738	UE-25 UZ#16	Tcpm	1630.5	1630.9	4.66	2.39	759.6	138.7	0.128
FR110	01026705	USW SD-7	Tcpuc	1668.3	1668.8	5.93	2.36	704.3	103.0	0.353
FR111	01026726	USW SD-12	Tcpuc	1776.3	1776.7	4.75	2.37	618.7	112.6	0.292
FR112	01026727	USW SD-12	Tcpm	1789.1	1789.5	4.77	2.38	671.4	120.1	0.245
FR113	01026706	USW SD-7	Tcpm	1791.8	1792.3	6.01	2.40	930.9	130.3	0.181
FR114	01026707	USW SD-7	Tcpm	1825.8	1826.3	5.96	2.39	999.2	142.3	0.106
FR115	01026728	USW SD-12	Tcpm	1832.9	1833.3	4.79	2.38	745.4	133.4	0.162
FR116	01026729	USW SD-12	Tcplv	1910.4	1910.8	4.78	2.38	582.5	104.1	0.346
FR117	01026721	USW SD-9	Tcpm	1975.8	1976.2	4.71	2.41	695.9	123.7	0.222
FR118	01026708	USW SD-7	Tcplv	2031.4	2031.9	5.84	2.40	845.1	122.3	0.231
FR119	01026722	USW SD-9	Tcplv	2039.8	2040.2	4.79	2.39	609.3	107.6	0.324

Table 6.5-5. Individual Specimens, Parent Boreholes and Descriptive Information (Continued)

UT Spec. No.	SMF Spec. ID	Borehole	Strat. Unit	Depth (ft)		Spec. Length (in.)	Spec. Dia. (in.)	Weight (g)	Total Unit Weight, γ_t (pcf)	Porosity (n)
FR120	01026730	USW SD-12	Tcpbt	2136.8	2137.2	4.38	2.36	573.9	113.7	0.286
FR121	01026731	USW SD-12	Tcbuv	2143.7	2144.1	4.85	2.40	666.3	115.8	0.272
FR122	01026709	USW SD-7	Tcbm	2300	2300.4	4.86	2.40	824.0	142.7	0.103
FR123	01026710	USW SD-7	Tcbm	2399.1	2399.6	5.37	2.41	940.8	146.4	0.080
FR124	01026760	USW SD-7	Tcblc	2462	2462.4	4.72	2.41	772.5	136.2	0.144
FR125	01026711	USW SD-7	Tcblv	2485.8	2486.2	4.61	2.41	667.7	121.1	0.239
FR126	01026712	USW SD-7	Tcblv	2522.1	2522.5	4.61	2.38	635.0	117.3	0.263
FR127	01026713	USW SD-7	Tcblv	2560.4	2560.8	4.74	2.37	573.0	103.8	0.348
FR128	01026714	USW SD-7	Tcbbt	2581.1	2581.5	4.69	2.38	643.9	117.6	0.261
FR129	01026715	USW SD-7	Tcbbt	2593.5	2593.9	4.63	2.38	701.7	129.8	0.184
FR130	01026716	USW SD-7	Tctuv	2600	2600.4	4.71	2.38	599.8	109.0	0.315
FR131	01031164-1	Surface	Tptpul	N/A	N/A	11.83	4.25	4910.0	111.6	0.299
FR132	01031166-1	Surface	Tptpmn			12.28	5.65	11612.0	143.6	0.097
FR133	01037508-1	Surface	Tptpul			7.90	4.24	3313.0	113.0	0.290
FR134	01037510-1	Surface	Tptpul			10.33	4.25	3995.0	103.7	0.348
FR135	01037512-1	Surface	Tptpul			9.42	4.24	3800.0	108.9	0.315

Source: DTN: MO0707FREEFREE.006 [DIRS 183287]; Wong and Stokoe 2007 [DIRS 183328].

NOTE: The depth column of the table has no relevance for the specimens developed from boulders that were collected on the surface.



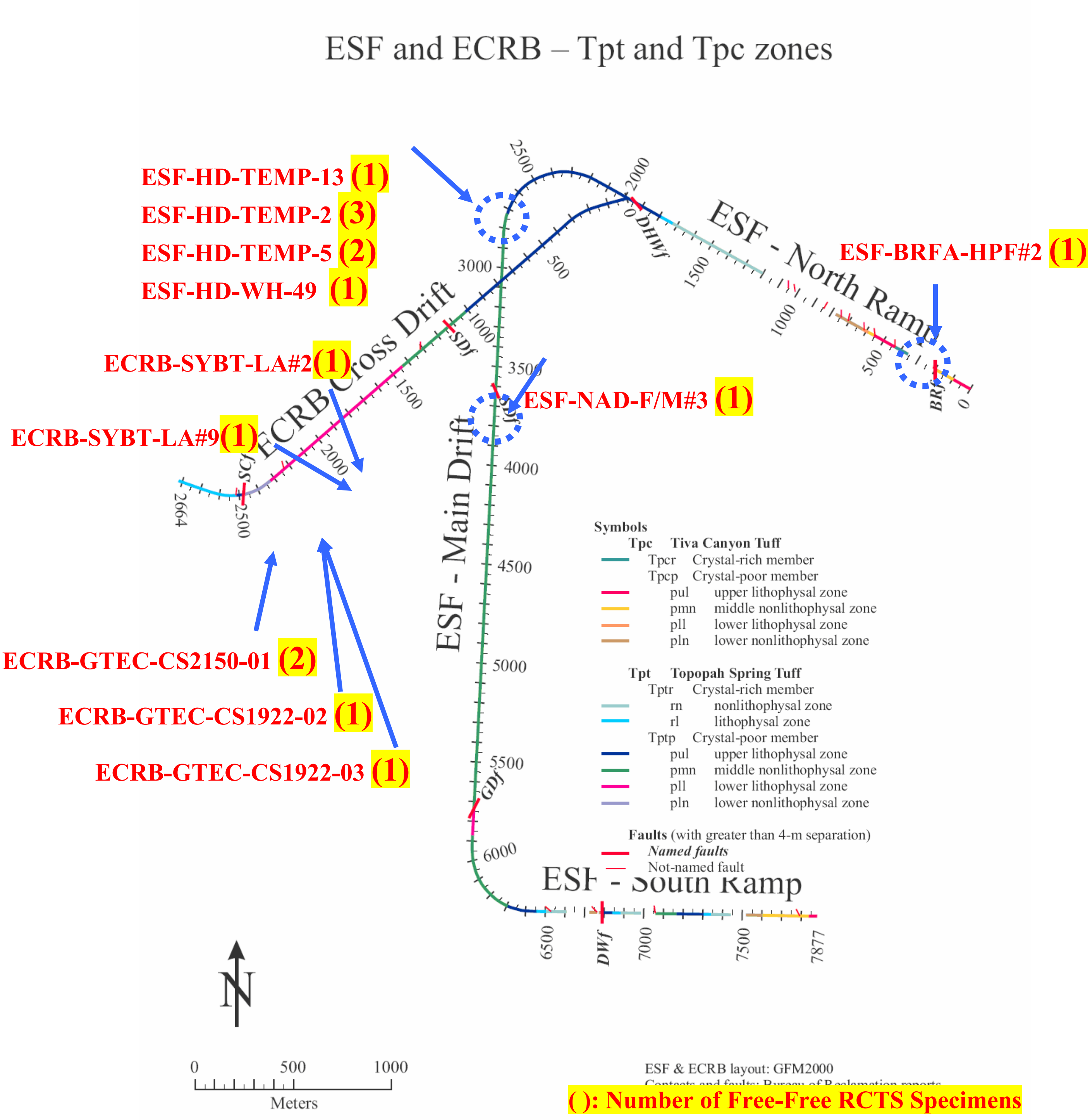
Source: Wong and Stokoe 2007 [DIRS 183328].

NOTE: The blue ellipse is placed around the borehole from which the samples were collected

Figure 6.5-32. Existing Boreholes in the Vicinity of Yucca Mountain from Which Tuff Cores Were Recovered

NOTE: The blue ellipse is placed around the borehole from which the samples were collected

Figure 6.5-33. Locations of Boreholes RF #14, RF #15, RF #16, RF #17, and RF #22



Source: Wong and Stokoe 2007 [DIRS 183328].

NOTE: The blue ellipse is placed around the borehole from which the samples were collected.

Figure 6.5-34. Parent Boreholes in the ESF and ECRB Tunnels from Which Tuff Cores Were Recovered

6.5.3.2. Test Methodology

Two general types of small-strain seismic tests are carried out using the URC set-up: (1) Free-Free resonance tests and (2) direct-travel-time tests. Shear wave velocity, V_S, shear modulus, G_{max}, and material damping ratio in shear, $D_{S\,min}$, can be measured in Free-Free resonance tests in torsional motion. Unconstrained compression wave velocity, V_C, Young's modulus, E_{max}, and material damping ratio in unconstrained compression, $D_{C\,min}$, can be measured in Free-Free resonance tests in longitudinal motion. Direct-travel-time measurements of compression waves also provide the constrained compression wave velocity, V_P, and constrained modulus, M_{max}. A sketch illustrating these three measurements is shown in Figure 6.5-35.

Free-Free resonance tests are performed by establishing longitudinal and torsional resonant vibrations to evaluate the dynamic properties of specimens. Free-Free boundary conditions are created by laying the rock specimens on soft cushions, to minimize the restriction of movements of the specimen. The excitation is created by different types of impact devices: (1) a small hand-held hammer for longitudinal vibration and (2) a "scissors" source or a tangential impact for torsional vibration. Resonant motions of the specimen created by the impacts are measured by accelerometer(s) on the free end opposite the source as illustrated in Figure 6.5-35. The output(s) of the accelerometer(s) are monitored with a dynamic signal analyzer that provides data acquisition and signal processing operations. All time-domain and frequency-domain data are saved in a data logger that is connected to the analyzer. Figure 6.5-36 illustrates the configuration of the equipment for the compressional (longitudinal) resonance test and direct-travel-time measurement. Figure 6.5-37 illustrates the configuration for the torsional resonance test.

The frequencies of the normal modes and geometrical shape of the frequency response curves (or power spectrum) are used in determining the dynamic properties of the specimens. First-mode resonant frequencies are measured and recorded in longitudinal and torsional motions. Unconstrained compression wave velocity, $V_{C,}$ is determined from Equation 6.5-2 and shear wave velocity, V_S, from Equation 6.5-3, as follows (Lewis 1990 [DIRS 183322]):

$$V_C = f_1\lambda/(C/C_B) \qquad \text{(Eq. 6.5-2)}$$

$$V_S = f_1\lambda \qquad \text{(Eq. 6.5-3)}$$

where

f_1 = first-mode resonant frequency (in longitudinal excitation for V_C and in torsional excitation for V_S)

λ = wavelength = 2L (for first-mode resonance)

L = length of the specimen

C/C_B = dimensionless velocity (a dimensionless correction factor for wavelength).

In the case of the V_C evaluations, correction for specimen length is not required if the first-mode wavelength is more than four times as large as the diameter of the test specimen (Stokoe et al. 1994 [DIRS 157264]). When the wavelength is less than four times the diameter, the correction factor shown in Figure 6.5-38 is used (Lewis 1990 [DIRS 183322]). Note that the parameter of 2a/λ is displayed on the horizontal axis in figure 6.5-38. The factor "a" is the specimen radius. Hence, 2a represents the specimen diameter. In these Free-Free tests, the added mass of the small accelerometers attached to the core specimen can be neglected; as documented in scientific notebook SCI-M&O-048-V1 (Wong and Stokoe 2007 [DIRS 183328]), they change mass in longitudinal resonance by less than 0.7% and the mass polar moment of inertia in torsional resonance by less than 2.8%. Since first mode resonance is being measured, the wave length, λ, is equal to twice the specimen length, L. Therefore, in these tests, the factor of 2a/λ was 0.25 when the height-to-diameter ratio of the specimen was two. The dimensionless correction factor (C/C_B), which increases the value of V_C, is on the order of 2% and was neglected. As noted above, this factor is even smaller when the height-to-diameter ratio exceeded two. The value of the dimensionless correction factor is shown in Figure 6.5-38 and is taken from the curve for first-mode resonance for material with ν = 0.3. Material damping ratios in both unconstrained compression ($D_{C\ min}$) and torsion ($D_{S\ min}$) are determined from the half-power bandwidth method for each mode of vibration using Equation 6.5-4 and Equation 6.5-5 (Richart et al. 1970 [DIRS 157258), respectively, as follows:

$$D_{C\ min} = D_{hp,C\ min} \cong \frac{f_{2C} - f_{1C}}{2 \times f_{rC}} \qquad \text{(Eq. 6.5-4)}$$

$$D_{S\ min} = D_{hp,S\ min} \cong \frac{f_{2S} - f_{1S}}{2 \times f_{rS}} \qquad \text{(Eq. 6.5-5)}$$

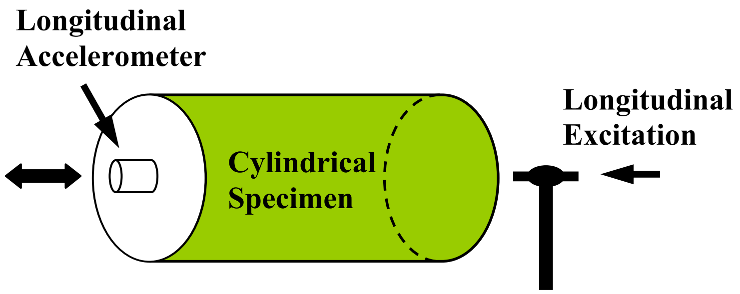
where

f_{rC} = first mode resonant frequency in compression
f_{1C} = lower frequency at $1/\sqrt{2}$ times the resonant amplitude in compression
f_{2C} = higher frequency at $1/\sqrt{2}$ times the resonant amplitude in compression
f_{rS} = first mode resonant frequency in torsion
f_{1S} = lower frequency at $1/\sqrt{2}$ times the resonant amplitude in torsion
f_{2S} = higher frequency at $1/\sqrt{2}$ times the resonant amplitude in torsion.

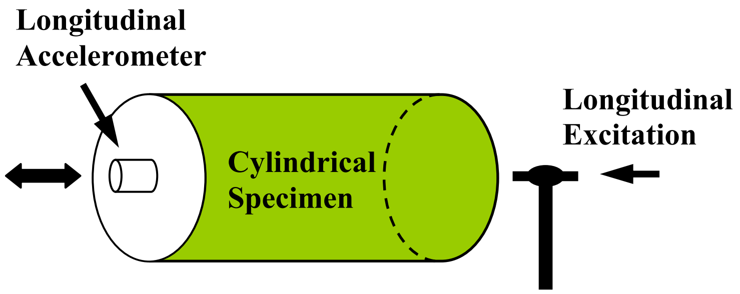
In addition to resonance testing, constrained compression wave velocity, V_P, can be measured between the free ends of the specimen using the direct-travel-time. The set-up for this measurement is identical to the set-up for the Free-Free resonance tests in longitudinal motion as shown in Figures 6.5-33(a) and 6.5-33(b). The value of V_P is calculated using Equation 6.5-6 as:

$$V_P = L/t \qquad \text{(Eq. 6.5-6)}$$

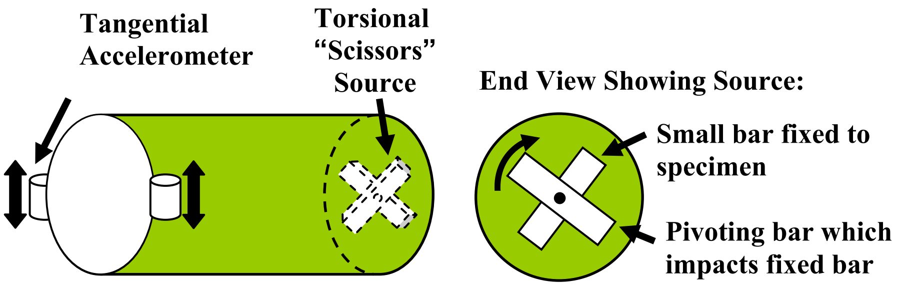
where L is the length of the specimen and t is the time shift between the input and output signals, which is the difference in time between the start point observed as the arrival of the hammer impact (input signal) and the arrival point observed in the arrival wave.



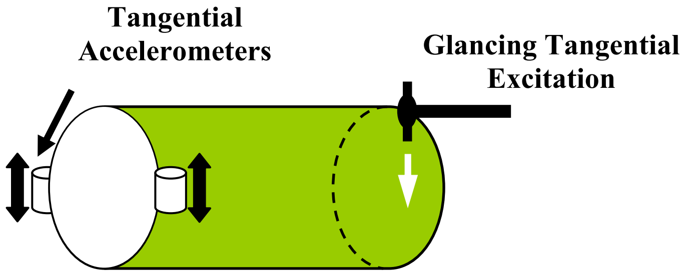
a. Compressional (Longitudinal) Resonance Test



b. Direct-Travel-Time of Constrained Compression Waves Measurement



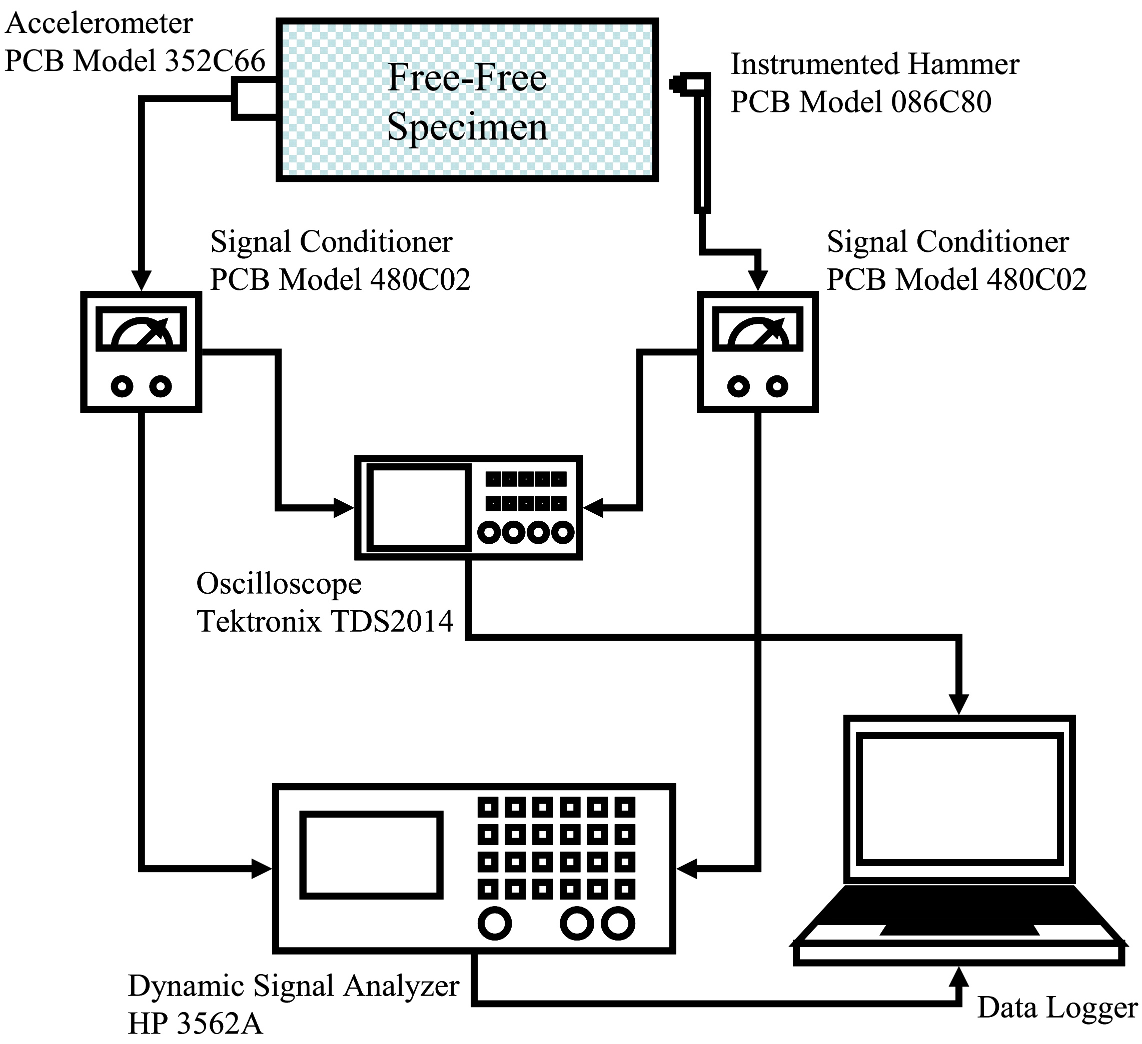
c. Torsional Resonance Test with a "Scissors" Source



d. Torsional Resonance Test with a Tangential Impact

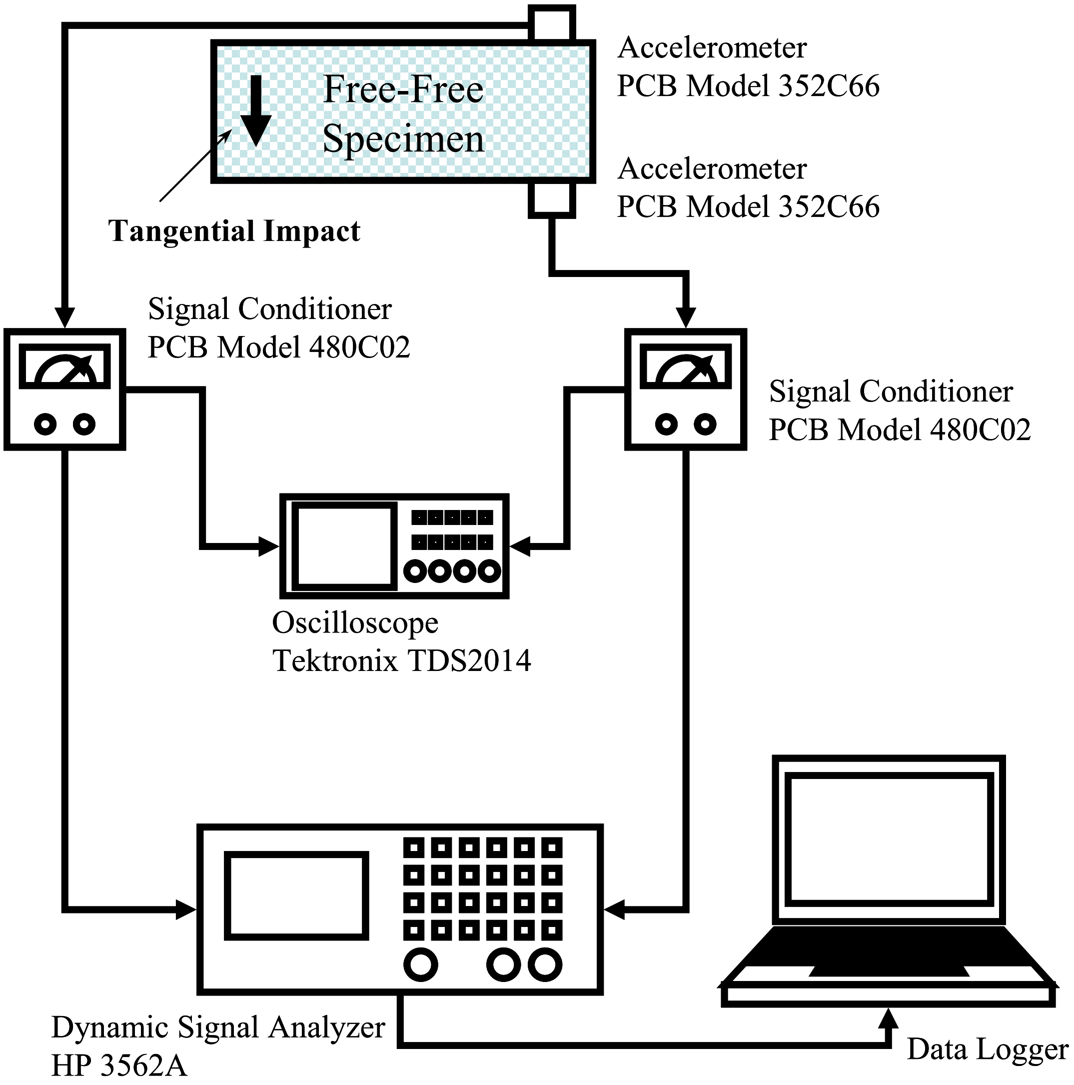
Source: Stokoe et al. 1994 [DIRS 157264].

Figure 6.5-35. General Test Set-Up Configurations for: (a) Compressional (Longitudinal) Resonance Test, (b) Direct-Travel-Time Measurement, and (c) and (d) Torsional Resonance Test on Unconfined Cylindrical Specimens



Source: Wong and Stokoe 2007 [DIRS 183328].

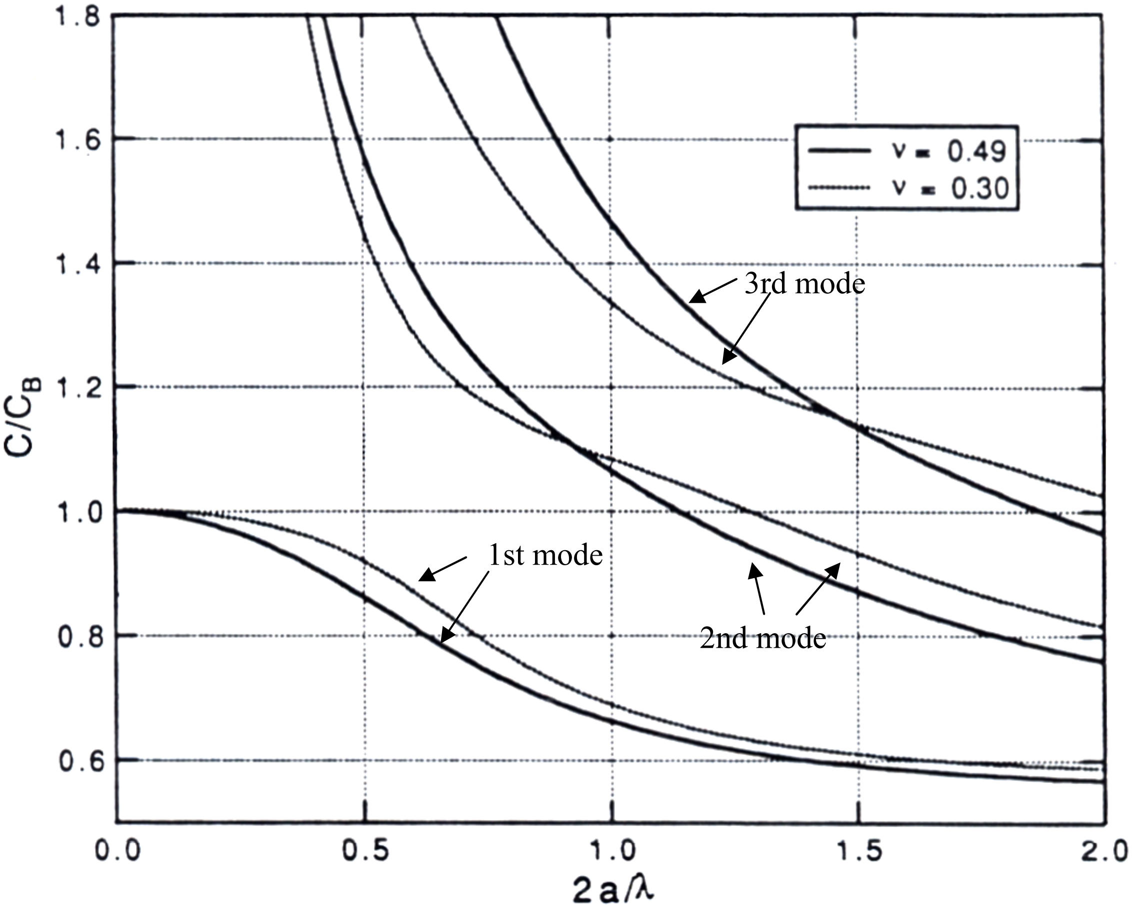
Figure 6.5-36. Configuration of Equipment for Compressional (Longitudinal) Resonance Tests and Direct-Travel-Time Measurement



Source: Wong and Stokoe 2007 [DIRS 183328].

Figure 6.5-37. Configuration of Equipment for Torsional Resonance Test

Known property metal specimens were used as reference specimens to evaluate the system compliance in the URC set-up (Stokoe et al. 1994 [DIRS 157264]). The tests of the metal specimens provide the proper selection of the wavelength-to-diameter ratio and resonance mode used to evaluate the stiffness of rock and soil samples. Increasing the frequency resolution of the analyzer will increase the digitization of the data at and around the resonant frequency, which will increase the resolution of the measurement spectrum resulting in an improved measurement of the stiffness and material damping throughout the specimen (Stokoe 1994 [DIRS 157264]).



Source: Lewis 1990 [DIRS 183322].

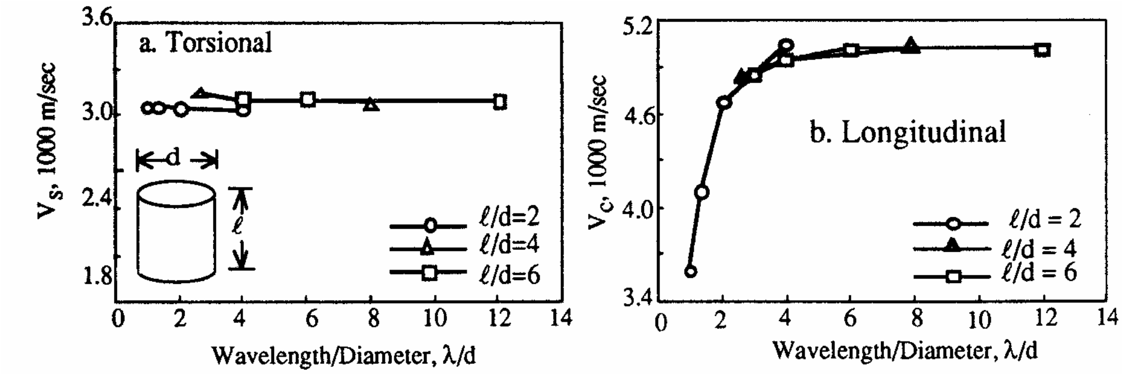
NOTES: C = phase velocity
C_B = bar velocity = V_C
C/C_B = dimensionless velocity
a = radius of specimen
λ = wavelength determined in the measurement mode
2a/λ = dimensionless wave number.

Figure 6.5-38. Frequency Spectrum for Longitudinal Waves in Resonance in a Cylindrical Rod as a Function of Dimensionless Wave Number

Three different aluminum specimens were used. One specimen was 30.5 cm in length and had a diameter of 15.2 cm. The other two specimens were 15.2 cm and 45.7 cm in length, with a diameter of 7.6 cm. Figure 6.5-39 illustrates the influence of wavelength on calculated wave velocities for the three aluminum reference specimens. The compressional wave velocity decreases as the wavelength-to-diameter ratio (λ/d) decreases, but the shear wave velocity shows little change with the ratio. The decrease in compressional wave velocity results from a violation of the plane wavefront assumption and excitation of more complex modes of vibration as the wavelength is close to the diameter of the specimen as suggested by Lewis (1990 [DIRS 183322]). The first mode can simply be a proper mode to evaluate both compressional and torsional stiffness. The further corrections for the specimen with (λ/d) < 2 can be made by using the correction factor discussed previously and shown in Figure 6.5-38.

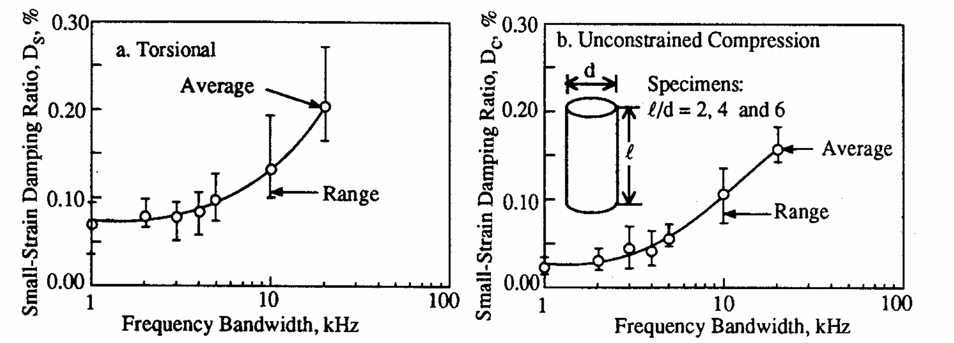
The small-strain material damping ratio values of the aluminum reference specimens measured using different frequency bandwidths and first-mode resonance are presented in Figure 6.5-40. The small-strain material damping ratio could be overestimated when a large frequency bandwidth is used. However, it is shown that for frequency bandwidths less than about 3 kHz, the damping ratios in both compression and shear become nearly constant. It should be also noted that these values between 0.02% and 0.06% were accurately measured and agree well with values reported in the literature (Sun 1993 [DIRS 183321]).

As a continuation of the evaluation of the Free-Free method, test specimens were cut from Yucca Mountain borehole samples, dimensions measured to determine the volume, and weighed to determine the specimen mass. The specimens were inspected for defects and a Free-Free resonant column test was performed on each specimen. The results of the Free-Free resonant column tests on the original specimens are documented in SN-M&O-SCI-048-V1, Supplement Volumes 6 and 7 (Wong and Stokoe 2007 [DIRS 183328]), and the data submittal to the TDMS was documented in SN-M&O-SCI-048-V1, Supplement Volume 9 (Wong and Stokoe 2007 [DIRS 183328]). The dimensions of the original cores changed in general through re-coring, cutting, and/or trimming processes. Free-Free resonant column tests were performed whenever these processes were used. The results of the Free-Free resonant column tests on the cored specimens are documented in SN-M&O-SCI-048-V1, Supplement Volumes 2 through 5 (Wong and Stokoe 2007 [DIRS 183328]) and compared with the results of the Fixed-Free resonant column and torsional shear tests on corresponding specimens. The data submittal to the TDMS was documented in SN-M&O-SCI-048-V1, Supplement Volume 9 (Wong and Stokoe 2007 [DIRS 183328]).



Source: Stokoe et al. 1994 [DIRS 157264].

Figure 6.5-39. Influence of Wavelength on Calculated Wave Velocities for Three Aluminum Reference Specimens



Source: Stokoe et al. 1994 [DIRS 157264].

Figure 6.5-40. Influence of Frequency Bandwidth on Measured Values of Material Damping for Three Aluminum Reference Specimens

6.5.3.3. Free-Free Results

A total of 135 tuff cores were selected for Free-Free URC testing. These cores were selected to represent a wide range in the tuff materials at the Yucca Mountain site. The number of specimens that were tested in each stratigraphic unit is presented in Table 6.5-6. As seen in the table, cores from a majority of the stratigraphic units at the site were tested. In addition to the 135 samples listed in Table 6.5-6, the 33 specimens tested using the Fixed-Free approach discussed in Section 6.5.2 were also Free-Free tested. Results of all Free-Free testing are displayed in Attachment VIII.

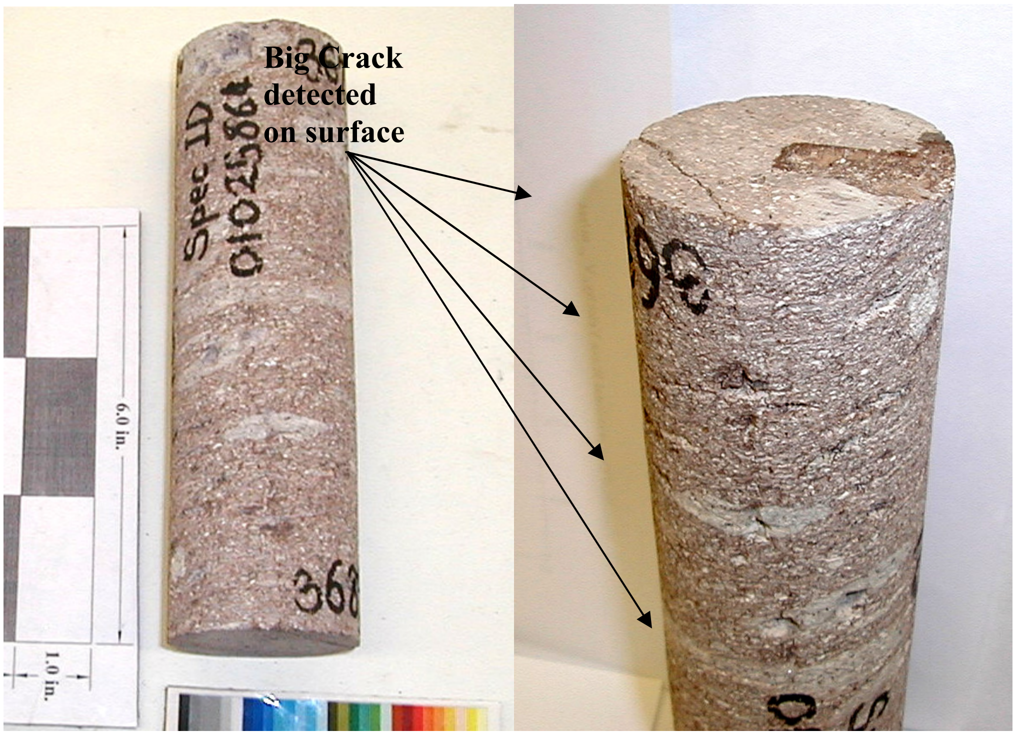
A listing of the properties of the 135 cores is presented in Table 6.5-5. The nominal lengths of the specimens ranged from 2.8 to 12.3 in. and the nominal diameters of the specimens ranged from 1.8 to 5.7 in. The measurements of total unit weights covered a wide range, from 65 to 148 pcf. These values were used to calculate estimated porosities for the specimens, with the assumptions that the specific gravity of the solid material is 2.55 and the water content of the tuff specimens was zero. Based on these assumptions, the range in calculated porosity estimates is from 0.073 to 0.59.

A summary of the test results for the 135 tuff specimens is given in Attachment VIII. Specimens FR1 through FR7 are non-Q data because they were tested before the accelerometers and the signal conditioners were calibrated. Specimens FR9, FR35, FR97, and FR102 were excluded from the data set as outliers in evaluating general trends determined with fitting lines because they had significant flaws. The general trends investigated were between: (1) seismic wave velocity and total unit weight, and (2) seismic wave velocity and estimated porosity. Figures 6.5-41, 6.5-42, and 6.5-43 show the photograph of Specimens FR9, FR35, and FR102. Flaws such as cracks, joints, and fractures can be clearly detected in the specimens and cause the specimens to have abnormal seismic wave velocities. Specimen FR97 is specified as an outlier in describing the general trends of the shear wave velocity and unconstrained compressional wave velocity because the specimen broke after the V_P measurement and before V_S and V_C measurements. Specimens FR24, FR54, FR77, and FR100 were also excluded as outliers in evaluating general trends between material damping ratios and seismic wave velocities because of flaws in these specimens. Pictures of these specimens are shown later in this section.

Table 6.5-6. Number of Specimens Tested in the URC Device from Each Stratigraphic Unit

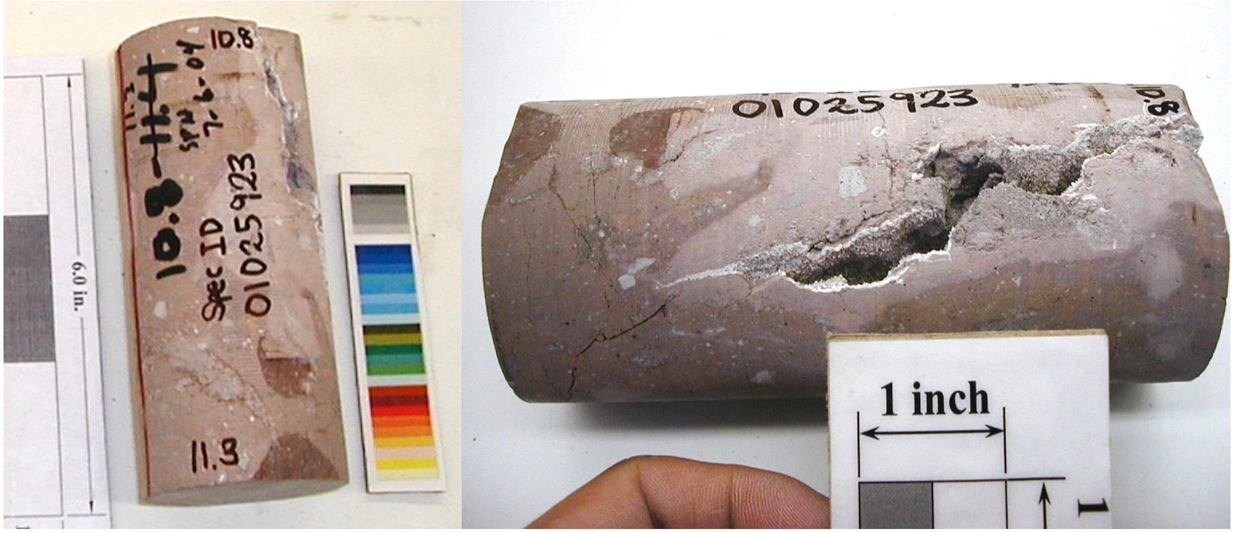
UNIVERSITY OF TEXAS DYNAMIC LABORATORY TESTING PROGRAM							
Stratigraphic Unit	**Unit Abbreviation**	**No. of Samples That were Tested**	**Sample Diameter (inches)**				
			1.6 - 1.8	**2.3 - 2.5**	**3.2 - 3.3**	**3.8 - 4.3**	**5.7**
RAINIER MESA	Tmr	2		2			
Pre-Rainier Mesa Bedded Tuff	Tmbt1	0					
TUFF UNIT X	Tpki	2		2			
TIVA CANYON TUFF							
Crystal-Rich, Vitric	Tpcrv	0					
Crystal-Rich, Nonlithophysal	Tpcrn	3		2	1		
Crystal-Rich, Lithophysal	Tpcrl	2		2			
Crystal-Poor, Upper Lithophysal	Tpcpul	3		3			
Crystal-Poor, Middle Nonlithophysal	Tpcpmn	2		2			
Crystal-Poor, Lower Lithphysal	Tpcpll	2		2			
Crystal-Poor, Lower Nonlithophysal	Tpcpln	2		1	1		
Crystal-Poor, Vitric	Tpcpv	2		2			
YUCCA MOUNTAIN TUFF	Tpy, Tpbt3	7		6	1		
PAH CANYON TUFF	Tpp, Tpbt2	5		4	1		
TOPOPAH SPRING TUFF							
Crystal-Rich, Vitric	Tptrv	0					
Crystal-Rich, Nonlithophysal	Tptrn	7		5	2		
Crystal-Rich, Lithophysal	Tptrl	2			2		
Crystal-Poor, Lithic-Rich	Tptpf/Tptrf	0					
Crystal-Poor, Upper Lithophysal	Tptpul	12	2	6		4	
Crystal-Poor, Middle Nonlithophysal	Tptpmn	9	1	7			1
Crystal-Poor, Lower Lithphysal	Tptpll	9	2	5		2	
Crystal-Poor, Lower Nonlithophysal	Tptpln	8		8			
Crystal-Poor, Vitric	Tptpv	5		5			
Pre-Topopah Spring Bedded Tuff	Tpbt1	0					
CALICO HILLS	Tac	10		6	4		
PROW PASS	Tcp	21		19	2		
Pre-Prow Pass Bedded Tuff	Tcpbt	1		1			
BULLFROG	Tcb	12		11	1		
Pre-Bullfrog Bedded Tuff	Tcbbt	2		2			
TRAM	Tct	5		5			
TOTAL NUMBER	**—**	**135**	**5**	**108**	**15**	**6**	**1**

Source: Wong and Stokoe 2007 [DIRS 183328]



NOTES: SMF ID.: 01025864
Stratigraphic Unit: Tptrn
Borehole: USW UZ-14
Depth: 367.6 to 368.3 ft.

Figure 6.5-41. Photograph of Specimen FR9



NOTES: SMF ID.: 01025923
Stratigraphic Unit: Tptpll
Borehole: ECRB-GTEC-CS1922-02
Depth: 10.8 to 11.3 ft

Figure 6.5-42. Photograph of Specimen FR35

NOTES: SMF ID.: 01025924
Stratigraphic Unit: Tptpll
Borehole: ECRB-GTEC-CS1922-03
Depth: 7.2 to 7.9 ft.

Figure 6.5-43. Photograph of Specimen FR102

General Relationship between Seismic Wave Velocities and Total Unit Weight

The general relationship between shear wave velocity (V_S) and total unit weight is shown in Figure 6.5-44. There is a distinct trend, with V_S increasing as γ_t increases. The least squares, best-fit line through the data is shown by the solid line in Figure 6.5-44. Much of the variability in the trend is thought to arise from “flaws” (cracks, lithophysae, etc.) that affect the small strain-stiffness, hence shear wave velocity, of the core.

Similar relationships between unconstrained compression wave velocity (V_C) and γ_t and between constrained compression wave velocity (V_P) and γ_t are shown in Figures 6.5-45 and 6.5-46, respectively. Just as with V_S, V_C and V_P show similar trends of V_C and V_P increasing as γ_t increases. The degree of fit in these relationships is slightly better (higher R^2 values) than the best-fit line in Figure 6.5-44.

Since the small-strain moduli are equal to the total unit weight times the square of the associated wave velocity, the small-strain moduli (shear, Young's modulus and constrained modulus) show the same trend of increasing moduli with increasing total unit weight as exhibited by the seismic wave velocities.

General Relationship between Seismic Wave Velocities and Porosity

The seismic wave velocities are re-plotted against estimated porosity in Figures 6.5-47 through 6.5-49. Even though the uncertainties in these plots are distinctly greater, because of the assumptions mentioned above (i.e., an "average" specific gravity of 2.55 and zero water content), these plots have been generated, because porosity is a more common property used to represent the physical state of rock specimens in rock mechanics. Porosity, n, is defined as the ratio of the void volume, V_v, to the total volume, V_T, of the specimen as: $n = V_v/V_T$. In geotechnical engineering, void ratio, e, is commonly used to represent the amount of void space in a specimen. The void ratio (e) is defined as the ratio of the void volume to the solid volume, V_S, of the specimen as: $e = V_v/V_S$. The porosity and void ratio are related as follows:

$$\mathrm{n} = \frac{e}{1+e} \qquad \text{(Eq. 6.5-7)}$$

The void ratio is related with the total unit weight (γ_t) of the specimen as follows:

$$\gamma_t = \frac{(1+\mathrm{w})\,\mathrm{G}_s \cdot \gamma_w}{1+\mathrm{e}} \qquad \text{(Eq. 6.5-8)}$$

where

w = water content (%)
G_s = specific gravity (≈ 2.55)
γ_w = total unit weight of water (= 62.4 pcf).

Therefore, the estimated porosity for each specimen was calculated from the total unit weight and the two assumptions used in this investigation. The first assumption is that the specific gravity (G_s) of the solid part of the tuff specimen is 2.55. The assumed value of the specific gravity is based on the study by Buesch (1996 [DIRS 100106]). As an indication of the effect of this assumption, there are implicit error bars on the calculated porosity estimates that vary from ±0.012 for the higher-end porosity value of 0.495, to ±0.021 for the lower-end porosity value of 0.116. The second assumption is that the water content (w) is zero for all of the tuff specimens from Yucca Mountain. This assumption is not evaluated quantitatively; however, it would probably add significantly less uncertainty to the calculation of the estimated porosity for each specimen.

The general relationships between V_S, V_C and V_P, and estimated porosity (n) are shown in Figures 6.5-47, 6.5-48, and 6.5-49, respectively. There is a strong trend, with seismic wave velocity decreasing as porosity increases. The least squares, best-fit curves through the data represent the general relationship in each figure. The trends are opposite to those shown in Figures 6.5-44 through 6.5-46 because γ_t and n are inversely proportional.

General Relationship between Shear Wave Velocities and Poisson's Ratio

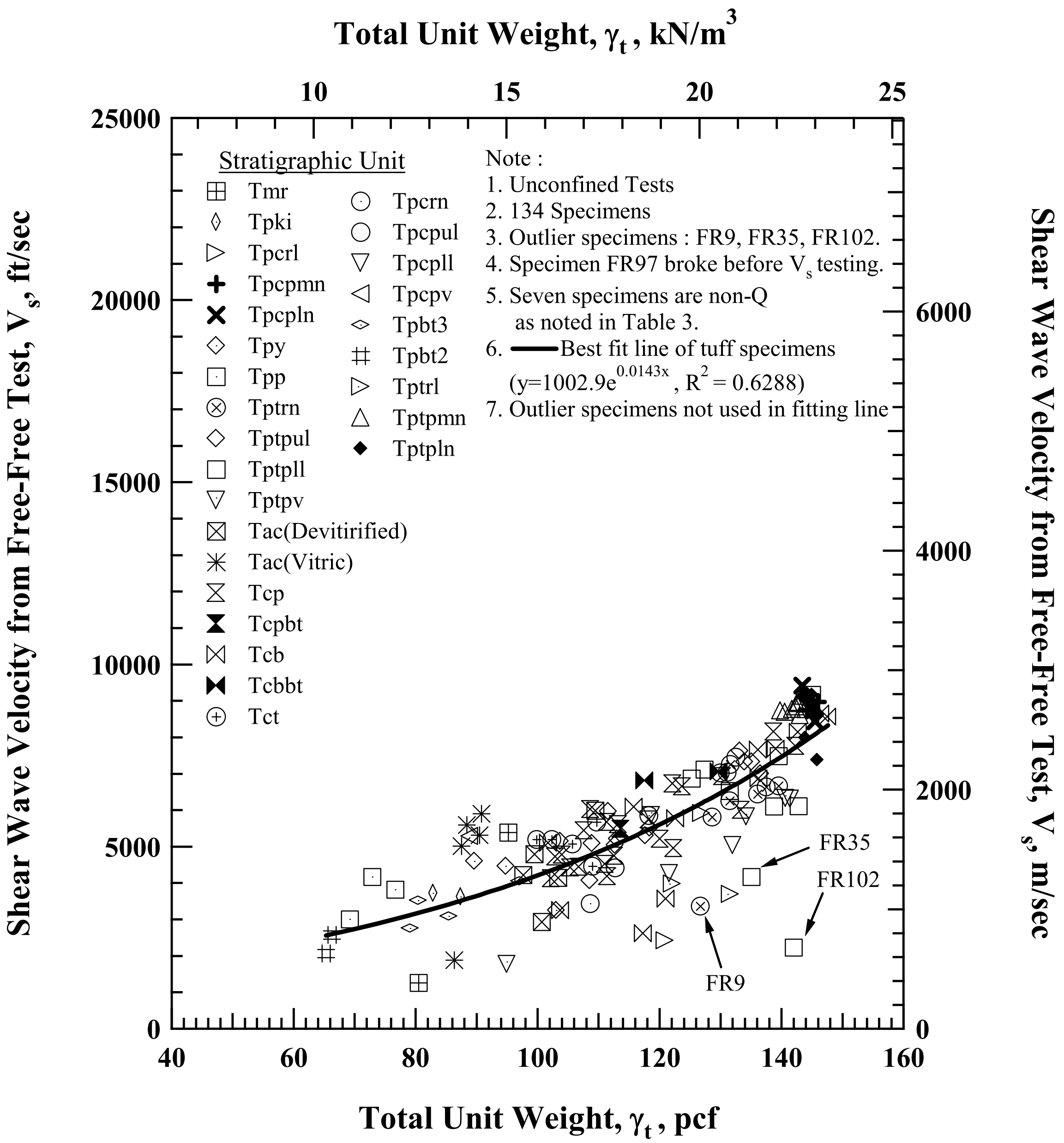
By measuring shear modulus (G_{max}), unconstrained Young's modulus (E_{max}), and constrained modulus (M_{max}), Poisson's ratio can be computed. For an isotropic material assumption, two out of the three moduli are necessary for the calculation of Poisson's ratio. Hence, three kinds of Poisson's ratios can be calculated according to the combination of the three moduli as follows;

$$\nu_{MG} = \frac{M_{max} - 2G_{max}}{2(M_{max} - G_{max})} \qquad \text{(Eq. 6.5-9)}$$

$$\nu_{EG} = \frac{E_{max} - 2G_{max}}{2G_{max}} \qquad \text{(Eq. 6.5-10)}$$

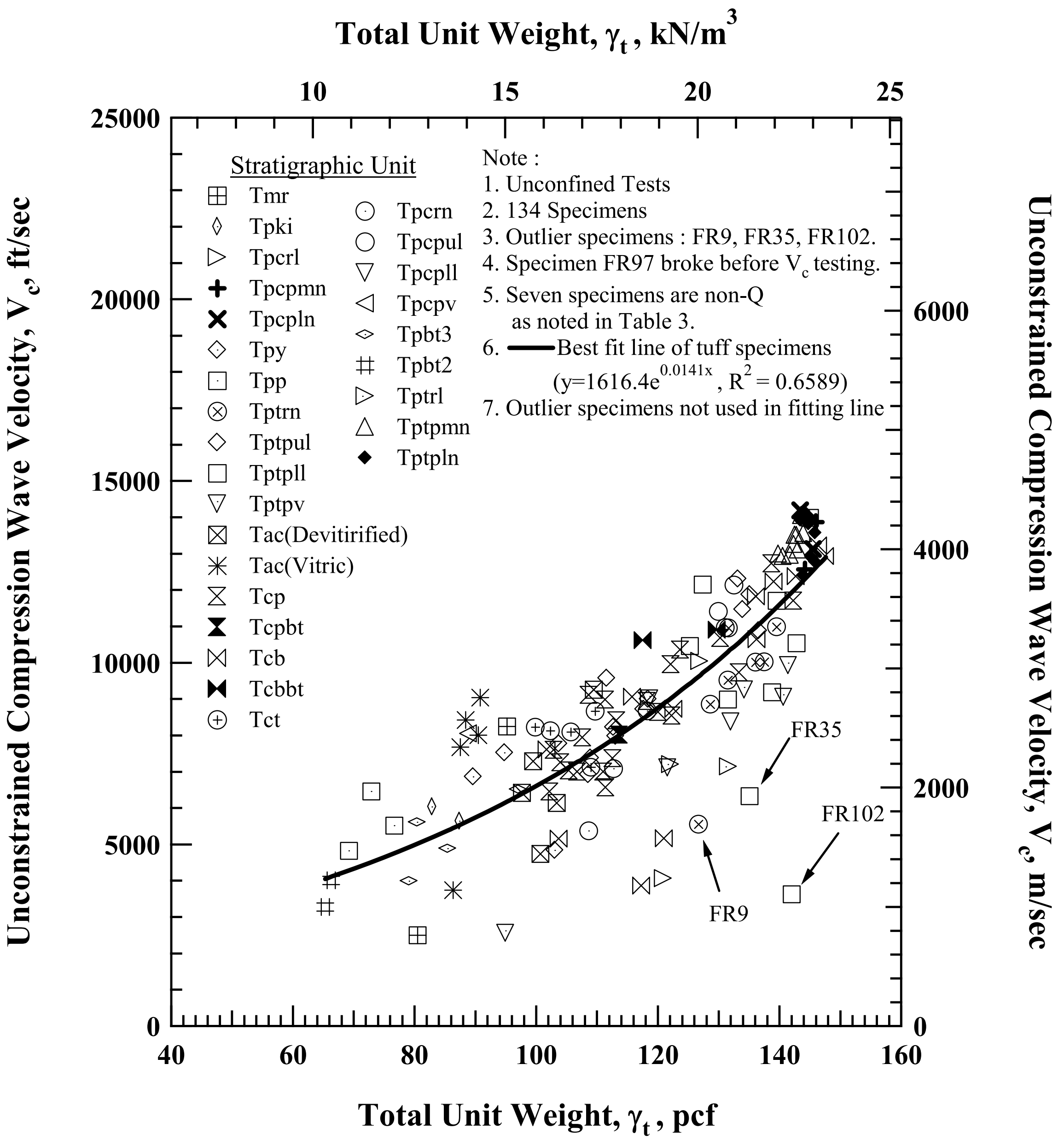
$$\nu_{ME} = \frac{M_{max} - E_{max} + \sqrt{9M_{max}^2 + E_{max}^2 - 10M_{max}E_{max}}}{5M_{max} - E_{max} + \sqrt{9M_{max}^2 + E_{max}^2 - 10M_{max}E_{max}}} \qquad \text{(Eq. 6.5-8)}$$

Out of three types of Poisson's ratio, ν_{MG} is selected to represent values of Poisson's ratio for tuff specimens because ν_{MG} values are more consistent with values ranging between 0.1 and 0.4. Figure 6.5-50 shows the relation between Poisson's ratios and shear wave velocities. The results in the figure show a weak correlation between ν and V_S, with Poisson's ratio decreasing as the shear wave velocity increases. Figure 6.5-51 presents the relation between Poisson's ratio and constrained compression wave velocity. As seen in this figure, the constrained compression wave and Poisson's ratio are poorly correlated (indicated by the very small R^2 value), because of the natural scatter of this inhomogeneous material.



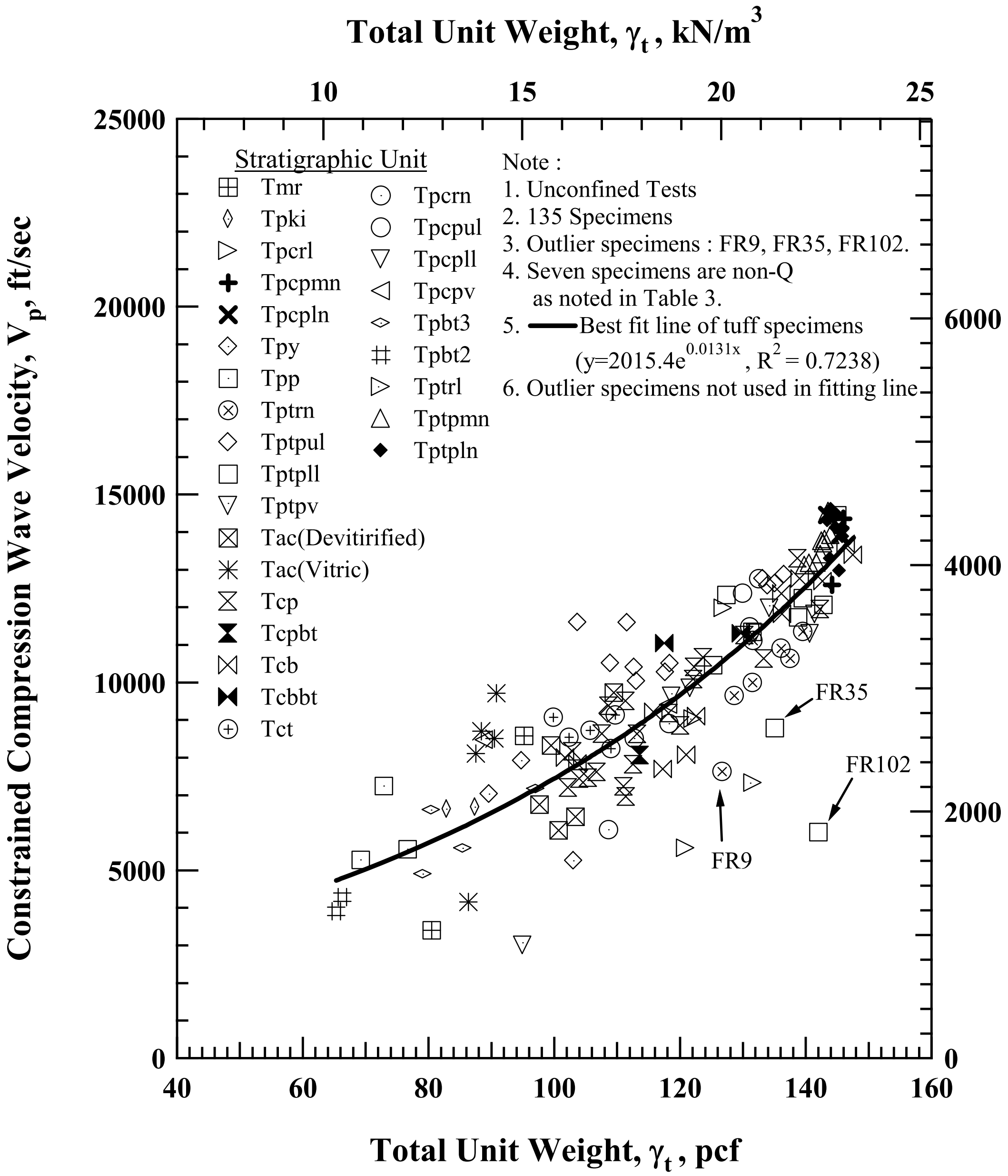
Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-44. Variation in Shear Wave Velocity with Total Unit Weight from Free-Free Resonant Column Tests of 134 Tuff Specimens



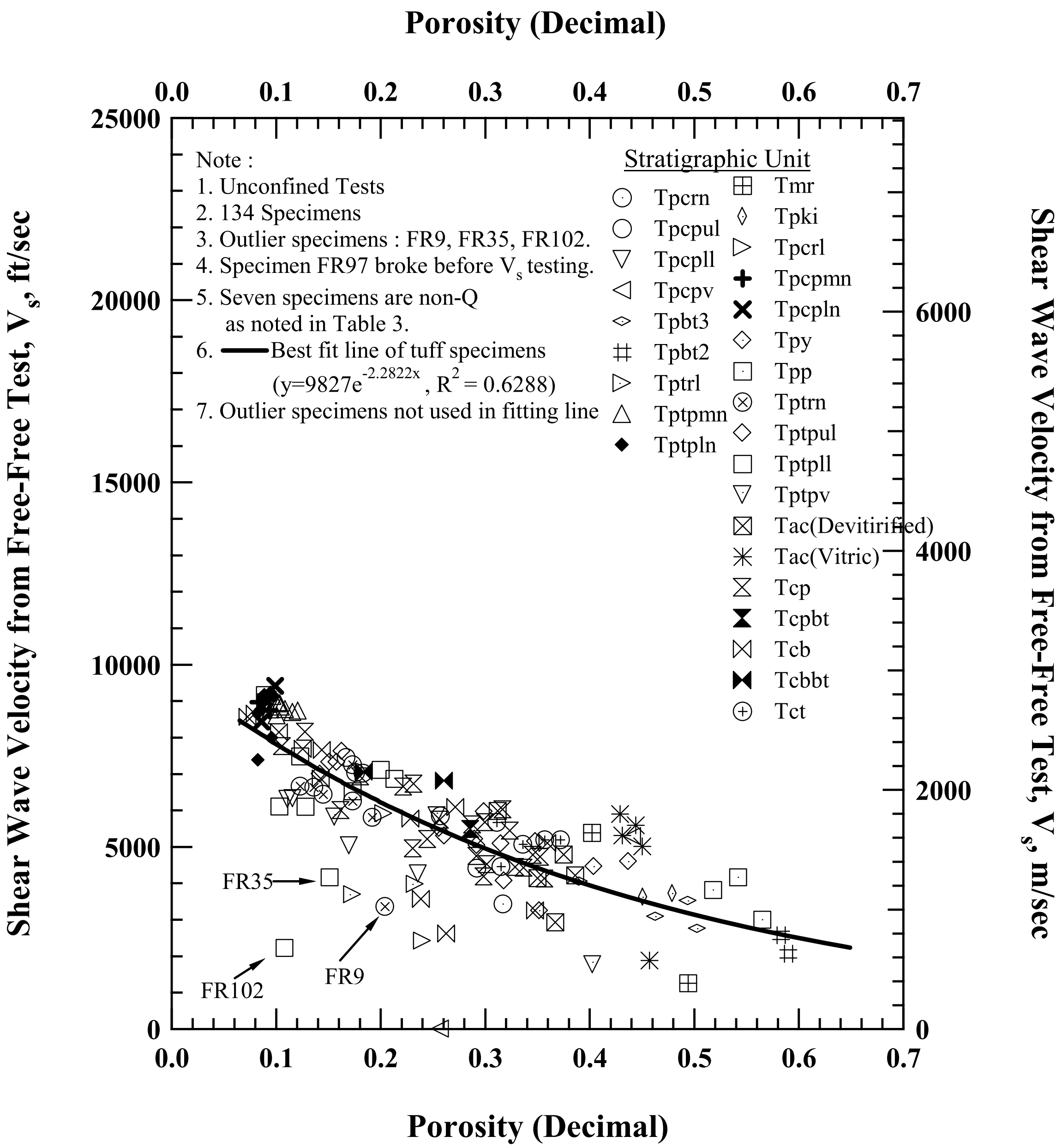
Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-45. Variation in Unconstrained Compression Wave Velocity with Total Unit Weight from Free-Free Resonant Column Tests of 134 Tuff Specimens



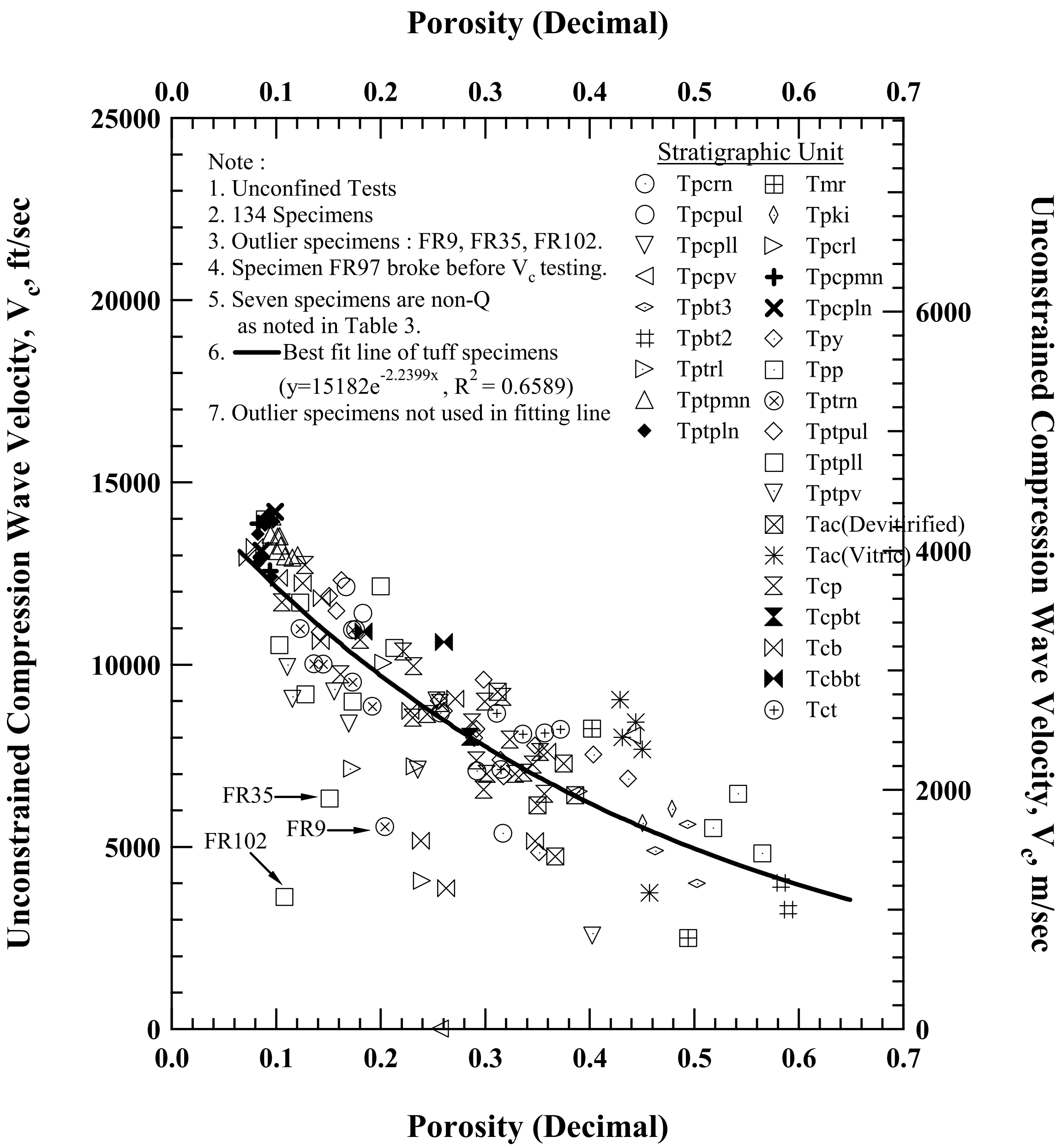
Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-46. Variation in Constrained Compression Wave Velocity with Total Unit Weight from Free-Free Resonant Column Tests of 135 Tuff Specimens



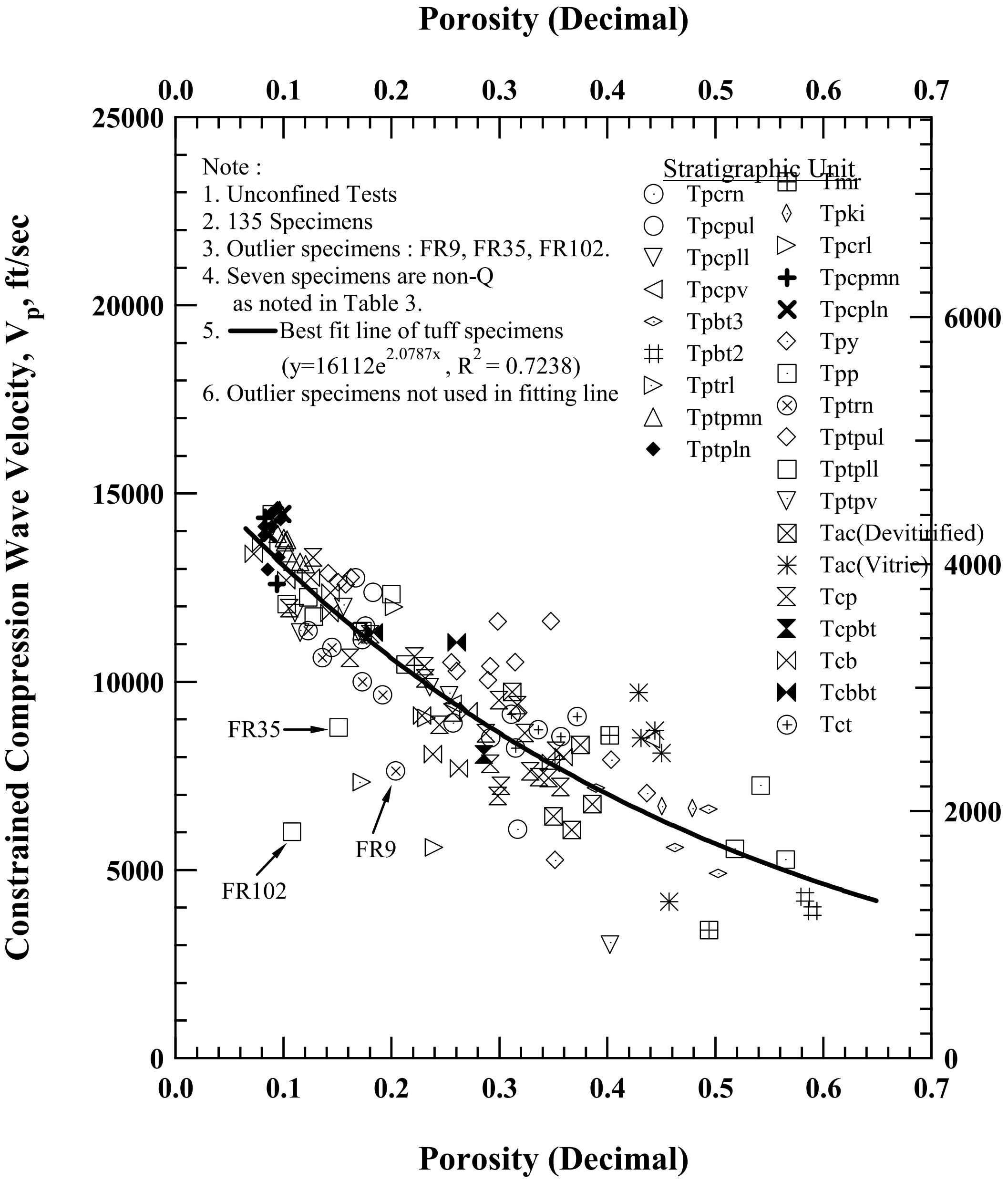
Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-47. Variation in Shear Wave Velocity with Porosity from Free-Free Resonant Column Tests of 134 Tuff Specimens



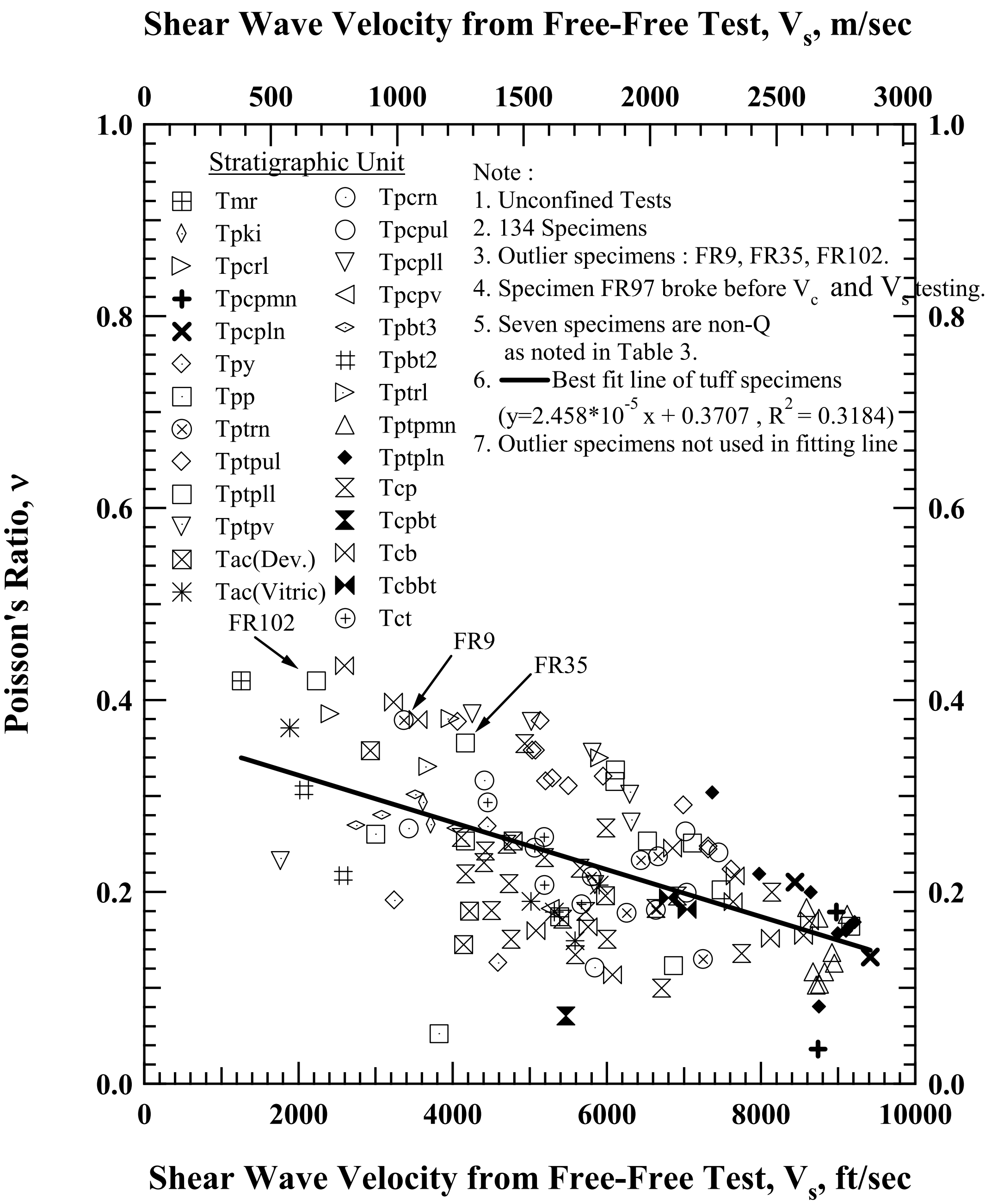
Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-48. Variation in Unconstrained Compression Wave Velocity with Porosity from Free-Free Resonant Column Tests of 134 Tuff Specimens



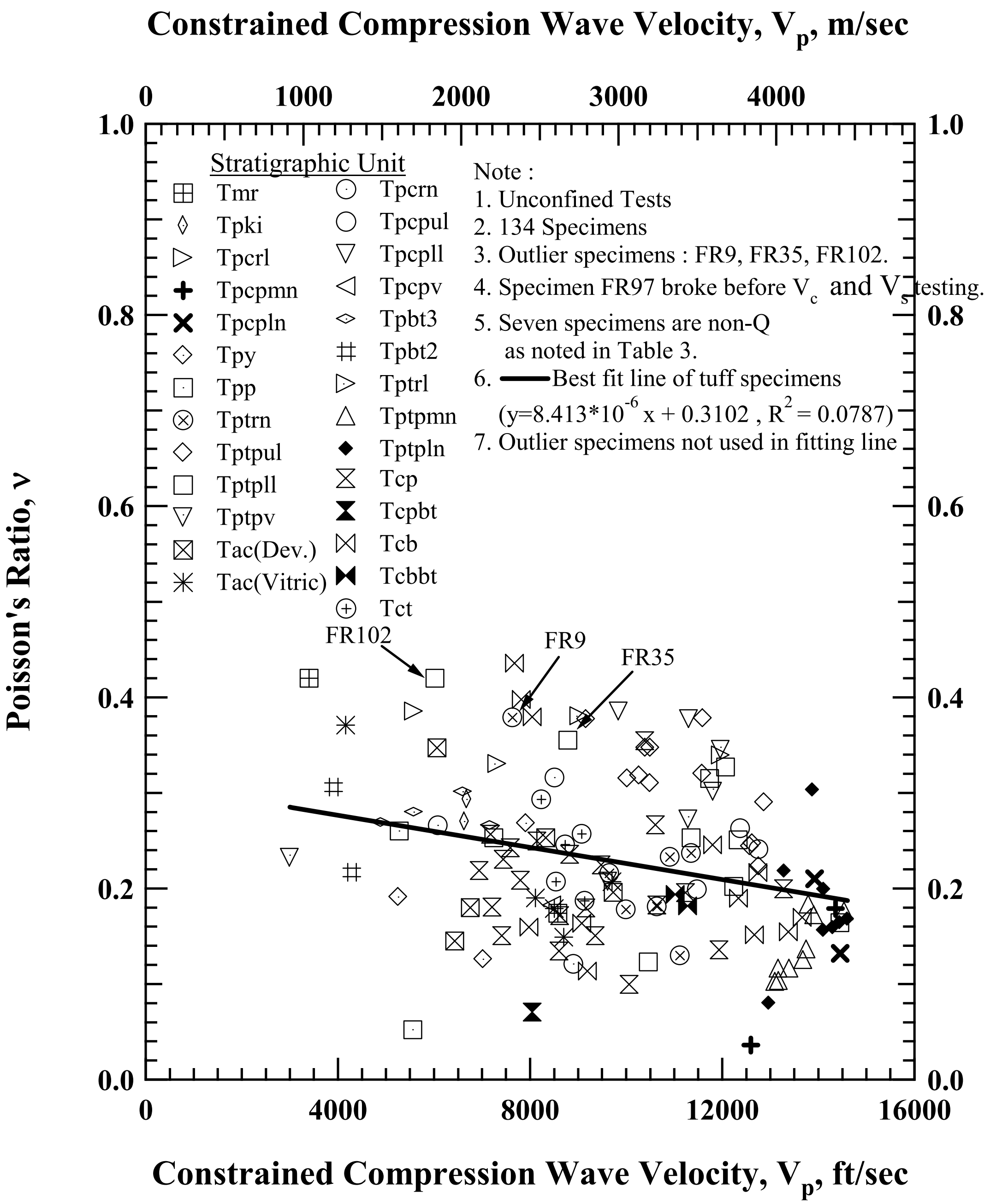
Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-49. Variation in Constrained Compression Wave Velocity with Porosity from Free-Free Resonant Column Tests of 135 Tuff Specimens



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-50. Variation in Poisson's Ratio with Shear Wave Velocity from Free-Free Resonant Column Tests of 134 Tuff Specimens



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-51. Variation in Poisson's Ratio with Constrained Compression Wave Velocity from Free-Free Resonant Column Tests of 134 Tuff Specimens

General Relationship between Material Damping Ratio and Seismic Wave Velocities

The general relationship between material damping ratio in shear ($D_{S\ min}$) and shear wave velocity (V_S) is shown in Figure 6.5-52. The general relationship between the material damping ratio in unconstrained compression ($D_{C\ min}$) and unconstrained compression wave velocity (V_C) is shown in Figure 6.5-53. Both shear and unconstrained compression wave velocities show similar trends versus the material damping ratios, with material damping ratios decreasing modestly with increase in wave velocity.

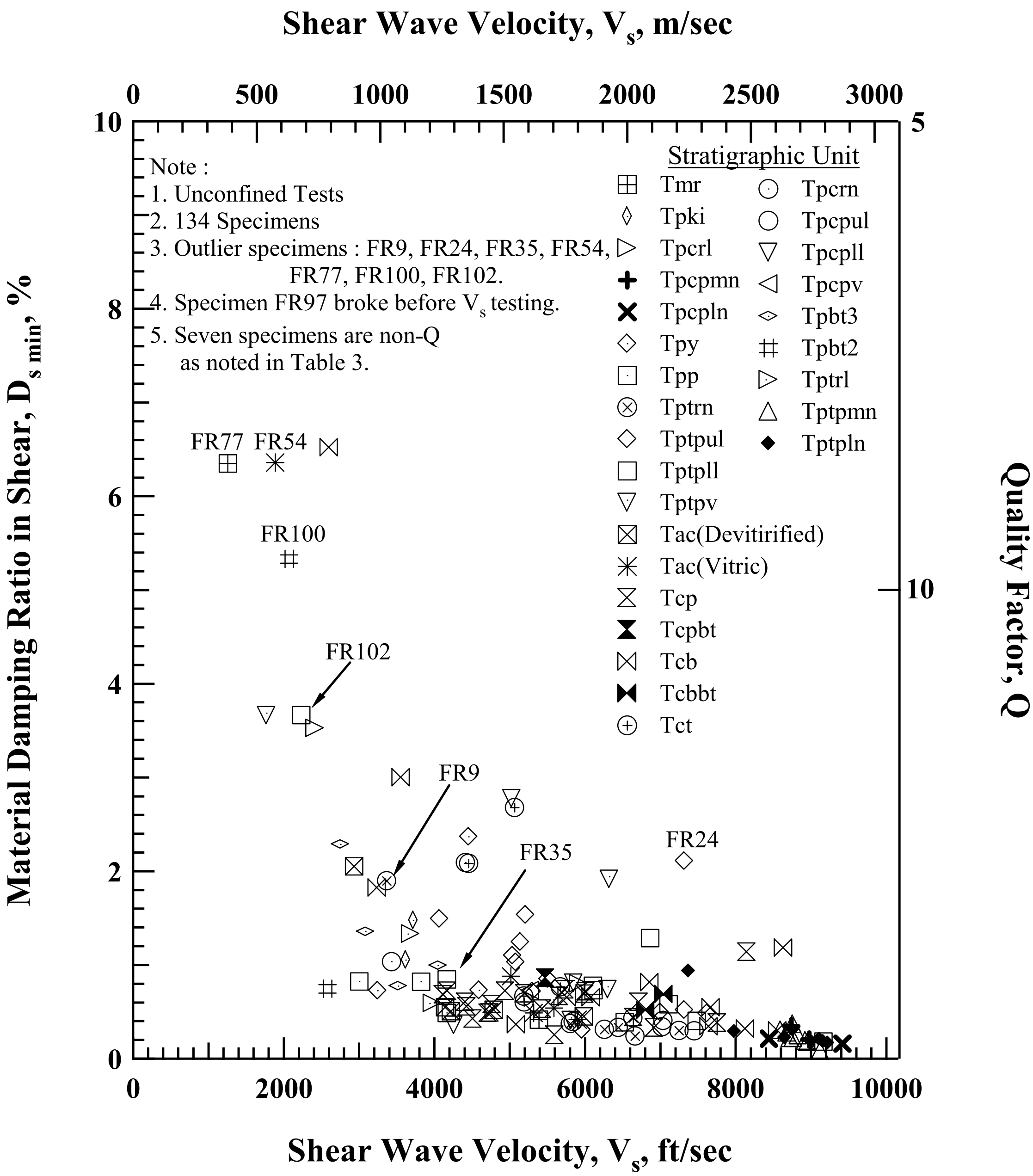
General Relationship between $D_{S\ min}$ and $D_{C\ min}$

The general relationship between material damping ratio in shear ($D_{S\ min}$) and material damping ratio in unconstrained compression ($D_{C\ min}$) is shown in Figure 6.5-54. As seen in the figure, $D_{S\ min}$ increases as $D_{C\ min}$ increases, with the values of $D_{S\ min}$ slightly greater than $D_{C\ min}$. The larger values of $D_{S\ min}$ and $D_{C\ min}$, defined as values greater than 1.0%, are felt to be mostly caused by "flaws" in the cores. Therefore, it is instructive to investigate the relationship between $D_{S\ min}$ and $D_{C\ min}$ for those cores with material damping values less than 1.0%. This comparison is show in Figure 6.5-55. The unity line is shown by the solid line in the figure and the least square, best-fit relationship is shown by the dashed line. As seen in Figure 6.5-55, the general relationship is given by:

$$D_{C\ min} = 0.87\ D_{S\ min}$$

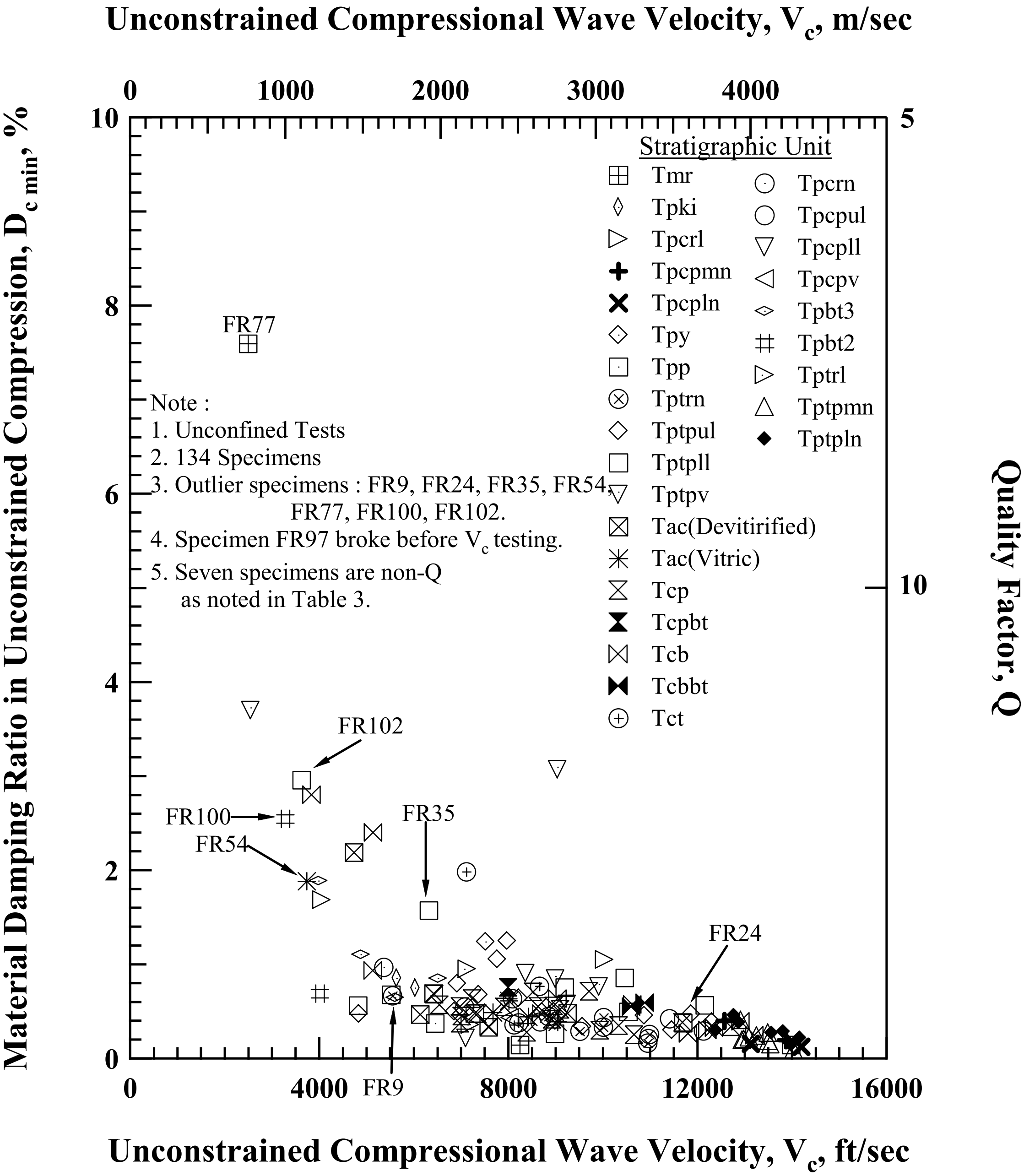
Outlier Specimens of Material Damping Ratio

A total of eight specimens are specified as outliers in describing the general trend of material damping ratio. Four specimens, FR9, FR35, FR97, and FR102, are excluded because they are already outliers in describing the seismic wave velocities. Another four specimens, FR25, FR54, FR77, and FR100, are also excluded in describing the general trend of material damping ratio because of the flaws present in the specimens. Figures 6.5-56 through 6.5-59 show the photographs of the additional four outlier specimens that are excluded from the material damping ratios trends. Specimen FR25 shown in Figure 6.5.56 clearly displays the large voids and lithophysae that impacted the measured results. FR54 shown in Figure 6.5.57 clearly displays small cracks that break through to the surface of the sample and also affect the measured properties for this sample. These flaws distort the resonance motion of the specimens and produce the outlier material damping ratio values. Specimens FR77 and FR100 shown in Figures 6.5.58 and 6.5.59 have very soft surfaces that would crumble apart with the touch of a finger. Although they do not show a detectable flaw in appearance, they have a high probability of internal flaws due to their softness. For all four of these samples, their material damping ratios were biased when compared with the material damping ratio of the similar tuff specimens from the same or similar geologic units. Hence, they are excluded as outliers in representing the general trend of material damping ratio.



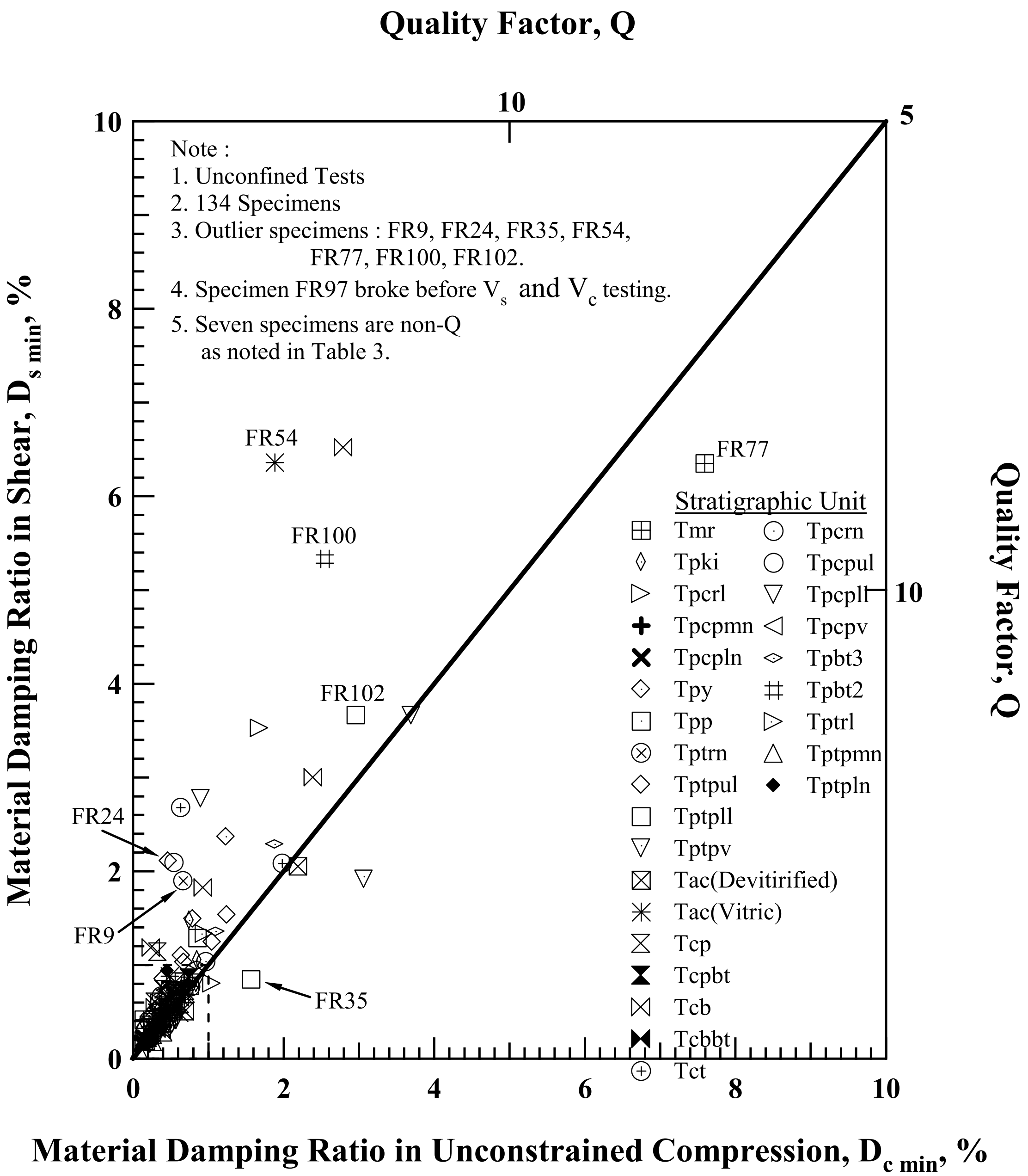
Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-52. Variation in Material Damping Ratio in Shear with Shear Wave Velocity from Free-Free Resonant Column Tests of 134 Tuff Specimens



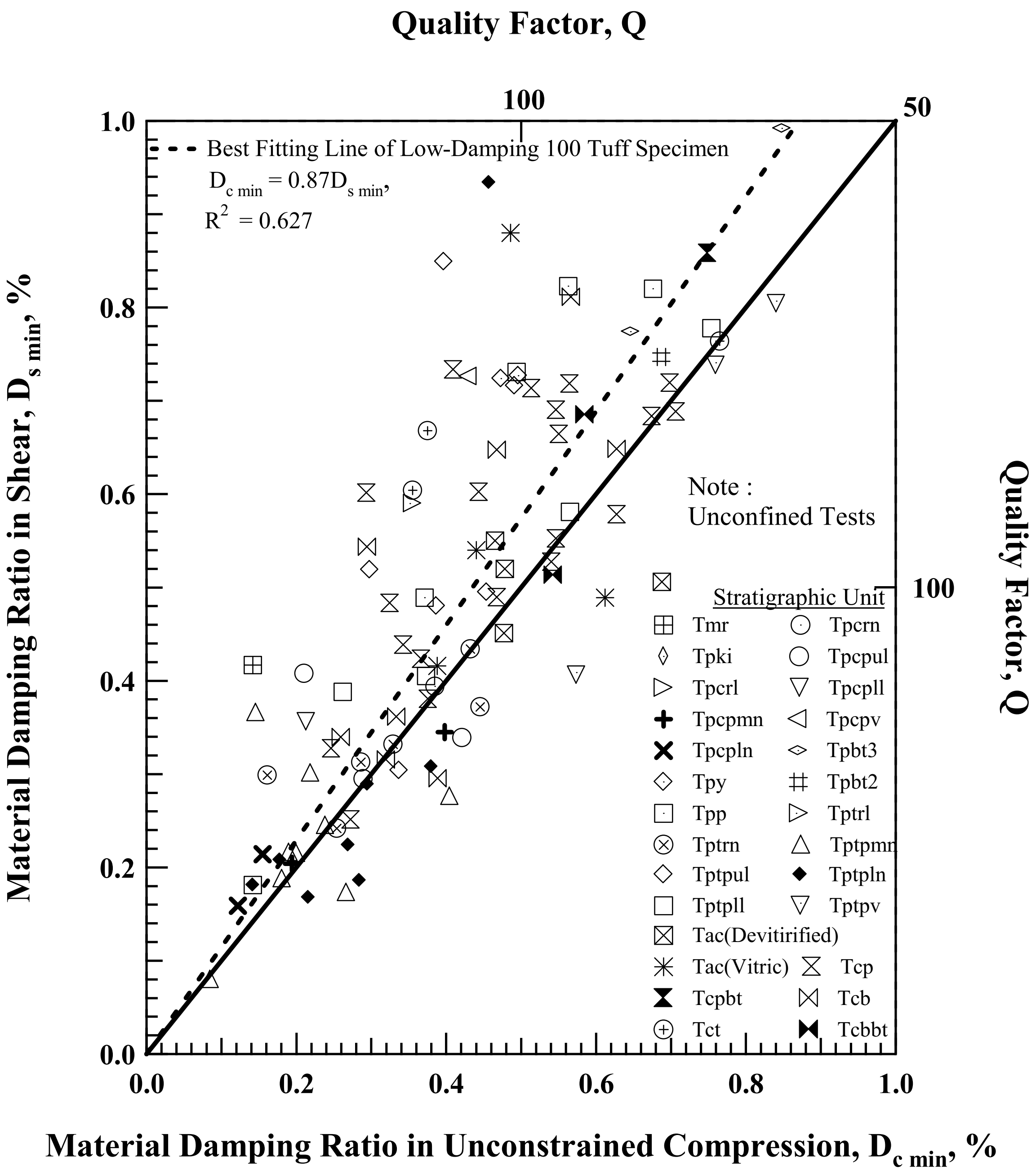
Source: DTN:MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-53. Variation in Material Damping Ratio in Unconstrained Compression with Unconstrained Compression Wave Velocity from Free-Free Resonant Column Tests of 134 Tuff Specimens



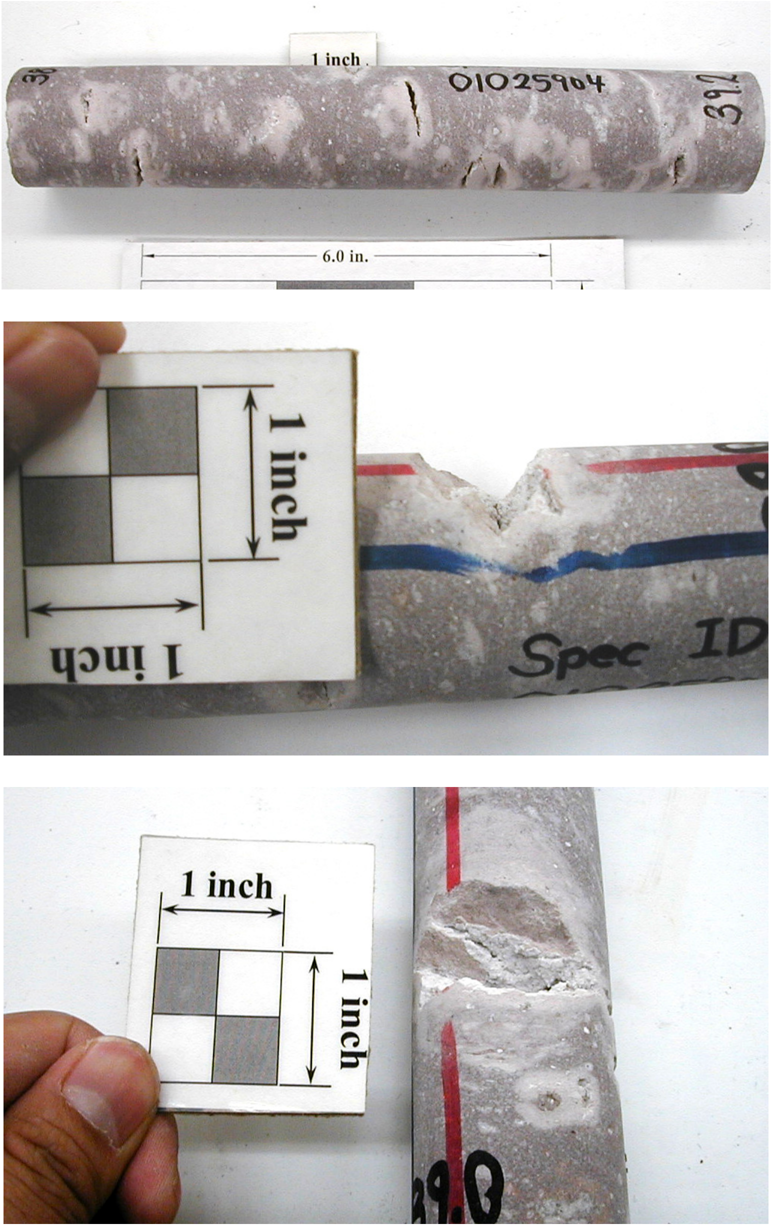
Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-54. Relationship between Material Damping Ratios in Shear and Unconstrained Compression; Free-Free Resonant Column Tests of 134 Tuff Specimens



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

Figure 6.5-55. Relationship between Material Damping Ratios in Shear and Unconstrained Compression; Free-Free Resonant Column Tests of 100 Tuff Specimens with Material Damping Ratios Less Than 1.0%

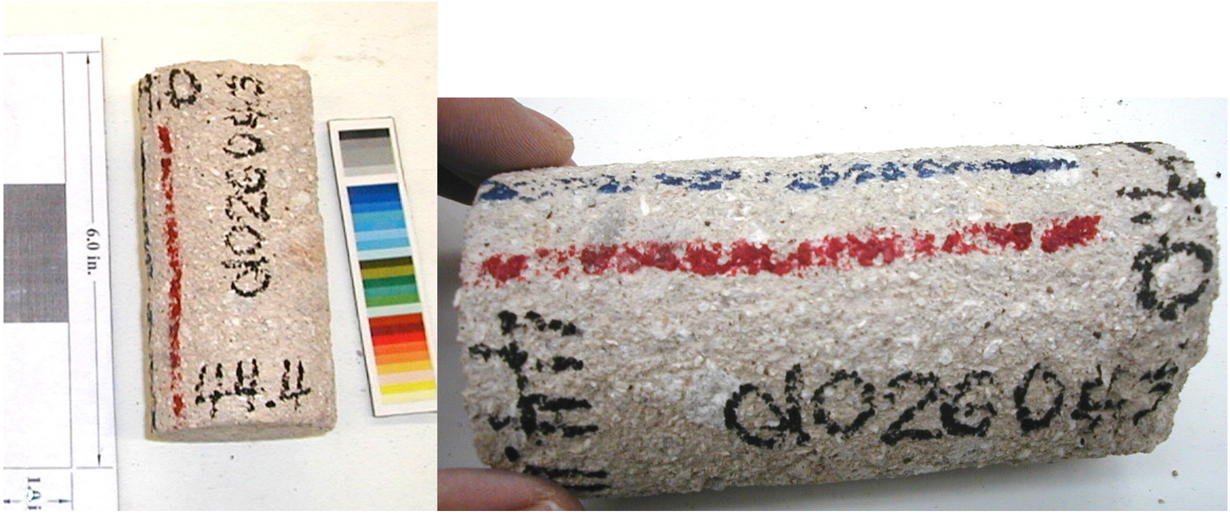


NOTES: SMF ID.: 01025904
Stratigraphic Unit: Tptpul
Borehole: ESF-HD-TEMP-13
Depth: 38.3 to 39.2 ft.

Figure 6.5-56. Photograph of Specimen FR24

NOTES: SMF ID.: 01025898
Stratigraphic Unit: Tac(Vitric)
Borehole: USW SD-7
Depth: 1468.2 to 1468.9 ft.

Figure 6.5-57. Photograph of Specimen FR54



NOTES: SMF ID.: 01026043
Stratigraphic Unit: Tmr
Borehole: UE-25 NRG#2b
Depth: 44.0 to 44.4 ft.

Figure 6.5-58. Photograph of Specimen FR77

NOTES: SMF ID.: 01026003
Stratigraphic Unit: Tpbt2
Borehole: USW SD-9
Depth: 248.0 to 249.0 ft.

Figure 6.5-59. Photograph of Specimen FR100

Seismic Wave Velocity Profile versus Depth

The seismic wave velocities measured in the URC tests were compiled according to the geologic units present at Yucca Mountain and as a function of depth. This provides a means of viewing variations in seismic wave velocity with depth and geologic unit. The depths presented in Table 6.5-7 for the units are based on the average depth identified in scientific notebook SN-M&O-SCI-048-V1 (Wong and Stokoe 2007 [DIRS 183328]). The depths are assumed and are not intended to present actual depths at which the samples were collected; they are provided strictly so that the information can be presented stratigraphically in the data plots. A statistical analysis of the results was performed using the same method described in Section 6.2.5.2. The distribution of seismic wave velocity for each stratigraphic unit was assumed to have a log-normal distribution. Also, Table 6.5-7 presents the median, 16-percentile and 84-percentile values of the seismic wave velocities of each stratigraphic unit. Using these values, profiles of seismic wave velocities versus depth from the cores were established. The V_S profile over the entire depth is shown in Figure 6.5-60. Expanded profiles of shear wave velocities are shown in Figures 6.5-61, 6.5-62, and 6.5-63. As seen in the figures, the distribution of seismic wave velocities of the cores shows a reasonable trend with stratigraphic unit. The shear wave velocities decrease from the highest to the lowest velocities in the following order; nonlithophysal welded tuff (Tpcrn, Tpcpmn, Tpcpln, Tptrn, Tptpmn, Tptpln), lithosphysal welded tuff (Tpcrl, Tpcpul, Tpcpll, Tptrl, Tptpul, Tptpll), moderately welded tuff (Tcp, Tcb, Tct), and non-welded tuff (Tmr, Tpki, Tpp, Tpy, Tac). Figure 6.5-64 presents the comparison of shear wave velocity values of the Tiva Canyon Tuff and the Topopah Spring Tuff units. The variation of shear wave velocities along the depth in both stratigraphic units shows a similar pattern. This comparison shows that similar geological processes occurred in both units (i.e., both units represent eruptive occurrences or cooling units).

The same series of figures is shown for the unconstrained compression wave velocity (V_C) as follows: (1) Figure 6.5-65 presents the summary profile and (2) Figures 6.5-66, 6.5-67, and 6.5-68 show expanded profiles. The series of figures is also repeated for the constrained compression wave velocity profile (V_P) in Figures 6.5-69 through 6.5-72. As in the V_S profile, the V_C and V_P profiles show the same trends with stratigraphic units.

Figures 6-5.60 through 6-5.62 present a comparison of the in-situ shear wave velocity ranges determined with the SASW tests with the shear wave velocities measured in the Free-Free URC tests in the laboratory. The red dot and solid line shows the shear wave velocity range measured in tunnel. The block dot and solid line shows the shear wave velocity range measured from the ground surface. The shear wave velocities in the field are generally less than the shear wave velocities measured in the laboratory. This is to due to the presence of fractures, cracks, and other flaws in the field measurements that do not occur in the intact cores tested in the laboratory. The overall variation of the shear wave velocities in field with the stratigraphic units shows much less correlation than the variation of the shear wave velocities measured in the laboratory.

Table 6.5-7. Median, 16 Percentile and 84 Percentile of Seismic Wave Velocities in Each Stratigraphic Unit

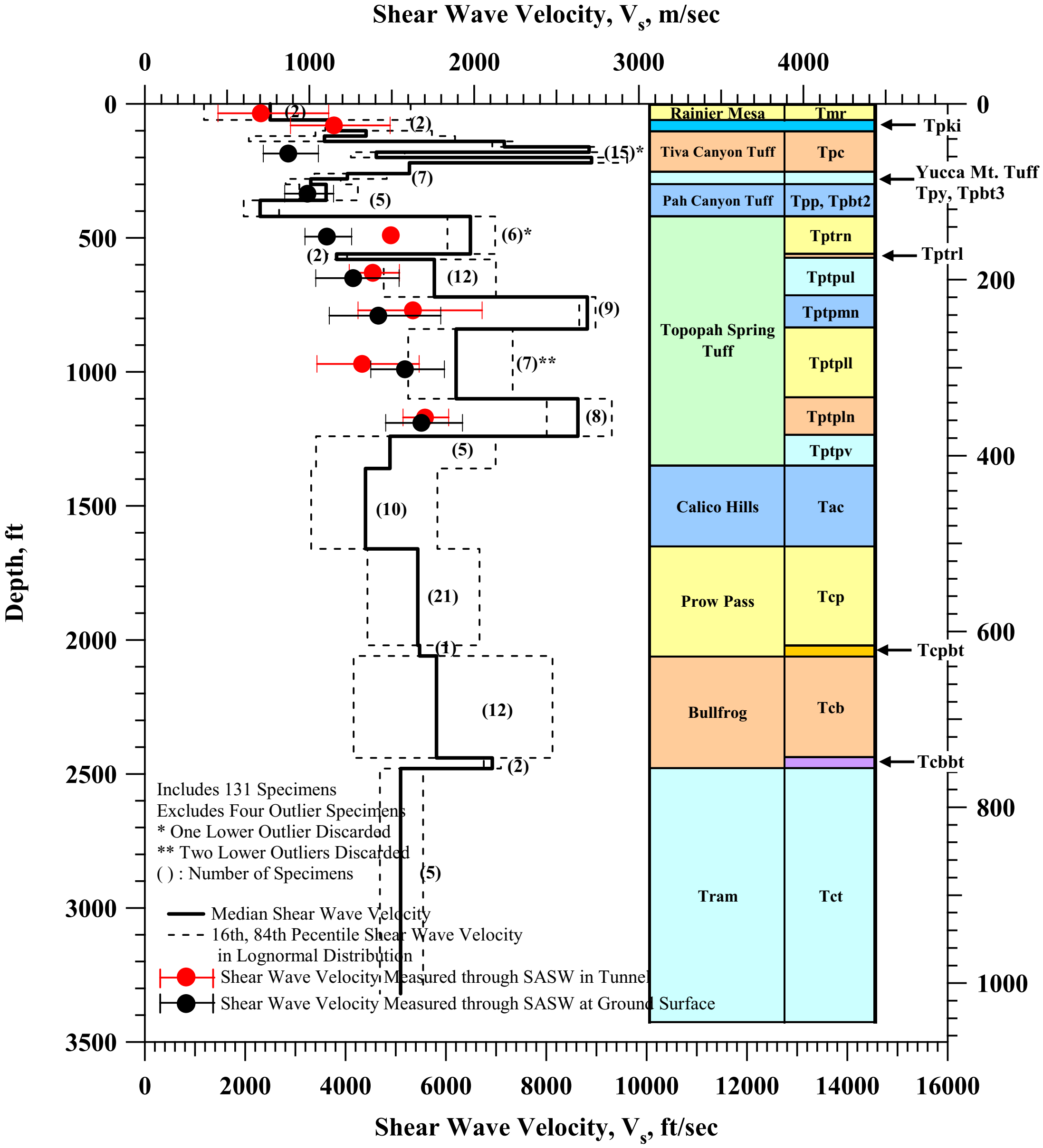
Strat. Unit	No. of Specimens	Depth of Unit (ft)		V_s (fps)			V_c (fps)			V_p (fps)		
		Top	Bottom	Median	16th Percentile	84th Percentile	Median	16th Percentile	84th Percentile	Median	16th Percentile	84th Percentile
Tmr	2	0	60	2,497	1,177	5,297	4,283	2,193	8,363	5,108	2,916	8,946
Tpki	2	60	100	3,668	3,597	3,740	5,828	5,556	6,113	6,656	6,618	6,694
Tpcrn	3	100	120	4,409	3,399	5,718	6,855	5,446	8,629	7,685	6,340	9,316
Tpcrl	2	120	140	3,579	2,072	6,183	6,042	3,481	10,487	7,803	4,818	12,638
Tpcpul	3	140	160	7,165	6,926	7,412	11,486	10,915	12,086	12,185	11,549	12,856
Tpcpmn	2	160	180	8,855	8,691	9,022	13,188	12,307	14,132	13,419	12,245	14,707
Tpcpll	2	180	200	4,612	4,108	5,178	7,683	6,852	8,616	10,525	9,552	11,598
Tpcpln	2	200	220	8,901	8,242	9,612	13,639	12,910	14,409	14,184	13,812	14,566
Tpcpv	$1^{(1)}$	220	260	5,273	5,273	5,273	8,039	8,039	8,039	8,902	8,272	9,580
Tpy	3	260	280	4,035	3,377	4,822	6,260	5,052	7,757	6,599	5,415	8,041
Tpbt3	4	280	300	3,306	2,803	3,900	5,141	4,203	6,288	5,978	5,065	7,055
Tpp	3	300	360	3,615	3,078	4,246	5,540	4,795	6,400	5,935	4,986	7,064
Tpbt2	2	360	420	2,297	1,970	2,677	3,610	3,138	4,153	4,091	3,834	4,365
Tptrn	$6^{(2)}$	420	540	6,491	6,033	6,983	10,022	9,237	10,873	10,589	9,951	11,267
Tptrl	2	540	560	3,824	3,628	4,031	7,164	7,118	7,210	8,084	6,984	9,358
Tptpul	12	560	700	5,771	4,760	6,997	9,158	7,529	11,141	11,169	9,996	12,481
Tptpmn	9	700	840	8,817	8,657	8,980	13,307	12,942	13,681	13,610	13,157	14,077
Tptpll	$7^{(3)}$	840	1100	6,203	5,248	7,330	9,610	7,900	11,691	11,107	9,844	12,531
Tptpln	8	1100	1240	8,633	8,007	9,308	13,421	12,780	14,093	13,952	13,400	14,527
Tptpv	5	1240	1360	4,886	3,415	6,990	7,428	5,144	10,726	8,871	6,072	12,960
Tac	10	1360	1660	4,397	3,316	5,830	6,851	5,330	8,807	7,451	5,939	9,347
Tcp	21	1660	2020	5,438	4,434	6,670	8,491	6,986	10,319	8,989	7,454	10,840
Tcpbt	1	2020	2060	5,475	5,475	5,475	8,004	8,004	8,004	8,052	8,052	8,052
Tcb	12	2060	2440	5,814	4,159	8,126	8,849	6,284	12,459	10,275	8,202	12,871
Tcbbt	2	2440	2480	6,924	6,756	7,096	10,750	10,551	10,953	11,159	10,979	11,342
Tct	5	2480	3300	5,096	4,684	5,545	8,023	7,482	8,603	8,734	8,370	9,115

Notes : (1) One specimen broken after V_p test and V_c and V_s test

(2) Data of One Outlier Specimen Discarded

(3) Data of Two Outlier Specimens Discarded

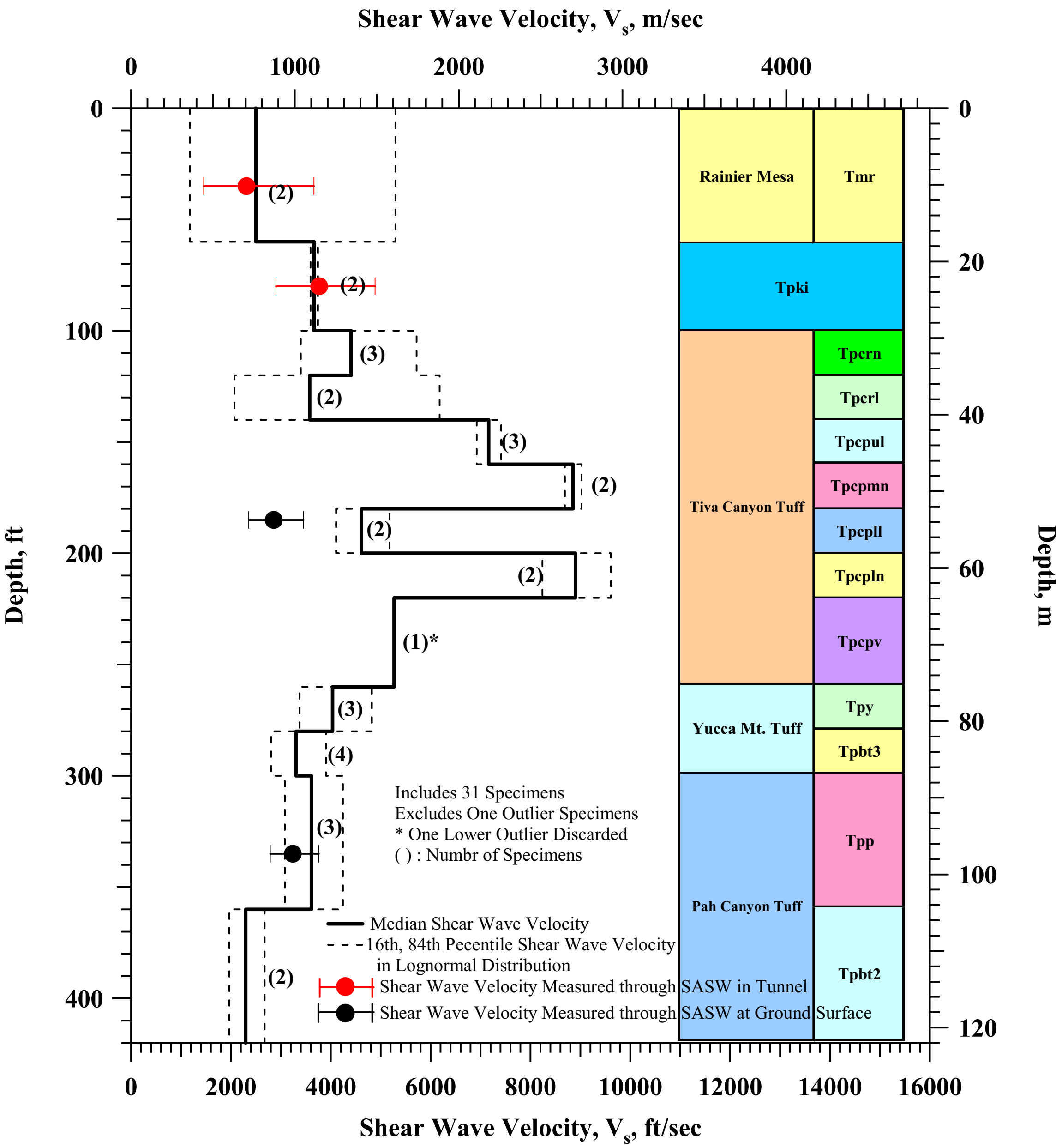
NOTE: Information presented in this table was developed following the steps identified in Section 6.2.5.2 of this report and using DTN: MO0707FREEFREE.006 [DIRS 183287].



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

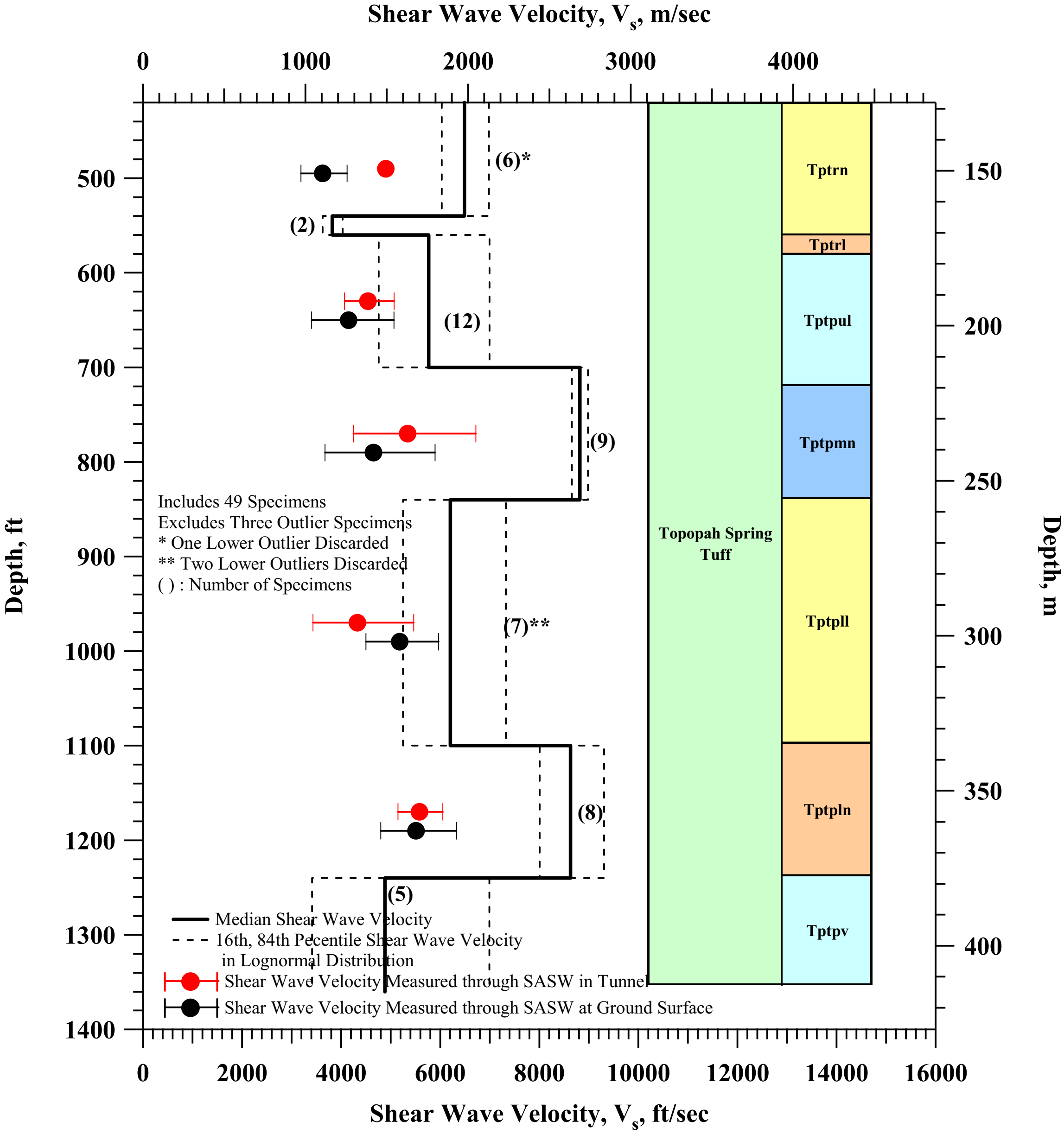
Figure 6.5-60. Summary Profile of Shear Wave Velocity vs. Depth from Free-Free Resonant Column Tests; Depth 0 ft ~ 3,500 ft



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

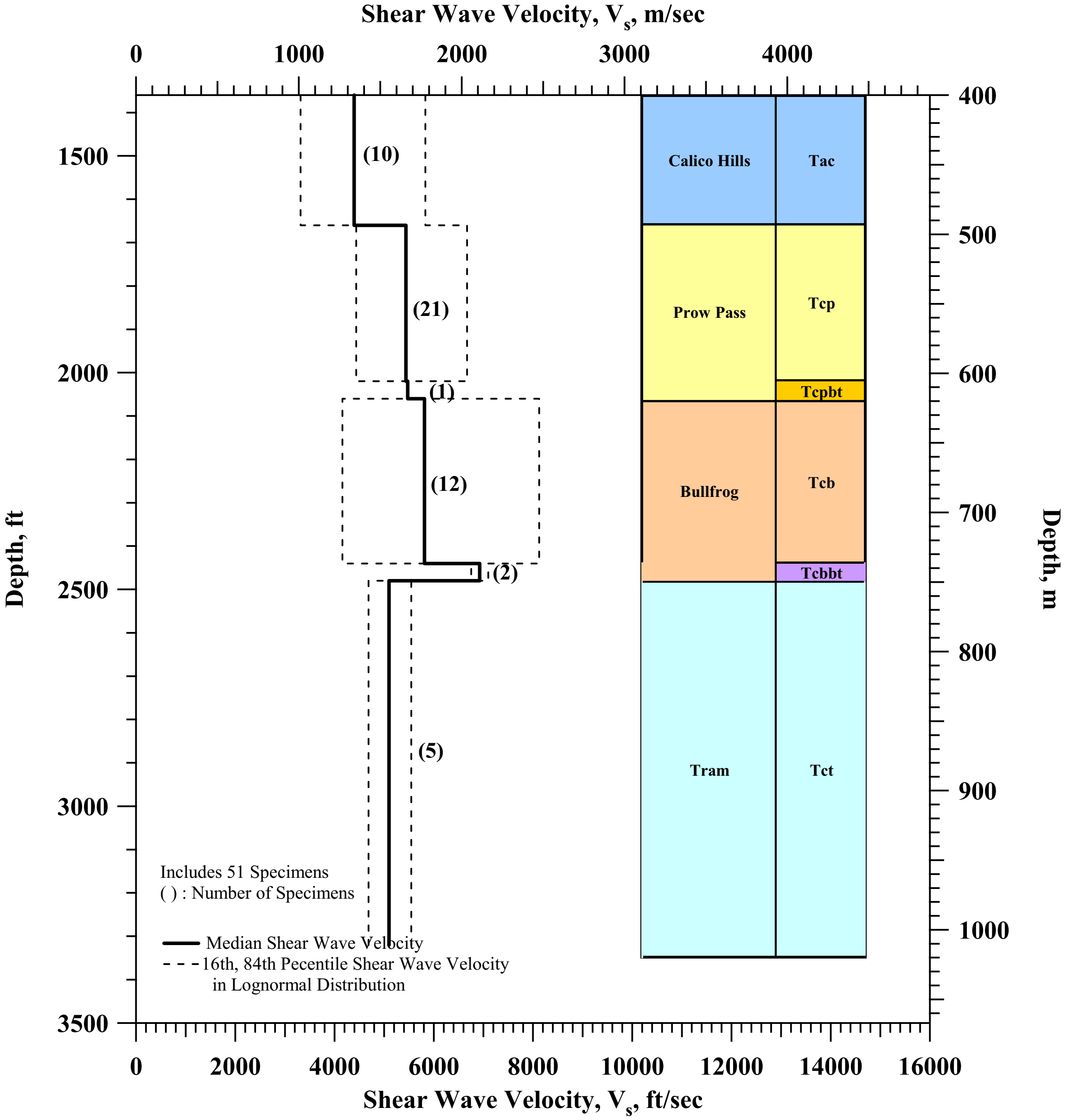
Figure 6.5-61. Expanded Profile of Shear Wave Velocity versus Depth from Free-Free Resonant Column Tests; Depth 0 ft ~ 420 ft



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

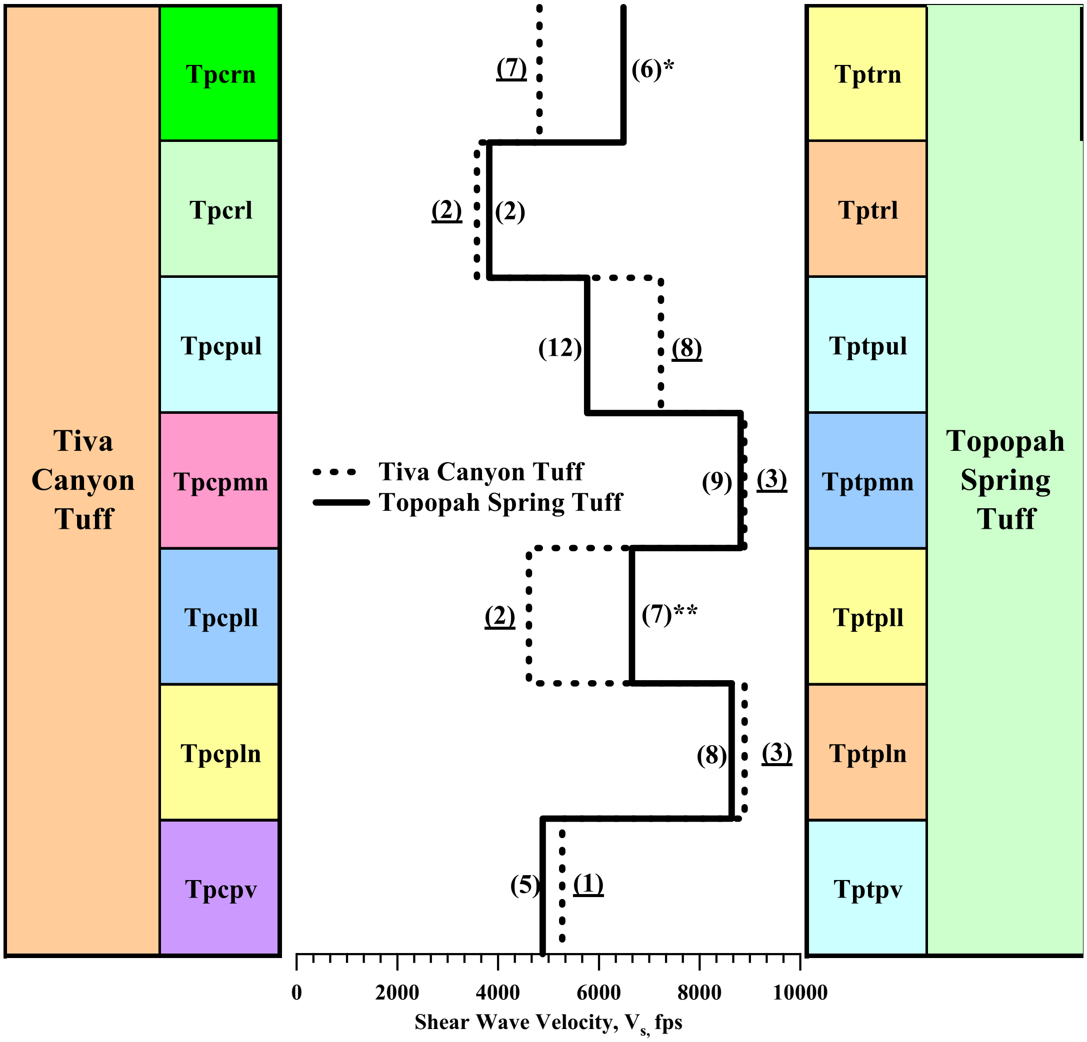
Figure 6.5-62. Expanded Profile of Shear Wave Velocity versus Depth from Free-Free Resonant Column Tests; Depth 420 ft ~ 1,360 ft



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

Figure 6.5-63. Expanded Profile of Shear Wave Velocity versus Depth from Free-Free Resonant Column Tests; Depth 1,360 ft ~ 3,500 ft



Notes : * One lower outlier discarded

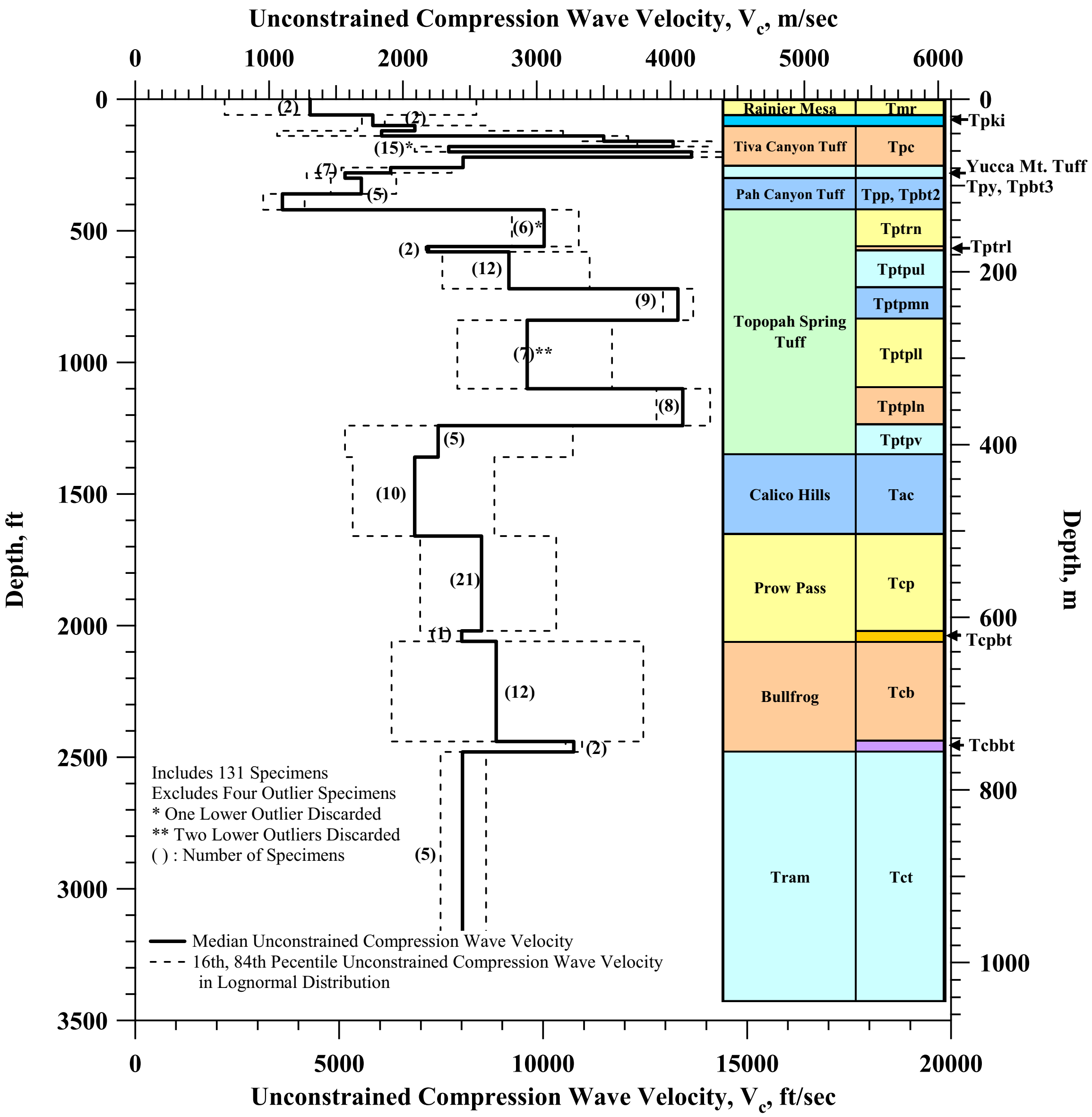
** Two Outlier discarded

( ) : Number of specimen from Tiva Canyon Tuff

( ) : Number of specimen from Topopah Spring Tuff

Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

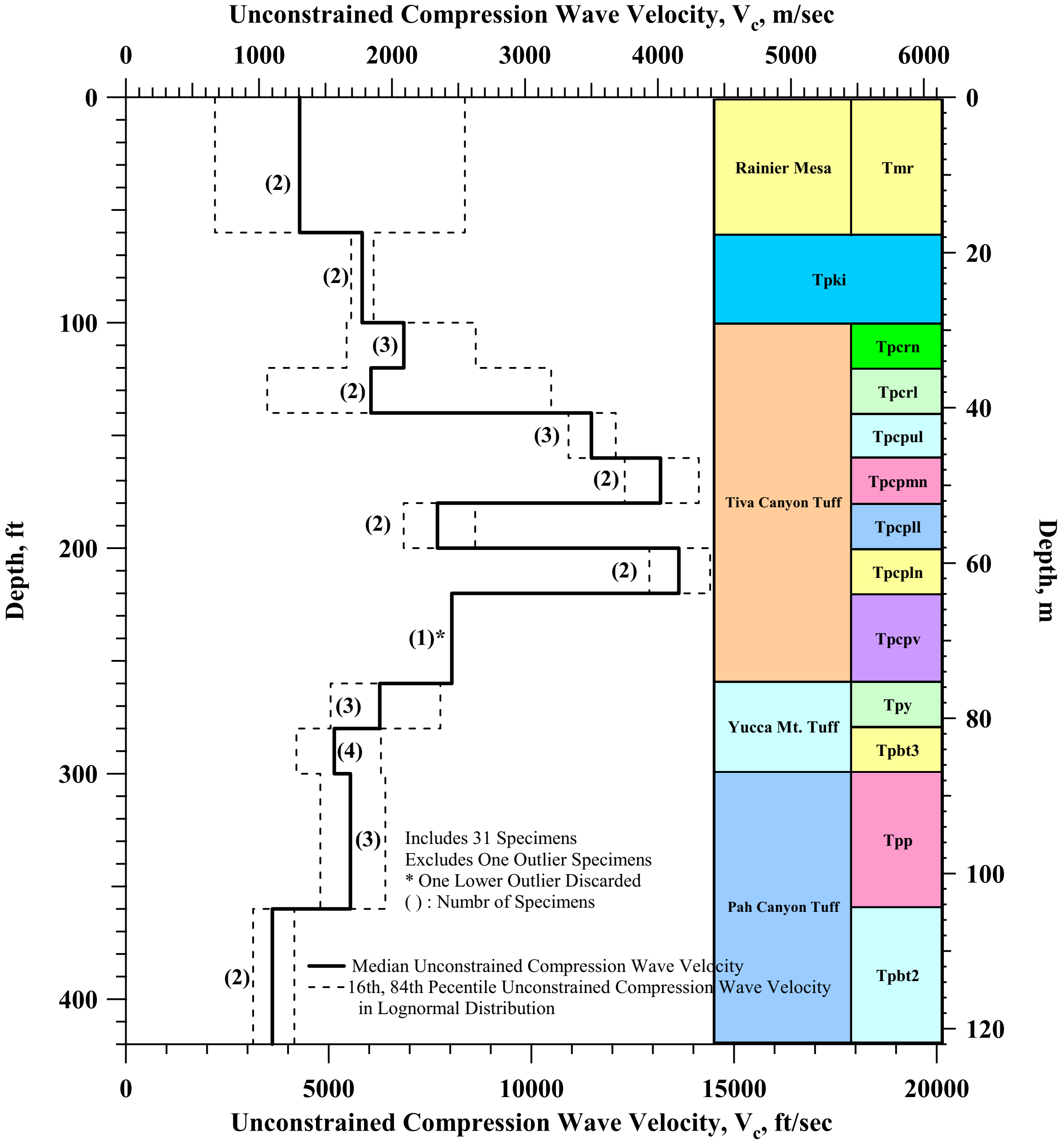
Figure 6.5-64. Comparison of Shear Wave Velocity Values of Tiva Canyon Tuff and Topopah Spring Tuff as Determined from Free-Free Resonant Column Tests



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, and Tpbt1.

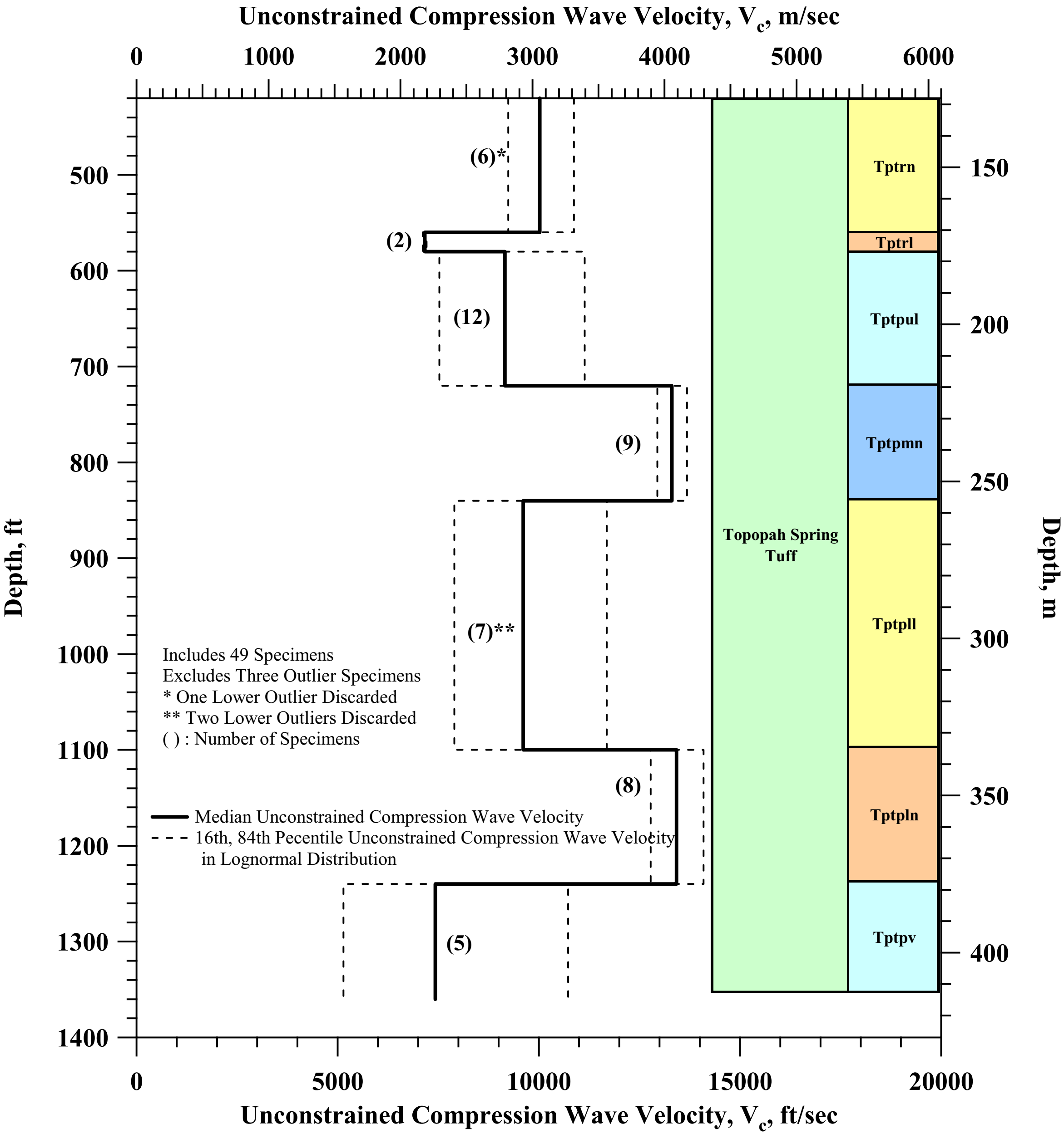
Figure 6.5-65. Summary Profile of Unconstrained Compression Wave Velocity vs. Depth from Free-Free Resonant Column Tests; Depth 0 ft ~ 3,500 ft



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

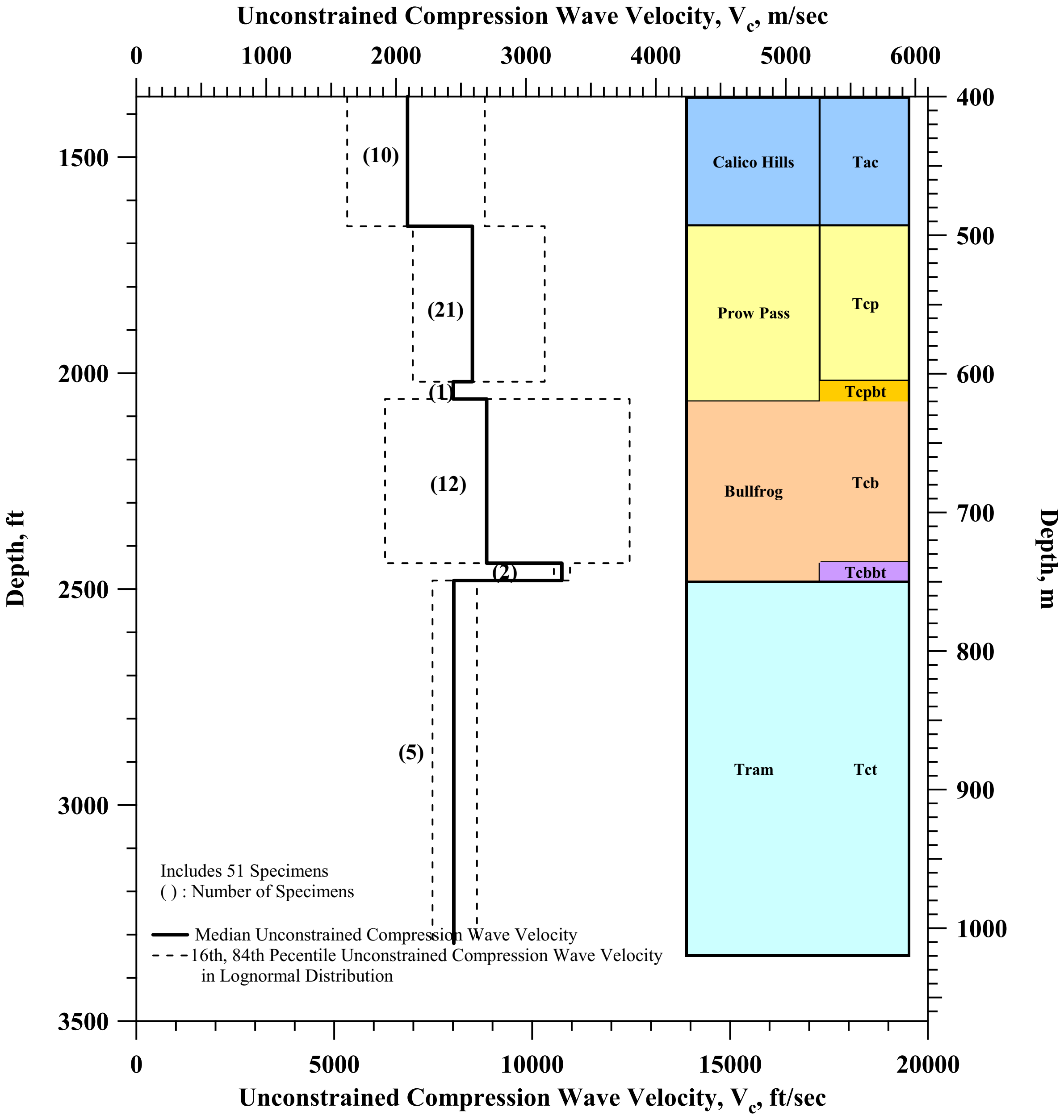
Figure 6.5-66. Expanded Profile of Unconstrained Compression Wave Velocity vs. Depth from Free-Free Resonant Column Tests; Depth 0 ft ~ 420 ft



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

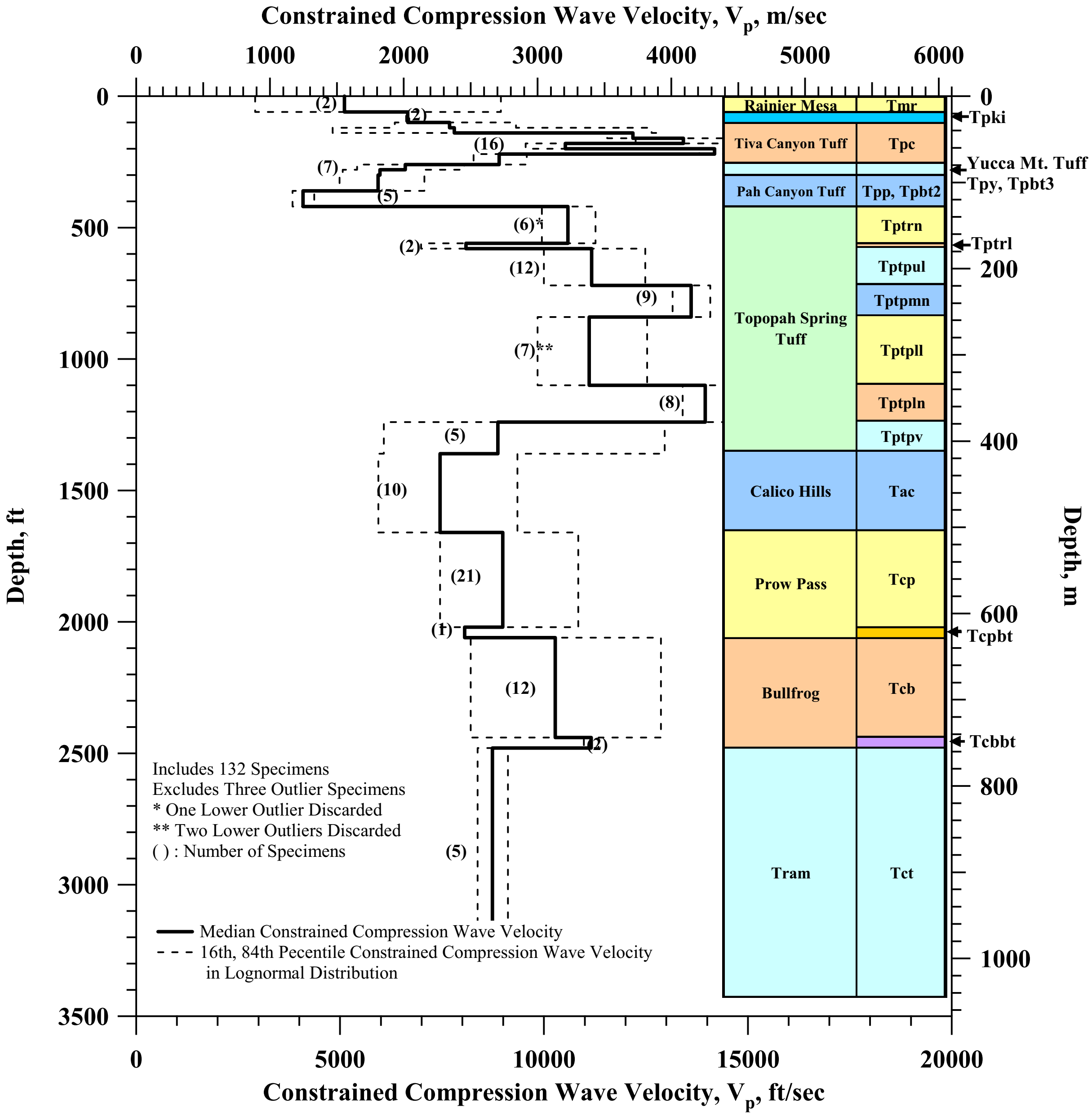
Figure 6.5-67. Expanded Profile of Unconstrained Compression Wave Velocity vs. Depth from Free-Free Resonant Column Tests; Depth 420 ft ~ 1,360 ft



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

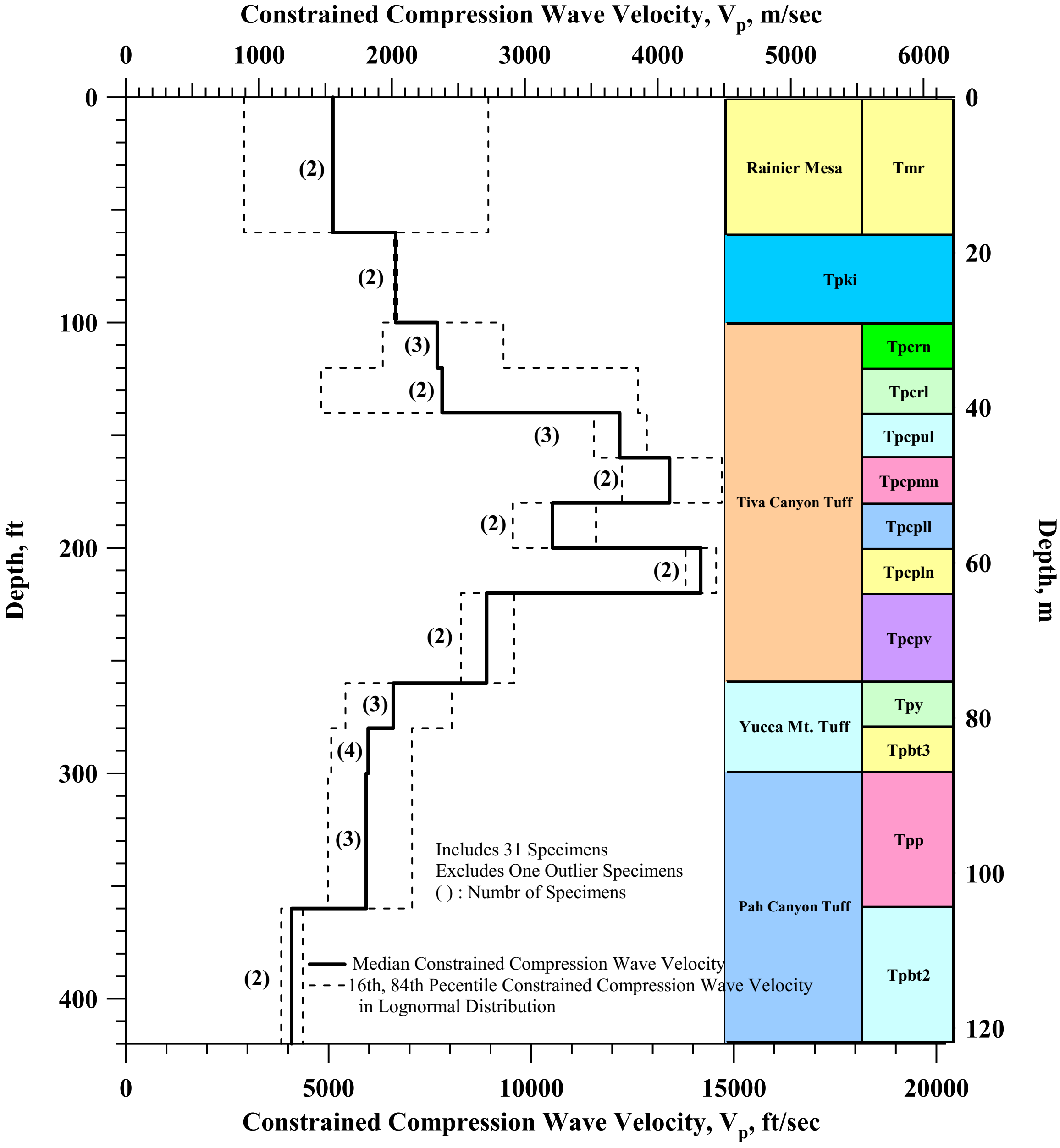
Figure 6.5-68. Expanded Profile of Unconstrained Compression Wave Velocity vs. Depth from Free-Free Resonant Column Tests; Depth 1,360 ft ~ 3,500 ft



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

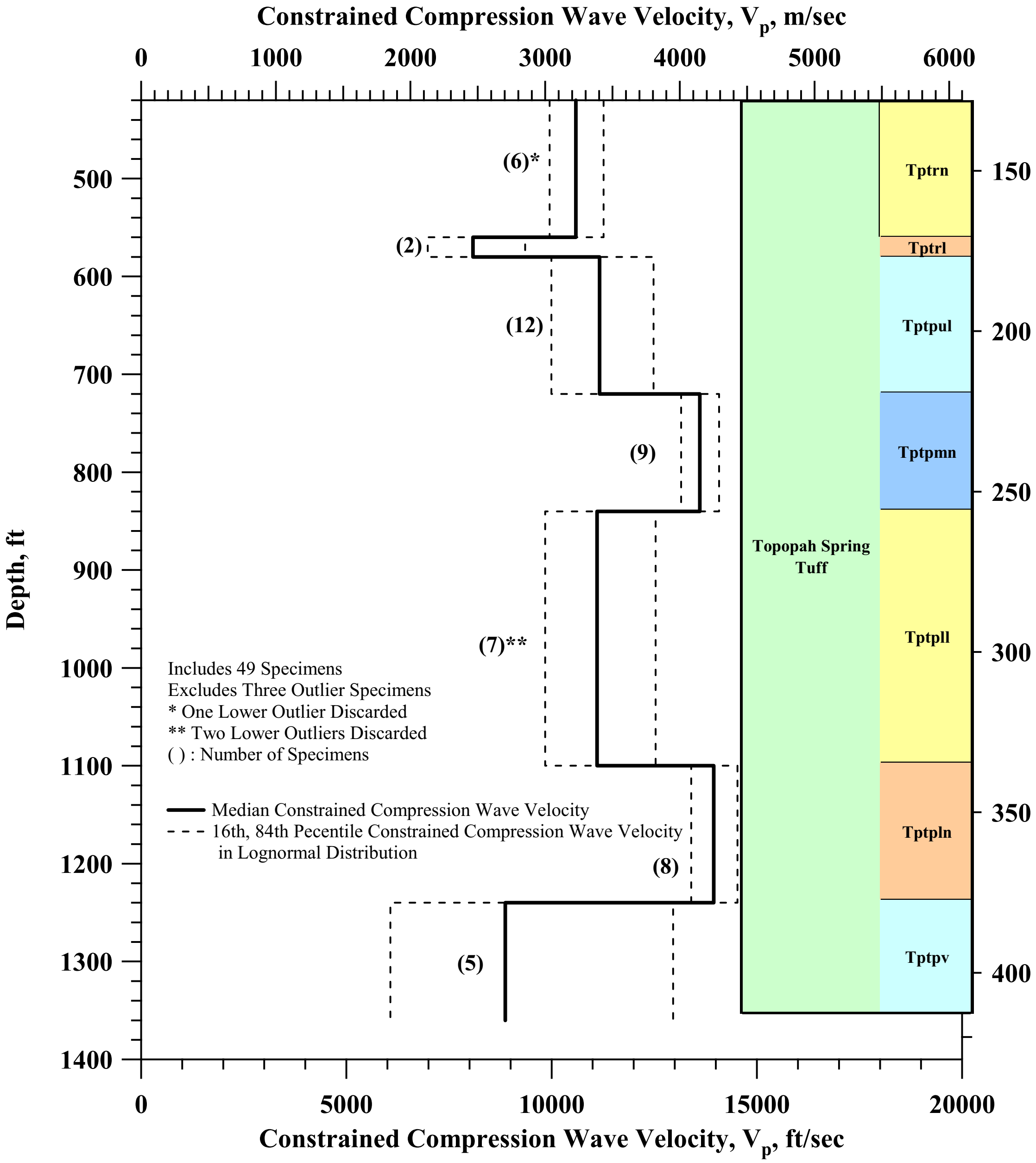
Figure 6.5-69. Summary Profile of Constrained Compression Wave Velocity vs. Depth from Free-Free Resonant Column Tests; Depth 0 ft ~ 3,500 ft



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

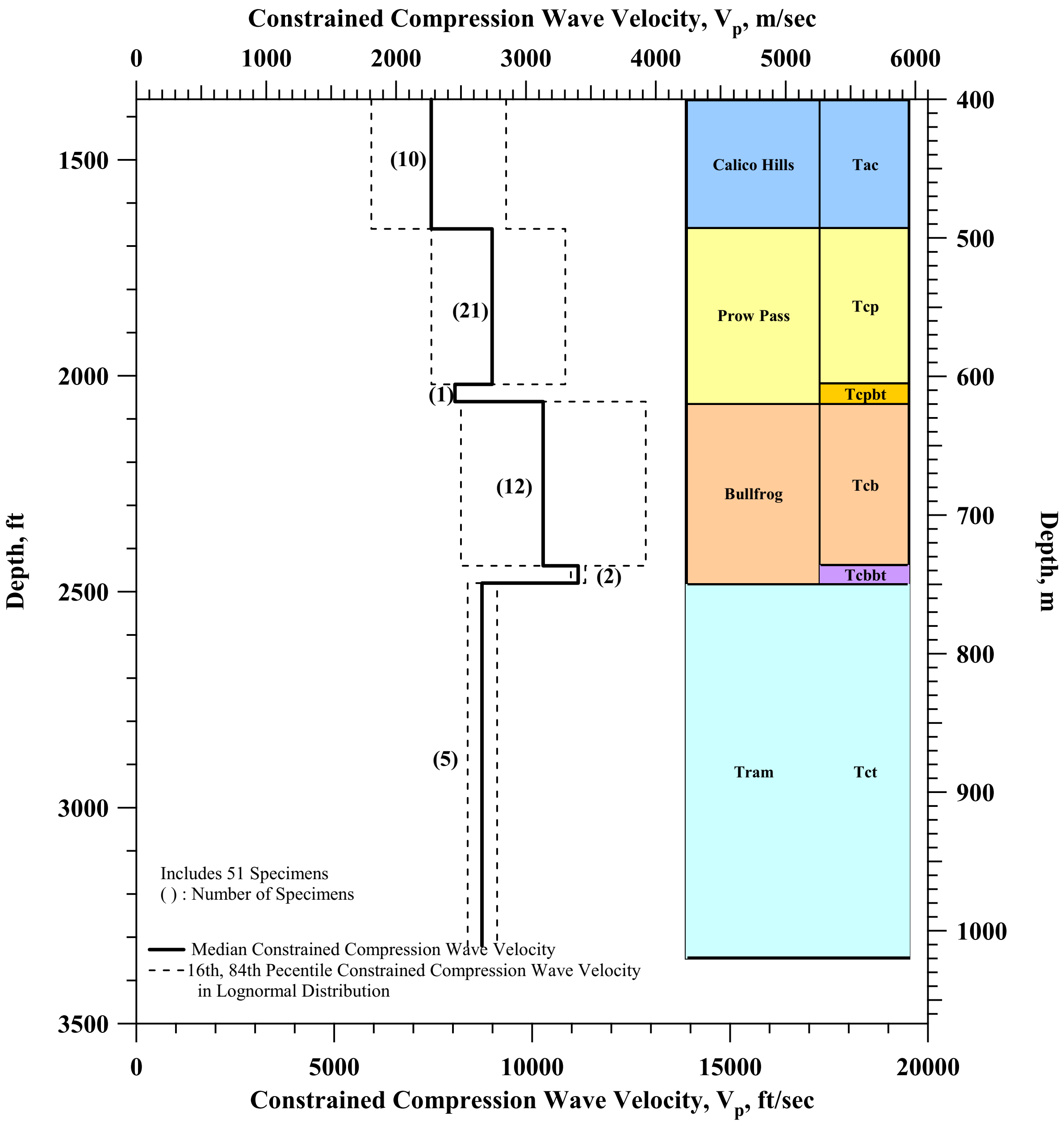
Figure 6.5-70. Expanded Profile of Constrained Compression Wave Velocity vs. Depth from Free-Free Resonant Column Tests; Depth 0 ft ~ 420 ft



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

Figure 6.5-71. Expanded Profile of Constrained Compression Wave Velocity vs. Depth from Free-Free Resonant Column Tests; Depth 420 ft ~ 1,360 ft



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

Figure 6.5-72. Expanded Profile of Constrained Compression Wave Velocity vs. Depth from Free-Free Resonant Column Tests; Depth 1,360 ft ~ 3,500 ft

Material Damping Ratio Profile versus Depth

Table 6.5-8 presents the median, 16th-percentile, and 84th-percentile values of the material damping ratios of each stratigraphic unit measured in the laboratory with the core. The test results generally indicate large differences between stratigraphic units when the material damping ratios are used for making the comparisons, as opposed to using seismic wave velocities for the comparisons. This is likely an artifact of the material damping ratio being more sensitive to flaws in the specimens than the seismic wave velocities. The summary profiles of material damping ratios in shear ($D_{S\ min}$) and material damping ratios in unconstrained compression ($D_{C\ min}$) are shown in Figures 6.5-73 and 6.5-74, respectively.

Table 6.5-8. Median, 16th-Percentile and 84th-Percentile of Material Damping Ratios in Each Stratigraphic Unit

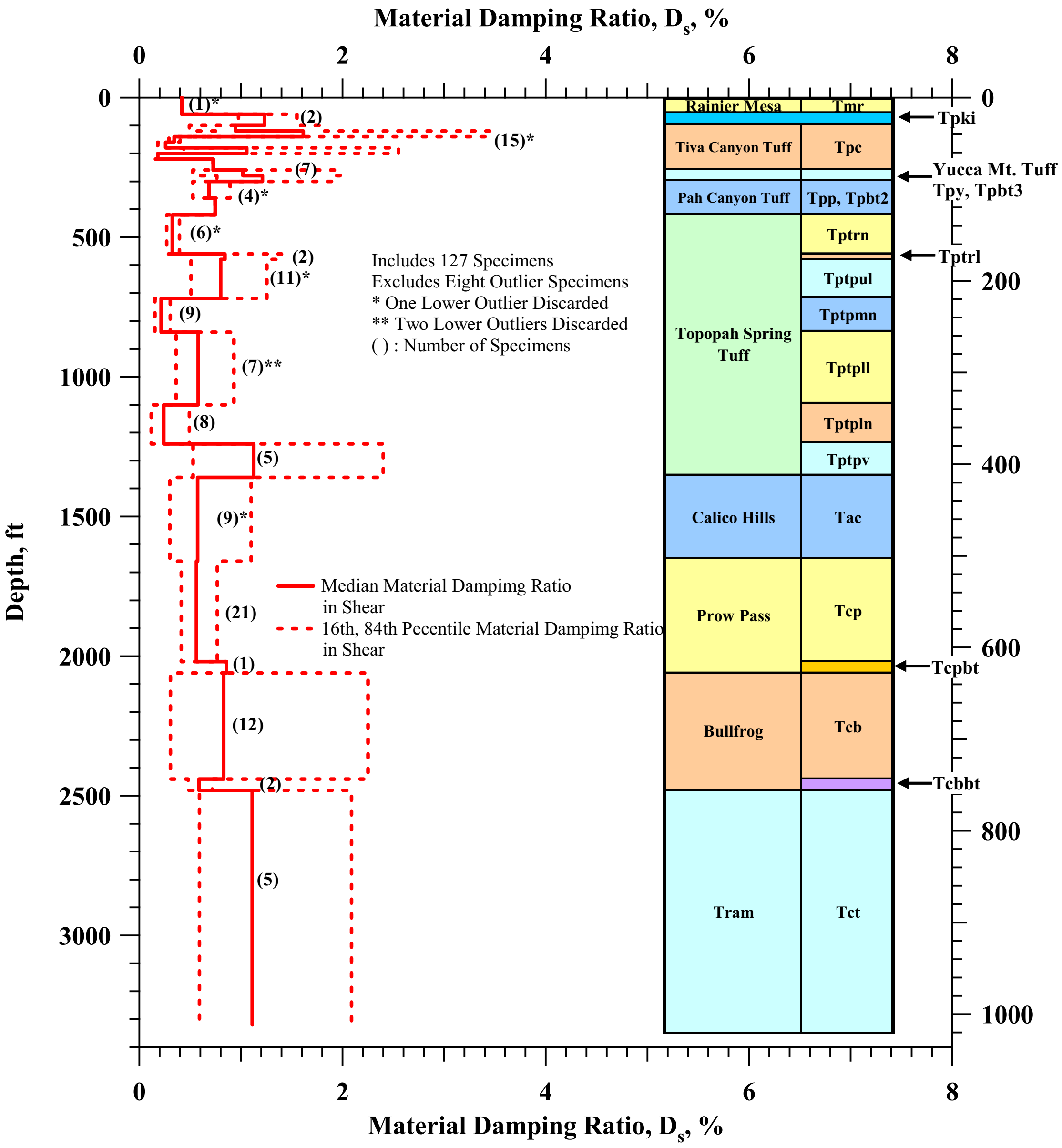
Strat. Unit	No. of Specimens	Depth of Unit (ft)		$D_{s\ min}$ (%)			$D_{c\ min}$ (%)		
		Top	Bottom	Median	16th Percentile	84th Percentile	Median	16th Percentile	84th Percentile
Tmr	1(2)	0	60	0.42	0.42	0.42	0.14	0.14	0.14
Tpki	2	60	100	1.23	0.97	1.55	0.80	0.73	0.87
Tpcrn	3	100	120	0.95	0.49	1.82	0.57	0.36	0.89
Tpcrl	2	120	140	1.61	0.76	3.45	1.29	0.94	1.78
Tpcpul	3	140	160	0.34	0.29	0.40	0.29	0.21	0.41
Tpcpmn	2	160	180	0.26	0.18	0.37	0.27	0.17	0.42
Tpcpll	2	180	200	1.06	0.44	2.55	0.42	0.20	0.89
Tpcpln	2	200	220	0.18	0.15	0.22	0.14	0.12	0.16
Tpcpv	1(1)	220	260	0.73	0.73	0.73	0.43	0.43	0.43
Tpy	3	260	280	1.02	0.53	1.98	0.63	0.37	1.09
Tpbt3	4	280	300	1.21	0.76	1.93	1.01	0.64	1.59
Tpp	3	300	360	0.69	0.53	0.89	0.52	0.39	0.68
Tpbt2	1(2)	360	420	0.75	0.75	0.75	0.69	0.69	0.69
Tptrn	6(2)	420	540	0.33	0.27	0.40	0.30	0.22	0.42
Tptrl	2	540	560	0.84	0.51	1.40	0.55	0.30	0.98
Tptpul	11(2)	560	700	0.80	0.51	1.26	0.55	0.34	0.88
Tptpmn	9	700	840	0.22	0.15	0.30	0.20	0.13	0.29
Tptpll	7(3)	840	1100	0.58	0.36	0.93	0.49	0.34	0.72
Tptpln	8	1100	1240	0.24	0.12	0.49	0.26	0.18	0.37
Tptpv	5	1240	1360	1.13	0.53	2.40	1.38	0.67	2.82
Tac	9(2)	1360	1660	0.57	0.30	1.10	0.53	0.26	1.09
Tcp	21	1660	2020	0.56	0.41	0.77	0.45	0.33	0.60
Tcpbt	1	2020	2060	0.86	0.86	0.86	0.75	0.75	0.75
Tcb	12	2060	2440	0.83	0.31	2.25	0.55	0.23	1.31
Tcbbt	2	2440	2480	0.59	0.48	0.72	0.56	0.53	0.59
Tct	5	2480	3300	1.11	0.59	2.09	0.64	0.31	1.30

Notes : (1) One specimen broken after V_p test and V_c and V_s test

(2) Data of One Outlier Specimen Discarded

(3) Data of Two Outlier Specimens Discarded

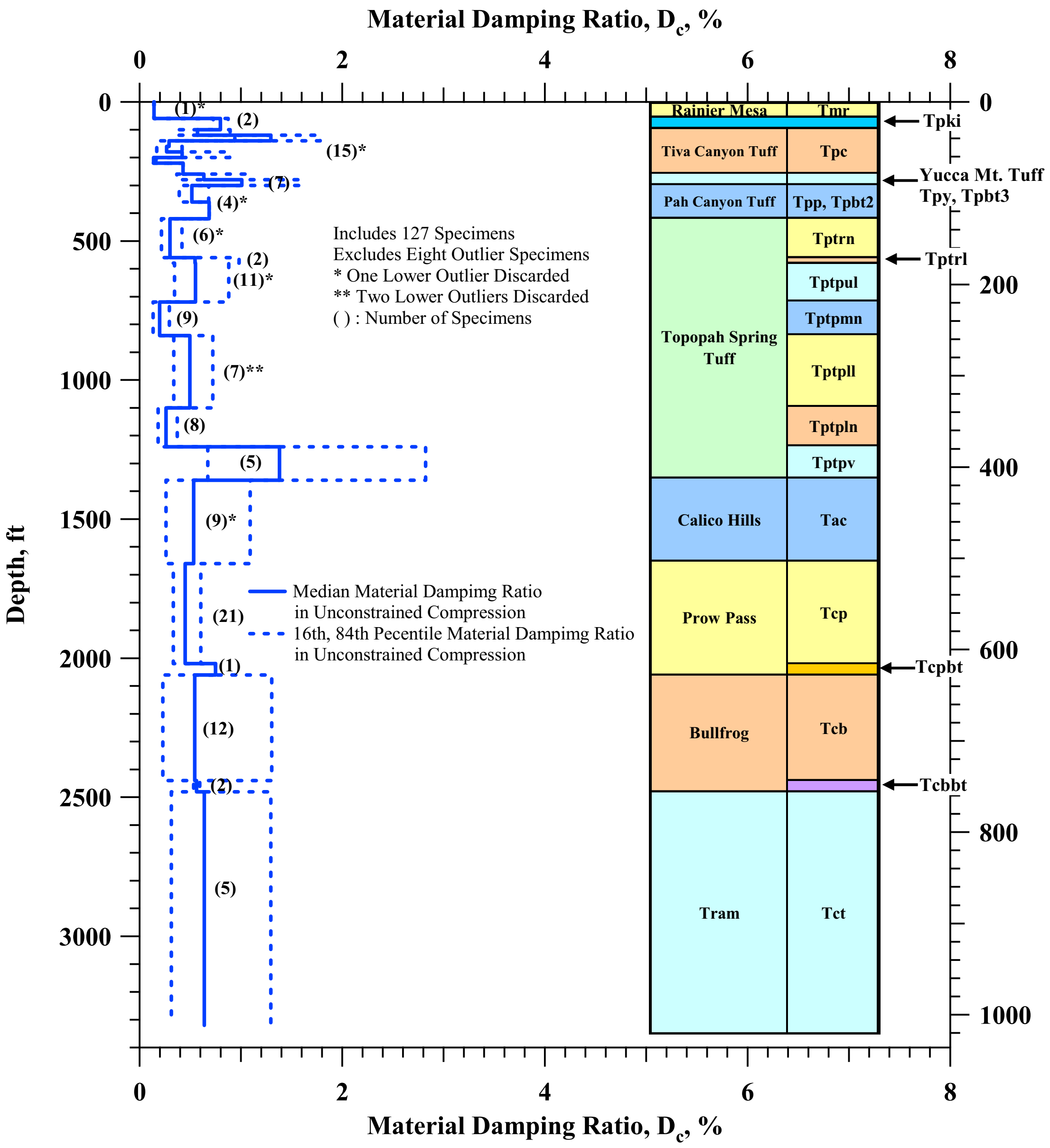
NOTE: Information presented in this table was developed following the steps identified in Section 6.2.5.2 of this report and using DTN: MO0707FREEFREE.006 [DIRS 183287].



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

Figure 6.5-73. Summary Profile of Material Damping Ratio in Shear versus Depth from Free-Free Resonant Column Tests



Source: DTN: MO0707FREEFREE.006 [DIRS 183287].

NOTE: The thicknesses of Rainier Mesa Tuff (Tmr), Tpki, and Tiva Canyon Tuff (Tpc) are assumed as follows: Tmr = 60 ft, Tpki = 40 ft, Tpc = 160 ft. The following material types are not included because of the lack of rock samples from these thin layers: Tpcrv, Tptrv, Tptpf/Tptrf, Tpbt1.

Figure 6.5-74. Summary Profile of Material Damping Ratio in Unconstrained Compression versus Depth from Free-Free Resonant Column Tests

7. CONCLUSION

This technical report presents data that were acquired for use in geotechnical analyses for the ITS structure foundations and in the development of seismic ground motion inputs for design and safety analysis. The types of data addressed are borehole logs, test pit logs, photomosaic maps, ring density tests, physical properties tests, shear wave velocity profiles, compression-wave velocity profiles, low-strain Poisson's ratio, low-strain shear modulus, normalized shear modulus variation with shear-strain, damping ratio in shear, damping ratio variation with shear-strain, unconstrained compression wave velocity, Young's modulus, material damping ratio in unconstrained compression, constrained compression wave velocity, constrained modulus, and total density.

7.1. SUMMARY

Field and geotechnical laboratory data are presented for three distinct geographic areas:

- The NPF Area, which includes the previously characterized WHB Area and the Aging Pad Area
- Surface locations over the planned repository footprint, including the crest of Yucca Mountain, Bleach Bone Ridge, Drill Hole Wash, Coyote Wash, Fran Ridge, Tea Cup Wash, and other areas
- The ESF and ECRB drifts.

In addition, geotechnical laboratory data are presented for a range of tuff materials acquired from the NPF Area and in the vicinity of Yucca Mountain.

Data Acquired at the NPF and Aging Pad Areas

Section 6.2 summarizes the results of the explorations and tests performed from 2004 through early 2007 in the NPF Area for the ITS structures. The type of exploration or test and the report section where the results are presented are as follows:

- 6.2.2 – Repository Facilities drilling program
- 6.2.3 – Static geotechnical laboratory testing of sonic core
- 6.2.4 – Mapping and logging of test pits
- 6.2.5 – SASW surveys in the NPF and Aging Pad Areas.

Data Acquired from Surface Testing in the Vicinity of the Repository Waste Emplacement Area

Section 6.3 summarizes the results of the SASW testing performed from 2004 through 2006, which overlaid the repository footprint or areas around Yucca Mountain that were of geologic interest. Areas outside the repository footprint were selected based on their geologic profiles, which indicated that geologic units of interest (Calico Hills and Prow Pass) were within 1,000 ft.

At these depths SASW surveys were able to sample the velocity of these units. Twenty-five SASW surveys were carried out over the repository footprint or at nearby sites of geologic interest.

Data Acquired in the ESF and ECRB Cross-Drift

Section 6.4 summarizes the data that were acquired in 2004 and 2005 along the North Ramp, Main Drift, and South Ramp of the ESF and in the ECRB cross-drift. Forty-five SASW surveys were carried out in the underground facilities to investigate the shear wave velocities of the exposed geologic units.

SASW Data Conclusions

The SASW data presented in this report, along with SASW data documented in previous reports, provide part of the technical basis for understanding the velocity characteristics of the repository block and the surface facilities area. In combination with velocity data from boreholes and an understanding of the geologic structure of the Yucca Mountain vicinity, they allow the velocities, their uncertainties, and their variability to be defined for ground motion site-response modeling.

Based on the profiling depth achieved by SASW testing, the results show that the seismic source, “Liquidator,” was an excellent source for deeper profiling. This source is more powerful in the low-frequency range (0.5 to 4.0 Hz) than a traditional vibroseis or other seismic source. On average, the profiling depth achieved with Liquidator is three to four times deeper than the depths achieved with the traditional vibroseis or bulldozer used in 2000 and 2001.

As shown by the profiles in Figures 6.2-15 and 6.2-16 (excluding the higher-velocity V_S profiles at Sites NPF 2 and 14 and NPF 3 and 9, and excluding the profile at Site NPF 28, which is located in a complicated, geologic transition zone) the shear wave velocity structures at the NPF sites and AP sites are quite uniform, in the top 1,100 ft and 600 ft, respectively. In contrast, at the sites within and near the repository waste emplacement area footprint, there is a large variation in the profiles (see Figure 6.3-2) if all 24 sites are grouped together. However, if the 24 V_S profiles of these YM sites are divided into different velocity groups (nine stiffer profiles, ten softer profiles, and six “neutral” or in-between profiles as shown in Figures 6.3-4, 6.3-5, and 6.3-6, respectively), the V_S ranges of stiffer and softer profiles over the waste emplacement area at depth are consistent with the higher and lower velocity groups of Tptpmn from tunnel measurements, the major type of tuff in the ESF and ECRB tunnels at a depth of about 1,000 ft. The comparisons are shown in Figures 6.4-16, 6.4-17, and 6.4.18. One possible reason for the stiffer material at the nine sites shown in Figure 6.3-4 is less fracturing and lithophysae and more welding in these materials at depth.

Data Acquired from Dynamic Laboratory Testing of YMP Tuff Specimens

Section 6.5 summarizes the dynamic laboratory data that were acquired from 2004 through 2006 on tuff specimens selected from various boreholes distributed throughout the Yucca Mountain area. Results for the RCTS testing consist of: resonant column and torsional shear (RCTS) tests were performed in the Soil and Rock Dynamic Laboratory at the UTACED laboratory on a total of 33 tuff specimens from various units below the Tiva Canyon Tuff. Combined RCTS equipment was used to investigate the dynamic characteristics of the specimens. The dynamic characteristics of shear modulus, G, and the material damping ratio in shear, D. The influence of the following variables on G and D were studied:

- Isotropic confining pressure, σ_o
- Total Unit Weight γ_t
- Shearing strain, γ
- Loading frequency, *f*.

Based on the RCTS testing results, the following conclusions were reached:

- In general, intact tuff specimens exhibited little to no dependency of σ_o (isotropic confining pressure) on both G_{max} and D_{min}. Two exceptions out of 33 specimens exhibited moderate pressure dependency on $G_{max,}$, with G_{max} increasing with increases in pressure (over a range of confining pressures from 20.8 to 451.4 psi (0.14 to 3.11 MPa)). These exceptions are bedded tuff specimens from the pre-Yucca Mountain bedded tuff (Tpbt3) and pre-Pah Canyon bedded tuff (Tpbt2) units. These two bedded tuff samples have two of the three lowest total unit weights, γ_t, as well as the lowest values of the small-strain modulus, G_{max}, of all the tests performed.

- The effect of excitation frequency was investigated by performing small-strain TS tests and comparing the results with results from the RC tests. Over a range of 0.1 to 300Hz, G is independent of frequency, and D has small, inconsistent changes. A few specimens could not be tested in the TS mode because of difficulty in exciting slow-cyclic motion in pure torsion in specimens with relatively large “flaws” (crack, lithophysae, etc.).

- The linear range where both G and D are constant and equal to G_{max} and D_{min}, respectively, is followed by a nonlinear range where G decreases and D increases as γ increases.

Results for Free-Free testing consist of: testing of 135 samples from the Rainer Mesa Tuff down to the Tram Tuff units. Approximately four to eight samples were selected and tested from each major geologic unit. Data include shear wave velocity and small strain shear modulus, total unit weight, and material damping ratio.

Based on the Free-Free testing results, the following conclusions were reached:

- The samples ranged in total unit weight from 62 to 150 pcf. In all cases, seismic wave velocities (V_S, V_C, and V_P) have a distinct increasing trend with increasing total unit weight. The small-strain moduli are directly related to associated wave velocities, the same trend of increasing moduli with increasing total unit weight exists as found for wave velocities.

- The general relationships between seismic wave velocities (V_S, V_C, V_P) and the estimated porosities (n) show strong trends with each of the seismic wave velocities decreasing as the estimated porosities increase.

- Shear and unconstrained compression wave velocities show inversely proportional trends with material damping ratios. Material damping ratios decrease as seismic wave velocities increase.

- The general relationship between $D_{S\ min}$ and $D_{C\ min}$ is proportional, with $D_{S\ min}$ increasing as $D_{C\ min}$ increases. While there is considerable scatter in the data, the values of $D_{S\ min}$ are slightly greater than $D_{C\ min}$. For cores with material damping ratios less than 1.0%, this general relationship is given by:

$$D_{C\ min} = 0.87\ D_{S\ min}$$

- The distribution of seismic wave velocities measured from cores shows a trend with stratigraphic unit. From the cores recovered, the seismic wave velocities increased, as would be expected, in the following order: non-welded tuffs, moderately welded tuffs, highly welded lithophysal tuffs, and highly welded non-lithophysal tuffs.

- The material damping ratios of each stratigraphic unit are not as well correlated as the seismic wave velocities. The material damping ratios show wider variations than seismic wave velocities because material damping ratio is more sensitive to flaws in the specimens than the seismic wave velocities.

7.2. BENEFITS, UNCERTAINTIES, AND LIMITATIONS

7.2.1. SASW Testing Process

The SASW method has several benefits compared with other seismic field methods in evaluating shear wave velocity profiles. First, the SASW method is both nondestructive and non-intrusive, and can therefore be performed with little to no effect on the surrounding environment. Second, the SASW method does not require a borehole for the test to be performed. Thus, the expense and time of borehole drilling is not incurred. The SASW method is especially useful when used in conjunction with borehole methods to add V_S information between boreholes or extend coverage beyond the boreholes. Third, the SASW method is global in nature, potentially measuring soil and rock stiffness over large lateral extents approximately equal to the depth of the V_S profile. Fourth, the SASW method operates using wavelengths that are within the range of wavelengths excited by earthquakes (although they are considerably shorter than the longest wavelengths excited by earthquakes). Therefore, for earthquake applications, the SASW method provides soil and rock stiffness over a range in wavelengths that is appropriate for earthquake analysis.

The theoretical representation used to determine the shear wave velocity profile at a site is a one-dimensional layered profile, meaning there is an assumption of no lateral variation in shear wave velocities or layer thicknesses across the extent of the receiver array (hence uniform horizontal layers). Therefore, the profile that is presented represents a one-dimensional layered profile that fits the measured dispersion data. Note that the one-dimensional assumption used to reduce the SASW data is consistent with the use of the data in ground motion site-response, which employs a one-dimensional velocity representation. Note also that lateral variability can be observed qualitatively if it occurs from mismatches in the individual experimental dispersion curves from adjacent receiver spacings. When these cases occur, a footnote is placed with the final V_S profile and either multiple interpretations are presented or the depth of the V_S profile is reduced.

7.2.2. SASW Data for Emplacement Area

SASW data to characterize the velocity of the repository block are obtained from both surface surveys and subsurface surveys within the ESF and ECRB drifts. Surface-based SASW data presented in this report enhance the lateral and depth coverage of the repository waste emplacement footprint relative to the data reported in *Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analysis for the Yucca Mountain Site Characterization Project* (BSC 2002 [DIRS 157829]). The relationship of the location of SASW surveys to the waste emplacement area is shown in Figure 6.3-1. Access constraints and the rugged topography of some of the mountain limited the ability to collect data evenly across the repository footprint. To mitigate this limitation, data were also collected from outside the repository footprint in some areas, but as close to the footprint as logistical considerations allowed.

Use of a more energetic vibroseis source during the 2004–2006 SASW surveys, relative to the source used during the 2000–2001 surveys, enhanced the coverage of the repository block with respect to depth. Velocity profiles developed from SASW data in 2002 extended to a depth of about 700 ft. In 2002, velocity information was also available from SASW data collected in the ESF at a depth of about 1,000 ft. Velocities for the material between 700 ft and 1,000 ft were determined by interpolation. With the SASW data collected in 2004–2006 using the more energetic source (“Liquidator”), velocity profiles are developed to a depth of about 1,200 ft, avoiding the need for interpolation above the waste emplacement level. In addition, the velocity data obtained from SASW surveys in the subsurface in 2004–2006 greatly expand the number and coverage of lithostratigraphic units relative to those available in 2002.

7.2.3. SASW Data in the NPF Area

As for the emplacement area, SASW data collected in the NPF Area provide enhanced spatial and depth coverage relative to data collected in 2000-2001 surveys. Spatial coverage is not uniform, however, in part due to logistical constraints on data collection. For example, in that portion of the site where the muck pile is located, limitations on the coupling of geophones and the vibroseis truck to the ground precluded data collection using the SASW method. To characterize areas where SASW data have not been collected, analyses will need to rely on data from adjacent areas, other types of velocity data (e.g., downhole velocity surveys), and inferences based on geologic information.

7.2.4. RCTS Testing

The pressures used in RCTS testing represent the maximum pressures that the RCTS system can achieve, typically from each experiment this was in the range of 400 to 450 psi (2.8 to 3.1 MPa). Lithostratigraphic pressures at the waste emplacement horizon (approximately 755 feet below the Yucca Crest) may range from 305 to 682 psi (2.1 to 4.7 MPa) (DTN: SN0308F3710195.003 [DIRS 166458]). Although the confining pressures of 400 to 450 psi are within the range of expected lithostratigraphic pressures, previous static testing data (Martin et al. 1994 [DIRS 101432]), as well as the data presented in this report, show very little pressure dependency in the welded tuff materials.

The maximum shearing strain is limited by the torque that can be generated in the RCTS device and by the large stiffness of the tuff specimens with diameters of about 1.6 in (4.1 cm). For this testing, the maximum shearing strain was about 0.1% in the RC tests. This shearing strain could only be achieved with the resonant column (RC) test. The RC test builds on the dynamic amplification associated with resonating a specimen, which in turn creates the larger strains, and because the TS test is a "static" test which involves no amplification, these higher strains could not be achieved. Therefore, all discussions of nonlinear behavior are based on measurements performed in the higher strain range achieved in the RC tests.

When performing dynamic laboratory tests, the results are biased because the size of the test specimens limits their ability to reflect in situ conditions. Because of the high stiffness of the tuff specimens (at least relative to "soft" soils), only smaller diameter tuff cores (on the order of 1.6 in) can be tested. With these small specimen sizes, the samples tend to lack relatively large flaws (cracks, lithophysae, etc.), which would be encountered in situ. Therefore, the dynamic properties determined from these tests need to be interpreted in light of their bias. This is especially true for those geologic units that tend to have large lithophysae or significant fracturing.

7.2.5. Free-Free URC Tests

The Free-Free URC test provides the advantage that a variety of dynamic properties can be measured and evaluated quickly. These properties are shear wave velocity (V_S), unconstrained compression wave velocity (V_C), constrained compression wave velocity(V_P), shear modulus (G_{max}), unconstrained elastic modulus (E_{max}), constrained elastic modulus (M_{max}), material damping ratio in shear ($D_{S\ min}$), and material damping ratio in unconstrained compression ($D_{C\ min}$). In addition, Poisson's ratio (ν) can be computed through the measured seismic wave velocities. Another advantage of this test is that there is no size limitation on the test specimen. Therefore, larger specimens that tend to incorporate more of the variability seen in the in situ properties can be tested.

The Free-Free URC test method also has some limitations. As with most laboratory testing of field-collected samples, the specimens tend to represent the highest quality materials. Weaker materials tend to never reach the laboratory, as they will break apart in the field. Therefore, the in-situ seismic wave velocities measured in the field rock tend to be smaller than the results measured in the laboratory. Following this logic, in situ material damping ratios will be larger than the results of the laboratory tests due to the presence of cracks, joints, folds, faults and fractures in the field. Results of the Free-Free URC tests indicate the upper means of possible in situ seismic wave velocities and the lower means of possible material damping ratios. These mean values simplify the condition of the site and eliminate some of the uncertainties in the field.

As discussed in Section 6.5.3.2, the Free-Free URC testing methodology provides results that are likely biased with respect to in situ conditions. Specimens for laboratory testing tend to reflect better quality material and are limited in their ability to reflect features such as lithophysae and fractures that exist in situ. Because the Free-Free URC tests are unconfined, the results are most representative of shallow conditions. Finally, results of the Free-Free URC tests are for small strain and do not reflect any nonlinear behavior that might occur at higher strains. In using these data, the above limitations must be taken into account.

7.2.6. Accuracy of Contacts

Each of the lithostratigraphic units in the NPF Area has distinctive characteristics that enable identification of the unit and the bounding contacts; therefore, there is very small uncertainty in the identification of lithostratigraphic units. The contacts are formed from depositional, welding, or crystallization processes and can be sharp or gradational. For gradational contacts, even though the features are gradational across 3 to 10 ft, the criteria for identification of the contact typically permit identification within a few feet. In boreholes with core, the accuracy of the contact is typically plus or minus 1 ft; however, where recovery of core is poor, the accuracy of contact identification is increased. Borehole geophysical logs and the trends in lithostratigraphic thickness can be used in many of the boreholes to help resolve the depth to lithostratigraphic contacts and minimize the uncertainty of the contact to the estimated accuracy of plus or minus 5 ft.

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ATTACHMENT I

LOGS OF BOREHOLES DRILLED IN FY05

ATTACHMENT I
LOGS OF BOREHOLES DRILLED IN FY05

Exploratory drilling in the NPF area began in March 2005 and concluded in July 2005 at the locations shown on Figure 6.2-1 in Section 6.2.2. The drilling program was developed to gain an understanding of subsurface geologic conditions. Eighteen new boreholes are included in this attachment (see Table 6.2-1). The boreholes are designated RF#42 through RF#60, excluding RF#57. Borehole RF#57 was to be drilled as a deep borehole targeting the Tiva Canyon middle nonlithphysal unit. Drilling was completed in sufficient time to include only the depth of alluvium for RF#57 in this report. Thus, when reference is made to the borehole logs for RF#42 through RF#60, the reader should recall that there is no log associated with RF#57.

Given the difficulty of collecting useful information regarding geotechnical properties in alluvial material with significant gravel, cobble, and boulder-size material, the project elected to drill using the sonic coring method. This method provided improved recovery of alluvial materials over other methods.

The borehole logs were initiated in the field and finalized based on examination by the U.S. Bureau of Reclamation (USBR) in the Sample Management Facility (SMF). The final logs are presented in alphanumeric order beginning on the following page. The final logs may also be found in DTN: GS070683114233.005 [DIRS 182109].

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-42

SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/4/2005 FINISHED: 5/5/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 764,633.04 E 571,142.
TOTAL DEPTH: 118.9 ft.
DEPTH TO BEDROCK: 75.4 ft.

STATE: Nevada
GROUND ELEVATION: 3634.87
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Ostergerg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 118.90' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

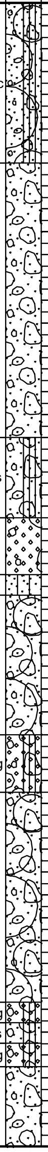
Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 118.9' (TD)

Hole Completion:
Back fill hole from 118.9' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.



DEPTH	GEOLOGIC UNIT [USCS]	CLASSIFICATION AND PHYSICAL CONDITION
		0.0 to 75.4 ft. QUATERNARY ALLUVIUM (Qal):
5	(SP-SM)gc	**0.0 to 7.0 ft. POORLY GRADED SAND WITH SILT, GRAVEL AND COBBLES (SP-SM)gc:** About 55 percent coarse to fine, subangular sand; about 30 percent coarse to fine, hard, subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 120 mm; dry, brown, no reaction with HCl. Organic material present.
10 15	(GP)s	**7.0 to 19.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 55 percent coarse to fine, hard, subangular gravel; about 45 percent coarse to fine, subangular sand, coarse sand-size particles fractured with hammer blow; about 5 percent nonplastic fines; maximum size 75 mm; dry, pink, light brown, strong reaction with HCl.
20	(GP-GM)s	**19.0 to 22.5 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s:** About 55 percent coarse to fine, hard, subangular gravel; about 35 percent coarse to fine, subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 55 mm; dry, pinkish gray, strong reaction with HCl.
	(SW)g	**22.5 to 25.0 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 55 percent coarse to fine, angular to subangular sand; about 40 percent predominantly fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 25 mm; dry, gray, moderate reaction with HCl.
25	SM	**25.0 to 25.9 ft. SILTY SAND (SM):** About 70 percent coarse to fine, subangular to subrounded sand; about 30 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, subangular to subrounded gravel; maximum size 10 mm; dry, gray, strong reaction with HCl.
30	(GP)sc	**25.9 to 32.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 60 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; trace of hard, subangular to subrounded cobbles; maximum size 150 mm; dry, pink, strong reaction with HCl.
	(SW-SM)g	**32.0 to 34.5 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 60 percent coarse to fine, subangular to subrounded sand; about 25 percent predominantly fine, hard, subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 45 mm; dry, gray, strong reaction with HCl.
35 40	(GP)sc	**34.5 to 43.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 60 percent coarse to fine, hard, angular to subrounded gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 105 mm; dry, gray, strong reaction with HCl.
	(SW-SM)g	**43.7 to 44.6 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 60 percent coarse to fine, angular to subangular sand; about 30 percent predominantly fine, hard, subangular to subrounded gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 25 mm; dry, pinkish gray, strong reaction with HCl.
45	(GP-GM)s	**44.6 to 45.5 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s:**About 55 percent predominantly fine, hard, subangular gravel; about 35 percent coarse to fine, subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 60 mm; dry, gray, strong reaction with HCl.
	(SW-SM)g	**45.5 to 46.5 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 70
	(GP)s	

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-42

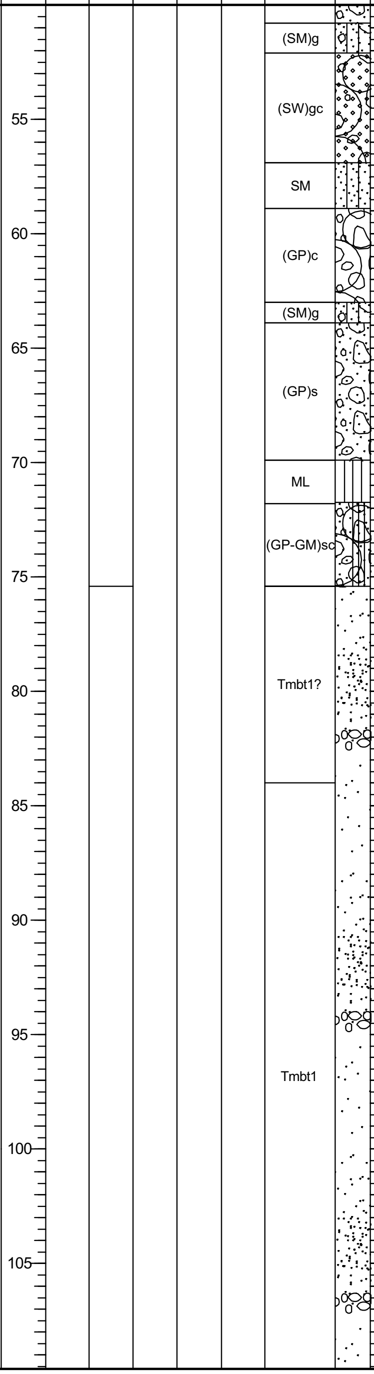
SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/4/2005 FINISHED: 5/5/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 764,633.04 E 571,142.
TOTAL DEPTH: 118.9 ft.
DEPTH TO BEDROCK: 75.4 ft.

STATE: Nevada
GROUND ELEVATION: 3634.87
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					



percent coarse to fine, subangular sand; about 20 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 10 mm; dry, pinkish gray, strong reaction with HCl.

46.5 to 50.8 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 60 percent coarse to fine, hard, angular gravel; about 35 percent coarse to fine, angular sand; about 5 percent nonplastic fines; maximum size 80 mm; dry, gray, no reaction with HCl.

50.8 to 52.1 ft. SILTY SAND WITH GRAVEL (SM)g: About 55 percent coarse to fine, subangular sand; about 30 percent predominantly fine, hard, subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 20 mm; dry, gray, strong reaction with HCl.

52.1 to 56.9 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 65 percent coarse to fine, subangular sand; about 35 percent coarse to fine, hard, subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 100 mm; dry, pinkish gray, strong reaction with HCl.

56.9 to 58.9 ft. SILTY SAND (SM): About 70 percent coarse to fine, subangular sand; about 30 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, subangular to subrounded gravel; maximum size 65 mm; dry, gray, strong reaction with HCl.

58.9 to 63.0 ft. POORLY GRADED GRAVEL WITH COBBLES (GP)c: About 85 percent coarse to fine, hard, angular gravel; about 10 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 150 mm; dry, gray, strong reaction with HCl.

63.0 to 63.9 ft. SILTY SAND WITH GRAVEL (SM)g. About 40 percent coarse to fine, subangular sand; about 30 percent predominantly fine, hard, subangular gravel; about 30 percent nonplastic fines with quick dilatancy and low toughness; maximum size 20 mm; dry, light gray, strong reaction with HCl.

63.9 to 69.9 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 65 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; maximum size 70 mm; dry, gray, strong reaction with HCl.

69.9 to 71.8 ft. SANDY SILT (ML): About 55 percent nonplastic fines with quick dilatancy and low toughness; about 45 percent coarse to fine, subangular sand; trace of predominantly fine, hard, subangular gravel; maximum size 10 mm; dry, gray, strong reaction with HCl.

71.8 to 75.4 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 25 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 110 mm; dry, gray, strong reaction with HCl.

75.4 to 84.0 ft. PRE-RAINIER MESA TUFF BEDDED TUFF? (Tmbt1):
Bedded tuff, nonwelded, consists primarily of silt to fine sand size fragments of feldspar, pumice, glass shards, and crystallized welded tuff fragments in a calcite cemented volcanic ash matrix, very pale brown. Contains 2 to 5 percent pumice locally, 2 to 3 percent crystallized welded tuff fragments, 15 to 25 percent calcite fragments (strong reaction with HCl). From 75.4 to 79.0 ft is an incipient paleosol. From 82.0 to 83.0 ft are scattered cobble size clasts of crystallized welded tuff, caliche coated. This may be fill.

84.0 to 113.6 ft. PRE-RAINIER MESA TUFF BEDDED TUFF (Tmbt1):
Bedded tuff, nonwelded, partially clay altered, pink, with white calcite stringers. Contains 5 to 20 percent pumice, 1 to 4 percent lithic fragments composed of crystallized welded tuff, matrix is predominantly fine to medium sand size crystal fragments in calcite cemented volcanic ash, with 1 to 20 percent crystal fragments of quartz, sanidine and plagioclase, less than 1 percent biotite, less than 1 percent magnetite.

Tephra from 89.0 to 93.8 ft, nonwelded, composed of 50 to 60 percent altered pumice, 5 to 10 percent lithic fragments, 10 to 20 percent crystal fragments of quartz and altered feldspar, less than 1 percent biotite, and less than 1 percent magnetite, white.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-42

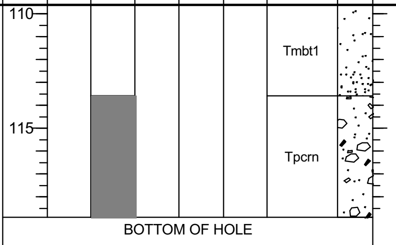
SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/4/2005 FINISHED: 5/5/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 764,633.04 E 571,142.
TOTAL DEPTH: 118.9 ft.
DEPTH TO BEDROCK: 75.4 ft.

STATE: Nevada
GROUND ELEVATION: 3634.87
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					



113.6 to 118.9 ft. TIVA CANYON TUFF CRYSTAL-RICH MEMBER NONLITHOPHYSAL ZONE (Tpcrn):
Pyroclastic flow, densely welded, crystallized, reddish gray, dark reddish-gray, reddish-black. Contains 5 to 25 percent pumice, 10 to 15 percent crystal fragments of sanidine and plagioclase, less than 1 percent biotite, and pyroxene.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-43

SHEET 1 OF 2

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/16/2005 FINISHED: 5/17/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,375.54 E 570,709.32
TOTAL DEPTH: 110.1 ft.
DEPTH TO BEDROCK: 90.5 ft.

STATE: Nevada
GROUND ELEVATION: 3669.90
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 110.1' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

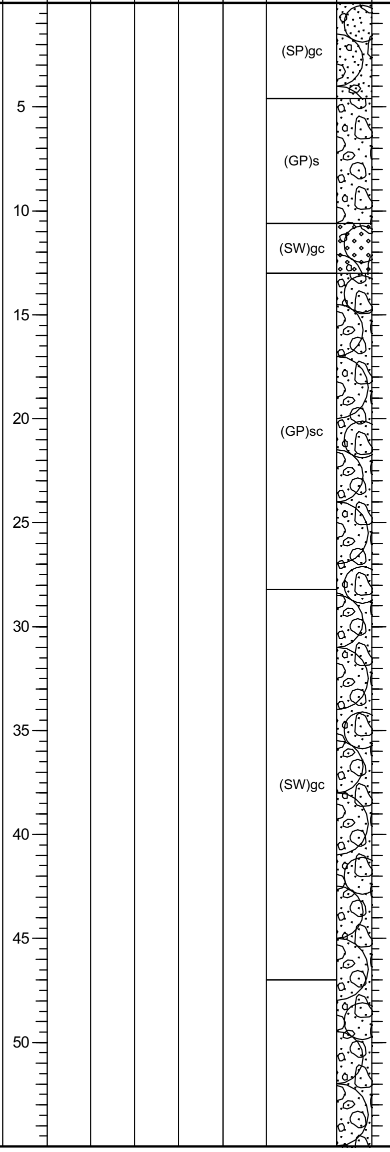
Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.00' to 110.1' (TD)

Hole Completion:
Back fill hole from 110.1' (TD) up to 00.0' (ground surface) with Bentonite Chips. Pull casing.



0.0 to 19.4 ft. PAD FILL:

0.0 to 4.6 ft. POORLY GRADED SAND WITH GRAVEL AND COBBLES (SP)gc: About 55 percent predominantly coarse to medium, subangular sand; about 45 percent coarse to fine, hard, subangular gravel; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 130 mm; moist, brown, strong reaction with HCl.

4.6 to 10.6 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 75 percent coarse to fine, hard, angular to subrounded gravel; about 25 percent coarse to fine, angular to subangular sand; trace of nonplastic fines with quick dilatancy and low toughness; maximum size 105 mm; moist, light yellowish brown, gray, weak to moderate reaction with HCl.

10.6 to 13.0 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 70 percent coarse to fine, angular to subangular sand; about 30 percent coarse to fine, hard, angular to subangular gravel; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 100 mm; moist, brown, strong reaction with HCl.

13.0 to 28.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, subangular to subrounded gravel; about 40 percent coarse to fine, angular to subrounded sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 120 mm; moist, yellowish brown, yellowish tan, gray, strong reaction with HCl.

19.4 to 90.5 ft. QUATERNARY ALLUVIUM (Qal):

28.2 to 47.0 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 60 percent coarse to fine, subangular sand; about 40 percent coarse to fine, hard, subangular gravel; trace of nonplastic fines, trace of hard, subangular cobbles; maximum size 90 mm; dry, tan, gray, no to strong reaction with HCl.

47.0 to 68.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 150 mm; dry, gray, tan, weak to strong reaction with HCl. Core removed from 64.2 to 65.5 ft.

COMMENTS: Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-43

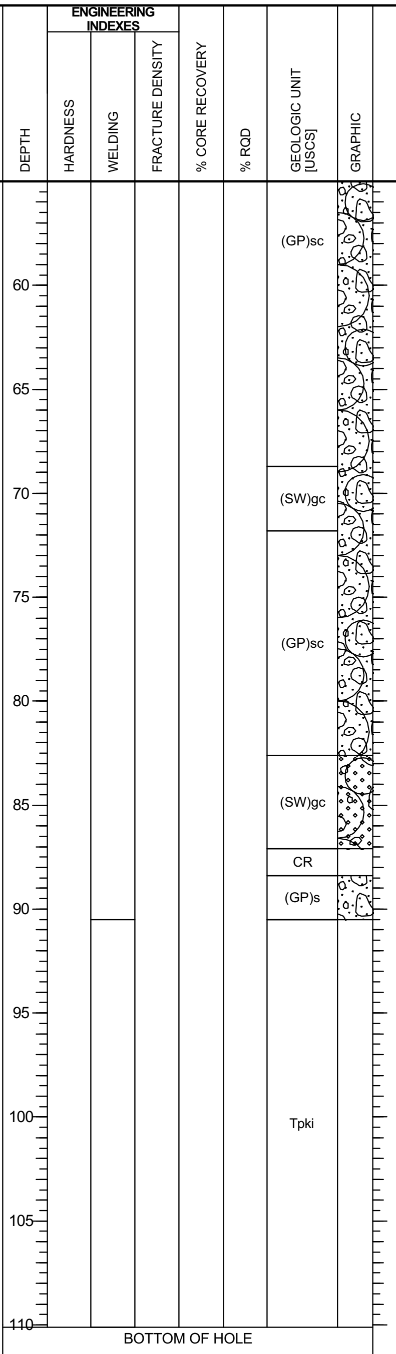
SHEET 2 OF 2

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/16/2005 FINISHED: 5/17/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,375.54 E 570,709.32
TOTAL DEPTH: 110.1 ft.
DEPTH TO BEDROCK: 90.5 ft.

STATE: Nevada
GROUND ELEVATION: 3669.90
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES



CLASSIFICATION AND PHYSICAL CONDITION

68.7 to 71.8 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 60 percent coarse to fine, angular to subangular sand; about 40 percent coarse to fine, hard, subangular gravel; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 155 mm; dry, gray, strong reaction with HCl.

71.8 to 82.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, subangular gravel; about 45 percent coarse to fine, subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 105 mm; dry, gray, strong reaction with HCl. Core removed from 75.4 to 76.7 ft.

82.6 to 87.1 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 60 percent coarse to fine, subangular sand; about 40 percent coarse to fine, angular to subangular gravel; trace of nonplastic fines; trace of subangular cobbles; maximum size 100 mm; dry, very pale brown, strong reaction with HCl.

87.1 to 88.4 ft. CORE REMOVED

88.4 to 90.5 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 55 percent coarse to fine, angular to subangular gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; maximum size 60 mm; dry, light gray, strong reaction with HCl.

90.5 to 110.1. COMB PEAK IGNIMBRITE - TUFF "X" (Tpki):
Pyroclastic flow, nonwelded, crystallized to partially altered, primarily volcanic ash, locally caliche cemented, very pale brown, 1 to 20 percent pumice, 1 to 3 percent lithic fragments of crystallized moderately to densely welded tuff, less than 1 percent crystal fragments of sanidine and plagioclase, less than 1 percent biotite and pyroxene, slight to moderate reaction with HCl.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-44

SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/18/2005 FINISHED: 5/23/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,418.81 E 570,828.46
TOTAL DEPTH: 143.5 ft.
DEPTH TO BEDROCK: 108.0 ft.

STATE: Nevada
GROUND ELEVATION: 3676.33
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 143.5' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 143.5' (TD)

Hole Completion:
Back fill hole from 143.5' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.

DEPTH

5
10
15
20
25
30
35
40
45

GEOLOGIC UNIT [USCS]

(GP)sc
(GP-GM)sc
(SW)g
(GP)sc

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 26.8 ft. PAD FILL:

0.0 to 31.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 70 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; trace of nonplastic fines; dry, light gray, gray, pink, weak to strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; remainder minus 3-inch; maximum size 85 mm.

26.8 to 108.0 ft. QUATERNARY ALLUVIUM (Qal):

31.0 to 38.3 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, light brown, moderate reaction with HCl. Iron staining on gravel.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; remainder minus 3-inch; maximum size 75 mm.

38.3 to 39.0 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 75 percent coarse to fine, angular to subangular sand; about 20 percent predominantly fine, hard, angular gravel; about 5% nonplastic fines; maximum size 25 mm; dry, light brown, strong reaction with HCl. Iron staining on gravel.

39.0 to 48.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, light gray and pink, no to strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular cobbles; remainder minus 3-inch; maximum size 90 mm.

48.2 to 52.6 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 65 percent coarse to fine, angular to subangular sand; about 25 percent predominantly fine, hard,

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-44

SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/18/2005 FINISHED: 5/23/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,418.81 E 570,828.46
TOTAL DEPTH: 143.5 ft.
DEPTH TO BEDROCK: 108.0 ft.

STATE: Nevada
GROUND ELEVATION: 3676.33
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
							(SW-SM)g		angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 35 mm; dry, pinkish gray, weak reaction with HCl.
	55						(GP)sc		**52.6 to 55.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, subangular gravel; about 45 percent coarse to fine, angular sand; trace of nonplastic fines; dry, pink, strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 15 percent hard, subangular cobbles; remainder minus 3-inch; maximum size 120 mm.
	60						(SW)gc		**55.7 to 63.7 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 50 percent coarse to fine, angular sand; about 45 percent coarse to fine, hard, angular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 80 mm; dry, pinkish gray, strong reaction with HCl.
	65						(GP)sc		**63.7 to 66.1 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 60 percent predominantly fine, hard, angular gravel; about 40 percent coarse to fine, angular sand; trace of nonplastic fines; dry, light brown, moderate reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular cobbles; maximum size 110 mm; remainder minus 3-inch.
							(SW-SM)g		**66.1 to 68.2 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 55 percent coarse to fine, subangular sand; about 35 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 35 mm; dry, pink, strong reaction with HCl.
	70 75 80 85 90 95 100						(GP)sc		**68.2 to 101.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, pinkish white, strong reaction with HCl. Core removed from 98.2 to 99.4 ft. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and angular to subangular cobbles; maximum size 95 mm; remainder minus 3-inch.
	105						(SW)gc		**101.0 to 108.0 ft. POORLY GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 65 percent coarse to fine, angular to subangular sand; about 35 percent coarse to fine, subangular gravel; trace of nonplastic fines; trace of subangular cobbles; maximum size 125 mm; dry, pink, strong reaction with HCl.
							Tpki		**108.0 to 121.4 ft. COMB PEAK IGNIMBRITE - TUFF "X" (Tpki):** Pyroclastic flow, nonwelded, crystallized and partially silicified, white, 10 to 40 percent pumice,

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-44

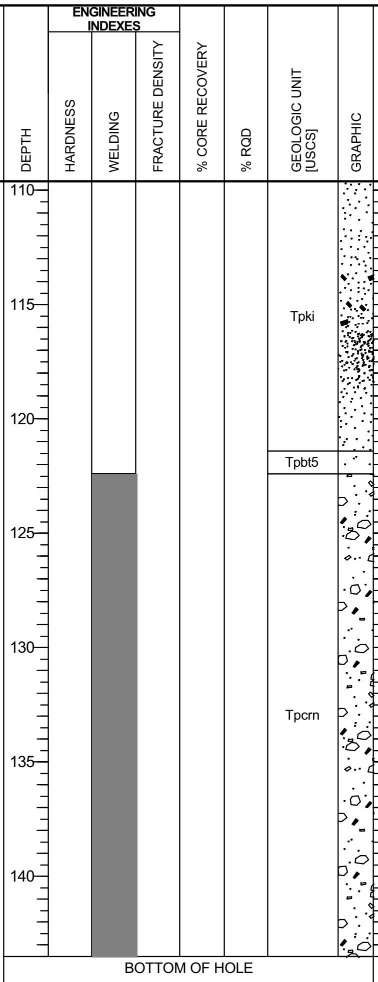
SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/18/2005 FINISHED: 5/23/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,418.81 E 570,828.46
TOTAL DEPTH: 143.5 ft.
DEPTH TO BEDROCK: 108.0 ft.

STATE: Nevada
GROUND ELEVATION: 3676.33
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES



CLASSIFICATION AND PHYSICAL CONDITION

locally 50 to 60 percent pumice, less than 1 to 5 percent lithic fragments of crystallized, densely welded tuff, less than 1 to 2 percent crystal fragments of sanidine, plagioclase and quartz, less than 1 percent biotite, and very minor hornblende, less than 1 percent scattered manganese oxides, scattered relict glass bubbles, slightly to moderately reactive with HCl (calcite veinlets).

121.4 to 122.4 ft. POST-TIVA CANYON TUFF BEDDED TUFF (Tpbt5):
Bedded tuff, nonwelded, clay altered, light red with dark red mottling, 3 to 7 percent clay altered pumice, 10 to 20 percent lithic fragments of welded tuff, 1 to 2 percent crystal fragments of sanidine, plagioclase, and lesser quartz (less than 1 percent), less than 1 percent biotite, less than 1 percent magnetite. Scattered fragments of Tpcrn3 at base.

122.4 to 143.5 ft. TIVA CANYON CRYSTAL RICH NONLITHOPHYSAL ZONE (Tpcrn):
Pyroclastic flow, moderately to densely welded, crystallized, pale red, pinkish gray, 5 to 20 percent pumice, less than 1 percent lithic fragments of welded tuff, 5 to 13 percent crystal fragments of sanidine and plagioclase, less than 1 percent biotite, hornblende, and pyroxene. Interval from 125.2 to 128.6 ft has fractures filled with pinkish-white tuffaceous sandstone with fine-grained densely welded and crystallized tuff as lithic clasts, and locally derived fragments of various sizes.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-45

SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/1/2005 FINISHED: 6/6/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,268.13 E 571,021.95
TOTAL DEPTH: 125.5 ft.
DEPTH TO BEDROCK: 93.0 ft.

STATE: Nevada
GROUND ELEVATION: 3650.02
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 125.5' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8 " casing from 0.00' to 125.50' (TD)

Hole Completion:
Back fill hole from 125.5' up to 0.00'
(ground surface) with Bentonite Chips. Pull casing.

DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]
	HARDNESS	WELDING	FRACTURE DENSITY			
						(GP)sc
5						
						(SW)gc
10						
						(GP)sc
15						
						(SW)gc
20						
						(GP)sc
25						
30						(SW)g
						(GP)s
35						(SW-SM)g
						(GP)sc
40						
						(SW-SM)g
45						(GP)sc

GRAPHIC

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 91.6 ft. QUATERNARY ALLUVIUM (Qal):

0.0 to 7.3 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse fine, hard, subangular gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines, trace of hard subangular cobbles; maximum size 130 mm; moist, reddish brown to light reddish brown, strong reaction with HCl.

7.3 to 9.1 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 55 percent coarse to fine, subangular sand; about 40 percent coarse to fine, hard, subangular gravel; about 5 percent nonplastic fines, trace of hard subangular cobbles; maximum size 80 mm; dry, light brown, moderate reaction with HCl.

9.1 to 16.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; dry, light reddish brown, moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 130 mm; remainder minus 3-inch.

16.6 to 18.0 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 55 percent coarse to fine, angular to subangular sand; about 45 percent coarse to fine, hard, angular to subangular gravel; trace of nonplastic fines; dry, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 15 percent hard, subangular cobbles; maximum size 110 mm; remainder minus 3-inch.

18.0 to 28.1 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 125 mm; dry, pink, no reaction with HCl.

28.1 to 31.6 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 65 percent coarse to fine, angular sand; about 35 percent predominantly fine, hard, angular gravel; trace of nonplastic fines; maximum size 60 mm; dry, pink, moderate reaction with HCl.

31.6 to 34.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 55 percent predominantly fine, hard, subangular gravel; about 45 percent coarse to fine, angular sand; trace of nonplastic fines; maximum size 70 mm; dry, pinkish gray, strong reaction with HCl.

34.0 to 35.2 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 65 percent coarse to fine, angular sand; about 25 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, pink, weak reaction with HCl.

35.2 to 42.5 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 45 percent coarse to fine, hard, subangular gravel; about 35 percent coarse to fine, subangular to angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 100 mm; dry, pink, strong reaction with HCl.

42.5 to 43.4 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 60 percent coarse to fine, subangular sand; about 30 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 40 mm; dry, pink, strong reaction with HCl.

43.4 to 46.4 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 15 percent hard, subangular cobbles; maximum size 100 mm; remainder minus 3-inch.

46.4 to 59.0 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 50

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

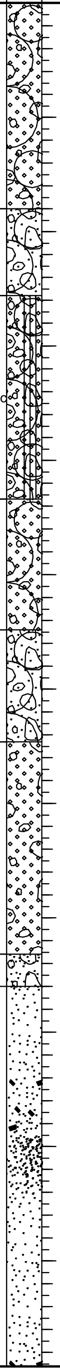
GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-45

SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/1/2005 FINISHED: 6/6/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,268.13 E 571,021.95
TOTAL DEPTH: 125.5 ft.
DEPTH TO BEDROCK: 93.0 ft.

STATE: Nevada
GROUND ELEVATION: 3650.02
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung



NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					
	55						(SW)gc		percent coarse to fine, angular to subangular sand; about 45 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 115 mm; dry, pink to pinkish gray, weak to strong reaction with HCl.
	60						(GP)sc		**59.0 to 62.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 65 percent coarse to fine, hard, subangular gravel; about 35 percent coarse to fine, subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 135 mm; dry, pink, strong reaction with HCl.
	65 70						(SW-SM)gc		**62.8 to 71.7 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc:** About 60 percent coarse to fine, angular to subangular sand; about 30 percent predominantly fine, angular to subangular gravel, gravel-size particles fractured with hammer blow; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pink, strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular and drilled cobbles; maximum size 150 mm; remainder minus 3-inch.
	75						(SW)gc		**71.7 to 77.4 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 55 percent coarse to fine, angular to subangular sand; about 40 percent predominantly fine, hard, angular to subangular gravel; about 5 percent nonplastic fines, dry, pinkish gray, weak reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 100 mm; remainder minus 3-inch.
	80						(GP)sc		**77.4 to 82.3 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 85 percent coarse to fine, hard, angular to subangular gravel; about 10 percent coarse to fine, subangular sand; about 5 percent nonplastic fines; dry, pinkish gray, strong reaction with HCl. Core removed from 78.9 to 80.6 ft. TOTAL SAMPLE (BY VOLUME): About 15 percent hard, subangular cobbles; maximum size 220 mm; remainder minus 3-inch.
	85 90						(SW)g		**82.3 to 91.6 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 60 percent coarse to fine, subangular sand; about 35 percent coarse to fine, hard, subangular gravel; about 5 percent nonplastic fines; maximum size 70 mm; dry, pink, strong reaction with HCl. Core removed from 90.6 to 91.6 ft.
							Mvf		**91.6 to 93.0 ft: MIOCENE(?) VALLEY FILL (Mvf):** Predominantly subrounded fragments of Tuff "X" and lesser crystallized welded tuff in a very fine to medium grained sand matrix of quartz, feldspar, and welded tuff, very pale brown. Generally no reaction with HCl. Scattered root casts.
	95 100 105						Tpki		**93.0 to 125.5 ft: COMB PEAK IGNIMBRITE - TUFF "X" (Tpki):** Pyroclastic flow, nonwelded, crystallized, white, 15 to 35 percent pumice, 1 to 10 percent lithic fragments of welded tuff, less than 1 percent crystal fragments of sanidine, plagioclase, biotite and hornblende."

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-45

SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/1/2005 FINISHED: 6/6/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,268.13 E 571,021.95
TOTAL DEPTH: 125.5 ft.
DEPTH TO BEDROCK: 93.0 ft.

STATE: Nevada
GROUND ELEVATION: 3650.02
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					
	110								
	115						Tpki		
	120								
	125								

BOTTOM OF HOLE

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-46

SHEET 1 OF 2

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/12/2005 FINISHED: 5/16/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 764,889.91 E 570,602.74
TOTAL DEPTH: 103.5 ft.
DEPTH TO BEDROCK: 84.2 ft.

STATE: Nevada
GROUND ELEVATION: 3669.22
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 103.5' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.00' to 103.5' (TD)

Hole Completion:
Back fill hole from 103.5' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.

GEOLOGIC UNIT [USCS]	CLASSIFICATION AND PHYSICAL CONDITION
(GP)sc	**0.0 to 27.2 ft. PAD FILL** **0.0 to 1.5 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent predominantly fine, hard, angular to subangular gravel; about 40 percent coarse to fine, subangular sand; about 5 percent nonplastic fines, trace of hard subangular cobbles; maximum size 110 mm; dry, gray, strong reaction with HCl. Pad fill.
(GP-GM)sc	**1.5 to 7.7 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc:** About 55 percent predominantly fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness, trace of hard, subangular cobbles; maximum size 100 mm; dry, gray, no reaction with HCl. Pad fill.
(GP)sc	**7.7 to 20.3 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent predominantly fine, hard, angular to subangular gravel; about 40 to 45 percent coarse to fine, angular to subangular sand; trace to 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 90 mm; moist, light gray to light reddish brown, no to strong reaction with HCl. Pad fill
(SW)g	**20.3 to 21.9 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 70 percent coarse to fine, subangular sand; about 25 percent predominantly fine, hard, subangular gravel; about 5 percent nonplastic fines; maximum size 60 mm; moist, gray, no reaction with HCl. Pad fill.
(GP)sc	**21.9 to 27.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard subangular cobbles; maximum size 100 mm; moist, gray, no reaction with HCl. Pad fill.
(GP)sc	**27.2 to 84.2 ft. QUATERNARY ALLUVIUM (Qal)** **27.2 to 49.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, subangular, gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 120 mm; moist, pink, light reddish brown, strong reaction with HCl.
(SW)gc	**49.0 to 55.8 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 80 percent coarse to fine, angular to subangular sand; about 15 percent predominantly fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 120 mm; dry, pink, no reaction with HCl.
(GP)s	**55.8 to 58.4 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 65 percent predominantly fine, hard, angular gravel; about 35 percent coarse to fine, subangular sand; trace of nonplastic fines; maximum size 75 mm; dry, pink, strong reaction with HCl.
CR	58.4 to 59.8 ft. CORE REMOVED

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-46

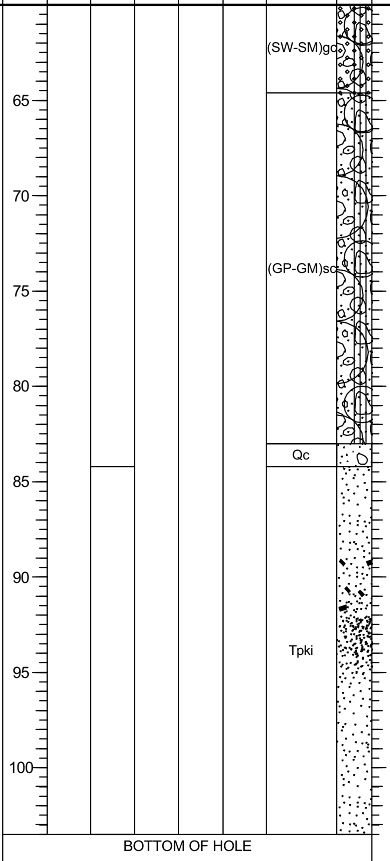
SHEET 2 OF 2

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/12/2005 FINISHED: 5/16/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 764,889.91 E 570,602.74
TOTAL DEPTH: 103.5 ft.
DEPTH TO BEDROCK: 84.2 ft.

STATE: Nevada
GROUND ELEVATION: 3669.22
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					



59.8 to 64.6 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc:
About 70 percent coarse to fine, subangular sand; About 20 percent coarse to fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 80 mm; dry, pinkish gray and pink, strong reaction with HCl.

64.6 to 83.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND ANC COBBLES (GP-GM)sc:
About 55 percent coarse to fine, hard, subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 130 mm; dry, pinkish gray and pink, strong reaction with HCl. Core removed from 68.3 to 69.5 ft.

83.0 to 84.2 ft. COLLUVIUM (Qc):
Primarily weathered and reworked Tuff "X", caliche cemented (strong reaction with HCl). Contains gravel to cobble size fragments of Tuff "X" with caliche coatings.
84.2 to 103.5 ft. COMB PEAK IGNIMBRITE - TUFF "X" (Tpki):
Pyroclastic flow, nonwelded, crystallized, white, 15 to 25 percent pumice, 1 to 3 percent volcanic lithic fragments, about 2 percent crystal fragments of altered feldspar, and rare quartz, biotite and hornblende.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-47

SHEET 1 OF 3

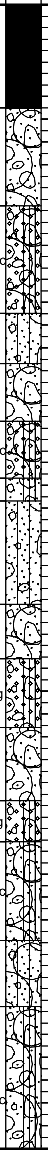
FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 7/12/2005 FINISHED: 7/13/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,746.68 E 571,076.62
TOTAL DEPTH: 122.3 ft.
DEPTH TO BEDROCK: 97.0 ft.

STATE: Nevada
GROUND ELEVATION: 3663.86
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]
	HARDNESS	WELDING	FRACTURE DENSITY			
						No Recovery
5						(GP)sc
10						(SW-SM)gc
						(SM)g
15						(GP)sc
						(SW-SM)gc
20						(GP)s
						(SM)g
25						(GP)sc
30						(SW-SM)g
						(GP)sc
35						(SW-SM)g
						(GP-GM)sc
40						(SM)gc
45						(GP-GM)sc

GRAPHIC



NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 122.3' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 122.3' (TD)

Hole Completion:
Back fill hole from 122.3' up to 0.0' (ground surface) with Bentonite Chips. Pull casing.

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 90.0 ft. QUATERNARY ALLUVIUM (Qal)

0.0 to 4.5 ft. NO CORE RECOVERED

4.5 to 8.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 to 75 percent coarse to fine, hard, angular to subangular gravel; about 20 to 35 percent coarse to fine, angular sand; trace to 5 percent nonplastic fines; trace of hard subangular cobbles; maximum size 85 mm; dry, pink, weak to strong reaction with HCl. Caliche present.

8.8 to 13.5 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 55 percent coarse to fine, subangular sand; about 35 percent predominantly fine, hard, angular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pink, weak reaction with HCl. Caliche present.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, angular cobbles; maximum size 145 mm; remainder minus 3-inch.

13.5 to 15.7 ft. SILTY SAND WITH GRAVEL (SM)g: About 65 percent coarse to fine, angular to subangular sand; about 20 percent predominantly fine, hard, angular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 60 mm; dry, pink, strong reaction with HCl. Caliche present.

15.7 to 18.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent predominantly fine, hard, angular to subangular gravel; about 35 percent coarse to fine, subangular sand; about 5 percent nonplastic fines; trace of hard, drilled and subangular cobbles; maximum size 130 mm; dry, pinkish gray, strong reaction with HCl. Caliche present.

18.2 to 20.7 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 50 percent coarse to fine, angular to subangular sand; about 40 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 80 mm; dry, pinkish gray, strong reaction with HCl.

20.7 to 21.7 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 70 percent predominantly fine, hard, angular to subangular gravel; about 25 percent coarse to fine, angular sand; about 5 percent nonplastic fines; maximum size 60 mm; dry, pink, strong reaction with HCl.

21.7 to 26.2 ft. SILTY SAND WITH GRAVEL (SM)g: About 45 percent coarse to fine, angular to subangular sand; about 40 percent predominantly fine, hard, subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 60 mm; dry, pinkish gray, strong reaction with HCl.

26.2 to 28.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent predominantly fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, pink, moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and subrounded cobbles; maximum size 110 mm; remainder minus 3-inch.

28.6 to 31.6 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 50 percent coarse to fine, angular sand; about 40 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 40 mm; dry, pink, no reaction with HCl.

31.6 to 34.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent predominantly coarse, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pink, moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular cobbles; maximum size 100 mm; remainder minus 3-inch.

34.8 to 36.6 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 55 percent coarse to fine, angular to subangular sand; about 35 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 65 mm; dry, pinkish gray, moderate reaction with HCl.

36.6 to 40.9 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent predominantly fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, weak reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 150 mm; remainder minus 3-inch.

40.9 to 43.8 ft. SILTY SAND WITH GRAVEL AND COBBLES (SM)gc: About 40 percent coarse to fine, angular sand; about 30 percent predominantly coarse, hard, angular to subangular gravel; about 30 percent nonplastic fines with quick dilatancy and low toughness; dry, light gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 15 percent hard, drilled and subangular cobbles; maximum size 130 mm; remainder minus 3-inch.

43.8 to 51.9 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 60 percent predominantly coarse, hard, angular gravel; about 30 percent coarse to fine,

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

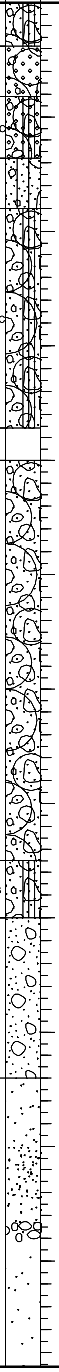
GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-47

SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 7/12/2005 FINISHED: 7/13/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,746.68 E 571,076.62
TOTAL DEPTH: 122.3 ft.
DEPTH TO BEDROCK: 97.0 ft.

STATE: Nevada
GROUND ELEVATION: 3663.86
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung



NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					
									angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 105 mm; dry, pinkish gray, strong reaction with HCl.
							(SW)gc		**51.9 to 54.1 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 55 percent coarse to fine, angular sand; about 40 percent predominantly fine, hard, angular gravel; about 5 percent nonplastic fines; trace of hard, angular to subangular cobbles; maximum size 80 mm; dry, light reddish brown, moderate reaction with HCl.
	55						(SW-SM)gc		**54.1 to 56.8 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc:** About 55 percent coarse to fine, angular to subangular sand; about 35 percent predominantly coarse, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, drilled and angular to subangular cobbles; maximum size 85 mm; dry, pinkish gray, strong reaction with HCl.
							(SM)g		**56.8 to 59.0 ft. SILTY SAND WITH GRAVEL (SM)g:** About 65 percent coarse to fine, angular to subangular sand; about 20 percent predominantly fine, hard, angular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 20 mm; dry, pinkish gray, strong reaction with HCl.
	60 65						(GP-GM)sc		**59.0 to 68.6 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc:** About 50 percent predominantly coarse, hard, angular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
							CR		**68.6 to 70.0 ft. CORE REMOVED**
	70 75 80 85						(GP)sc		**70.0 to 87.5 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 50 to 65 percent predominantly fine to predominantly coarse, hard, angular to subangular gravel; about 30 to 45 percent coarse to fine, angular to subangular sand; trace to 5 percent nonplastic fines; trace of hard, angular to subangular cobbles; maximum size 130 mm; dry, pink, no to strong reaction with HCl. Core removed from 81.6 to 83.0 ft.
							(GP-GM)s		**87.5 to 90.0 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s:** About 55 percent predominantly fine, hard, angular gravel; about 35 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, pinkish gray, moderate reaction with HCl.
	90 95						Qal/Col		**90.0 to 97.0 ft. ALLUVIUM/COLLUVIUM (Qal/Col):** Bedded, white, silt and very fine sand size fragments of welded tuff and lesser felsic crystals, caliche cemented (strong reaction with HCl), less than 10 percent densely welded tuff fragments up to 1 cm.
	100 105						Tmbt1		**97.0 to 122.3 ft. PRE-RAINIER MESA TUFF BEDDED TUFF (Tmbt1):** Bedded tuff, nonwelded, crystallized, slightly clay altered, white and pinkish white, calcite veinlets and fracture coatings near top of bed, 2 to 20 percent pumice, less than 1 to 15 percent lithic fragments of welded tuff or lava flow, less than 1 to 3 percent crystal fragments of sanidine, feldspar and quartz, less than 1 percent biotite.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-47

SHEET 3 OF 3

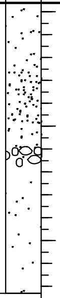
FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 7/12/2005 FINISHED: 7/13/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,746.68 E 571,076.62
TOTAL DEPTH: 122.3 ft.
DEPTH TO BEDROCK: 97.0 ft.

STATE: Nevada
GROUND ELEVATION: 3663.86
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

Source: GS070683114233.005 [DIRS 182109]TDR-MGR-GE-000010 REV 00

NOTES	DEPTH	ENGINEERING INDEXES HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	110								
	115								
							Tmbt1		
	120								



BOTTOM OF HOLE

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-48

SHEET 1 OF 3

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: Midway Valley	COORDINATES: N 765,474.33 E 571,386.99	GROUND ELEVATION: 3653.64
BEGUN: 4/11/2005 FINISHED: 4/14/2005	TOTAL DEPTH: 159.3 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 113.3 ft.	HOLE LOGGED BY: George Eatman
		REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 159.3' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 159.3' (TD)

Hole Completion:
Back fill hole from 159.3' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.

DEPTH / GEOLOGIC UNIT [USCS]

DEPTH: 5, 10, 15, 20, 25, 30, 35, 40, 45

GEOLOGIC UNIT [USCS]
SM
(GM)sc
(GP)s.
SM
(GP)s
(GP-GM)sc
(SM)c
(GP)s
(SW-SM)g
(GP-GM)s
SM
(GP)s
(GP-GM)s
(SW-SM)g
SM
(SM)g
(SW-SM)g
(GP-GM)s
SM
(GP)s
(SW)g
(SW-SM)g
(GP-GM)s

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 113.3 ft. QUATERNARY ALLUVIUM (Qal)

0.0 to 2.2 ft. SILTY SAND (SM): About 85 percent coarse to fine, subangular to subrounded sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; trace of coarse to fine, hard, subangular to subrounded gravel; maximum size 75 mm; dry, brown, no reaction with HCl. Grass and roots present. Topsoil.

2.2 to 3.8 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc: About 60 percent coarse to fine, hard, angular to subrounded gravel; about 25 percent coarse to fine, subangular to subrounded sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subrounded cobbles; maximum size 95 mm, dry, light tan, strong reaction with HCl.

3.8 to 4.5 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 55 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; maximum size 20 mm, dry, brown, moderate reaction with HCl. Grass and plant material present.

4.5 to 4.7 ft. SILTY SAND (SM): About 85 percent coarse to fine, angular to subangular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, angular gravel; maximum size 55 mm, dry, gray, strong reaction with HCl.

4.7 to 6.3 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 50 percent predominantly fine, hard, angular to subangular gravel; about 45 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; maximum size 75 mm, dry, light brown, strong reaction with HCl.

6.3 to 9.5 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 65 percent predominantly fine, hard, angular gravel; about 25 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular to subrounded cobbles; maximum size 100 mm, dry, light tan, strong reaction with HCl.

9.5 to 10.2 ft. SILTY SAND WITH COBBLES (SM)c: About 70 percent coarse to fine, angular to subangular sand; about 30 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, angular to subangular gravel; trace of hard subangular to subrounded cobbles; maximum size 105 mm, dry, gray, strong reaction with HCl.

10.2 to 12.5 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 50 percent coarse to fine, hard, angular to subangular gravel; about 45 percent coarse to fine, subangular sand; about 5 percent nonplastic fines; maximum size 55 mm, dry, tan, strong reaction with HCl.

12.5 to 14.5 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 65 percent coarse to fine, angular to subangular sand; about 25 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 45 mm, dry, gray, strong reaction with HCl.

14.5 to 17.6 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 60 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 35 mm, dry, tan, strong reaction with HCl.

17.6 to 18.7 ft. SILTY SAND (SM): About 80 percent coarse to fine, hard, subangular to subrounded sand; about 20 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, subangular gravel; maximum size 25 mm, dry, tan, strong reaction with HCl.

18.7 to 22.3 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; maximum size 65 mm, dry, tan to light brown, strong reaction with HCl.

22.3 to 23.8 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 70 percent coarse to fine, hard, angular gravel; about 20 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 70 mm, dry, gray, strong reaction with HCl.

23.8 to 24.3 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 65 percent coarse to fine, angular to subangular sand; about 25 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 40 mm, dry, gray, strong reaction with HCl.

24.3 to 25.8 ft. SILTY SAND (SM): About 85 percent coarse to fine, subangular to subrounded sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, subangular to subrounded gravel; maximum size 25 mm, dry, gray, strong reaction with HCl.

25.8 to 31.0 ft. SILTY SAND WITH GRAVEL (SM)g: About 65 percent coarse to fine, angular to subrounded sand; about 20 percent predominantly fine, hard, angular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 70 mm, dry, tan, strong reaction with HCl.

31.0 to 31.6 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 70 percent predominantly fine, angular to subangular sand; about 20 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 40 mm, dry, gray to tan, no reaction with HCl.

31.6 to 33.3 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 50 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 25 mm, dry, gray to tan, no reaction with HCl.

33.3. to 34.4 ft. SILTY SAND (SM): About 60 percent coarse to fine, hard, subangular sand; about 25 percent nonplastic fines with quick dilatancy and low toughness; about 10 percent predominantly fine, hard, subangular gravel; maximum size 60 mm, dry, gray, moderate reaction with HCl.

34.4 to 37.3 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 70 percent coarse to

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-48

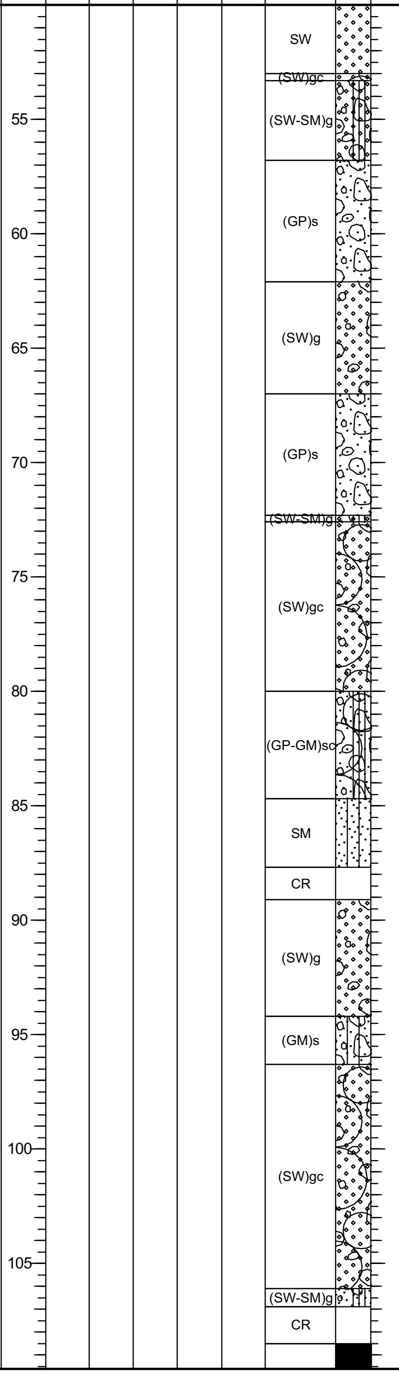
SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/11/2005 FINISHED: 4/14/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,474.33 E 571,386.99
TOTAL DEPTH: 159.3 ft.
DEPTH TO BEDROCK: 113.3 ft.

STATE: Nevada
GROUND ELEVATION: 3653.64
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES | DEPTH | ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION



fine, hard, angular to subangular gravel; about 25 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; maximum size 60 mm, dry, gray, strong reaction with HCl.

37.3 to 39.0 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 65 percent coarse to fine, angular to subangular sand; about 35 percent coarse to fine, hard, angular to subangular gravel; trace of nonplastic fines; maximum size 45 mm, dry, light brown and tan, no to strong reaction with HCl.

39.0 to 41.2 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 65 percent coarse to fine, angular to subangular sand; about 25 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 35 mm, dry, tan, strong reaction with HCl.

41.2 to 50.0 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 55 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm, dry, gray, strong reaction with HCl.

50.0 to 53.0 ft. WELL GRADED SAND (SW): About 90 percent coarse to fine, angular to subangular sand; about 5 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 130 mm, dry, tan, strong reaction with HCl.

53.0 to 53.3 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 55 percent coarse to fine, angular to subangular sand; about 40 percent predominantly fine, hard, angular gravel; about 5 percent nonplastic fines; trace of subangular to subrounded cobbles; maximum size 140 mm, dry, light gray, weak to moderate reaction with HCl.

53.3 to 56.8 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 60 percent coarse to fine, angular to subangular sand; about 30 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 45 mm, dry, gray, strong reaction with HCl.

56.8 to 62.1 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 55 percent coarse to fine, hard, subangular to subrounded gravel; about 40 percent coarse to fine, subangular to subrounded sand; about 5 percent nonplastic fines; maximum size 60 mm, dry, tan, strong reaction with HCl.

62.1 to 67.0 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 70 percent coarse to fine, angular to subangular sand; about 15 percent coarse to fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 25 mm, dry, gray, strong reaction with HCl.

67.0 to 72.3 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; maximum size 55 mm, dry, tan, strong reaction with HCl.

72.3 to 72.6 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 70 percent coarse to fine, angular to subangular sand; about 20 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 35 mm, dry, gray, strong reaction with HCl.

72.6 to 80.0 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 70 percent coarse to fine, angular to subangular sand; about 25 percent predominantly fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular to subrounded cobbles; maximum size 120 mm, dry, light brown, strong reaction with HCl.

80.0 to 84.7 ft: POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc. About 50 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular to subrounded cobbles; maximum size 80 mm, dry, gray, strong reaction with HCl.

84.7 to 87.7 ft. SILTY SAND (SM): About 75 percent coarse to fine, subangular to subrounded sand; about 25 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, subangular to subrounded gravel; maximum size 70 mm, dry, tan, strong reaction with HCl.

87.7 to 89.1 ft. CORE REMOVED

89.1 to 94.2 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 50 percent coarse to fine, angular sand; about 45 percent coarse to fine, hard, angular gravel; about 5 percent nonplastic fines; maximum size 65 mm, dry, tan, strong reaction with HCl.

94.2 to 96.3 ft. SILTY GRAVEL WITH SAND (GM)s: About 40 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 25 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm, dry, gray, strong reaction with HCl.

96.3 to 106.1 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 70 to 80 percent coarse to fine, angular to subrounded sand; about 15 to 25 percent coarse to fine, hard, angular to subrounded gravel; about 5 percent nonplastic fines; trace of hard, drilled and angular cobbles; maximum size 140 mm, dry, tan and light tan, strong reaction with HCl. Core removed from 97.2 to 99.0 ft.

106.1 to 106.9 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 65 percent coarse to fine, subangular sand, coarse sand-size particles fractured with hammer blow; about 25 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 15 mm; dry, gray, strong reaction with HCl.

106.9 to 108.5 ft. CORE REMOVED

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-48

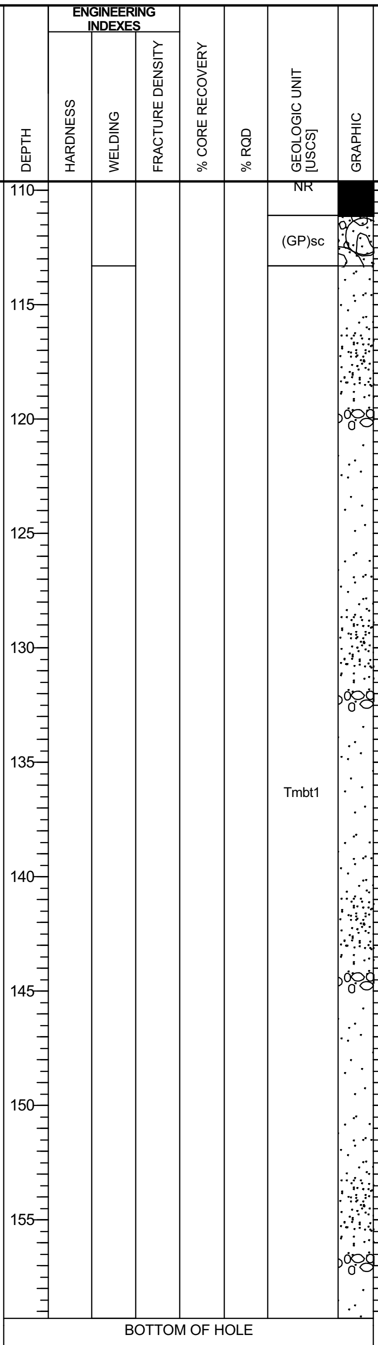
SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/11/2005 FINISHED: 4/14/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,474.33 E 571,386.99
TOTAL DEPTH: 159.3 ft.
DEPTH TO BEDROCK: 113.3 ft.

STATE: Nevada
GROUND ELEVATION: 3653.64
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES



CLASSIFICATION
AND PHYSICAL CONDITION

108.5 to 111.1 ft. NO RECOVERY INTERVAL

111.1 to 113.3 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of angular cobbles; maximum size 95 mm; dry, light yellowish tan, strong reaction with HCl.

113.3 to 159.3 ft. PRE-RAINIER MESA TUFF BEDDED TUFF (Tmbt1): Pyroclastic flow(?) at the top of the unit, and bedded tuffs below, nonwelded, partially clay altered, 3 to 25 percent pumice, less than 1 to 10 percent lithic fragments of welded crystallized tuff, less than 1 to 6 percent crystal fragments of quartz, sanidine, and plagioclase, less than 1 percent biotite, lesser hornblende and altered pyroxene(?). Bedded tuff is reworked from 156.7 to 159.3 ft and consists predominantly of fine to very fine sand size fragments of quartz, feldspar, and crystallized welded tuff in a clay altered matrix, less than 1 percent crystal fragments of sanidine, plagioclase, biotite, hornblende(?), and magnetite.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-49

SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/6/2005 FINISHED: 4/11/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,058.84 E 571,421.14
TOTAL DEPTH: 142.9 ft.
DEPTH TO BEDROCK: 112.9 ft.

STATE: Nevada
GROUND ELEVATION: 3668.78
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 142.9' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

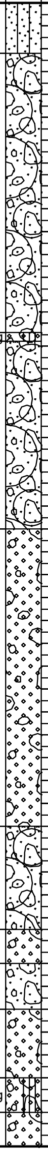
Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 142.9' (TD)

Hole Completion:
Back fill hole from 142.9' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.

DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	HARDNESS	WELDING	FRACTURE DENSITY					
								**0.0 to 112.9 ft. QUATERNARY ALLUVIUM (Qal)**
						SM		**0.0 to 2.2 ft. SILTY SAND (SM):** About 85 percent coarse to fine, subangular to subrounded sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, subangular to subrounded gravel; maximum size 90 mm; dry, brown, no reaction with HCl. Grass and roots present, topsoil.
5 10						(GP)sc		**2.2 to 14.4 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, angular to subrounded gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 80 mm; dry, gray, pink, strong reaction with HCl.
						(SW-SM)g		**14.4 to 14.8 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 55 percent angular to subangular sand; about 35 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 35 mm; dry, gray, strong reaction with HCl.
15 20						(GP)sc		**14.8 to 23.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular, sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 120 mm; dry, pink to reddish yellow, strong reaction with HCl.
25 30 35						(SW)g		**23.0 to 36.0 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 70 percent coarse to fine, angular to subrounded sand; about 30 percent coarse to fine, hard, angular to subrounded gravel; trace of nonplastic fines with quick dilatancy and low toughness; maximum size 75 mm; dry, gray, pink, no to strong reaction with HCl.
40						(GP)sc		**36.0 to 40.5 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, angular to subangular, gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 115 mm; dry, pink, gray, no reaction with HCl.
						(SW)g		**40.5 to 42.0 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 70 percent coarse to fine, subangular sand; about 25 percent predominantly fine, subangular gravel; about 5 percent nonplastic fines; maximum size 55 mm; dry, pink, strong reaction with HCl.
						(GP)s		**42.0 to 44.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 60 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, subangular sand; trace of nonplastic fines; maximum size 70 mm; pink, strong reaction with HCl.
45						(SW)g		**44.0 to 47.0 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 65 percent coarse to fine, angular to subangular sand; about 30 percent coarse to fine, hard, subangular gravel; about 5 percent nonplastic fines; maximum size 70 mm; dry, gray, pinkish white, moderate to strong reaction with HCl.
						(SW-SM)g		**47.0 to 48.5 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 60 percent coarse to fine, angular to subangular sand; about 30 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 80 mm; dry, gray, strong reaction with HCl.

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-49

SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/6/2005 FINISHED: 4/11/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,058.84 E 571,421.14
TOTAL DEPTH: 142.9 ft.
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STATE: Nevada
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ANGLE FROM HORIZONTAL: -90°
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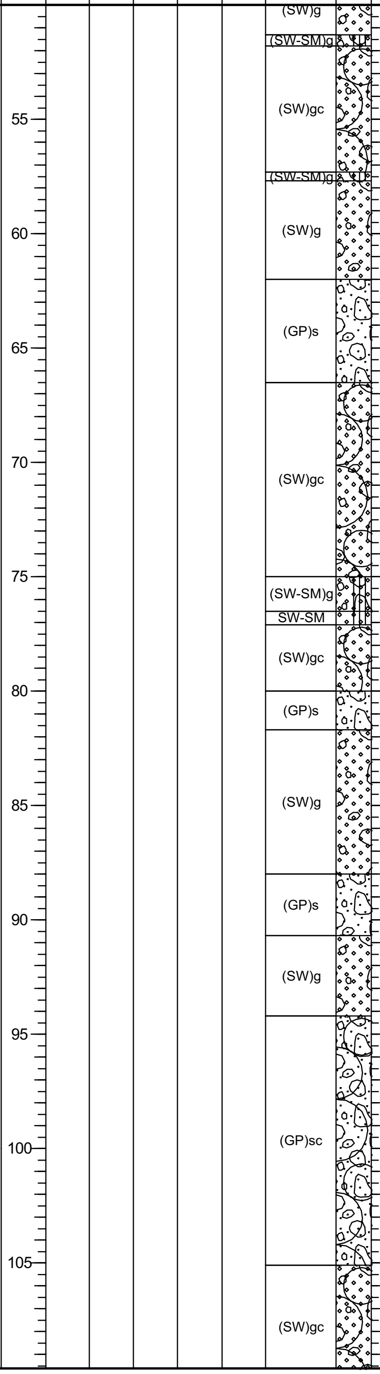
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					



48.5 to 51.3 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 70 percent coarse to fine, angular to subangular sand; about 25 percent coarse to fine, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 85 mm; dry, gray, strong reaction with HCl.

51.3 to 51.8 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 70 percent coarse to fine, subangular to subrounded sand; about 20 percent predominantly fine, hard, subangular to subrounded gravel; about 10 percent nonplastic fines with low dry strength and quick dilatancy; maximum size 15 mm; dry, gray, strong reaction with HCl.

51.8 to 57.3 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 65 percent coarse to fine, subangular sand; about 30 percent coarse to fine, hard, subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 115 mm; dry, pink, gray, no to strong reaction with HCl.

57.3 to 57.7 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 60 percent coarse to fine, angular to subangular sand; about 30 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 15 mm; dry, gray, strong reaction with HCl.

57.7 to 62.0 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 60 percent coarse to fine, angular to subangular sand; about 35 percent coarse to fine, hard, angular to subangular gravel; trace to 5 percent nonplastic fines; maximum size 115 mm; dry, pink, gray, strong reaction with HCl.

62.0 to 66.5 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 60 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, subangular sand; trace of nonplastic fines; maximum size 80 mm; dry, gray, moderate reaction with HCl.

66.5 to 75.0 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 60 percent coarse to fine, angular to subangular sand; about 35 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 95 mm; dry, pink, gray, no to strong reaction with HCl.

75.0 to 76.5 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 60 percent coarse to fine, subangular sand; about 30 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 55 mm; dry, pink, moderate reaction with HCl.

76.5 to 77.1 ft. WELL GRADED SAND WITH SILT (SW-SM): About 85 percent coarse to fine, subangular sand; about 5 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 45 mm; dry, gray, strong reaction with HCl.

77.1 to 80.0 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 60 percent coarse to fine, angular to subangular sand; about 35 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 85 mm; dry, no to strong reaction with HCl.

80.0 to 81.7 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 55 percent coarse to fine, hard, subangular gravel; about 45 percent coarse to fine, subangular sand; trace of nonplastic fines; maximum size 90 mm; dry, pink, no reaction with HCl.

81.7 to 88.0 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 60 percent coarse to fine, angular to subangular sand; about 35 percent predominantly fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 65 mm; dry, pink, gray, no to weak reaction with HCl.

88.0 to 90.7 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 80 percent coarse to fine, hard, angular to subangular gravel; about 20 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; maximum size 65 mm; dry, gray, weak reaction with HCl.

90.7 to 94.2 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 70 percent coarse to fine, subangular sand; about 25 percent predominantly fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 45 mm; dry, gray, moderate to strong reaction with HCl.

94.2 to 105.1 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 100 mm; dry, pink, pinkish white, strong reaction with HCl. Core removed from 95.1 to 96.7 ft.

105.1 to 110.5 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 70 percent coarse to fine, subangular sand; about 25 percent coarse to fine, hard, angular to subangular, gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 90 mm; dry, gray, strong reaction with HCl. Core removed from 106.6 to 108.3 ft.

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-49

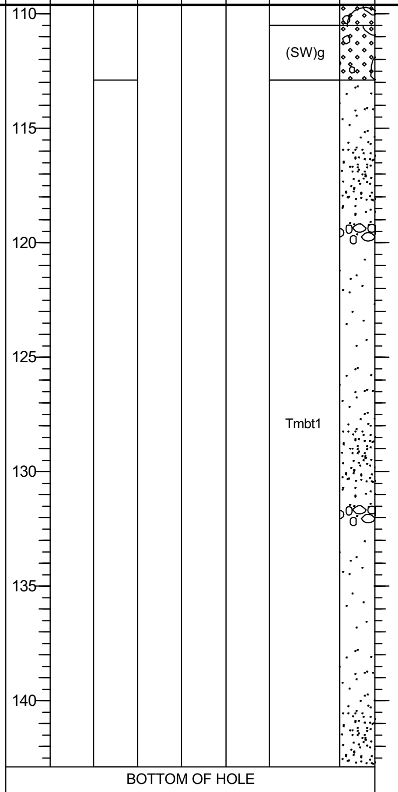
SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/6/2005 FINISHED: 4/11/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,058.84 E 571,421.14
TOTAL DEPTH: 142.9 ft.
DEPTH TO BEDROCK: 112.9 ft.

STATE: Nevada
GROUND ELEVATION: 3668.78
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					



110.5 to 112.9 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 60 percent coarse to fine, angular to subangular sand; about 35 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 100 mm; dry, gray, strong reaction with HCl.

112.9 to 142.9 ft. PRE-RAINIER MESA TUFF BEDDED TUFF (Tmbt1): Bedded tuffs interbedded with tephras.

The bedded tuff is nonwelded, poorly consolidated, locally cemented, white, light gray, composed of ash and very fine to medium sand size crystal fragments, 5 to 15 percent pumice (locally 25 percent), rare to 1 percent volcanic lithic fragments. Portions of the bedded tuff is probably reworked.

The Tephra is nonwelded, vitric, poorly consolidated, locally altered, locally cemented, white, 20 to 98 percent pumice, rare to 15 percent lithic fragments, less than 1 percent to abundant vitric shards and fragments, 1 to 2 percent crystal fragments of quartz and sanidine, rare biotite.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-50

SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/14/2005 FINISHED: 4/19/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,785. E 571,698.02
TOTAL DEPTH: 155.5 ft.
DEPTH TO BEDROCK: 123.2 ft.

STATE: Nevada
GROUND ELEVATION: 3656.26
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 103.5' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

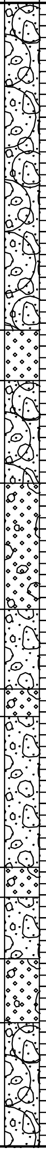
Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 155.5' (TD)

Hole Completion:
Back fill hole from 155.5' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.



DEPTH	ENGINEERING INDEXES HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	CLASSIFICATION AND PHYSICAL CONDITION
							0.0 to 123.2 ft. QUATERNARY ALLUVIUM (Qal)
5 10						(GP)sc	**0.0 to 14.3 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 65 percent coarse to fine, hard, angular to subrounded gravel; about 30 percent coarse to fine, angular to subrounded sand; about 5 percent nonplastic fines; trace of hard drilled cobbles; maximum size 150 mm; moist, reddish brown, light reddish brown, light gray, moderate to mostly strong reaction with HCl. Some organic materials present near the top.
15						SW	**14.3 to 16.5 ft. WELL GRADED SAND (SW):** About 90 percent coarse to fine, angular to subangular sand; about 10 percent predominantly fine, hard, subangular gravel; trace of nonplastic fines; maximum size 30 mm; moist, pink, strong reaction with HCl.
20						(GP)sc	**16.5 to 21.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 80 percent coarse to fine, hard, angular gravel; about 20 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; moist, reddish brown, moderate reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled cobbles; maximum size 130 mm; remainder minus 3-inch.
25						(SW)g	**21.0 to 26.5 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 60 percent coarse to fine, angular to subangular sand; about 40 percent predominantly fine, hard, angular to subangular gravel; trace of nonplastic fines; maximum size 40 mm; moist, reddish brown, light gray, no to strong reaction with HCl.
						(GP)s	**26.5 to 30.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 55 percent predominantly fine, hard, angular to subangular gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; maximum size 50 mm; moist, light reddish brown, no reaction with HCl.
30						(SW)g	**30.0 to 31.2 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 55 percent coarse to fine, angular to subangular sand; about 45 percent predominantly fine, hard, angular to subangular gravel; trace of nonplastic fines; maximum size 65 mm; moist, light reddish brown, no reaction with HCl.
35						(GP)s	**31.2 to 37.8 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 60 percent predominantly fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; maximum size 50 mm; moist, reddish brown, weak reaction with HCl.
						(SW)g	**37.8 to 39.1 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 55 percent coarse to fine, subangular to subrounded sand; about 45 percent predominantly fine, hard, angular to subangular gravel; trace of nonplastic fines; maximum size 70 mm; moist, light reddish brown, pink, strong reaction with HCl.
40						(GP)s	**39.1 to 41.8 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 65 percent coarse to fine, hard, angular to subrounded gravel; about 30 percent coarse to fine, subangular to subrounded sand; about 5 percent nonplastic fines; maximum size 70 mm; dry to moist, pink, light gray, light reddish brown, strong reaction with HCl.
						(SW)g	**41.8 to 44.6 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 55 percent coarse to fine, angular to subangular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 45 mm; moist, light gray, pink, no to strong reaction with HCl.
45						(GP)sc	**44.6 to 51.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; moist, pink, light reddish brown, light gray, strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular to subrounded cobbles; maximum size 85 mm; remainder minus 3-inch.

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

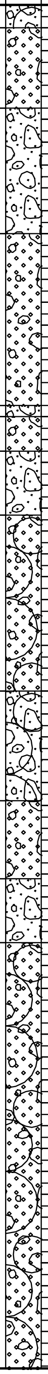
GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-50

SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/14/2005 FINISHED: 4/19/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,785. E 571,698.02
TOTAL DEPTH: 155.5 ft.
DEPTH TO BEDROCK: 123.2 ft.

STATE: Nevada
GROUND ELEVATION: 3656.26
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					
							(SW)g		**51.0 to 54.5 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 70 percent coarse to fine, angular to subangular sand; about 30 percent predominantly fine, hard, angular to subangular gravel; trace of nonplastic fines; maximum size 25 mm; moist, pinkish gray, light reddish brown, strong reaction with HCl.
	55						(GP)s		**54.5 to 60.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 55 percent coarse to fine, hard, subangular gravel; about 45 percent coarse to fine, subangular to subrounded sand; trace of nonplastic fines; maximum size 45 mm; moist, pinkish gray, strong reaction with HCl.
	60 65						(SW)g		**60.0 to 67.5 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 70 percent coarse to fine, angular to subangular sand; about 25 percent predominantly fine, hard, angular to subangular gravel; trace to 5 percent nonplastic fines; maximum size 40 mm; moist, light gray, pink, pinkish gray, strong reaction with HCl.
							(GP)s		**67.5 to 68.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 60 percent coarse to fine, hard, angular gravel; about 35 percent, coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; maximum size 65 mm; moist, light gray, strong reaction with HCl.
							(SW)g		**68.0 to 69.5 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 55 percent coarse to fine, angular to subangular sand; about 40 percent predominantly fine, hard, angular gravel; about 5 percent nonplastic fines; maximum size 30 mm; moist, light gray, strong reaction with HCl.
	70						(GP)s		**69.5 to 72.3 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 55 percent predominantly fine, hard, angular gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; maximum size 60 mm; moist, light gray, strong reaction with HCl.
	75						(SW)gc		**72.3 to 80.0 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 70 percent coarse to fine, angular to subrounded sand; about 25 percent predominantly fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; moist, pinkish gray, strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
	80						(GP)sc		**80.0 to 84.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 60 percent predominantly fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; moist, pink, strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular cobbles; maximum size 85 mm; remainder minus 3-inch.
	85						(SW)g		**84.8 to 88.2 ft. WELL GRADED SAND WITH GRAVEL (SW)g:** About 80 percent coarse to fine, angular to subangular sand; about 15 percent predominantly fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 25 mm; moist, pink, light gray, strong reaction with HCl.
	90						(GP)s		**88.2 to 91.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 60 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; maximum size 45 mm; moist, pink, light gray, strong reaction with HCl.
	95 100 105						(SW)gc		**91.0 to 112.8 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 65 percent coarse to fine, angular to subangular sand; about 30 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 120 mm; moist, pinkish gray, pink, light gray, weak to strong reaction with HCl. Core removed from 91.6 to 93.1 ft., and from 105.4 to 107.2 ft.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-50

SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/14/2005 FINISHED: 4/19/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,785. E 571,698.02
TOTAL DEPTH: 155.5 ft.
DEPTH TO BEDROCK: 123.2 ft.

STATE: Nevada
GROUND ELEVATION: 3656.26
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES

DEPTH

ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY

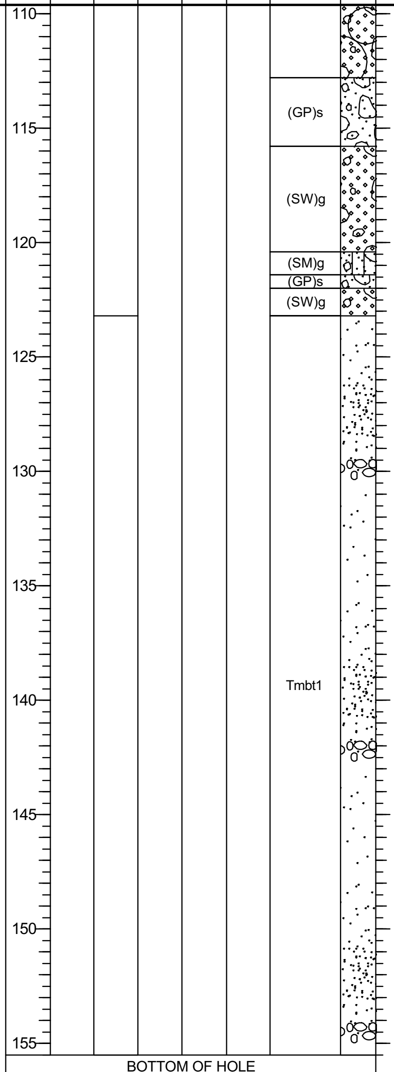
% CORE RECOVERY

% RQD

GEOLOGIC UNIT [USCS]

GRAPHIC

CLASSIFICATION AND PHYSICAL CONDITION



112.8 to 115.8 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 60 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; maximum size 80 mm; moist, pink, strong reaction with HCl.

115.8 to 120.4 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 70 percent coarse to fine, angular to subangular sand; about 25 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 50 mm; moist, gray, strong reaction with HCl. Core removed from 116.5 to 118.2 ft.

120.4 to 121.4 ft. SILTY SAND WITH GRAVEL (SM)g: About 45 percent coarse to fine, angular to subangular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 45 mm; moist, light gray, strong reaction with HCl.
121.4 TO 122.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 70 percent coarse to fine, hard, angular gravel; about 30 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; maximum size 90 mm; moist, gray, strong reaction with HCl.
122.0 to 123.2 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 65 percent coarse to fine, angular to subangular sand; about 30 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 30 mm; moist, pink, gray, strong reaction with HCl.
123.2 to 155.5 ft. PRE-RAINIER MESA TUFF BEDDED TUFF (Tmbt1):
Bedded tuffs with tephras.

The bedded tuff is nonwelded, partially consolidated, vitric, with zones of intense clay alteration, very pale brown and white, 10 to 40 percent pumice, 3 to 50 percent crystal fragments of quartz and sanidine.

The tephra is nonwelded, poorly to partially consolidated, vitric, with some possibly reworked zones, very friable locally, light brown, pale brown, pink, and white, 2 to 40 percent pumice, ash with less than 1 to 10 percent felsic crystal fragments, less than 1 percent and locally absent volcanic lithic fragments, less than 1 percent or 10 to 15 percent locally of volcanic glass fragments.

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-51

SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 3/29/2005 FINISHED: 3/31/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,313.71 E 571,672.09
TOTAL DEPTH: 156.7 ft.
DEPTH TO BEDROCK: 128.4 ft.

STATE: Nevada
GROUND ELEVATION: 3671.96
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 156.7' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 156.7' (TD)

Hole Completion:
Back fill hole from 156.7' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.

DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	HARDNESS	WELDING	FRACTURE DENSITY					
5 10 15 20 25						(GM)sc		**0.0 to 128.4 ft. QUATERNARY ALLUVIUM (Qal)** **0.0 to 26.6 ft SILTY GRAVEL WITH SAND AND COBBLES (GM)sc:** About 50 percent coarse to fine, hard, angular to subrounded gravel; about 35 percent coarse to fine, angular to subrounded sand; about 15 percent nonplastic fines with quick dilatancy and low toughness, trace of hard, subangular to subrounded cobbles; maximum size 110 mm; dry, light reddish brown, pink, no reaction with HCl near top of hole, to strong reaction with depth.
						SM		**26.6 to 26.9 ft SILTY SAND (SM):** About 55 percent coarse to fine, subangular to subrounded sand; about 40 percent nonplastic fines with quick dilatancy and low toughness; about 5 percent predominantly fine, hard, subangular to subrounded gravel; maximum size 60 mm; dry, light gray, strong reaction with HCl.
30 35						(GP)sc		**26.9 to 39.4 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 65 percent coarse to fine, hard, angular to subrounded gravel; about 35 percent coarse to fine, angular to subrounded sand; trace of nonplastic fines; trace of hard, subrounded cobbles; maximum size 80 mm, dry, pink, no reaction with HCl.
40						(SW-SM)g		**39.4 to 42.6 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 70 percent coarse to fine, subangular to subrounded sand; about 20 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 30 mm, dry, pink, no reaction with HCl.
45						(GP-GM)sc		**42.6 to 46.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc:** About 50 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, subangular to subrounded sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subrounded cobbles; maximum size 80 mm; dry, pink, no reaction with HCl.
						(GM)s		**46.0 to 50.0 ft. SILTY GRAVEL WITH SAND (GM)s:** About 45 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, subangular to subrounded sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 30 mm, dry, pink, strong reaction with HCl.

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-51

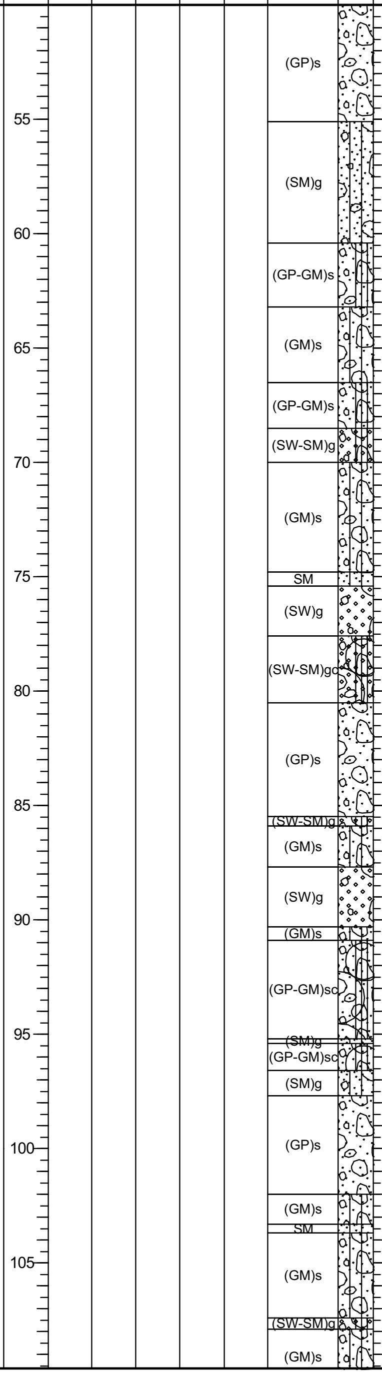
SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 3/29/2005 FINISHED: 3/31/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,313.71 E 571,672.09
TOTAL DEPTH: 156.7 ft.
DEPTH TO BEDROCK: 128.4 ft.

STATE: Nevada
GROUND ELEVATION: 3671.96
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					



50.0 to 55.1 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 65 percent coarse to fine, hard, angular gravel; about 30 percent coarse to fine, subangular to subrounded sand; about 5 percent nonplastic fines; maximum size 75 mm; dry, pink, strong reaction with HCl.

55.1 to 60.4 ft. SILTY SAND WITH GRAVEL (SM)g: About 50 percent coarse to fine, angular to subrounded sand; about 35 percent predominantly fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 65 mm; dry, pink, strong reaction with HCl.

60.4 to 63.2 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 60 percent coarse to fine, hard, subangular to subrounded gravel; about 30 percent coarse to fine, subangular to subrounded sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 85 mm, dry, pink, strong reaction with HCl.

63.2 to 66.5 ft. SILTY GRAVEL WITH SAND (GM)s: About 60 percent coarse to fine, hard, angular to subangular gravel; about 25 percent coarse to fine, subangular to subrounded sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 70 mm; dry, pink, strong reaction with HCl.

66.5 to 68.5 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 50 percent predominantly fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subrounded sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 65 mm; dry, pink, strong reaction with HCl.

68.5 to 70.0 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 70 percent coarse to fine, subangular to subrounded sand; about 20 percent coarse to fine, hard, subangular to subrounded gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 90 mm; dry, pink, strong reaction with HCl.

70.0 to 74.8 ft. SILTY GRAVEL WITH SAND (GM)s: About 45 percent coarse to fine, hard, subangular to subrounded gravel; about 35 percent coarse to fine, subangular to subrounded sand; about 20 percent nonplastic fines with quick dilatancy and low toughness; maximum size 40 mm; dry, pinkish gray, strong reaction with HCl.

74.8 to 75.4 ft. SILTY SAND (SM): About 75 percent coarse to fine, subangular to subrounded sand; about 25 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, subangular gravel; maximum size 60 mm; dry, light gray, strong reaction with HCl.

75.4 to 77.6 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 65 percent coarse to fine, subangular to subrounded sand; about 30 percent coarse to fine, hard, angular to subrounded gravel; about 5 percent nonplastic fines; maximum size 85 mm; dry, pink, strong reaction with HCl.

77.6 to 80.5 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 60 percent coarse to fine, angular to subrounded sand; about 30 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subrounded cobbles; maximum size 115 mm; dry, pink, strong reaction with HCl.

80.5 to 85.5 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, subangular to subrounded sand; about 5 percent nonplastic fines; maximum size 130 mm; dry, pink, light reddish brown, no reaction with HCl.

85.5 to 85.9 ft. POORLY GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 50 percent coarse to fine, subangular to subrounded sand; about 25 percent predominantly fine, hard, angular to subangular gravel; about 25 percent nonplastic fines with quick dilatancy and low toughness; maximum size 35 mm; dry, pinkish gray, strong reaction with HCl.

85.9 to 87.7 ft. SILTY GRAVEL WITH SAND (GM)s: About 40 percent predominantly fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 25 percent nonplastic fines with quick dilatancy and low toughness; maximum size 60 mm; dry, pinkish gray, strong reaction with HCl.

87.7 to 90.3 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 75 percent coarse to fine, subangular to subrounded sand; about 20 percent predominantly fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 60 mm; dry, light gray, strong reaction with HCl.

90.3 to 90.9 ft. SILTY GRAVEL WITH SAND (GM)s: About 70 percent coarse to fine, hard, angular to subangular gravel; about 15 percent coarse to fine, subangular to subrounded sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, light gray, strong reaction with HCl.

90.9 to 95.2 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subrounded cobbles; maximum size 85 mm; dry, pinkish gray, strong reaction with HCl.

95.2 to 95.4 ft. SILTY SAND WITH GRAVEL(SM)g: About 60 percent coarse to fine, angular to subangular sand; about 25 percent predominantly fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 35 mm; dry, light gray, strong reaction with HCl.

95.4 to 96.6 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 80 mm; dry, pink, strong reaction with HCl.

96.6 to 97.7 ft. SILTY SAND WITH GRAVEL (SM)g: About 50 percent coarse to fine, angular to subangular sand; about 25 percent coarse to fine, hard, subangular gravel; about 25 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, light gray, strong reaction with HCl.

97.7 to 102.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 55 percent coarse to fine, hard, angular to subrounded gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; maximum size 105 mm; dry, pinkish gray, strong reaction with HCl.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-51

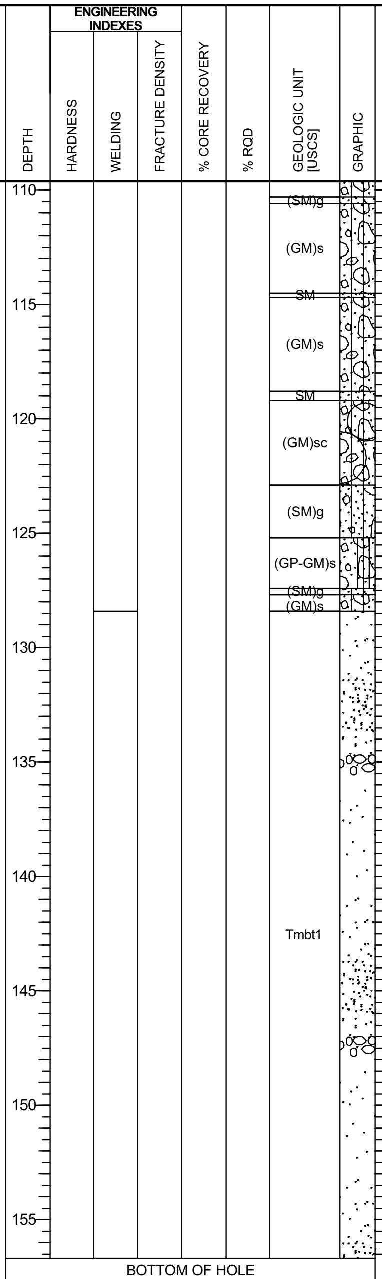
SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 3/29/2005 FINISHED: 3/31/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,313.71 E 571,672.09
TOTAL DEPTH: 156.7 ft.
DEPTH TO BEDROCK: 128.4 ft.

STATE: Nevada
GROUND ELEVATION: 3671.96
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES



CLASSIFICATION
AND PHYSICAL CONDITION

Core removed from 100.4 to 101.4 ft.
102.0 to 103.3 ft. SILTY GRAVEL WITH SAND (GM)s: About 40 percent predominantly fine, hard, angular to subangular gravel; about 30 percent nonplastic fines with quick dilatancy and low toughness; about 20 percent coarse to fine, angular to subangular sand; maximum size 60 mm; dry, pinkish gray, strong reaction with HCl.
103.3 to 103.7 ft. SILTY SAND (SM): About 60 percent coarse to fine, subangular to subrounded sand; about 40 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, subangular gravel; maximum size 15 mm; dry, light gray, strong reaction with HCl.
103.7 to 107.4 ft. SILTY GRAVEL WITH SAND (GM)s: About 55 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular to subangular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 80 mm; dry, pink, strong reaction with HCl.
107.4 to 107.9 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 60 percent coarse to fine, angular to subangular sand; about 30 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 30 mm; dry, pink, strong reaction with HCl.
107.9 to 110.3 ft. SILTY GRAVEL WITH SAND (GM)s: About 45 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, subangular to subrounded sand; about 20 percent nonplastic fines with quick dilatancy and low toughness; maximum size 65 mm; dry, light gray, strong reaction with HCl.
110.3 to 110.6 ft. SILTY SAND WITH GRAVEL (SM)g: About 65 percent coarse to fine, angular to subangular sand; about 20 percent predominantly fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 125 mm; dry, light gray, strong reaction with HCl.
110.6 to 114.5 ft. SILTY GRAVEL WITH SAND (GM)s: About 45 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular to subangular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 60 mm; dry, pinkish gray, strong reaction with HCl. Core removed from 111.5 to 112.3 ft.
114.5 to 114.7 ft. SILTY SAND (SM): About 80 percent coarse to fine, subangular to subrounded sand; about 20 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, angular to subangular gravel; maximum size 15 mm; dry, light gray, strong reaction with HCl.
114.7 to 118.8 ft. SILTY GRAVEL WITH SAND (GM)s: About 55 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular to subangular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 40 mm; dry, pink, strong reaction with HCl.
118.8 to 119.2 ft. SILTY SAND (SM): About 65 percent coarse to fine, subangular to subrounded sand; about 35 percent nonplastic fines with quick dilatancy and low toughness; trace of predominantly fine, hard, angular to subangular gravel; maximum size 25 mm; dry, light gray, strong reaction with HCl.
119.2 to 122.9 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc: About 50 percent coarse to fine, hard, angular gravel; about 30 percent coarse to fine, angular sand; about 20 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 85 mm; dry, pinkish gray, strong reaction with HCl. Core removed from 121.1 to 121.7 ft.
122.9 to 125.2 ft. SILTY SAND WITH GRAVEL (SM)g: About 35 percent coarse to fine, subangular to subrounded sand; about 35 percent nonplastic fines with quick dilatancy and low toughness; about 30 percent coarse to fine, hard, subangular to subrounded gravel; maximum size 50 mm; dry, light gray, strong reaction with HCl.
125.2 to 127.4 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 65 percent coarse to fine, hard, angular to subangular gravel; about 25 percent coarse to fine, subangular to subrounded sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 55 mm; dry, pinkish gray, strong reaction with HCl.
127.4 to 127.7 ft. SILTY SAND WITH GRAVEL (SM)g: About 60 percent coarse to fine, angular to subangular sand; about 25 percent predominantly fine, hard, angular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 25 mm; dry, light gray, strong reaction with HCl.
127.7 to 128.4 ft. SILTY GRAVEL WITH SAND (GM)s: About 45 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 20 percent nonplastic fines with quick dilatancy and low toughness; maximum size 45 mm; dry, pink, strong reaction with HCl.
128.4 to 156.7 ft. PRE-RAINIER MESA TUFF BEDDED TUFF (Tmbt1):

128.4 to 129.9 ft: Bedded tuff, nonwelded, pinkish white, consists primarily of silt to very fine sand size fragments of quartz, feldspar, and crystallized welded tuff in a calcite cemented as matrix, 1 to 2 percent pumice, 1 to 2 percent lithic fragments of crystallized welded tuff.

129.9 to 153.6 ft: Ignimbrite, nonwelded, vitric, bedded, white, 10 to 15 percent pumice, 1 percent lithic fragments of crystallized welded tuff, 15 percent crystal fragments of sanidine, plagioclase and quartz, less than 1 percent biotite and magnetite. There is a paleosol at the base of the unit, from 153.4 to 153.6 ft.

153.6 to 156.7 ft: Bedded/reworked tuff, nonwelded, crystallized, pink, 10 to 15 percent pumice, 5 to 10 percent crystal fragments of quartz and feldspar, less than 1 percent of biotite and hornblende, less than 1 percent lith

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-52

SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 3/31/2005 FINISHED: 4/5/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,557.02 E 571,914.65
TOTAL DEPTH: 184.7 ft.
DEPTH TO BEDROCK: 164.7 ft.

STATE: Nevada
GROUND ELEVATION: 3672.37
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 184.7' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

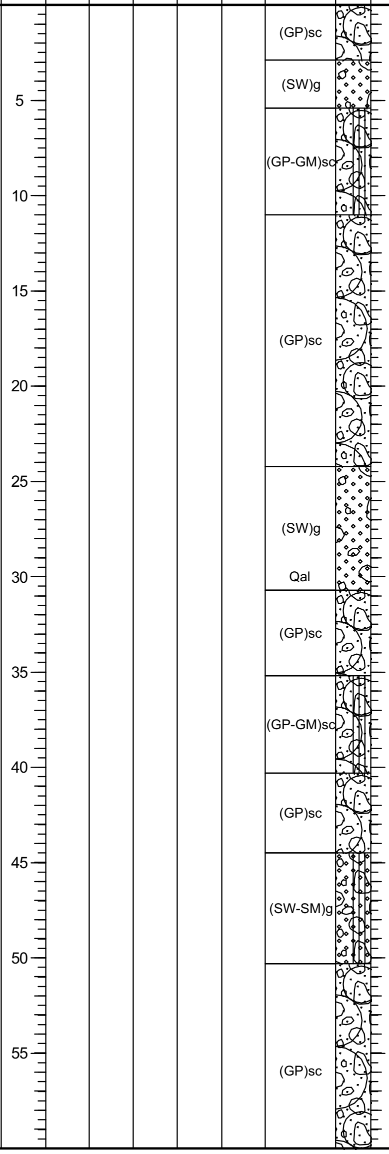
Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.00' to 184.7' (TD)

Hole Completion:
Back fill hole from 184.7' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.



0.0 to 164.7 ft. QUATERNARY ALLUVIUM (Qal):

0.0 to 2.9 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, angular to subangular gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; dry, reddish brown, moderate reaction with HCl. Topsoil with organic material.

TOTAL SAMPLE (BY VOLUME): About 20 percent hard, subangular cobbles; maximum size 115 mm; remainder minus 3-inch.

2.9 to 5.4 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 55 percent coarse to fine, subangular sand; about 45 percent predominantly fine, hard, subangular gravel; trace of nonplastic fines; maximum size 65 mm; dry, light reddish brown, moderate reaction with HCl. Some organic material present.

5.4 to 11.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 110 mm; dry, pink, weak reaction with HCl.

11.0 to 24.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 130 mm; dry, light reddish brown, pink, no reaction with HCl.

24.2 to 30.7 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 80 percent coarse to fine, angular sand; about 20 percent predominantly fine, hard, angular gravel; trace of nonplastic fines; maximum size 50 mm; dry, pink, no reaction with HCl.

30.7 to 35.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 120 mm; dry, light reddish brown, no reaction with HCl.

35.2 to 40.3 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 60 percent coarse to fine, hard, angular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 110 mm; dry, pinkish gray, no reaction with HCl.

40.3 to 44.5 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular gravel; about 35 percent coarse to fine, angular sand; trace of nonplastic fines; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subrounded cobbles; maximum size 150 mm; remainder minus 3-inch.

44.5 to 50.3 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 65 percent coarse to fine, angular sand; about 25 percent predominantly fine, hard, angular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 55 mm; dry, pinkish gray, moderate reaction with HCl.

50.3 to 61.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 170 mm; dry, light reddish brown, pink, weak to strong reaction with HCl.

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-52

SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 3/31/2005 FINISHED: 4/5/2005
DEPTH TO WATER: Not Encountered
PROJECT: Yucca Mountain Project
COORDINATES: N 766,557.02 E 571,914.65
TOTAL DEPTH: 184.7 ft.
DEPTH TO BEDROCK: 164.7 ft.
STATE: Nevada
GROUND ELEVATION: 3672.37
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					
									61.6 to 68.4 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 50 percent coarse to fine, angular to subangular sand; about 40 percent predominantly fine, hard, angular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 150 mm; dry, pinkish gray, no reaction with HCl.
	65						(SW-SM)gc		
									68.4 to 104.5 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, pink, pinkish gray, weak to strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 150 mm; remainder minus 3-inch.
	70								
	75								
	80								
	85						(GP)sc		
	90								
	95						Qal		
	100								
									104.5 to 107.9 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent predominantly coarse, hard, angular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 25 percent hard, subangular cobbles; maximum size 100 mm; remainder minus 3-inch. **107.9 to 109.5 ft. CORE REMOVED**
	105						(GP-GM)sc		
							CR		
	110								
									109.5 to 148.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 70 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; dry, pink, pinkish gray, light gray, no to strong reaction with HCl. Core removed from 115.7 to 117.7 ft, 128.7 to 130.1 ft, and 136.7 to 138.0 ft. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, angular to subangular cobbles; maximum size 170 mm; remainder minus 3-inch.
	115								
	120								
	125								
							(GP)sc		
	130								

WHB2_LOG SONICII.GPJ SONICII.GDT 1/3/08

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-52

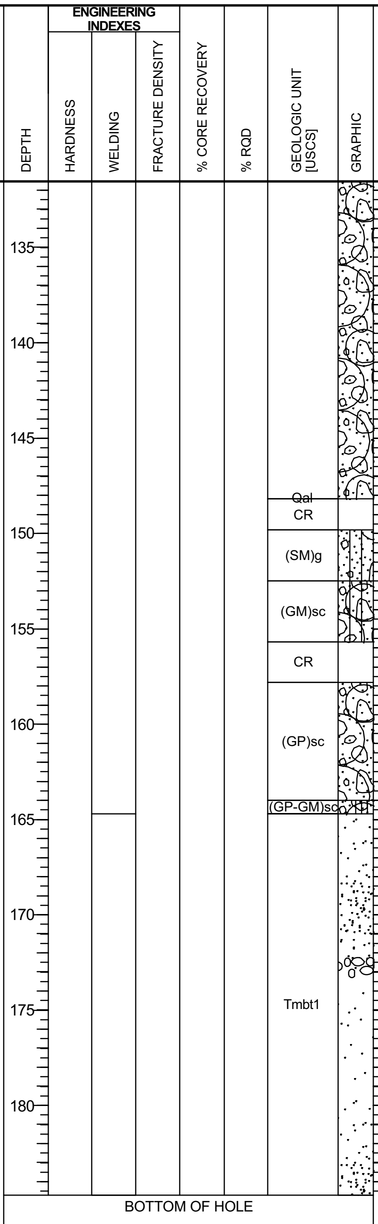
SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 3/31/2005 FINISHED: 4/5/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,557.02 E 571,914.65
TOTAL DEPTH: 184.7 ft.
DEPTH TO BEDROCK: 164.7 ft.

STATE: Nevada
GROUND ELEVATION: 3672.37
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES



CLASSIFICATION AND PHYSICAL CONDITION

148.2 to 149.8 ft. CORE REMOVED

149.8 to 152.5 ft. SILTY SAND WITH GRAVEL (SM)g: About 45 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 70 mm; dry, pink, no reaction with HCl.

152.5 to 155.7 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc: About 50 percent coarse to fine, hard, angular gravel; about 35 percent coarse to fine, angular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 120 mm; remainder minus 3-inch.

155.7 to 157.8 ft. CORE REMOVED

157.8 to 164.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 75 percent coarse to fine, hard, angular gravel; about 20 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pinkish gray, light reddish brown, , strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular cobbles; maximum size 170 mm; remainder minus 3-inch.

164.0 to 164.7 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent predominantly fine, hard, angular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 40 percent hard, subangular cobbles; maximum size 140 mm; remainder minus 3-inch.

164.7 to 184.7 ft. PRE-RAINIER MESA TUFF BEDDED TUFF (Tmbt1):
Tephra and bedded tuff.

164.7 to 174.6 ft: Tephra, nonwelded, bedded, poorly lithified (almost completely disaggregated by drilling), vitric, white, 10 to 30 percent pumice, rare lithic fragments of volcanic rock, 5 to 15 percent and locally 40 percent crystal fragments of sanidine and quartz, less than 1 percent biotite. At the top of the unit, from 164.7 to 164.8 may be a paleosol, very pale brown.

174.6 to 176.7 ft: Bedded tuff, aeolian(?), fine grained, crystal-lithic siltstone, with very fine crystal fragments and glass shards. May be an incipient paleosol.

176.7 to 178.2 ft: Sample removed.

178.2 to 184.7 ft: Tephra, nonwelded, bedded, reworked, pale brown to very pale brown, 5 to 10 percent pumice, rare lithic fragments of crystallized tuff or obsidian, 4 to 7 percent crystal fragments of quartz and sanidine, less than 1 percent biotite, lithified/cemented nodules of the tephra (up to 2 cm) occur throughout.

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-53

SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/20/2005 FINISHED: 4/25/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,039.7 E 571,947.85
TOTAL DEPTH: 160.6 ft.
DEPTH TO BEDROCK: 138.2 ft.

STATE: Nevada
GROUND ELEVATION: 3661.30
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES | DEPTH | ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 160.6' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

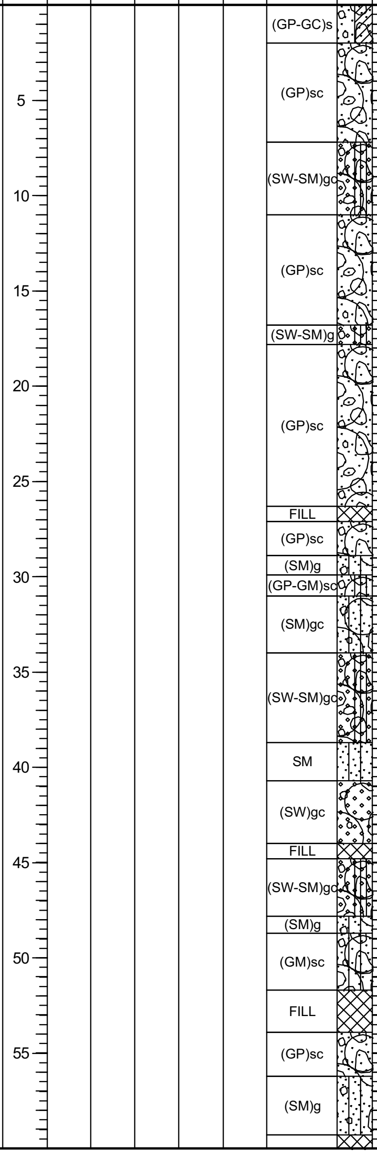
Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 160.6' (TD)

Hole Completion:
Back fill hole from 160.6' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.



0.0 to 137.6 ft. QUATERNARY ALLUVIUM (Qal)

0.0 to 2.0 ft. POORLY GRADED GRAVEL WITH CLAY AND SAND (GP-GC)s: About 50 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, angular sand; about 10 percent fines of low plasticity, with slow dilatancy and medium toughness; maximum size 70 mm; dry, light reddish brown, no reaction with HCl. Topsoil with organic material.
2.0 to 7.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, subangular gravel; about 35 percent coarse to fine, subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 110 mm; dry, pinkish gray, strong reaction with HCl.
7.2 to 11.0 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 55 percent coarse to fine, angular sand; about 35 percent coarse to fine, hard, angular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 110 mm; dry, pink, strong reaction with HCl.

11.0 to 16.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular gravel; about 35 percent coarse to fine, angular sand; trace of nonplastic fines; dry, light reddish brown, no reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 90 mm; remainder minus 3-inch.

16.8 to 17.8 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 65 percent coarse to fine, subangular sand; about 25 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, pink, weak reaction with HCl.
17.8 to 26.3 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular sand; trace of nonplastic fines; dry, pink, weak reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular cobbles; maximum size 135 mm; remainder minus 3-inch.

26.3 to 27.1 ft. FILL
27.1 to 28.9 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, subangular gravel; about 35 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 95 mm; dry, pinkish gray, no reaction with HCl.
28.9 to 29.9 ft. SILTY SAND WITH GRAVEL (SM)g: About 65 percent coarse to fine, angular sand; about 20 percent coarse to fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 30 mm; dry, pinkish gray, no reaction with HCl.
29.9 to 31.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 55 percent coarse to fine, hard, angular gravel; about 35 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 100mm; dry, pink, strong reaction with HCl.
31.0 to 34.0 ft. SILTY SAND WITH GRAVEL AND COBBLES (SM)gc: About 50 percent coarse to fine, angular to subangular sand; about 35 percent coarse to fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 95 mm; dry, light reddish brown, strong reaction with HCl.
34.0 to 38.7 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 55 percent coarse to fine, angular sand; about 35 percent coarse to fine, hard, angular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, no reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
38.7 to 40.7 ft. SILTY SAND (SM): About 75 percent coarse to fine, angular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; about 10 percent coarse to fine, hard, angular to subangular gravel; maximum size 70 mm; dry, pink, no reaction with HCl.
40.7 to 44.0 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 50 percent coarse to fine, angular sand; about 45 percent coarse to fine, hard, angular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 120 mm; dry, light reddish brown, no reaction with HCl.
44.0 to 44.8 ft. FILL
44.8 to 47.8 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 55 percent coarse to fine, angular sand; about 35 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
47.8 to 48.7 ft. SILTY SAND WITH GRAVEL (SM)g: About 60 percent coarse to fine, angular to subangular sand; about 25 percent nonplastic fines with quick dilatancy and low toughness; about 15 percent predominantly fine, hard, angular gravel; maximum size 35 mm; dry, pinkish gray, weak reaction with HCl.

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-53

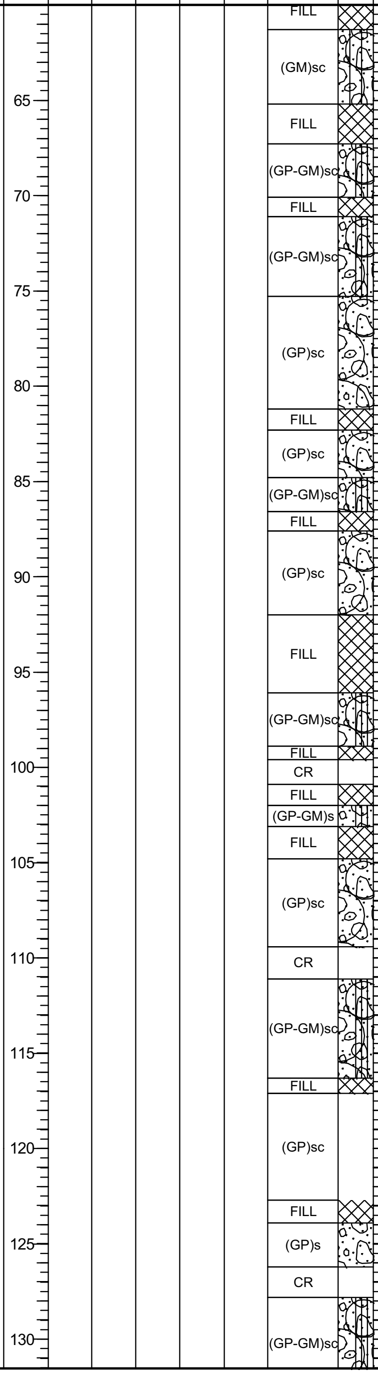
SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/20/2005 FINISHED: 4/25/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,039.7 E 571,947.85
TOTAL DEPTH: 160.6 ft.
DEPTH TO BEDROCK: 138.2 ft.

STATE: Nevada
GROUND ELEVATION: 3661.30
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES | DEPTH | ENGINEERING INDEXES: HARDNESS, WELDING, FRACTURE DENSITY | % CORE RECOVERY | % RQD | GEOLOGIC UNIT [USCS] | GRAPHIC | CLASSIFICATION AND PHYSICAL CONDITION



48.7 to 51.7 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 115 mm; dry, light reddish brown, no reaction with HCl.
51.7 to 53.9 ft. FILL
53.9 to 56.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 95 mm; dry, pink, no reaction with HCl.
56.2 to 59.3 ft. SILTY SAND WITH GRAVEL (SM)g: About 50 percent coarse to fine, angular sand; about 35 percent coarse to fine, hard, angular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 70 mm; dry, pink, no reaction with HCl.
59.3 to 61.3 ft. FILL
61.3 to 65.2 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc: About 50 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, weak reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 20 percent hard, subangular cobbles; maximum size 180 mm; remainder minus 3-inch.
65.2 to 67.3 ft. FILL
67.3 to 70.1 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, light reddish brown, no to strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 20 percent hard, drilled cobbles; maximum size 175 mm; remainder minus 3-inch.
70.1 to 71.1 ft. FILL
71.1 to 75.3 ft: POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc. About 60 percent predominantly fine to coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, light gray, pinkish gray, no to strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 15 percent hard, drilled and subangular cobbles; maximum size 150 mm; remainder minus 3-inch.
75.3 to 81.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, subangular sand; about 5 percent nonplastic fines; dry, pinkish gray, no reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and subangular cobbles; maximum size 110 mm; remainder minus 3-inch.
81.2 to 82.3 ft. FILL
82.3 to 84.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; trace of nonplastic fines; dry, pinkish gray, moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 20 percent hard, drilled and subangular cobbles; maximum size 130 mm; remainder minus 3-inch.
84.8 to 86.6 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 130 mm; dry, pinkish gray, strong reaction with HCl.
86.6 to 87.6 ft. FILL
87.6 to 92.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, very angular sand; about 5 percent nonplastic fines; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 95 mm; remainder minus 3-inch.
92.0 to 96.1 ft. FILL
96.1 to 98.9 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 55 percent coarse to fine, hard, angular gravel; about 25 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular cobbles; maximum size 130 mm; remainder minus 3-inch.
98.9 to 99.6 ft. FILL
99.6 to 100.9 ft. CORE REMOVED
100.9 to 102.0 ft. FILL
102.0 to 103.1 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 55 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, pink, no reaction with HCl.
103.1 to 104.8 ft. FILL
104.8 to 109.4 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 15 percent hard, drilled and subangular cobbles; maximum size 150 mm; remainder minus 3-inch.
109.4 to 111.1 ft. CORE REMOVED
111.1 to 116.3 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 30 percent hard, drilled cobbles; maximum size 210 mm; remainder minus 3-inch.
116.3 to 117.1 ft. FILL
117.1 to 122.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular sand;

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-53

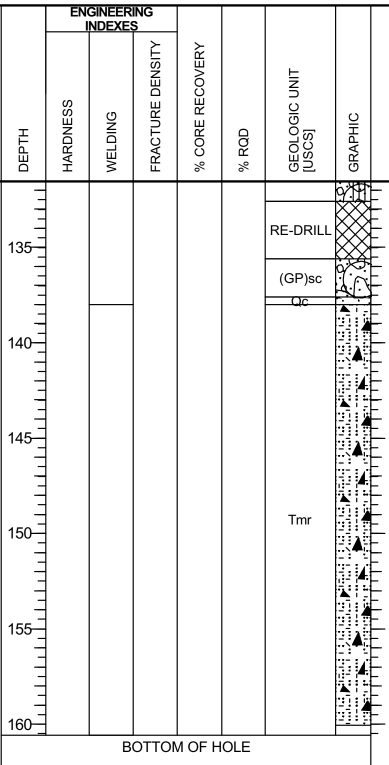
SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/20/2005 FINISHED: 4/25/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,039.7 E 571,947.85
TOTAL DEPTH: 160.6 ft.
DEPTH TO BEDROCK: 138.2 ft.

STATE: Nevada
GROUND ELEVATION: 3661.30
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES



CLASSIFICATION AND PHYSICAL CONDITION

about 5 percent nonplastic fines; trace of hard, subrounded cobbles; maximum size 85 mm; dry, pinkish gray, strong reaction with HCl.
122.7 to 123.9 ft. FILL
123.9 to 126.2 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 65 percent coarse to fine, hard, subangular gravel; about 30 percent coarse to fine, angular sand; about 5 percent nonplastic fines; maximum size 60 mm; dry, pinkish gray, strong reaction with HCl.
126.2 to 127.8 ft. CORE REMOVED
127.8 to 132.6ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness, dry, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and subangular cobbles; maximum size 165 mm; remainder minus 3-inch.
132.6 to 135.6 ft. RE-DRILL
135.6 to 137.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine to predominantly coarse, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, pink, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and angular cobbles; maximum size 130 mm; remainder minus 3-inch.
137.6 to 138.0 ft. COLLUVIUM (Qc):
Caliche cemented ash, generally consists of fine to medium sand size fragments of quartz, feldspar, and welded tuff in a caliche/ash matrix, white to pinkish white, with white caliche stringers, less than 1 percent biotite and magnetite.
138.2 to 160.6 ft. RAINIER MESA TUFF (Tmr):
Volcanic tuff, nonwelded, vitric, poorly consolidated (broken by drilling process into sand size fragments), white, 20 to 35 percent pumice, 1 percent lithic fragments of welded tuff, 10 to 20 percent crystal fragments of sanidine, plagioclase and quartz, less than 1 percent biotite. Caliche cemented at top of unit from 138.0 to 139.0 ft, strong reaction with HCl.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-54

SHEET 1 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/25/2005 FINISHED: 4/27/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,278.9 E 572,190.12
TOTAL DEPTH: 196.7 ft.
DEPTH TO BEDROCK: 183.0 ft.

STATE: Nevada
GROUND ELEVATION: 3661.64
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES: HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 196.7' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

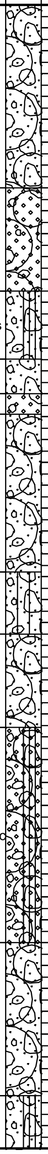
Casing Record:
8" casing from 0.0' to 196.7' (TD)

Hole Completion:
Back fill hole from 196.7' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.

DEPTH / GEOLOGIC UNIT [USCS]

DEPTH	GEOLOGIC UNIT [USCS]
0.0–8.0	(GP)sc
8.0–12.5	(SW)gc
12.5–15.5	(GP-GM)s
15.5–17.0	(GP)s
17.0–17.9	(SW)g
17.9–24.8	(GP)sc
24.8–27.5	(GM)s
27.5–31.6	(GP)sc
31.6–41.0	(SW-SM)gc
41.0–47.7	(GP)sc
47.7–	

Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45



CLASSIFICATION AND PHYSICAL CONDITION

0.0 to183.0 ft. QUATERNARY ALLUVIUM (Qal)

0.0 to 8.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, subangular to subrounded gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, drilled and subangular cobbles; maximum size 115 mm; moist near surface to dry at depth, strong brown to light yellowish brown, strong reaction with HCl.

8.0 to 12.5 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 50 percent coarse to fine, angular to subangular sand; about 45 percent coarse to fine, hard, subangular gravel; about 5 percent nonplastic fines with no dry strength and quick dilatancy; trace of hard, subrounded cobbles; maximum size 125 mm, dry, light brownish gray, no reaction with HCl.

12.5 to 15.5 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 50 percent predominantly fine, hard, subangular gravel; about 40 percent coarse to fine, subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 65 mm, dry, yellow, no reaction with HCl.

15.5 to 17.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 65 percent coarse to fine, hard, subangular to subrounded gravel; about 35 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; maximum size 75 mm; dry, very pale brown, moderate reaction with HCl.

17.0 to 17.9 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 65 percent coarse to fine, angular sand; about 30 percent predominantly fine, hard, subangular gravel; about 5 percent nonplastic fines; maximum size 35 mm; dry, very pale brown, moderate reaction with HCl.

17.9 to 24.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, subangular gravel; about 35 percent coarse to fine, subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 105 mm; dry, very pale brown, moderate reaction with HCl.

24.8 to 27.5 ft. SILTY GRAVEL WITH SAND (GM)s: About 45 percent predominantly fine, hard, subangular gravel; about 40 percent coarse to fine, subangular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, light gray, strong reaction with HCl.

27.5 to 31.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 50 percent coarse to fine, hard, angular to subangular gravel; about 45 percent coarse to fine, subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 100 mm; dry, very pale brown, no reaction with HCl.

31.6 to 41.0 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 60 percent coarse to fine, angular to subangular sand; about 25 percent coarse to fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 110 mm; dry, white, light gray, pale brown, and light olive gray, no to strong reaction with HCl.

41.0 to 47.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 50 percent coarse to fine, hard, angular to subangular gravel; about 45 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, drilled and subangular cobbles; maximum size 140 mm; dry, pale yellow, no to weak reaction with HCl.

47.7 to 52.2 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 55 percent coarse to fine, hard, subangular gravel; about 35 percent coarse to fine, subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-54

SHEET 2 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/25/2005 FINISHED: 4/27/2005
DEPTH TO WATER: Not Encountered
PROJECT: Yucca Mountain Project
COORDINATES: N 766,278.9 E 572,190.12
TOTAL DEPTH: 196.7 ft.
DEPTH TO BEDROCK: 183.0 ft.
STATE: Nevada
GROUND ELEVATION: 3661.64
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					
							(GP-GM)s		mm; dry, pale yellow, strong reaction with HCl.
							(SM)g		**52.2 to 54.1 ft. SILTY SAND WITH GRAVEL (SM)g:** About 60 percent coarse to fine, angular to subangular sand; about 20 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, light brownish gray, strong reaction with HCl.
	55 60 65						(GP)sc		**54.1 to 69.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 60 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; trace of hard, drilled and subangular to subrounded cobbles; maximum size 120 mm; dry, light gray and pale yellow, weak to strong reaction with HCl.
	70						SM		**69.7 to 70.5 ft. SILTY SAND (SM):** About 70 percent coarse to fine, subangular sand; about 20 percent nonplastic fines with quick dilatancy and low toughness; about 10 percent predominantly fine, hard, angular to subangular gravel; maximum size 20 mm; dry, light gray, strong reaction with HCl.
	75						(GP)sc		**70.5 to 75.3 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 70 percent coarse to fine, hard, subangular gravel; about 30 percent coarse to fine, subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 100 mm; dry, light olive gray, strong reaction with HCl.
							SM		**75.3 to 76.3 ft. SILTY SAND (SM):** About 80 percent coarse to fine, angular to subangular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; about 5 percent predominantly fine, hard, angular to subangular gravel; maximum size 45 mm; dry, light brownish gray, strong reaction with HCl.
	80						(GP)sc		**76.3 to 81.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent, coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 130 mm; dry, pale yellow, moderate reaction with HCl.
							(SW-SM)g		**81.6 to 82.6 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 70 percent coarse to fine, subangular sand; about 20 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 20 mm; dry, pinkish gray, strong reaction with HCl.
	85						(GP)sc		**82.6 to 88.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 70 percent, coarse to fine, hard, subangular gravel; about 30 percent, coarse to fine, subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 150 mm; dry, pinkish gray, moderate reaction with HCl.
	90						(SW-SM)g		**88.0 to 90.5 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 70 percent coarse to fine, subangular sand; about 20 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 45 mm; dry, pinkish gray, moderate reaction with HCl.
	95						(GP)sc		**90.5 to 95.3 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 70 percent coarse to fine, hard, angular to subangular gravel; about 25 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 130 mm; dry, pink and light gray, no to strong reaction with HCl.
							(SW-SM)g		**95.3 to 97.0 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 50 percent coarse to fine, subangular sand; about 40 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 60 mm; dry, pinkish gray, moderate reaction with HCl.
	100						(GP)sc		**97.0 to 100.4 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 60 percent coarse to fine, hard, subangular gravel; about 35 percent coarse to fine, subangular sand; about 5 percent nonplastic fines; trace of hard, angular cobbles; maximum size 120 mm; dry, pink, strong reaction with HCl.
							(SW)gc		**100.4 to 102.5 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 55 percent coarse to fine, subangular sand; about 35 percent coarse to fine, hard, subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 85 mm; dry, pinkish gray, strong reaction with HCl.
	105						(GP)sc		**102.5 to 107.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 75 percent coarse to fine, hard, angular to subangular gravel; about 25 percent coarse to fine, subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 120 mm; dry, pink, strong reaction with HCl.
							(SW-SM)g		**107.2 to 108.0 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 70 percent coarse to fine, subangular sand; about 20 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-54

SHEET 3 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/25/2005 FINISHED: 4/27/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,278.9 E 572,190.12
TOTAL DEPTH: 196.7 ft.
DEPTH TO BEDROCK: 183.0 ft.

STATE: Nevada
GROUND ELEVATION: 3661.64
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC
		HARDNESS	WELDING	FRACTURE DENSITY				
	110 115 120 125 130 135 140 145 150 155 160 165						(GP)sc (SM)g (GP)sc (SM)g CR (SW)gc SM (GP)sc CR (GP-GM)sc (GP)sc (SW-SM)g (GP)sc CR (SM)g	

CLASSIFICATION AND PHYSICAL CONDITION

30 mm; dry, pinkish gray, strong reaction with HCl.
108.0 to 110.9 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 85 percent coarse to fine, hard, angular to subangular gravel; about 15 percent coarse to fine, subangular sand; trace of nonplastic fines; dry, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 20 percent hard, drilled, and subangular to subrounded cobbles; maximum size 150 mm; remainder minus 3-inch.
110.9 to 111.9 ft. SILTY SAND WITH GRAVEL (SM)g: About 60 percent coarse to fine, subangular sand; about 25 percent predominantly fine, hard, subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, pinkish gray, strong reaction with HCl.
111.9 to 118.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 140 mm; remainder minus 3-inch.
118.0 to 119.0 ft. SILTY SAND WITH GRAVEL (SM)g: About 60 percent coarse to fine, angular to subangular sand; about 20 percent predominantly fine, hard, angular to subangular gravel; about 20 percent nonplastic fines with quick dilatancy and low toughness; maximum size 110 mm; dry, light gray, moderate reaction with HCl.
119.0 to 120.7 ft. CORE REMOVED
120.7 to 124.4 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 55 percent coarse to fine, angular to subangular sand; about 45 percent coarse to fine, hard, angular to subangular gravel; trace of nonplastic fines; trace of hard, drilled and subangular cobbles; maximum size 150 mm; dry, light brown, strong reaction with HCl.
124.4 to 124.9 ft. SILTY SAND (SM): About 75 percent coarse to fine, subangular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; about 10 percent predominantly fine, hard, angular to subangular gravel; maximum size 85 mm; dry, light gray, strong reaction with HCl.
124.9 to 143.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; dry, light brown to pinkish gray, weak reaction with HCl. Core removed from 128.0 to 129.3 ft.

TOTAL SAMPLE (BY VOLUME): About 15 percent hard, drilled and subangular cobbles; maximum size 150 mm; remainder minus 3-inch.

143.7 to 145.6 ft. CORE REMOVED

145.6 to 147.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 140 mm; dry, pink, strong reaction with HCl.
147.0 to 155.9 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 110 mm; dry, light brown, no reaction with HCl. Core removed from 153.1 to 154.2 ft.

155.9 to 156.7 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 65 percent coarse to fine, angular to subangular sand; about 25 percent predominantly fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 60 mm; dry, pinkish gray, no reaction with HCl.
156.7 to 165.5 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 25 to 30 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, pink, weak to strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 45 percent hard, drilled and subangular cobbles; maximum size 150 mm; remainder minus 3-inch.

165.5 to 166.7 ft. CORE REMOVED

166.7 to 167.4 ft. SILTY SAND WITH GRAVEL (SM)g: About 65 percent coarse to fine, angular to subangular sand; about 20 percent predominantly fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-54

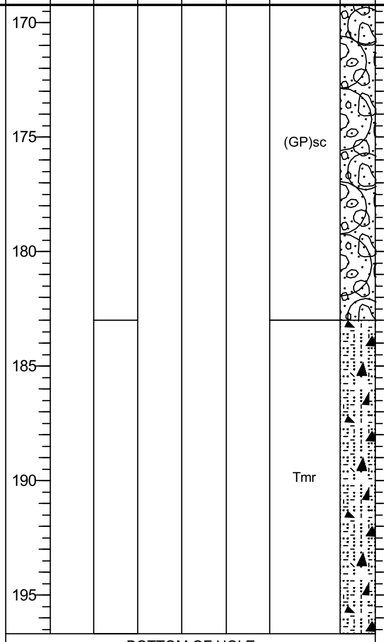
SHEET 4 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 4/25/2005 FINISHED: 4/27/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 766,278.9 E 572,190.12
TOTAL DEPTH: 196.7 ft.
DEPTH TO BEDROCK: 183.0 ft.

STATE: Nevada
GROUND ELEVATION: 3661.64
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					



15 mm; dry, pinkish gray, strong reaction with HCl.

167.4 to 183.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, pink, moderate to strong reaction with HCl. Core removed 175.2 to 177.1 ft.

TOTAL SAMPLE (BY VOLUME): About 25 percent hard, drilled and subangular cobbles; maximum size 200 mm; remainder minus 3-inch.

183.0 to 196.7 ft. RAINIER MESA TUFF (Tmr):
Ignimbrite, nonwelded, poorly consolidated, partially crystallized, white, 20 to 30 percent pumice, 2 to 3 percent lithic fragments of welded tuff, 10 to 20 percent crystal fragments of quartz, sanidine, and plagioclase, less than 1 percent biotite.

BOTTOM OF HOLE

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-55

SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/1/2005 FINISHED: 6/6/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,112.32 E 571,531.31
TOTAL DEPTH: 154.2 ft.
DEPTH TO BEDROCK: 110.2 ft.

STATE: Nevada
GROUND ELEVATION: 3642.22
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 154.2' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

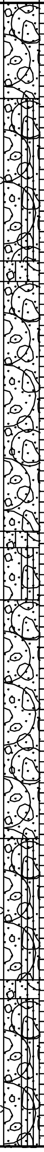
Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 154.2' (TD)

Hole Completion:
Back fill hole from 154.2' up to 0.0'
(ground surface) with Bentonite Chips. Pull casing.



DEPTH	ENGINEERING INDEXES HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	CLASSIFICATION AND PHYSICAL CONDITION
						(GP)sc	**0.0 to 110.2 ft. QUATERNARY ALLUVIUM (Qal):** **0.0 to 4.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 80 percent coarse to fine, hard, angular gravel; about 20 percent coarse to fine, angular sand; trace of nonplastic fines; dry, light reddish brown, strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 15 percent hard, subangular cobbles; maximum size 110 mm; remainder minus 3-inch.
5 10						(GP-GM)sc	**4.6 to 12.4 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc:** About 60 percent coarse to fine, hard, angular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and subangular cobbles; maximum size 130 mm; remainder minus 3-inch.
						(SM)g	**12.4 to 13.4 ft. SILTY SAND WITH GRAVEL (SM)g:** About 55 percent coarse to fine, angular sand; about 25 percent predominantly fine, hard, angular gravel; about 20 percent nonplastic fines with quick dilatancy and low toughness; maximum size 45 mm; dry, pink, strong reaction with HCl.
15 20 25						(GP)sc	**13.4 to 25.4 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 80 mm; dry, pinkish gray, strong reaction with HCl.
						(SM)g	**25.4 to 26.2 ft. SILTY SAND WITH GRAVEL (SM)g:** About 60 percent coarse to fine, angular sand; about 20 percent predominantly fine, hard, angular to subangular gravel; about 20 percent nonplastic fines with quick dilatancy and low toughness; maximum size 30 mm, dry, pinkish gray, strong reaction with HCl.
						(GP-GM)s	**26.2 to 28.7 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s:** About 60 percent coarse to fine, hard, angular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 70 mm; dry, pinkish gray, no reaction with HCl.
30 35 40						(GP)sc	**28.7 to 40.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 85mm; dry, pinkish gray, strong reaction with HCl.
45						(GP-GM)sc	**40.2 to 47.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc:** About 65 percent coarse to fine, hard, angular gravel; about 20 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 125 mm; dry, pinkish gray, strong reaction with HCl.
						(SM)g	**47.0 to 47.9 ft. SILTY SAND WITH GRAVEL (SM)g:** About 55 percent coarse to fine, angular sand; about 30 percent predominantly fine, hard, angular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 30 mm, dry, pinkish gray, strong reaction with HCl.
50						(GP-GM)sc	**47.9 to 58.4 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc:** About 60 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 90 mm; dry, pinkish gray, strong reaction with HCl.

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-55

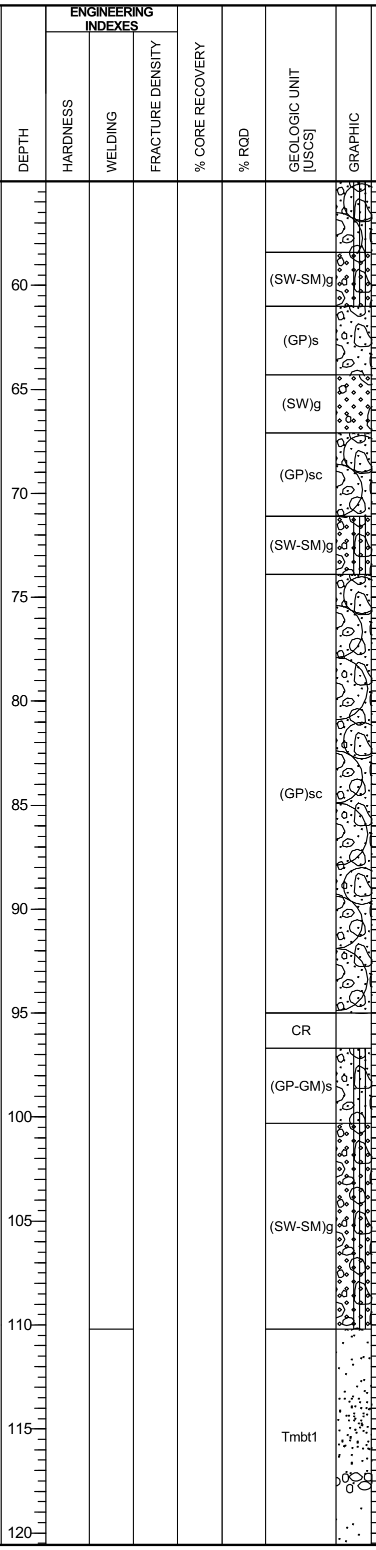
SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/1/2005 FINISHED: 6/6/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,112.32 E 571,531.31
TOTAL DEPTH: 154.2 ft.
DEPTH TO BEDROCK: 110.2 ft.

STATE: Nevada
GROUND ELEVATION: 3642.22
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES



CLASSIFICATION AND PHYSICAL CONDITION

58.4 to 61.0 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 50 percent coarse to fine, angular to subangular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness, maximum size 65 mm, dry, pink, strong reaction with HCl.

61.0 to 64.3 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 65 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; trace of nonplastic fines; maximum size 55 mm; dry, pink, strong reaction with HCl.

64.3 to 67.1 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 55 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 65 mm; dry, strong reaction with HCl.

67.1 to 71.1 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, drilled and subangular cobbles; maximum size 125 mm; remainder minus 3-inch.

71.1 to 73.9 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 50 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 60 mm; dry, pinkish gray, strong reaction with HCl.

73.9 to 95.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular sand; trace of nonplastic fines; trace of hard, drilled and subangular cobbles; maximum size 125 mm; dry, pink, pinkish gray, strong reaction with HCl. Core removed from 82.3 to 83.7 ft.

95.0 to 96.7 ft. CORE REMOVED

96.7 to 100.3 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 50 percent coarse to fine, hard, subangular gravel; about 35 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 65 mm; dry, pink, strong reaction with HCl.

100.3 to 110.2 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 50 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 30 mm; dry, pink, strong reaction with HCl. Core removed from 106.3 to 108.0 ft.

110.2 to 144.4 ft. PRE-RAINIER MESA TUFF BEDDED TUFF (Tmbt1): Bedded tuff, nonwelded, locally altered, locally reworked, crystallized, white, pinkish white, pink, very pale brown, 2 to 15 percent pumice,1 to 15 percent lithic fragments of crystallized welded tuff, 2 to 25 percent crystal fragments of quartz, sanidine, plagioclase, less than 1 percent biotite, hornblende, and magnetite, calcite veinlets locally, weak to strong reaction with HCl. Interval from 110.0 to 113.0 ft consists of calcite cemented ash and 5 to 20 percent silt to very fine sand size fragments of quartz, feldspar, and crystallized welded tuff, with less than 1 percent pumice and less than 1 percent lithic fragments.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

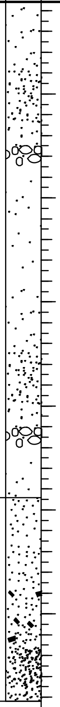
GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-55

SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/1/2005 FINISHED: 6/6/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,112.32 E 571,531.31
TOTAL DEPTH: 154.2 ft.
DEPTH TO BEDROCK: 110.2 ft.

STATE: Nevada
GROUND ELEVATION: 3642.22
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung



NOTES	DEPTH	ENGINEERING INDEXES HARDNESS	 WELDING	 FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	125								
	130						Tmbt1		
	135								
	140								
	145						Tpki		**144.4 to 154.2 ft. COMB PEAK IGNIMBRITE - TUFF "X" (Tpki):** Pyroclastic flow, nonwelded, crystallized below 146.4 ft, white, 20 to 25 percent pumice, 2 to 3 percent lithic fragments of crystallized welded tuff, 1 percent crystal fragments of sanidine and plagioclase, less than 1 percent of biotite and magnetite.
	150								

BOTTOM OF HOLE

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-56

SHEET 1 OF 5

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/6/2005 FINISHED: 7/7/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,439.36 E 571,857.22
TOTAL DEPTH: 416.9 ft.
DEPTH TO BEDROCK: 129.9 ft.

STATE: Nevada
GROUND ELEVATION: 3646.81
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0 to 337.4'. Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit to 337.4'. Change over to 4" coring system with 4.56" Rotosonic Carbide button bit. Advance 6" casing as hole is cored from 337.4' to 416.9' (TD).

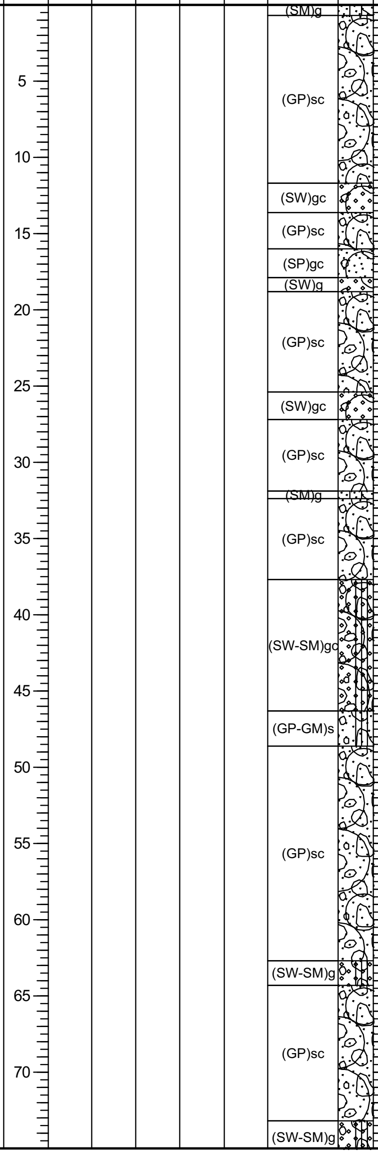
Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 337.4'. 6" casing from 337.4' to 416.9' (TD).

Hole Completion:
Back fill hole from 416.9' up to 0.0' (ground surface) with Bentonite Chips. Pull casing.



CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 129.7 ft: QUATERNARY ALLUVIUM (Qal).

0.0 to 0.7 ft. SILTY SAND WITH GRAVEL (SM)g: About 40 percent coarse to fine, subangular sand; about 30 percent coarse to fine, hard, subangular gravel; about 30 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, light reddish brown, weak reaction with HCl.
0.7 to 11.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, light reddish brown, reddish yellow, moderate reaction with HCl. Appears iron stained.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, drilled and subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
11.7 to 13.6 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 60 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 130 mm; dry, light reddish brown, weak reaction with HCl.
13.6 to 16.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 50 percent coarse to fine, hard, angular gravel; about 45 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, pink, moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and subangular cobbles; maximum size 140 mm; remainder minus 3-inch.
16.0 to 17.9 ft. POORLY GRADED SAND WITH GRAVEL AND COBBLES (SP)gc: About 55 percent coarse to fine, subangular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 20 percent hard, drilled and subangular cobbles; maximum size 175 mm; remainder minus 3-inch.
17.9 to 18.8 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 60 percent coarse to fine, angular sand; about 35 percent predominantly fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 60 mm; dry, pinkish gray, strong reaction with HCl.
18.8 to 25.4 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; dry, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 20 percent hard, drilled and subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
25.4 to 27.2 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 55 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular gravel; about 5 percent nonplastic fines; dry, pink, moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 30 percent hard, drilled and subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
27.2 to 31.9 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 50 percent coarse to fine, hard, angular gravel; about 45 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, drilled and subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
31.9 to 32.4 ft. SILTY SAND WITH GRAVEL (SM)g: About 45 percent coarse to fine, angular sand; about 35 percent predominantly fine, hard, angular gravel; about 20 percent nonplastic fines with quick dilatancy and low toughness; maximum size 40 mm; dry, pinkish gray, strong reaction with HCl.
32.4 to 37.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; trace to 5 percent nonplastic fines; dry, light reddish brown, pinkish gray, no to strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, drilled and subangular cobbles; maximum size 130 mm; remainder minus 3-inch.
37.7 to 46.3 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 50 percent coarse to fine, angular to subangular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular cobbles; maximum size 125 mm; remainder minus 3-inch.
46.3 to 48.6 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 50 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 90 mm; dry, pinkish gray, strong reaction with HCl.
48.6 to 62.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: about 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace to 5 percent nonplastic fines; trace of hard, drilled and subangular cobbles; maximum size 120 mm; dry, pink, weak to strong reaction with HCl.
62.7 to 64.3 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 60 percent coarse to fine, angular to subangular sand; about 30 percent coarse to fine, hard, angular

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

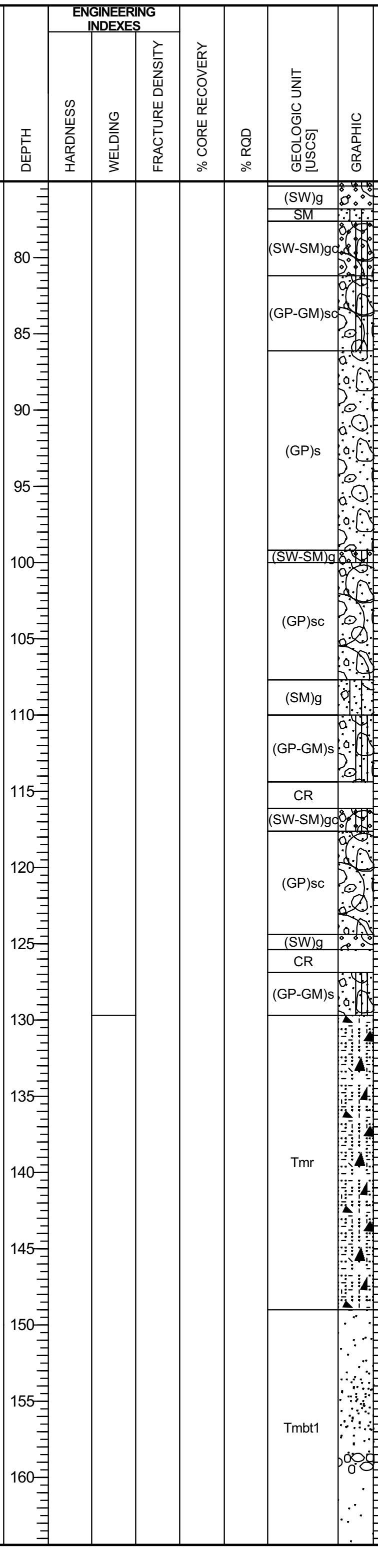
WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-56

SHEET 2 OF 5

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/6/2005 FINISHED: 7/7/2005
DEPTH TO WATER: Not Encountered
PROJECT: Yucca Mountain Project
COORDINATES: N 765,439.36 E 571,857.22
TOTAL DEPTH: 416.9 ft.
DEPTH TO BEDROCK: 129.9 ft.
STATE: Nevada
GROUND ELEVATION: 3646.81
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES



CLASSIFICATION AND PHYSICAL CONDITION

to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 90 mm; dry, pink, strong reaction with HCl.
64.3 to 73.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
73.2 to 75.3 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 60 percent coarse to fine, angular sand; about 30 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 55 mm; dry, pink, no reaction with HCl.
75.3 to 76.8 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 50 percent coarse to fine, subangular sand; about 45 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; maximum size 75 mm; dry, pinkish gray, weak reaction with HCl.
76.8 to 77.6 ft. SILTY SAND (SM): About 60 percent coarse to fine, angular to subangular sand; about 30 percent nonplastic fines with quick dilatancy and low toughness; about 10 percent predominantly fine, hard, angular to subangular gravel; maximum size 25 mm; dry, light gray, moderate reaction with HCl.
77.6 to 81.2 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 50 percent coarse to fine, angular to subangular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, drilled and subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
81.2 to 86.1 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness, trace of hard, drilled and subangular cobbles; maximum size 120 mm; dry, pinkish gray, moderate reaction with HCl.
86.1 to 99.2 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; maximum size 100 mm; dry, pink, pinkish gray, moderate to strong reaction with HCl. Core removed from 92.7 to 94.3 ft.
99.2 to 99.8 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 60 percent coarse to fine, angular sand; about 30 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 45 mm; dry, pink, moderate reaction with HCl.
99.8 to 107.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; trace to 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 100 mm; dry, pink, pinkish gray, strong reaction with HCl. Core removed from 104.9 to 106.3 ft.
107.7 to 110.0 ft. SILTY SAND WITH GRAVEL (SM)g: About 60 percent coarse to fine, angular to subangular sand; about 25 percent predominantly fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 80 mm; dry, pink, strong reaction with HCl.
110.0 to 114.4 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 50 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 90 mm; dry, light gray, pink, strong reaction with HCl.
114.4 to 116.1 ft. CORE REMOVED
116.1 to 117.6 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 50 percent coarse to fine, angular to subangular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 20 percent hard, drilled and subangular cobbles; maximum size 140 mm; remainder minus 3-inch.
117.6 to 124.4 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 70 percent coarse to fine, hard, angular to subangular gravel; about 25 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and subangular cobbles; maximum size 125 mm; remainder minus 3-inch.
124.4 to 125.4 ft. WELL GRADED SAND WITH GRAVEL (SW)g: About 55 percent coarse to fine, angular to subangular sand; about 40 percent predominantly fine, hard, subangular gravel; about 5 percent nonplastic fines; maximum size 95 mm; dry, pink, strong reaction with HCl.
125.4 to 126.9 ft. CORE REMOVED
126.9 to 129.7 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 50 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, subangular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, pink, strong reaction with HCl.
129.7 to 149.0 ft: RAINIER MESA TUFF (Tmr):
Tephra and bedded tuff, nonwelded, vitric, locally altered, locally poorly consolidated, pinkish white, 10 to 20 percent pumice, less than 1 percent densely welded and crystallized lithic fragments, 10 to 20 percent crystal fragments of quartz, plagioclase and sanidine, less than 1 percent biotite.
149.0 to 226.0 ft: PRE-RAINIER MESA TUFF BEDDED TUFF (Tmbt1):
Interbedded ignimbrite, bedded tuff and fallout tephra.

The ignimbrite is nonwelded, bedded, vitric, locally clay altered, pink, white, 15 to 40 percent pumice, 1 to 3 percent lithic fragments of welded tuff, less than 1 to 2 percent glass fragments, 5 to 7 percent crystal fragments of quartz, sanidine and plagioclase, less than 1 percent biotite.

The fallout tephra is nonwelded, primarily fine grained ash and locally coarse grained lithic and crystal rich ash, locally zeolitized, pinkish white.

The bedded tuff is nonwelded, vitric, locally partially crystallized, locally altered and locally zeolitized, locally poorly consolidated, locally reworked, light gray, very pale brown, white and pink, 3 to 30 percent pumice, less than 1 to 15 percent lithic fragments of welded tuff, 5 to 15 percent crystal fragments of quartz, san

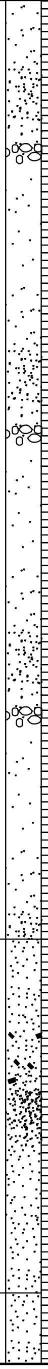
GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-56

SHEET 3 OF 5

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/6/2005 FINISHED: 7/7/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,439.36 E 571,857.22
TOTAL DEPTH: 416.9 ft.
DEPTH TO BEDROCK: 129.9 ft.

STATE: Nevada
GROUND ELEVATION: 3646.81
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung



NOTES	DEPTH	ENGINEERING INDEXES HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	165								
	170								
	175								
	180								
	185								
	190								
	195						Tmbt1		
	200								
	205								
	210								
	215								
	220								
	225								**226.0 to 249.2 ft: POST TUFF "X" BEDDED TUFF (Tpkbt):** Bedded tuff, nonwelded, clay altered, pink, very pale brown, 3 to 20 percent pumice, 2 to 5 percent lithic fragments of welded tuff, quartz absent. From 226.0 to 228.5 ft may be an incipient paleosol.
	230								
	235								
							Tpkbt		
	240								
	245								
	250						Tpki		**249.2 to 392.7 ft: COMB PEAK IGNIMBRITE - TUFF "X" (Tpki):** 249.2 to 255.6 ft: Ignimbrite, nonwelded, vitric, slightly altered, pink, 3 to 5 percent pumice. This is the upper nonwelded vitric zone of Tpki.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

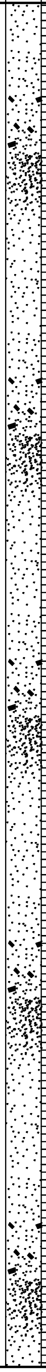
GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-56

SHEET 4 OF 5

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/6/2005 FINISHED: 7/7/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,439.36 E 571,857.22
TOTAL DEPTH: 416.9 ft.
DEPTH TO BEDROCK: 129.9 ft.

STATE: Nevada
GROUND ELEVATION: 3646.81
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					
	255								255.6 to 392.7 ft: Pyroclastic flow, nonwelded, crystallized, locally altered, white, pinkish white and pale brown, 15 to 30 percent pumice, 2 to 5 percent lithic fragments of welded tuff, 1 to 2 percent crystal fragments of quartz and feldspar, less than 1 percent of biotite, hornblende and magnetite.
	260								
	265								
	270								
	275								
	280								
	285								
	290								
	295								
	300						Tpki		
	305								
	310								
	315								
	320								
	325								
	330								
	335								
	340								

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-56

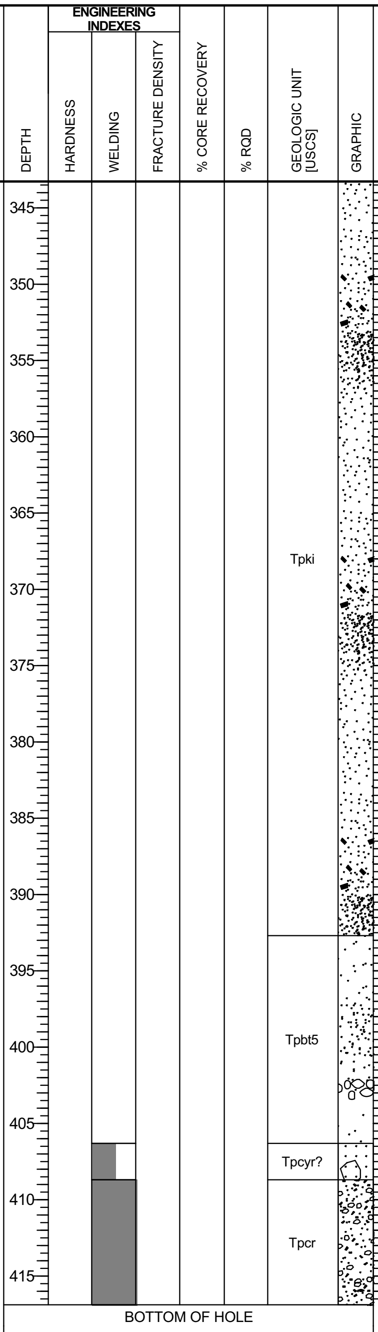
SHEET 5 OF 5

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 6/6/2005 FINISHED: 7/7/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 765,439.36 E 571,857.22
TOTAL DEPTH: 416.9 ft.
DEPTH TO BEDROCK: 129.9 ft.

STATE: Nevada
GROUND ELEVATION: 3646.81
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES



CLASSIFICATION AND PHYSICAL CONDITION

392.7 to 406.3 ft: POST-TIVA CANYON TUFF BEDDED TUFF (Tpbt5):
Bedded tuff, nonwelded, partially reworked, partially clay altered, pink, white, very pale brown, 2 to 30 percent pumice, 1 to 3 percent lithic fragments of welded tuff, 2 to 6 percent crystal fragments of quartz, sanidine and plagioclase, less than 1 to 1 percent biotite, pyroxene and magnetite.

406.3 to 408.7 ft: TUFF OF PINYON PASS (Tpcyr?):
Pyroclastic flow, partially welded, crystallized, pale red, 10 to 15 percent pumice, less than 1 percent lithic fragments of welded tuff, 1 percent crystal fragments of plagioclase, sanidine and quartz, less than 1 to 2 percent biotite and pyroxene.
408.7 to 416.9 ft: TIVA CANYON TUFF CRYSTAL-RICH MEMBER (Tpcr):
Pyroclastic flow, densely welded, vitric to crystallized, weak red, pale red, very dark gray, 5 to 20 percent pumice, less than 1 percent lithic fragments of welded tuff, 7 to 15 percent crystal fragments of plagioclase and sanidine, less than 1 to 1 percent biotite and pyroxene.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-58

SHEET 1 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: FINISHED: 5/11/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 763,061.43 E 571,072.57
TOTAL DEPTH: 150.7 ft.
DEPTH TO BEDROCK: 134.2 ft.

STATE: Nevada
GROUND ELEVATION: 3667.70
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 150.7' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

Drilling Conditions:

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 150.7' (TD)

Hole Completion:
Back fill hole from 150.7' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing.

DEPTH	ENGINEERING INDEXES HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
						(GP)s		**0.0 to 134.2 ft. QUATERNARY ALLUVIUM (Qal)** **0.0 to 2.8 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:** About 55 percent coarse to fine, hard, subangular to subrounded gravel; about 45 percent coarse to fine, subangular to subrounded sand; trace of nonplastic fines; maximum size 115 mm; moist, brown, strong reaction with HCl. Topsoil.
5								**2.8 to 19.6 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 65 percent coarse to fine, angular to subangular sand; about 30 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 125 mm; dry to moist, light brown, gray, strong reaction with HCl.
10						(SW)gc		
15								
20						(GP)sc		**19.6 to 24.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, subangular to subrounded gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 170 mm; dry, light brown, strong reaction with HCl.
25						(SM)g		**24.7 to 25.6 ft. SILTY SAND WITH GRAVEL (SM)g:** About 65 percent coarse to fine, subangular sand; about 20 percent nonplastic fines with quick dilatancy and low toughness; about 15 percent predominantly fine, hard, angular to subangular gravel; maximum size 70 mm; dry, gray, strong reaction with HCl. **25.6 to 45.5 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; trace to 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 130 mm; dry, light brown, gray, strong reaction with HCl.
30								
35						(GP)sc		
40								
45								**45.5 to 80.6 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 60 percent coarse to fine, angular to subangular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; trace of hard, subangular cobbles; maximum size 130 mm; dry, light brown, gray, tan, no to strong reaction with HCl.
50								

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

WHB2_LOG SONICII.GPJ SONICII.GDT 12/05/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-58

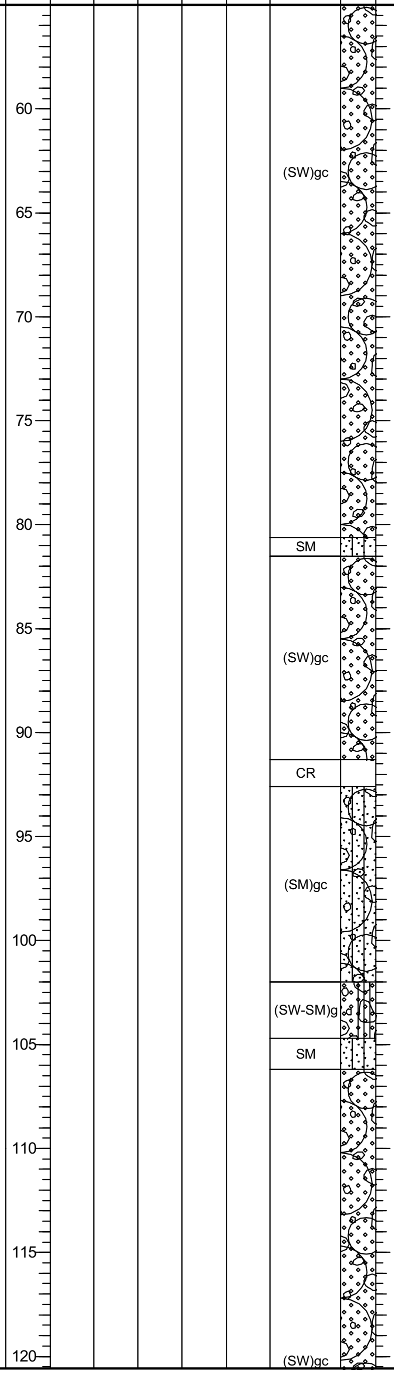
SHEET 2 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: FINISHED: 5/11/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 763,061.43 E 571,072.57
TOTAL DEPTH: 150.7 ft.
DEPTH TO BEDROCK: 134.2 ft.

STATE: Nevada
GROUND ELEVATION: 3667.70
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES
DEPTH
ENGINEERING INDEXES
HARDNESS
WELDING
FRACTURE DENSITY
% CORE RECOVERY
% RQD
GEOLOGIC UNIT [USCS]
GRAPHIC
CLASSIFICATION AND PHYSICAL CONDITION



80.6 to 81.5 ft. SILTY SAND (SM): About 70 percent coarse to fine, subangular sand; about 20 percent nonplastic fines with quick dilatancy and low toughness; about 10 percent predominantly fine, hard, angular to subangular gravel; maximum size 50 mm; dry, strong reaction with HCl.
81.5 to 91.3 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 70 percent coarse to fine, angular to subangular sand; about 30 percent coarse to fine, hard, angular to subangular gravel; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 120 mm; dry, gray, strong reaction with HCl.

91.3 to 92.6 ft. CORE REMOVED

92.6 to 102.0 ft. SILTY SAND WITH GRAVEL AND COBBLES (SM)gc: About 50 percent coarse to fine, subangular sand; about 35 percent coarse to fine, hard, subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 110 mm; dry, gray, strong reaction with HCl.

102.0 to 104.7 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 60 percent coarse to fine, subangular sand; about 30 percent coarse to fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 95 mm; dry, gray, strong reaction with HCl.
104.7 to 106.2 ft. SILTY SAND (SM): About 75 percent coarse to fine, subangular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; about 10 percent predominantly fine, hard, subangular gravel; maximum size 60 mm; dry, gray, strong reaction with HCl.
106.2 to 134.2 ft. POORLY GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 60 percent coarse to fine, angular to subangular sand; about 35 percent coarse to fine, hard, subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 190 mm; dry, pink, gray, strong reaction with HCl. Core removed from 106.8 to 108.1 ft, 118.4 to 119.7 ft, and 130.6 to 132.2 ft.

WHB2_LOG SONICII.GPJ SONICII.GDT 12/05/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-58

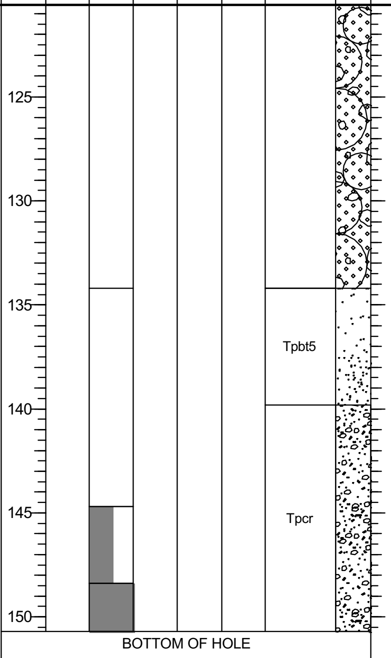
SHEET 3 OF 3

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: FINISHED: 5/11/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 763,061.43 E 571,072.57
TOTAL DEPTH: 150.7 ft.
DEPTH TO BEDROCK: 134.2 ft.

STATE: Nevada
GROUND ELEVATION: 3667.70
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



134.2 to 139.8 ft. POST TIVA CANYON TUFF BEDDED TUFF (Tpbt5): Tephra and fallout tephra, reworked, partially vitric, predominantly clay altered ash, white, 1 to 5 percent pumice increasing with depth to partly pumice supported, less than 1 percent volcanic lithic fragments, less than 1 to 10 percent phenocrysts of sanidine and quartz, less than 1 percent hornblende, and biotite.

139.8 to 150.7 ft. TIVA CANYON CRYSTAL-RICH MEMBER (Tpcr): Pyroclastic flow, variably vitric and crystallized, nonwelded at the top increasing to densely welded at depth, locally silicified or clay altered, white to very pale brown, light gray to weak red, black, 5 to 20 percent pumice, less than 1 to 5 percent lithic fragments of volcanic tuff, lithics absent locally at depth, 2 to 12 percent crystal fragments of sanidine and plagioclase, less than 1 percent biotite, pyroxene and hornblende. Minor fractures with calcite and zeolite/clay filling increasing with depth.

WHB2_LOG SONICII.GPJ SONICII.GDT 12/05/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-59

SHEET 1 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/25/2005 FINISHED: 5/31/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 762,347.29 E 571,406.69
TOTAL DEPTH: 179.0 ft.
DEPTH TO BEDROCK: 155.3 ft.

STATE: Nevada
GROUND ELEVATION: 3664.55
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 200 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Dale
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored 0.0' to 179.0' (TD). Drill string inside casing consists of 3½" single wall drill pipe with 6.163" Rotosonic Carbide button bit.

Drilling Conditions:

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

Fluid Loss Interval:
NA

Casing Record:
8" casing from 0.0' to 179.0' (TD)

Hole Completion:
Back fill hole from 179.0' (TD) up to 0.0' (ground surface) with Bentonite Chips. Pull casing

DEPTH	GEOLOGIC UNIT [USCS]
	(GP)sc
5	
10	(SW-SM)gc
15	
20	(GP)sc
25	
30	
	(SW)g
35	
40	(GP)sc
45	
	(SW)gc

0.0 to 154.8 ft. QUATERNARY ALLUVIUM (Qal)

0.0 to 8.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, subangular gravel; about 40 percent coarse to fine, angular sand; trace to 5 percent nonplastic fines; trace of hard, drilled and angular to subangular cobbles; maximum size 130 mm; dry, reddish brown, light reddish brown, weak to moderate reaction with HCl.

8.6 to 12.0 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 55 percent coarse to fine, subangular sand; about 35 percent coarse to fine, hard, subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, reddish yellow, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, drilled and subangular cobbles; maximum size 170 mm; remainder minus 3-inch.
12.0 to 31.9 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; trace to 5 percent nonplastic fines; dry, pink, light reddish brown, moderate to strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; maximum size 145 mm; remainder minus 3-inch.

31.9 to 34.8 ft. WELL GRADED SAND WITH GRAVEL (SW)g: **About 50 percent coarse to fine, angular sand; about 45 percent coarse to fine, hard, subangular gravel; about 5 percent nonplastic fines; maximum size 60 mm; dry, pink, strong reaction with HCl.**

34.8 to 45.5 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles maximum size 120 mm; dry, pink, strong reaction with HCl.

45.5 to 52.5 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 50 percent coarse to fine, angular sand; about 45 percent coarse to fine, hard, subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 95 mm; dry, pink, no reaction with HCl.

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-59

SHEET 2 OF 4

FEATURE: Waste Handling Building	PROJECT: Yucca Mountain Project	STATE: Nevada
LOCATION: Midway Valley	COORDINATES: N 762,347.29 E 571,406.69	GROUND ELEVATION: 3664.55
BEGUN: 5/25/2005 FINISHED: 5/31/2005	TOTAL DEPTH: 179.0 ft.	ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER: Not Encountered	DEPTH TO BEDROCK: 155.3 ft.	HOLE LOGGED BY: George Eatman
		REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES HARDNESS	WELDING	FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
	55 60 65 70						(GP)sc		**52.5 to 72.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 65 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine; angular sand; trace to 5 percent nonplastic fines; dry, pink, pinkish gray, strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
							(SW-SM)g		**72.0 to 73.6 ft WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 50 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 40 mm; dry, pinkish gray, strong reaction with HCl.
	75 80						(GP-GM)s		**73.6 to 82.2 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s:** About 60 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 70 mm; dry, pinkish gray, strong reaction with HCl.
							(SW-SM)g		**82.2 to 83.5 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g:** About 60 percent coarse to fine, angular sand; about 30 percent coarse to fine, hard, angular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 30 mm; dry, pinkish gray, moderate reaction with HCl.
	85						(GP)sc		**83.5 to 88.1 ft POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 60 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular sand; trace of nonplastic fines; trace of hard, subangular cobbles; maximum size 105 mm; dry, light reddish brown, moderate reaction with HCl.
							(GM)s		**88.1 to 89.5 ft. SILTY GRAVEL WITH SAND (GM)s:** About 45 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular sand; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 25 mm; dry, pinkish gray, strong reaction with HCl.
	90						(GP-GM)s		**89.5 to 92.0 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s:** About 50 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 70 mm; dry, pinkish gray, moderate reaction with HCl.
	95						(SM)gc		**92.0 to 95.5 ft. SILTY SAND WITH GRAVEL AND COBBLES (SM)gc:** About 45 percent coarse to fine, angular to subangular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; dry, pinkish gray, moderate to strong reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and angular to subangular cobbles; maximum size 150 mm; remainder minus 3-inch.
							(SW)gc		**95.5 to 100.0 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc:** About 55 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 120 mm; dry, pink, weak to moderate reaction with HCl.
	100						CORE REMOVED		**100.0 to 101.9 ft CORE REMOVED**
	105						(GP)sc		**101.9 to 105.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:** About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pink, weak to moderate reaction with HCl. TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and subangular cobbles; maximum size 120 mm; remainder minus 3-inch.
							(SP-SM)gc		**105.8 to 111.6 ft. POORLY GRADED SAND WITH SILT, GRAVEL AND COBBLES (SP-SM)gc:** About 60 percent coarse to medium, angular sand; about 25 percent predominantly fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 190 mm; dry, light gray, moderate reaction with HCl

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-59

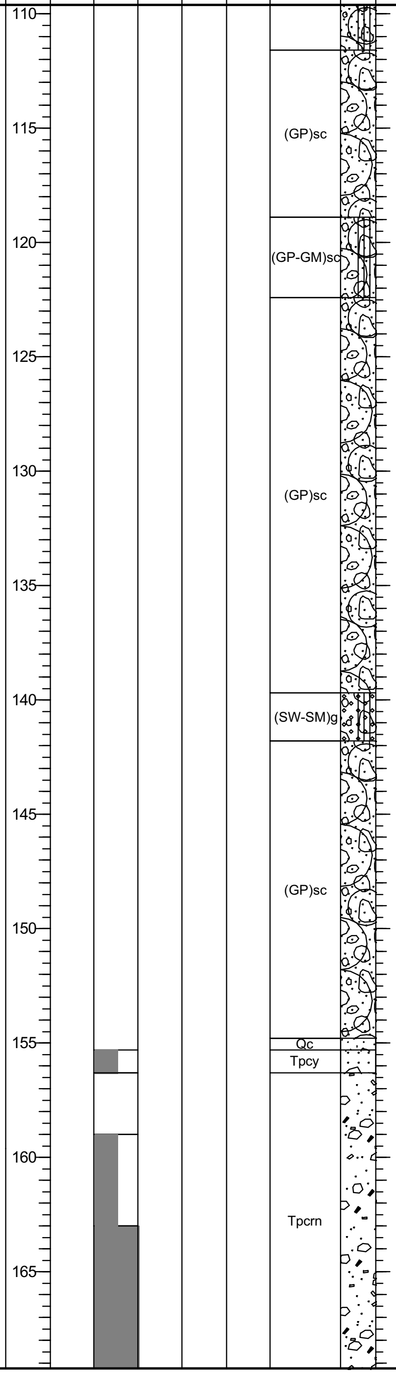
SHEET 3 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/25/2005 FINISHED: 5/31/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 762,347.29 E 571,406.69
TOTAL DEPTH: 179.0 ft.
DEPTH TO BEDROCK: 155.3 ft.

STATE: Nevada
GROUND ELEVATION: 3664.55
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION



TOTAL SAMPLE (BY VOLUME): About 45 percent hard, drilled cobbles; maximum size 190 mm; remainder minus 3-inch.

111.6 to 118.9 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard, angular to subangular cobbles; maximum size 105 mm; dry, pink, pinkish gray, strong reaction with HCl. Core removed from 113.1 to 115.1 ft.

118.9 to 122.4 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; about 10 percent nonplastic fines with low dry strength, quick dilatancy and low toughness; trace of hard, angular to subangular cobbles; maximum size 115 mm; dry, pink, strong reaction with HCl.

122.4 to 139.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pink, pinkish gray, no to strong reaction with HCl. Core removed from 131.9 to 133.5 ft.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, drilled and angular to subangular cobbles; maximum size 175 mm; remainder minus 3-inch.

139.7 to 141.8 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 50 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 40 mm; dry, pinkish gray, strong reaction with HCl.

141.8 to 154.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard, angular to subangular cobbles; maximum size 120 mm; dry, pink, strong reaction with HCl. Core removed from 145.4 to 147.4 ft.

154.8 to 155.3 ft. COLLUVIUM (Qc):
Colluvium consists of welded tuff fragments (red), gravel to cobble size in a caliche matrix (very pale brown).

155.3 to 156.3 ft. TUFF OF PINYON PASS (Tpcy):
Pyroclastic flow, partially to moderately welded, crystallized, dusky red, 1 to 2 percent pumice, 5 to 15 percent lithic fragments of moderately welded tuff, 5 percent crystal fragments of sanidine and lesser plagioclase, 1 percent biotite and lesser hornblende and pyroxene.

156.3 to 179.0 ft. TIVA CANYON TUFF CRYSTAL-RICH NONLITHOPHYSAL ZONE (Tpcrn):
Pyroclastic flow, nonwelded near top increasing to densely welded with depth, mostly crystallized, but vitric locally, very pale brown, pink, reddish brown, and very dark gray, pumice 2 to 15 percent, less than 1 percent lithic fragments of crystallized welded tuff near top of unit and absent at depth, 3 to 14 percent crystal fragments of sanidine and plagioclase, less than 1 to 2 percent biotite, pyroxene, hornblende and magnetite.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

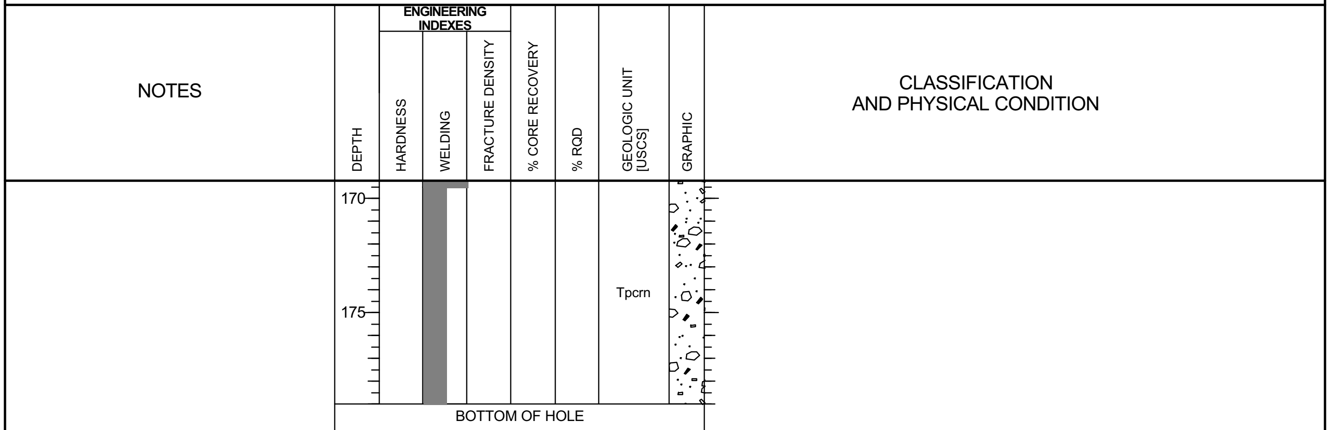
GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-59

SHEET 4 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/25/2005 FINISHED: 5/31/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 762,347.29 E 571,406.69
TOTAL DEPTH: 179.0 ft.
DEPTH TO BEDROCK: 155.3 ft.

STATE: Nevada
GROUND ELEVATION: 3664.55
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung



WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-60

SHEET 1 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/23/2005 FINISHED: 5/31/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 761,667.27 E 571,808.8
TOTAL DEPTH: 195.6 ft.
DEPTH TO BEDROCK: 144.5 ft.

STATE: Nevada
GROUND ELEVATION: 3650.09
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES: HARDNESS	ENGINEERING INDEXES: WELDING	ENGINEERING INDEXES: FRACTURE DENSITY	% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION

Purpose of Hole:
Repository Facilities Geotechnical Investigations

Drill Equipment:
GP24 300 RS (Sonic Drill Rig)
Flatbed combination water and pipe truck with boom for moving drill pipe and casing.

Driller:
Travis Osterberg
Boart Longyear Drill Services

Drilling Method:
Rotosonic
Advance 8" casing as hole is cored. 0.0' to 173.0'. 6.163" Rotosonic Carbide button bit. Drill string inside casing consists of 3½" single wall drill pipe. Change over to 4" coring system. Advance 6 " casing as hole is drilled. 173.0' to 195.6' (TD). 4.56" Rotosonic Carbide button bit.

Drilling Conditions:
Not Reported

Drilling Fluid:
Small amounts of drilling additives were added to help in advancing casing.

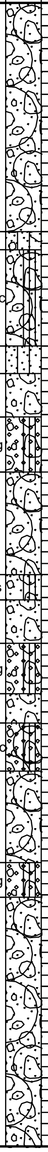
Fluid Loss Interval:
NA

Casing Record:
8 " casing from 0.0' to 173.0'
6 " casing from 172.96' to 195.61' (TD)

Hole Completion:
Back fill hole from 195.6' (TD) up to 0. 0'
(ground surface) with Bentonite Chips. Pull casing.

DEPTH: 5, 10, 15, 20, 25, 30, 35, 40, 45

GEOLOGIC UNIT [USCS]:
(GP)sc
(SM)g
(GP-GM)sc
SM
(GP)s
(SW-SM)g
(GP)sc
(GP-GM)s
(GP)s
(SW-SM)g
(GP)s
(SW-SM)gc
(GP)sc
(SW-SM)g
(GP)sc



0.0 to 144.5 ft. QUATERNARY ALLUVIUM (Qal)

0.0 to 10.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, angular to subangular cobbles; maximum size 130 mm; dry, light reddish brown, pink, weak to strong reaction with HCl.

10.0 to 10.8 ft. SILTY SAND WITH GRAVEL (SM)g: About 55 percent coarse to fine, angular sand; about 30 percent predominantly fine, hard, angular to subangular gravel; about 15 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, pinkish gray, weak to moderate reaction with HCl.

10.8 to 15.0 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 60 percent coarse to fine, hard, angular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, angular to subangular cobbles; maximum size 135 mm; dry, pink, strong reaction with HCl.

15.0 to 16.2 ft SILTY SAND (SM): About 60 percent coarse to fine, angular sand; about 30 percent nonplastic fines with quick dilatancy and low toughness; about 10 percent coarse to fine, hard, angular gravel; maximum size 65 mm; dry, pinkish gray, strong reaction with HCl.

16.2 to 18.1 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 75 percent coarse to fine, hard, angular to subangular gravel; about 25 percent coarse to fine, angular sand; trace of nonplastic fines; maximum size 80 mm; dry, pink, strong reaction with HCl.

18.1 to 20.5 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 55 percent coarse to fine, angular sand; about 35 percent coarse to fine, hard, angular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 50 mm; dry, pink, strong reaction with HCl.

20.5 to 25.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pink, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; remainder minus 3-inch; maximum size 115 mm.

25.0 to 26.1 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 50 percent predominantly fine, hard, subangular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 40 mm; dry, light reddish brown, moderate to strong reaction with HCl.

26.1 to 28.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 50 percent coarse to fine, hard, angular to subangular gravel; about 45 percent coarse to fine, angular sand; about 5 percent nonplastic fines; maximum size 70 mm; dry, light reddish brown, weak to moderate reaction with HCl.

28.0 to 30.2 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 55 percent coarse to fine, angular sand; about 35 percent predominantly fine, hard, angular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 70 mm; dry, pink, weak to moderate reaction with HCl.

30.2 to 31.5 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular sand; about 5 percent nonplastic fines; maximum size 70mm; dry, light reddish brown, weak reaction with HCl.

31.5 to 33.6 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 50 percent coarse to fine, angular to subangular sand; about 40 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, angular to subangular cobbles; maximum size 100 mm; dry, pink, strong reaction with HCl.

33.6 to 37.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular gravel; about 30 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard angular cobbles; maximum size 90 mm; dry, pinkish gray, moderate reaction with HCl.

37.6 to 39.1 ft. WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM)g: About 50 percent coarse to fine, angular sand; about 40 percent predominantly fine, hard, angular gravel, a few gravel-size particles fractured with hammer blow; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 45 mm; dry, pinkish gray, strong reaction with HCl.

39.1 to 58.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 70 percent coarse to fine, hard, angular to subangular gravel; about 25 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard angular to subangular cobbles; maximum size 110 mm; dry, pink, light gray, no to strong reaction with HCl.

COMMENTS: **Descriptions of the material may not reflect in situ geologic conditions due to mechanical degradation of the sample by the Sonic drilling method.**

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-60

SHEET 2 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/23/2005 FINISHED: 5/31/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 761,667.27 E 571,808.8
TOTAL DEPTH: 195.6 ft.
DEPTH TO BEDROCK: 144.5 ft.

STATE: Nevada
GROUND ELEVATION: 3650.09
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					

DEPTH: 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105

GEOLOGIC UNIT [USCS]:
(SW-SM)gc
(GP)sc
(SW-SM)gc
(GP-GM)sc
(SM)g
(GP)s
(GP-GM)sc
(GP)sc
(SM)g
(GP)sc
(SW)gc
(GP)sc
(SW-SM)gc
(GP)sc

58.0 to 60.0 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 55 percent coarse to fine, angular sand; about 35 percent coarse to fine, hard, angular to subrounded gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pink, weak to moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 15 percent hard, angular to subangular cobbles; remainder minus 3-inch; maximum size 80 mm.

60.0 to 66.6 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 40 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pinkish gray, strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, angular to subangular cobbles; remainder minus 3-inch; maximum size 120 mm.

66.6 to 67.6 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 60 percent coarse to fine, angular sand; about 30 percent predominantly fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pink, weak reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; remainder minus 3-inch; maximum size 105 mm.

67.6 to 68.5 ft. POORLY GRADED GRAVEL WITH SILT, SAND, AND COBBLES (GP-GM)sc: About 55 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; dry, pink, no to weak reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 5 percent hard, subangular cobbles; remainder minus 3-inch; maximum size 80 mm.

68.5 to 69.2 ft. SILTY SAND WITH GRAVEL (SM)g: About 55 percent coarse to fine, angular sand; about 30 percent nonplastic fines with quick dilatancy and low toughness; about 15 percent predominantly fine, hard, angular to subangular gravel; maximum size 35 mm; dry, pinkish gray, moderate to strong reaction with HCl.

69.2 to 72.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)s: About 60 percent coarse fine, hard, angular to subangular gravel; about 35 percent coarse to fine angular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 85 mm; dry, pink, strong reaction with HCl.

72.0 to 74.5 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 100 mm; dry, pinkish gray, strong reaction with HCl.

74.5 to 86.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 110 mm; dry, pink, moderate to strong reaction with HCl.

86.8 to 87.7 ft. SILTY SAND WITH GRAVEL (SM)g: About 50 percent coarse to fine, angular sand; about 35 percent nonplastic fines with quick dilatancy and low toughness; About 15 percent predominantly fine, hard, angular gravel; maximum size 50 mm; dry, light gray, strong reaction with HCl.

87.7 to 90.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 80 mm; dry, pinkish gray, strong reaction with HCl.

90.0 to 93.3 ft. WELL GRADED SAND WITH GRAVEL AND COBBLES (SW)gc: About 55 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 130 mm; dry, pinkish gray, strong reaction with HCl.

93.3 to 102.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pink, pinkish gray, weak to strong reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and subangular cobbles; remainder minus 3-inch; maximum size 160 mm.

102.2 to 105.9 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 55 percent coarse to fine, angular sand; about 35 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low dry strength; dry, pink, moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and subangular cobbles; remainder minus 3-inch; maximum size 120 mm.

105.9 to 108.9 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 70 percent coarse to fine, hard, angular to subangular gravel; about 25 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 105 mm; dry, pink, strong reaction with HCl.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-60

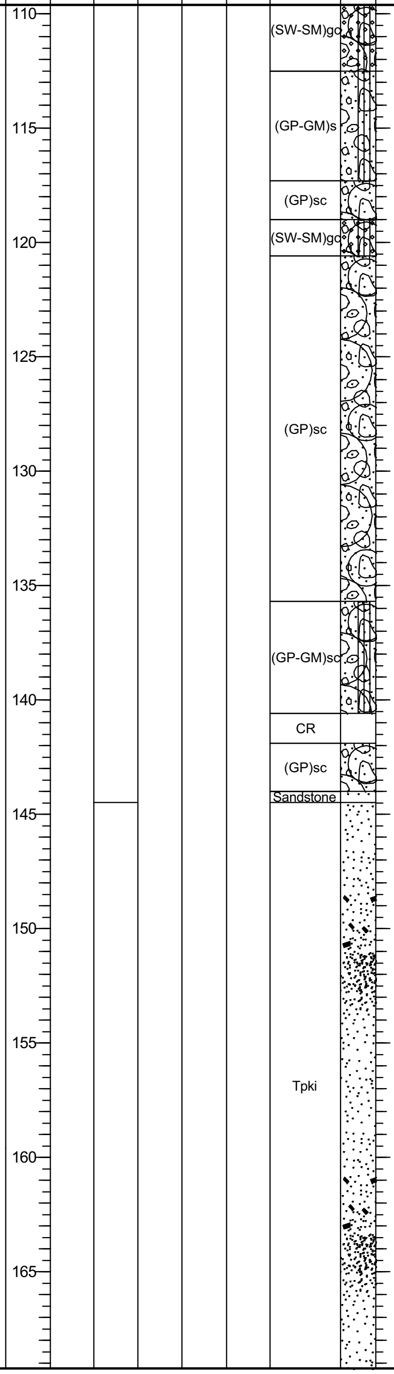
SHEET 3 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/23/2005 FINISHED: 5/31/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 761,667.27 E 571,808.8
TOTAL DEPTH: 195.6 ft.
DEPTH TO BEDROCK: 144.5 ft.

STATE: Nevada
GROUND ELEVATION: 3650.09
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES	DEPTH	ENGINEERING INDEXES			% CORE RECOVERY	% RQD	GEOLOGIC UNIT [USCS]	GRAPHIC	CLASSIFICATION AND PHYSICAL CONDITION
		HARDNESS	WELDING	FRACTURE DENSITY					



108.9 to 112.5 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 50 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, angular to subangular cobbles; maximum size 100 mm; dry, pinkish gray, strong reaction with HCl.

112.5 to 117.3 ft. POORLY GRADED GRAVEL WITH SILT AND SAND (GP-GM)s: About 50 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; maximum size 70 mm; dry, pinkish gray, no reaction with HCl.

117.3 to 119.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular to subangular sand; about 5 percent nonplastic fines; dry, pinkish gray, no to weak reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 20 percent hard, drilled and subangular cobbles; remainder minus 3-inch; maximum size 130 mm.
119.0 to 120.6 ft. WELL GRADED SAND WITH SILT, GRAVEL AND COBBLES (SW-SM)gc: About 50 percent coarse to fine, angular sand; about 40 percent coarse to fine, hard, angular to subangular gravel; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 100 mm; dry, pink, strong reaction with HCl.
120.6 to 135.7 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 60 percent coarse to fine, hard, angular to subangular gravel; about 35 percent coarse to fine, angular sand; about 5 percent nonplastic fines; dry, pink, pinkish gray, no to moderate reaction with HCl.

TOTAL SAMPLE (BY VOLUME): About 10 percent hard, drilled and angular to subangular cobbles; remainder minus 3-inch; maximum size 150 mm.

135.7 to 140.6 ft. POORLY GRADED GRAVEL WITH SILT, SAND AND COBBLES (GP-GM)sc: About 50 percent coarse to fine, hard, angular gravel; about 40 percent coarse to fine, angular sand; about 10 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular cobbles; maximum size 120 mm; dry, pink, no reaction with HCl.

140.6 to 141.9 ft. CORE REMOVED

141.9 to 144.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: About 65 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular sand; about 5 percent nonplastic fines; trace of hard, subangular cobbles; maximum size 100 mm; dry, pinkish gray, strong reaction with HCl.
144.0 to 144.5 ft. SANDSTONE:
Sandstone, fine grained, very dark gray.
144.5 to 176.1 ft. COMB PEAK IGNIMBRITE - TUFF "X" (Tpki):
Ignimbrite, nonwelded, partially clay altered, white, 25 to 60 percent pumice, 2 to 7 percent and locally greater than 10 percent volcanic lithic fragments, about 3 percent crystal fragments of sanidine and biotite with rare magnetite.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

GEOLOGIC LOG OF DRILL HOLE NO. UE25 RF-60

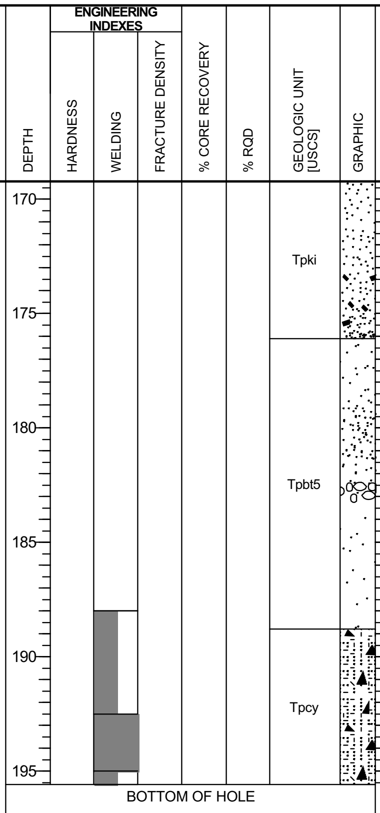
SHEET 4 OF 4

FEATURE: Waste Handling Building
LOCATION: Midway Valley
BEGUN: 5/23/2005 FINISHED: 5/31/2005
DEPTH TO WATER: Not Encountered

PROJECT: Yucca Mountain Project
COORDINATES: N 761,667.27 E 571,808.8
TOTAL DEPTH: 195.6 ft.
DEPTH TO BEDROCK: 144.5 ft.

STATE: Nevada
GROUND ELEVATION: 3650.09
ANGLE FROM HORIZONTAL: -90°
HOLE LOGGED BY: George Eatman
REVIEWED BY: Robert Lung

NOTES



CLASSIFICATION AND PHYSICAL CONDITION

176.1 to 188.8 ft. POST-TIVA CANYON TUFF BEDDED TUFF (Tpbt5):
Bedded tuff, tephra and ignimbrite.

176.1 to179.7 ft: Bedded tuff, nonwelded, reworked, moderately indurated, pink, predominantly fine sand size felsic crystal fragments and tuff fragments, 3 to 15 percent pumice.

179.7 to 184.3 ft: Tephra, nonwelded, partially clay altered, vitric, very pale brown, 20 percent pumice, 5 percent crystal fragments of biotite and sanidine with rare magnetite.

184.3 to 187.0 ft: Ignimbrite, nonwelded, moderately indurated, clay altered, reddish-yellow, pumice obscured or absent, 3 percent crystal fragments of biotite, less than 1 percent crystal fragments of sanidine and other minerals, 2 percent lithic fragments.

187.0 to 188.8 ft: Sample removed at drill site, contact with underlying Tpcy contained within sample interval.

188.8 to 195.6 ft. TUFF OF PINYON PASS (Tpcy):
Ignimbrite, partially to densely welded, pink, gray, black, 5 to 10 percent pumice, less than 1 percent volcanic lithic fragments, 5 to 10 percent crystal fragments of sanidine and biotite with minor pyroxene.

WHB2_LOG SONICII.GPJ SONICII.GDT 6/25/07

ATTACHMENT II

TEST PIT LOGS, PHOTOMOSAIC MAPS, AND RING DENSITY DATA

ATTACHMENT II
TEST PIT LOGS, PHOTOMOSAIC MAPS, AND RING DENSITY DATA

II.1 LOGS OF TEST PITS TP-WHB-5, TP-WHB-6, AND TP-WHB-7

Beginning in August 2006, three test pits were excavated to analyze engineering properties of the alluvium in the Waste Handling Building (WHB) sub-area of the North Portal Facilities (NPF) area. Test pits TP-WHB-5, TP-WHB-6, and TP-WHB-7 were surveyed and located as shown on Figure 6.2-1 in Section 6.2.4. This attachment presents the geologic logs (DTN: GS070583114233.003 [DIRS 183296]) of the three test pits, TP-WHB-5, TP-WHB-6, and TP-WHB-7, that were excavated in the WHB area, which is a sub-area in the NPF area. Test pit logs are presented in alphanumeric order beginning on the following page.

7-1336-A (1-86)
Bureau of Reclamation

LOG OF TEST PIT OR AUGER HOLE

SHEET 1 OF 1
HOLE NO. TP-WHB-5

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: Waste Handling Building
GROUND ELEVATION: 3672.3
COORDINATES: N 766,398 E 571,768
METHOD OF EXPLORATION: John Deere 992 D-LC Trackhoe
APPROXIMATE DIMENSIONS: 68 ft x 68 ft x 19.1 ft. deep
HOLE LOGGED BY: George Eatman
TOTAL DEPTH: 19.1 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 8/14/2006

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(SP-SC)c	0.0 to 1.8 ft: POORLY GRADED SAND WITH CLAY AND COBBLES (SP-SC)c. About 80 percent coarse to fine, angular to subrounded sand; about 10 percent fines of medium plasticity, with high dry strength, slow dilatancy, and medium toughness; about 10 percent coarse to fine, hard, angular to subangular gravel; trace of hard subangular to subrounded cobbles; trace of organics; maximum size 200 mm; dry, brown, moderate reaction with HCl. IN-PLACE CONDITION: Soft, no to weak caliche cementation, roots present, topsoil.
(SP)gc	1.8 to 3.8 ft: POORLY GRADED SAND WITH GRAVEL AND COBBLES (SP)gc. About 60 percent coarse to fine, subangular to subrounded sand; about 35 percent coarse to fine, hard, angular to subangular gravel; about 5 percent nonplastic fines with quick dilatancy and low toughness; trace of hard, subrounded cobbles; maximum size 300 mm; dry, yellowish red to buff, strong reaction with HCl. IN-PLACE CONDITION: Hard, moderate to strong cementation.
(GP)scb	3.8 to 19.0 ft: POORLY GRADED GRAVEL WITH SAND, COBBLES AND BOULDERS (GP)scb. About 70 percent coarse to fine, hard, angular to subangular gravel; about 30 percent coarse to fine, angular to subrounded sand; trace of nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular to subrounded cobbles; trace of hard, subangular to subrounded boulders; maximum size 420 mm; dry, predominantly reddish brown, upper 3 ft is light gray, moderate to strong reaction with HCl. From 3.8 to 6.8 ft the volume of cobbles and boulders is about 25 percent. IN-PLACE CONDITION: Hard, weak to strong cementation, stratified appearance, some caliche cemented layers.

REMARKS:

7-1336-A (1-86)
Bureau of Reclamation

LOG OF TEST PIT OR AUGER HOLE

SHEET 1 OF 2
HOLE NO. TP-WHB-6

FEATURE: Waste Handling Building
LOCATION: Waste Handling Building
COORDINATES: N 766,696 E 572,372
APPROXIMATE DIMENSIONS: 68 ft x 68 ft x 18.1 ft. deep
TOTAL DEPTH: 18.1 ft. DEPTH TO WATER: N/A

PROJECT: Yucca Mountain Project
GROUND ELEVATION: 3668.3
METHOD OF EXPLORATION: John Deere 992 D-LC Trackhoe
HOLE LOGGED BY: George Eatman
DATE EXCAVATED: 8/16/2006

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(SP)gc	0.0 to 1.0 ft: POORLY GRADED SAND WITH GRAVEL AND COBBLES (SP)gc. About 60 percent coarse to fine, subangular to subrounded sand; about 40 percent coarse to fine, hard, subangular to subrounded gravel; trace of nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular to rounded cobbles; maximum size 135 mm; dry, light reddish brown, moderate to strong reaction with HCl. IN-PLACE CONDITION: Soft, weak caliche cementation, some roots present, topsoil.
(GP)sc	1.0 to 4.9 ft: POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc. About 60 percent coarse to fine, hard, angular to subrounded gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular to rounded cobbles; maximum size 135 mm; dry, yellowish red and reddish brown, no to moderate reaction with HCl. IN-PLACE CONDITION: Soft to hard, weak to predominantly strong cementation.
(SP)gc	4.9 to 7.0 ft: POORLY GRADED SAND WITH GRAVEL AND COBBLES (SP)gc. About 60 percent coarse to fine, subangular to subrounded sand; about 40 percent coarse to fine, hard, angular to subangular gravel; trace of nonplastic fines with quick dilatancy and low toughness; trace of hard subangular to rounded cobbles; maximum size 165 mm; dry, light reddish brown, no to moderate reaction with HCl. IN-PLACE CONDITION: Soft to hard, weak to moderate cementation. Near base of wall is a caliche layer having a strong reaction with HCl.

REMARKS:

7-1336-A (1-86)
Bureau of Reclamation

LOG OF TEST PIT OR AUGER HOLE

SHEET 2 OF 2
HOLE NO. TP-WHB-6

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: Waste Handling Building
GROUND ELEVATION: 3668.3
COORDINATES: N 766,696 E 572,372
METHOD OF EXPLORATION: John Deere 992 D-LC Trackhoe
APPROXIMATE DIMENSIONS: 68 ft x 68 ft x 18.1 ft. deep
HOLE LOGGED BY: George Eatman
TOTAL DEPTH: 18.1 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 8/16/2006

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(GP)sc	7.0 to 13.0 ft: POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc. About 60 percent coarse to fine, hard, angular to subrounded gravel; about 40 percent coarse to fine, angular to subrounded sand; trace of nonplastic fines with quick dilatancy and low toughness; trace to about 20 percent (locally) of hard subangular to rounded cobbles; maximum size 300 mm; dry, gray and light reddish brown, no to strong reaction with HCl. IN-PLACE CONDITION: Soft to hard, weak to strong caliche cementation. Rough caliche coating on gravel.
(SP)gc	13.0 to 18.1 ft: POORLY GRADED SAND WITH GRAVEL AND COBBLES (SP)gc. About 70 percent coarse to fine, angular to subangular sand; about 30 percent coarse to fine, hard, angular to subangular gravel; trace of nonplastic fines with quick dilatancy and low toughness; trace to about 20 percent (locally) of hard, subangular to rounded cobbles; maximum size 200 mm; dry, light reddish brown to gray, moderate to strong reaction with HCl. IN-PLACE CONDITION: Soft to firm, mostly weak cementation with some caliche stringers.

REMARKS:

7-1336-A (1-86)
Bureau of Reclamation

LOG OF TEST PIT OR AUGER HOLE

SHEET 1 OF 3
HOLE NO. TP-WHB-7

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: Waste Handling Building
GROUND ELEVATION: 3681.4
COORDINATES: N 767,137 E 572,812
METHOD OF EXPLORATION: John Deere 992 D-LC Trackhoe
APPROXIMATE DIMENSIONS: 68 ft x 68 ft x 18.4 ft. deep
HOLE LOGGED BY: George Eatman
TOTAL DEPTH: 18.4 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 9/12/2006

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(SP)gc	0.0 to 0.9 ft: POORLY GRADED SAND WITH GRAVEL AND COBBLES (SP)gc. About 70 percent coarse to fine, angular sand; about 25 percent coarse to fine, hard, angular to subangular gravel; about 5 percent fines of medium plasticity with medium dry strength, slow dilatancy and medium toughness; trace of hard subangular to rounded cobbles; maximum size 175 mm; dry, reddish brown to yellowish red, moderate reaction with HCl. IN-PLACE CONDITION: Very soft, no cementation, roots present, topsoil.
(GP)sc	0.9 to 6.0 ft: POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc. About 55 percent coarse to fine, hard, subangular to subrounded gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines with quick dilatancy and low toughness; trace of hard subangular to rounded cobbles; maximum size 225 mm; dry, reddish brown to light gray, strong reaction with HCl. IN-PLACE CONDITION: Soft to hard, weak to moderate cementation, caliche layer.
(SP)gc	6.0 to 8.0 ft: POORLY GRADED SAND WITH GRAVEL AND COBBLES (SP)gc. About 55 percent coarse to fine, angular to subangular sand; about 45 percent coarse to fine, hard, angular to subrounded gravel; trace of nonplastic fines with quick dilatancy and low toughness; trace of hard subangular to rounded cobbles; maximum size 175 mm; dry, light reddish brown, no to strong reaction with HCl. IN-PLACE CONDITION: Medium hard to hard, moderate cementation, broken surfaces of cobbles and gravel visible in wall.

REMARKS:

7-1336-A (1-86)
Bureau of Reclamation

LOG OF TEST PIT OR AUGER HOLE

SHEET 2 OF 3
HOLE NO. TP-WHB-7

FEATURE: Waste Handling Building
PROJECT: Yucca Mountain Project
LOCATION: Waste Handling Building
GROUND ELEVATION: 3681.4
COORDINATES: N 767,137 E 572,812
METHOD OF EXPLORATION: John Deere 992 D-LC Trackhoe
APPROXIMATE DIMENSIONS: 68 ft x 68 ft x 18.4 ft. deep
HOLE LOGGED BY: George Eatman
TOTAL DEPTH: 18.4 ft. DEPTH TO WATER: N/A
DATE EXCAVATED: 9/12/2006

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
(GP)sc	8.0 to 12.0 ft: POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc. About 60 percent coarse to fine, hard, angular to subrounded gravel; about 40 percent coarse to fine, angular to subangular sand; trace of nonplastic fines with quick dilatancy and low toughness; trace of hard subangular to rounded cobbles; maximum size 225 mm; dry, reddish brown to light gray, strong reaction with HCl. IN-PLACE CONDITION: Moderately hard to hard, weak to strong cementation. Broken surfaces of cobbles and gravel visible in wall.
(GP/SP)c	12.0 to 14.0 ft: POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP/SP)c. About 50 percent coarse to fine, hard, angular to subrounded gravel; about 50 percent coarse to fine, angular to subrounded sand; trace of nonplastic fines with quick dilatancy and low toughness; trace of hard subangular to rounded cobbles; maximum size 135 mm; dry, pinkish gray to light reddish brown, strong reaction with HCl. IN-PLACE CONDITION: Firm to hard, weak to strong cementation.
(GP)scb	14.0 to 16.0 ft: POORLY GRADED GRAVEL WITH SAND, COBBLES AND BOULDERS (GP)scb. About 55 percent coarse to fine, hard, angular to subangular gravel; about 45 percent coarse to fine, angular to subangular sand; trace of nonplastic fines with quick dilatancy and low toughness; trace of hard, subangular to rounded cobbles; trace of hard, subrounded boulders; maximum

REMARKS:

7-1336-A (1-86)
Bureau of Reclamation

LOG OF TEST PIT OR AUGER HOLE

SHEET 3 OF 3
HOLE NO. TP-WHB-7

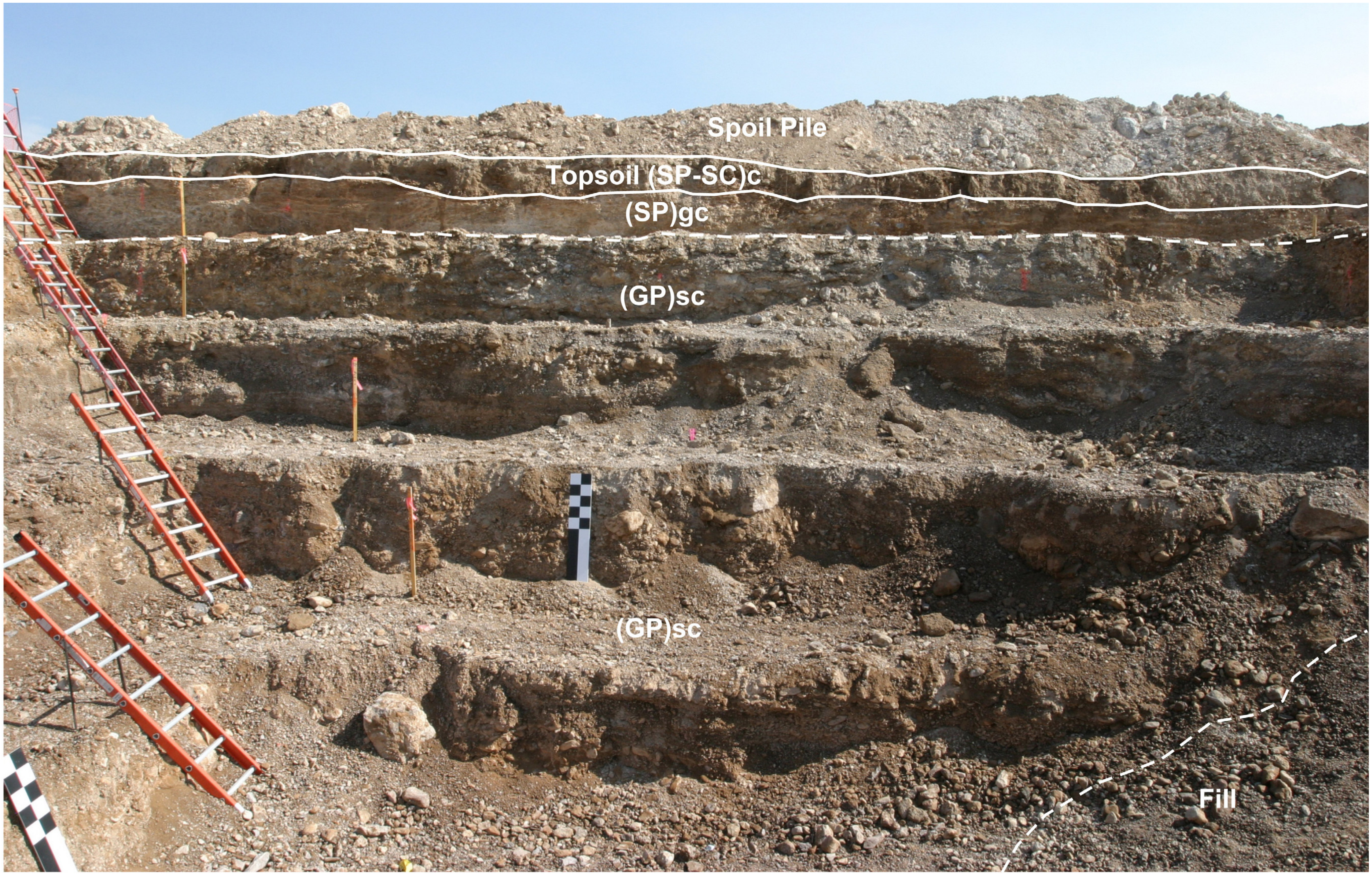
FEATURE: Waste Handling Building
LOCATION: Waste Handling Building
COORDINATES: N 767,137 E 572,812
APPROXIMATE DIMENSIONS: 68 ft x 68 ft x 18.4 ft. deep
TOTAL DEPTH: 18.4 ft. DEPTH TO WATER: N/A
PROJECT: Yucca Mountain Project
GROUND ELEVATION: 3681.4
METHOD OF EXPLORATION: John Deere 992 D-LC Trackhoe
HOLE LOGGED BY: George Eatman
DATE EXCAVATED: 9/12/2006

CLASSIFICATION GROUP SYMBOL	CLASSIFICATION AND DESCRIPTION OF MATERIAL
	size 425 mm; dry, reddish brown to light gray, no to strong reaction with HCl. IN-PLACE CONDITION: Soft to hard, weak to strong cementation.
(SP)g	16.0 to 18.5 ft: POORLY GRADED SAND WITH GRAVEL (SP)g. About 60 percent coarse to fine, subangular to subrounded sand: about 40 percent coarse to fine, hard, angular to subrounded gravel; trace of nonplastic fines with quick dilatancy and low toughness; maximum size 65 mm; dry, light gray, brown, no reaction with HCl. IN-PLACE CONDITION: Soft, weak cementation, with a few small caliche lenses.

REMARKS:

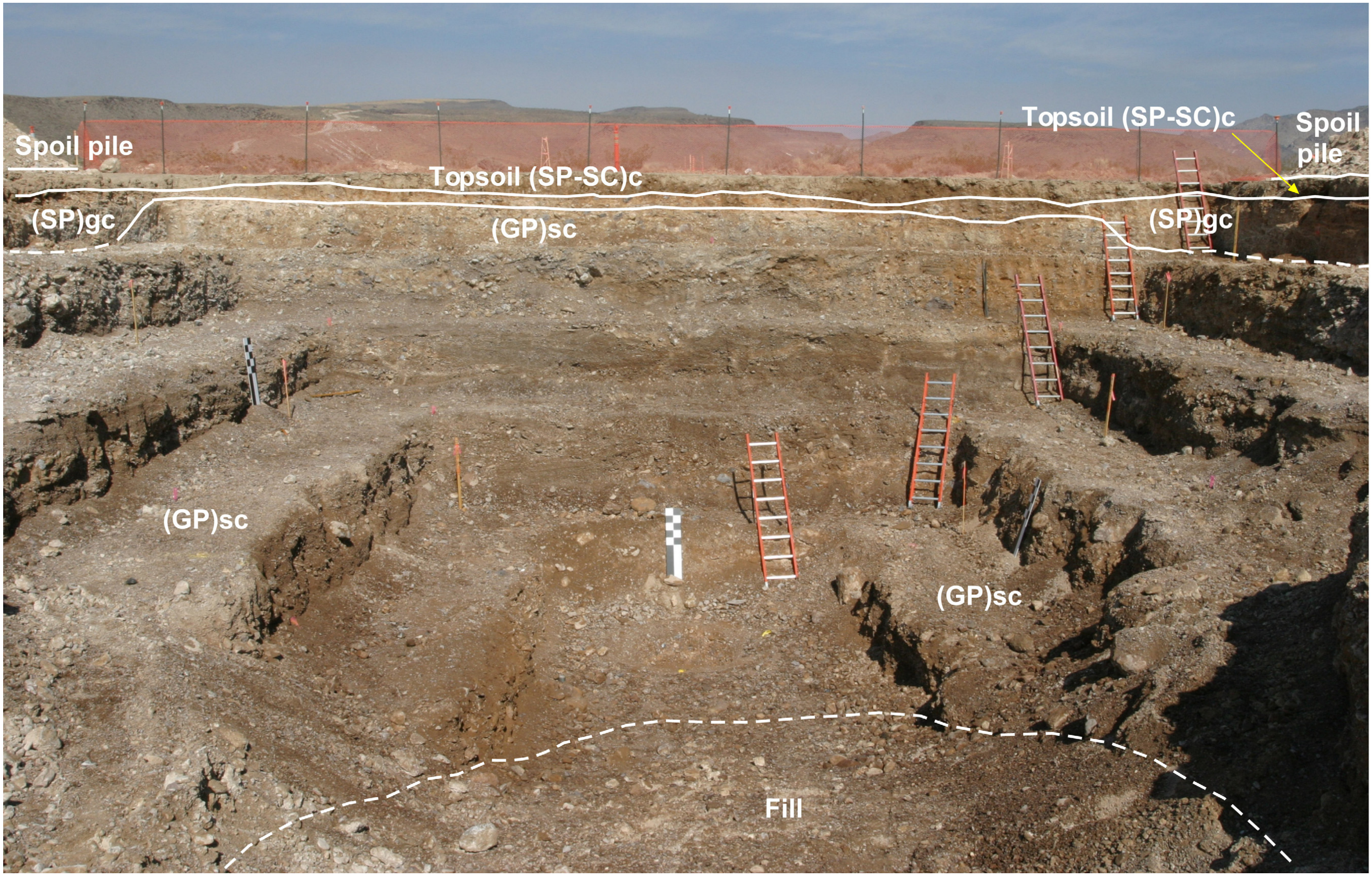
II.2 PHOTOMOSAIC MAPS OF TEST PITS TP-WHB-5, TP-WHB-6, AND TP-WHB-7

Beginning in August 2006, three test pits were excavated to analyze engineering properties of the alluvium in the Waste Handling Building (WHB) sub-area of the North Portal Facilities (NPF) area. Test pits TP-WHB-5, TP-WHB-6, and TP-WHB-7 were surveyed and located as shown in Figure 6.2-1 in Section 6.2.4. This attachment presents a series of three geologic maps for each of the three test pits excavated in the WHB area (DTN: GS070583114233.003 [DIRS183296]). The geologic mapping is superimposed on a photomosaic of the test pits. Each figure covers one of the side slopes of the test pit (mapping was not performed on the bottom of the pit or on the access ramp into the pit, which occupied the fourth side of each pit). Photomosaic maps of the test pits are presented in alphanumeric order beginning on the following page.



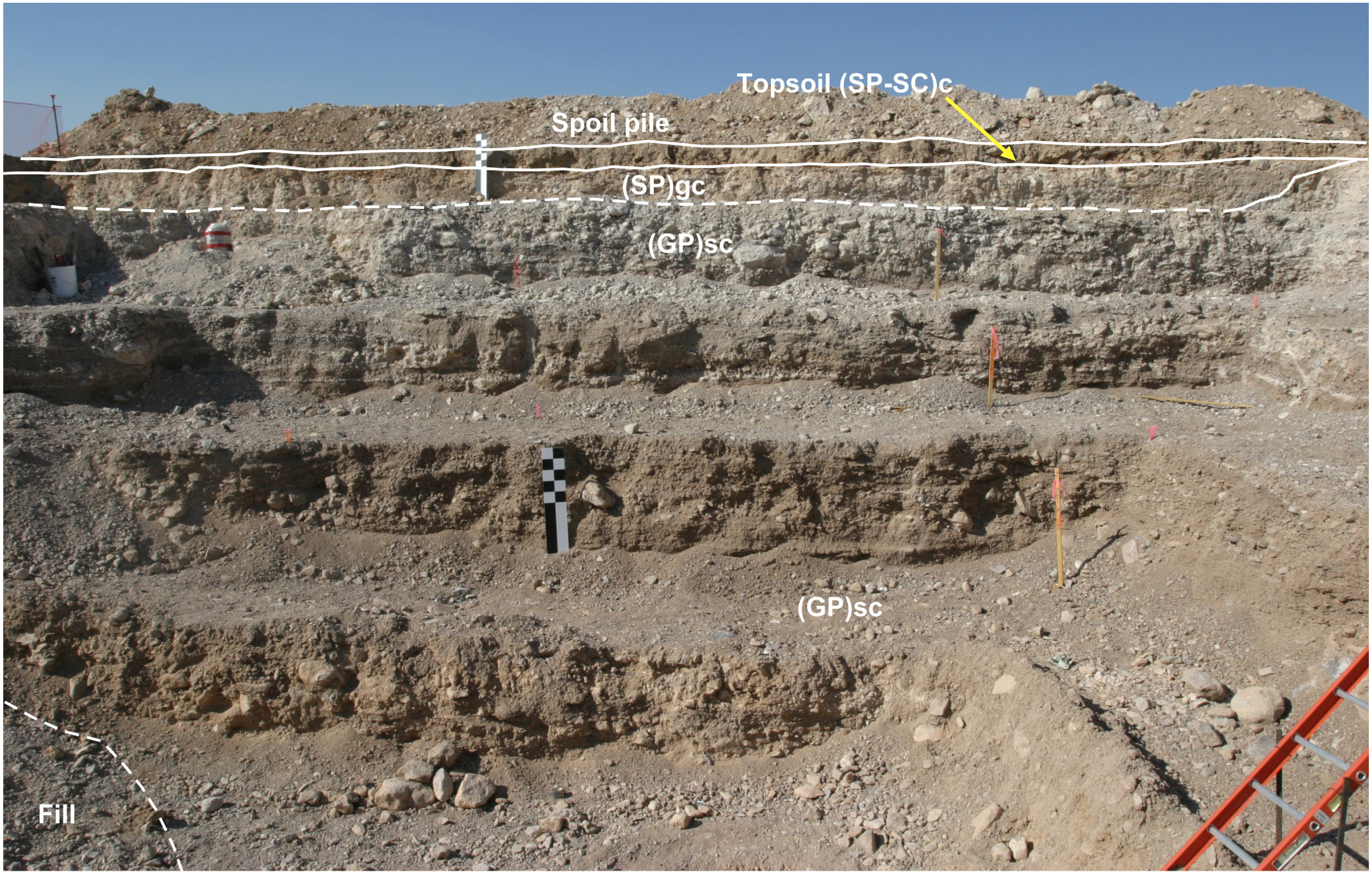
NOTE: Soil units are specific to test pit and do not correspond to other pits.

Figure II-1. Test Pit TP-WHB-5 East Wall



NOTE: Soil units are specific to test pit and do not correspond to other pits.

Figure II-2. Test Pit TP-WHB-5 North Wall

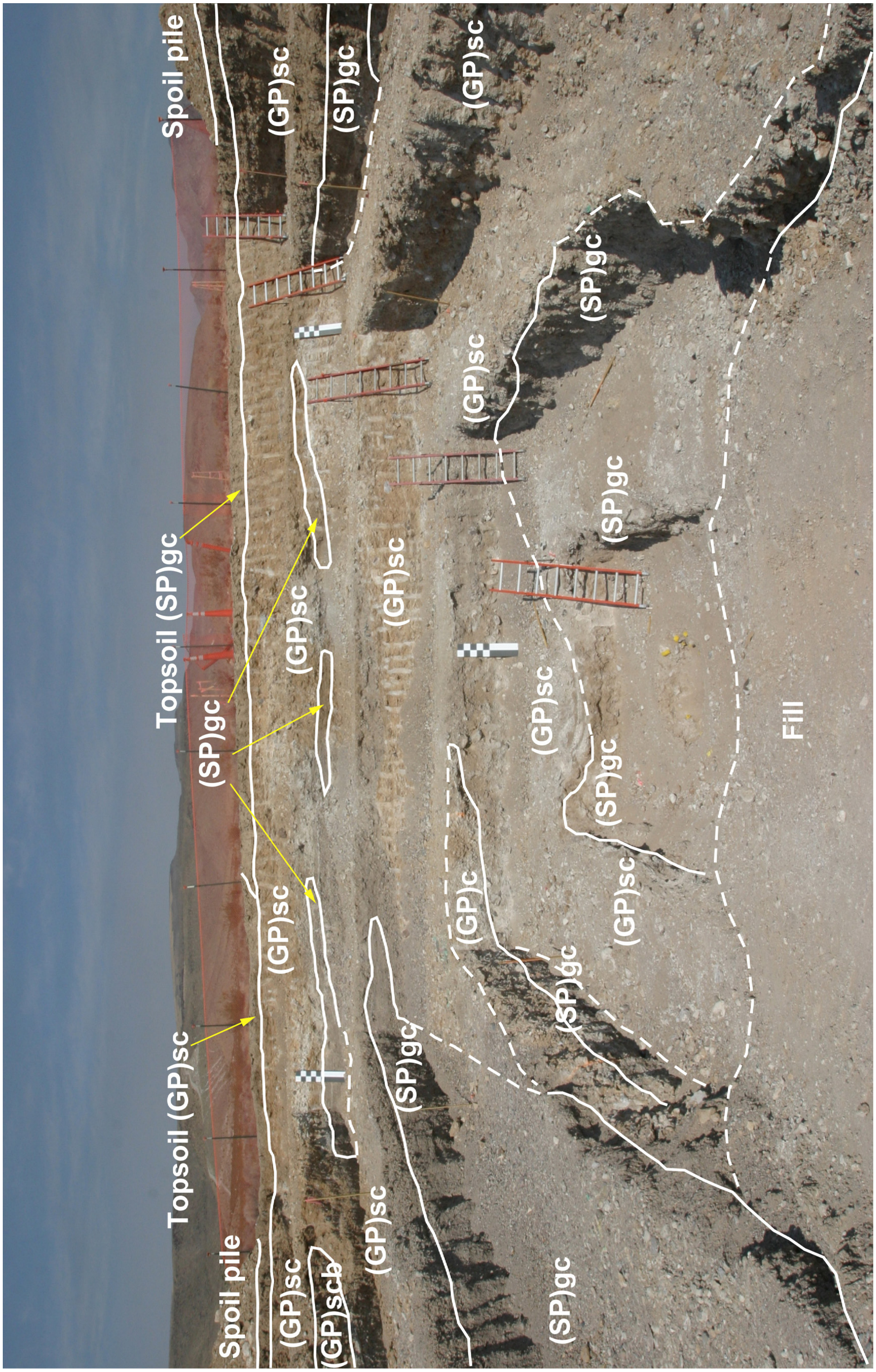


NOTE:	Soil units are specific to test pit and do not correspond to other pits.

Figure II-3.	Test Pit TP-WHB-5 West Wall

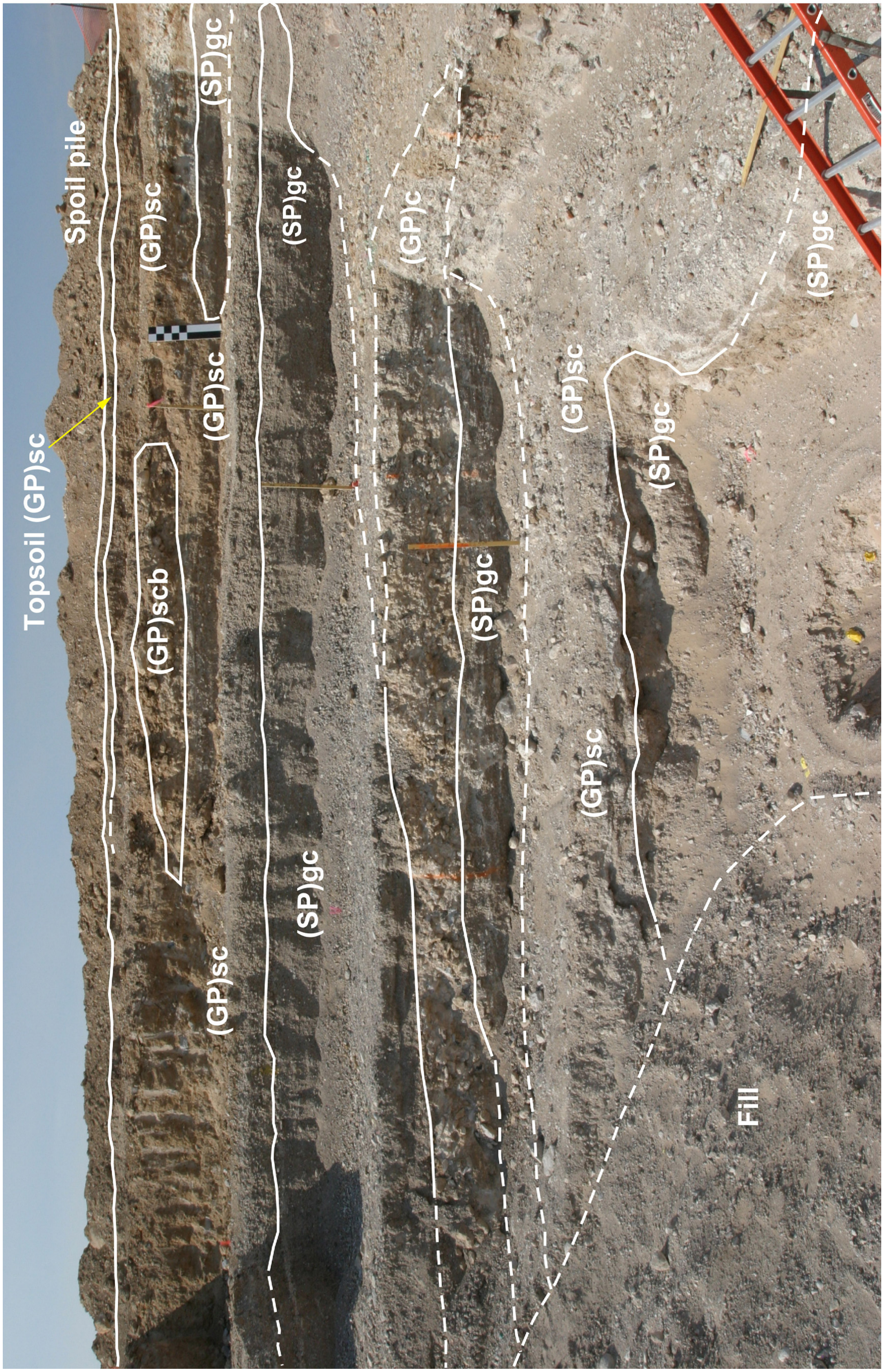
NOTE: Soil units are specific to test pit and do not correspond to other pits.

Figure II-4. Test Pit TP-WHB-6 East Wall



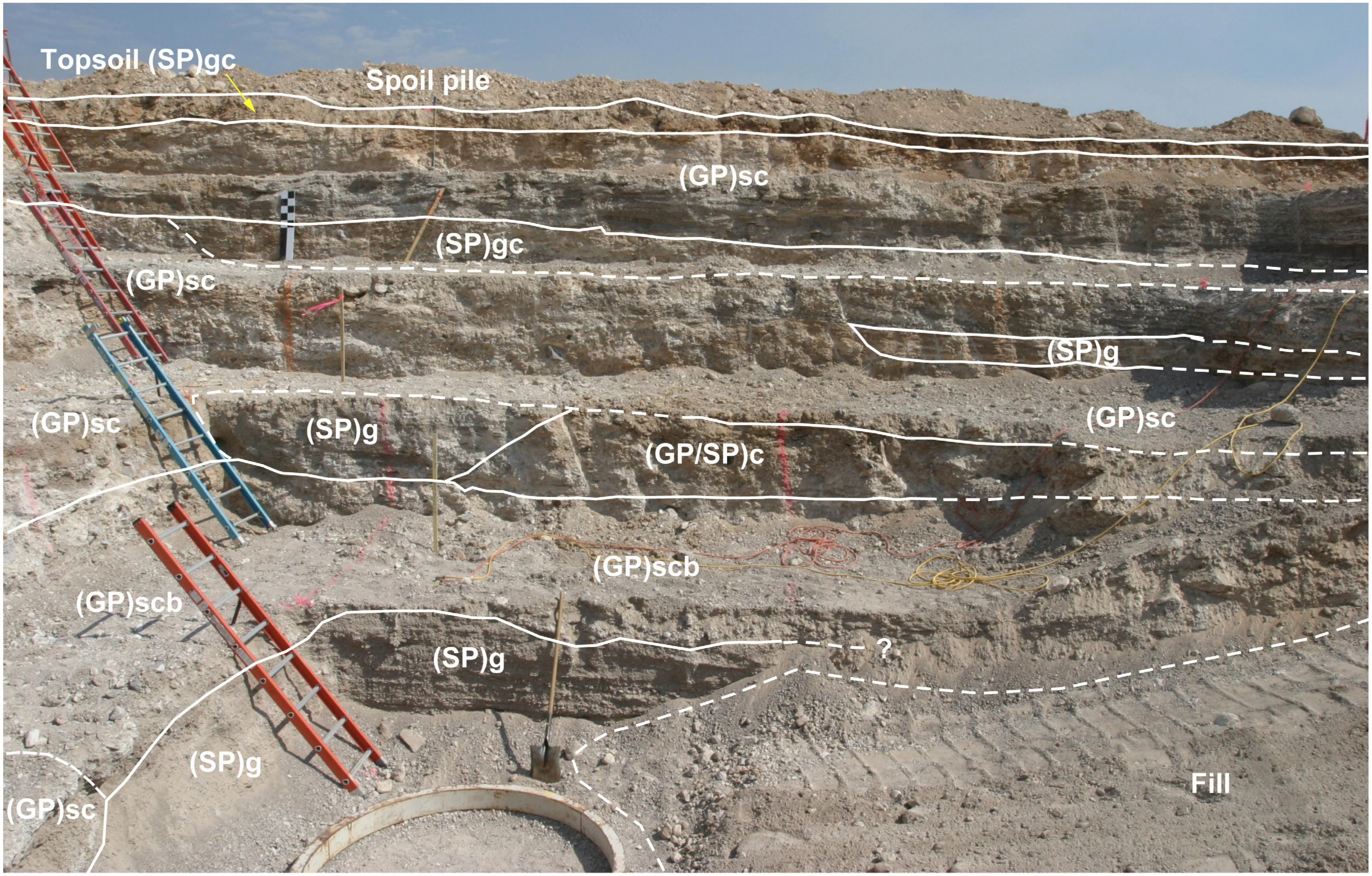
NOTE:	Soil units are specific to test pit and do not correspond to other pits.

Figure II-5.	Test Pit TP-WHB-6 North Wall



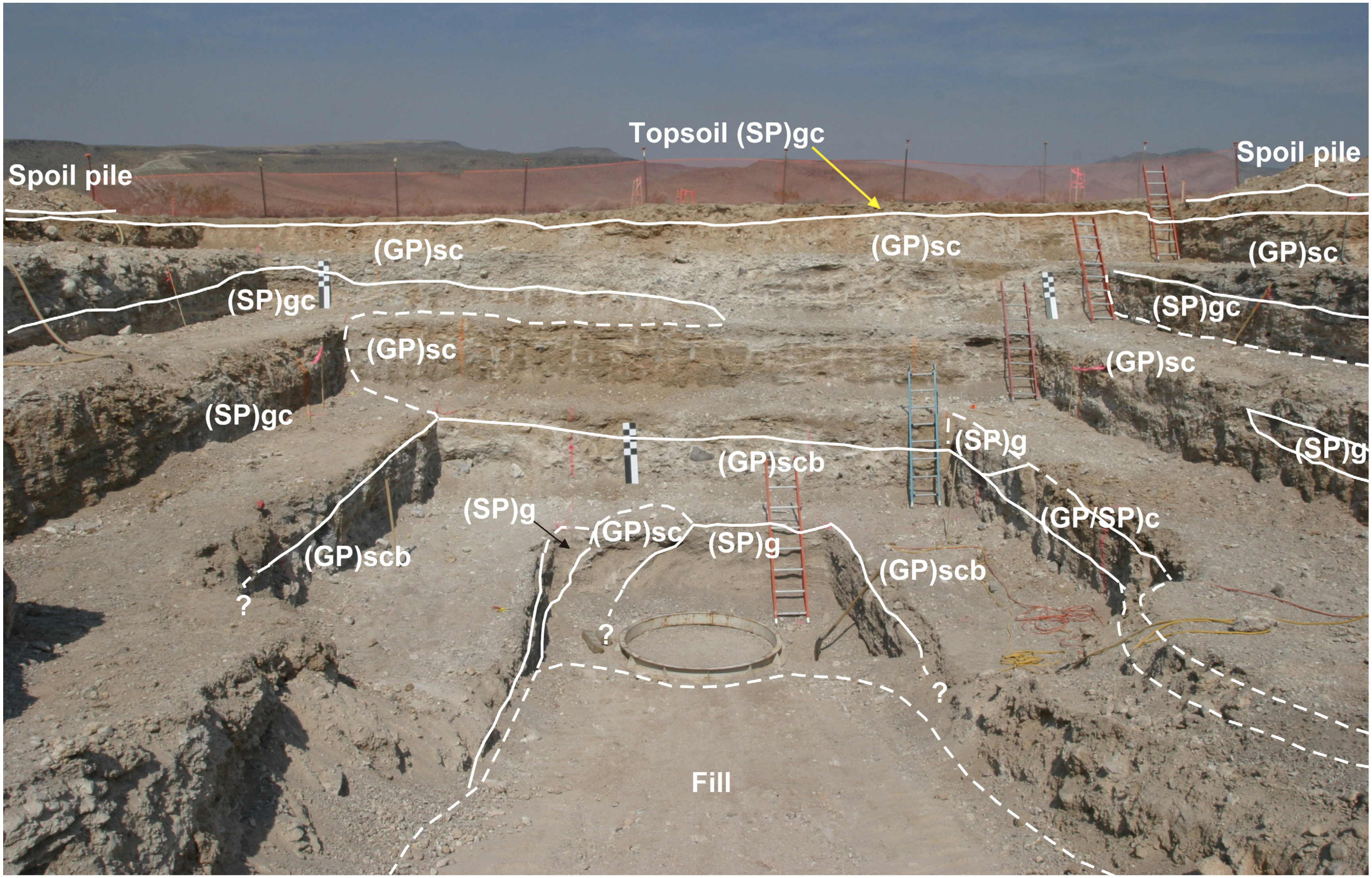
NOTE: Soil units are specific to test pit and do not correspond to other pits.

Figure II-6. Test Pit TP-WHB-6 West Wall



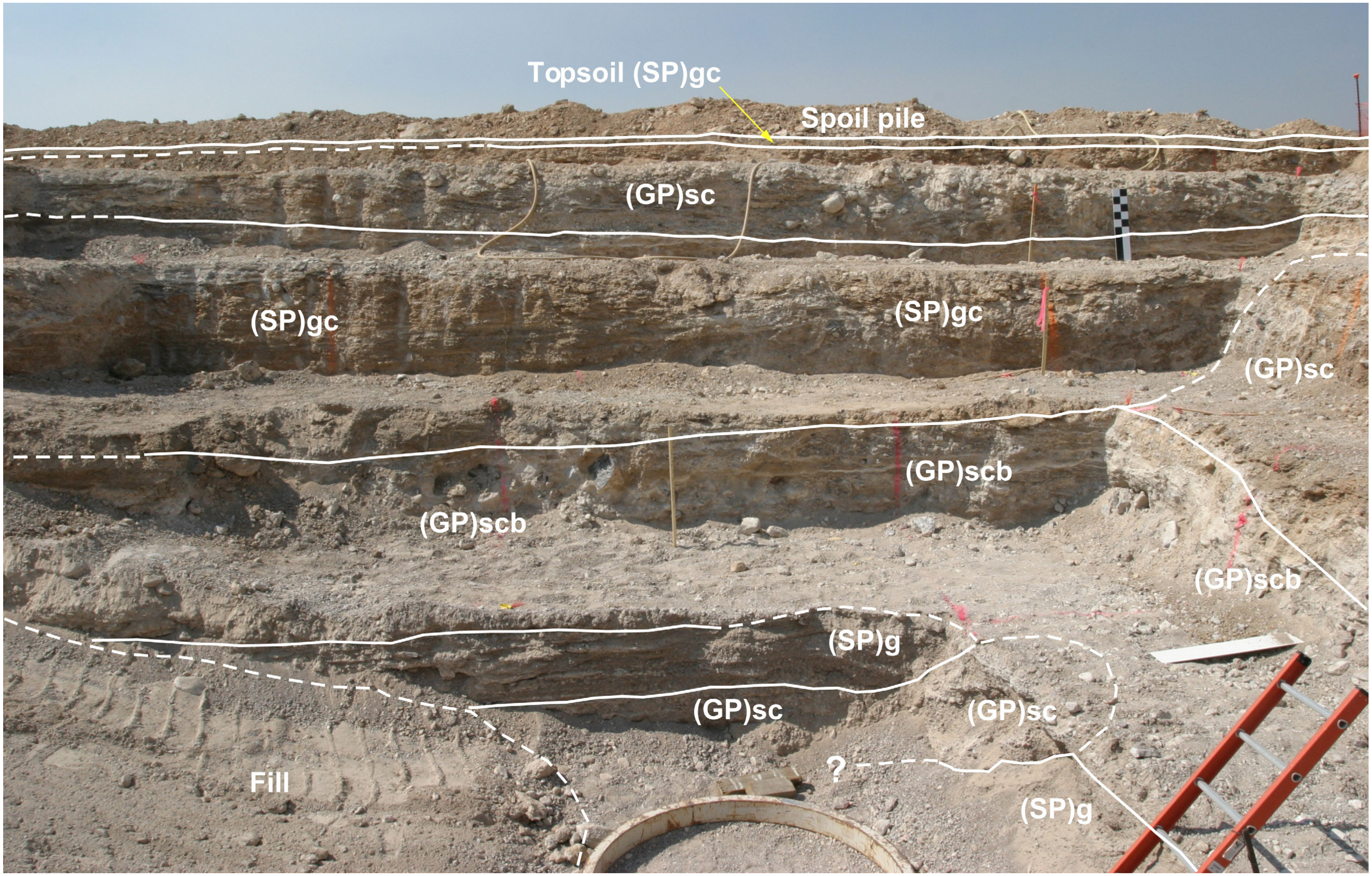
NOTE: Soil units are specific to test pit and do not correspond to other pits.

Figure II-7. Test Pit TP-WHB-7 East Wall



NOTE: Soil units are specific to test pit and do not correspond to other pits.

Figure II-8. Test Pit TP-WHB-7 North Wall



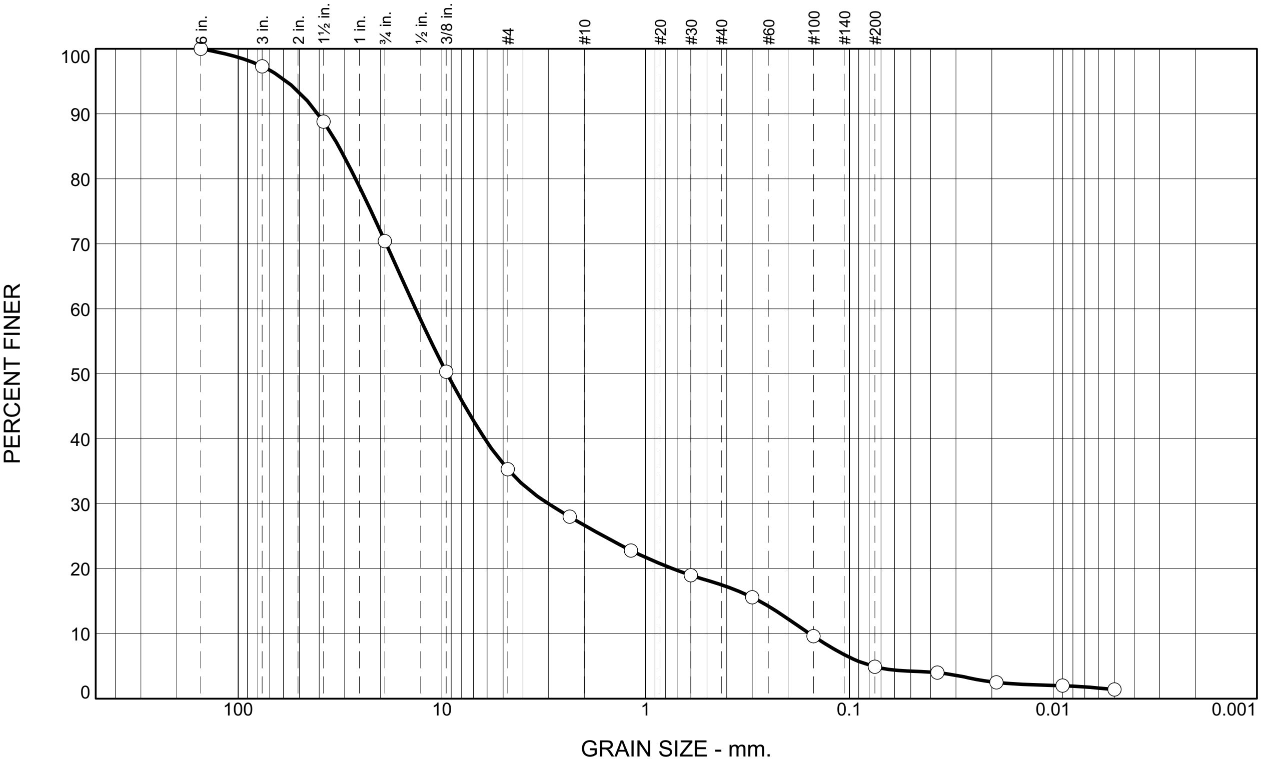
NOTE: Soil units are specific to test pit and do not correspond to other pits.

Figure II-9. Test Pit TP-WHB-7 West Wall

II.3 RING DENSITY DATA FROM PITS TP-WHB-5, TP-WHB-6, AND TP-WHB-7

Nine 6-foot water replacement ring density tests were performed within the test pits. The water replacement ring density tests were performed where greater than 20% of the particles (on a weight basis) were retained on the 1.5-inch (37.5-mm) sieve. Samples were collected and sent to the U.S. Bureau of Reclamation Soils Laboratory in Denver, Colorado, for physical properties testing and laboratory classification (USCS). Ring density data from DTN: GS070683114233.004 [DIRS 183297] are presented beginning on the following page.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
2.7	26.9	35.1	8.6	9.2	12.6	3.5	1.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	97.3		
1.5in	88.8		
.75in	70.4		
.375in	50.3		
#4	35.3		
#8	28.0		
#16	22.8		
#30	19.0		
#50	15.6		
#100	9.6		
#200	4.9		
.037mm	4.0		
.019mm	2.5		
.009mm	2.0		
.005mm	1.4		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Total Sample as Recieved

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 32.1011 D_{60}= 13.4469 D_{50}= 9.4178
D_{30}= 3.0078 D_{15}= 0.2759 D_{10}= 0.1568
C_u= 85.78 C_c= 4.29

Classification

USCS= AASHTO=

Remarks

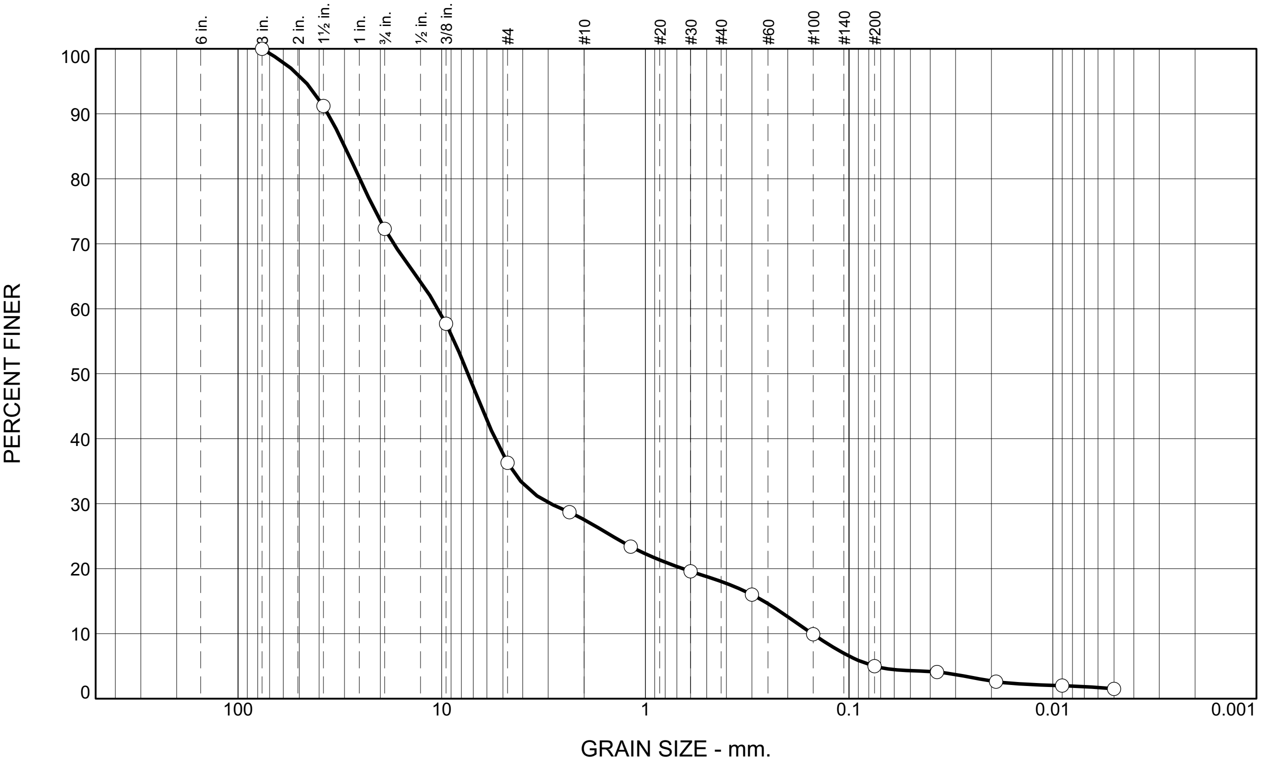
Sample Number: 65A-819
Location: SMF #01041600
Date: 10/20/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Shehorn **Checked By:** Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	27.7	36.0	8.8	9.5	13.0	3.5	1.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	91.2		
.75in	72.3		
.375in	57.7		
#4	36.3		
#8	28.7		
#16	23.4		
#30	19.6		
#50	16.0		
#100	9.9		
#200	5.0		
.037mm	4.1		
.019mm	2.6		
.009mm	2.0		
.005mm	1.5		

* (no specification provided)

Material Description

6-foot Ring Density test excavations sample
Poorly graded gravel with silt and sand
Plus 3-inch material removed from computations

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 29.9486 D_{60}= 10.4306 D_{50}= 7.4341
D_{30}= 2.9157 D_{15}= 0.2630 D_{10}= 0.1516
C_u= 68.79 C_c= 5.38

Classification

USCS= GP-GM AASHTO=

Remarks

Minus No. 4 Specific Gravity = 2.50
Plus No. 4 Apparent Specific Gravity = 2.41
Absorption = 6.3 %

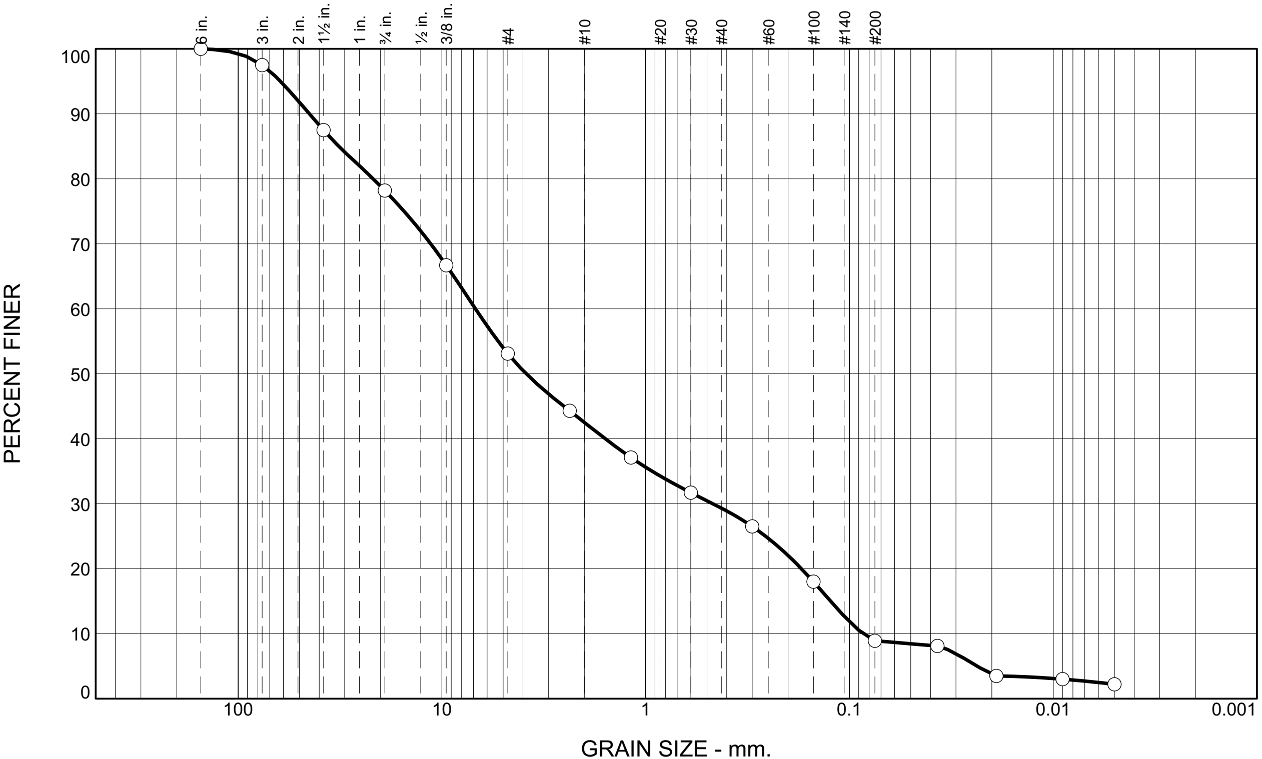
Sample Number: 65A-819
Location: SMF #01041600
Date: 10/20/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Shehorn **Checked By:** Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
2.5	19.3	25.1	10.6	13.2	20.4	6.7	2.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	97.5		
1.5in	87.5		
.75in	78.2		
.375in	66.7		
#4	53.1		
#8	44.3		
#16	37.1		
#30	31.7		
#50	26.5		
#100	18.0		
#200	8.9		
.037mm	8.1		
.019mm	3.5		
.009mm	3.0		
.005mm	2.2		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Total Sample as Recieved

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 31.9554 D_{60}= 6.8454 D_{50}= 3.8587
D_{30}= 0.4685 D_{15}= 0.1238 D_{10}= 0.0857
C_u= 79.86 C_c= 0.37

Classification

USCS= AASHTO=

Remarks

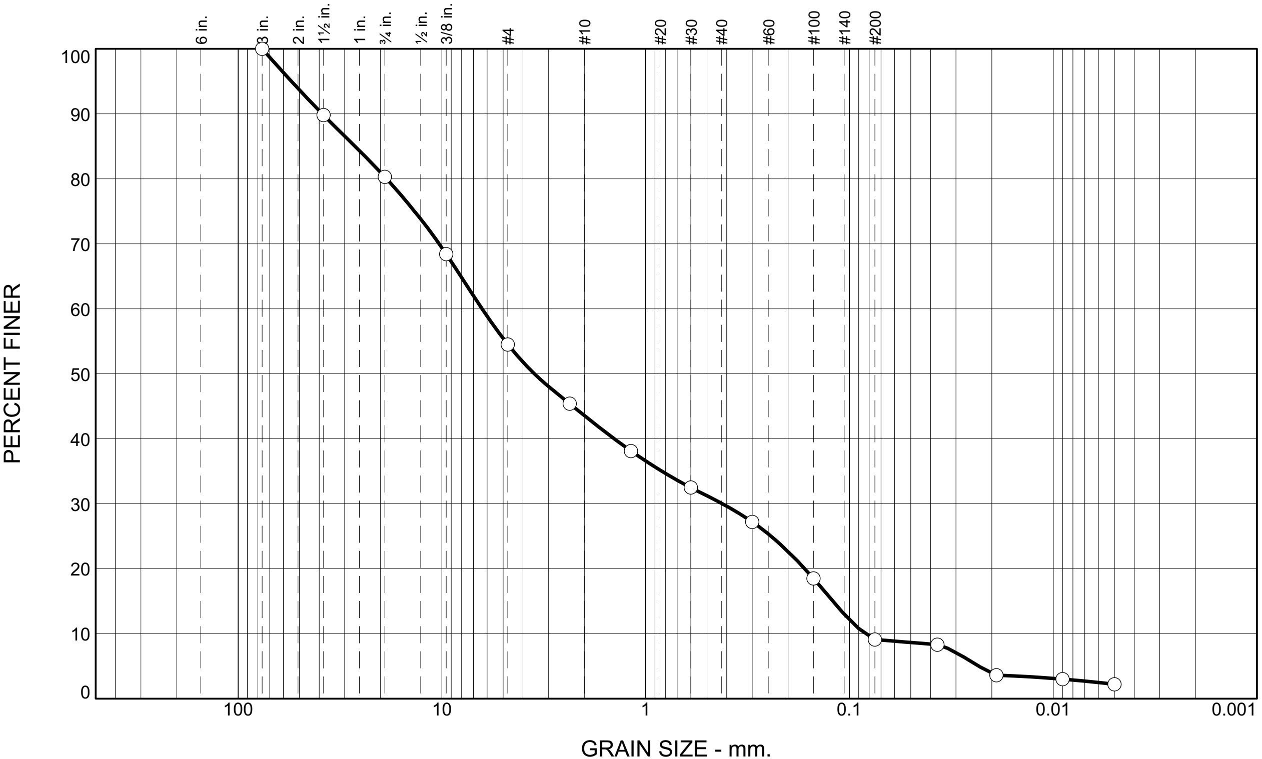
Sample Number: 65A-820
Location: SMF #01041601
Date: 10/20/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Shehorn **Checked By:** Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	19.7	25.8	10.9	13.5	21.0	6.9	2.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	89.8		
.75in	80.3		
.375in	68.4		
#4	54.5		
#8	45.4		
#16	38.1		
#30	32.5		
#50	27.2		
#100	18.5		
#200	9.1		
.037mm	8.3		
.019mm	3.6		
.009mm	3.0		
.005mm	2.2		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Poorly graded sand with silt and gravel
Plus 3-inch material removed from computations

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 26.6920 D_{60}= 6.3465 D_{50}= 3.5029
D_{30}= 0.4218 D_{15}= 0.1207 D_{10}= 0.0837
C_u= 75.79 C_c= 0.33

Classification

USCS= SP-SM AASHTO=

Remarks

Minus No. 4 Specific Gravity = 2.56
Plus No. 4 Apparent Specific Gravity = 2.47
Absorption = 6.7 %

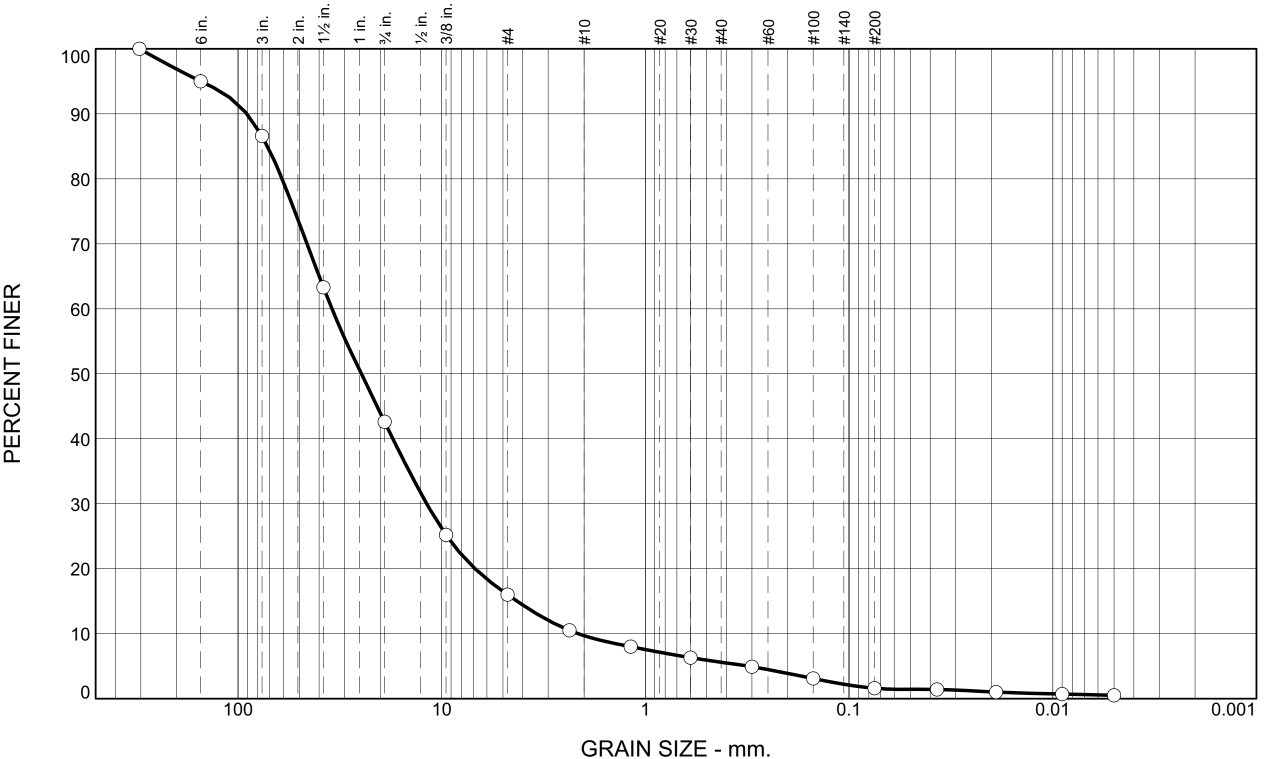
Sample Number: 65A-820
Location: SMF #01041601
Date: 10/20/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Shehorn **Checked By:** Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
13.4	44.0	26.6	6.3	4.1	4.0	1.1	0.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
12	100.0		
6in	95.0		
3in	86.6		
1.5in	63.3		
.75in	42.6		
.375in	25.2		
#4	16.0		
#8	10.5		
#16	8.0		
#30	6.3		
#50	4.9		
#100	3.1		
#200	1.6		
.037mm	1.4		
.019mm	1.0		
.009mm	0.7		
.005mm	0.5		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Total Sample as Recieved

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 71.5736 D_{60}= 34.5448 D_{50}= 24.8372
D_{30}= 11.8598 D_{15}= 4.2702 D_{10}= 2.1416
C_u= 16.13 C_c= 1.90

Classification

USCS= AASHTO=

Remarks

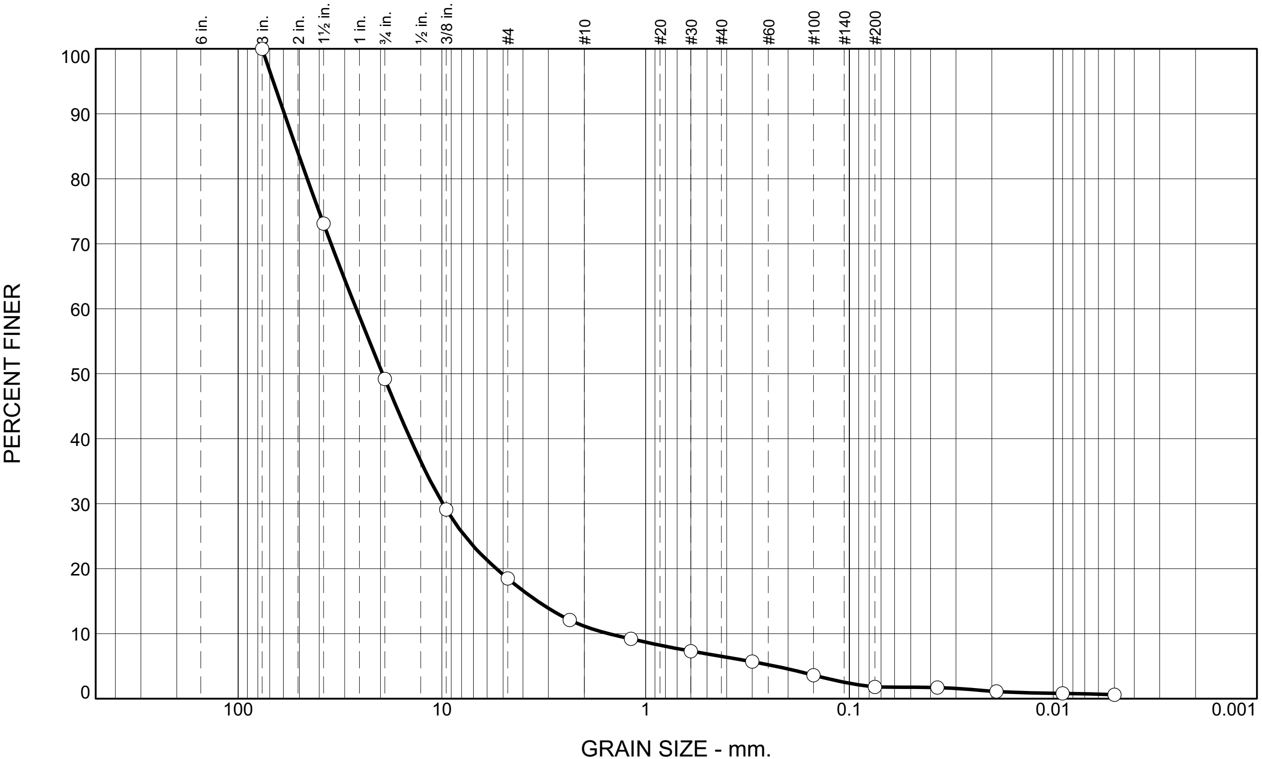
Sample Number: 65A-821
Location: SMf #01041602
Date: 12/15/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	50.8	30.7	7.3	4.7	4.7	1.2	0.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	73.1		
.75in	49.2		
.375in	29.1		
#4	18.5		
#8	12.1		
#16	9.2		
#30	7.3		
#50	5.7		
#100	3.6		
#200	1.8		
.037mm	1.7		
.019mm	1.1		
.009mm	0.8		
.005mm	0.6		

* (no specification provided)

Material Description

6-foot Ring Density test excavations sample
Well-graded gravel with sand
plus 3-inch material removed from computations

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 52.1297 D_{60}= 26.3116 D_{50}= 19.5190
D_{30}= 9.9096 D_{15}= 3.3872 D_{10}= 1.5168
C_u= 17.35 C_c= 2.46

Classification

USCS= GW AASHTO=

Remarks

Minus No. 4 Specific Gravity = 2.50
Plus No. 4 Apparent Specific Gravity = 2.45
Absorption = 4.5 %

Sample Number: 65A-821
Location: SMF #01041602

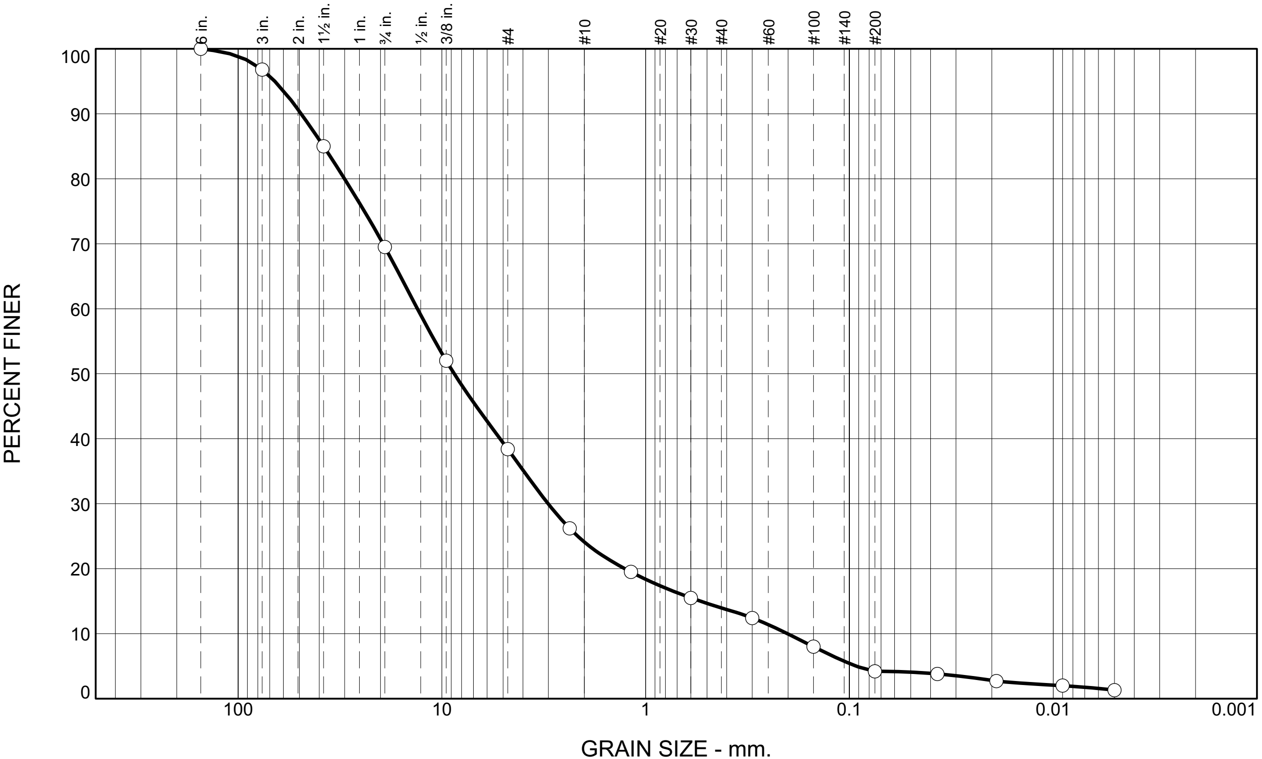
Date: 10/20/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Shehorn **Checked By:** Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
3.2	27.3	31.1	14.3	10.1	9.8	2.9	1.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	96.8		
1.5in	85.0		
.75in	69.5		
.375in	52.0		
#4	38.4		
#8	26.2		
#16	19.5		
#30	15.5		
#50	12.4		
#100	8.0		
#200	4.2		
.037mm	3.8		
.019mm	2.7		
.009mm	2.0		
.005mm	1.3		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Total Sample as Recieved

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 38.1000 D_{60}= 13.1791 D_{50}= 8.7000
D_{30}= 3.0071 D_{15}= 0.5378 D_{10}= 0.2012
C_u= 65.51 C_c= 3.41

Classification

USCS= AASHTO=

Remarks

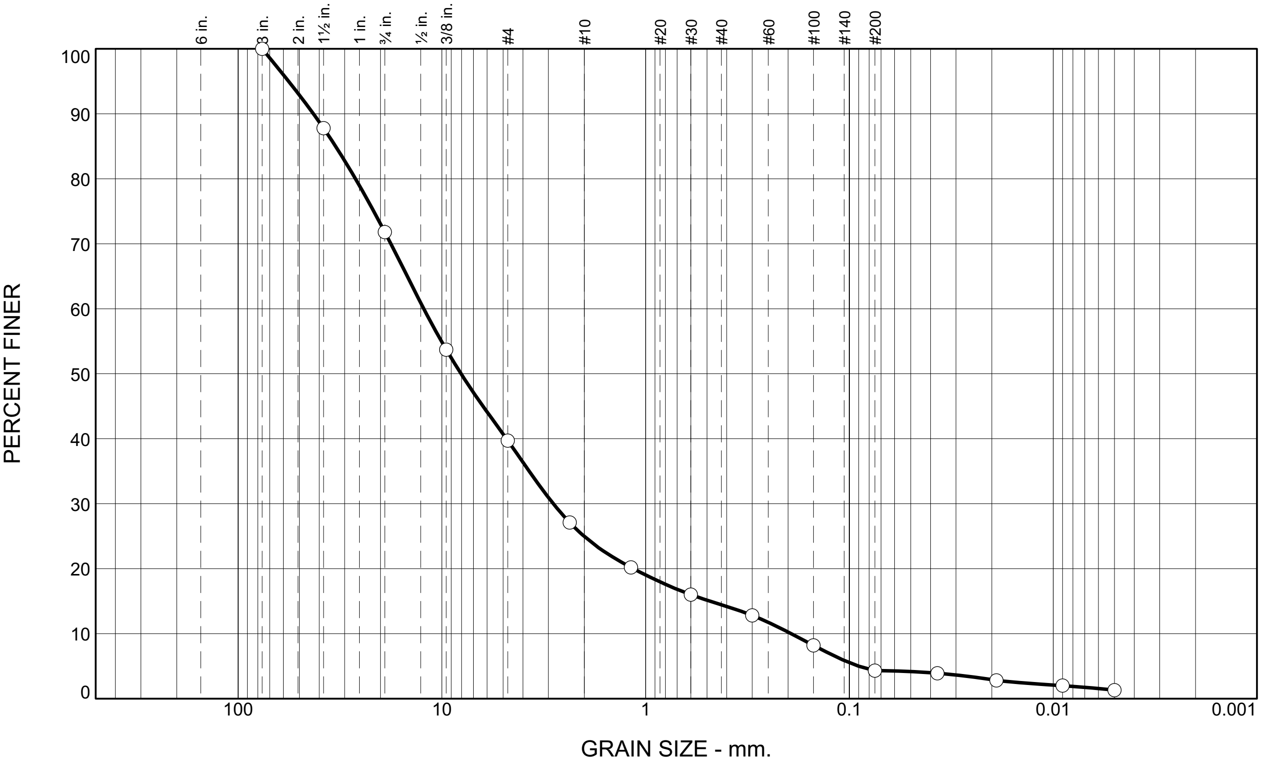
Sample Number: 65A-822
Location: SMF #01041603
Date: 12/15/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Schafer / Shehorn **Checked By:** Shehorn / Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	28.2	32.1	14.7	10.6	10.1	3.0	1.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	87.8		
.75in	71.8		
.375in	53.7		
#4	39.7		
#8	27.1		
#16	20.2		
#30	16.0		
#50	12.8		
#100	8.2		
#200	4.3		
.037mm	3.9		
.019mm	2.8		
.009mm	2.0		
.005mm	1.3		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Poorly graded gravel with sand
Plus 3-inch material removed from computations

Atterberg Limits

PL= NP
LL= NP
PI= NP

Coefficients

D_{85}= 33.2444
D_{60}= 12.2541
D_{50}= 8.0609
D_{30}= 2.8357
D_{15}= 0.4829
D_{10}= 0.1931
C_u= 63.47
C_c= 3.40

Classification

USCS= GP
AASHTO=

Remarks

Minus No. 4 Specific Gravity = 2.52
Plus No. 4 Apparent Specific Gravity = 2.41
Absorption 5.7 %

Sample Number: 65A-822
Location: SMF #01041603

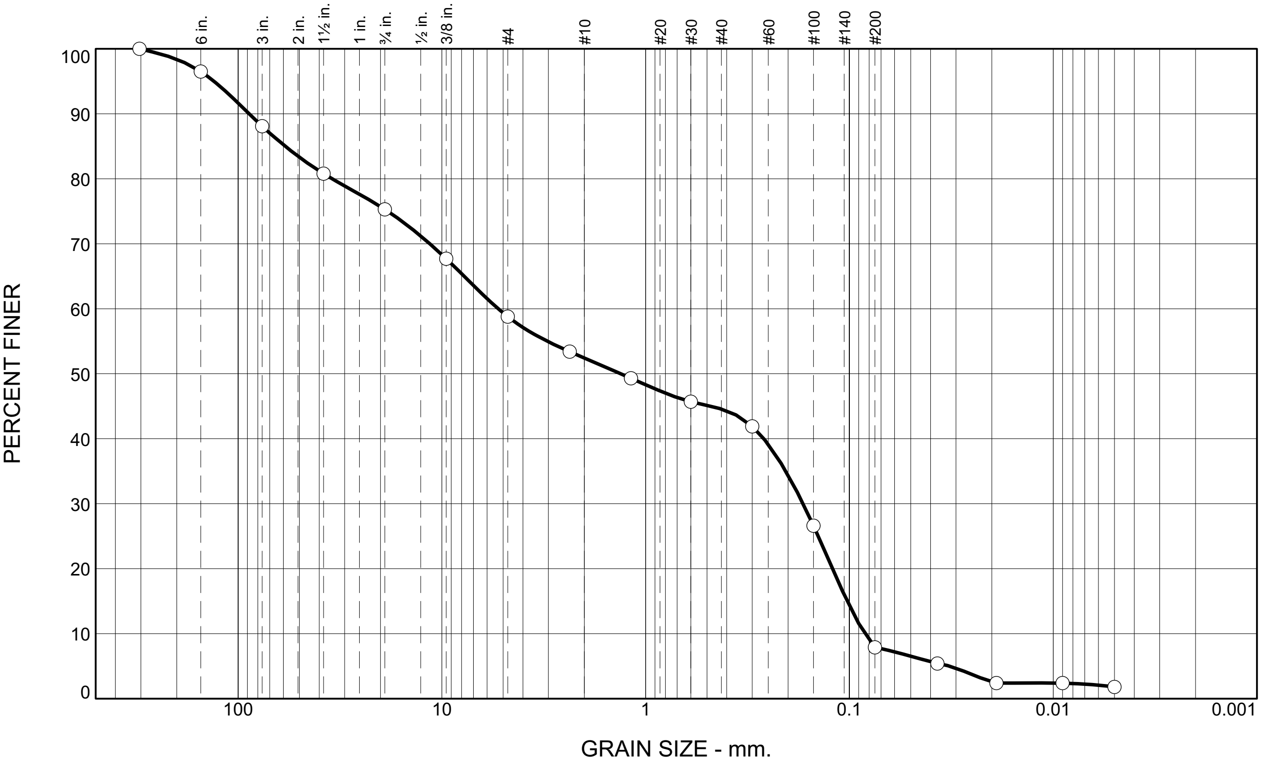
Date: 12/15/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A
Figure

Tested By: Shehorn
Checked By: Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
11.9	12.8	16.5	6.4	7.8	36.7	6.1	1.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
12in	100.0		
6in	96.5		
3in	88.1		
1.5in	80.8		
.75in	75.3		
.375in	67.7		
#4	58.8		
#8	53.4		
#16	49.3		
#30	45.7		
#50	41.9		
#100	26.6		
#200	7.9		
.037mm	5.4		
.019mm	2.4		
.009mm	2.4		
.005mm	1.8		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Total Sample as Recieved

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 58.6251 D_{60}= 5.2858 D_{50}= 1.3267
D_{30}= 0.1687 D_{15}= 0.1026 D_{10}= 0.0841
C_u= 62.84 C_c= 0.06

Classification

USCS= AASHTO=

Remarks

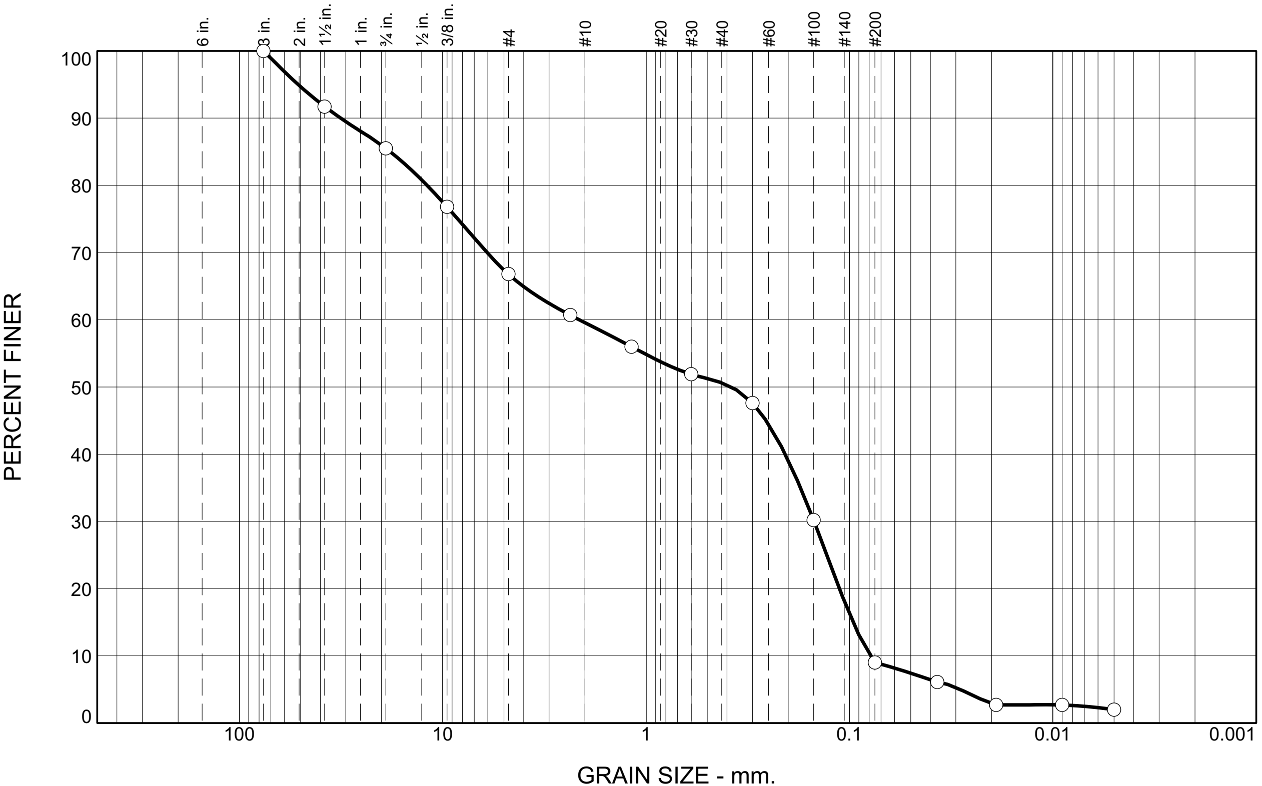
Sample Number: 65A-823
Location: SMF #01041604
Date: 10/20/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Schaffer / Shehorn **Checked By:** Shehorn / Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	14.5	18.7	7.2	9.0	41.6	7.0	2.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	91.7		
.75in	85.5		
.375in	76.8		
#4	66.8		
#8	60.7		
#16	56.0		
#30	51.9		
#50	47.6		
#100	30.2		
#200	9.0		
.037mm	6.1		
.019mm	2.7		
.009mm	2.7		
.005mm	2.0		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Poorly graded sand with silt and gravel
Plus 3-inch material removed from computations

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 18.1356 D_{60}= 2.1313 D_{50}= 0.3810
D_{30}= 0.1491 D_{15}= 0.0960 D_{10}= 0.0791
C_u= 26.95 C_c= 0.13

Classification

USCS= SP-SM AASHTO=

Remarks

Minus No. 4 Specific Gravity = 2.50
Plus No. 4 Apparent Specific Gravity = 2.44
Absorption 6.54 %

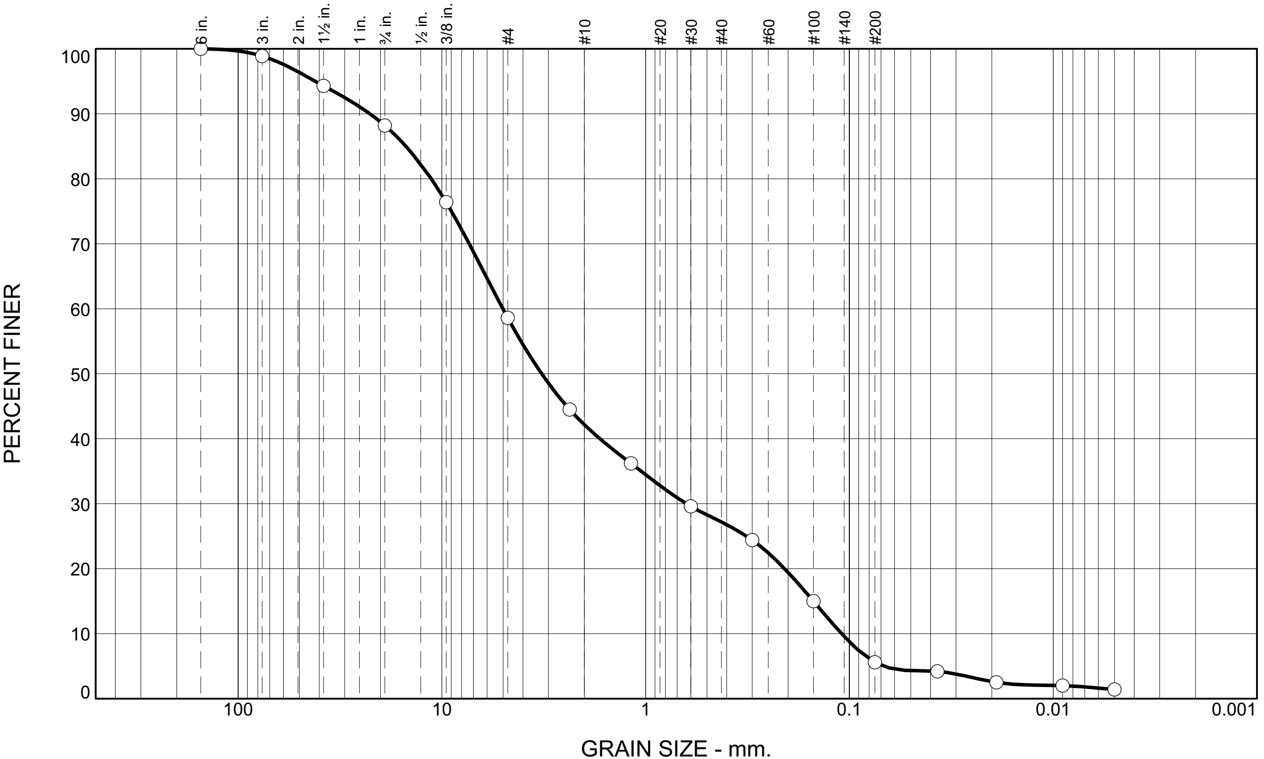
Sample Number: 65A-823
Location: SMF #01041604

Date: 10/20/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
1.1	10.7	29.6	16.4	15.0	21.6	4.2	1.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	98.9		
1.5in	94.3		
.75in	88.2		
.375in	76.4		
#4	58.6		
#8	44.5		
#16	36.2		
#30	29.6		
#50	24.4		
#100	15.0		
#200	5.6		
.037mm	4.2		
.019mm	2.5		
.009mm	2.0		
.005mm	1.4		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Total Sample as Recieved

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 15.0174 D_{60}= 5.0222 D_{50}= 3.2302
D_{30}= 0.6304 D_{15}= 0.1500 D_{10}= 0.1093
C_u= 45.93 C_c= 0.72

Classification

USCS= AASHTO=

Remarks

Sample Number: 65A-824
Location: SMF #01041700

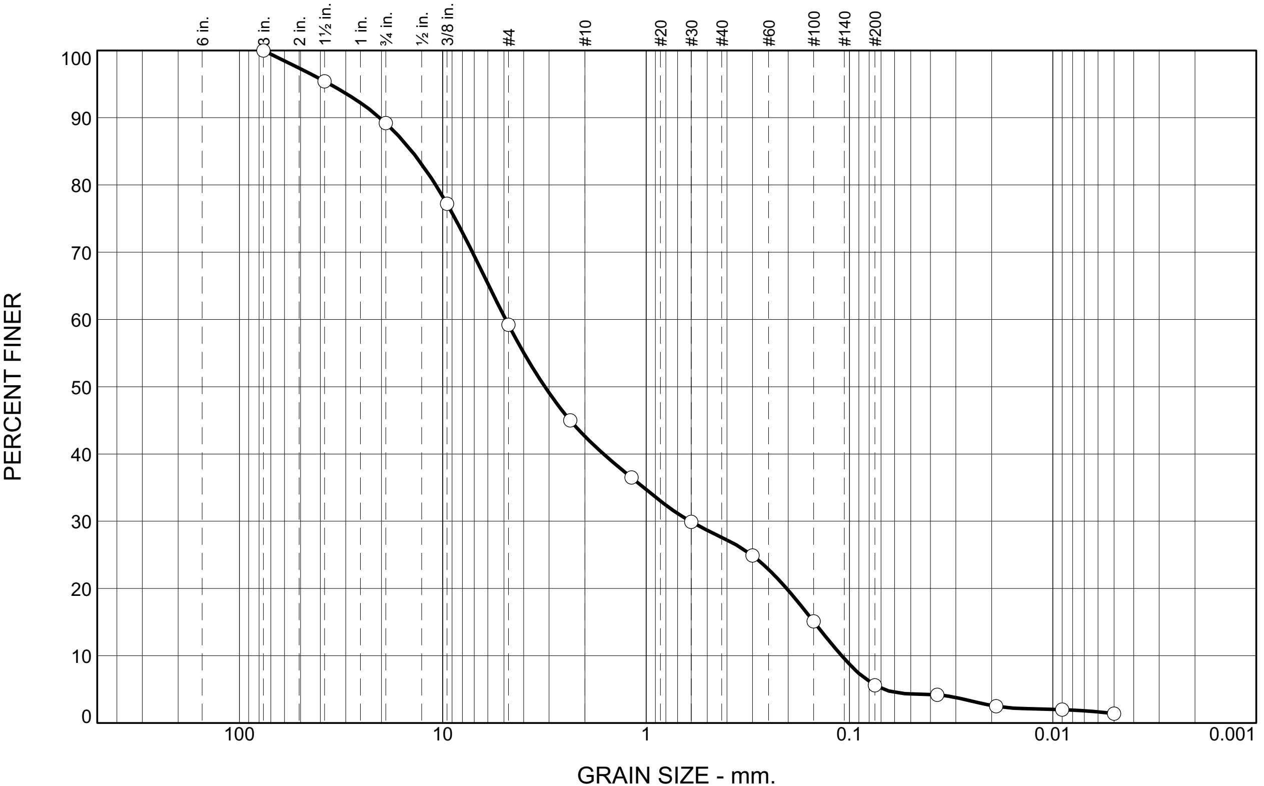
Date: 12/15/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	10.8	30.0	16.6	15.0	22.0	4.2	1.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	95.4		
.75in	89.2		
.375in	77.2		
#4	59.2		
#8	45.0		
#16	36.5		
#30	29.9		
#50	24.9		
#100	15.1		
#200	5.6		
.037mm	4.2		
.019mm	2.5		
.009mm	2.0		
.005mm	1.4		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Poorly graded sand with silt and gravel
plus 3-inch material removed from computations

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 14.1736 D_{60}= 4.9033 D_{50}= 3.1415
D_{30}= 0.6079 D_{15}= 0.1491 D_{10}= 0.1093
C_u= 44.87 C_c= 0.69

Classification

USCS= SP-SM AASHTO=

Remarks

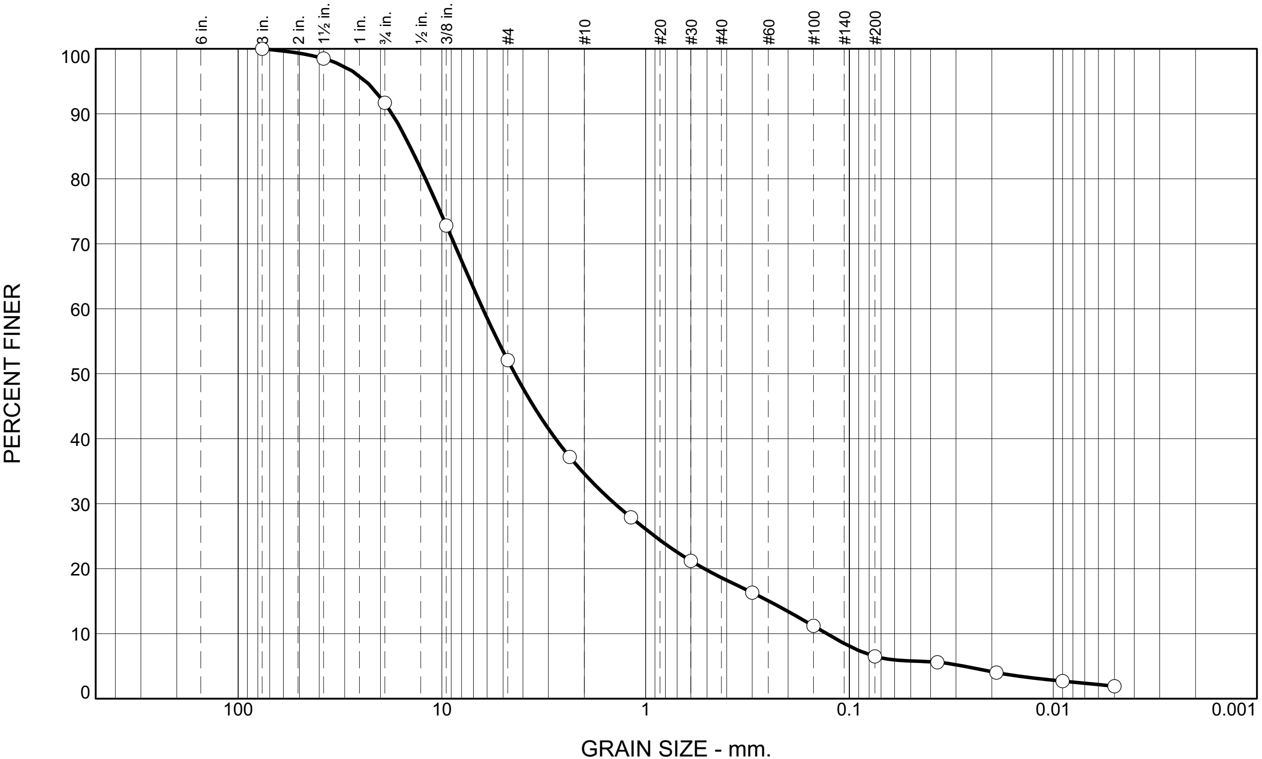
Minus No. 4 Specific Gravity =2.58
plus No. 4 Apparent Specific Gravity = 2.46
Absorption = 6.6 %

Sample Number: 65A-824
Location: SMF #01041700
Date: 12/15/2006

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	8.3	39.6	17.5	16.0	12.1	4.6	1.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	98.5		
.75in	91.7		
.375in	72.8		
#4	52.1		
#8	37.2		
#16	27.9		
#30	21.2		
#50	16.3		
#100	11.2		
#200	6.5		
.037mm	5.6		
.019mm	4.0		
.009mm	2.7		
.005mm	1.9		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Well-graded gravel with silt and sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 14.3057 D_{60}= 6.2917 D_{50}= 4.3767
D_{30}= 1.4138 D_{15}= 0.2486 D_{10}= 0.1292
C_u= 48.71 C_c= 2.46

Classification

USCS= GW-GM AASHTO=

Remarks

Minus No. 4 Specific Gravity = 2.52
Plus No. 4 Apparent Specific Gravity = 2.46
Absorption = 6.61 %

Sample Number: 65A-825
Location: SMF #01041605

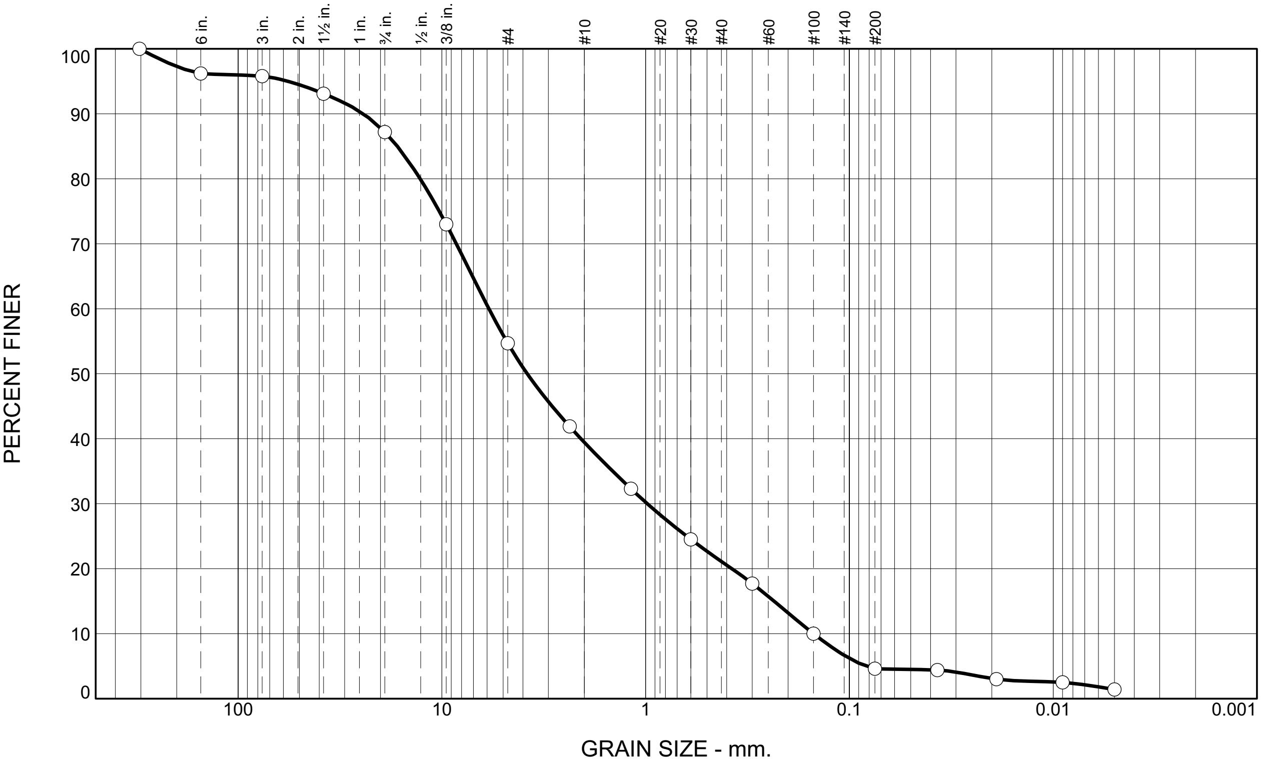
Date: 12/15/2007

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
4.2	8.6	32.5	15.2	18.4	16.5	3.2	1.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
12in	100.0		
6in	96.2		
3in	95.8		
1.5in	93.1		
.75in	87.2		
.375in	73.0		
#4	54.7		
#8	41.9		
#16	32.3		
#30	24.5		
#50	17.7		
#100	10.0		
#200	4.6		
.037mm	4.4		
.019mm	3.0		
.009mm	2.5		
.005mm	1.4		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Total Sample as Recieved

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 16.5257	D_{60}= 5.8754	D_{50}= 3.8092
D_{30}= 0.9802	D_{15}= 0.2343	D_{10}= 0.1500
C_u= 39.17	C_c= 1.09	

Classification

USCS= AASHTO=

Remarks

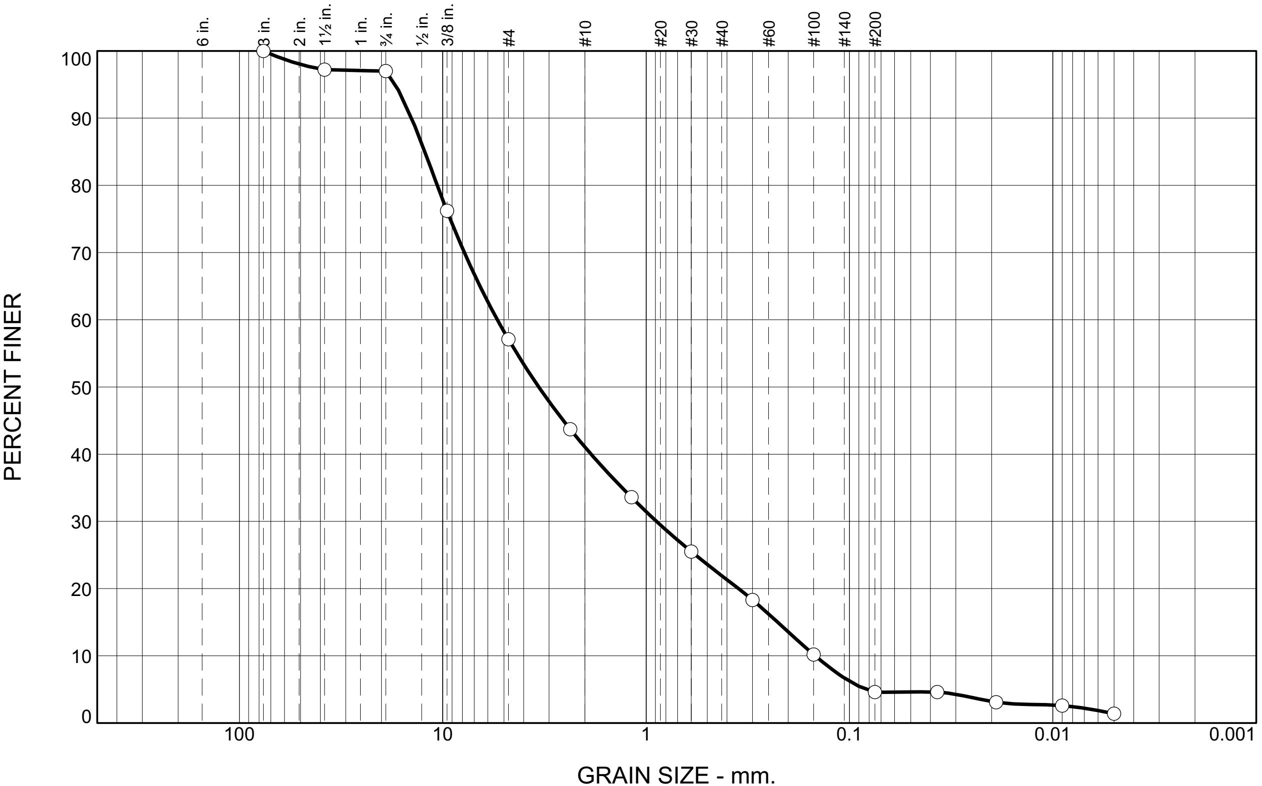
Sample Number: 65A-826
Location: SMf #01041606
Date: 1/19/2007

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	3.0	39.9	16.0	19.2	17.3	3.2	1.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	97.2		
.75in	97.0		
.375in	76.2		
#4	57.1		
#8	43.7		
#16	33.6		
#30	25.5		
#50	18.3		
#100	10.2		
#200	4.6		
.037mm	4.6		
.019mm	3.1		
.009mm	2.6		
.005mm	1.4		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Poorly graded sand with gravel
plus 3-inch material removed from computations

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 12.2435 D_{60}= 5.3845 D_{50}= 3.3701
D_{30}= 0.8880 D_{15}= 0.2255 D_{10}= 0.1474
C_u= 36.54 C_c= 0.99

Classification

USCS= SP AASHTO=

Remarks

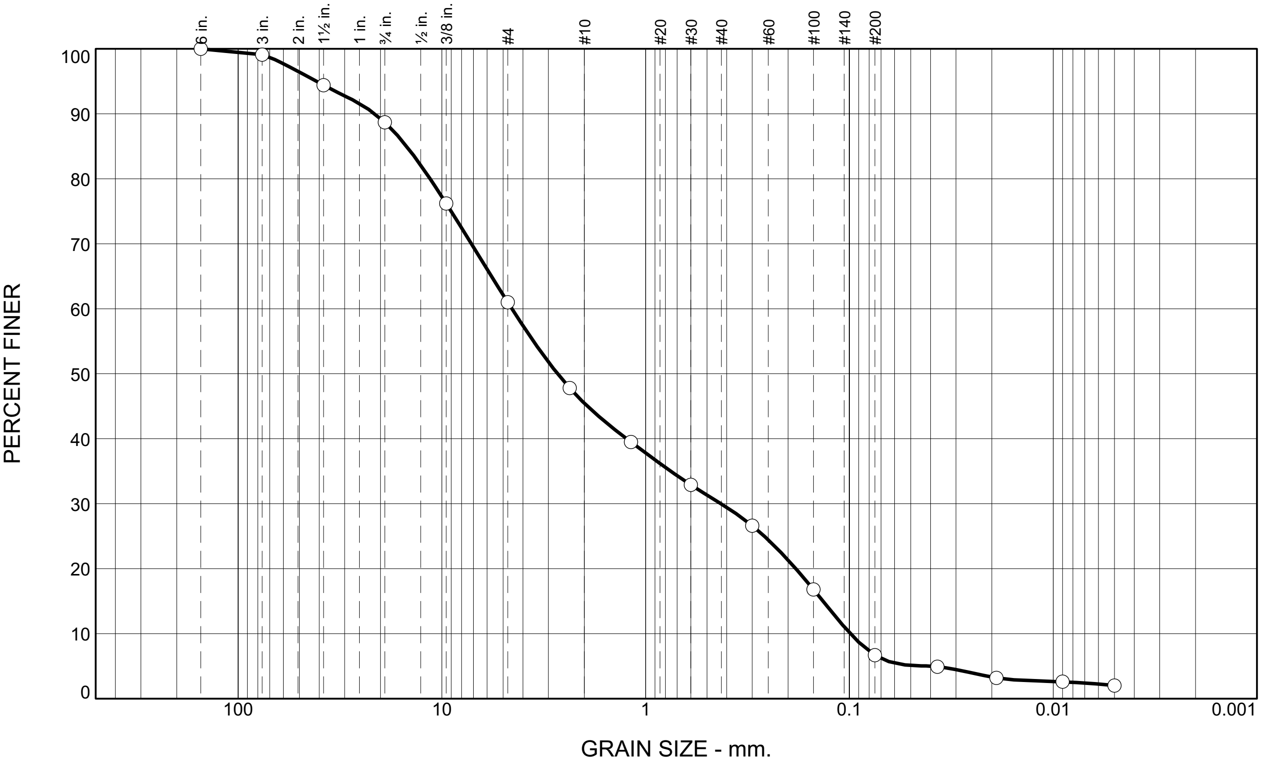
Minus No. 4 Specific Gravity = 2.51
Plus No. 4 Apparent Specific Gravity = 2.47
Absorption 6.5 %

Sample Number: 65A-826
Location: SMF #01041606
Date: 1/19/2007

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.9	10.4	27.7	15.5	15.5	23.3	4.7	2.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	99.1		
1.5in	94.4		
.75in	88.7		
.375in	76.2		
#4	61.0		
#8	47.8		
#16	39.5		
#30	32.9		
#50	26.6		
#100	16.8		
#200	6.7		
.037mm	4.9		
.019mm	3.2		
.009mm	2.6		
.005mm	2.0		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Total Sample as Recieved

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 14.8852 D_{60}= 4.5320 D_{50}= 2.7055
D_{30}= 0.4270 D_{15}= 0.1348 D_{10}= 0.0991
C_u= 45.75 C_c= 0.41

Classification

USCS= AASHTO=

Remarks

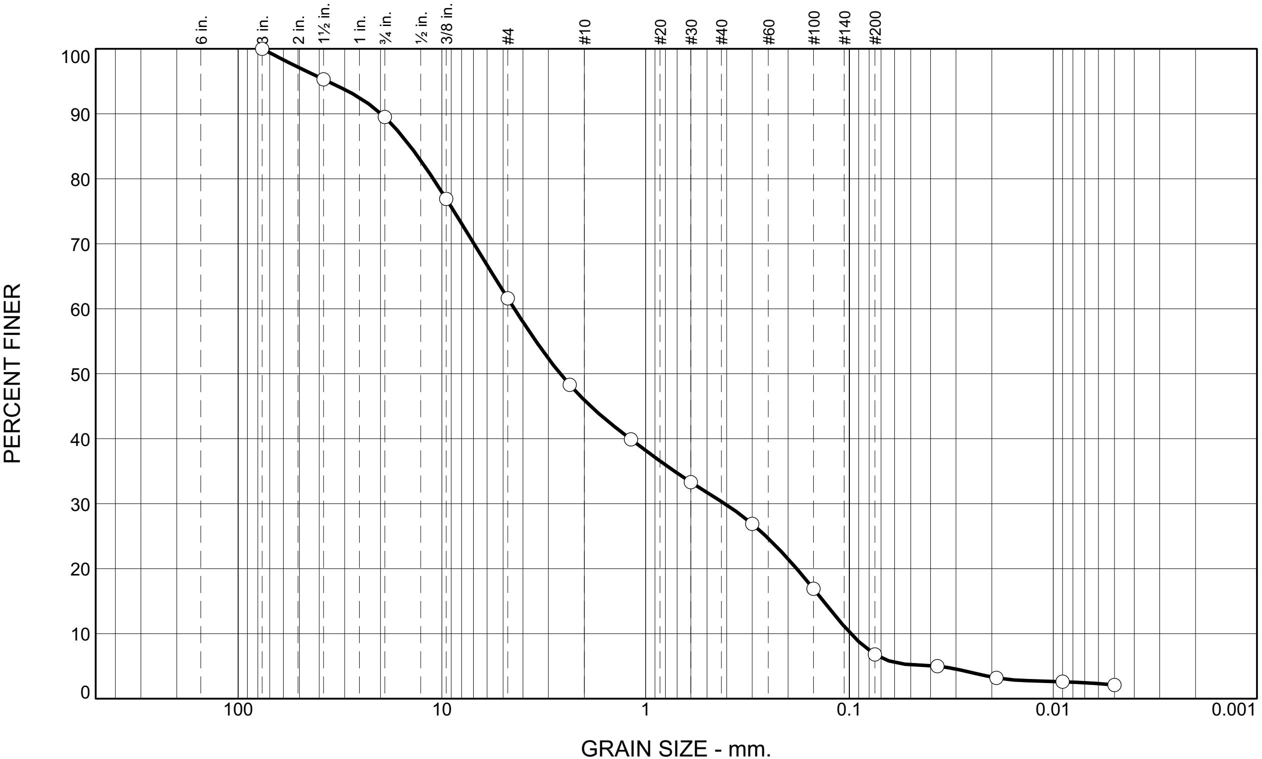
Sample Number: 65A-827
Location: SMF #01041607
Date: 1/19/2007

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	10.5	27.9	15.7	15.6	23.5	4.7	2.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	95.3		
.75in	89.5		
.375in	76.9		
#4	61.6		
#8	48.3		
#16	39.9		
#30	33.3		
#50	26.9		
#100	16.9		
#200	6.8		
.037mm	5.0		
.019mm	3.2		
.009mm	2.6		
.005mm	2.1		

* (no specification provided)

Material Description

6-foot Ring Density test excavation sample
Poorly graded sand with silt and gravel
plus 3-inch material removed from computations

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 14.2724 D_{60}= 4.4074 D_{50}= 2.6235
D_{30}= 0.4094 D_{15}= 0.1341 D_{10}= 0.0985
C_u= 44.75 C_c= 0.39

Classification

USCS= SP-SM AASHTO=

Remarks

Minus No. 4 Specific Gravity = 2.51
Plus No. 4 Apparent Specific Gravity = 2.49
Absorption 5.6 %

Sample Number: 65A-827
Location: SMF #01041607

Date: 1/19/2007

BUREAU OF RECLAMATION

Client: Department of Energy
Project: Yucca Mountain Project
In-place Density Samples
Project No: 65A **Figure**

Tested By: Shehorn **Checked By:** Schaffer

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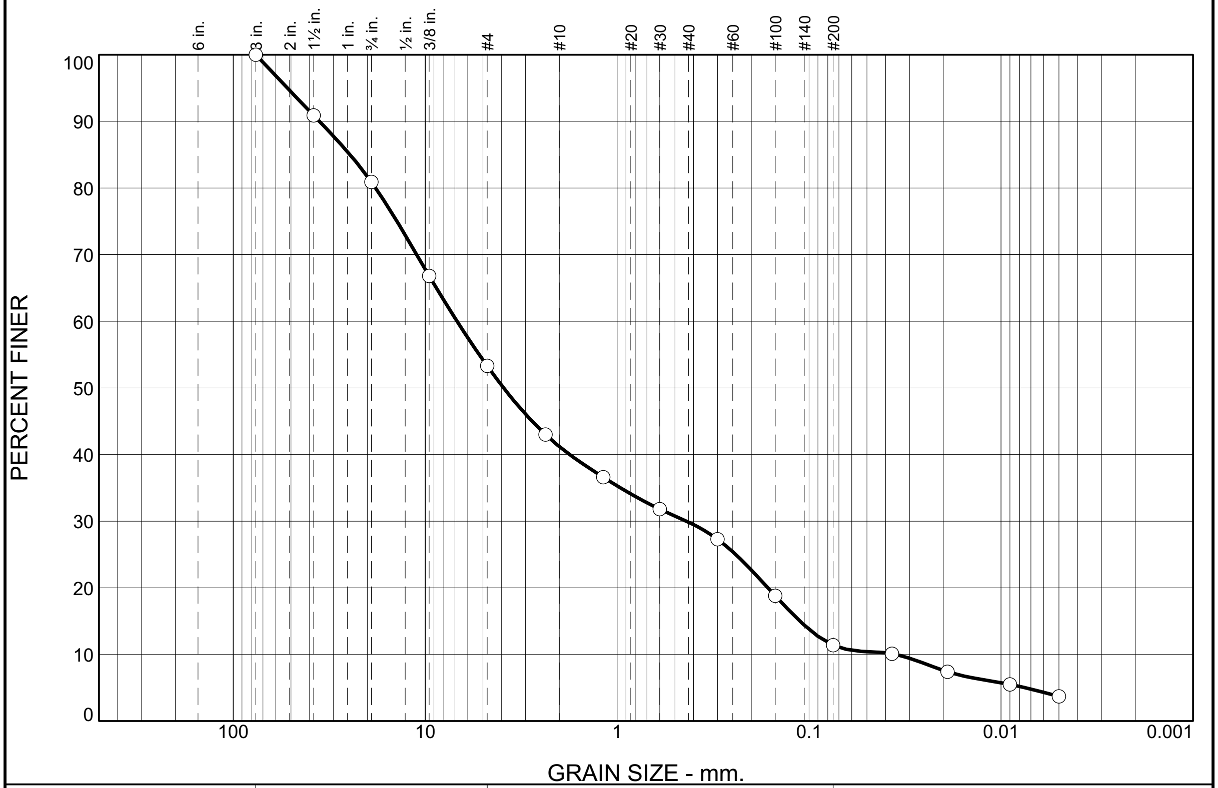
ATTACHMENT III

STATIC GEOTECHNICAL LABORATORY TESTING OF SONIC CORE

ATTACHMENT III
STATIC GEOTECHNICAL LABORATORY TESTING OF SONIC CORE

At the completion of the 2005 drilling program, alluvium samples from boreholes RF#47 and RF#52 were collected and tested using standard physical properties tests as discussed in Section 6.2-3. The boreholes are located on Figure 6.2-1. The sonic core alluvium samples recovered from these boreholes were sent to the U.S. Bureau of Reclamation Soils Laboratory in Denver, Colorado. Detailed laboratory testing results and gradation curve plots are from DTN: GS080183114233.001 [DIRS 184671] and are presented beginning on the following page.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	19.1	27.6	12.1	11.4	18.4	7.7	3.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	90.9		
.75in	80.9		
.375in	66.8		
#4	53.3		
#8	43.0		
#16	36.6		
#30	31.8		
#50	27.3		
#100	18.8		
#200	11.4		
.037mm	10.1		
.019mm	7.4		
.009mm	5.5		
.005mm	3.7		

* (no specification provided)

Material Description

Poorly graded gravel with silt and sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 24.6082 D_{60}= 6.8188 D_{50}= 3.9002
D_{30}= 0.4365 D_{15}= 0.1117 D_{10}= 0.0355
C_u= 192.20 C_c= 0.79

Classification

USCS= GP-GM AASHTO=

Remarks

+No. 4 Specific Gravity = 2.51
-No. 4 Apparent Specific Gravity = 2.43
Absorption = 5.5 %

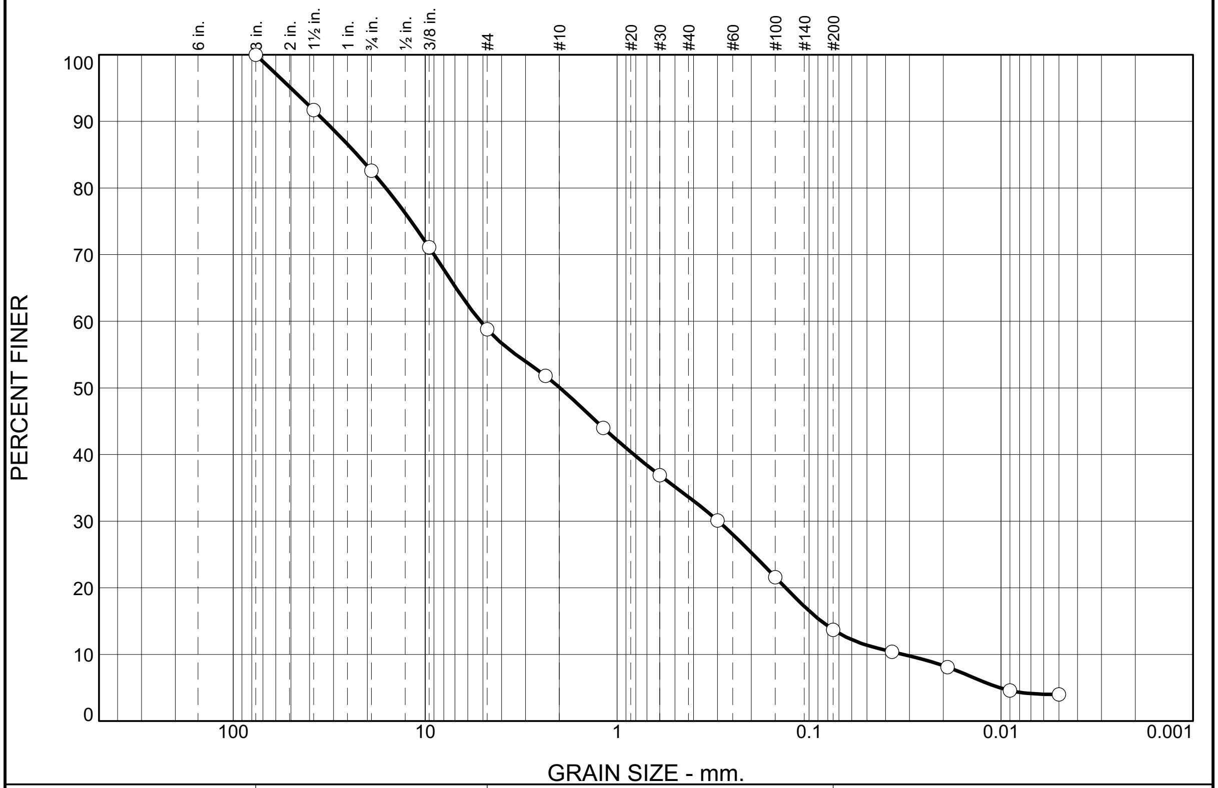
Sample Number: 65A-X692 **Depth:** 4.50-8.80 ft
Location: UE-25 RF #47 **Date:** 8/22/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 1

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	17.4	23.8	8.7	16.5	19.9	9.7	4.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3"	100.0		
1-1/2"	91.7		
3/4"	82.6		
3/8"	71.1		
#4	58.8		
#8	51.8		
#16	44.0		
#30	36.9		
#50	30.1		
#100	21.6		
#200	13.7		
.037mm	10.4		
.019mm	8.1		
.009mm	4.6		
.005mm	4.0		

* (no specification provided)

Material Description

Silty sand with gravel
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 22.5789 D_{60}= 5.1601 D_{50}= 1.9821
D_{30}= 0.2973 D_{15}= 0.0866 D_{10}= 0.0323
C_u= 159.87 C_c= 0.53

Classification

USCS= SM AASHTO=

Remarks

-No. 4 Specific Gravity -2.49
+No. 4 Apparent Specific Gravity =2.44
Absorption = 6.4 %

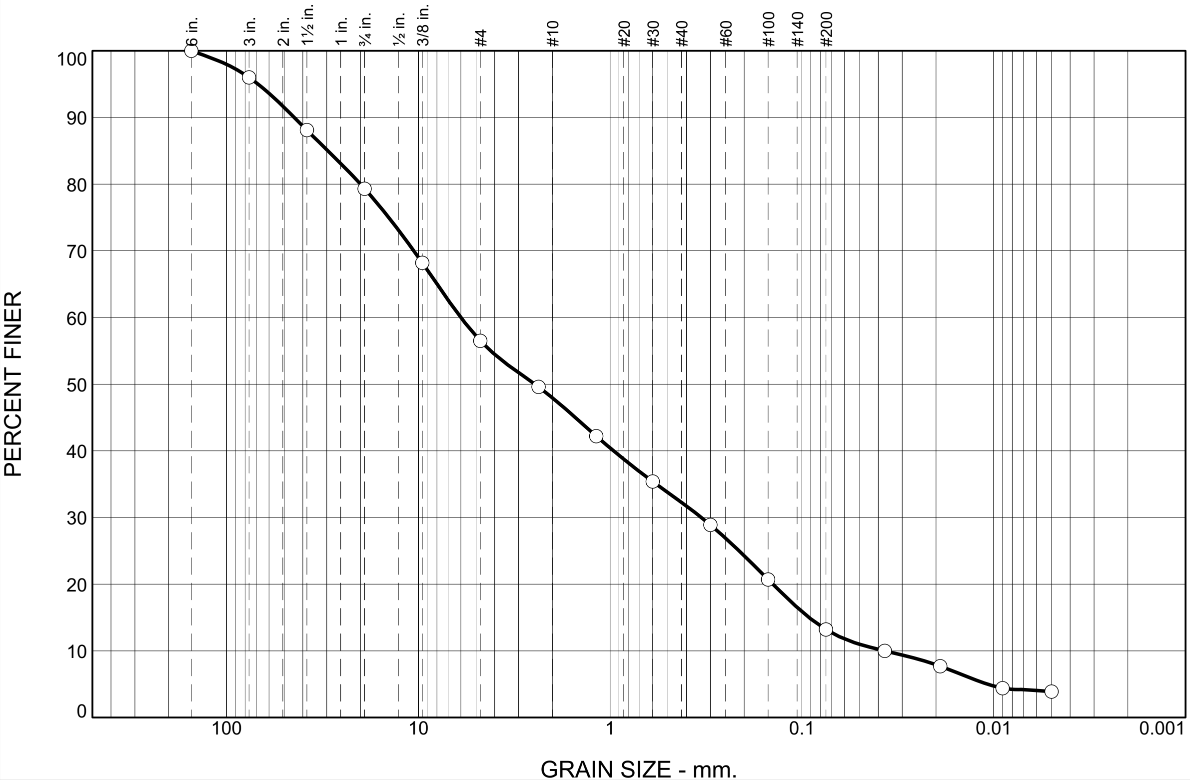
Sample Number: 65A-X693 (minus 3") **Depth:** 8.80-13.50 ft
Location: UE-25 RF #47 **Date:** 8/23/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 2

Tested By: Schaffer/Shehon **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
4.0	16.7	22.8	8.5	15.7	19.1	9.3	3.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	96.0		
1.5in	88.1		
.75in	79.3		
.375in	68.2		
#4	56.5		
#8	49.6		
#16	42.2		
#30	35.4		
#50	28.9		
#100	20.7		
#200	13.2		
.037mm	10.0		
.019mm	7.7		
.009mm	4.4		
.005mm	3.9		

* (no specification provided)

Material Description

Silty sand with gravel
Note sample contains Plus 3-inch material, classification may change when base on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 29.5999 D_{60}= 5.9982 D_{50}= 2.4643
D_{30}= 0.3342 D_{15}= 0.0918 D_{10}= 0.0370
C_u= 162.11 C_c= 0.50

Classification

USCS= SM AASHTO=

Remarks

-No. 4 Specific Gravity = 2.49
+No.4 Apparent Specific Gravity = 2.44
Absorption = 6.4 %

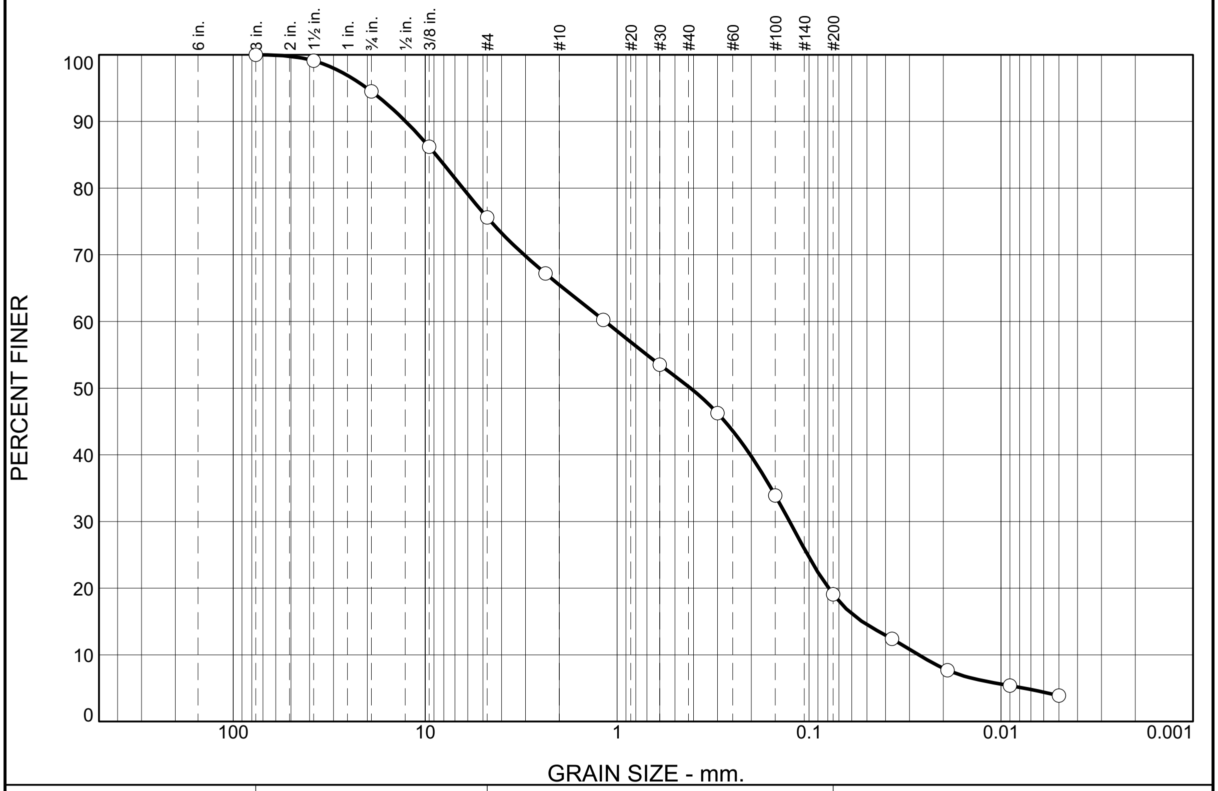
Sample Number: 65A-X693 **Depth:** 8.80-13.50 ft
Location: UE-25 RF #47 **Date:** 8/22/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 3

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	5.5	18.9	10.1	15.3	31.1	15.2	3.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	99.1		
.75in	94.5		
.375in	86.2		
#4	75.6		
#8	67.2		
#16	60.2		
#30	53.5		
#50	46.2		
#100	33.9		
#200	19.1		
.037mm	12.4		
.019mm	7.7		
.009mm	5.4		
.005mm	3.9		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 8.7816 D_{60}= 1.1532 D_{50}= 0.4154
D_{30}= 0.1264 D_{15}= 0.0529 D_{10}= 0.0268
C_u= 42.96 C_c= 0.52

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specifi Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.46
Absorption = 6.4 %

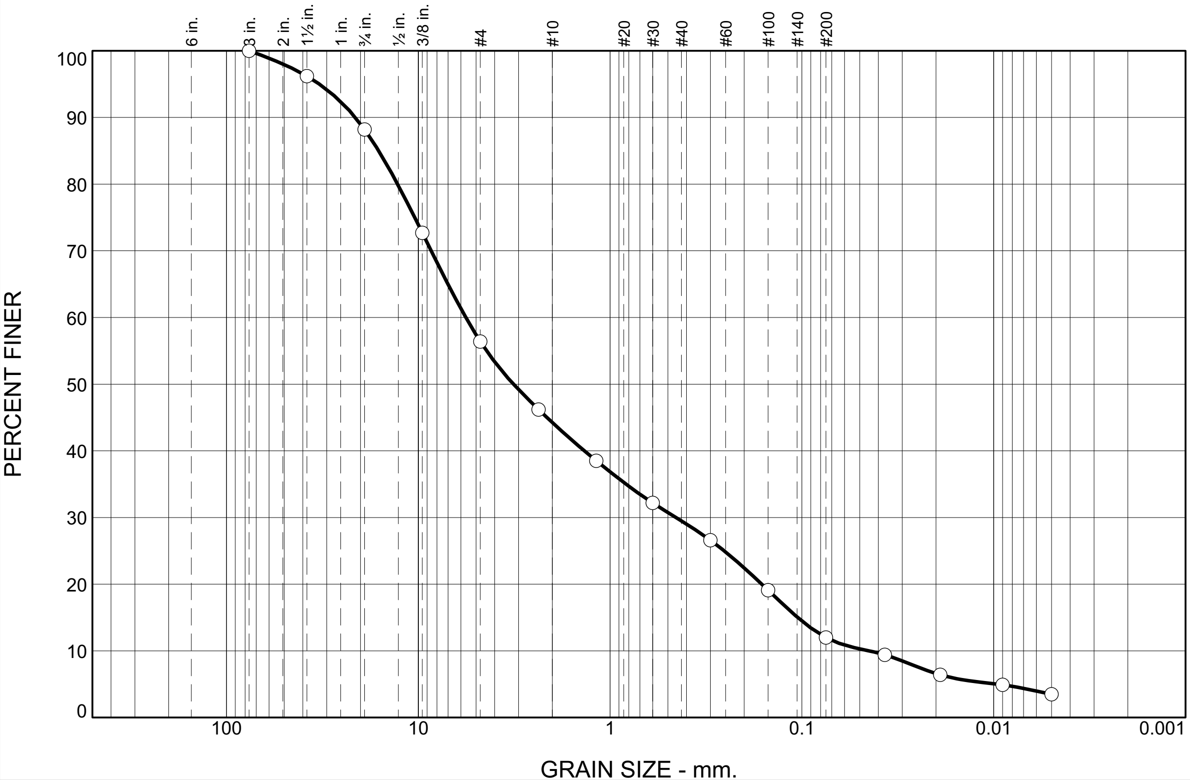
Sample Number: 65A-X694 **Depth:** 13.50-15.70 ft
Location: UE-25 RF #47 **Date:** 8/25/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 4

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	11.8	31.8	12.1	14.8	17.5	8.5	3.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	96.2		
.75in	88.2		
.375in	72.7		
#4	56.4		
#8	46.2		
#16	38.5		
#30	32.2		
#50	26.6		
#100	19.1		
#200	12.0		
.037mm	9.4		
.019mm	6.4		
.009mm	4.9		
.005mm	3.5		

* (no specification provided)

Material Description

Poorly graded sand with silt and gravel
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 16.0891 D_{60}= 5.6505 D_{50}= 3.1932
D_{30}= 0.4535 D_{15}= 0.1051 D_{10}= 0.0450
C_u= 125.57 C_c= 0.81

Classification

USCS= SP-SM AASHTO=

Remarks

-No.4 Specific Gravity = 2
+No.4 Apparent Specific Gravity = 2.47
Absorption = 5.1 %

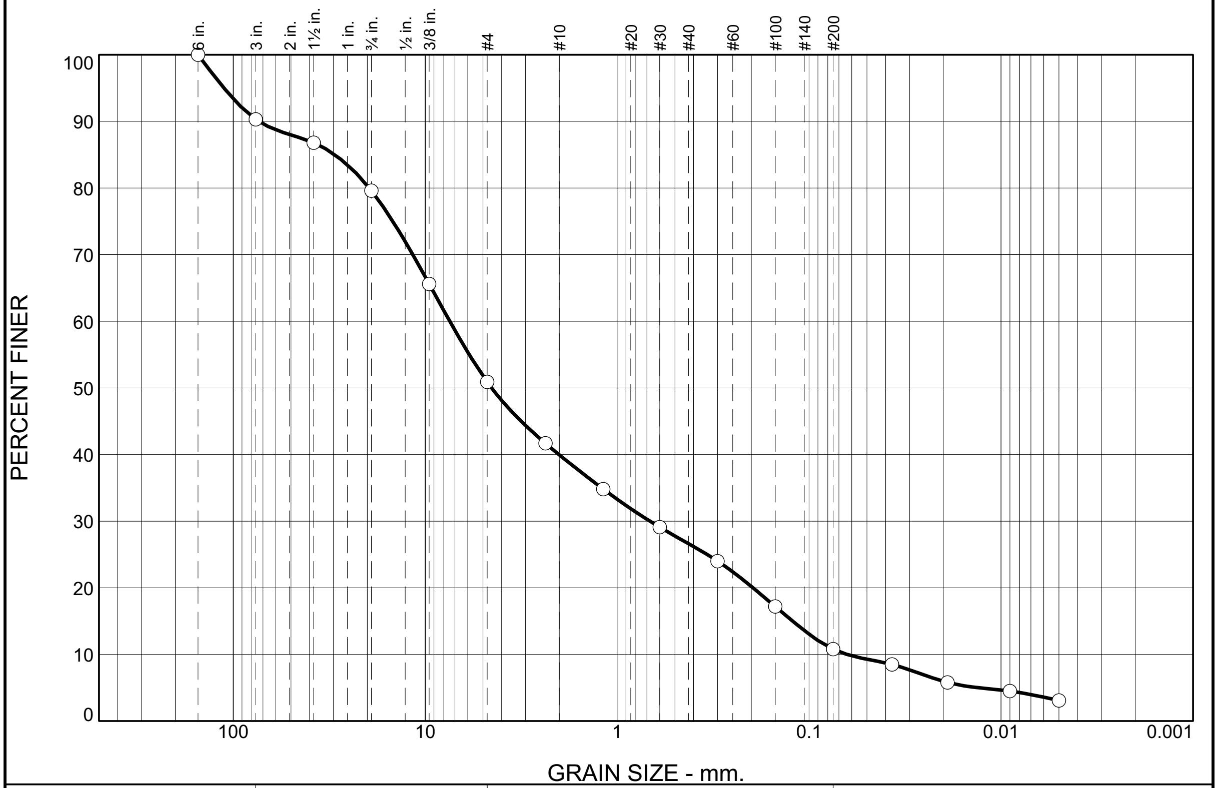
Sample Number: 65A-X695 **Depth:** 15.70-18.20 ft
Location: UE-25 RF #47 **Date:** 8/24/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 5

Tested By: Schaffer **Checked By:** Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
9.7	10.7	28.7	10.9	13.4	15.8	7.7	3.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	90.3		
1.5in	86.8		
.75in	79.6		
.375in	65.6		
#4	50.9		
#8	41.7		
#16	34.8		
#30	29.1		
#50	24.0		
#100	17.2		
#200	10.8		
.037mm	8.5		
.019mm	5.8		
.009mm	4.5		
.005mm	3.1		

* (no specification provided)

Material Description

Poorly graded sand with silt and gravel
Note sample contains Plus 3-inch material, classification may change when base on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 29.5663 D_{60}= 7.4365 D_{50}= 4.5042
D_{30}= 0.6750 D_{15}= 0.1220 D_{10}= 0.0635
C_u= 117.13 C_c= 0.97

Classification

USCS= SP-SM AASHTO=

Remarks

-No. 4 Specific Gravity = 2.52
+No. 4 Apparent Specific Gravity = 2.47
Absorption = 5.1 %

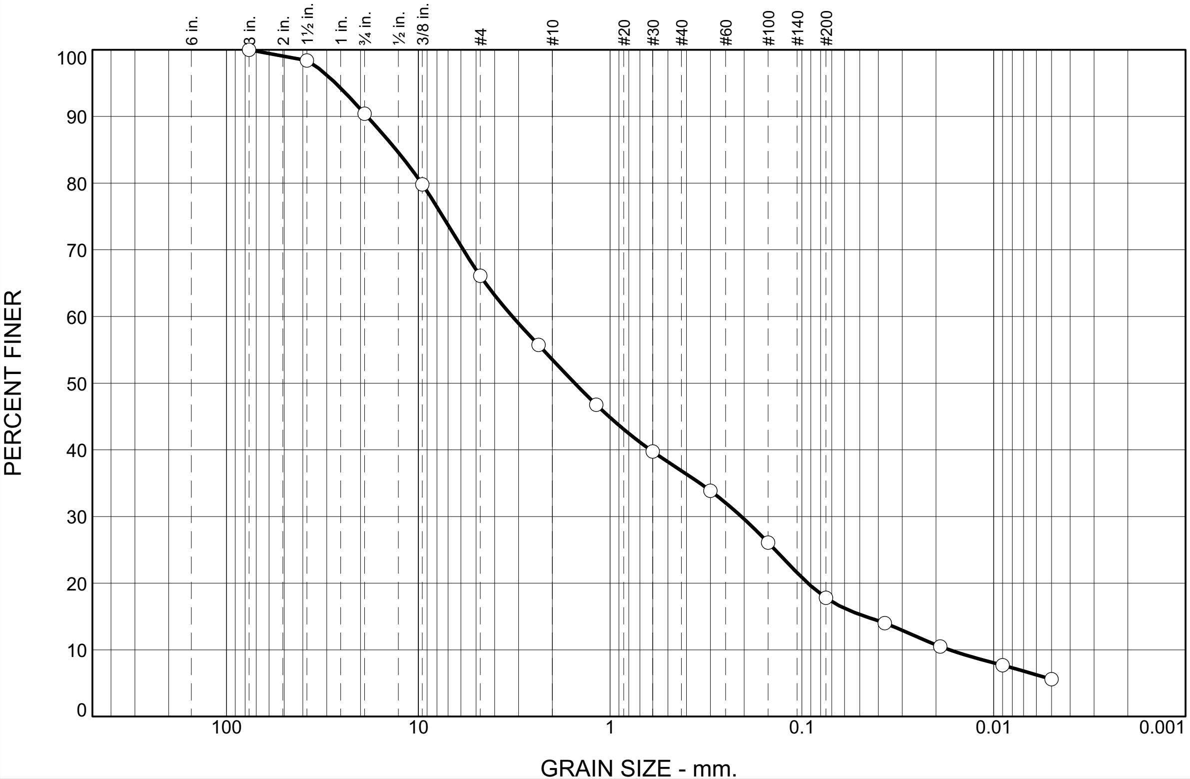
Sample Number: 65A-X695 **Depth:** 15.70-18.20 ft
Location: UE-25 RF #47 **Date:** 8/22/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 6

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	9.6	24.3	12.6	16.6	19.1	12.2	5.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	98.4		
.75in	90.4		
.375in	79.8		
#4	66.1		
#8	55.7		
#16	46.8		
#30	39.8		
#50	33.9		
#100	26.1		
#200	17.8		
.037mm	14.0		
.019mm	10.5		
.009mm	7.7		
.005mm	5.6		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 13.0412 D_{60}= 3.2309 D_{50}= 1.5308
D_{30}= 0.2071 D_{15}= 0.0466 D_{10}= 0.0170
C_u= 189.82 C_c= 0.78

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.50
+No.4 Apparent Specific Gravity = 2.44
Absorption = 5.7 %

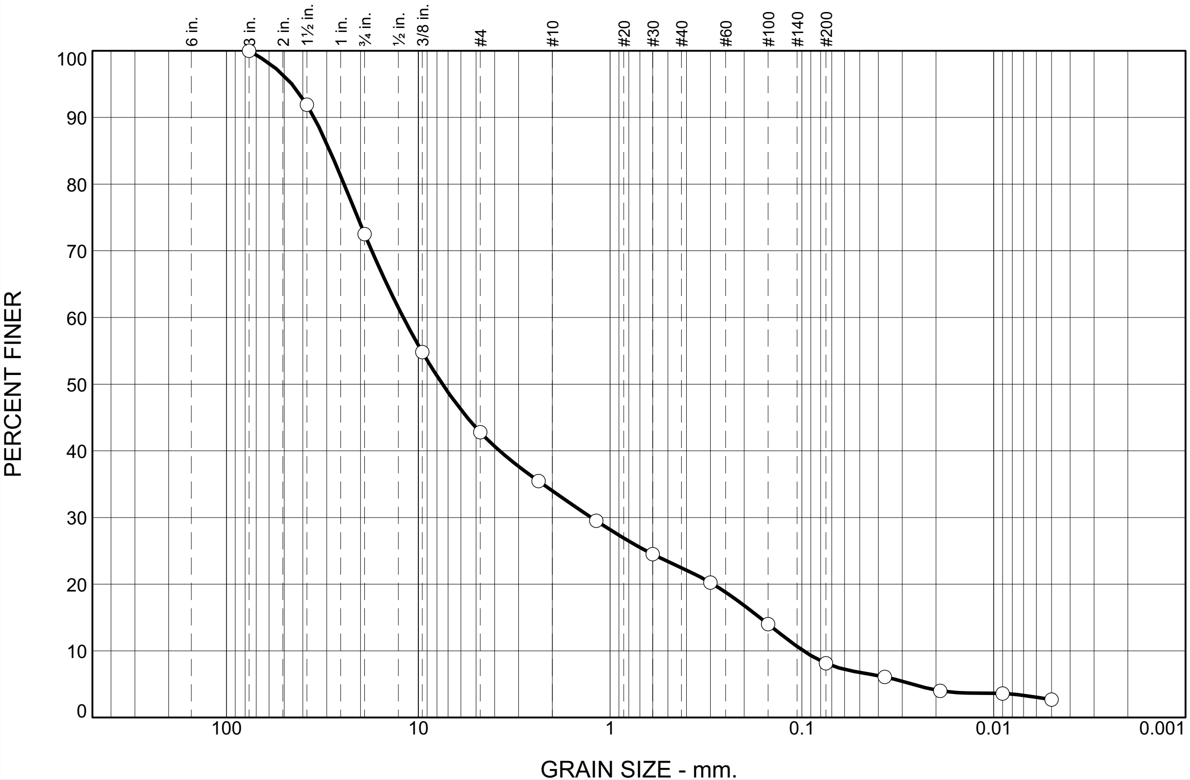
Sample Number: 65A-X696 **Depth:** 18.20-20.50 ft
Location: UE-25 RF #47 **Date:** 8/25/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 7

Tested By: Shehorn/Schaffer **Checked By:** Shehorn/Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	27.5	29.7	8.8	11.5	14.4	5.4	2.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	91.9		
.75in	72.5		
.375in	54.8		
#4	42.8		
#8	35.5		
#16	29.5		
#30	24.5		
#50	20.2		
#100	14.0		
#200	8.1		
.037mm	6.1		
.019mm	4.0		
.009mm	3.6		
.005mm	2.7		

* (no specification provided)

Material Description

Well-graded gravel with silt and sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 28.8772 D_{60}= 11.9710 D_{50}= 7.4855
D_{30}= 1.2539 D_{15}= 0.1660 D_{10}= 0.0981
C_u= 122.02 C_c= 1.34

Classification

USCS= GW-GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.53
+No.4 Apparent Specific Gravity = 2.36
Absorption = 5.8 %

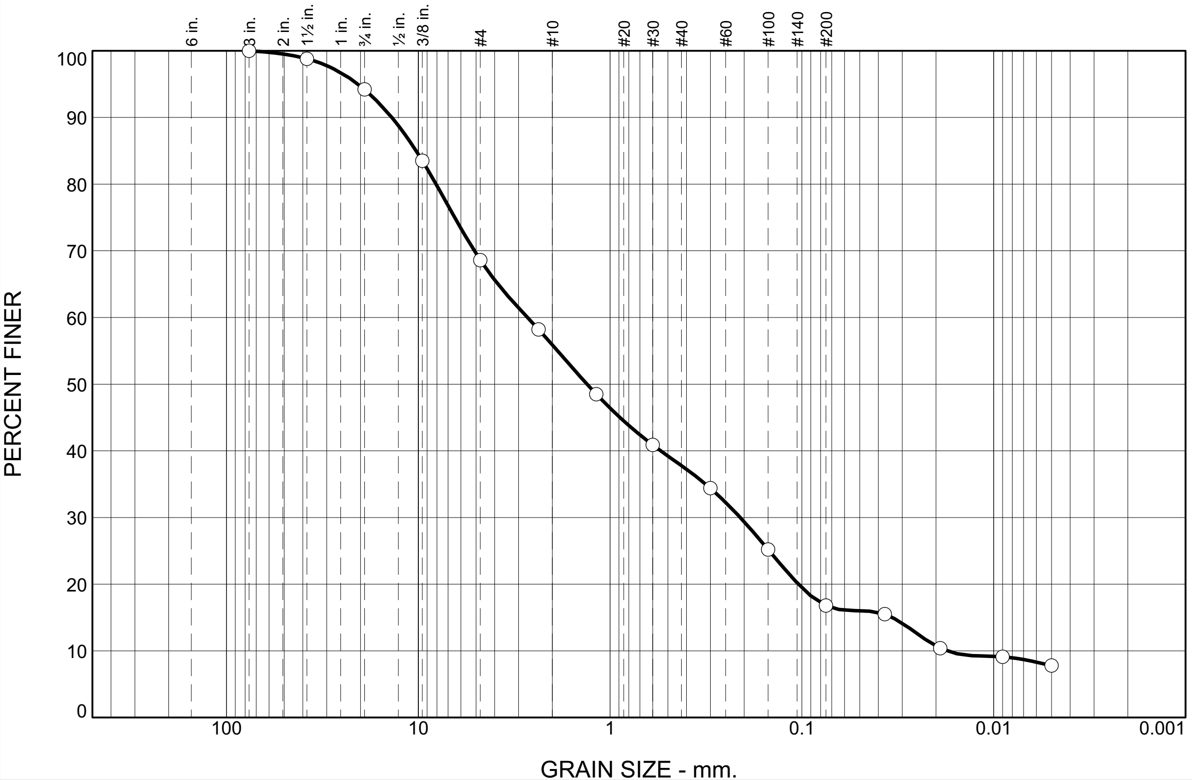
Sample Number: 65A-X697 **Depth:** 20.70-21.70 ft
Location: UE-25 RF #47 **Date:** 8/25/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 8

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	5.8	25.6	12.7	18.1	21.0	9.0	7.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	98.8		
.75in	94.2		
.375in	83.5		
#4	68.6		
#8	58.2		
#16	48.5		
#30	40.9		
#50	34.4		
#100	25.2		
#200	16.8		
.037mm	15.5		
.019mm	10.4		
.009mm	9.1		
.005mm	7.8		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 10.2763 D_{60}= 2.6966 D_{50}= 1.3195
D_{30}= 0.2099 D_{15}= 0.0337 D_{10}= 0.0176
C_u= 153.28 C_c= 0.93

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.51
+No.4 Apparent Specific Gravity = 2.49
Absorption = 6.1 %

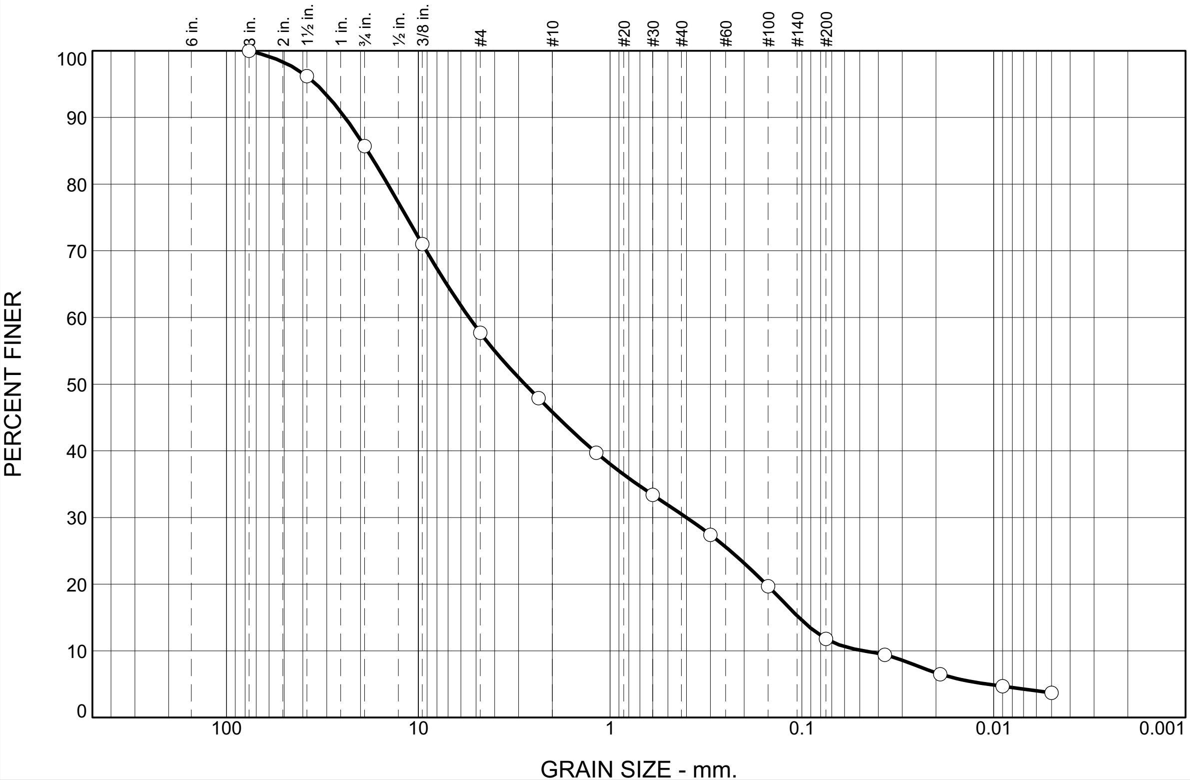
Sample Number: 65A-X698 **Depth:** 21.70-26.20 ft
Location: UE-25 RF #47 **Date:** 08/24/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 9

Tested By: Schaffer / Shehorn **Checked By:** Shehorn / Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	14.3	28.0	11.9	15.3	18.7	8.1	3.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	96.2		
.75in	85.7		
.375in	71.0		
#4	57.7		
#8	47.9		
#16	39.7		
#30	33.4		
#50	27.4		
#100	19.7		
#200	11.8		
.037mm	9.4		
.019mm	6.5		
.009mm	4.7		
.005mm	3.7		

* (no specification provided)

Material Description

Silty sand with gravel
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 18.3842 D_{60}= 5.4383 D_{50}= 2.7812
D_{30}= 0.4004 D_{15}= 0.1037 D_{10}= 0.0475
C_u= 114.39 C_c= 0.62

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.53
+No.4 Apparent Specific Gravity = 2.42
Absorption = 6.3 %

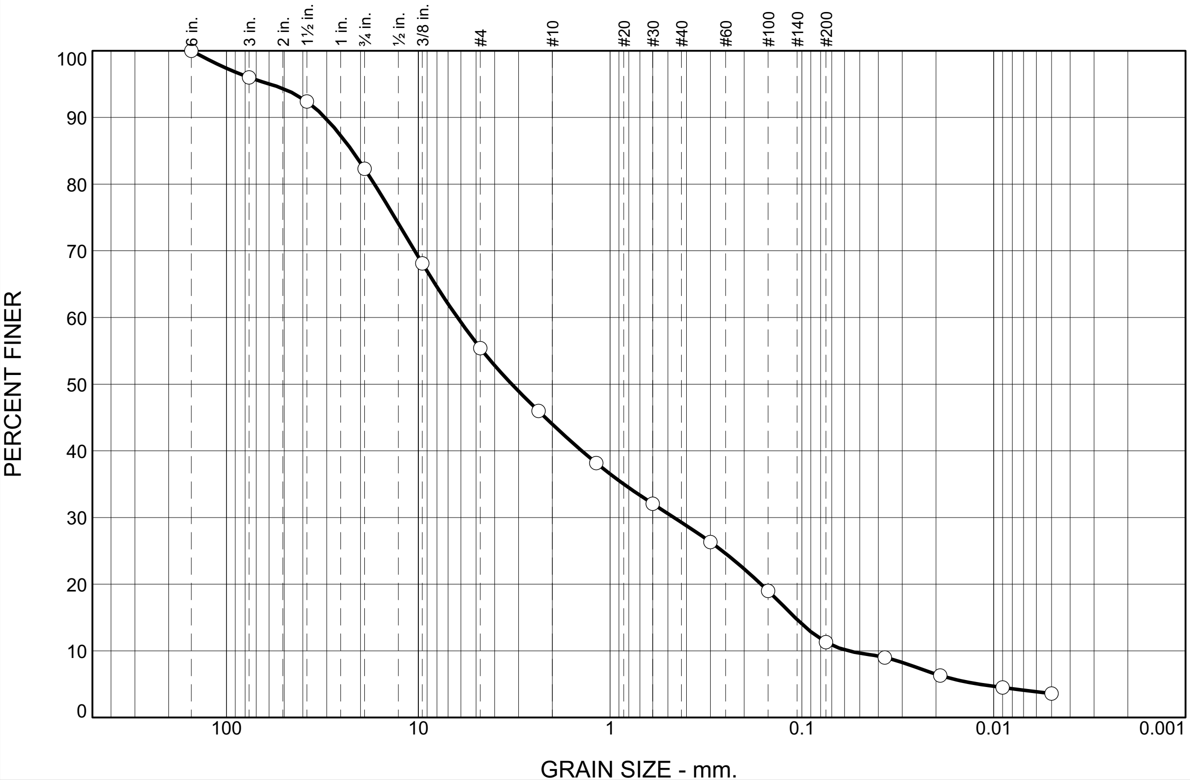
Sample Number: 65A-X699 (minus 3") **Depth:** 26.80-28.60 ft
Location: UE-25 RF #47 **Date:** 8/28/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 10

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
4.0	13.7	26.9	11.4	14.7	18.0	7.7	3.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	96.0		
1.5in	92.4		
.75in	82.3		
.375in	68.1		
#4	55.4		
#8	46.0		
#16	38.2		
#30	32.1		
#50	26.3		
#100	19.0		
#200	11.3		
.037mm	9.0		
.019mm	6.3		
.009mm	4.5		
.005mm	3.6		

* (no specification provided)

Material Description

Poorly graded sand with silt and gravel
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 22.0948 D_{60}= 6.2467 D_{50}= 3.2549
D_{30}= 0.4651 D_{15}= 0.1087 D_{10}= 0.0571
C_u= 109.44 C_c= 0.61

Classification

USCS= SP-SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.53
+No.4 Apparent Specific Gravity = 2.43
Absorption = 6.3 %

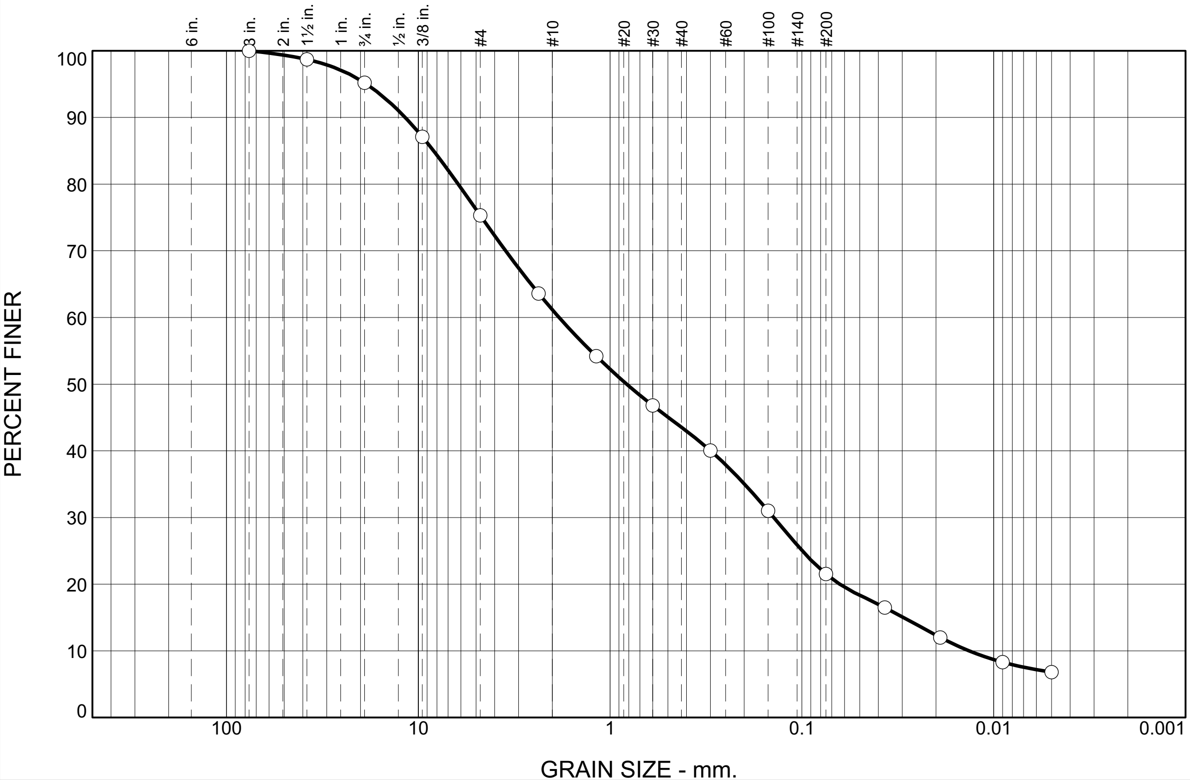
Sample Number: 65A-X699 **Depth:** 26.20-28.60 ft
Location: UE-25 RF #47
Date: 8/23/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 11

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	4.8	19.9	14.2	17.6	22.0	14.7	6.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	98.7		
.75in	95.2		
.375in	87.1		
#4	75.3		
#8	63.6		
#16	54.2		
#30	46.8		
#50	40.0		
#100	31.0		
#200	21.5		
.037mm	16.5		
.019mm	12.0		
.009mm	8.3		
.005mm	6.8		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 8.3250 D_{60}= 1.8442 D_{50}= 0.8187
D_{30}= 0.1402 D_{15}= 0.0295 D_{10}= 0.0134
C_u= 137.43 C_c= 0.79

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.51
+No.4 Apparent Specific Gravity = 2.45
Absorption = 6.3 %

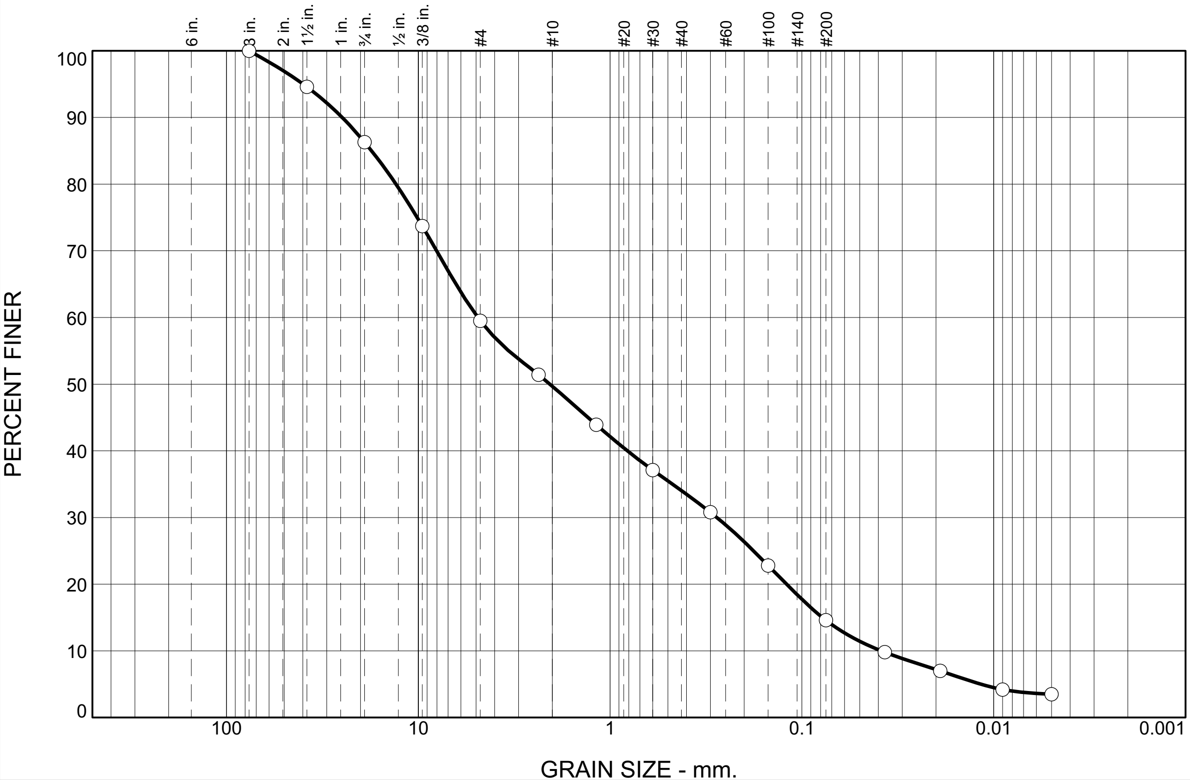
Sample Number: 65A-X700 **Depth:** 28.60-31.60 ft
Location: UE-25 RF #47 **Date:** 8/25/2006

**BUREAU
OF
RECLAMATION**

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 12

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	13.7	26.8	9.8	15.7	19.4	11.1	3.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	94.6		
.75in	86.3		
.375in	73.7		
#4	59.5		
#8	51.4		
#16	43.9		
#30	37.1		
#50	30.8		
#100	22.8		
#200	14.6		
.037mm	9.8		
.019mm	7.0		
.009mm	4.2		
.005mm	3.5		

* (no specification provided)

Material Description

Silty sand with gravel
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 17.5090 D_{60}= 4.8958 D_{50}= 2.0603
D_{30}= 0.2775 D_{15}= 0.0781 D_{10}= 0.0386
C_u= 126.98 C_c= 0.41

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.51
+No.4 Apparent Specific Gravity = 2.46
Absorption = 6.1 %

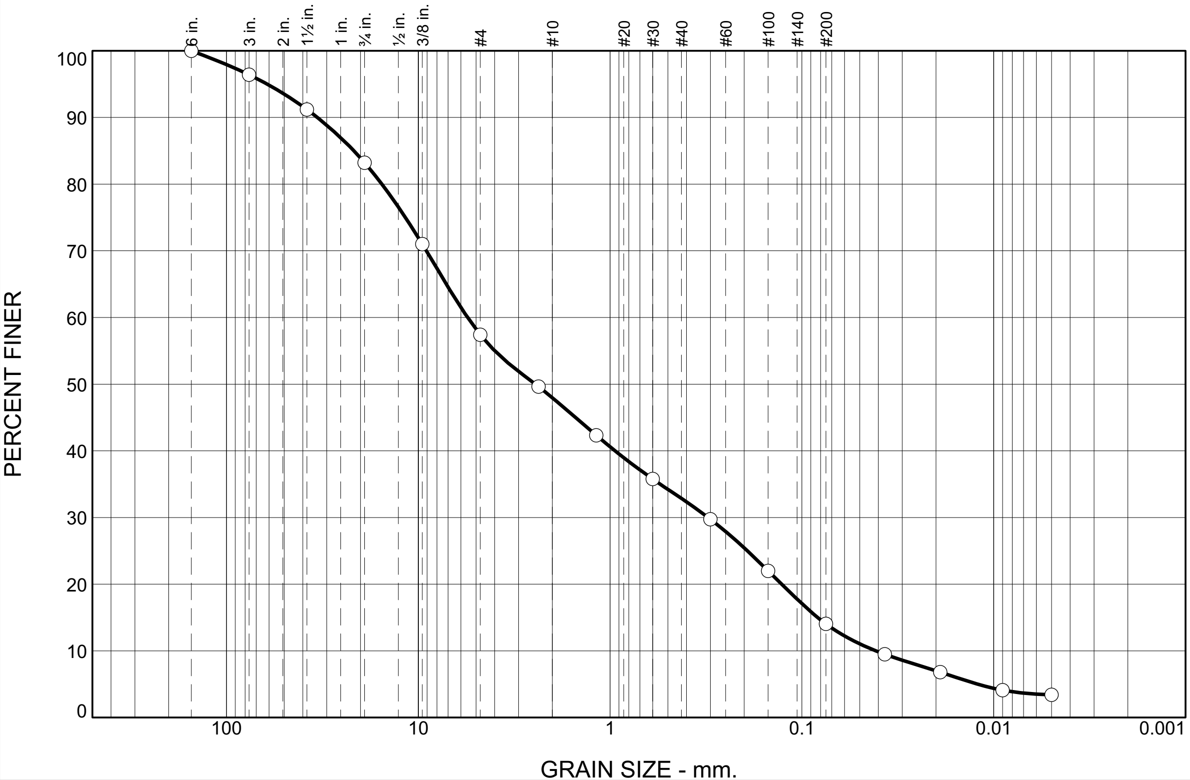
Sample Number: 65A-X701 (minus 3") **Depth:** 31.60-34.80 ft
Location: UE-25 RF #47 **Date:** 8/24/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 13

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
3.6	13.2	25.8	9.4	15.1	18.8	10.7	3.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	96.4		
1.5in	91.2		
.75in	83.2		
.375in	71.0		
#4	57.4		
#8	49.6		
#16	42.3		
#30	35.8		
#50	29.8		
#100	22.0		
#200	14.1		
.037mm	9.5		
.019mm	6.8		
.009mm	4.1		
.005mm	3.4		

* (no specification provided)

Material Description

Silty sand with gravel
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 21.6955 D_{60}= 5.5384 D_{50}= 2.4522
D_{30}= 0.3079 D_{15}= 0.0826 D_{10}= 0.0411
C_u= 134.64 C_c= 0.42

Classification

USCS= SM AASHTO=

Remarks

-No.4 specific Gravity = 2.51
+no. 4 Apparent Specific Gravity =2.46
Absorption = 6.1 %

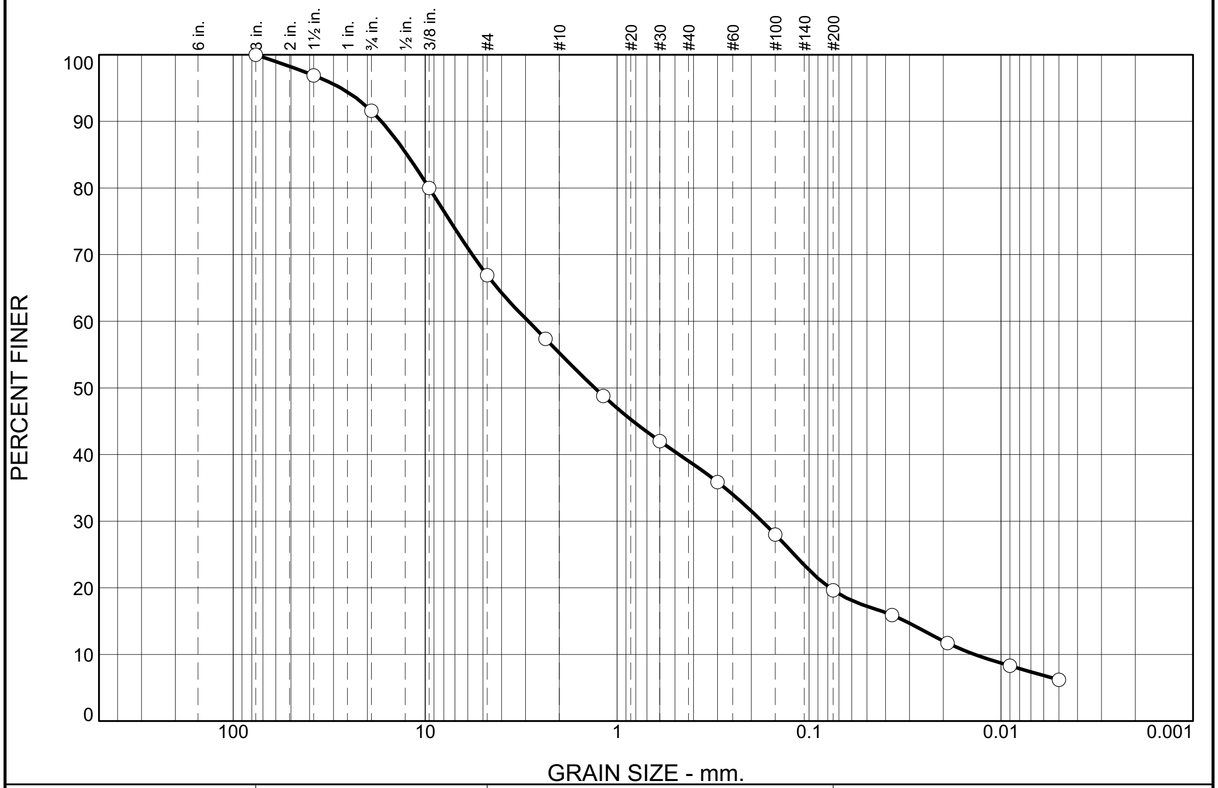
Sample Number: 65A-X701 **Depth:** 31.60-34.80 ft
Location: UE-25 RF #47 **Date:** 8/28/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 14

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	8.4	24.7	11.6	16.3	19.4	13.4	6.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	96.9		
.75in	91.6		
.375in	80.0		
#4	66.9		
#8	57.4		
#16	48.8		
#30	42.0		
#50	35.9		
#100	28.0		
#200	19.6		
.037mm	15.9		
.019mm	11.7		
.009mm	8.3		
.005mm	6.2		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 12.4105 D_{60}= 2.9124 D_{50}= 1.3092
D_{30}= 0.1758 D_{15}= 0.0316 D_{10}= 0.0137
C_u= 212.34 C_c= 0.77

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.41
Absorption = 6.3 %

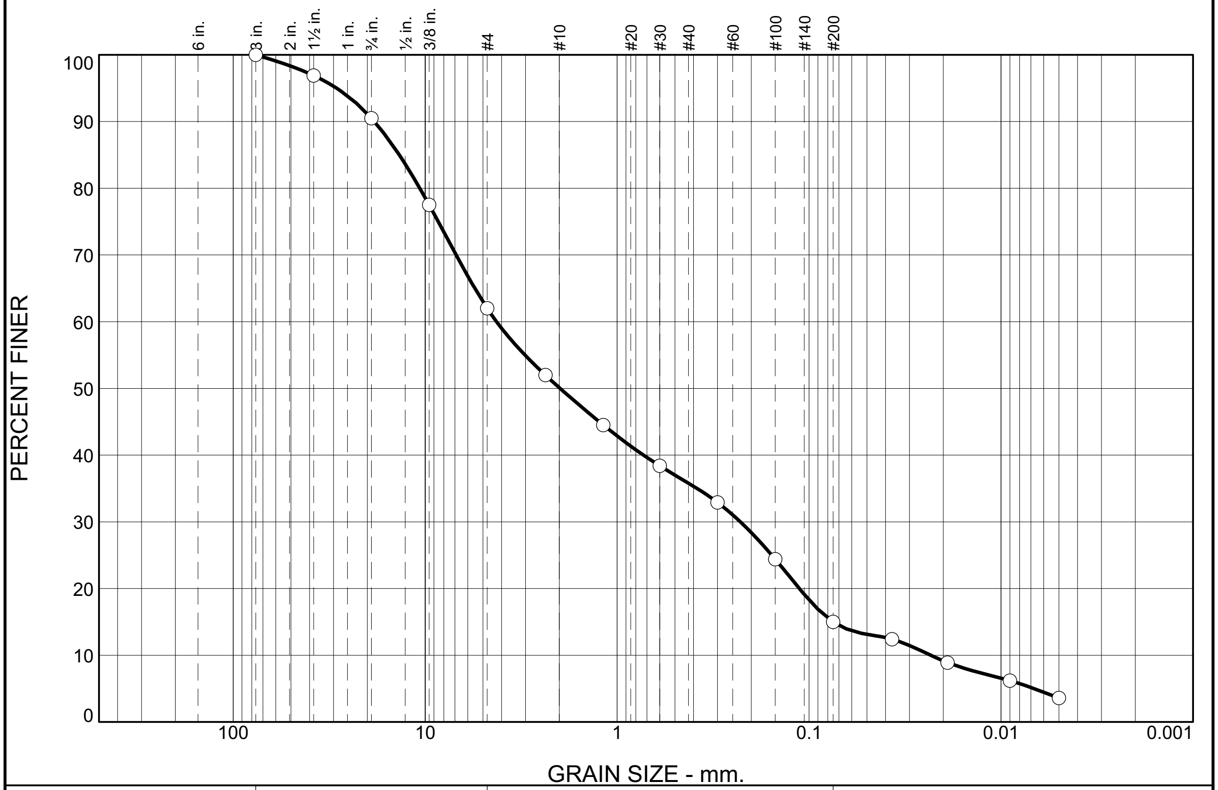
Sample Number: 65A-X702 **Depth:** 34.80-36.50 ft
Location: UE-25 RF #47
Date: 8/25/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 15

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	9.5	28.5	11.9	14.3	20.8	11.4	3.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	96.9		
.75in	90.5		
.375in	77.5		
#4	62.0		
#8	52.0		
#16	44.5		
#30	38.4		
#50	32.9		
#100	24.4		
#200	15.0		
.037mm	12.4		
.019mm	8.9		
.009mm	6.2		
.005mm	3.6		

* (no specification provided)

Material Description

Silty sand with gravel
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 13.6468 D_{60}= 4.2479 D_{50}= 1.9807
D_{30}= 0.2282 D_{15}= 0.0750 D_{10}= 0.0232
C_u= 182.97 C_c= 0.53

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.50
+No.4 Apprent Specific Gravity =2.46
Absorption =5.0 %

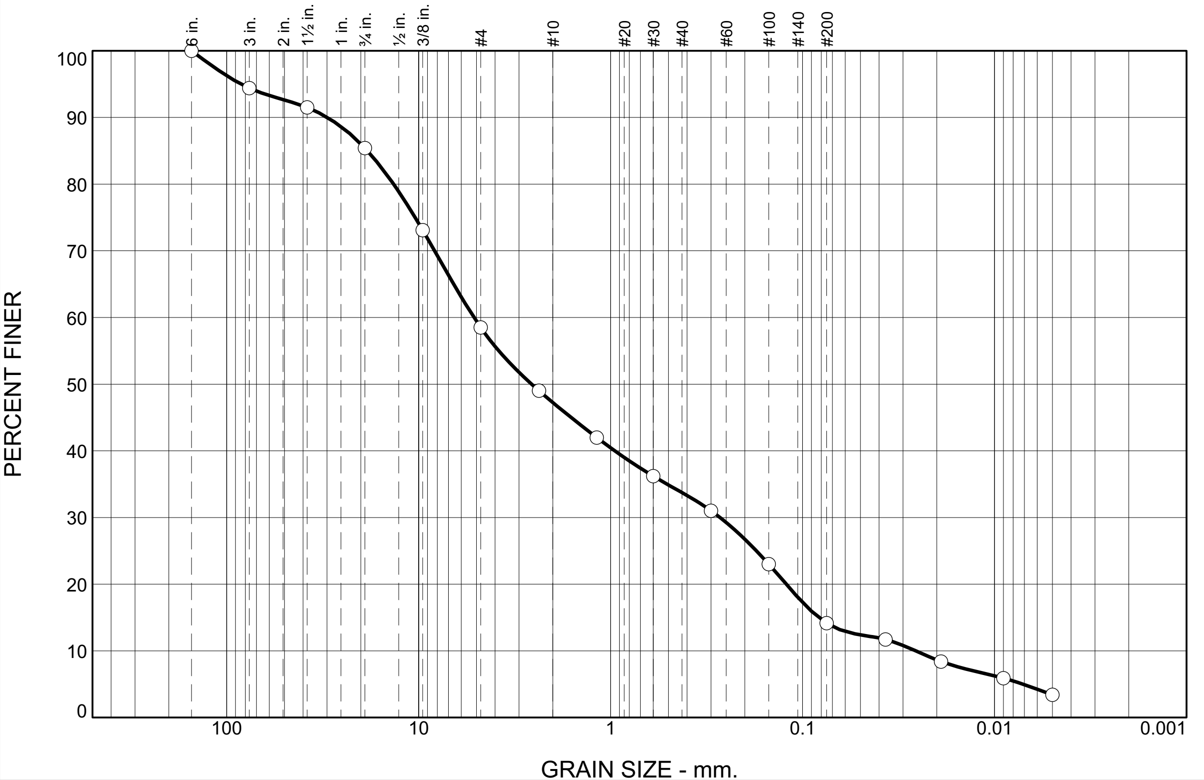
Sample Number: 65A-X703 (minus 3") **Depth:** 36.50-40.90 ft
Location: UE-25 RF #47 **Date:** 8/23/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 16

Tested By: Schaffer **Checked By:** Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
5.6	9.0	26.9	11.2	13.6	19.5	10.8	3.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	94.4		
1.5in	91.5		
.75in	85.4		
.375in	73.1		
#4	58.5		
#8	49.0		
#16	42.0		
#30	36.2		
#50	31.0		
#100	23.0		
#200	14.2		
.037mm	11.7		
.019mm	8.4		
.009mm	5.9		
.005mm	3.4		

* (no specification provided)

Material Description

Silty sand with gravel
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 18.4968 D_{60}= 5.1509 D_{50}= 2.5758
D_{30}= 0.2693 D_{15}= 0.0824 D_{10}= 0.0257
C_u= 200.15 C_c= 0.55

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.50
+No.4 Apparent Specific Gravity = 2.46
Absorption = 5.0 %

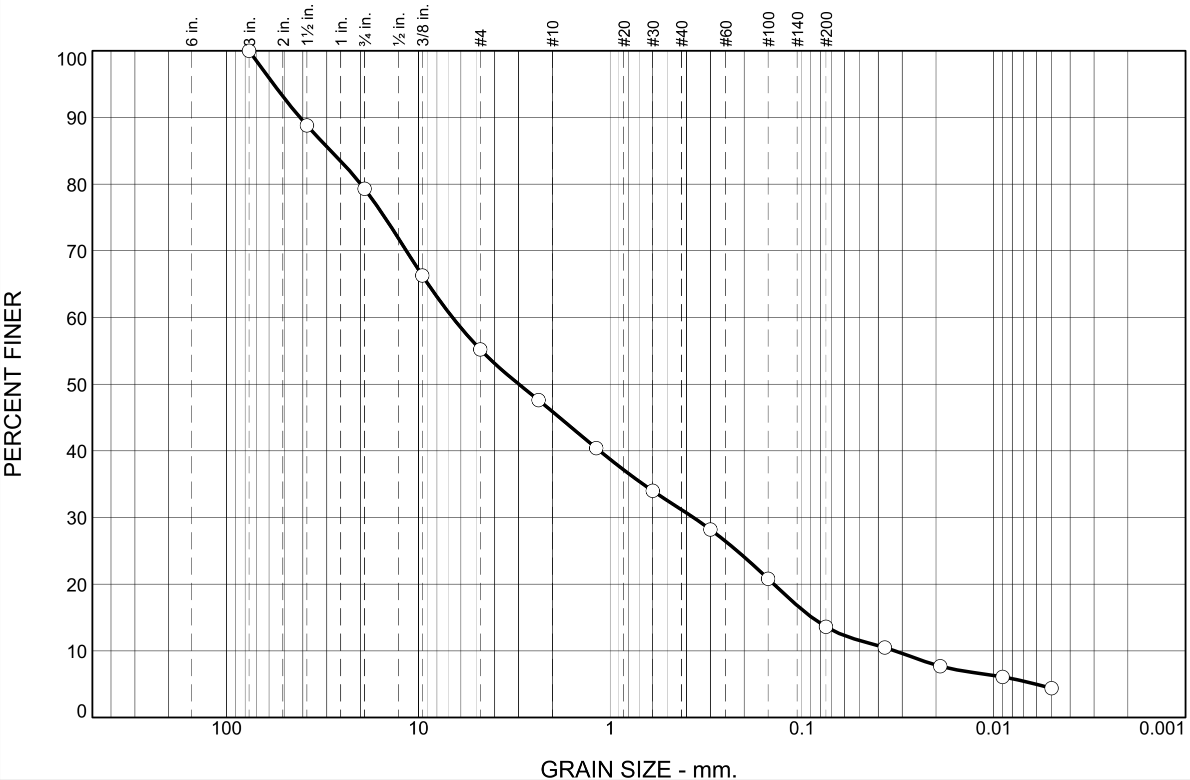
Sample Number: 65A-X703 **Depth:** 36.50-40.90 ft
Location: UE-25 RF #47 **Date:** 8/23/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 17

Tested By: Schaffer **Checked By:** Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	20.7	24.1	9.3	14.7	17.6	9.2	4.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	88.8		
.75in	79.3		
.375in	66.3		
#4	55.2		
#8	47.6		
#16	40.4		
#30	34.0		
#50	28.2		
#100	20.8		
#200	13.6		
.037mm	10.5		
.019mm	7.7		
.009mm	6.1		
.005mm	4.4		

* (no specification provided)

Material Description

Silty gravel with sand
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 28.5935 D_{60}= 6.6271 D_{50}= 2.9924
D_{30}= 0.3684 D_{15}= 0.0887 D_{10}= 0.0327
C_u= 202.42 C_c= 0.63

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.47
Absorption = 5.4 %

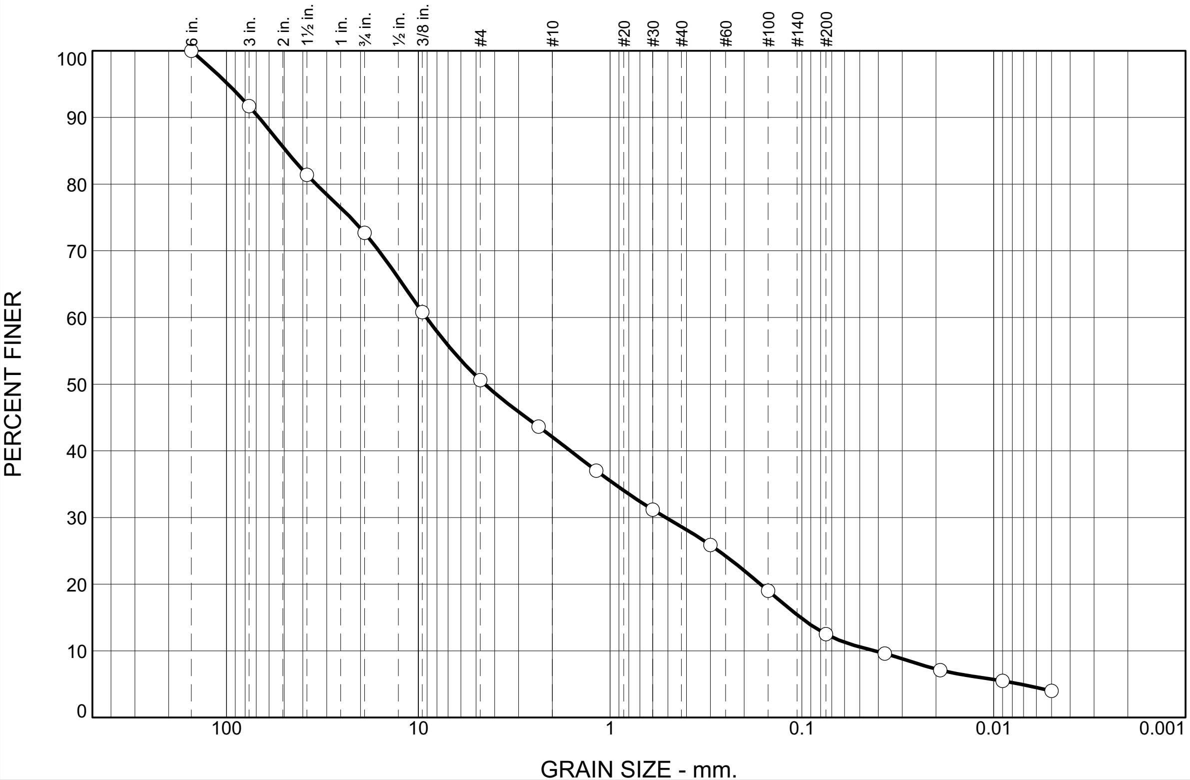
Sample Number: 65A-X704 (minus 3") **Depth:** 40.90-43.80 ft
Location: UE-25 RF #47 **Date:** 8/24/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 18

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
8.3	19.0	22.1	8.5	13.5	16.1	8.5	4.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	91.7		
1.5in	81.4		
.75in	72.7		
.375in	60.8		
#4	50.6		
#8	43.6		
#16	37.0		
#30	31.2		
#50	25.9		
#100	19.0		
#200	12.5		
.037mm	9.6		
.019mm	7.1		
.009mm	5.5		
.005mm	4.0		

* (no specification provided)

Material Description

Silty gravel with sand
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 48.8829 D_{60}= 9.0897 D_{50}= 4.5104
D_{30}= 0.5132 D_{15}= 0.1016 D_{10}= 0.0417
C_u= 217.96 C_c= 0.69

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.47
Absorption = 5.4 %

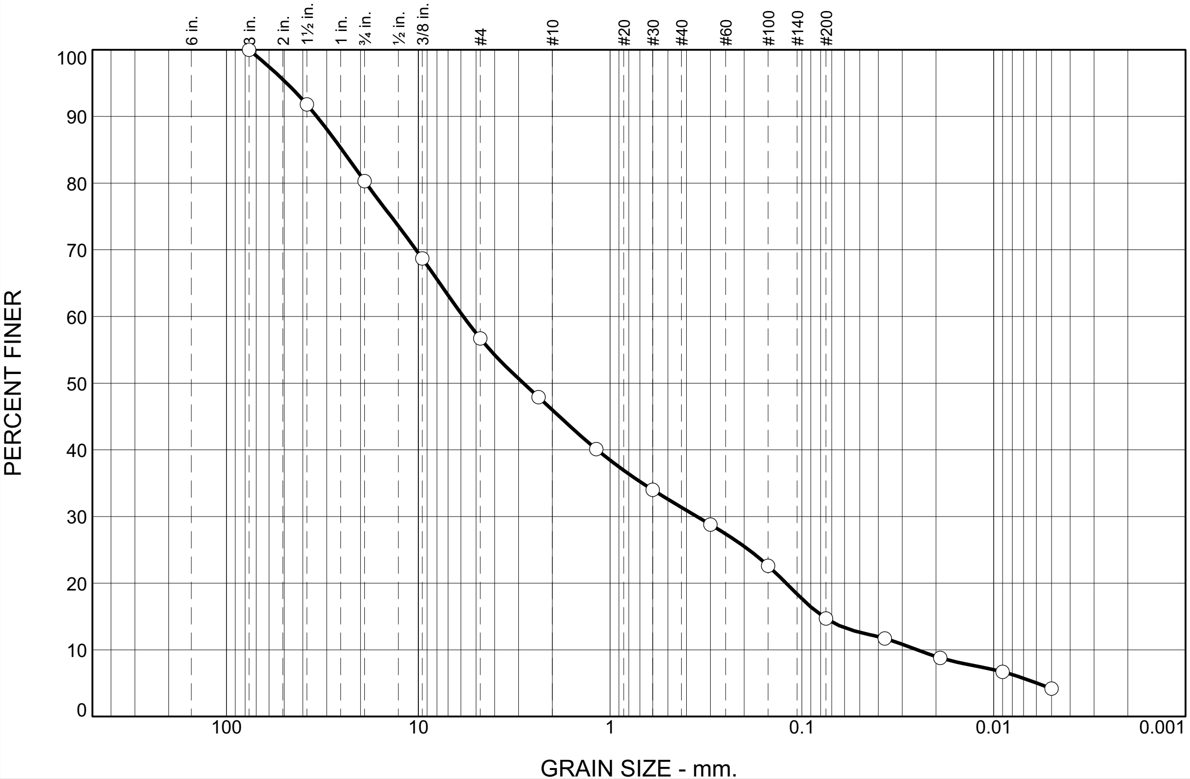
Sample Number: 65A-X704 **Depth:** 40.90-43.80 ft
Location: UE-25 RF #47 **Date:** 8/28/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 19

Tested By: Schaffer/Shehorn **Checked By:** Shehorn/Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	19.7	23.6	10.7	14.6	16.7	10.5	4.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	91.8		
.75in	80.3		
.375in	68.7		
#4	56.7		
#8	47.9		
#16	40.1		
#30	34.0		
#50	28.8		
#100	22.6		
#200	14.7		
.037mm	11.7		
.019mm	8.8		
.009mm	6.7		
.005mm	4.2		

* (no specification provided)

Material Description

Silty gravel with sand

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 25.0092 D_{60}= 5.8266 D_{50}= 2.8327

D_{30}= 0.3526 D_{15}= 0.0777 D_{10}= 0.0251

C_u= 232.51 C_c= 0.85

Classification

USCS= GM AASHTO=

Remarks

-No. 4 Specific Gravity is 2.49

+No. 4 Apparent Specifi Gravity = 2.44

Absorption = 5.1 %

Sample Number: 65A-X705 **Depth:** 43.80-51.00 ft

Location: UE-25 RF #47 **Date:** 8/23/2006

BUREAU OF RECLAMATION

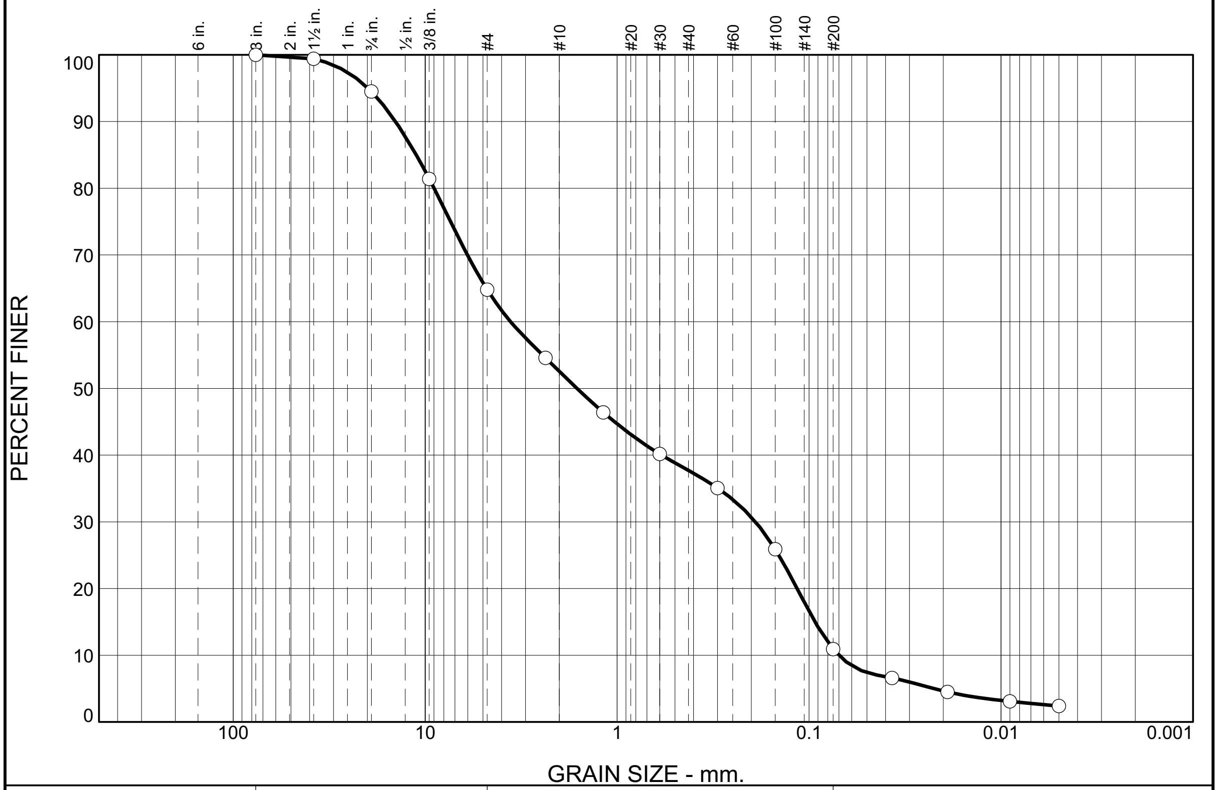
Client: Yucca Mountain Project

Project: Sonic Drill Core

Project No: 65A **Figure** 20

Tested By: Schaffer **Checked By:** Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	5.5	29.7	12.2	14.9	26.8	8.5	2.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	99.4		
.75in	94.5		
.375in	81.4		
#4	64.8		
#8	54.6		
#16	46.4		
#30	40.2		
#50	35.1		
#100	25.9		
#200	10.9		
.037mm	6.6		
.019mm	4.5		
.009mm	3.1		
.005mm	2.4		

* (no specification provided)

Material Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 11.1420 D_{60}= 3.5862 D_{50}= 1.6173
D_{30}= 0.1902 D_{15}= 0.0931 D_{10}= 0.0702
C_u= 51.09 C_c= 0.14

Classification

USCS= SP-SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.51
+No. 4 Apparent Specific Gravity = 2.46
Absorption = 5.6 %

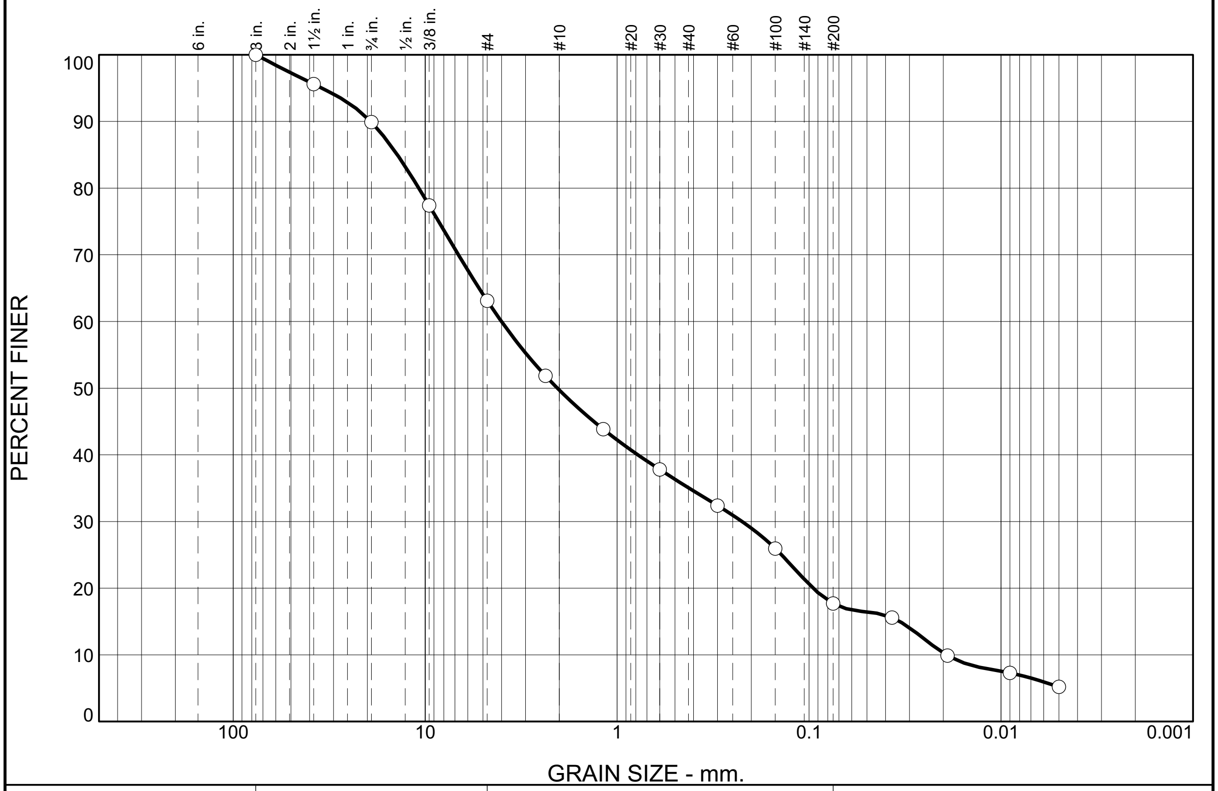
Sample Number: 65A-X706 **Depth:** 51.90-52.70 ft
Location: UE-25 RF #47 **Date:** 8/25/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 21

Tested By: Schaffer/Sheorn **Checked By:** Schaffer/Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	10.1	26.8	13.4	14.6	17.4	12.5	5.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	95.6		
.75in	89.9		
.375in	77.4		
#4	63.1		
#8	51.9		
#16	43.8		
#30	37.8		
#50	32.4		
#100	25.9		
#200	17.7		
.037mm	15.6		
.019mm	9.9		
.009mm	7.3		
.005mm	5.2		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 13.9562 D_{60}= 4.0031 D_{50}= 2.0470
D_{30}= 0.2234 D_{15}= 0.0336 D_{10}= 0.0193
C_u= 207.85 C_c= 0.65

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.51
+No. 4 Apparent Specific Gravity = 2.48
Absorption = 5.3 %

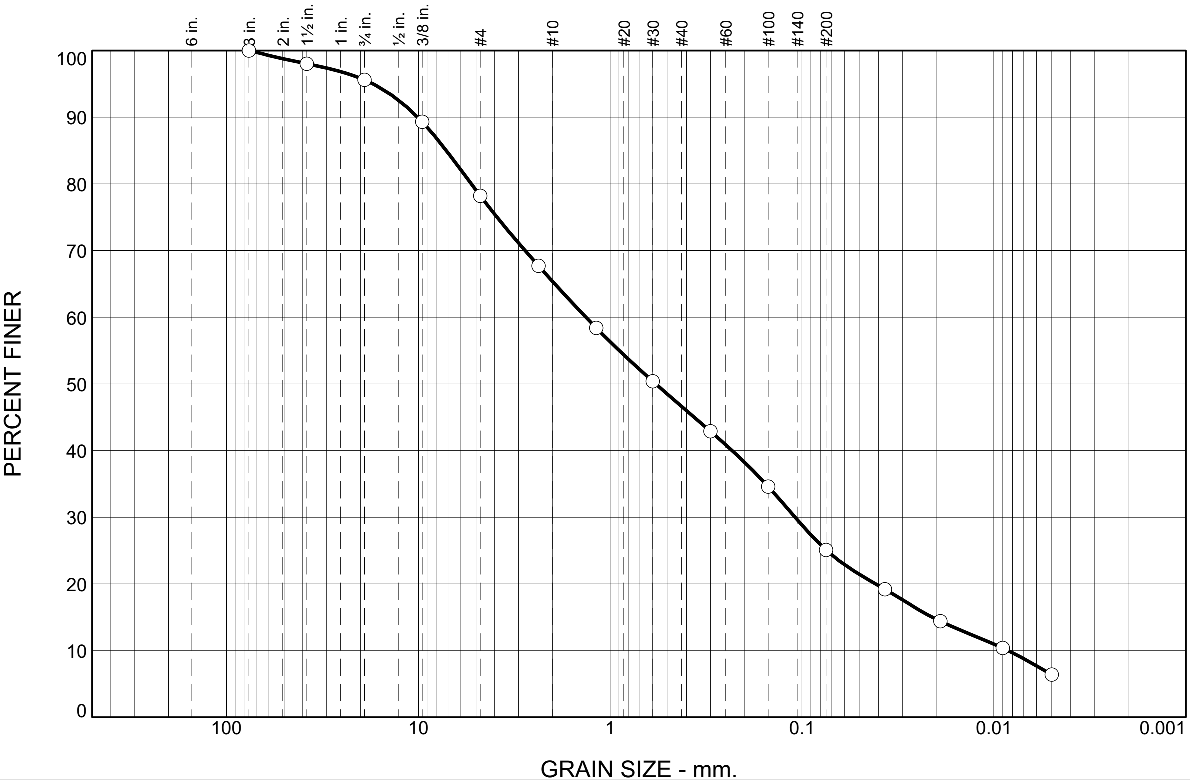
Sample Number: 65A-X707 **Depth:** 54.10-56.80 ft
Location: UE-25 RF #47 **Date:** 8/21/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 22

Tested By: Schaffer **Checked By:** Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	4.4	17.4	12.8	18.8	21.5	18.7	6.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	98.0		
.75in	95.6		
.375in	89.3		
#4	78.2		
#8	67.7		
#16	58.4		
#30	50.4		
#50	42.9		
#100	34.6		
#200	25.1		
.037mm	19.2		
.019mm	14.4		
.009mm	10.4		
.005mm	6.4		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 7.1438 D_{60}= 1.3372 D_{50}= 0.5787
D_{30}= 0.1087 D_{15}= 0.0209 D_{10}= 0.0084
C_u= 158.81 C_c= 1.05

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.48
+No.4 Apparent Specific Gravity =2.49
Absorption = 5.3 %

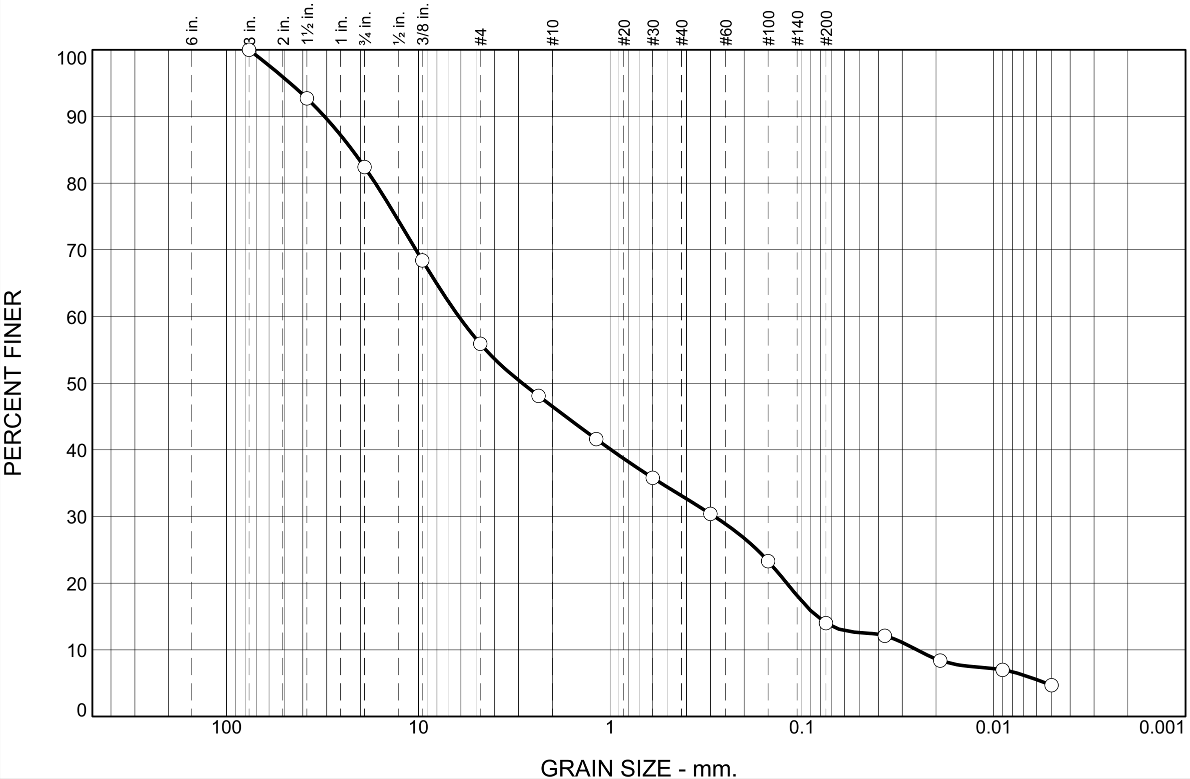
Sample Number: 65A-X708 **Depth:** 56.80-58.20 ft
Location: UE-25 RF #47 **Date:** 08/25/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 23

Tested By: Schaffer **Checked By:** Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	17.6	26.5	9.4	13.4	19.1	9.3	4.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	92.7		
.75in	82.4		
.375in	68.4		
#4	55.9		
#8	48.1		
#16	41.6		
#30	35.8		
#50	30.4		
#100	23.3		
#200	14.0		
.037mm	12.1		
.019mm	8.4		
.009mm	7.0		
.005mm	4.7		

* (no specification provided)

Material Description

Silty gravel with sand
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 22.1286 D_{60}= 6.1441 D_{50}= 2.8720
D_{30}= 0.2856 D_{15}= 0.0834 D_{10}= 0.0251
C_u= 244.45 C_c= 0.53

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.49
Absorption = 5.8 %

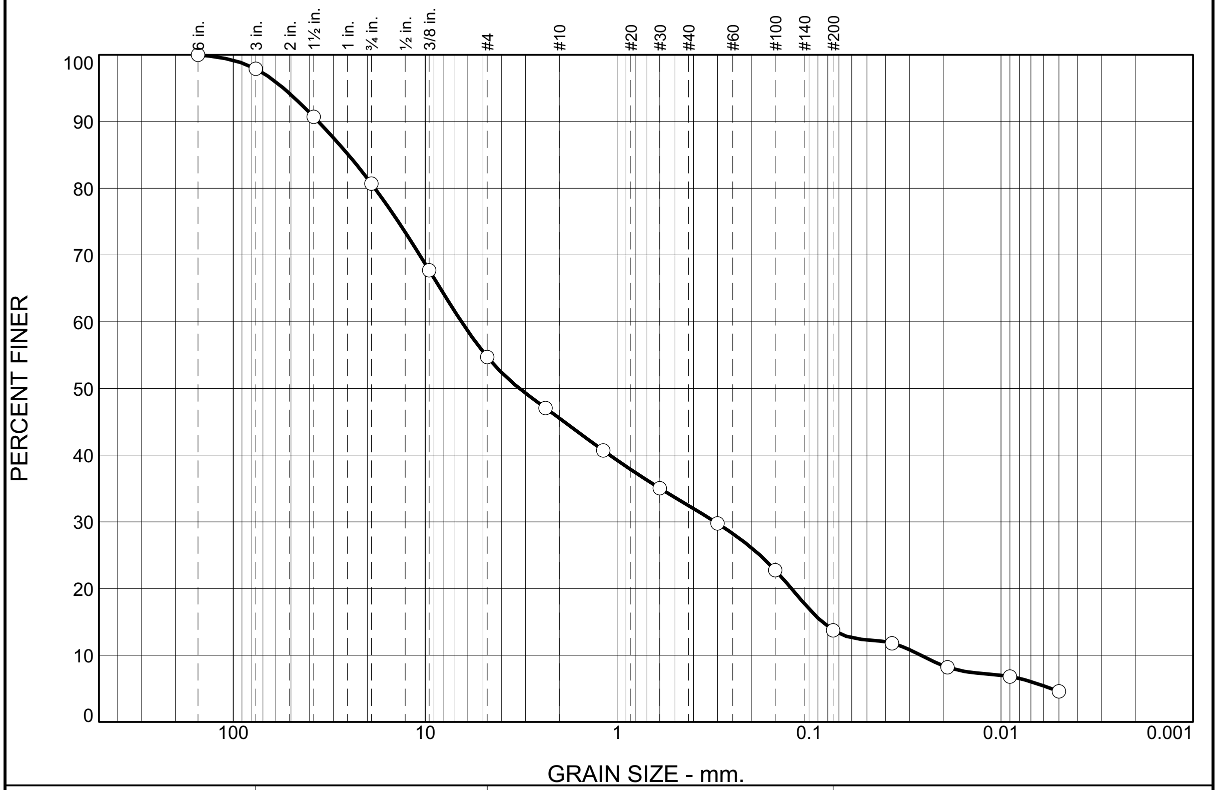
Sample Number: 65A-X709 (minus 3") **Depth:** 59.00-68.60 ft
Location: UE-25 RF #47 **Date:** 8/23/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 24

Tested By: Schaffer **Checked By:** Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
2.1	17.2	26.0	9.2	13.1	18.7	9.1	4.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	97.9		
1.5in	90.7		
.75in	80.7		
.375in	67.7		
#4	54.7		
#8	47.1		
#16	40.7		
#30	35.0		
#50	29.8		
#100	22.8		
#200	13.7		
.037mm	11.8		
.019mm	8.2		
.009mm	6.8		
.005mm	4.6		

* (no specification provided)

Material Description

Silty gravel with sand
Sample contains Plus 3-inch material, classification may change when base on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 25.0902 D_{60}= 6.4717 D_{50}= 3.2269
D_{30}= 0.3092 D_{15}= 0.0856 D_{10}= 0.0261
C_u= 247.51 C_c= 0.56

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.49
Absorption = 5.8 %

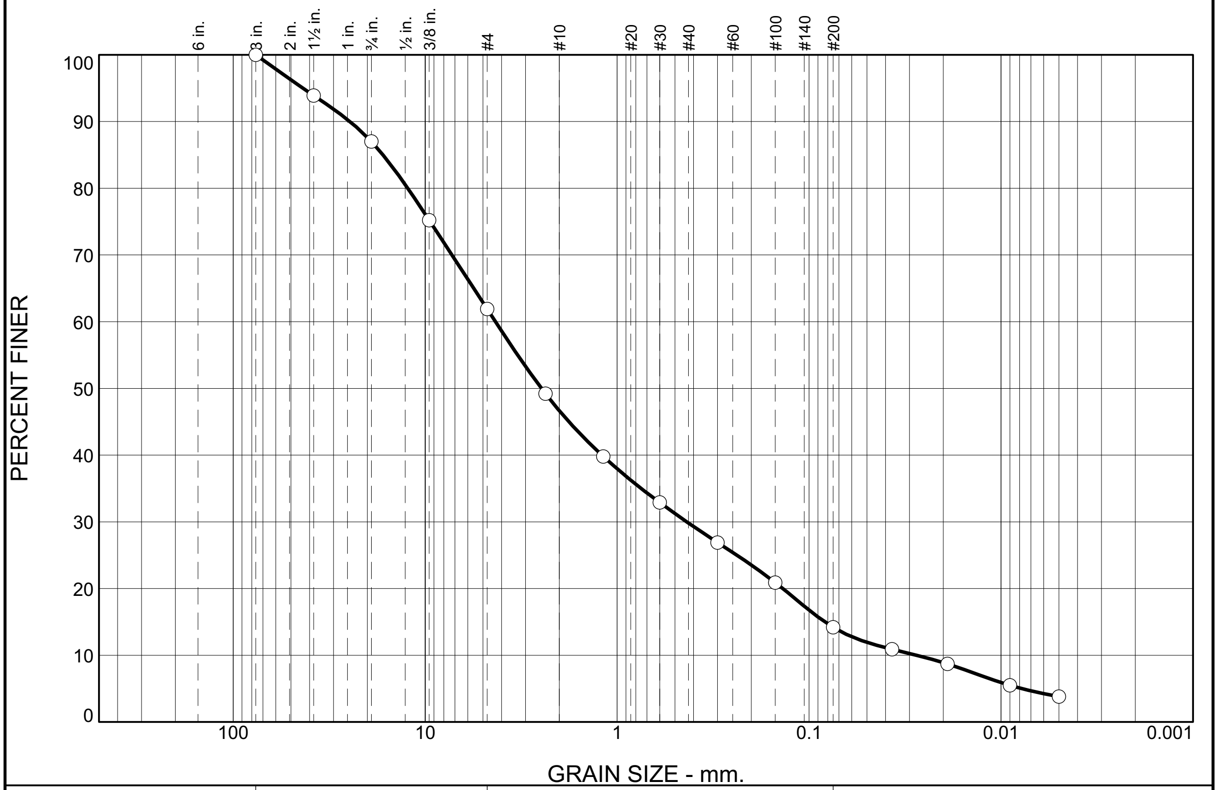
Sample Number: 65A-X709 **Depth:** 59.00-68.60 ft
Location: UE-25 RF #47 **Date:** 8/23/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 25

Tested By: Schaffer **Checked By:** Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	13.0	25.1	15.3	16.8	15.6	10.4	3.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	93.9		
.75in	87.0		
.375in	75.2		
#4	61.9		
#8	49.2		
#16	39.8		
#30	32.9		
#50	26.9		
#100	20.9		
#200	14.2		
.037mm	10.9		
.019mm	8.7		
.009mm	5.5		
.005mm	3.8		

* (no specification provided)

Material Description

Silty sand with gravel
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 16.5763 D_{60}= 4.3016 D_{50}= 2.4785
D_{30}= 0.4335 D_{15}= 0.0828 D_{10}= 0.0276
C_u= 155.78 C_c= 1.58

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.49
+No.4 Apparent Specific Gravity = 2.46
Absorption = 4.9 %

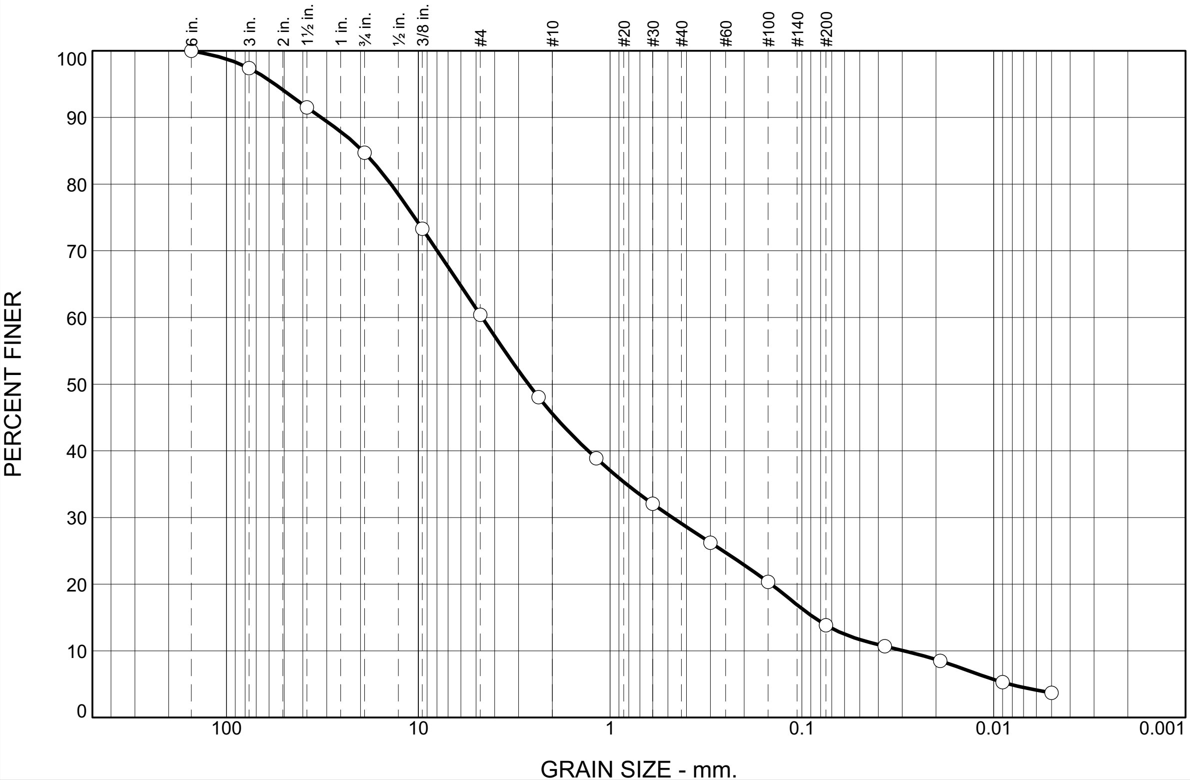
Sample Number: 65A-X710 (minus 3") **Depth:** 70.00-87.50 ft
Location: UE-25 RF #47 **Date:** 8/23/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 26

Tested By: Schaffer **Checked By:** Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
2.6	12.7	24.3	14.8	16.5	15.3	10.1	3.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	97.4		
1.5in	91.5		
.75in	84.7		
.375in	73.3		
#4	60.4		
#8	48.0		
#16	38.9		
#30	32.1		
#50	26.2		
#100	20.4		
#200	13.8		
.037mm	10.7		
.019mm	8.5		
.009mm	5.3		
.005mm	3.7		

* (no specification provided)

Material Description

Silty sand with gravel
Sample contains Plus 3-inch material, classification may change when base on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 19.5057 D_{60}= 4.6491 D_{50}= 2.6626
D_{30}= 0.4745 D_{15}= 0.0866 D_{10}= 0.0293
C_u= 158.50 C_c= 1.65

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.49
+No.4 Apparent Specific Gravity = 2.46
Absorption = 4.9 %

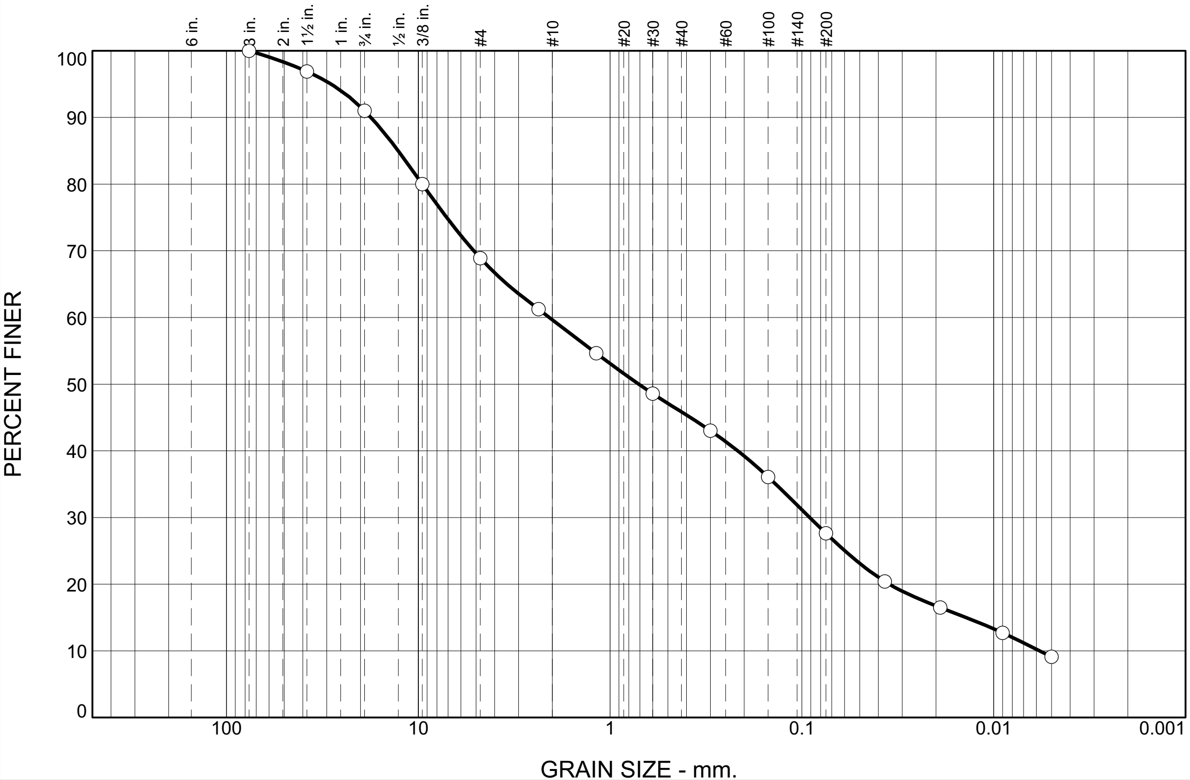
Sample Number: 65A-X710 **Depth:** 70.00-87.50 ft
Location: UE-25 RF #47 **Date:** 8/23/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 27

Tested By: Schaffer **Checked By:** Shehorn

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	9.0	22.1	9.3	13.7	18.3	18.5	9.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	96.9		
.75in	91.0		
.375in	80.0		
#4	68.9		
#8	61.2		
#16	54.6		
#30	48.6		
#50	43.0		
#100	36.1		
#200	27.6		
.037mm	20.4		
.019mm	16.5		
.009mm	12.7		
.005mm	9.1		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 12.7404 D_{60}= 2.0752 D_{50}= 0.7097
D_{30}= 0.0911 D_{15}= 0.0140 D_{10}= 0.0058
C_u= 360.16 C_c= 0.69

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.54
+No.4 Apparent Specific Gravity = 2.51
Absorption = 6.7%

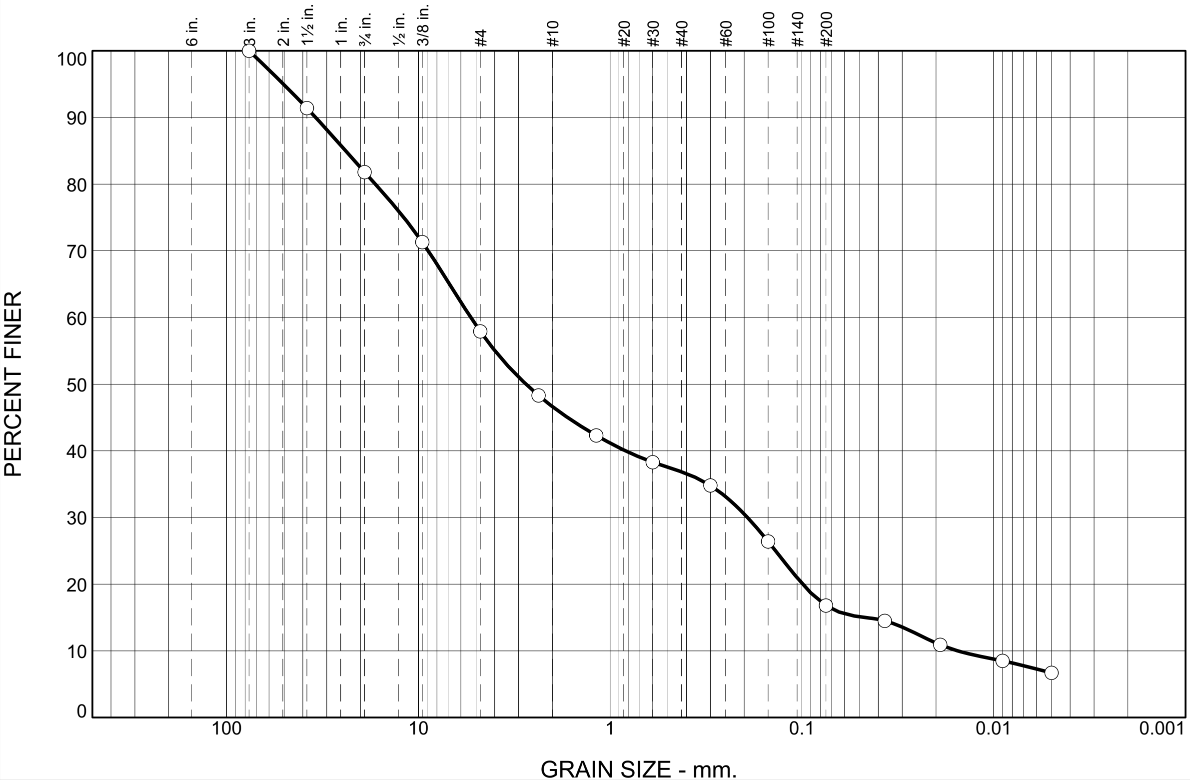
Sample Number: 65A-X711 **Depth:** 87.50-88.90 ft
Location: UE-25 RF #47
Date: 08/25/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 28

Tested By: Schaffer / Shehorn **Checked By:** Shehorn / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	18.2	23.9	11.3	9.7	20.1	10.1	6.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	91.4		
.75in	81.8		
.375in	71.3		
#4	57.9		
#8	48.3		
#16	42.3		
#30	38.3		
#50	34.8		
#100	26.4		
#200	16.8		
.037mm	14.5		
.019mm	10.9		
.009mm	8.5		
.005mm	6.7		

* (no specification provided)

Material Description

Silty gravel with sand
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 23.9226 D_{60}= 5.3275 D_{50}= 2.7491
D_{30}= 0.1924 D_{15}= 0.0466 D_{10}= 0.0154
C_u= 345.98 C_c= 0.45

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.54
+No.4 Apparent Specific Gravity 2.43
Absorption = 5.9 %

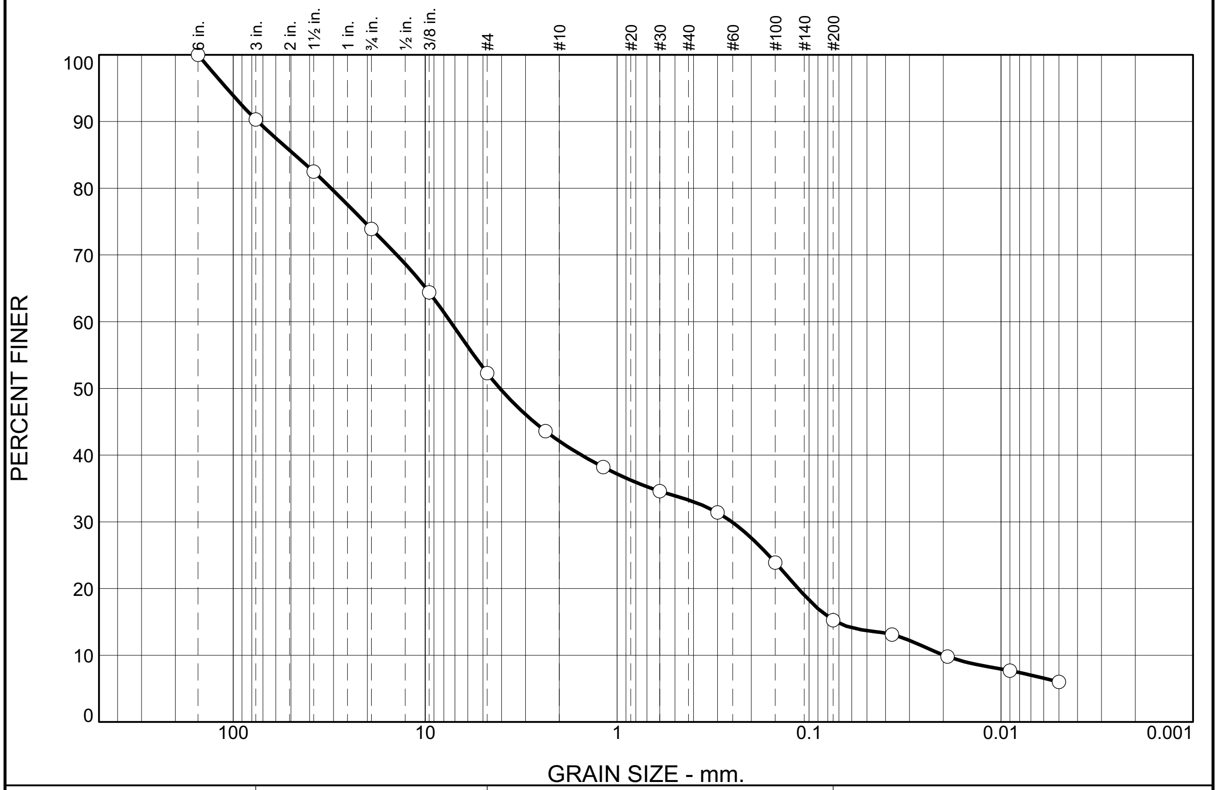
Sample Number: 65A-X802 (minus 3") **Depth:** 0.00-2.90 ft
Location: UE-25 RF #52 **Date:** 9/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 1

Tested By: Shehorn / Schaffer **Checked By:** Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
9.7	16.4	21.6	10.2	8.8	18.0	9.3	6.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	90.3		
1.5in	82.5		
.75in	73.9		
.375in	64.4		
#4	52.3		
#8	43.6		
#16	38.2		
#30	34.6		
#50	31.4		
#100	23.9		
#200	15.3		
.037mm	13.1		
.019mm	9.8		
.009mm	7.7		
.005mm	6.0		

* (no specification provided)

Material Description

Silty gravel with sand
Sample Contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 47.7078 D_{60}= 7.3790 D_{50}= 4.0775
D_{30}= 0.2527 D_{15}= 0.0723 D_{10}= 0.0198
C_u= 372.18 C_c= 0.44

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.54
+No.4 Apparent Specific Gravity = 2.43
Absorption = 5.9 %

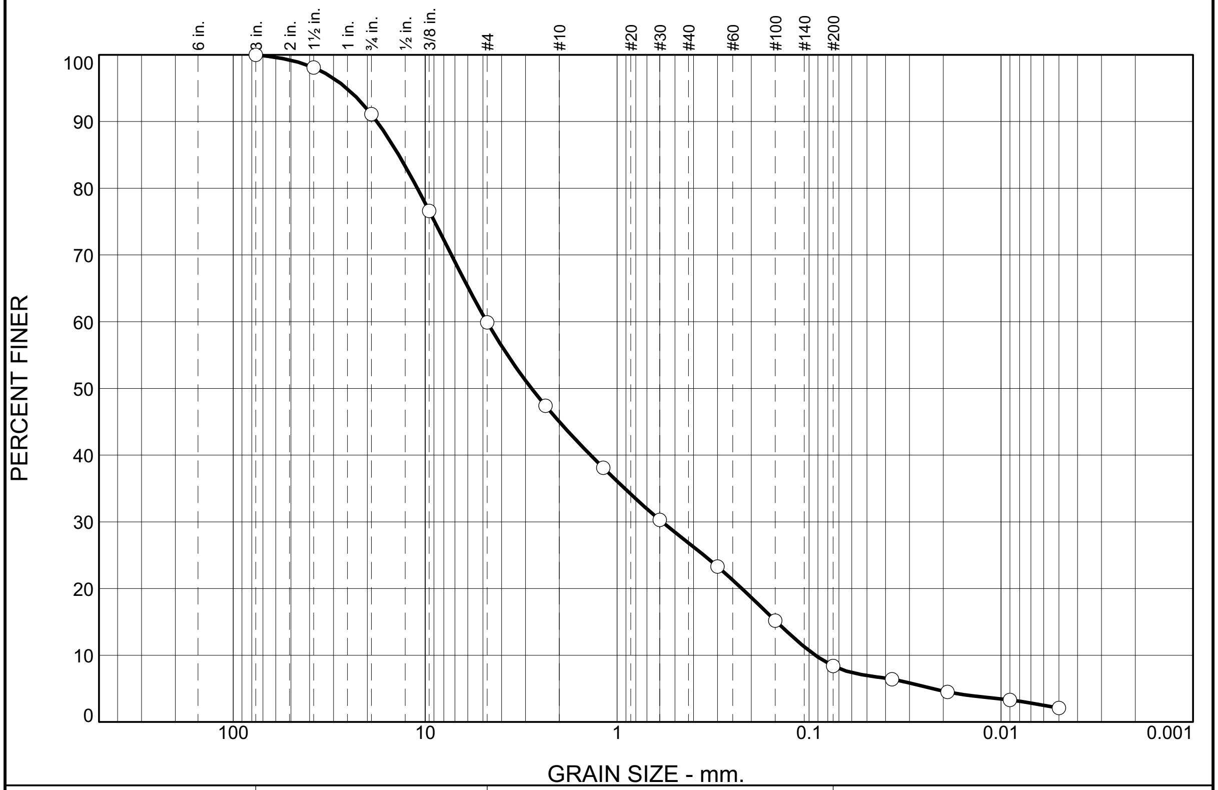
Sample Number: 65A-X802 **Depth:** 0.00-2.90 ft
Location: UE-25 RF #52
Date: 9/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 2

Tested By: Schaffer / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	8.9	31.2	14.9	18.2	18.4	6.3	2.1

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	98.1		
.75in	91.1		
.375in	76.6		
#4	59.9		
#8	47.4		
#16	38.1		
#30	30.3		
#50	23.3		
#100	15.2		
#200	8.4		
.037mm	6.4		
.019mm	4.5		
.009mm	3.3		
.005mm	2.1		

* (no specification provided)

Material Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 13.7371 D_{60}= 4.7720 D_{50}= 2.7904
D_{30}= 0.5829 D_{15}= 0.1475 D_{10}= 0.0928
C_u= 51.43 C_c= 0.77

Classification

USCS= SP-SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.54
+No.4 Apparent Specific Gravity = 2.50
Absorption = 5.6 %

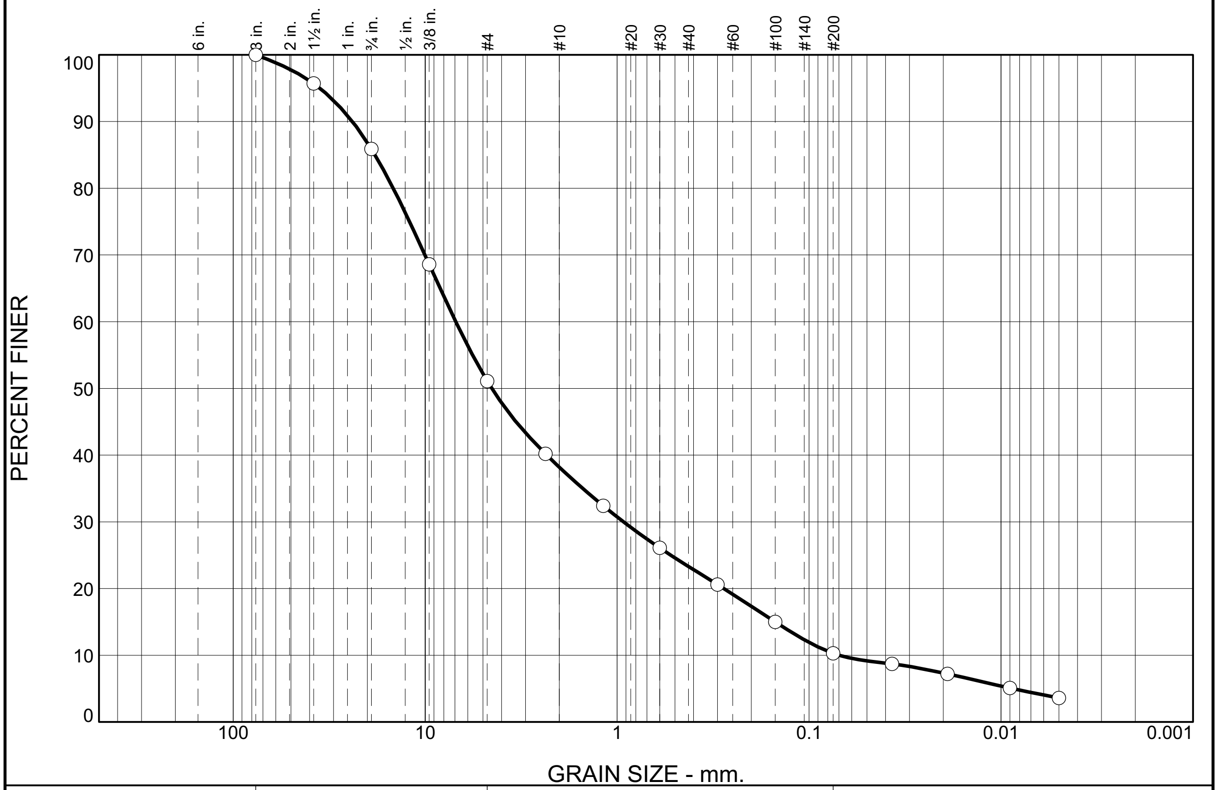
Sample Number: 65A-X803 **Depth:** 2.90-4.80 ft
Location: UE-25 RF #52 **Date:** 9/20/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 3

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	14.1	34.8	12.9	14.9	13.0	6.7	3.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	95.7		
.75in	85.9		
.375in	68.6		
#4	51.1		
#8	40.2		
#16	32.4		
#30	26.1		
#50	20.6		
#100	15.0		
#200	10.3		
.037mm	8.7		
.019mm	7.2		
.009mm	5.1		
.005mm	3.6		

* (no specification provided)

Material Description

Well-graded gravel with silt and sand
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 18.2381 D_{60}= 6.9210 D_{50}= 4.4968
D_{30}= 0.9257 D_{15}= 0.1500 D_{10}= 0.0696
C_u= 99.45 C_c= 1.78

Classification

USCS= GW-GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.46
Absorption = 4.8 %

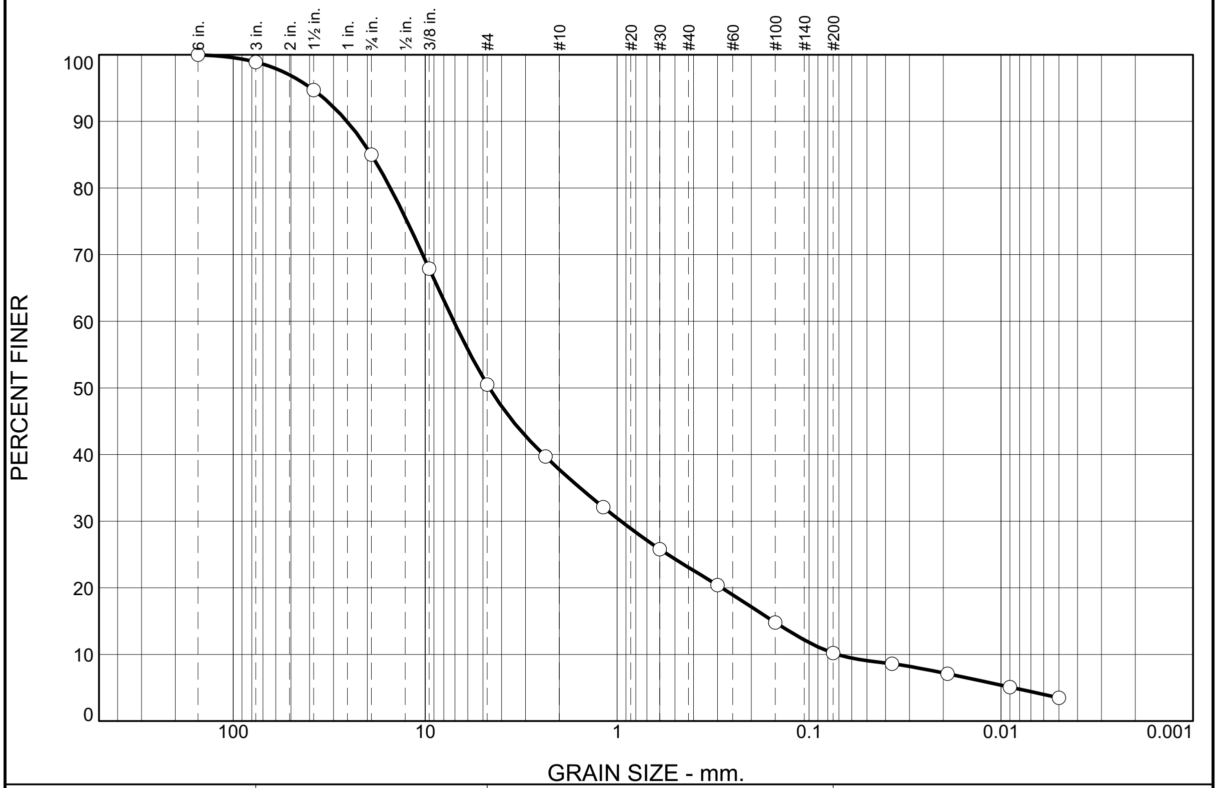
Sample Number: 65A-X804 (minus 3") **Depth:** 5.40-10.30 ft
Location: UE-25 RF #52 **Date:** 9/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 4

Tested By: Schaffer / Sheorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
1.1	13.9	34.5	12.8	14.6	12.9	6.7	3.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	98.9		
1.5in	94.7		
.75in	85.0		
.375in	67.9		
#4	50.5		
#8	39.7		
#16	32.1		
#30	25.8		
#50	20.4		
#100	14.8		
#200	10.2		
.037mm	8.6		
.019mm	7.1		
.009mm	5.1		
.005mm	3.5		

* (no specification provided)

Material Description

Well-graded gravel with silt and sand
Sample Contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 19.0500 D_{60}= 7.0947 D_{50}= 4.6343
D_{30}= 0.9540 D_{15}= 0.1538 D_{10}= 0.0714
C_u= 99.40 C_c= 1.80

Classification

USCS= GW-GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.46
Absorption = 4.8 %

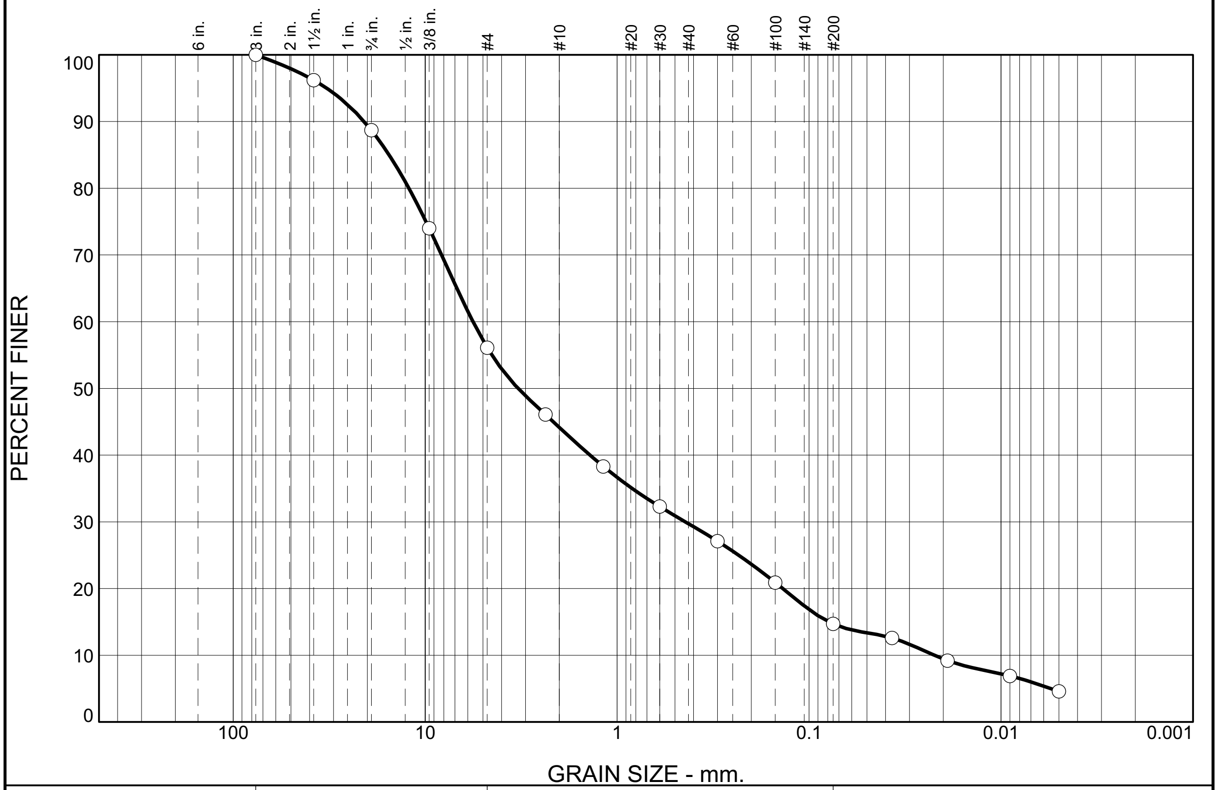
Sample Number: 65A-X804 **Depth:** 5.40-10.30 ft
Location: UE-25 RF #52 **Date:** 9/18/2006

**BUREAU
OF
RECLAMATION**

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 5

Tested By: Schaffer / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	11.3	32.6	11.9	14.5	15.0	10.1	4.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	96.2		
.75in	88.7		
.375in	74.0		
#4	56.1		
#8	46.1		
#16	38.3		
#30	32.3		
#50	27.1		
#100	20.9		
#200	14.7		
.037mm	12.6		
.019mm	9.2		
.009mm	6.9		
.005mm	4.6		

* (no specification provided)

Material Description

Silty gravel with sand
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 15.4223 D_{60}= 5.6369 D_{50}= 3.2780
D_{30}= 0.4412 D_{15}= 0.0789 D_{10}= 0.0223
C_u= 253.21 C_c= 1.55

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.50
+No.4 Specific Gravity = 2.51
Absorption = 6.1 %

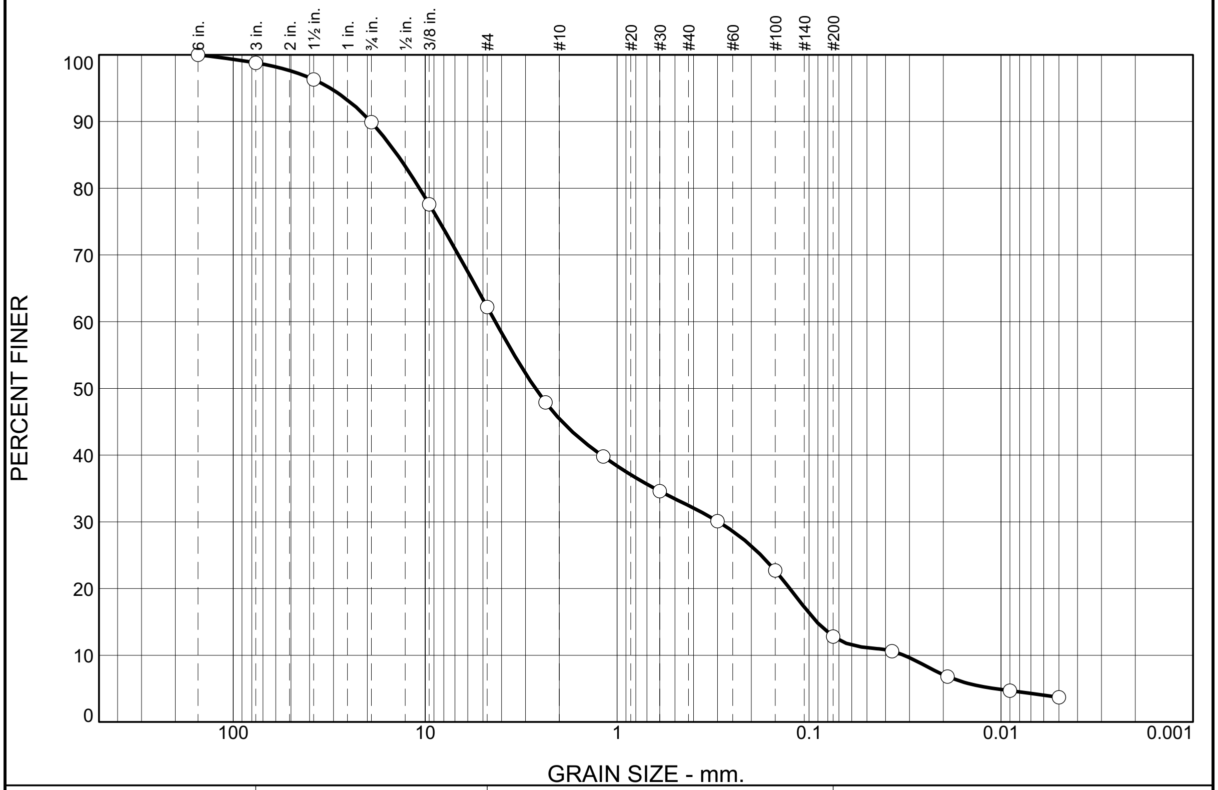
Sample Number: 65A-X805 (minus 3") **Depth:** 11.00-23.90 ft
Location: UE-25 RF #52 **Date:** 9/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 6

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
1.2	8.9	27.7	16.8	12.9	19.7	9.1	3.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	98.8		
1.5in	96.3		
.75in	89.9		
.375in	77.6		
#4	62.2		
#8	47.9		
#16	39.8		
#30	34.6		
#50	30.1		
#100	22.7		
#200	12.8		
.037mm	10.6		
.019mm	6.8		
.009mm	4.7		
.005mm	3.7		

* (no specification provided)

Material Description

Silty sand with gravel
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 13.9499 D_{60}= 4.3095 D_{50}= 2.6658
D_{30}= 0.2961 D_{15}= 0.0911 D_{10}= 0.0321
C_u= 134.20 C_c= 0.63

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.50
+No.4 Specific Gravity = 2.51
Absorption = 6.1 %

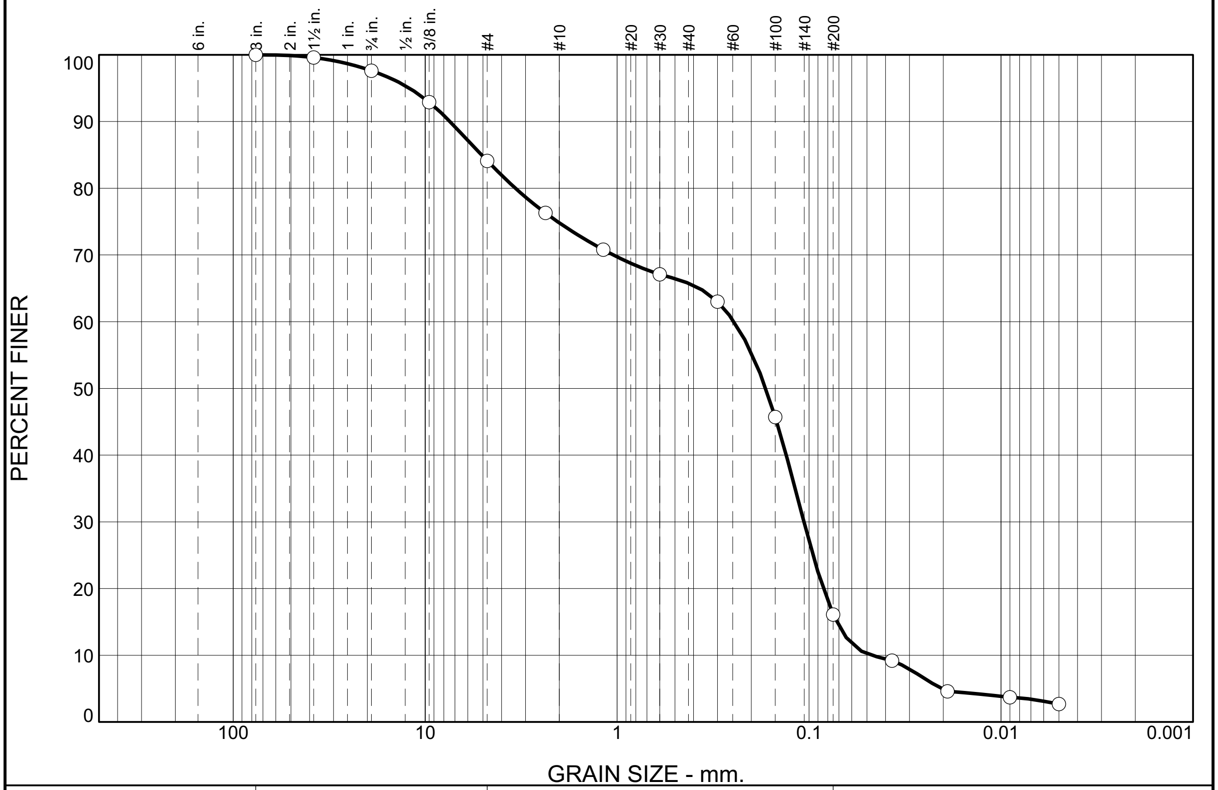
Sample Number: 65A-X805 **Depth:** 11.00-23.90 ft
Location: UE-25 RF #52 **Date:** 9/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 7

Tested By: Schaffer / Shehorn **Checked By:** Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	2.4	13.5	9.3	9.0	49.7	13.4	2.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	99.6		
.75in	97.6		
.375in	92.9		
#4	84.1		
#8	76.3		
#16	70.8		
#30	67.1		
#50	63.0		
#100	45.7		
#200	16.1		
.037mm	9.2		
.019mm	4.6		
.009mm	3.7		
.005mm	2.7		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 5.0878 D_{60}= 0.2461 D_{50}= 0.1681
D_{30}= 0.1065 D_{15}= 0.0719 D_{10}= 0.0474
C_u= 5.19 C_c= 0.97

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.43
+No.4 Apparent Specific Gravity = 2.49
Absorption = 6.9 %

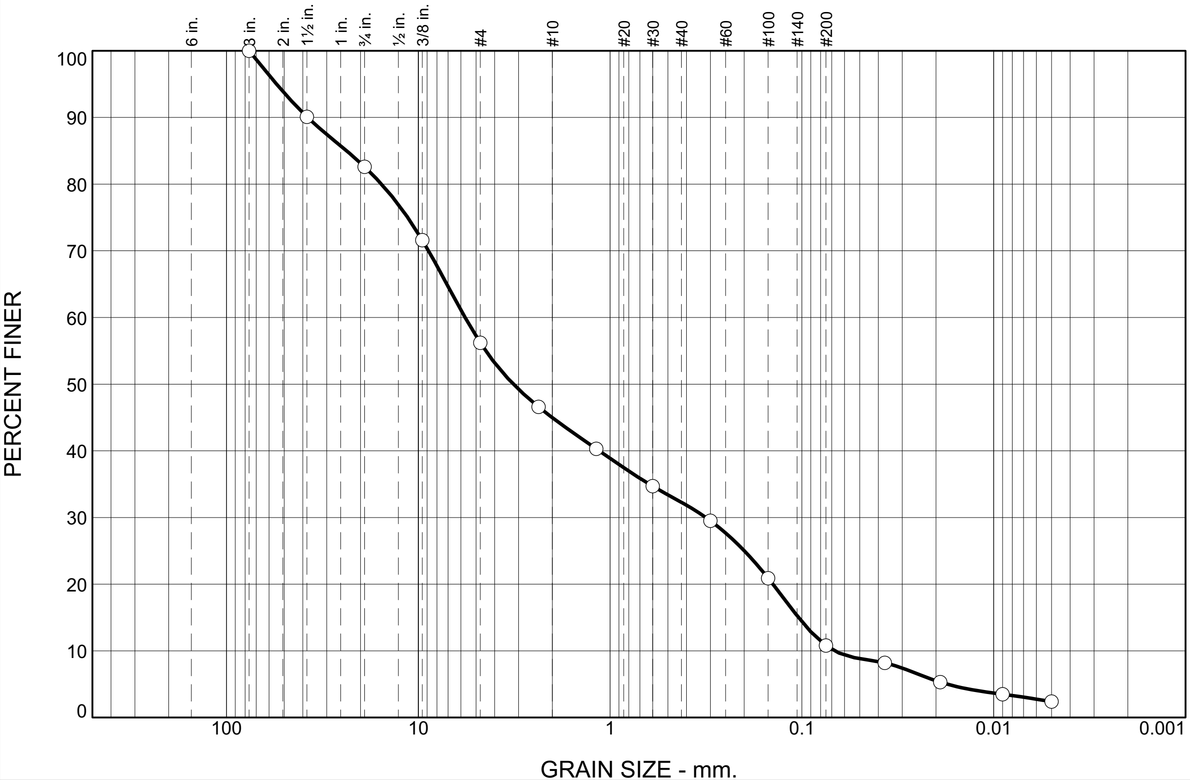
Sample Number: 65A-X806 **Depth:** 24.20-30.70 ft
Location: UE-25 RF #52 **Date:** 9/18/2006

**BUREAU
OF
RECLAMATION**

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 8

Tested By: Bowen / Shehorn **Checked By:** Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	17.4	26.4	11.2	12.7	21.5	8.4	2.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	90.1		
.75in	82.6		
.375in	71.6		
#4	56.2		
#8	46.6		
#16	40.3		
#30	34.7		
#50	29.5		
#100	20.9		
#200	10.8		
.037mm	8.2		
.019mm	5.3		
.009mm	3.5		
.005mm	2.4		

* (no specification provided)

Material Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 23.6774 D_{60}= 5.7023 D_{50}= 3.1940
D_{30}= 0.3173 D_{15}= 0.1042 D_{10}= 0.0677
C_u= 84.29 C_c= 0.26

Classification

USCS= SP-SM AASHTO=

Remarks

-No.4 Specific Gravity =
+No.4 Apparent Specific Gravity = 2.52
Absorption = 5.1 %

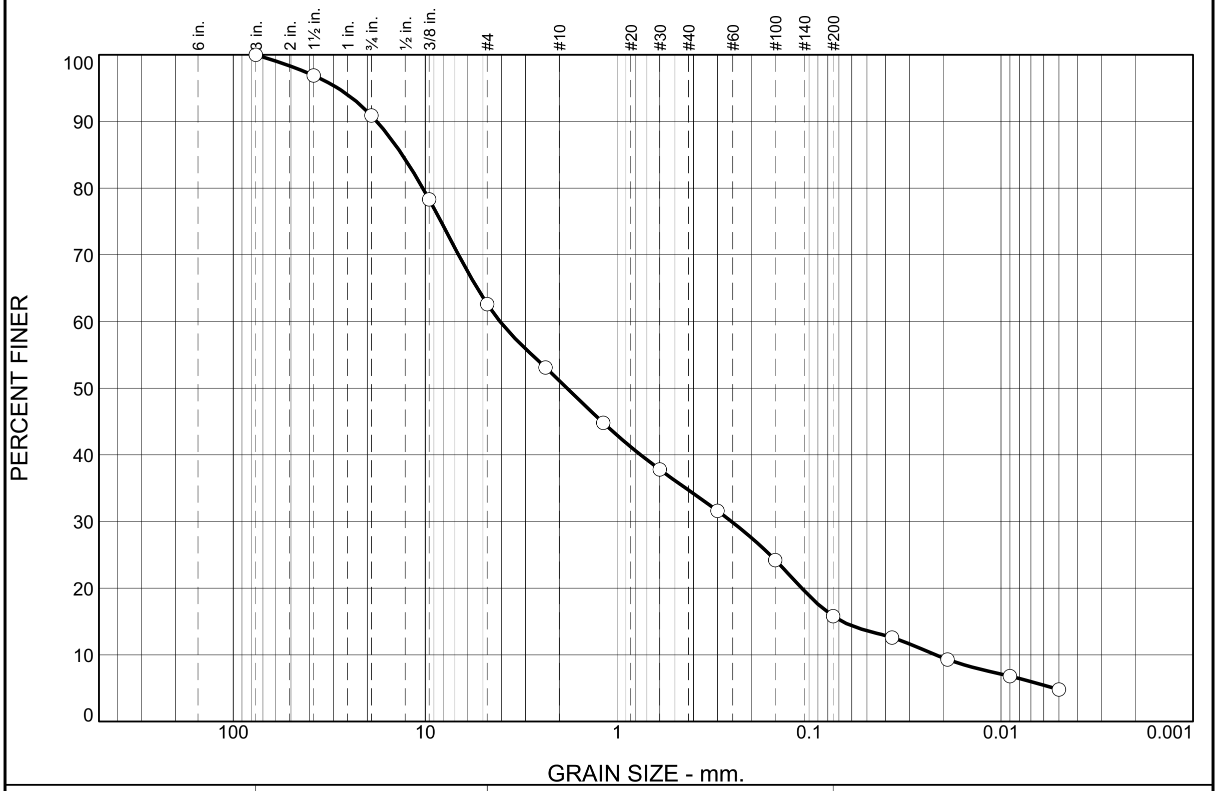
Sample Number: 65A-X807 **Depth:** 30.70-35.20 ft
Location: UE-25 RF #52 **Date:** 9/20/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 9

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	9.1	28.3	11.5	16.4	18.9	11.0	4.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	96.9		
.75in	90.9		
.375in	78.3		
#4	62.6		
#8	53.1		
#16	44.8		
#30	37.8		
#50	31.6		
#100	24.2		
#200	15.8		
.037mm	12.6		
.019mm	9.3		
.009mm	6.8		
.005mm	4.8		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 13.1602 D_{60}= 4.0739 D_{50}= 1.8213
D_{30}= 0.2534 D_{15}= 0.0673 D_{10}= 0.0219
C_u= 185.69 C_c= 0.72

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.51
+No.4 Apparent Specific Gravity = 2.50
Absorption = 6.0 %

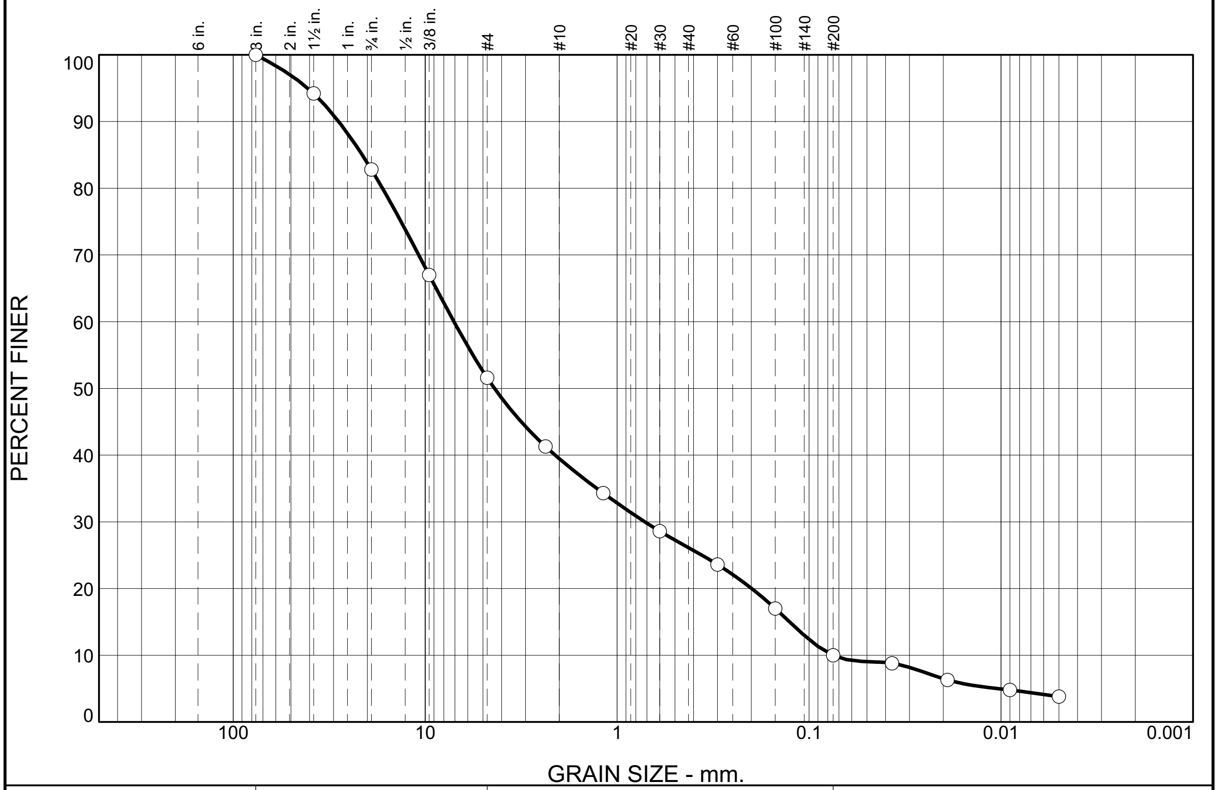
Sample Number: 65A-X808 **Depth:** 35.20-40.00 ft
Location: UE-25 RF #52
Date: 9/19/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 10

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	17.2	31.2	12.1	13.4	16.1	6.2	3.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	94.2		
.75in	82.8		
.375in	67.0		
#4	51.6		
#8	41.3		
#16	34.3		
#30	28.6		
#50	23.6		
#100	17.0		
#200	10.0		
.037mm	8.8		
.019mm	6.3		
.009mm	4.8		
.005mm	3.8		

* (no specification provided)

Material Description

Poorly graded gravel with silt and sand
Plus 3-ich material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 21.2728 D_{60}= 7.0738 D_{50}= 4.3493
D_{30}= 0.7180 D_{15}= 0.1263 D_{10}= 0.0750
C_u= 94.32 C_c= 0.97

Classification

USCS= GP-GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.50
Absorption = 6.5 %

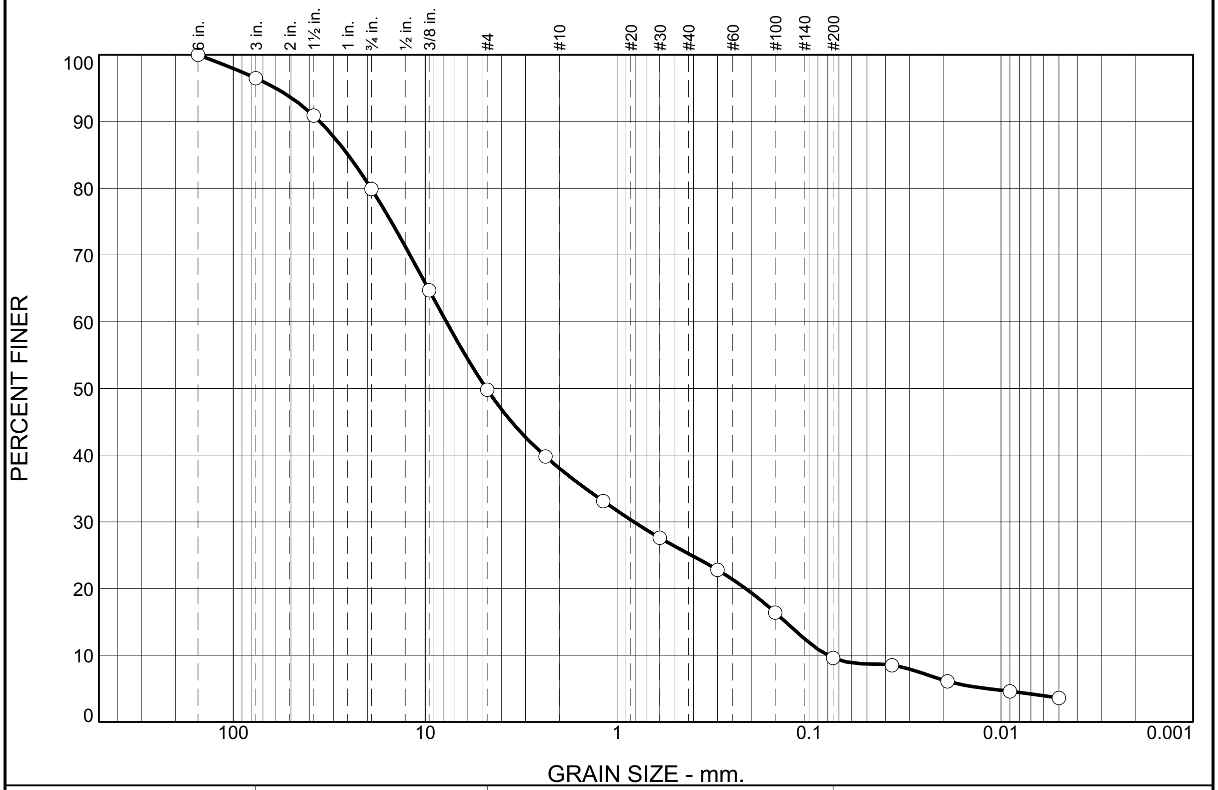
Sample Number: 65A-X809 (minus 3") **Depth:** 40.30-44.50 ft
Location: UE-25 RF #52 **Date:** 9/19/2006

**BUREAU
OF
RECLAMATION**

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 11

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
3.5	16.6	30.1	11.8	12.8	15.6	6.0	3.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	96.5		
1.5in	90.9		
.75in	79.9		
.375in	64.7		
#4	49.8		
#8	39.8		
#16	33.1		
#30	27.6		
#50	22.8		
#100	16.4		
#200	9.6		
.037mm	8.5		
.019mm	6.1		
.009mm	4.6		
.005mm	3.6		

* (no specification provided)

Material Description

Well-graded gravel with silt and sand
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP　LL= NP　PI= NP

Coefficients

D_{85}= 25.1874　D_{60}= 7.7562　D_{50}= 4.8022
D_{30}= 0.8188　D_{15}= 0.1325　D_{10}= 0.0801
C_u= 96.82　C_c= 1.08

Classification

USCS= GW-GM　AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.50
Absorption = 6.5 %

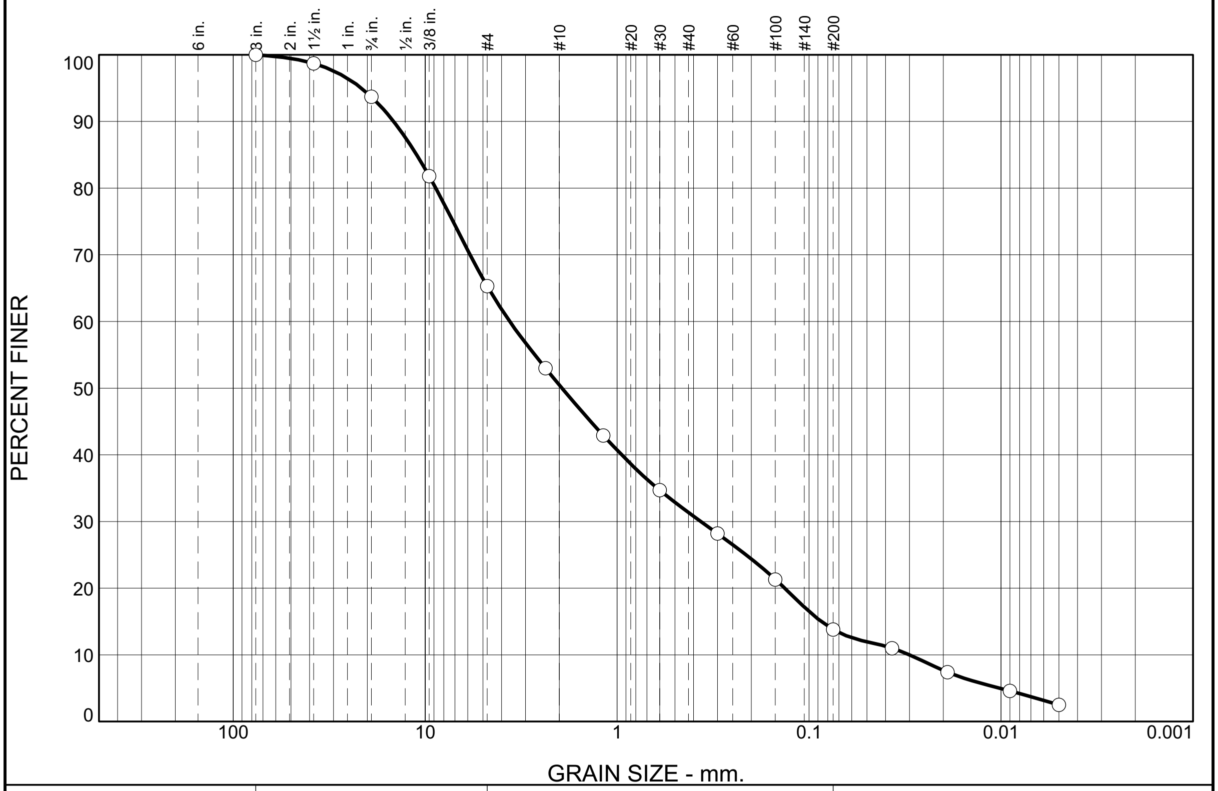
Sample Number: 65A-X809　**Depth:** 40.30-44.50 ft
Location: UE-25 RF #52　**Date:** 9/19/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A　**Figure** 12

Tested By: Bowen / Shehorn　**Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	6.3	28.4	14.8	19.2	17.5	11.3	2.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	98.7		
.75in	93.7		
.375in	81.8		
#4	65.3		
#8	53.0		
#16	42.9		
#30	34.7		
#50	28.2		
#100	21.3		
#200	13.8		
.037mm	11.0		
.019mm	7.4		
.009mm	4.6		
.005mm	2.5		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 11.0744 D_{60}= 3.6255 D_{50}= 1.9365
D_{30}= 0.3668 D_{15}= 0.0865 D_{10}= 0.0300
C_u= 120.69 C_c= 1.24

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.51
+No.4 Apparent Specific Gravity = 2.51
Absorption = 5.8 %

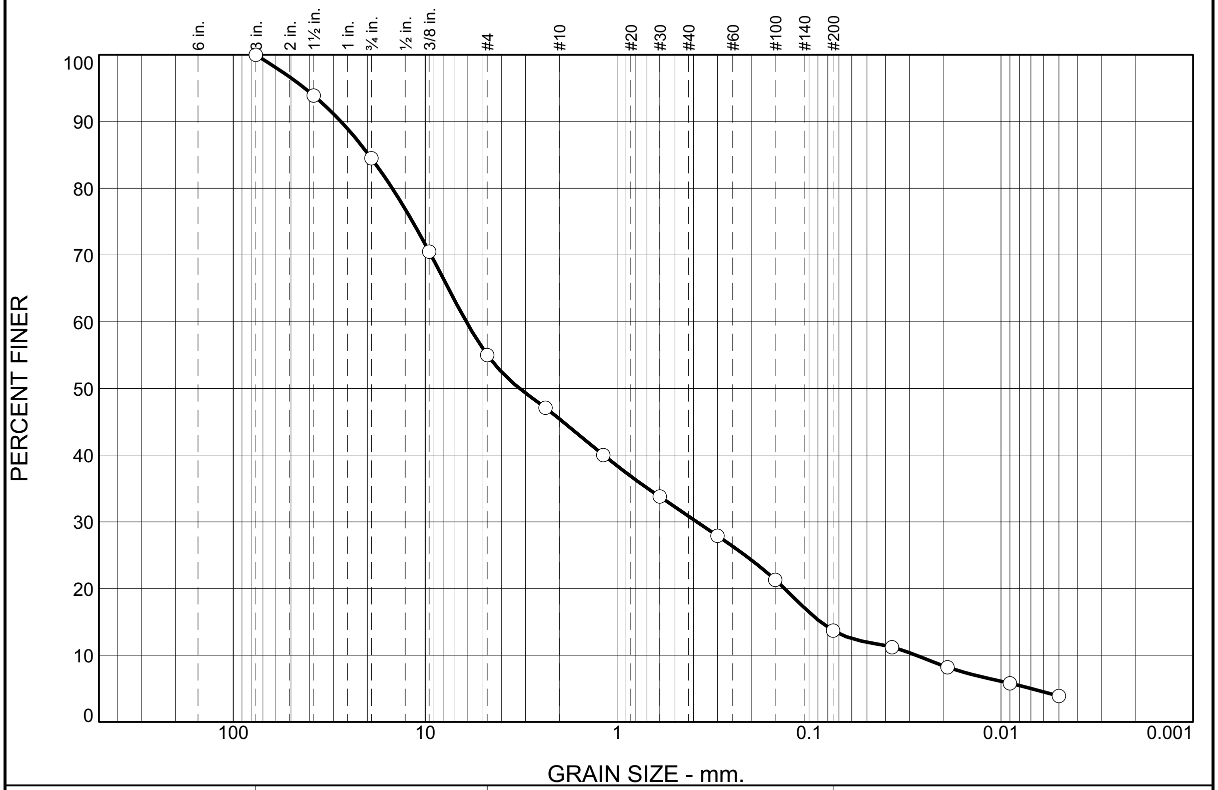
Sample Number: 65A-X810 **Depth:** 44.50-50.30 ft
Location: UE-25 RF #52 **Date:** 9/19/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 13

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	15.5	29.5	9.5	14.6	17.2	9.8	3.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	93.9		
.75in	84.5		
.375in	70.5		
#4	55.0		
#8	47.1		
#16	40.0		
#30	33.8		
#50	27.9		
#100	21.3		
#200	13.7		
.037mm	11.2		
.019mm	8.2		
.009mm	5.8		
.005mm	3.9		

* (no specification provided)

Material Description

Silty gravel with sand
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 19.6301 D_{60}= 6.1095 D_{50}= 3.2232
D_{30}= 0.3842 D_{15}= 0.0872 D_{10}= 0.0277
C_u= 220.81 C_c= 0.87

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity =
+No.4 Apparent Specific Gravity = 2.46
Absorption = 5.4 %

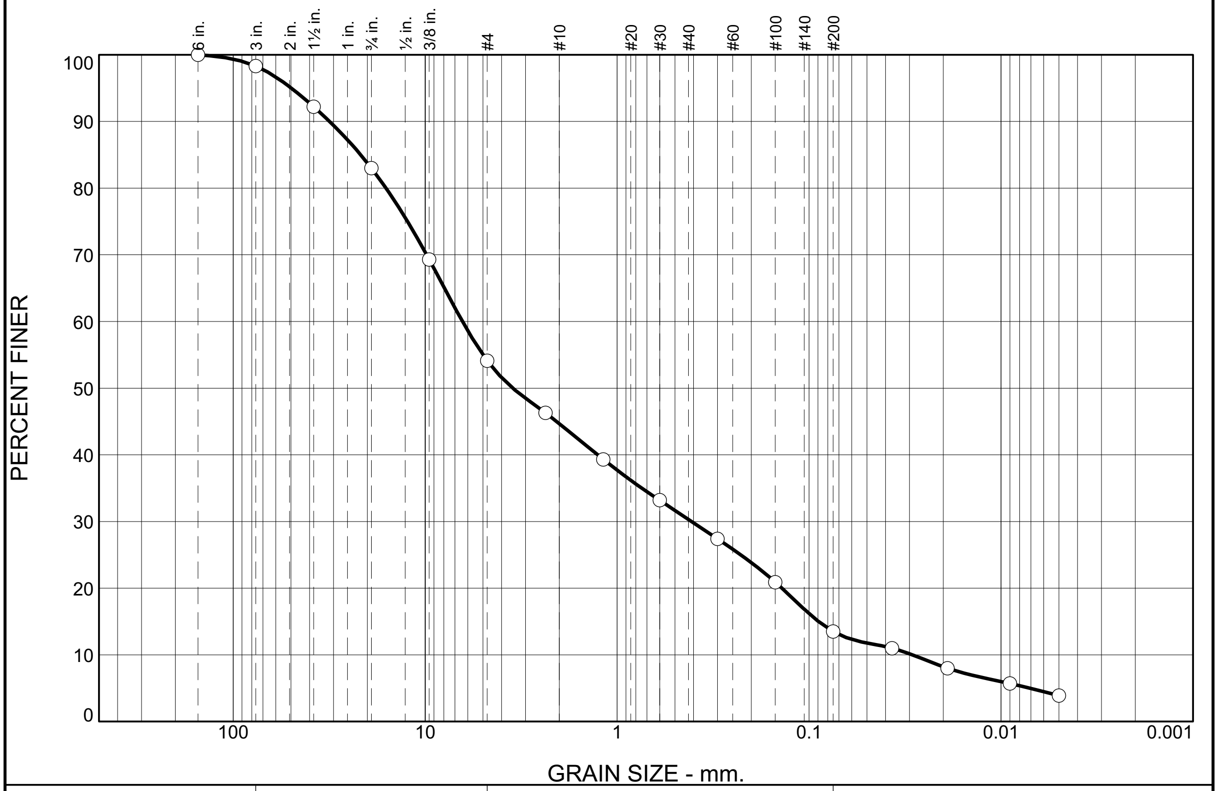
Sample Number: 65A-X811 (minus 3") **Depth:** 50.30-61.80 ft
Location: UE-25 RF #52 **Date:** 9/20/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 14

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
1.7	15.3	28.9	9.4	14.4	16.8	9.6	3.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	98.3		
1.5in	92.2		
.75in	83.0		
.375in	69.3		
#4	54.1		
#8	46.3		
#16	39.3		
#30	33.2		
#50	27.4		
#100	20.9		
#200	13.5		
.037mm	11.0		
.019mm	8.0		
.009mm	5.7		
.005mm	3.9		

* (no specification provided)

Material Description

Silty gravel with sand
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 21.6608 D_{60}= 6.3915 D_{50}= 3.4941
D_{30}= 0.4096 D_{15}= 0.0893 D_{10}= 0.0289
C_u= 220.97 C_c= 0.91

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity =
+No.4 Apparent Specific Gravity = 2.46
Absorption = 5.4 %

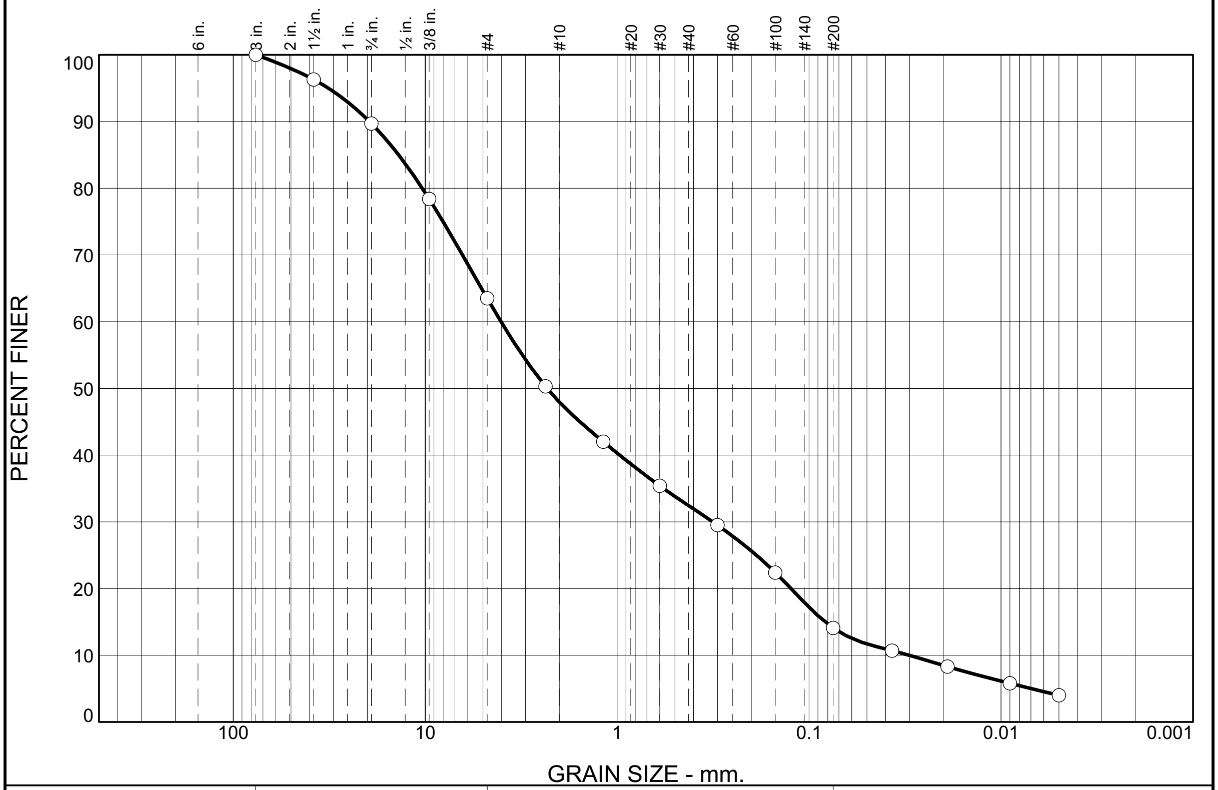
Sample Number: 65A-X811 **Depth:** 50.30-61.80 ft
Location: UE-25 RF #52 **Date:** 9/20/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 15

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	10.3	26.2	15.5	15.6	18.3	10.1	4.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	96.3		
.75in	89.7		
.375in	78.4		
#4	63.5		
#8	50.3		
#16	42.0		
#30	35.4		
#50	29.5		
#100	22.4		
#200	14.1		
.037mm	10.7		
.019mm	8.3		
.009mm	5.8		
.005mm	4.0		

* (no specification provided)

Material Description

Silty sand with gravel
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 13.7587 D_{60}= 4.0227 D_{50}= 2.3134
D_{30}= 0.3178 D_{15}= 0.0824 D_{10}= 0.0301
C_u= 133.44 C_c= 0.83

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity =
+No.4 Apparent Specific Gravity = 2.45
Absorption = 5.8 %

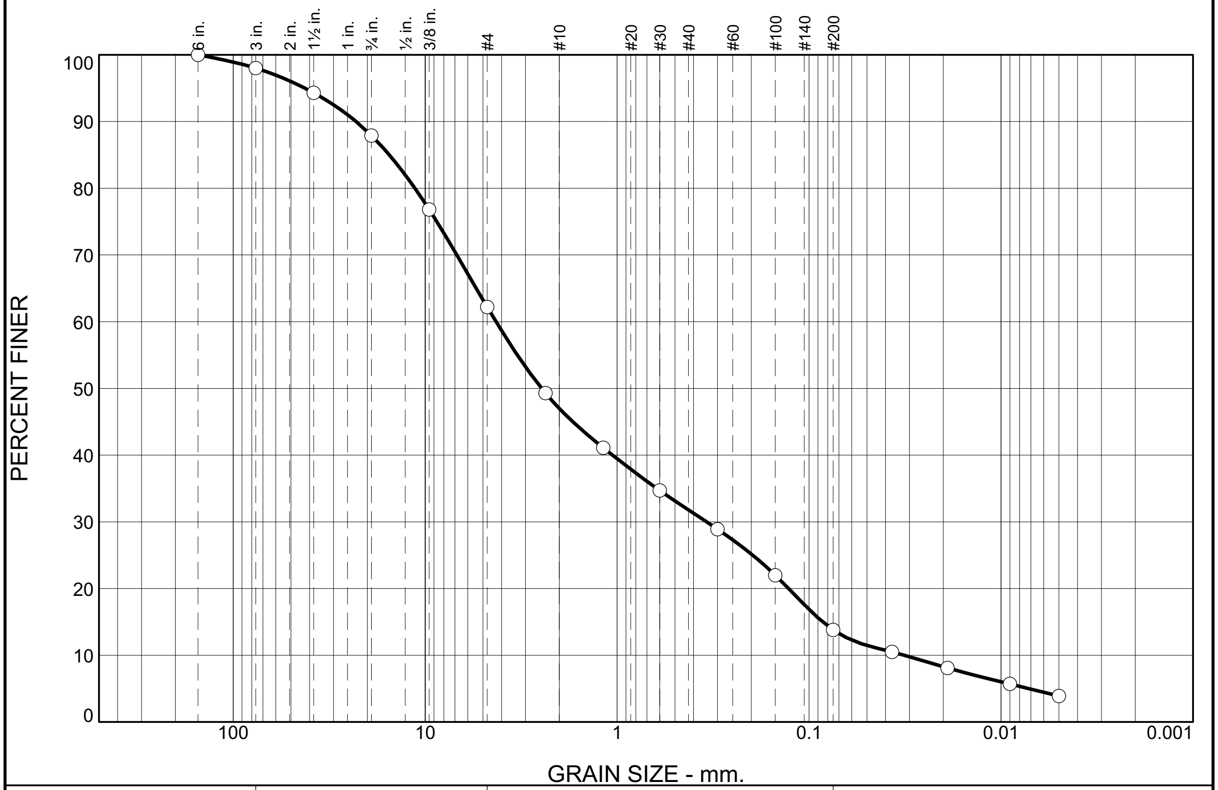
Sample Number: 65A-X812 (minus 3") **Depth:** 61.80-68.40 ft
Location: UE-25 RF #52 **Date:** 9/20/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 16

Tested By: Bowen / Shehorn **Checked By:** Schaeffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
2.0	10.1	25.7	15.2	15.2	18.0	9.9	3.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	98.0		
1.5in	94.3		
.75in	87.9		
.375in	76.8		
#4	62.2		
#8	49.3		
#16	41.1		
#30	34.7		
#50	28.9		
#100	22.0		
#200	13.8		
.037mm	10.5		
.019mm	8.1		
.009mm	5.7		
.005mm	3.9		

* (no specification provided)

Material Description

Silty sand with gravel
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 15.3787 D_{60}= 4.2716 D_{50}= 2.4710
D_{30}= 0.3418 D_{15}= 0.0850 D_{10}= 0.0319
C_u= 134.03 C_c= 0.86

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity =
+No.4 Apparent Specific Gravity = 2.45
Absorption = 6.0 %

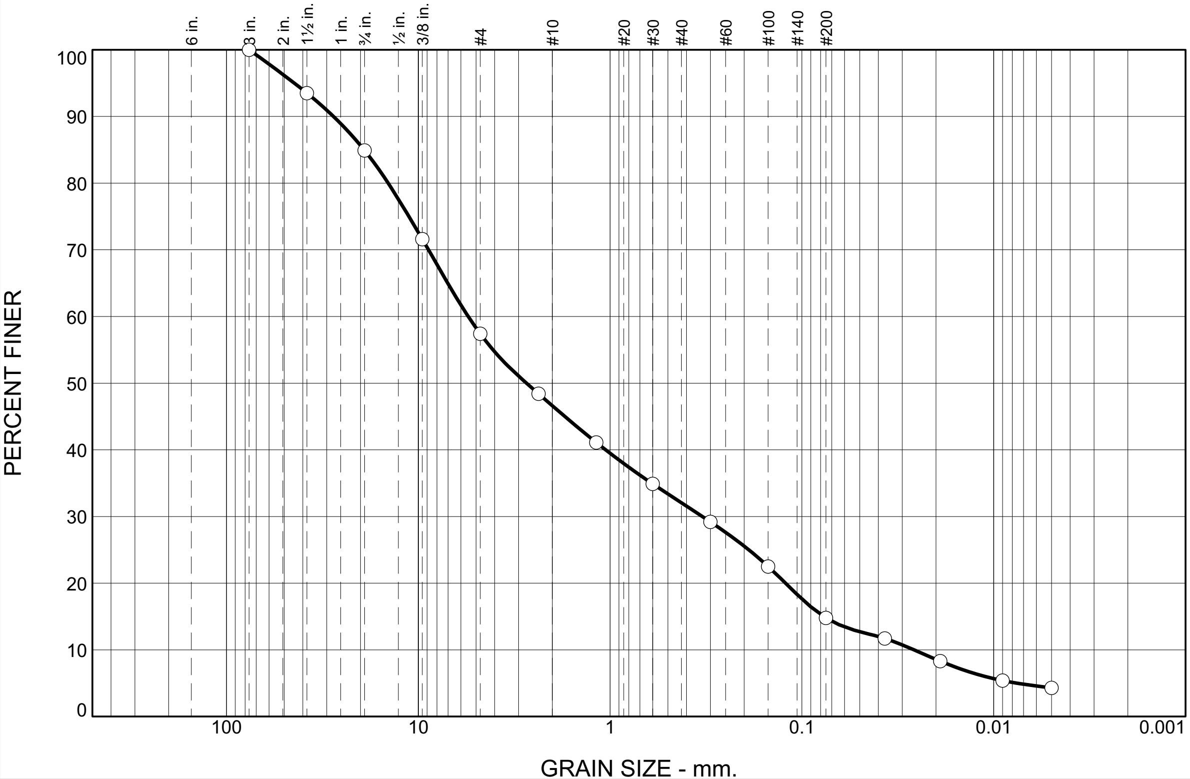
Sample Number: 65A-X812 **Depth:** 61.80-68.40 ft
Location: UE-25 RF #52 **Date:** 9/20/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 17

Tested By: Bowen / Shehorn **Checked By:** Schaffer

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	15.1	27.5	10.8	14.5	17.3	10.5	4.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	93.5		
.75in	84.9		
.375in	71.6		
#4	57.4		
#8	48.4		
#16	41.1		
#30	34.9		
#50	29.2		
#100	22.5		
#200	14.8		
.037mm	11.7		
.019mm	8.3		
.009mm	5.4		
.005mm	4.3		

* (no specification provided)

Material Description

Silty sand with gravel
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 19.1715 D_{60}= 5.4881 D_{50}= 2.7317
D_{30}= 0.3302 D_{15}= 0.0769 D_{10}= 0.0260
C_u= 210.95 C_c= 0.76

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.53
+No.4 Apparent Specific Gravity = 2.44
Absorption = 5.9 %

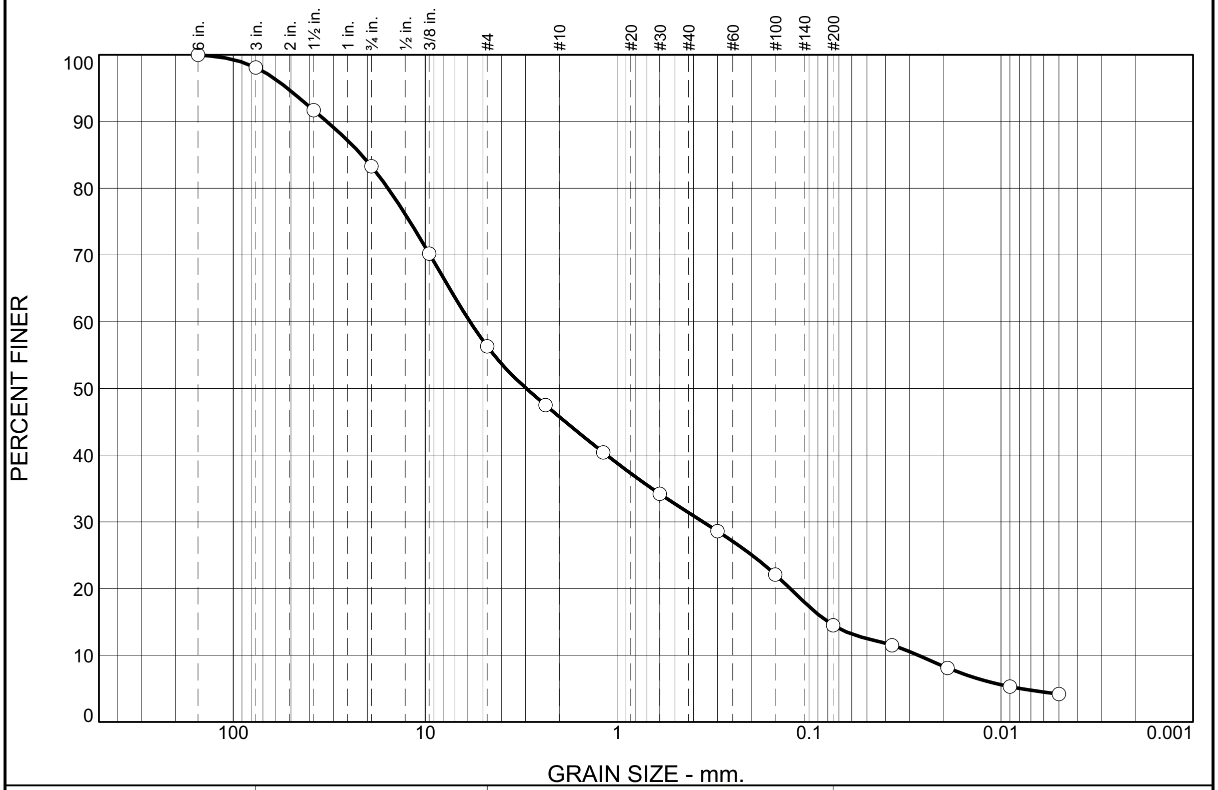
Sample Number: 65A-X-813 (minus 3") **Depth:** 68.40-104.50 ft
Location: UE-25 RF #52 **Date:** 9/19/2006

BUREAU
OF
RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 18

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
1.9	14.8	27.0	10.5	14.4	16.9	10.3	4.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	98.1		
1.5in	91.7		
.75in	83.3		
.375in	70.2		
#4	56.3		
#8	47.5		
#16	40.4		
#30	34.2		
#50	28.6		
#100	22.1		
#200	14.5		
.037mm	11.5		
.019mm	8.1		
.009mm	5.3		
.005mm	4.2		

* (no specification provided)

Material Description

Silty sand with gravel
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 21.4179 D_{60}= 5.8347 D_{50}= 2.9744
D_{30}= 0.3570 D_{15}= 0.0797 D_{10}= 0.0270
C_u= 216.09 C_c= 0.81

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.53
+No.4 Apparent Specific Gravity = 2.44
Absorption = 5.9 %

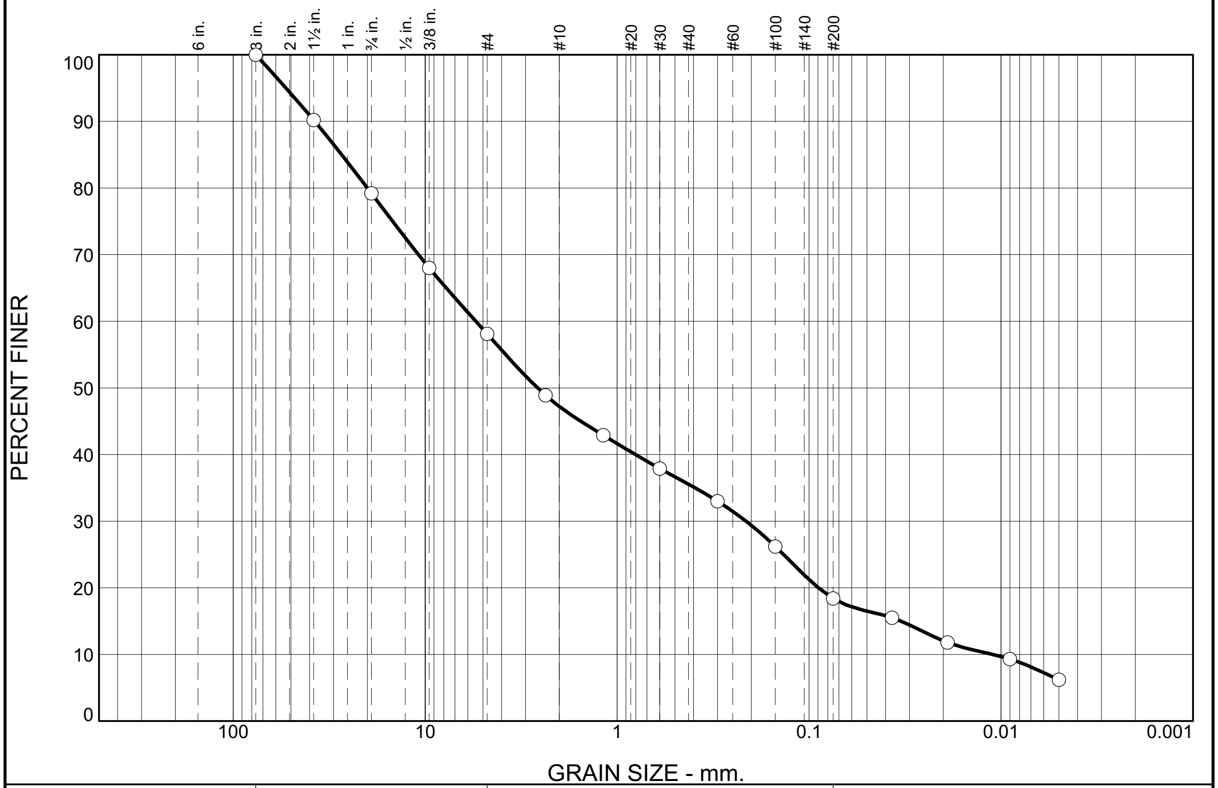
Sample Number: 65A-X-813 **Depth:** 68.40-104.50 ft
Location: UE-25 RF #52 **Date:** 9/19/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 19

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	20.8	21.1	10.9	11.7	17.1	12.2	6.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	90.2		
.75in	79.2		
.375in	68.0		
#4	58.1		
#8	48.9		
#16	42.9		
#30	37.9		
#50	33.0		
#100	26.2		
#200	18.4		
.037mm	15.5		
.019mm	11.8		
.009mm	9.3		
.005mm	6.2		

* (no specification provided)

Material Description

Silty gravel with sand
Plus 3-inch material Removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 27.2237 D_{60}= 5.4439 D_{50}= 2.5986
D_{30}= 0.2133 D_{15}= 0.0333 D_{10}= 0.0111
C_u= 491.67 C_c= 0.75

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.42
Absorption = 3.7 %

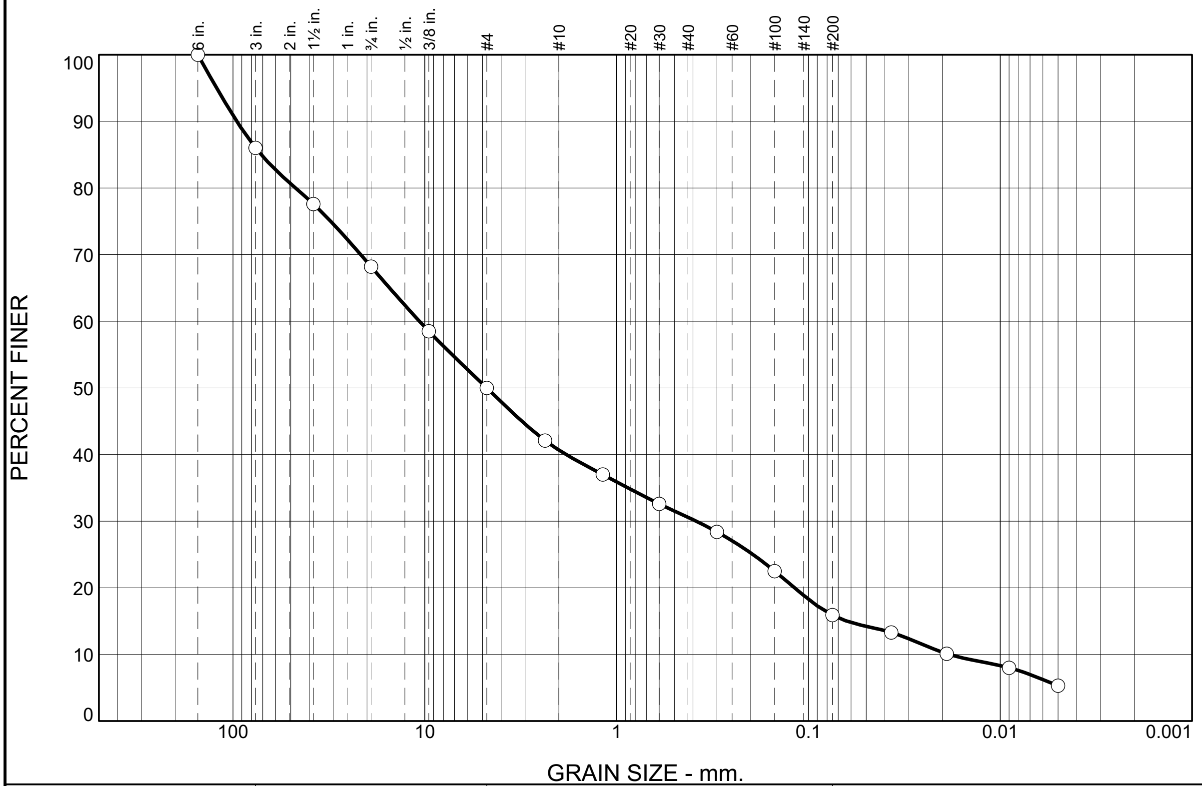
Sample Number: 65A-X814 (minus 3") **Depth:** 104.50-107.90 ft
Location: UE-25 RF #52 **Date:** 9/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 20

Tested By: Bowen / Sheorn **Checked By:** Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
14.0	17.8	18.2	9.3	10.1	14.7	10.6	5.3

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	86.0		
1.5in	77.6		
.75in	68.2		
.375in	58.5		
#4	50.0		
#8	42.1		
#16	37.0		
#30	32.6		
#50	28.4		
#100	22.5		
#200	15.9		
.037mm	13.3		
.019mm	10.1		
.009mm	8.0		
.005mm	5.3		

* (no specification provided)

Material Description

Silty gravel with sand
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 71.2632 D_{60}= 10.6664 D_{50}= 4.7500
D_{30}= 0.3855 D_{15}= 0.0631 D_{10}= 0.0185
C_u= 575.99 C_c= 0.75

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.42
Absorption = 3.7 %

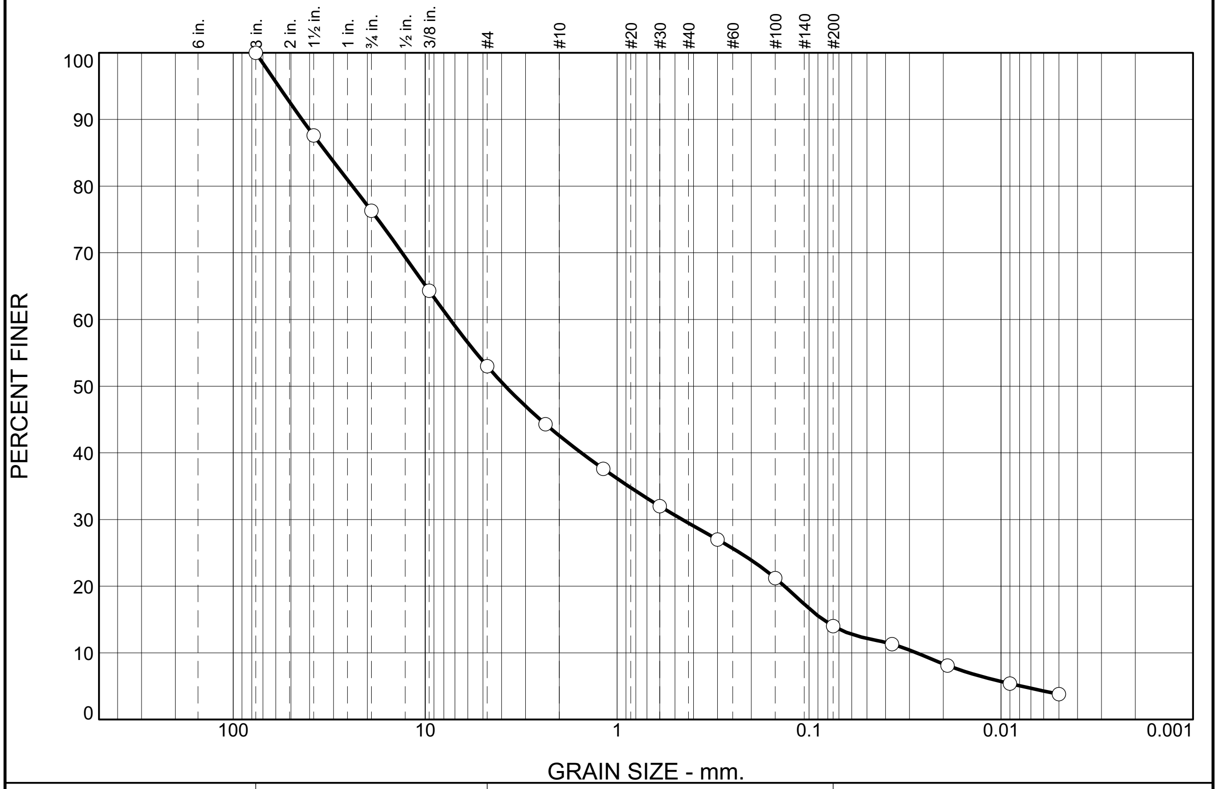
Sample Number: 65A-X814 **Depth:** 104.50-107.90 ft
Location: UE-25 RF #52 **Date:** 9/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 21

Tested By: Bowen / Sheorn **Checked By:** Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	23.7	23.3	10.4	13.1	15.5	10.2	3.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	87.6		
.75in	76.3		
.375in	64.3		
#4	53.0		
#8	44.3		
#16	37.6		
#30	32.0		
#50	27.0		
#100	21.2		
#200	14.0		
.037mm	11.3		
.019mm	8.1		
.009mm	5.4		
.005mm	3.8		

* (no specification provided)

Material Description

Silty gravel with sand
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 32.5738 D_{60}= 7.4087 D_{50}= 3.8202
D_{30}= 0.4575 D_{15}= 0.0847 D_{10}= 0.0276
C_u= 268.79 C_c= 1.02

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.86
Absorption = 15.8 %

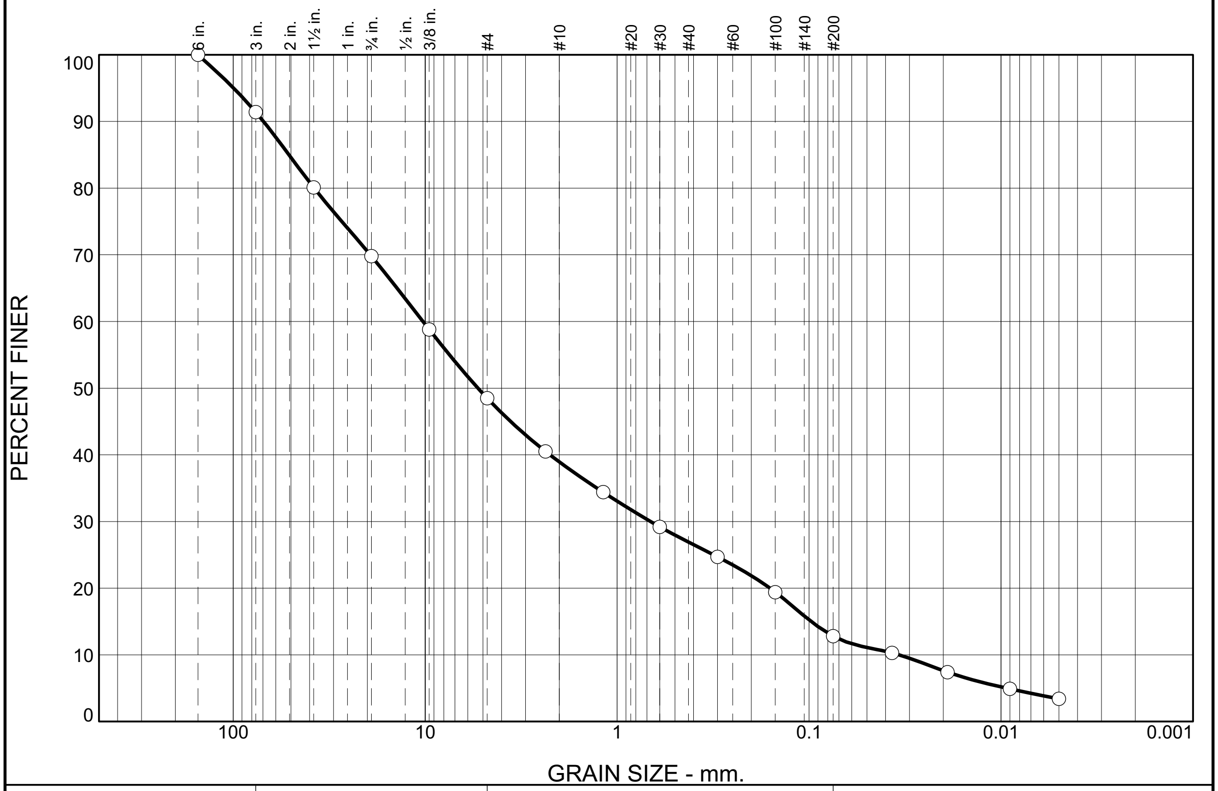
Sample Number: 65A-X815 (minus 3") **Depth:** 109.50-148.20 ft
Location: UE-25 RF #52 **Date:** 09/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 22

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
8.6	21.6	21.3	9.6	12.0	14.1	9.4	3.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	91.4		
1.5in	80.1		
.75in	69.8		
.375in	58.8		
#4	48.5		
#8	40.5		
#16	34.4		
#30	29.2		
#50	24.7		
#100	19.4		
#200	12.8		
.037mm	10.3		
.019mm	7.4		
.009mm	4.9		
.005mm	3.4		

* (no specification provided)

Material Description

Silty gravel with sand
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 51.2225 D_{60}= 10.2675 D_{50}= 5.3059
D_{30}= 0.6712 D_{15}= 0.0975 D_{10}= 0.0340
C_u= 302.39 C_c= 1.29

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.52
+No.4 Apparent Specific Gravity = 2.86
Absorption = 15.8 %

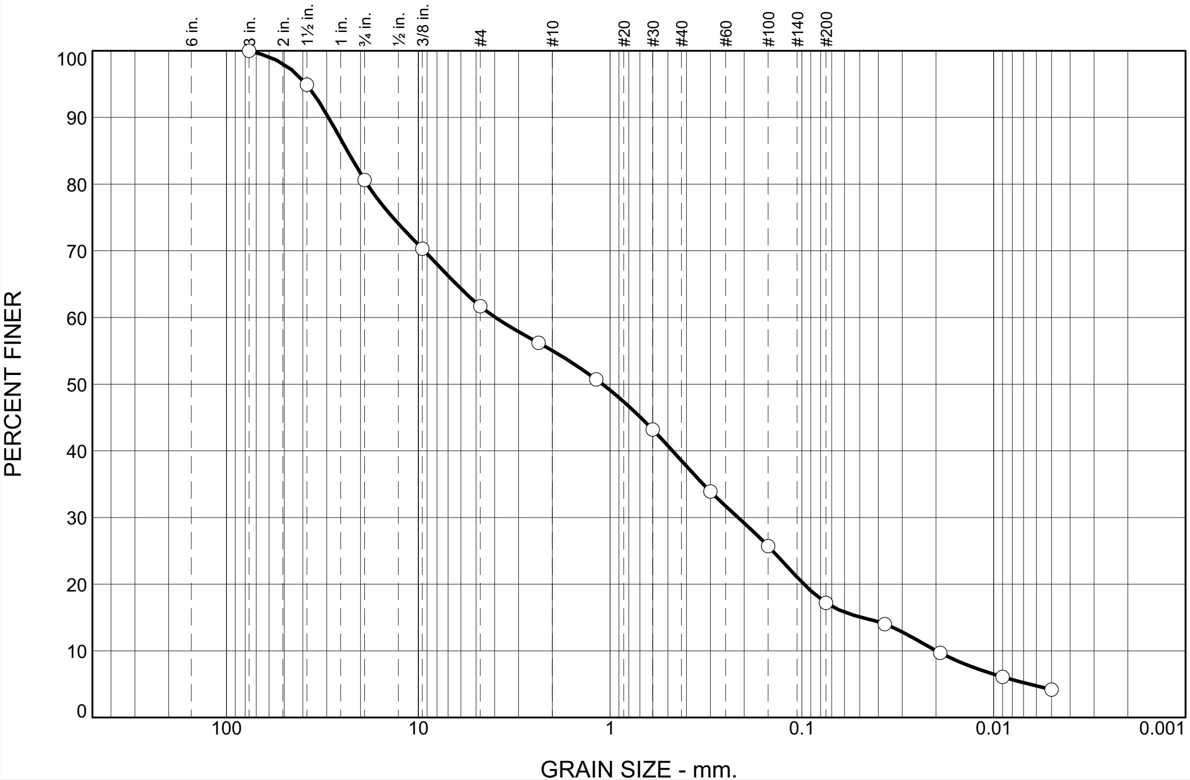
Sample Number: 65A-X815 **Depth:** 109.50-147.90 ft
Location: UE-25 RF #52
Date: 09/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 23

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	19.4	18.9	6.7	16.5	21.3	13.0	4.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	94.9		
.75in	80.6		
.375in	70.3		
#4	61.7		
#8	56.2		
#16	50.7		
#30	43.2		
#50	33.9		
#100	25.7		
#200	17.2		
.037mm	14.0		
.019mm	9.7		
.009mm	6.1		
.005mm	4.2		

* (no specification provided)

Material Description

Silty sand with gravel

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 23.4364 D_{60}= 3.9565 D_{50}= 1.0961
D_{30}= 0.2152 D_{15}= 0.0486 D_{10}= 0.0199
C_u= 198.93 C_c= 0.59

Classification

USCS= SM AASHTO=

Remarks

-No.4 Specific Gravity = 2.53
+No.4 Apparent Specific Gravity = 2.44
Absorption = 6.7 %

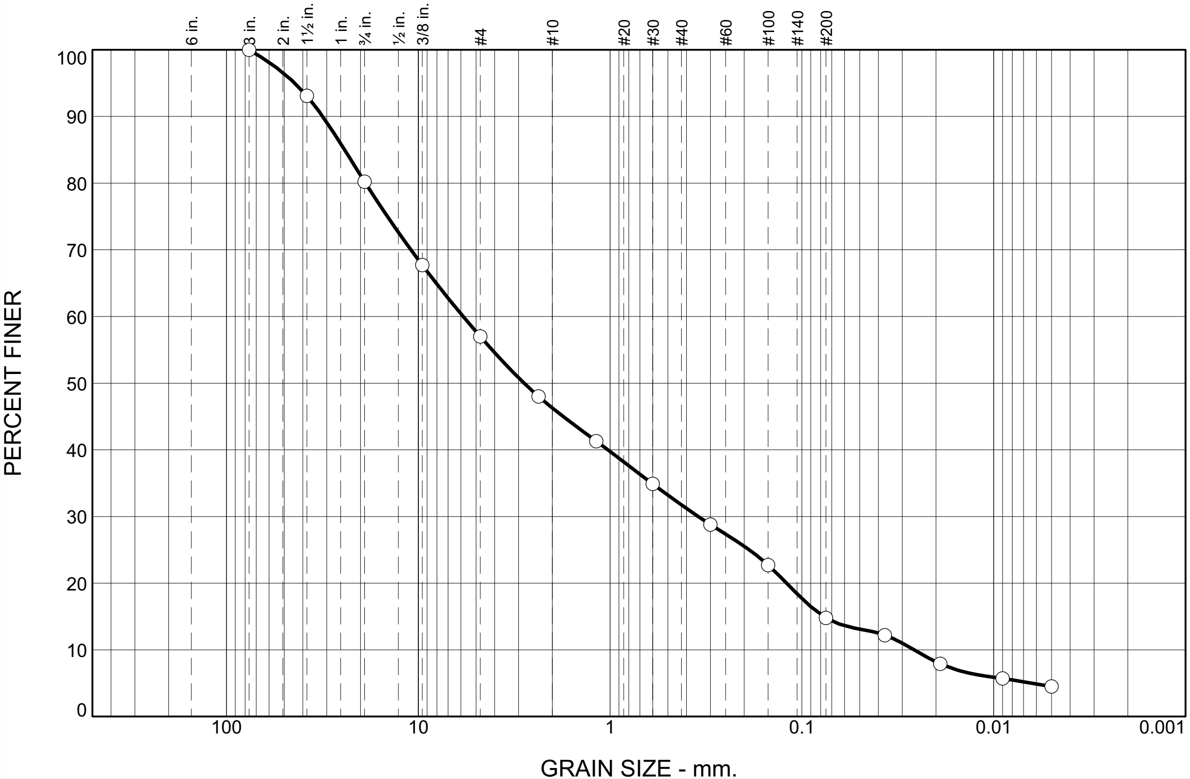
Sample Number: 65A-X816 **Depth:** 149.80-152.50 ft
Location: UE-25 RF #52 **Date:** 9/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 24

Tested By: Bowen / Sheorn **Checked By:** Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	19.8	23.2	10.7	14.6	16.9	10.3	4.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	93.1		
.75in	80.2		
.375in	67.7		
#4	57.0		
#8	48.0		
#16	41.3		
#30	34.9		
#50	28.8		
#100	22.7		
#200	14.8		
.037mm	12.2		
.019mm	7.9		
.009mm	5.7		
.005mm	4.5		

* (no specification provided)

Material Description

Silty gravel with sand
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 24.2220 D_{60}= 5.8341 D_{50}= 2.8062
D_{30}= 0.3471 D_{15}= 0.0770 D_{10}= 0.0260
C_u= 224.63 C_c= 0.80

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.54
+No.4 Apparent Specific Gravity = 2.44
Absorption = 5.0 %

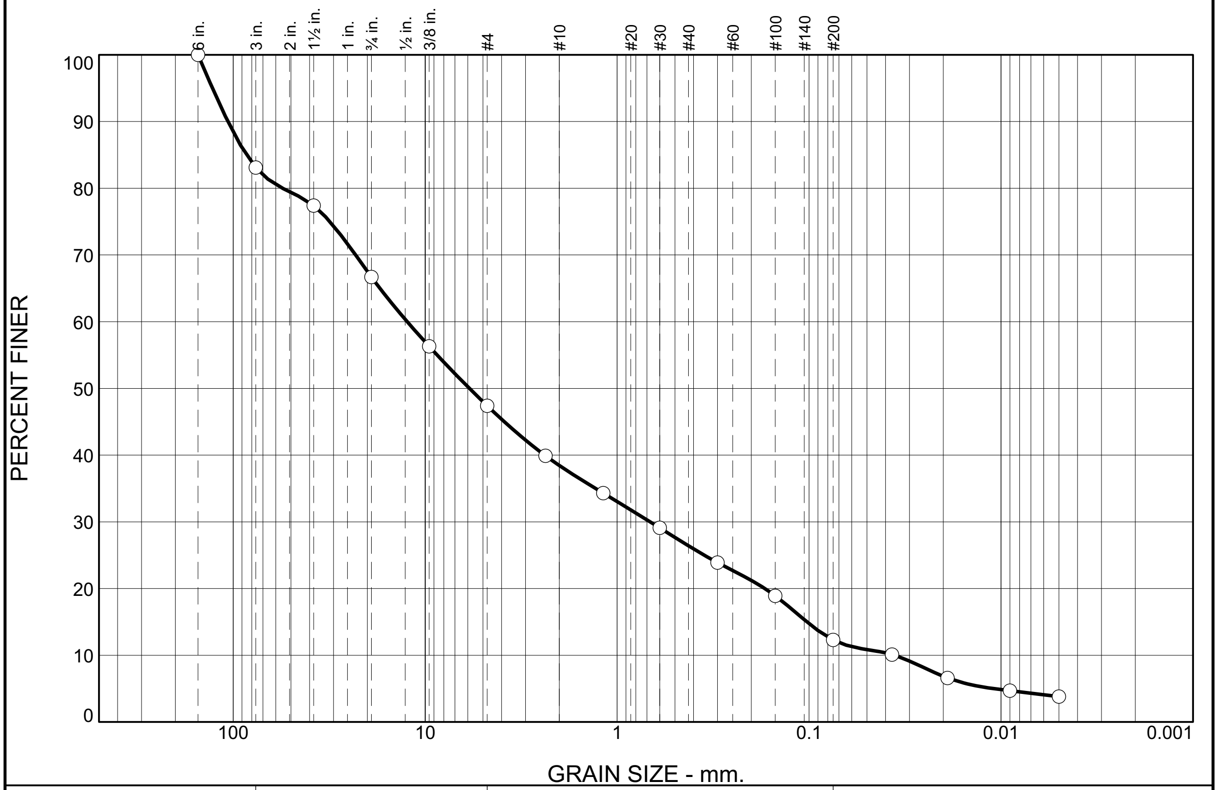
Sample Number: 65A-X817 (minus 3") **Depth:** 152.50-155.70 ft
Location: UE-25 RF #52 **Date:** 09/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 25

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
16.9	16.4	19.3	9.0	12.0	14.1	8.5	3.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	83.1		
1.5in	77.4		
.75in	66.7		
.375in	56.3		
#4	47.4		
#8	39.9		
#16	34.3		
#30	29.1		
#50	23.9		
#100	18.9		
#200	12.3		
.037mm	10.1		
.019mm	6.6		
.009mm	4.7		
.005mm	3.8		

* (no specification provided)

Material Description

Silty gravel with sand

Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 85.2571 D_{60}= 12.4034 D_{50}= 5.8785
D_{30}= 0.6735 D_{15}= 0.1026 D_{10}= 0.0360
C_u= 344.29 C_c= 1.02

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.54
+No.4 Apparent Specific Gravity = 2.44
Absorption = 5.0 %

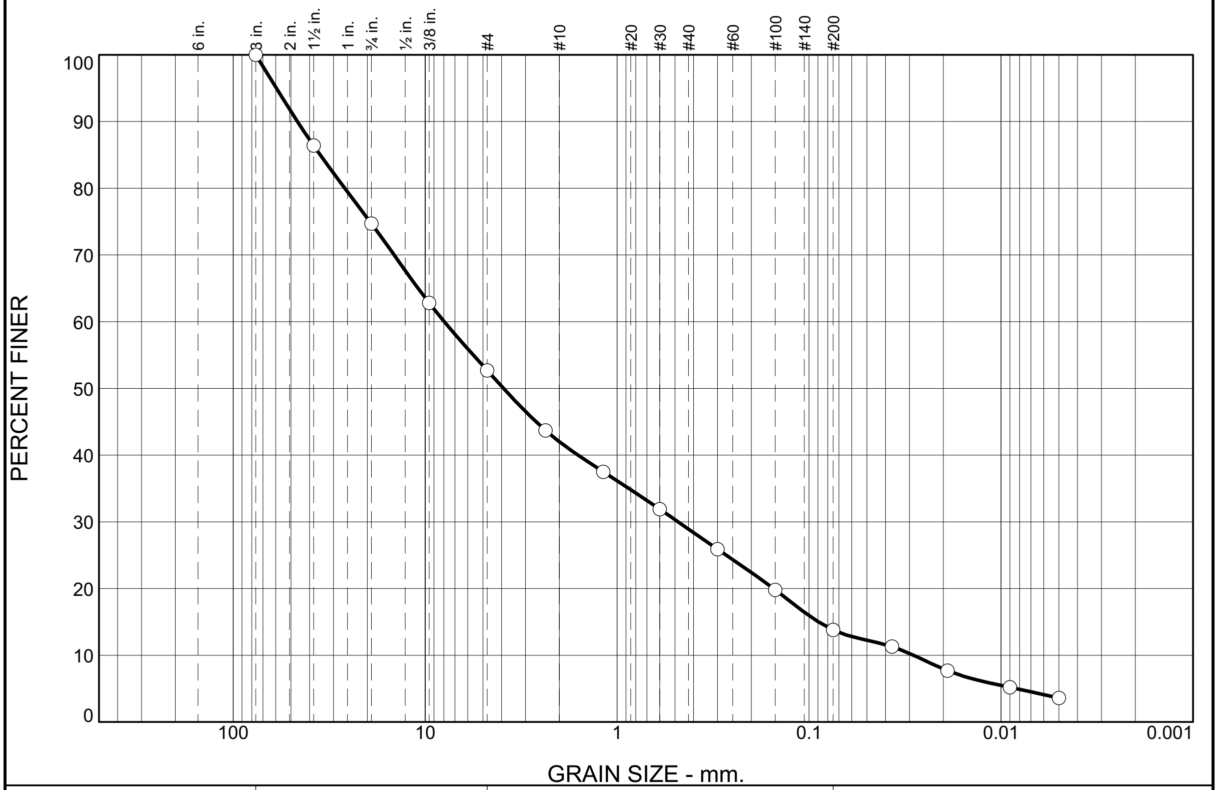
Sample Number: 65A-X817 **Depth:** 152.50-155.70 ft
Location: UE-25 RF #52
Date: 09/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 26

Tested By: Bowen / Shehorn **Checked By:** Hart / Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	25.3	22.0	10.7	13.1	15.1	10.2	3.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3in	100.0		
1.5in	86.4		
.75in	74.7		
.375in	62.8		
#4	52.7		
#8	43.7		
#16	37.5		
#30	31.9		
#50	25.9		
#100	19.8		
#200	13.8		
.037mm	11.3		
.019mm	7.7		
.009mm	5.2		
.005mm	3.6		

* (no specification provided)

Material Description

Silty gravel with sand
Plus 3-inch material removed

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 35.2116 D_{60}= 7.9509 D_{50}= 3.9031
D_{30}= 0.4813 D_{15}= 0.0893 D_{10}= 0.0285
C_u= 278.54 C_c= 1.02

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.53
+No.4 Apparent Specific Gravity = 2.45
Absorption = 4.7 %

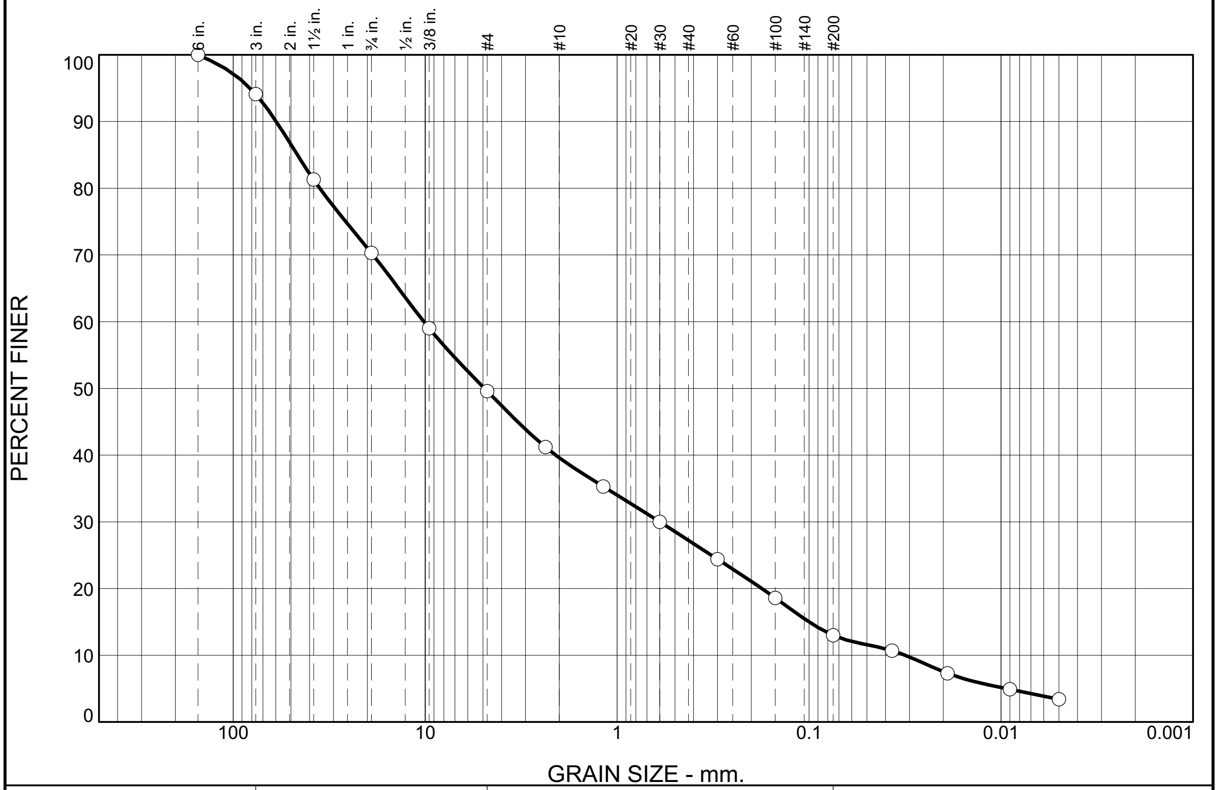
Sample Number: 65A-X818 (minus 3") **Depth:** 157.80-160.70 ft
Location: UE-25 RF #52 **Date:** 09/18/2006

BUREAU
OF
RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 27

Tested By: Bowen / Shehorn **Checked By:** Reo

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
5.9	23.8	20.7	10.0	12.4	14.2	9.6	3.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
6in	100.0		
3in	94.1		
1.5in	81.3		
.75in	70.3		
.375in	59.0		
#4	49.6		
#8	41.2		
#16	35.3		
#30	30.0		
#50	24.4		
#100	18.6		
#200	13.0		
.037mm	10.7		
.019mm	7.3		
.009mm	4.9		
.005mm	3.4		

* (no specification provided)

Material Description

Silty gravel with sand
Sample contains plus 3-inch material, classification may change when based on minus 3-inch material only

Atterberg Limits

PL= NP LL= NP PI= NP

Coefficients

D_{85}= 46.1994 D_{60}= 10.1611 D_{50}= 4.9013
D_{30}= 0.6000 D_{15}= 0.1001 D_{10}= 0.0316
C_u= 321.82 C_c= 1.12

Classification

USCS= GM AASHTO=

Remarks

-No.4 Specific Gravity = 2.53
+No.4 Apparent Specific Gravity = 2.45
Absorption = 4.7 %

Sample Number: 65A-X818 **Depth:** 157.80-160.70 ft
Location: UE-25 RF #52 **Date:** 09/18/2006

BUREAU OF RECLAMATION

Client: Yucca Mountain Project
Project: Sonic Drill Core
Project No: 65A **Figure** 28

Tested By: Bowen / Shehorn **Checked By:** Reo

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ATTACHMENT IV

SASW SHEAR WAVE VELOCITY PROFILES FROM (SURFACE) NPF SITES

ATTACHMENT IV
SASW SHEAR WAVE VELOCITY PROFILES FROM (SURFACE) NPF SITES

As outlined in Section 6.2.5, in 2004 and 2005, Spectral-Analysis-of-Surface-Wave (SASW) surveys were performed in the areas around the North Portal Facility (NPF). This testing consisted of 18 SASW surveys as listed in Table 6.2-5. Additionally, six sites were surveyed covering the planned aging pads as they existed in the 2004 design. These sites are designated as Aging Pad (AP) sites and are covered in Section 6.2.5.4 and listed in Table 6.2-9. The SASW theoretical dispersion curves generated from experimental dispersion curves and one-dimensional, layered, shear wave velocity (V_S) profiles for 18 surface sites around the NPF Area and six AP sites are presented in this attachment.

The theoretical dispersion curves were developed using WinSASW V. 1.23 (STN: 10588-1.23-00 [DIRS 159433]). The theoretical dispersion curve is fit to the experimental curve through an iterative forward modeling process. Tabular data for the theoretical dispersion curves and velocity profiles are contained in DTN: MO0609SASWSTDC.003 [DIRS 182125], while plots of the data are presented in the scientific notebook supplement accompanying the data package (Stokoe 2007 [DIRS 183327]).

In many cases multiple arrays were tested at each site. These arrays are numbered as T1 and/or T2. When no T1 is specified for the SASW line, only one array was tested at that location. The stratigraphic definitions shown on the plots are included for information purposes only. The stratigraphic information is from DTN: MO0012MWDGFM02.002 [DIRS 153777] queried by the software EarthVision v5.1 (STN: 10174-5.1-00 [DIRS 167994]). The theoretical dispersion curves and shear wave velocity profiles are presented in alphanumeric order beginning on page IV-7. Table IV-1 shows the As-Built survey coordinates (DTN: MO0701ABSRFLL2.000 [DIRS 182483]) for NPF sites and Table IV-2 shows the as-built survey coordinates for AP sites.

Table IV-1. As-Built Survey Coordinates for SASW NPF Sites

Location-Test-Point ID	Coord. Northing	Coord. Easting	Elev.	Scientific Notebook Page	Descriptor
NPF 1-T1-N	766065.37	570393.99	3681.66	65	SASW RF P-1-NEAR
NPF 1-T1-C	765841.68	570276.72	3680.43		SASW RF P-1-CENTER
NPF 1-T1-F	765421.16	570083.37	3680.14		SASW RF P-1-FAR
NPF 1-T2-N	766098.39	570413.09	3680.42	77	SASW RF P1-NEW-NEAR
NPF 1-T2-C	765869.34	570306.99	3680.28		SASW RF P1-NEW-CENTER
NPF 1-T2-F	765421.04	570083.78	3680.11		SASW RF P1-NEW-FAR
NPF 2-T1-N	764963.65	571080.89	3643.09	66	SASW RF P-2-NEAR
NPF 2-T1-C	764713.07	571088.25	3636.54		SASW RF P-2-CENTER
NPF 3-T1-N	766007.17	571013.73	3668.08	67	SASW RF P-3-NEAR
NPF 3-T1-C	765768.96	571088.43	3664.00		SASW RF P-3-CENTER
NPF 3-T1-F	764347.19	571563.40	3623.25		SASW RF P-3-FAR
NPF 9-T1-N	765539.95	571146.84	3656.98	123	SASW RF P9-NEAR
NPF 9-T1-C	764820.52	571356.81	3635.42		SASW RF P9-CENTER
NPF 9-T1-F	764099.77	571566.88	3623.87		SASW RF P9-FAR

Table IV-1. As-Built Survey Coordinates for SASW NPF Sites (Continued)

Location-Test-Point ID	Coord. Northing	Coord. Easting	Elev.	Scientific Notebook Page	Descriptor
NPF 10-T1-N	765451.20	571538.78	3650.43	125	SASW RF P10-NEAR
NPF 10-T1-C	766199.33	571480.13	3672.03		SASW RF P10-CENTER
NPF 10-T1-F	766945.61	571414.00	3686.28		SASW RF P10-FAR
NPF 12-T1-N	767384.94	572235.38	3693.35	127	SASW RF P12-NEAR
NPF 12-T1-C	766634.56	572265.22	3664.57		SASW RF P12-CENTER
NPF 12-T1-F	765885.16	572299.12	3651.50		SASW RF P12-FAR
NPF 14-T1-N	764551.51	570976.57	3636.89	123	SASW RF P14-NEAR
NPF 14-T1-C	763803.30	570926.16	3653.16		SASW RF P14-CENTER
NPF 14-T1-F	763054.69	570881.65	3674.55		SASW RF P14-FAR
NPF 16-T1-N	763398.40	570951.00	3661.87	78	SASW RF R16-NEAR
NPF 16-T1-C	763119.37	571053.01	3667.15		SASW RF R16-CENTER
NPF 16-T1-F	762552.00	571245.89	3671.71		SASW RF R16-FAR
NPF 17-T1-N	Not Found			79	SASW RF R17-NEAR
NPF 17-T1-C	Not Found				SASW RF R17-CENTER
NPF 17-T1-F	761413.40	571625.12	3655.79		SASW RF R17-FAR
NPF 17-T2-N	762866.26	571157.61	3669.57	99	SASW RF P17-NEAR
NPF 17-T2-C	762128.56	571470.26	3663.40		SASW RF P17-CENTER
NPF 17-T2-F	760646.83	572073.86	3631.66		SASW RF P17-FAR
NPF 19-T1-N	765222.23	571696.38	3643.44	151	SASW RF NPF 19-T1-NEAR
NPF 19-T1-C	765402.61	571870.58	3646.27		SASW RF NPF 19-T1-CENTER
NPF 19-T1-F	765759.82	572220.58	3648.23		SASW RF NPF 19-T1-FAR
NPF 20-T1-N	765694.63	571562.36	3657.74	153	SASW RF NPF 20-T1-NEAR
NPF 20-T1-C	766013.08	571878.85	3661.60		SASW RF NPF 20-T1-CENTER
NPF 20-T1-F	766640.84	572525.87	3665.69		SASW RF NPF 20-T1-FAR
NPF 21-T1-N	766057.99	571925.18	3661.61	153	SASW RF NPF 21-T1-NEAR
NPF 21-T1-C	765776.71	571641.02	3657.66		SASW RF NPF 21-T1-CENTER
NPF 21-T1-F	765218.90	571067.04	3649.24		SASW RF NPF 21-T1-FAR
NPF 22-T1-N	766528.26	571723.81	3675.87	156	SASW RF NPF 22-T1-NEAR
NPF 22-T1-C	766266.14	571578.25	3671.85		SASW RF NPF 22-T1-CENTER
NPF 22-T1-F	765739.70	571288.38	3661.43		SASW RF NPF 22-T1-FAR
NPF 22-T2-N	766404.43	571722.88	3672.69	156	SASW RF NPF 22-T2-NEAR
NPF 22-T2-C	766266.21	571578.01	3671.88		SASW RF NPF 22-T2-CENTER
NPF 22-T2-F	765988.32	571289.85	3667.26		SASW RF NPF 22-T2-FAR
NPF 23-T1-N	765132.31	571467.55	3643.92	156	SASW RF NPF 23-T1-NEAR
NPF 23-T1-C	765620.48	571353.85	3657.13		SASW RF NPF 23-T1-CENTER
NPF 23-T1-F	766595.37	571135.17	3684.66		SASW RF NPF 23-T1-FAR

Table IV-1. As-Built Survey Coordinates for SASW NPF Sites (Continued)

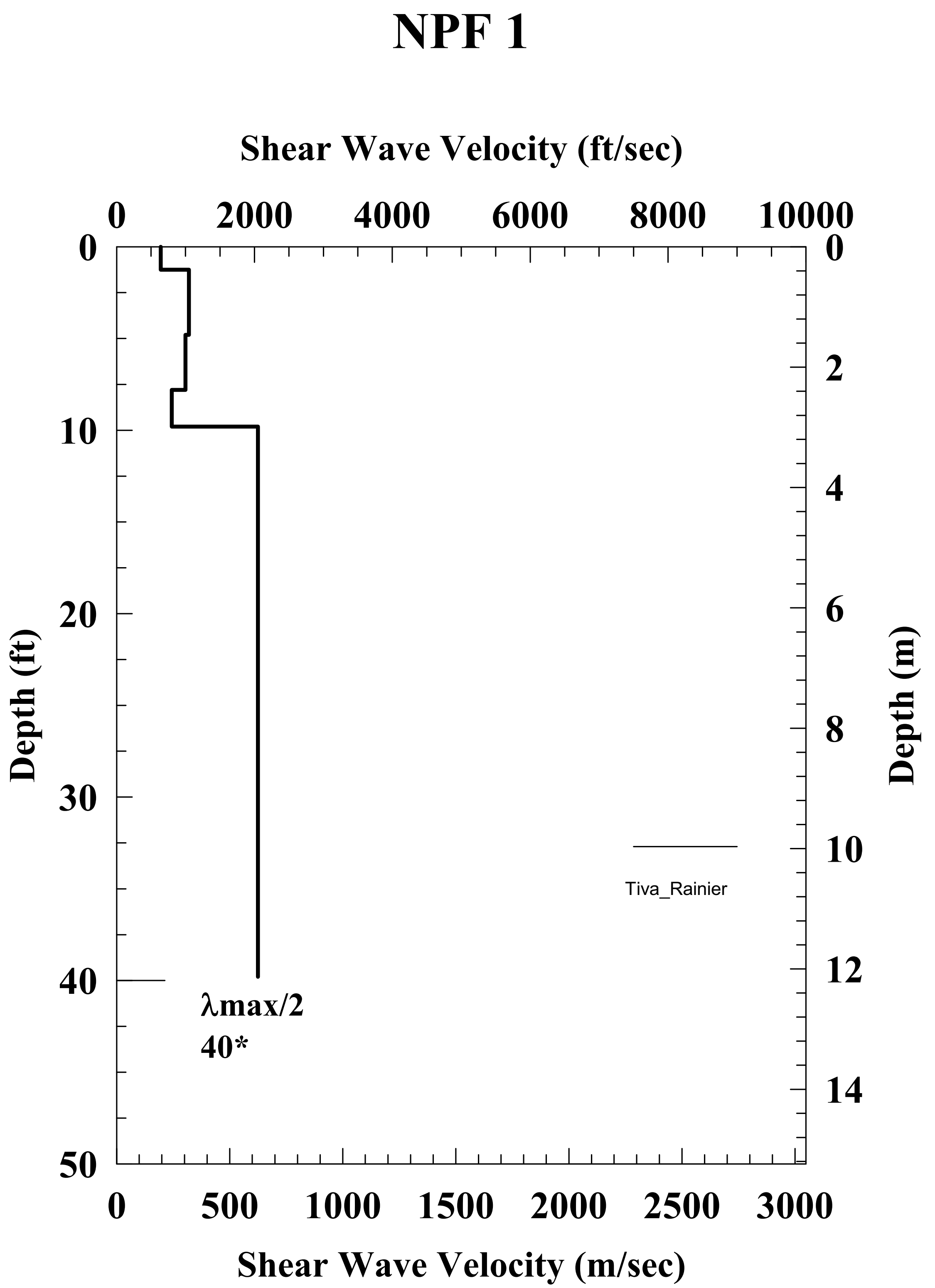
Location-Test-Point ID	Coord. Northing	Coord. Easting	Elev.	Scientific Notebook Page	Descriptor
NPF 23-T2-N	765376.32	571409.90	3651.15	157	SASW RF NPF 23-T2-NEAR
NPF 23-T2-C	766109.98	571252.36	3671.19		SASW RF NPF 23-T2-CENTER
NPF 23-T2-F	766847.01	571089.43	3691.95		SASW RF NPF 23-T2-FAR
NPF 24-T1-N	766687.71	571792.22	3672.53	158	SASW RF NPF 24-T1-NEAR
NPF 24-T1-C	765692.92	571690.62	3656.22		SASW RF NPF 24-T1-CENTER
NPF 24-T1-F	765194.51	571640.52	3643.08		SASW RF NPF 24-T1-FAR
NPF 25-T1-N	767277.20	571876.17	3691.80	159	SASW RF NPF 25-T1-NEAR
NPF 25-T1-C	766776.42	571880.07	3673.68		SASW RF NPF 25-T1-CENTER
NPF 25-T1-F	766527.23	571882.24	3672.83		SASW RF NPF 25-T1-FAR
NPF 25-T2-N	766376.58	571880.56	3670.35	159	SASW RF NPF 25-T2-NEAR
NPF 25-T2-C	766776.31	571880.03	3673.67		SASW RF NPF 25-T2-CENTER
NPF 25-T2-F	767576.75	571874.32	3703.32		SASW RF NPF 25-T2-FAR
NPF 26-T1-N	765984.07	572007.53	3658.36	161	SASW RF NPF 26-T1-NEAR
NPF 26-T1-C	766264.52	571901.84	3666.71		SASW RF NPF 26-T1-CENTER
NPF 26-T1-F	766816.17	571689.53	3678.48		SASW RF NPF 26-T1-FAR
NPF 27-T1-N	766225.00	571896.91	3665.40	163	SASW RF NPF 27-T1-NEAR
NPF 27-T1-C	765993.84	571668.86	3663.14		SASW RF NPF 27-T1-CENTER
NPF 27-T1-F	765530.04	571213.56	3656.50		SASW RF NPF 27-T1-FAR
NPF 28-T1-N	765966.25	570598.20	3676.39	198	SASW RF NPF 28-T1-NEAR
NPF 28-T1-C	765793.42	570497.91	3676.24		SASW RF NPF 28-T1-CENTER
NPF 28-T1-F	765404.64	570271.44	3676.33		SASW RF NPF 28-T1-FAR

Source: DTN: MO0701ABSRFLL2.000 [DIRS 182483].

Table IV-2. As-Built Survey Coordinates for SASW AP Sites

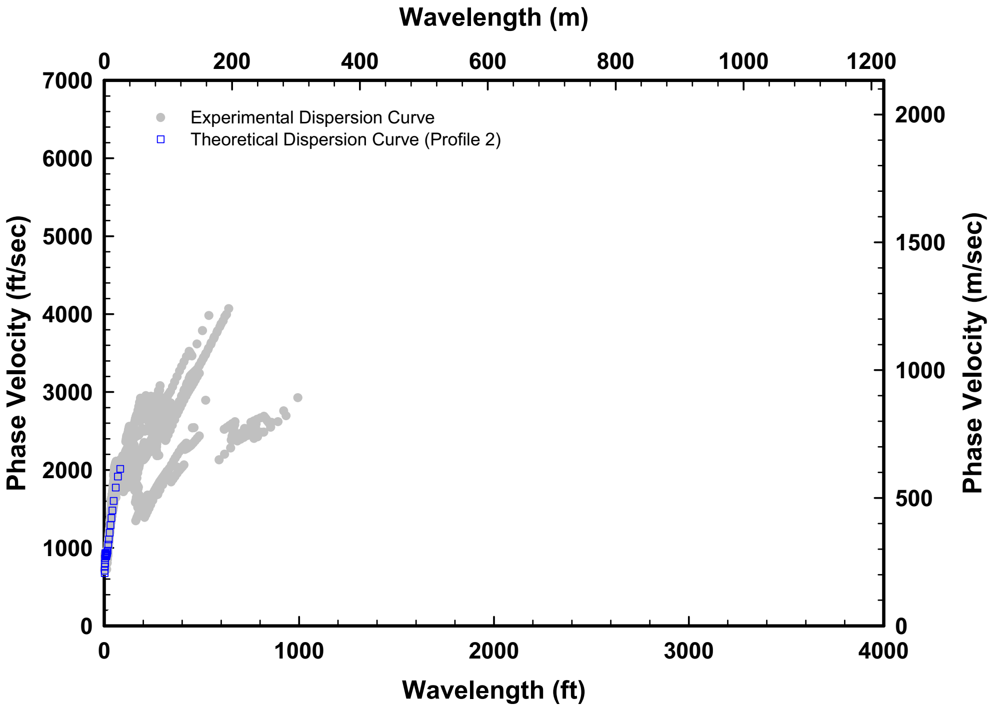
Location-Test-Point ID	Coord. Northing	Coord. Easting	Elev.	Scientific Notebook Page	Descriptor
AP 1-T1-N	767940.71	568917.64	3790.26	129	SASW RF A7-NEAR
AP 1-T1-C	768465.75	568931.69	3788.33		SASW RF A7-CENTER
AP 1-T1-F	769064.30	568982.65	3789.39		SASW RF A7-FAR
AP 3-T1-N	767994.99	569280.38	3773.95	130	SASW RF A8-NEAR
AP 3-T1-C	768515.01	569339.51	3764.07		SASW RF A8-CENTER
AP 3-T1-F	769109.05	569427.71	3784.18		SASW RF A8-FAR
AP 5-T1-N	767958.31	569629.76	3758.42	130	SASW RF A9-NEAR
AP 5-T1-C	768481.93	569588.42	3759.87		SASW RF A9-CENTER
AP 5-T1-F	769073.04	569792.81	3769.94		SASW RF A9-FAR
AP 6-T1-N	767903.58	568834.11	3793.60	164	SASW RF AP 6-T1-NEAR
AP 6-T1-C	767893.78	569233.06	3775.03		SASW RF AP 6-T1-CENTER
AP 6-T1-F	767874.14	570033.11	3740.00		SASW RF AP 6-T1-FAR
AP 6-T2-N	767882.93	569134.32	3778.39	164	SASW RF AP 6-T2-NEAR
AP 6-T2-C	767894.38	569233.54	3775.12		SASW RF AP 6-T2-CENTER
AP 6-T2-F	767918.60	569431.92	3766.96		SASW RF AP 6-T2-FAR
AP 7-T1-N	768176.56	568792.86	3799.90	166	SASW RF AP 7-T1-NEAR
AP 7-T1-C	768162.13	569242.04	3777.21		SASW RF AP 7-T1-CENTER
AP 7-T1-F	768132.03	570141.86	3737.81		SASW RF AP 7-T1-FAR
AP 7-T2-N	768187.86	568443.58	3818.87	166	SASW RF AP 7-T2-NEAR
AP 7-T2-C	768183.72	568542.06	3812.32		SASW RF AP 7-T2-CENTER
AP 7-T2-F	768179.50	568742.72	3802.96		SASW RF AP 7-T2-FAR
AP 8-T1-N	768572.01	568681.36	3797.17	167	SASW RF AP 8-T1-NEAR
AP 8-T1-C	768543.40	569181.04	3773.19		SASW RF AP 8-T1-CENTER
AP 8-T1-F	768486.97	570179.22	3744.69		SASW RF AP 8-T1-FAR
AP 8-T2-N	768591.93	568308.07	3818.30	167	SASW RF AP 8-T2-NEAR
AP 8-T2-C	768584.82	568433.21	3812.74		SASW RF AP 8-T2-CENTER
AP 8-T2-F	768571.06	568681.32	3797.22		SASW RF AP 8-T2-FAR

Source: DTN: MO0701ABSRFLL2.000 [DIRS 182483].



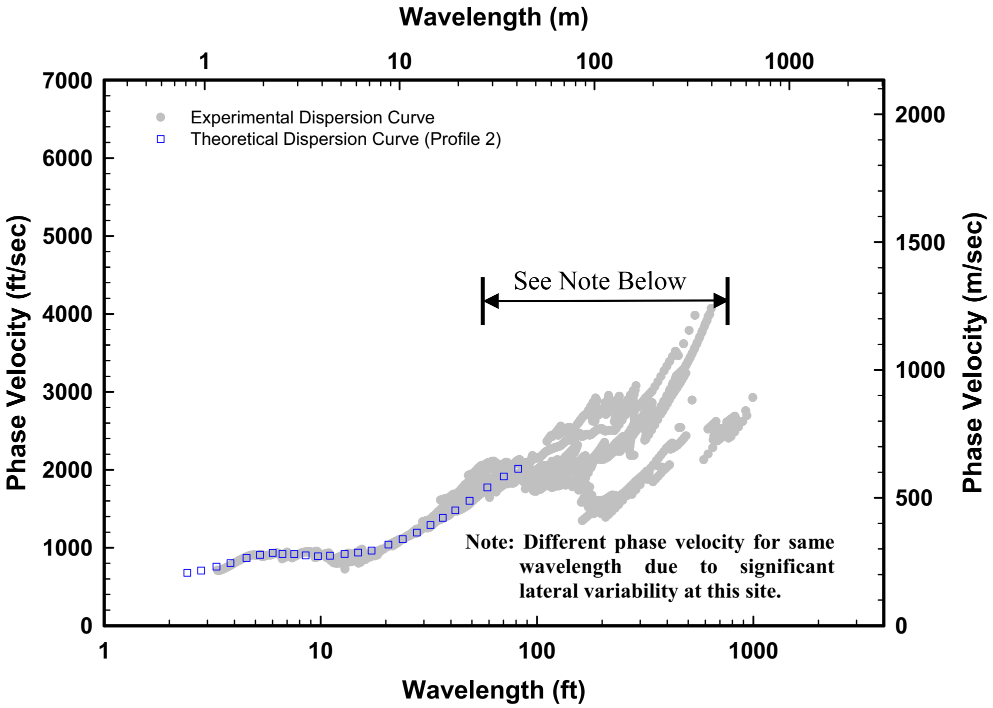
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-1. Shear Wave Velocity Profile Determined at NPF 1-T1 and NPF 1-T2



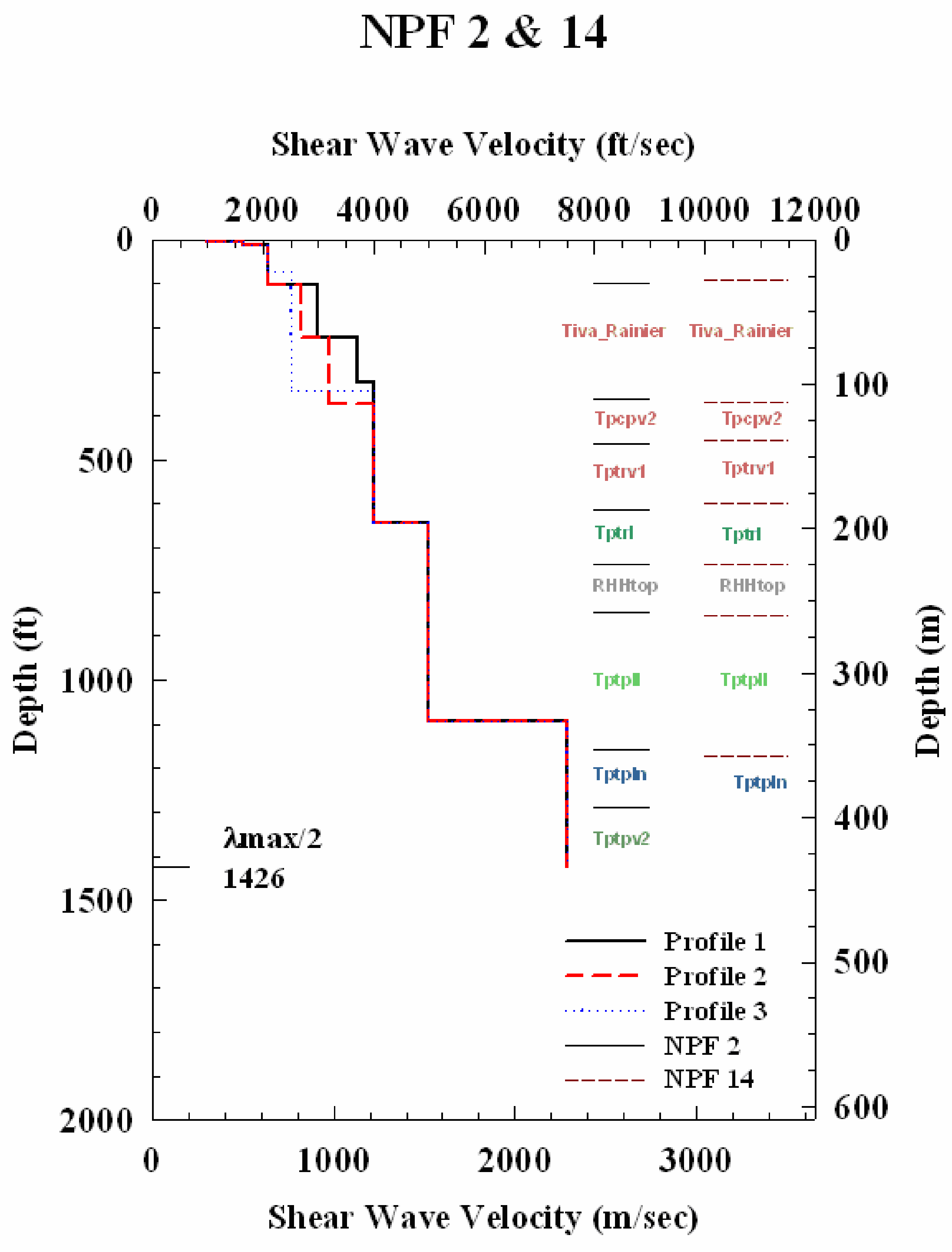
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-2. Experimental and Theoretical Dispersion Curves from NPF 1-T1 and NPF 1-T2; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

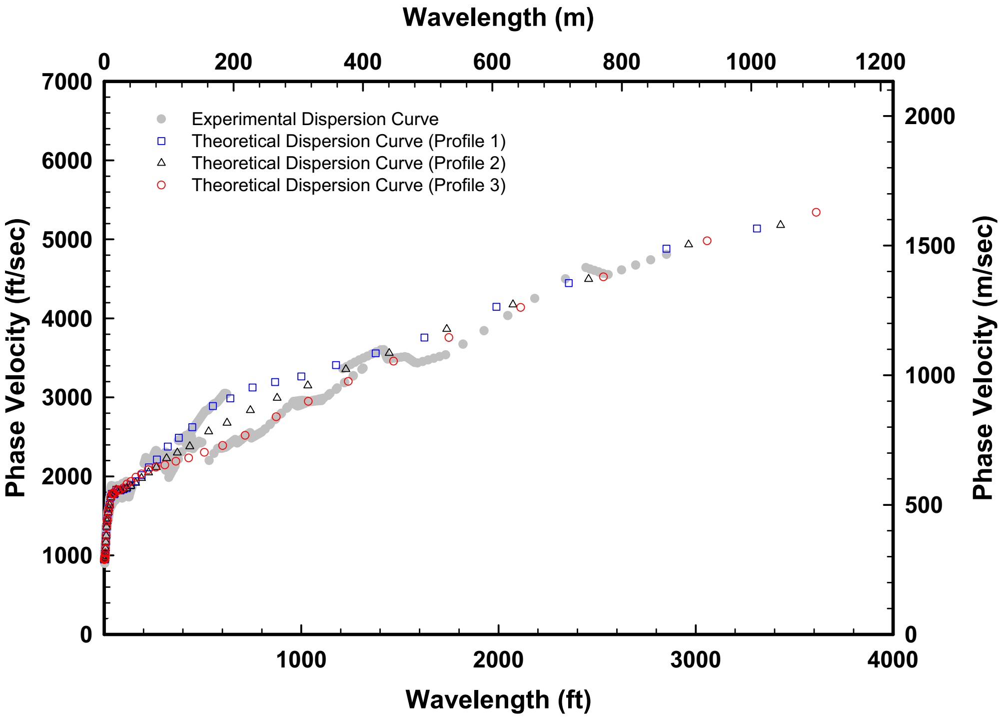
Figure IV-3. Experimental and Theoretical Dispersion Curves from NPF 1-T1 and NPF 1-T2; Logarithmic Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

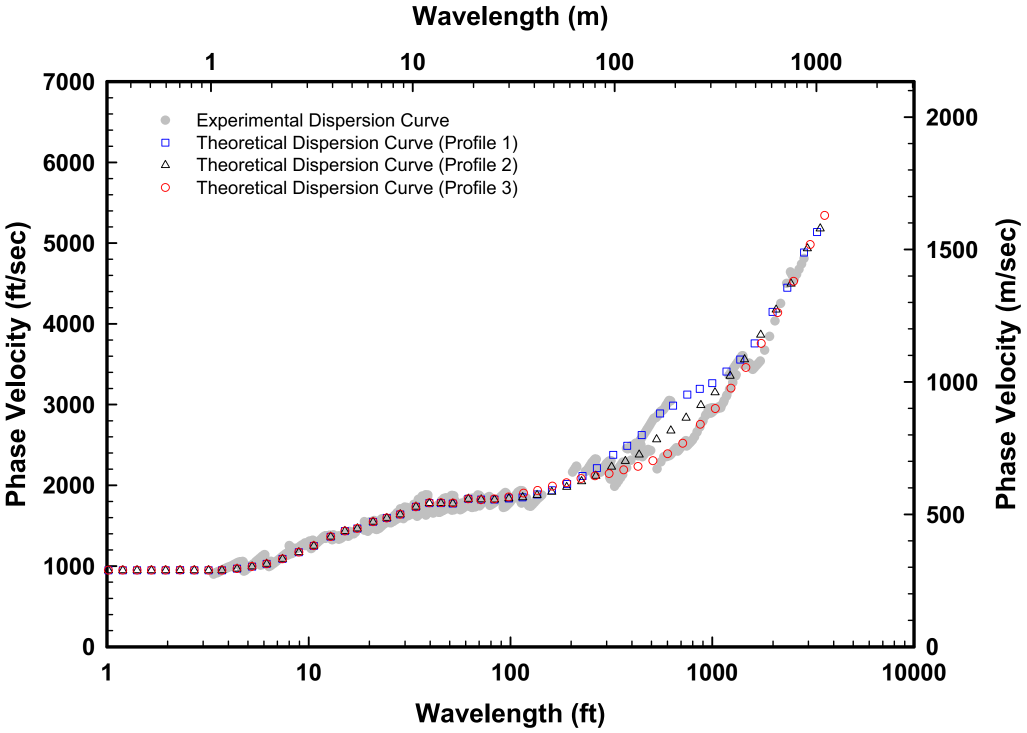
NOTE: The shear wave velocities are plotted for two different lines, NPF 2 and NPF 14.

Figure IV-4. Shear Wave Velocity Profile Determined at NPF 2 and NPF 14



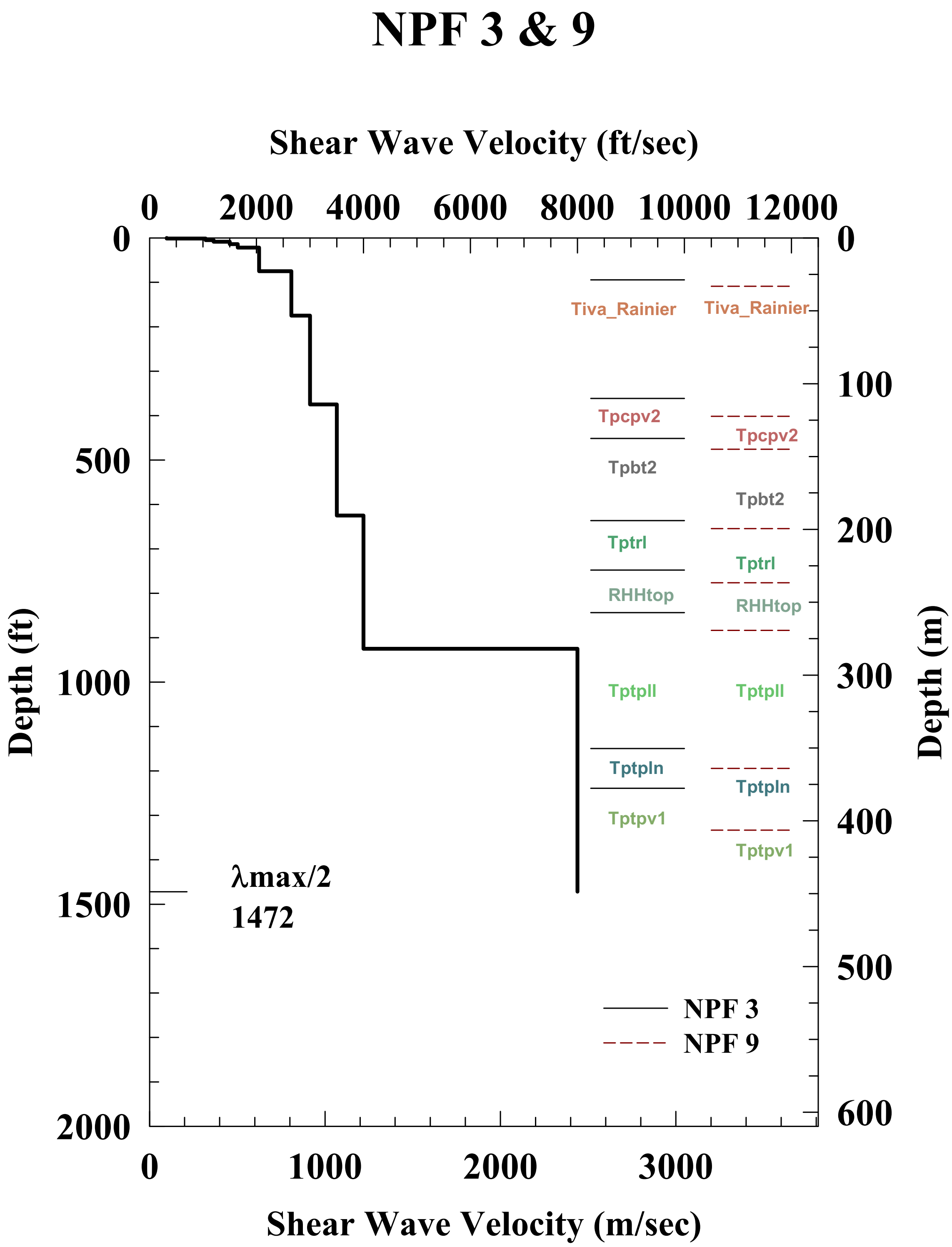
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-5. Experimental and Theoretical Dispersion Curves from NPF 2 and NPF 14; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

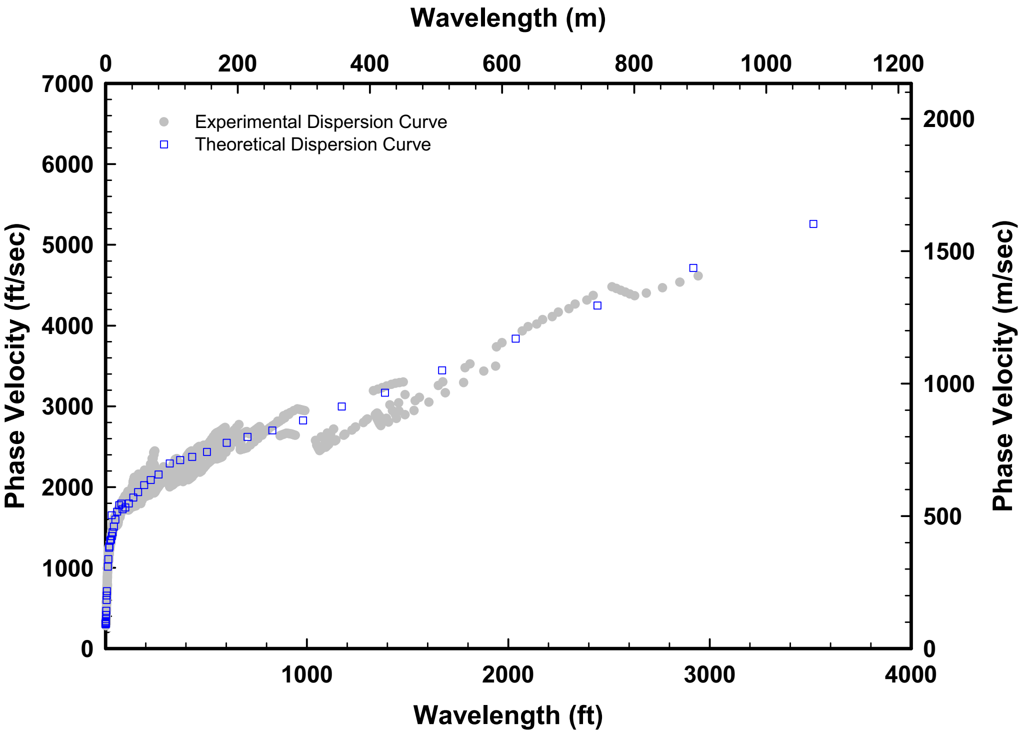
Figure IV-6. Experimental and Theoretical Dispersion Curves from NPF 2 and NPF 14; Logarithmic Wavelength Axis



Note: The shear wave velocities are plotted for two different lines NPF 3 and NPF 9.
NPF 3 longitude latitudes are Northing 765769.9 and Easting 571088.43
NPF 9 longitude latitudes are Northing 764820.5 and Easting 571356.81

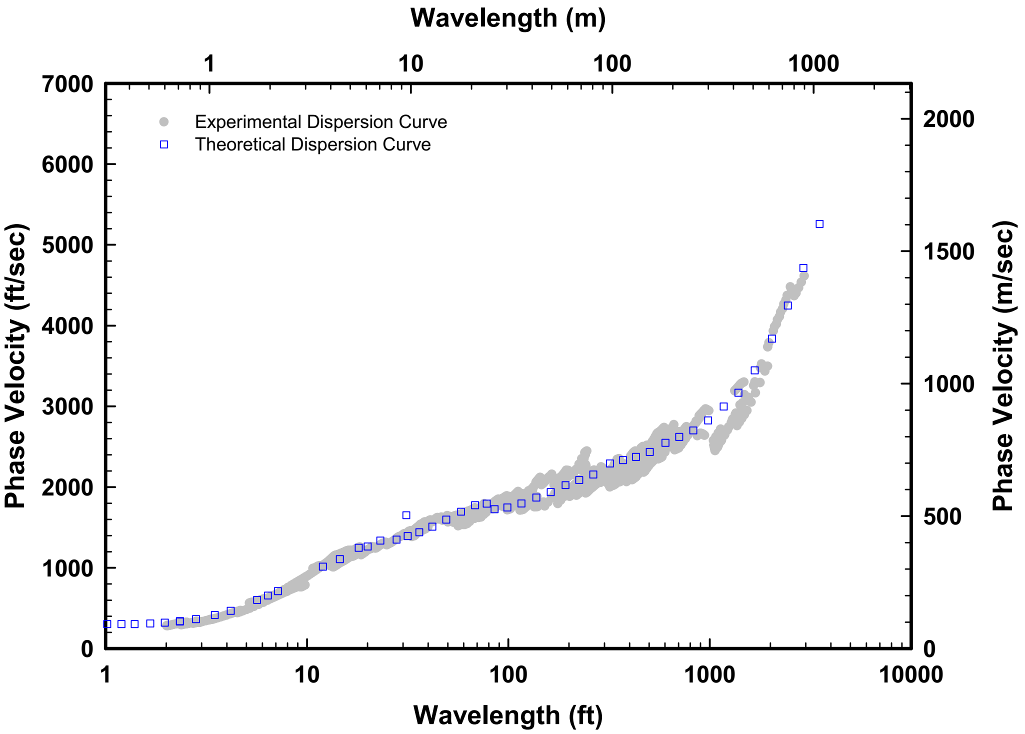
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-7. Shear Wave Velocity Profile Determined at NPF 3-T1 and NPF 9-T1



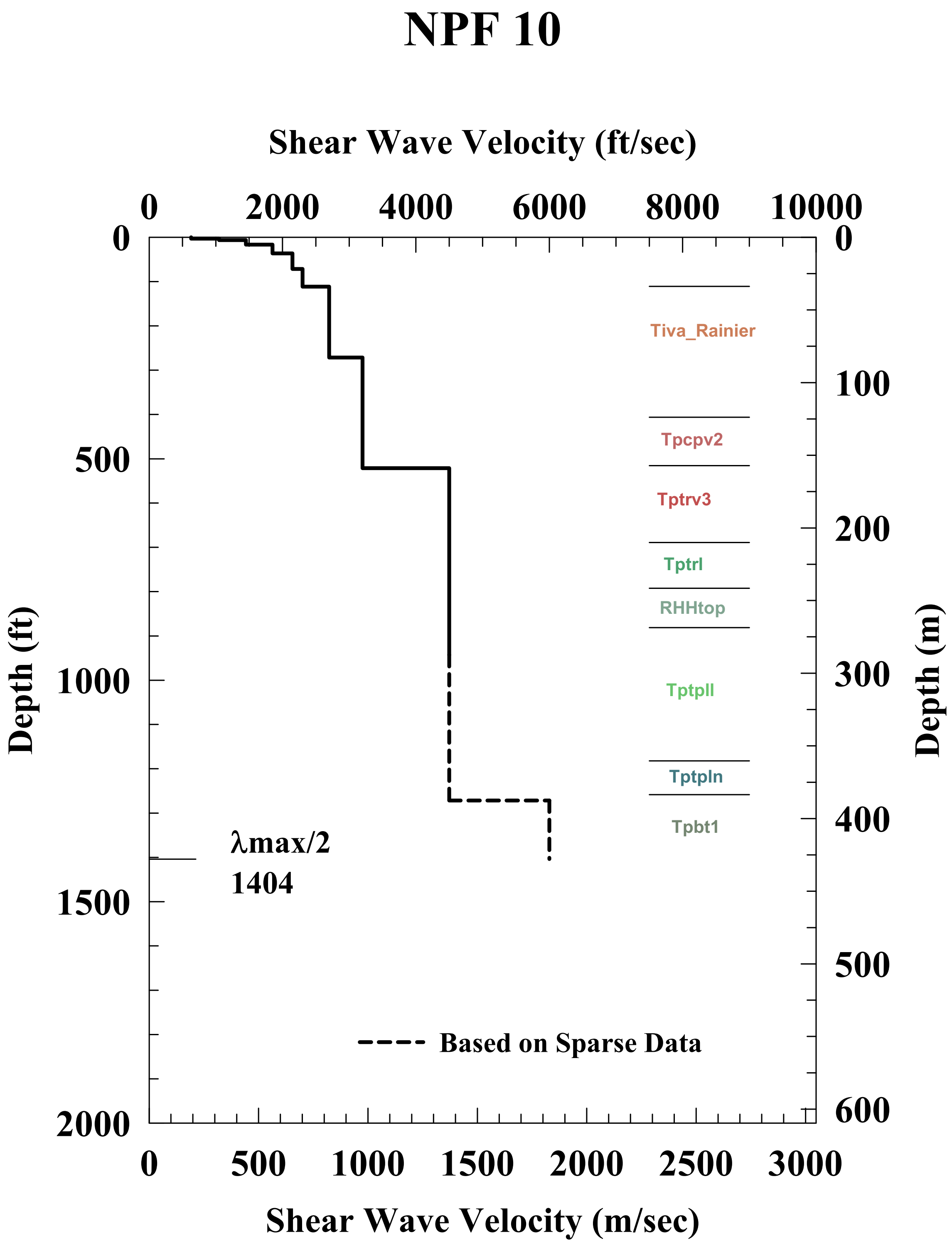
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-8. Experimental and Theoretical Dispersion Curves from NPF 3-T1 and NPF 9-T1; Linear Wavelength Axis



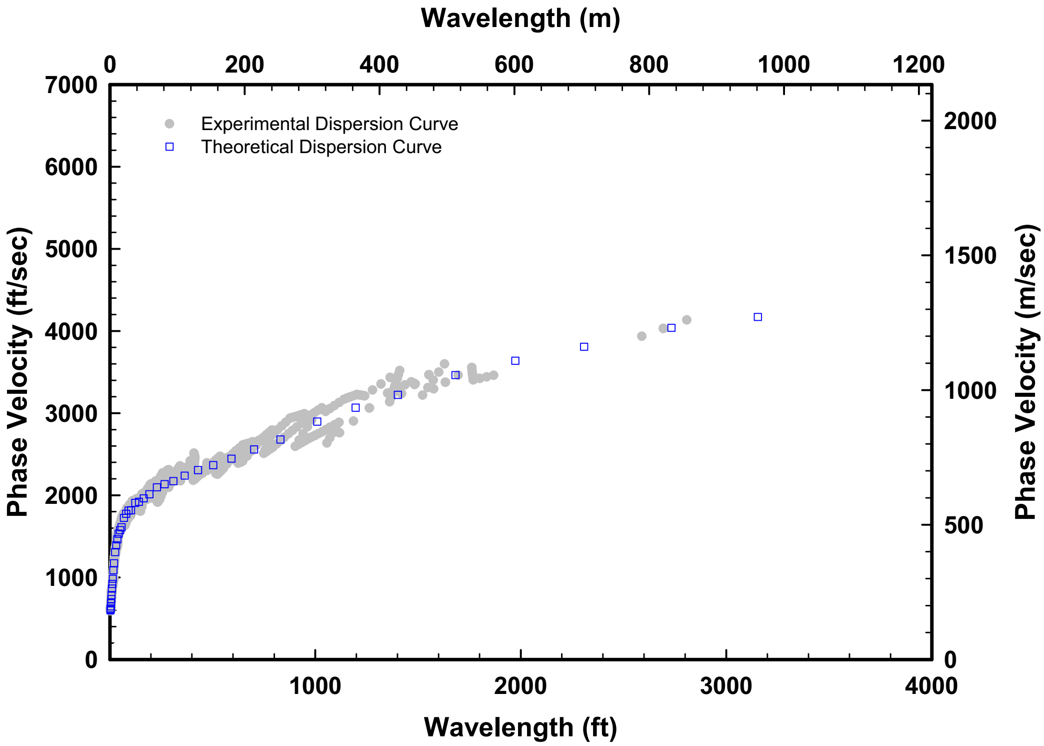
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-9. Experimental and Theoretical Dispersion Curves from NPF 3-T1 and NPF 9-T1; Logarithmic Wavelength Axis



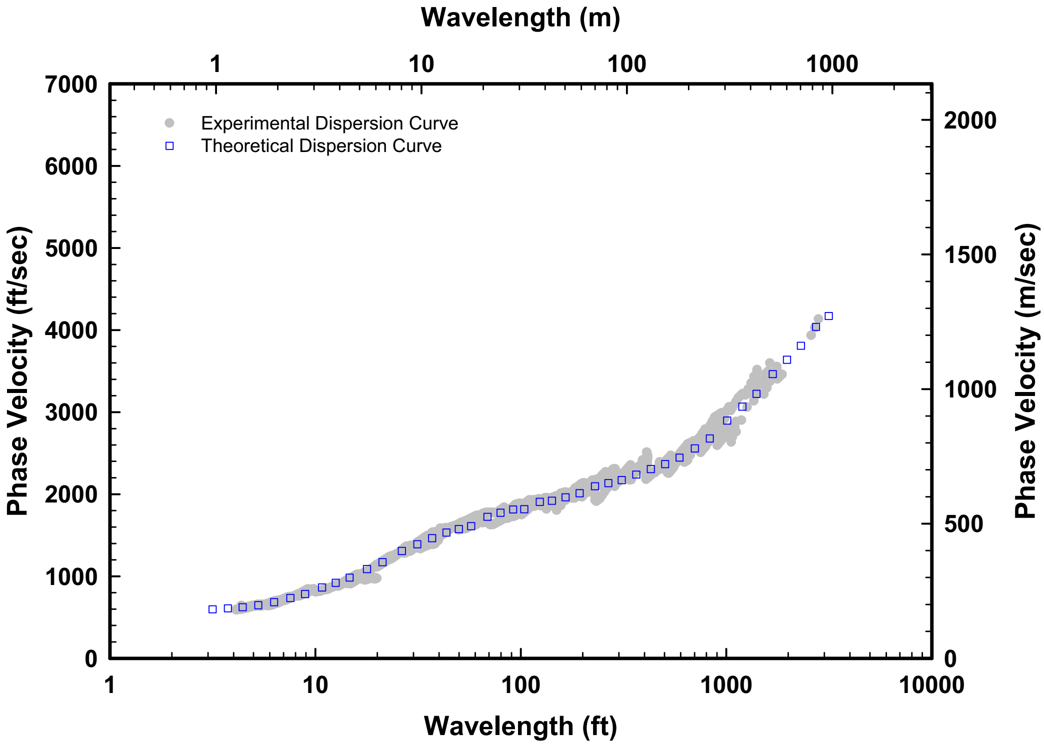
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-10. Shear Wave Velocity Profile Determined at NPF 10



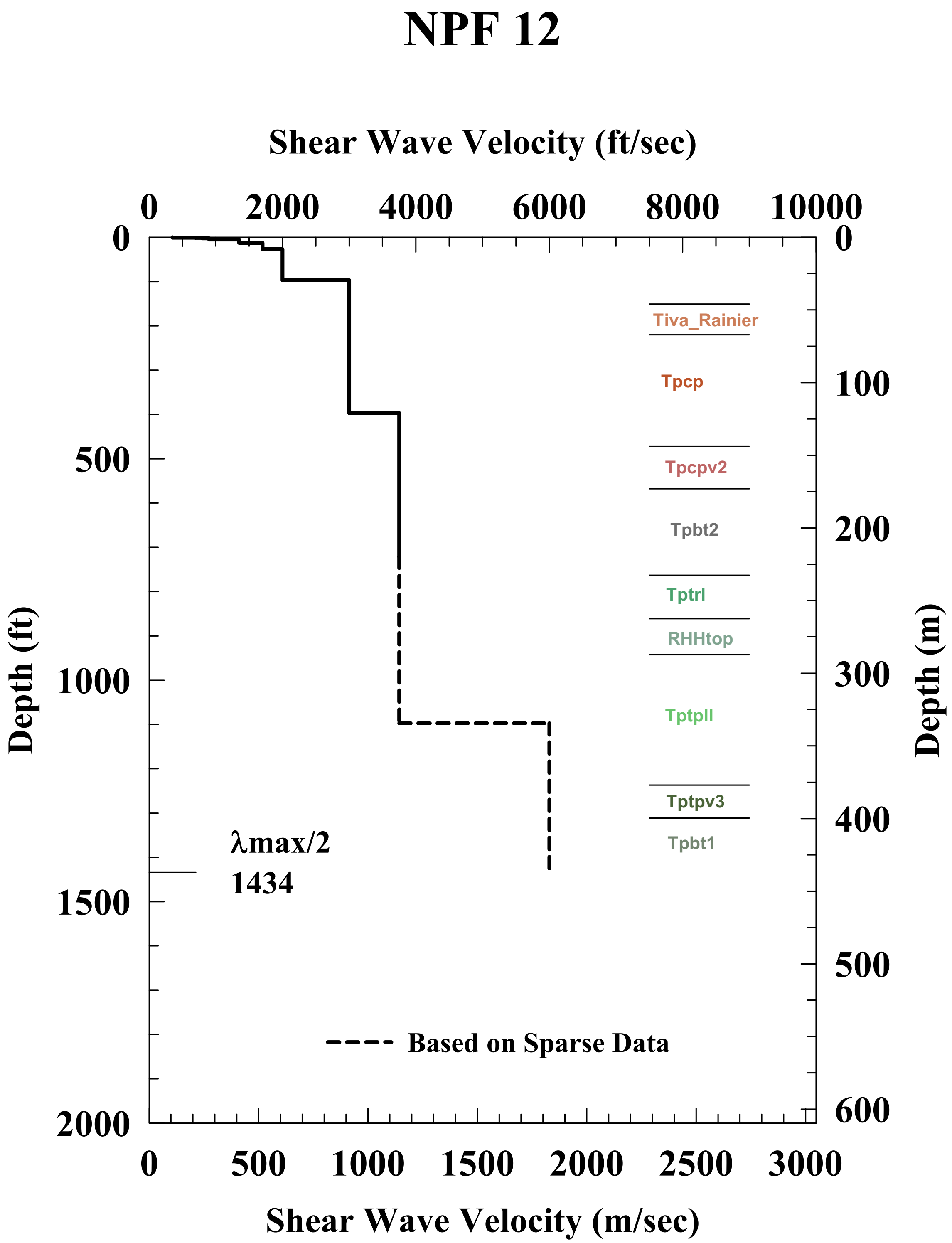
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-11. Experimental and Theoretical Dispersion Curves from NPF 10; Linear Wavelength Axis



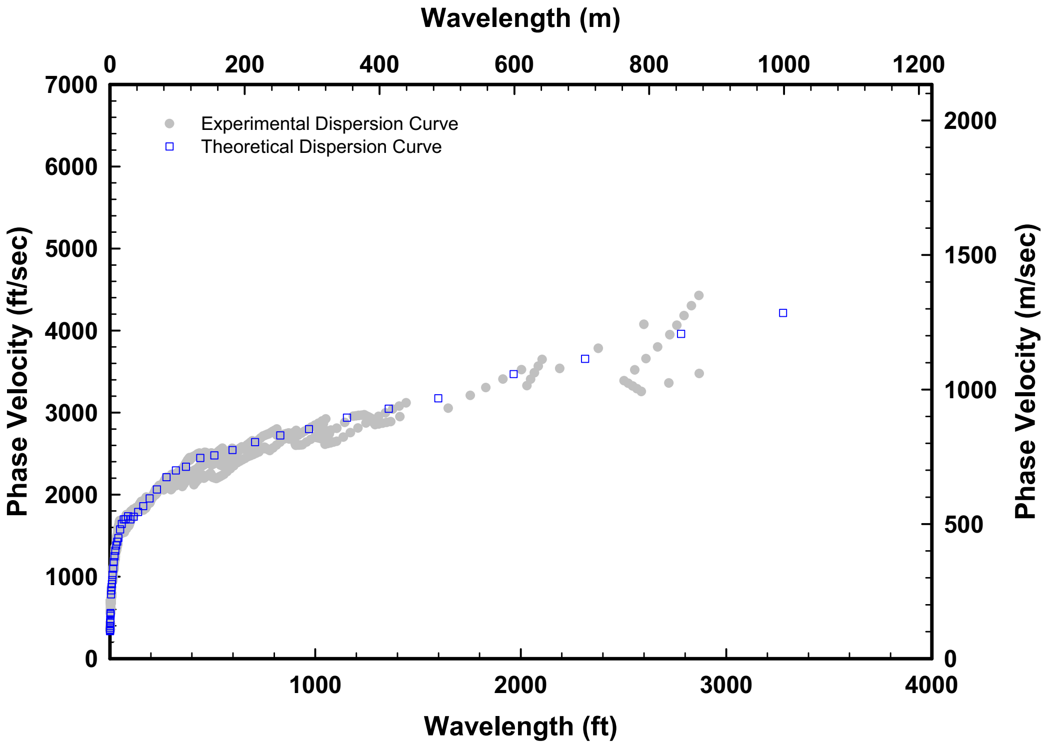
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-12. Experimental and Theoretical Dispersion Curves from NPF 10; Logarithmic Wavelength Axis



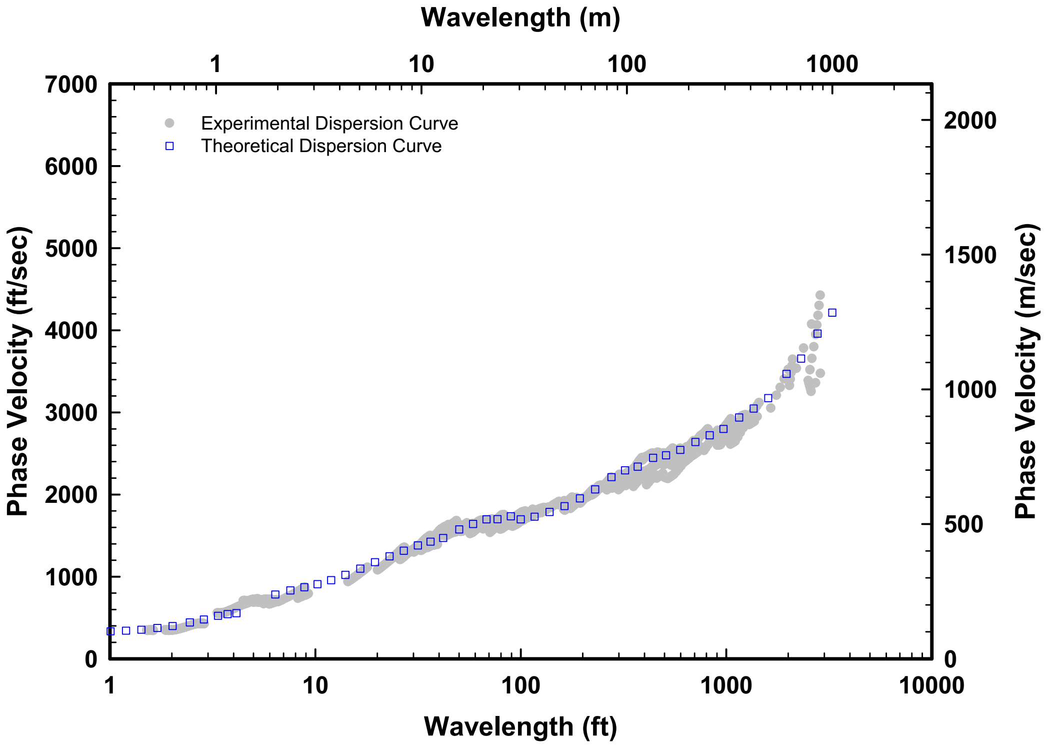
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-13. Shear Wave Velocity Profile Determined at NPF 12



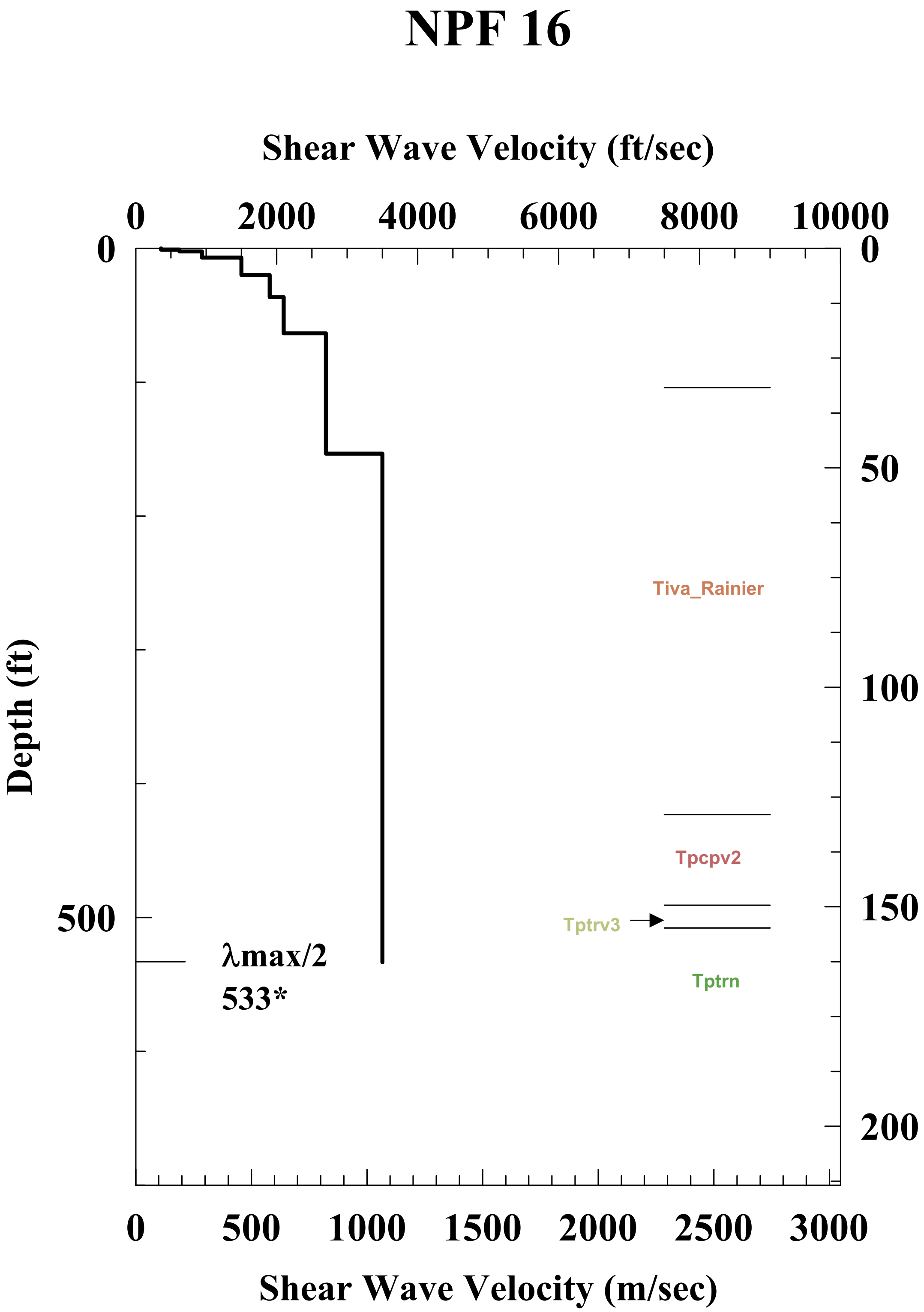
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-14. Experimental and Theoretical Dispersion Curves from NPF 12; Linear Wavelength Axis



Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

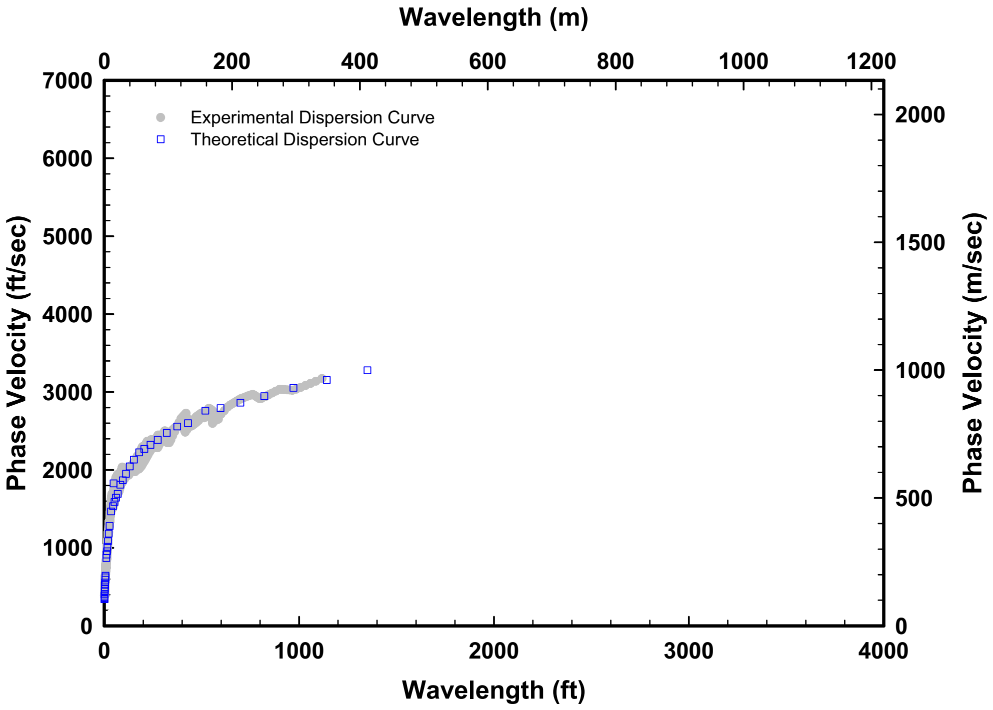
Figure IV-15. Experimental and Theoretical Dispersion Curves from NPF 12; Logarithmic Wavelength Axis



* Not λ_{max} / 2 because thin layer or profile due to large variation below this depth was removed. See "Developed data" sent to TDMS for details

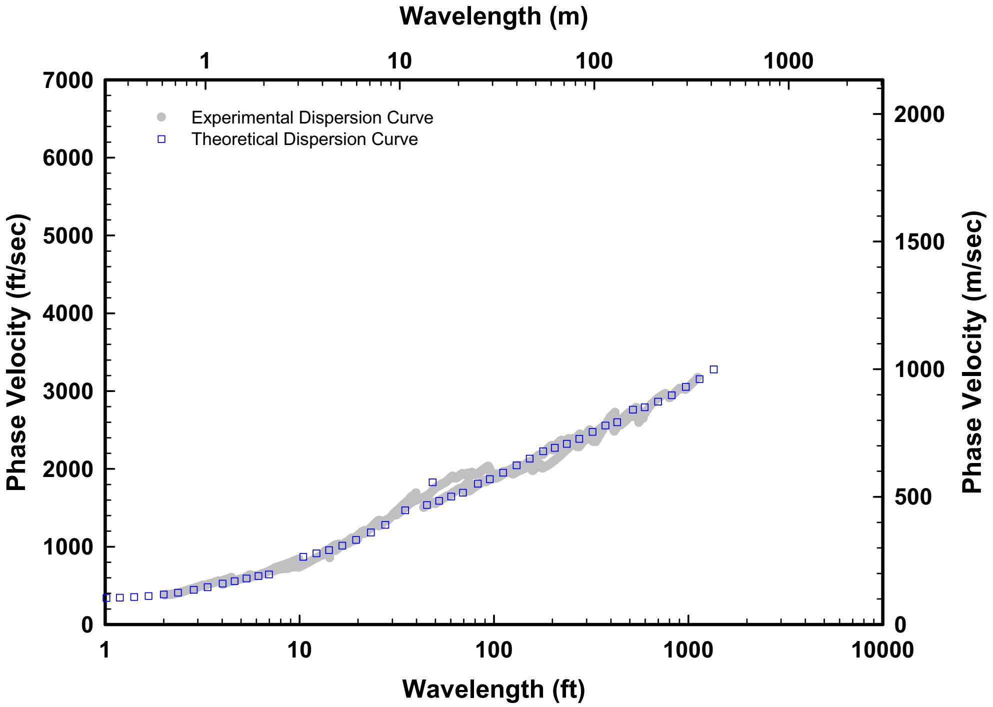
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-16. Shear Wave Velocity Profile Determined at NPF 16



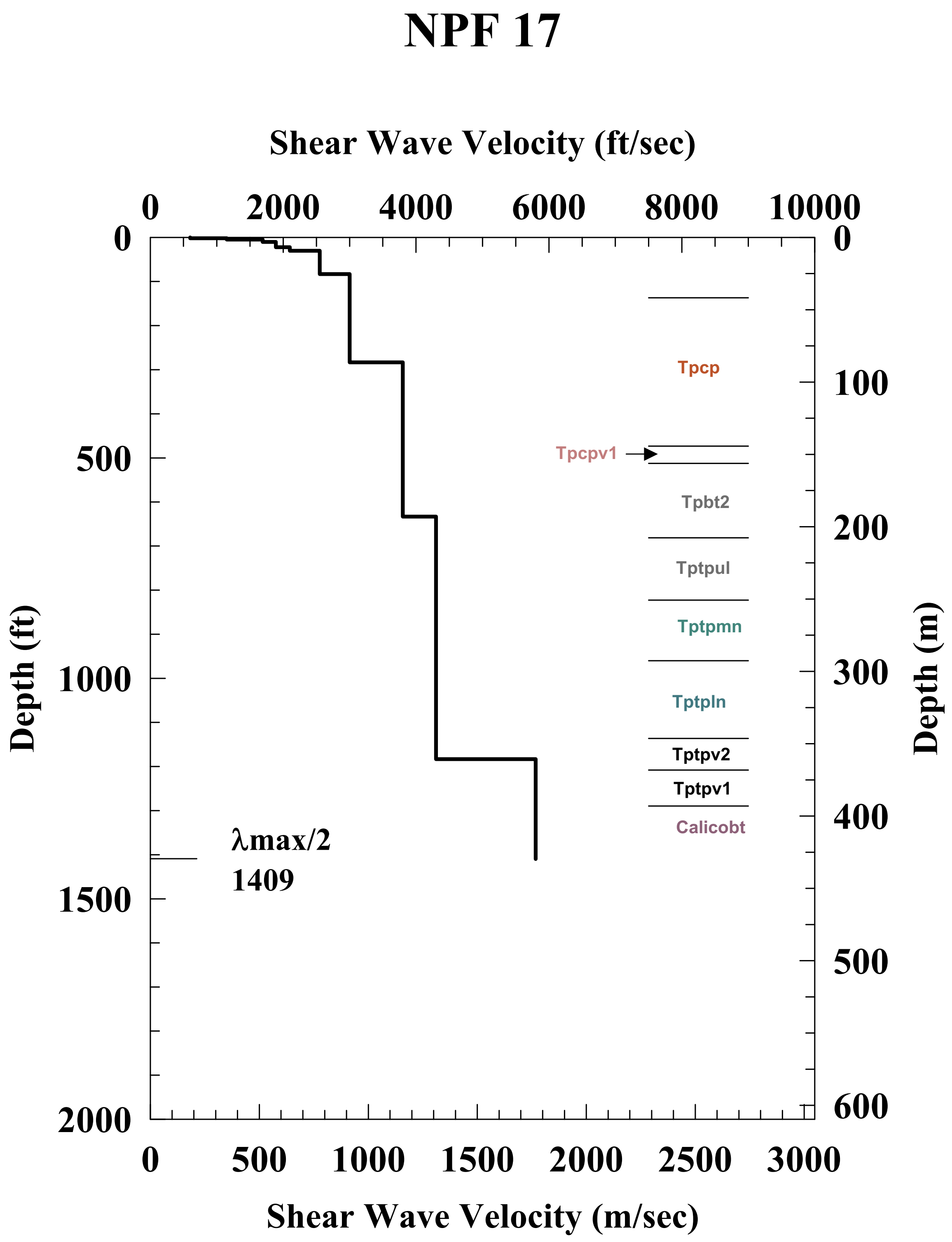
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-17. Experimental and Theoretical Dispersion Curves from NPF 16; Linear Wavelength Axis



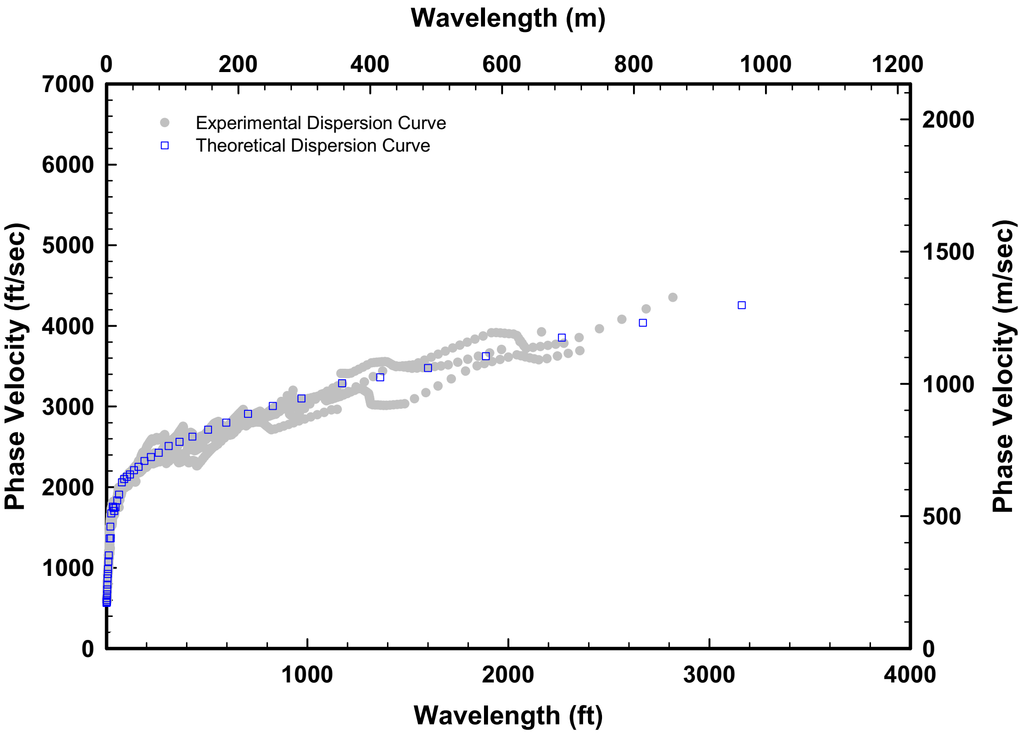
Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-18. Experimental and Theoretical Dispersion Curves from NPF16; Logarithmic Wavelength Axis



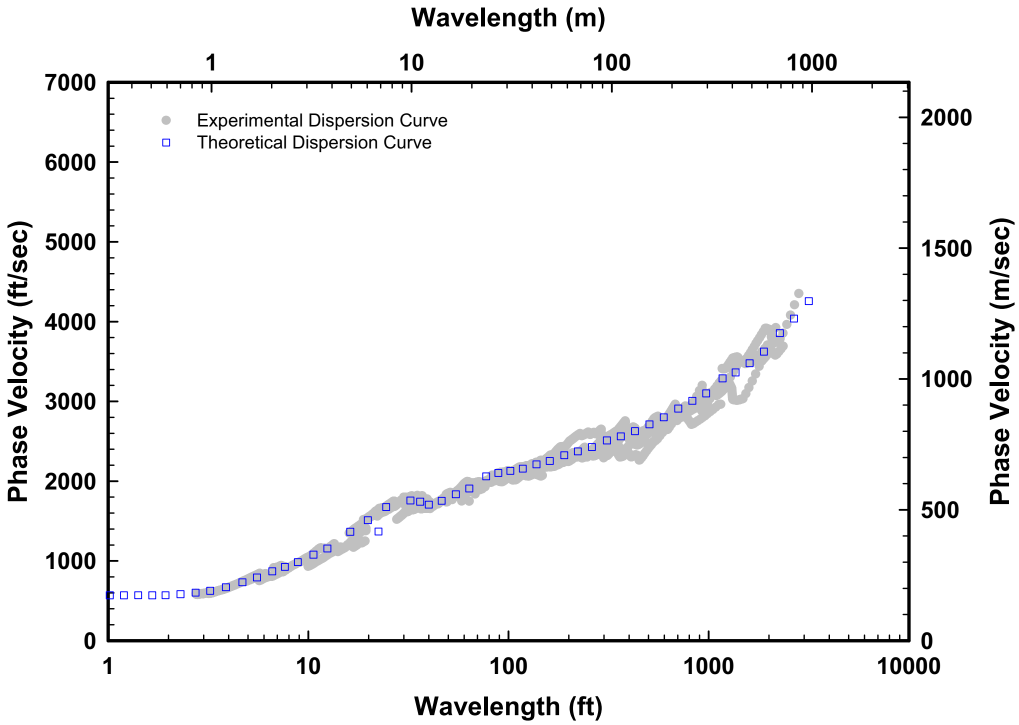
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-19. Shear Wave Velocity Profile Determined at NPF 17-T1 and NPF 17-T2



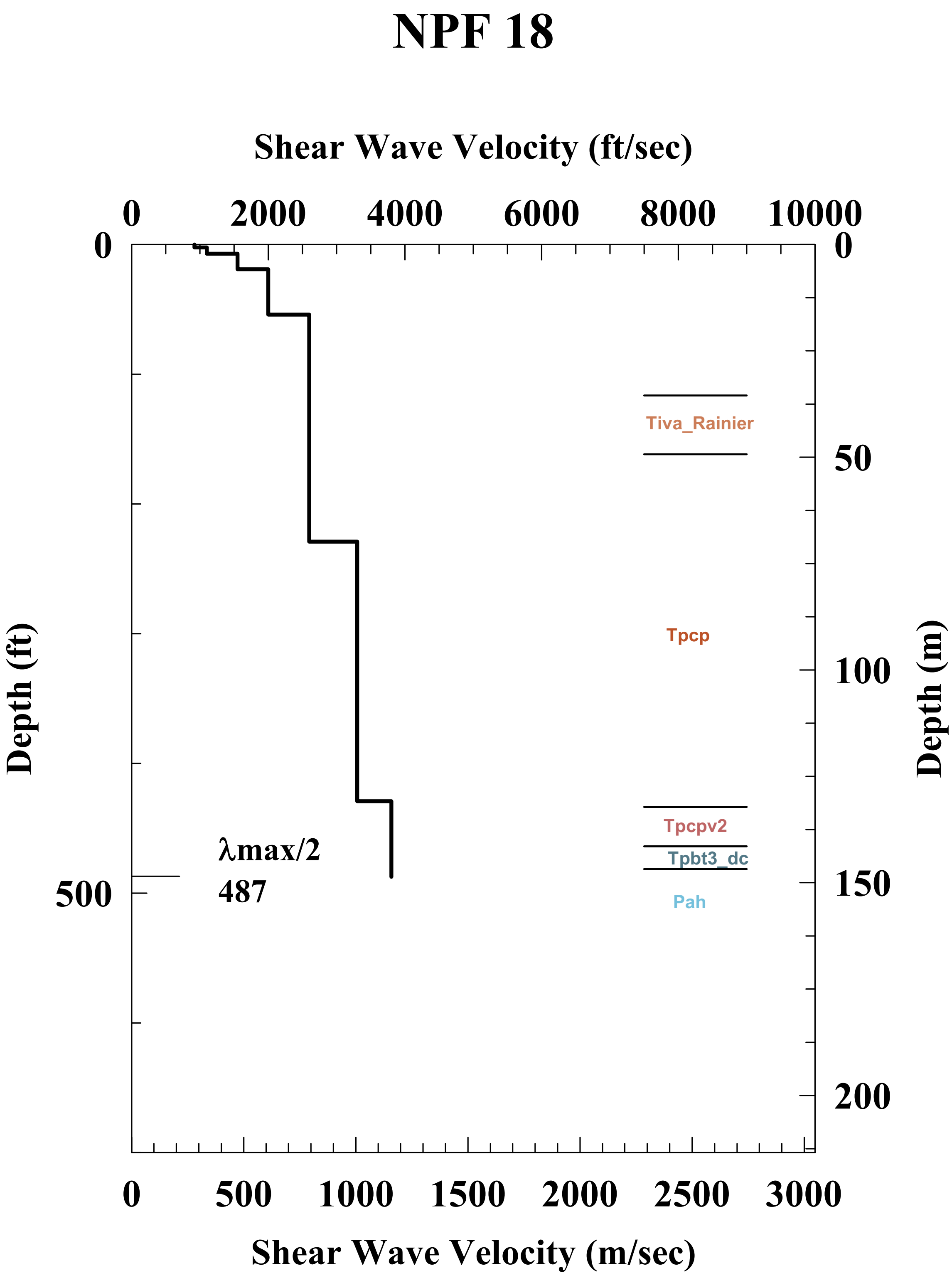
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-20. Experimental and Theoretical Dispersion Curves from NPF 17-T1 and NPF 17-T2; Linear Wavelength Axis



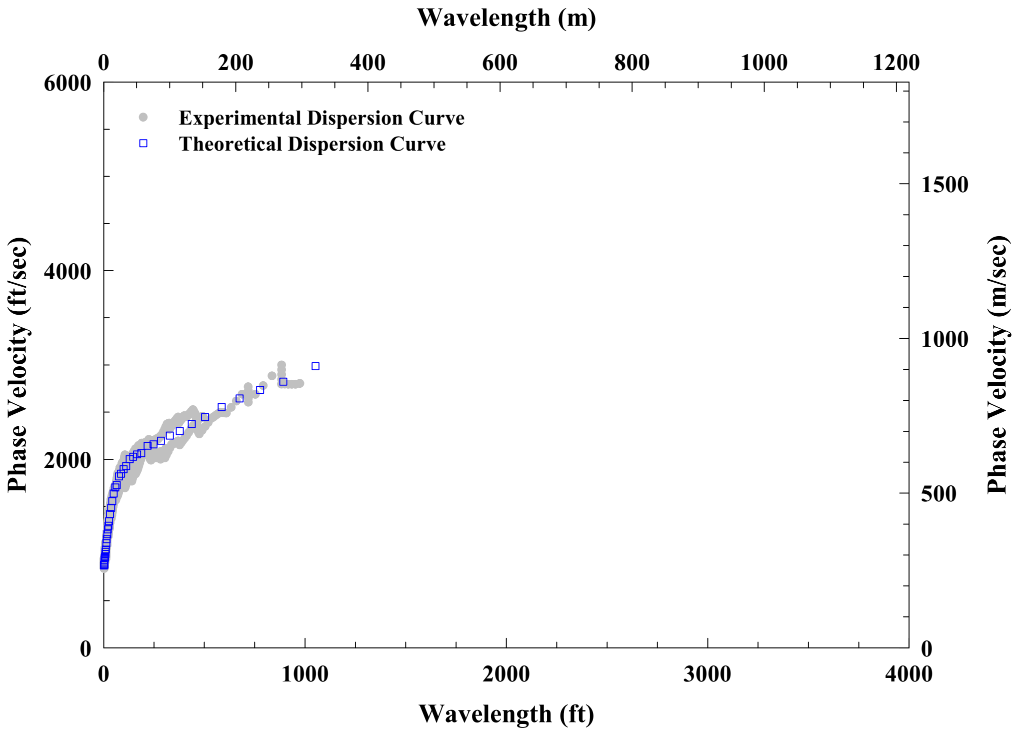
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-21. Experimental and Theoretical Dispersion Curves from NPF 17-T1 and NPF 17-T2; Logarithmic Wavelength Axis



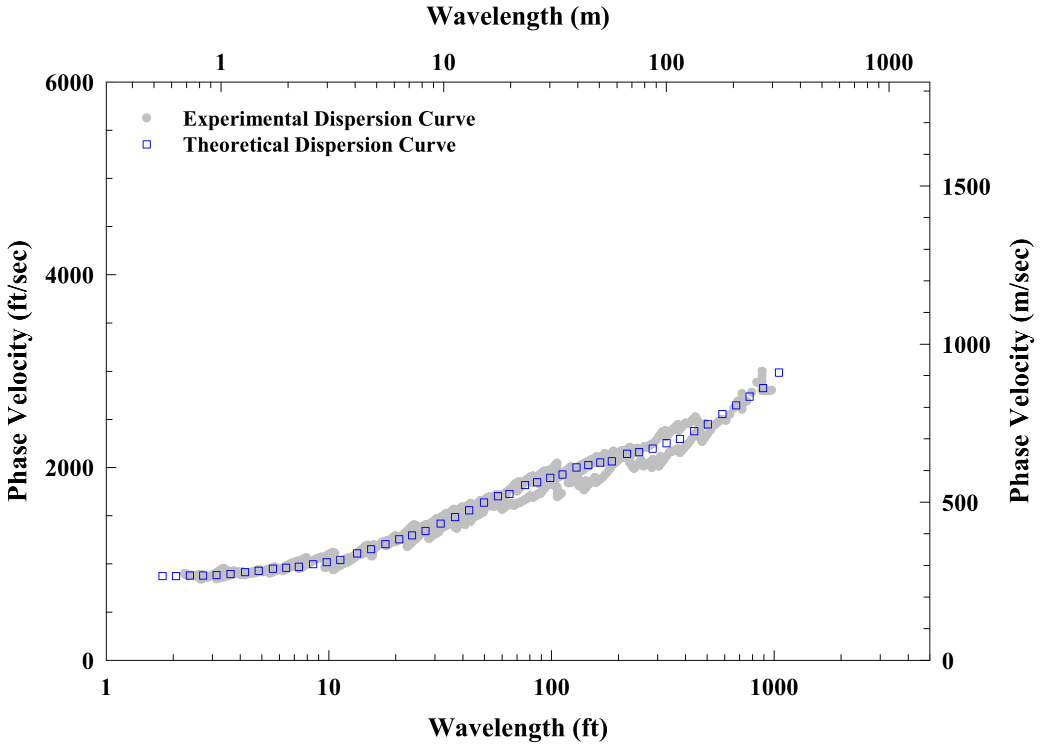
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-22. Shear Wave Velocity Profile Determined at NPF 18



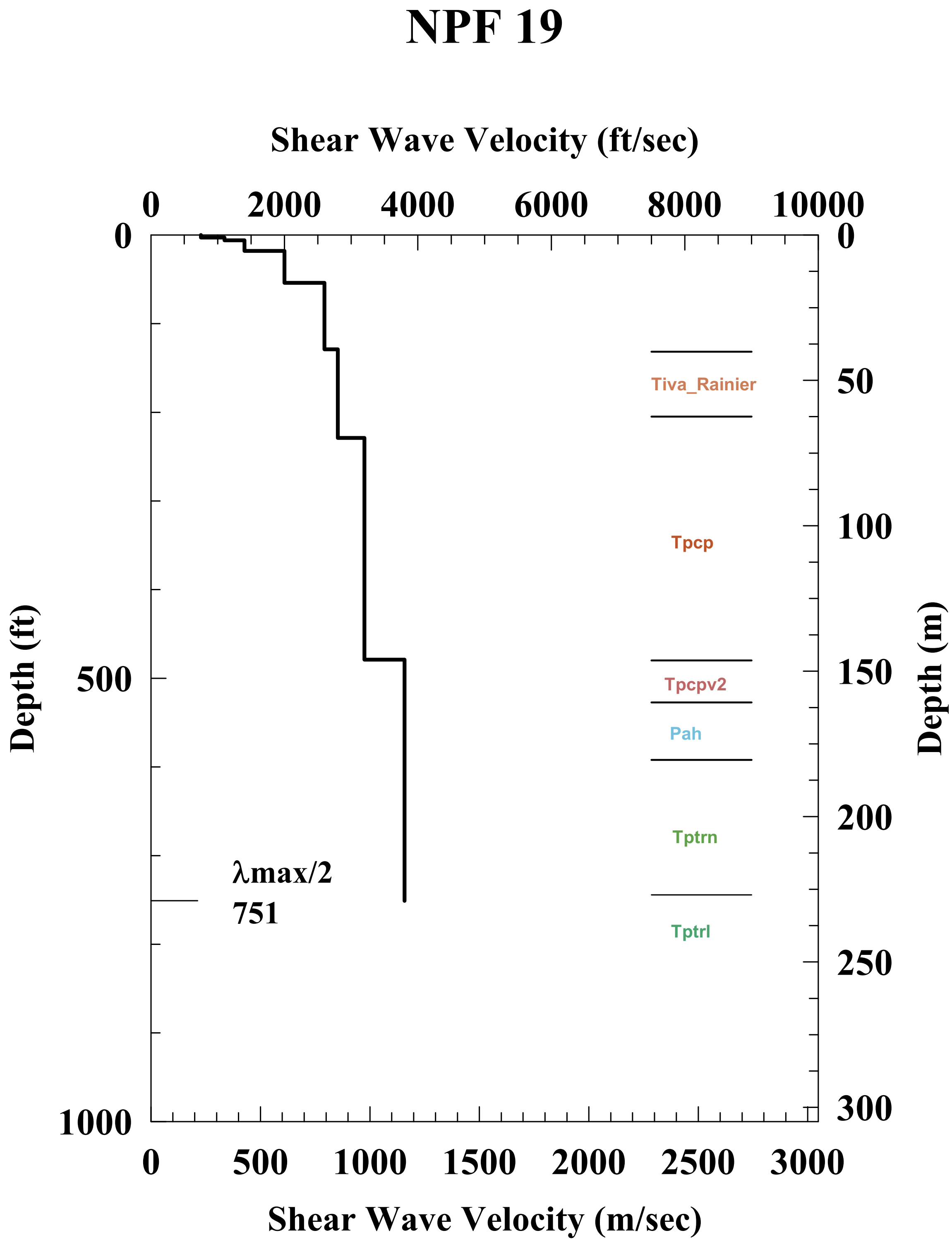
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-23. Experimental and Theoretical Dispersion Curves from NPF 18; Linear Wavelength Axis



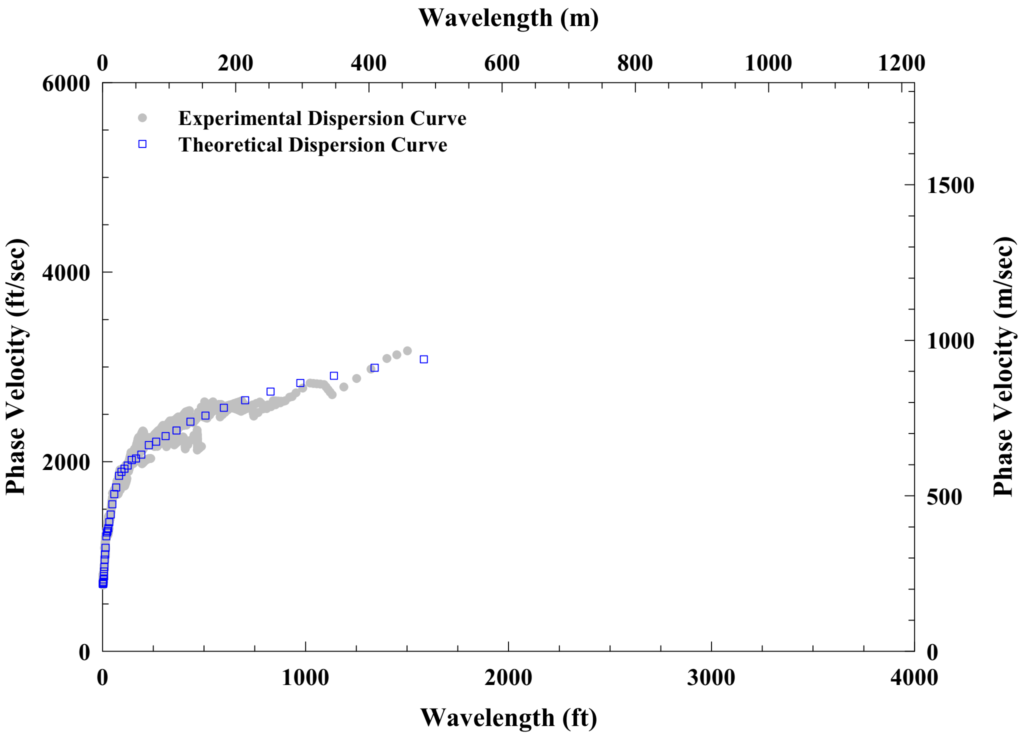
Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-24. Experimental and Theoretical Dispersion Curves from NPF 18; Logarithmic Wavelength Axis



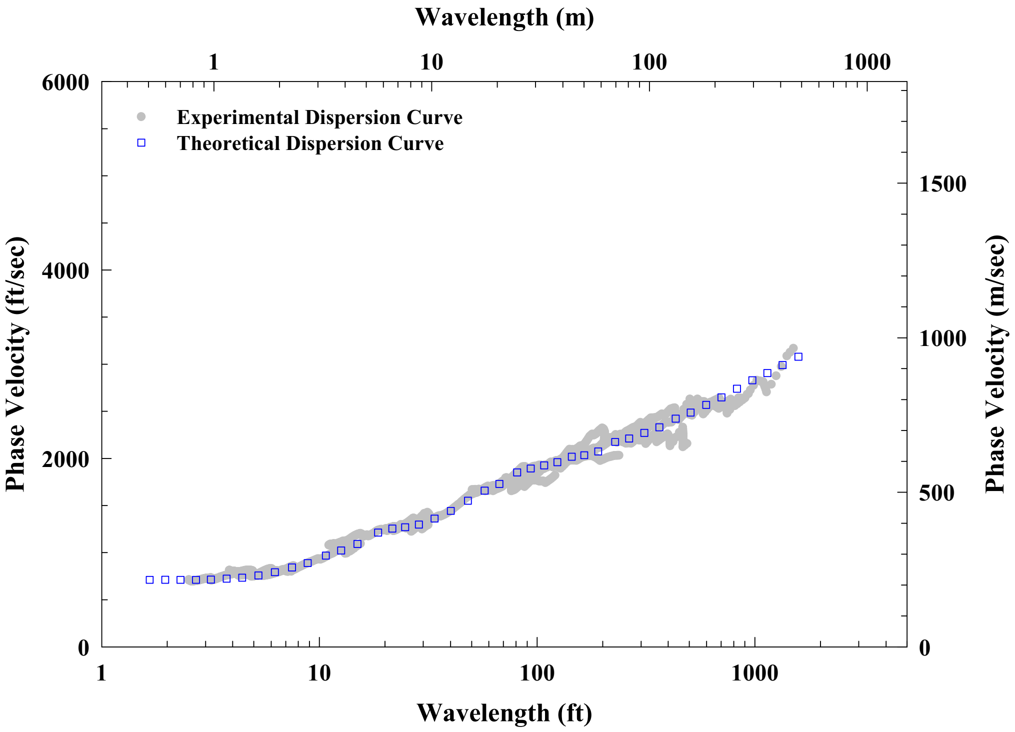
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-25. Shear Wave Velocity Profile Determined at NPF 19



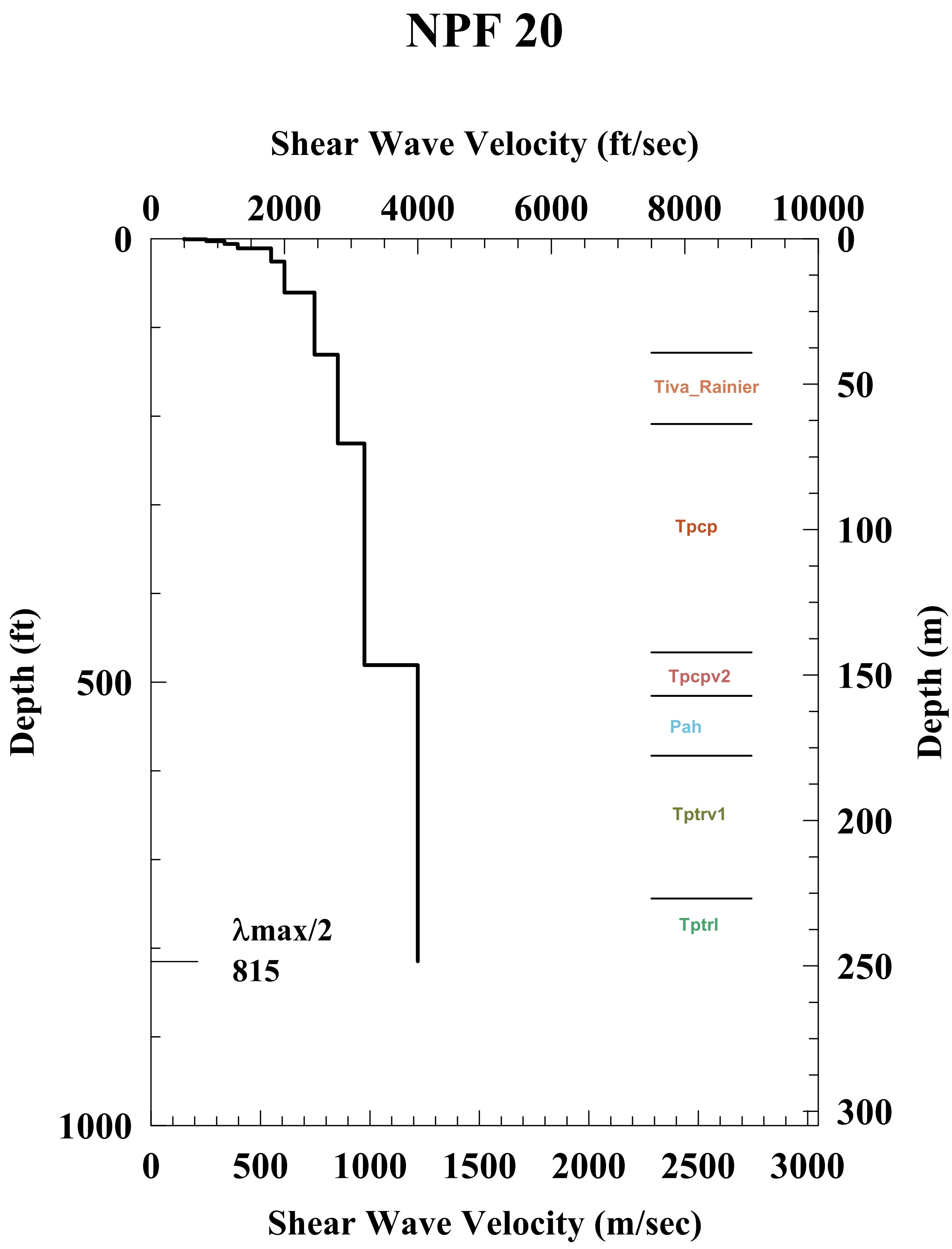
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-26. Experimental and Theoretical Dispersion Curves from NPF 19; Linear Wavelength Axis



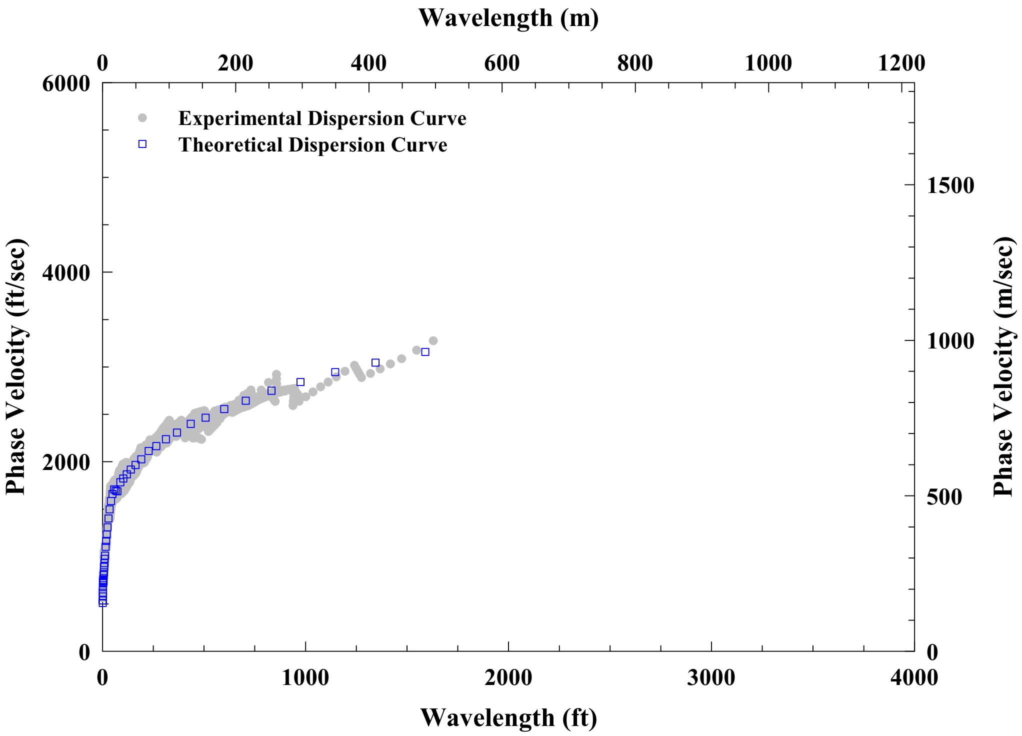
Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-27. Experimental and Theoretical Dispersion Curves from NPF 19; Logarithmic Wavelength Axis



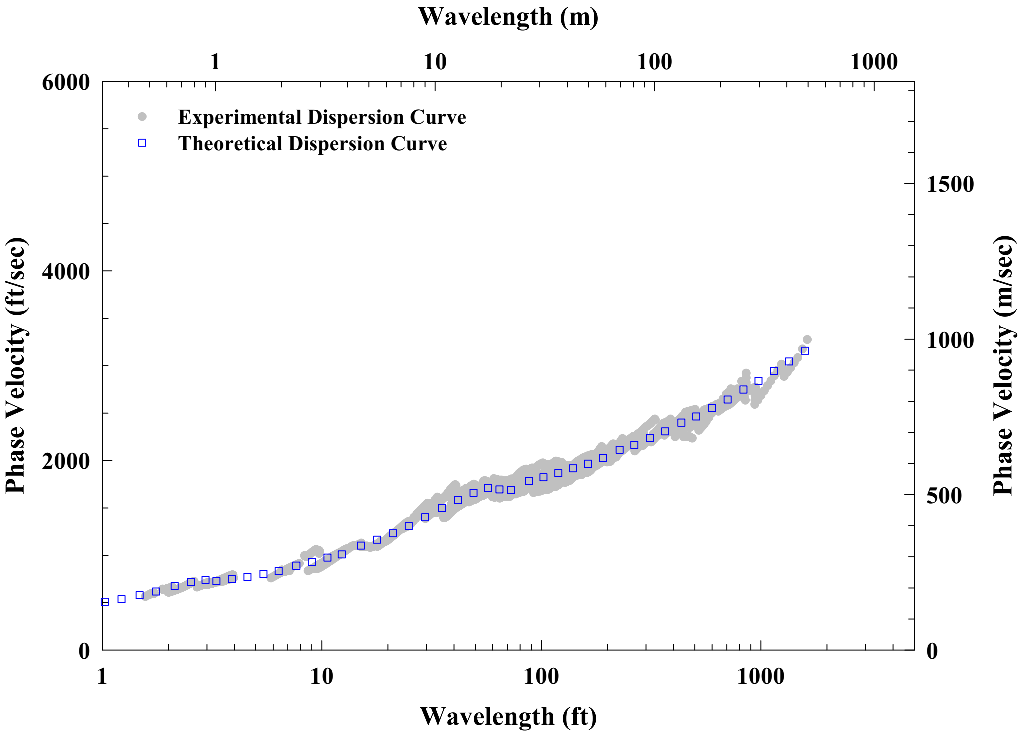
Source: DTN: MO0609SASWSTDC.003 [DIRS 18 2125]; Stokoe 2007 [DIRS 183327]; and DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-28. Shear Wave Velocity Profile Determined at NPF 20



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

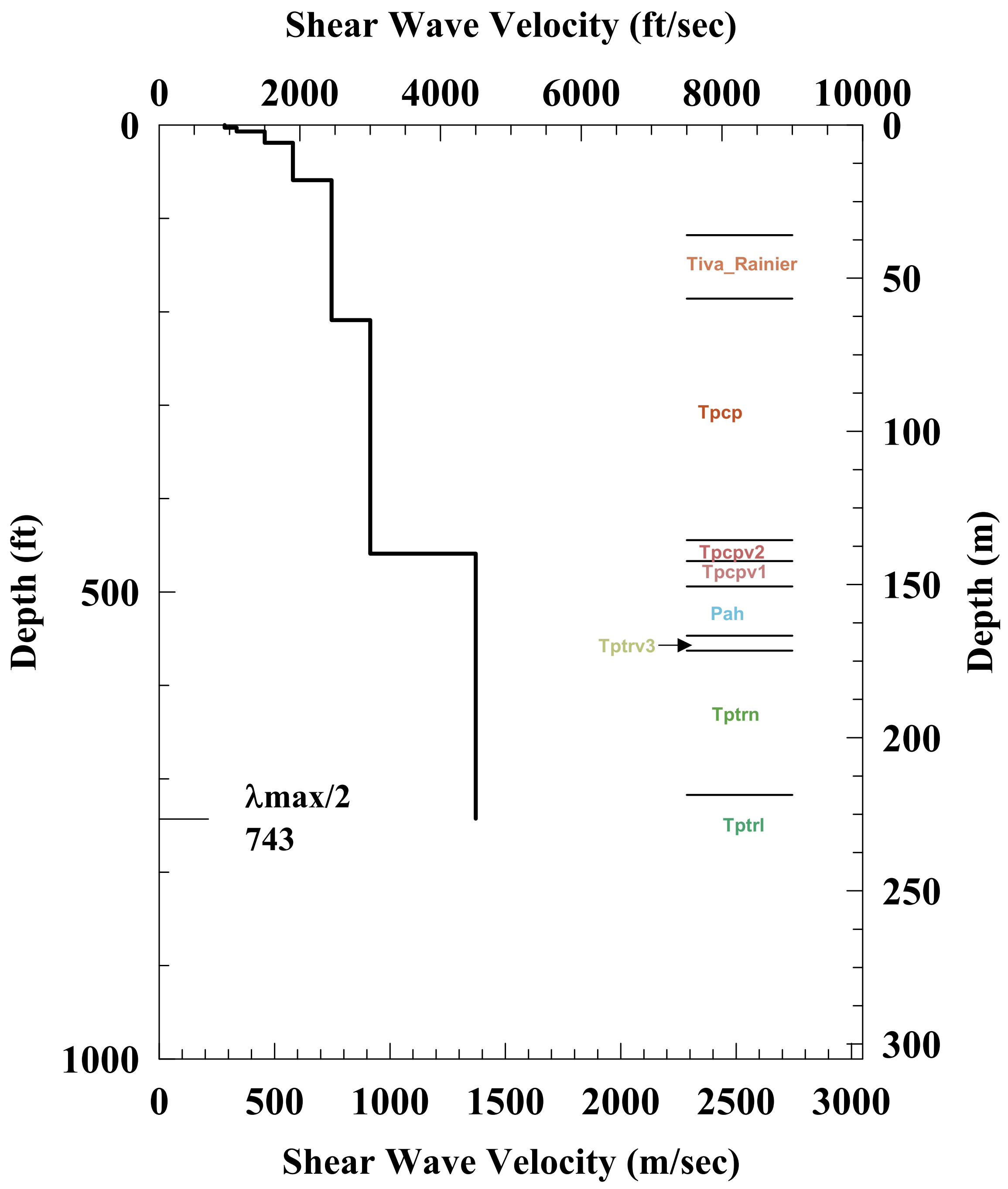
Figure IV-29. Experimental and Theoretical Dispersion Curves from NPF 20; Linear Wavelength Axis



Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

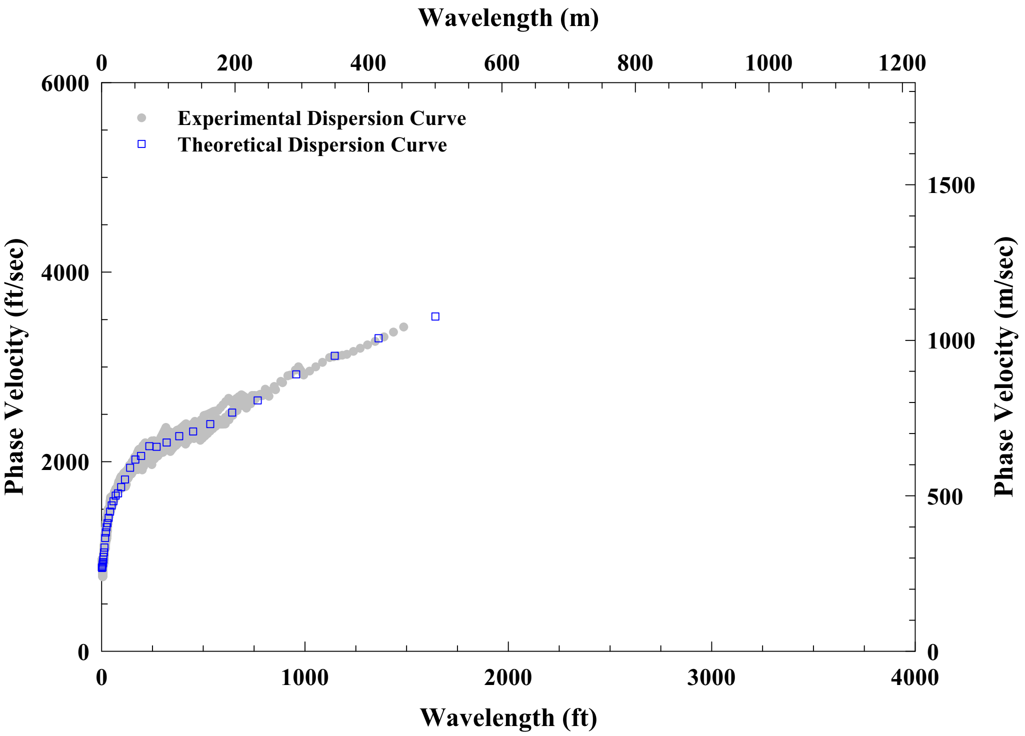
Figure IV-30. Experimental and Theoretical Dispersion Curves from NPF 20; Logarithmic Wavelength Axis

NPF 21



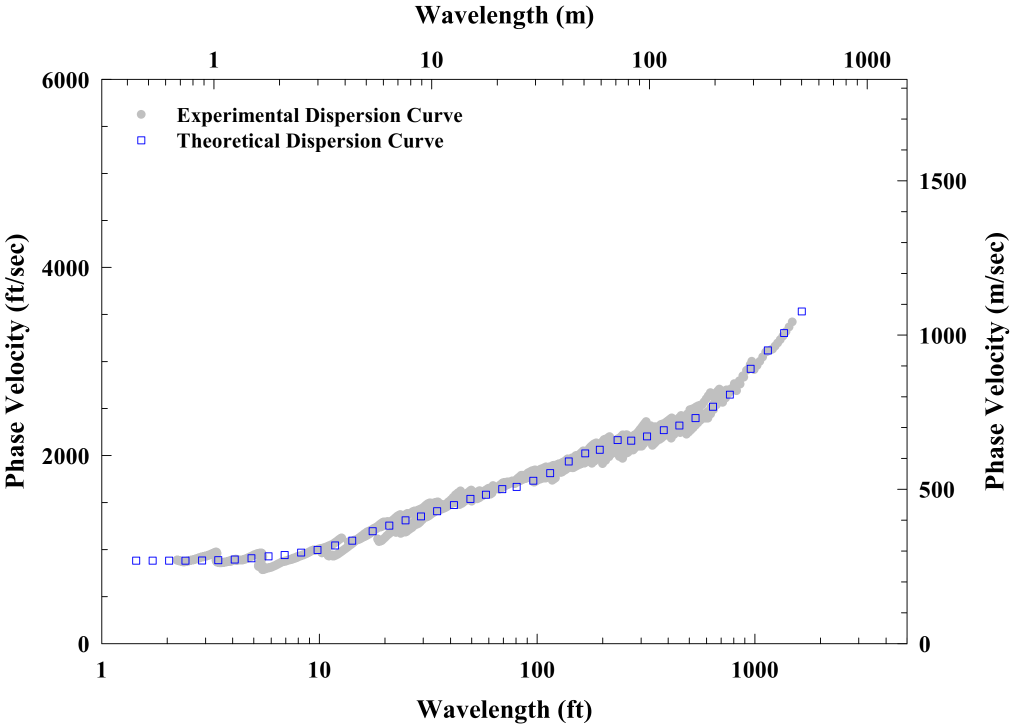
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-31.   Shear Wave Velocity Profile Determined at NPF 21



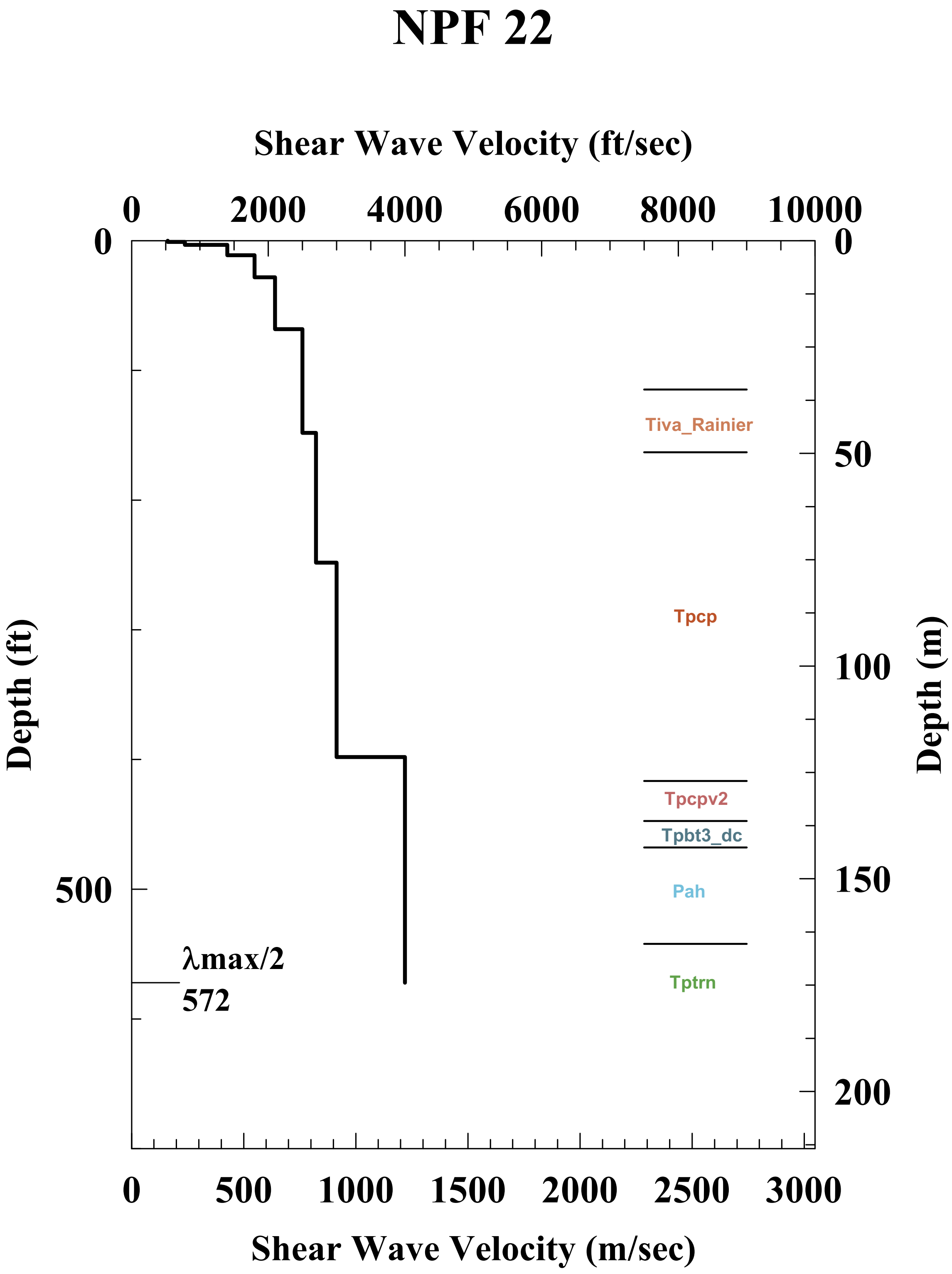
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-32. Experimental and Theoretical Dispersion Curves from NPF 21; Linear Wavelength Axis



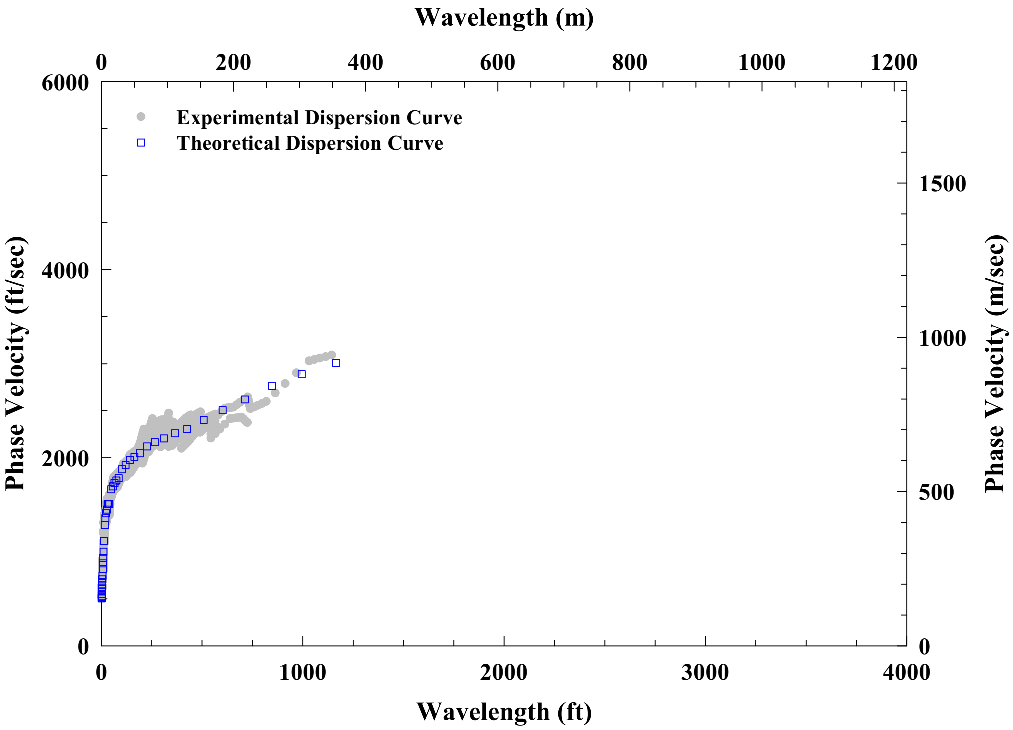
Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-33. Experimental and Theoretical Dispersion Curves from NPF 21; Logarithmic Wavelength Axis



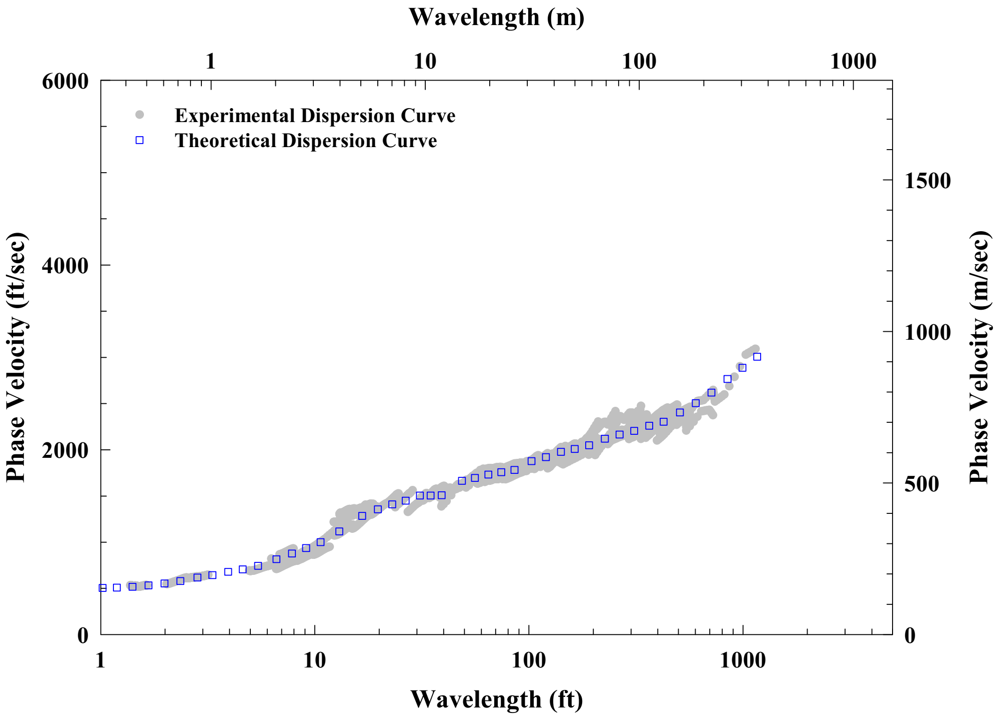
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-34. Shear Wave Velocity Profile Determined at NPF 22-T1 and NPF 22-T2



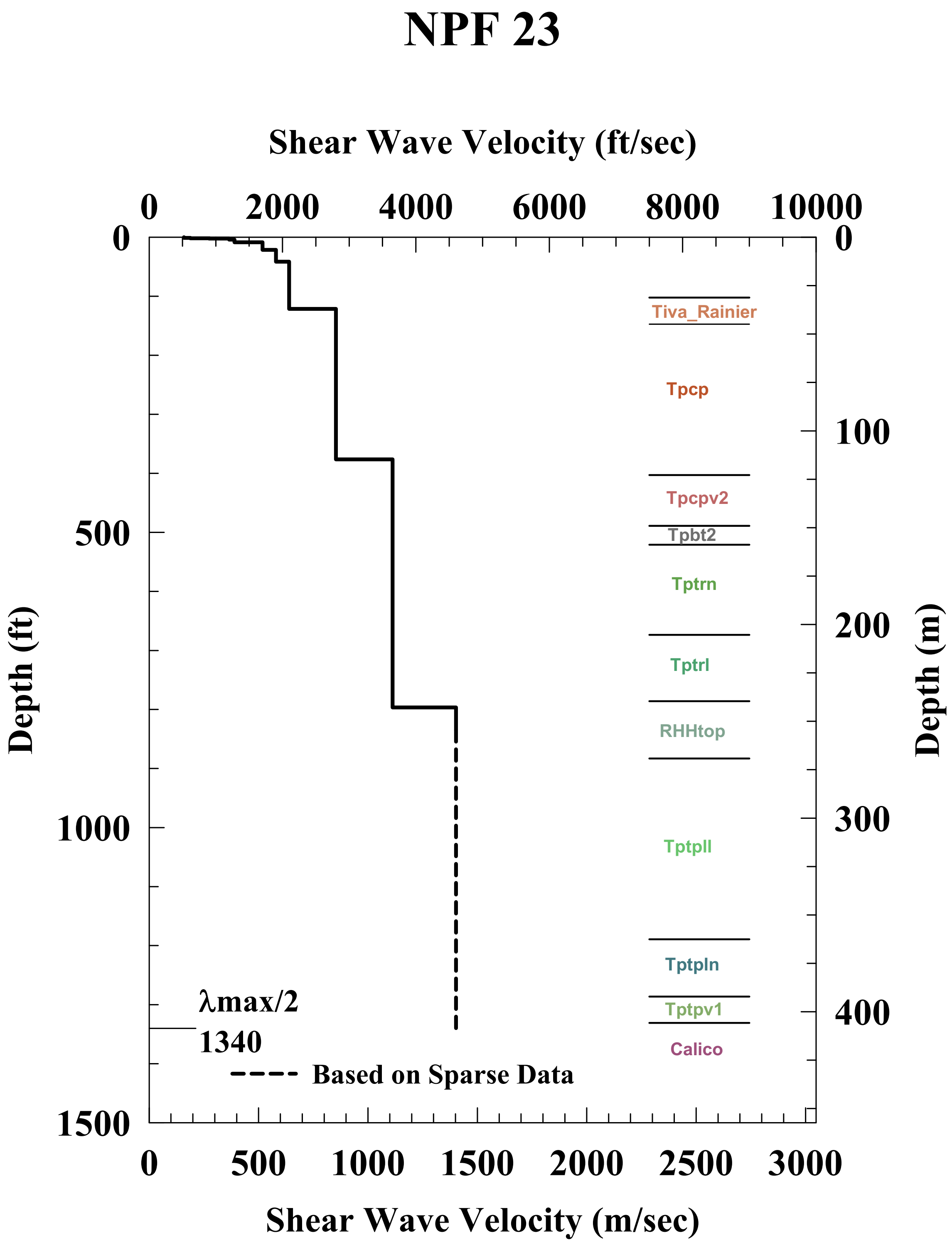
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-35. Experimental and Theoretical Dispersion Curves from NPF 22-T1 and NPF 22-T2; Linear Wavelength Axis



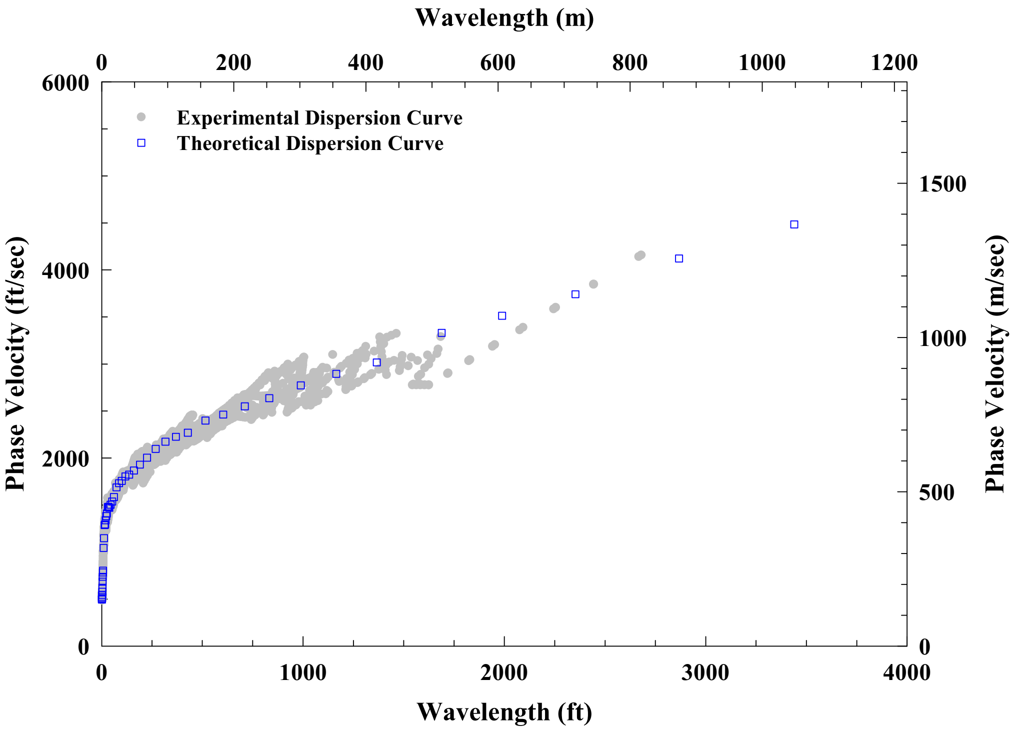
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-36. Experimental and Theoretical Dispersion Curves from NPF 22-T1 and NPF 22-T2; Logarithmic Wavelength Axis



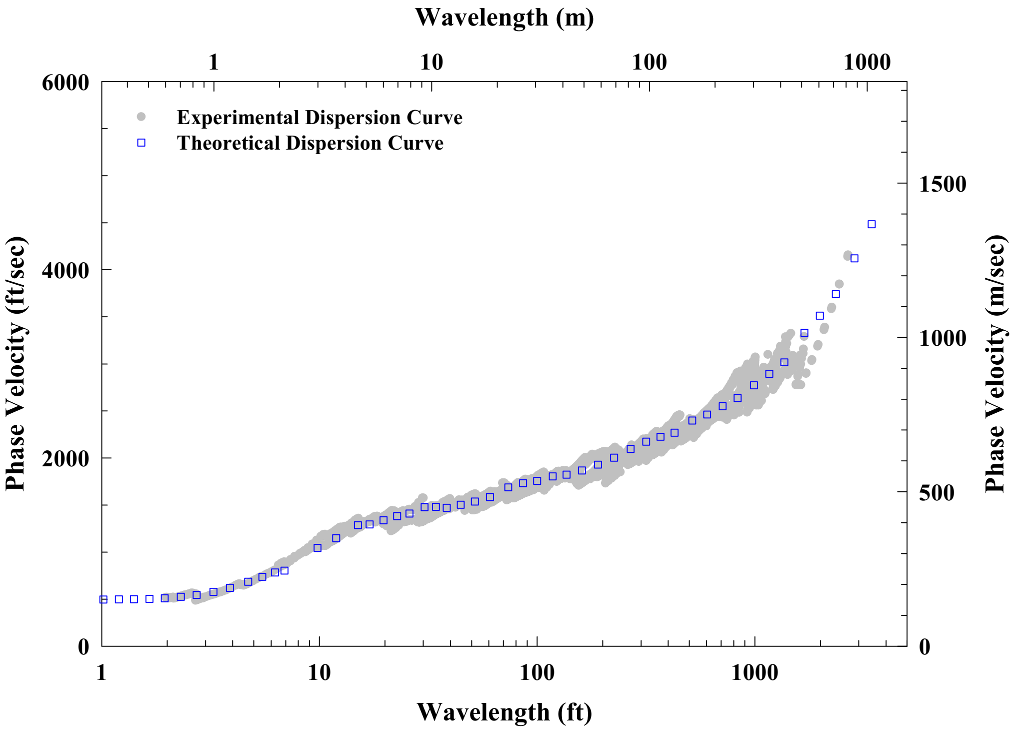
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-37. Shear Wave Velocity Profile Determined at NPF 23-T1 and NPF 23-T2



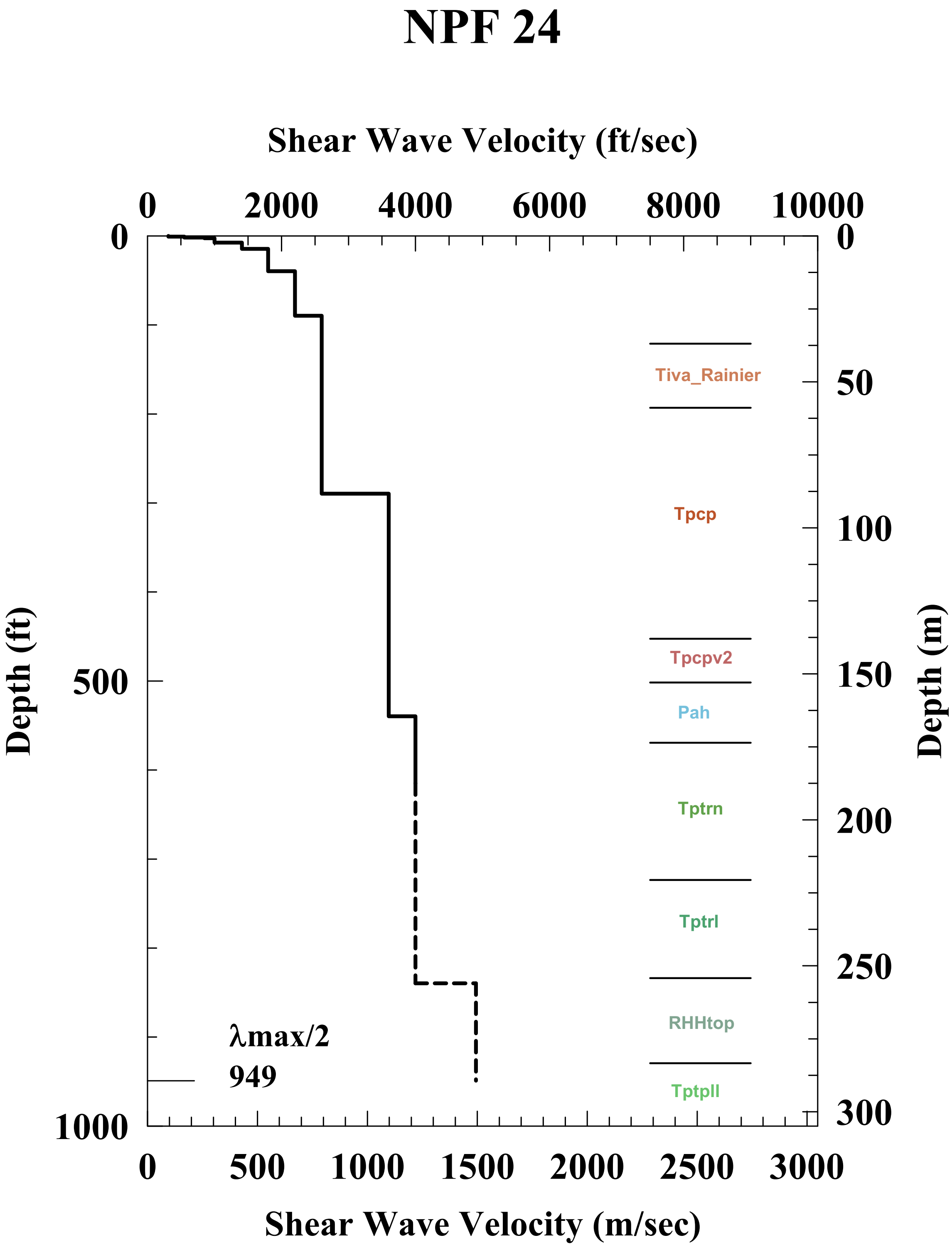
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-38. Experimental and Theoretical Dispersion Curves from NPF 23-T1 and NPF 23-T2; Linear Wavelength Axis



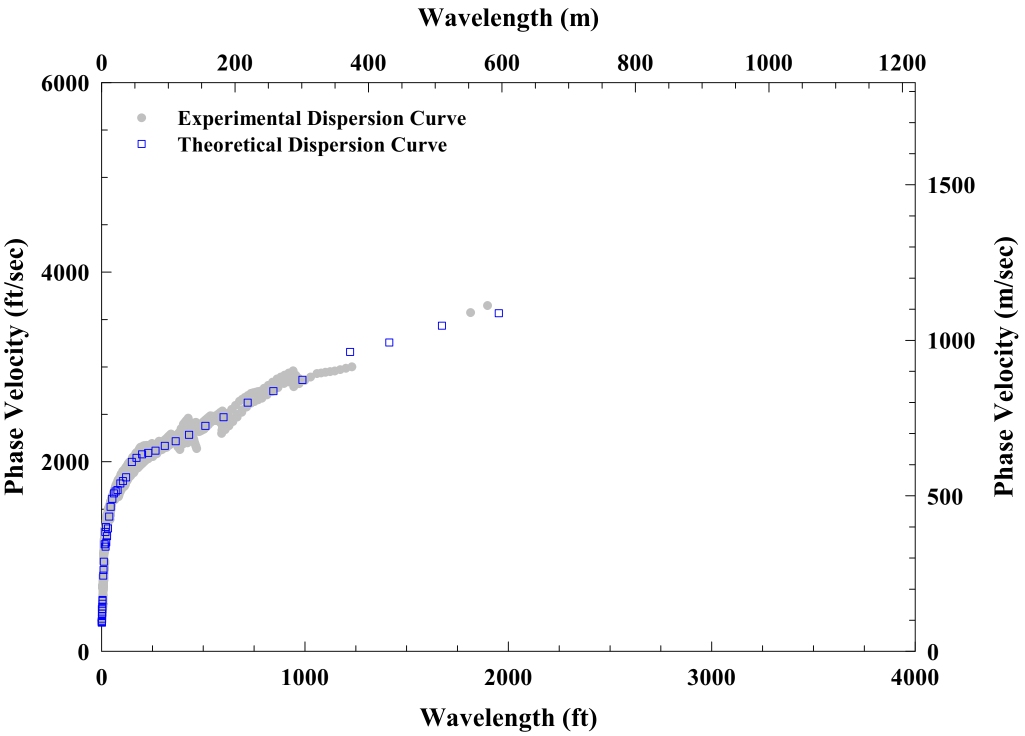
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-39. Experimental and Theoretical Dispersion Curves from NPF 23-T1 and NPF 23-T2; Logarithmic Wavelength Axis



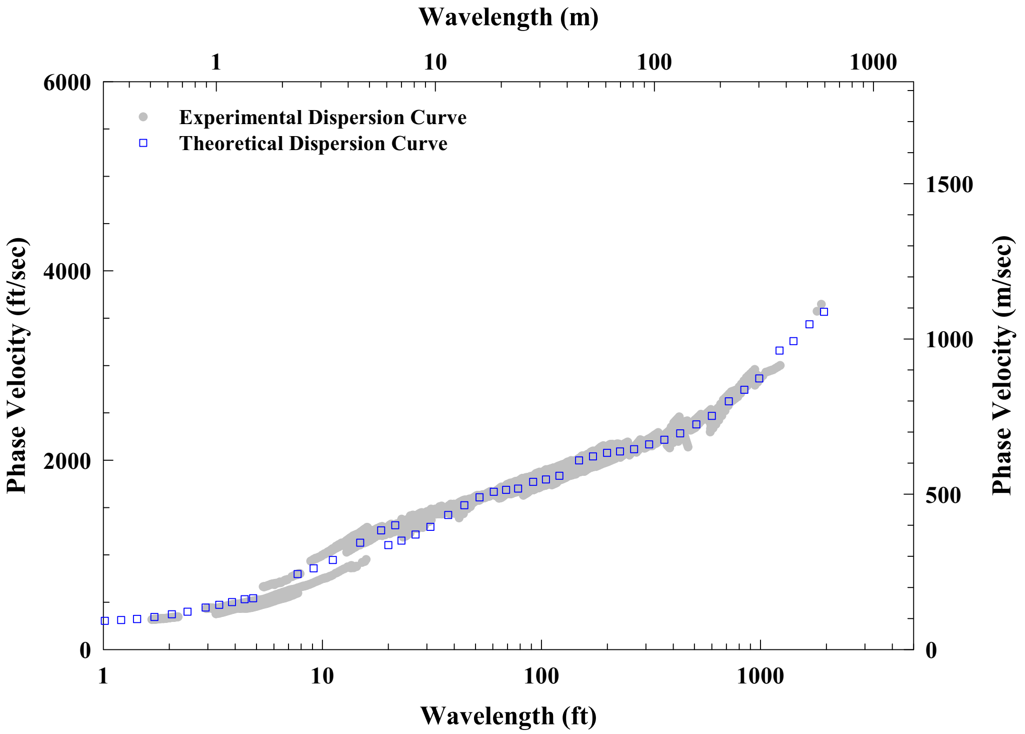
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-40. Shear Wave Velocity Profile Determined at NPF 24



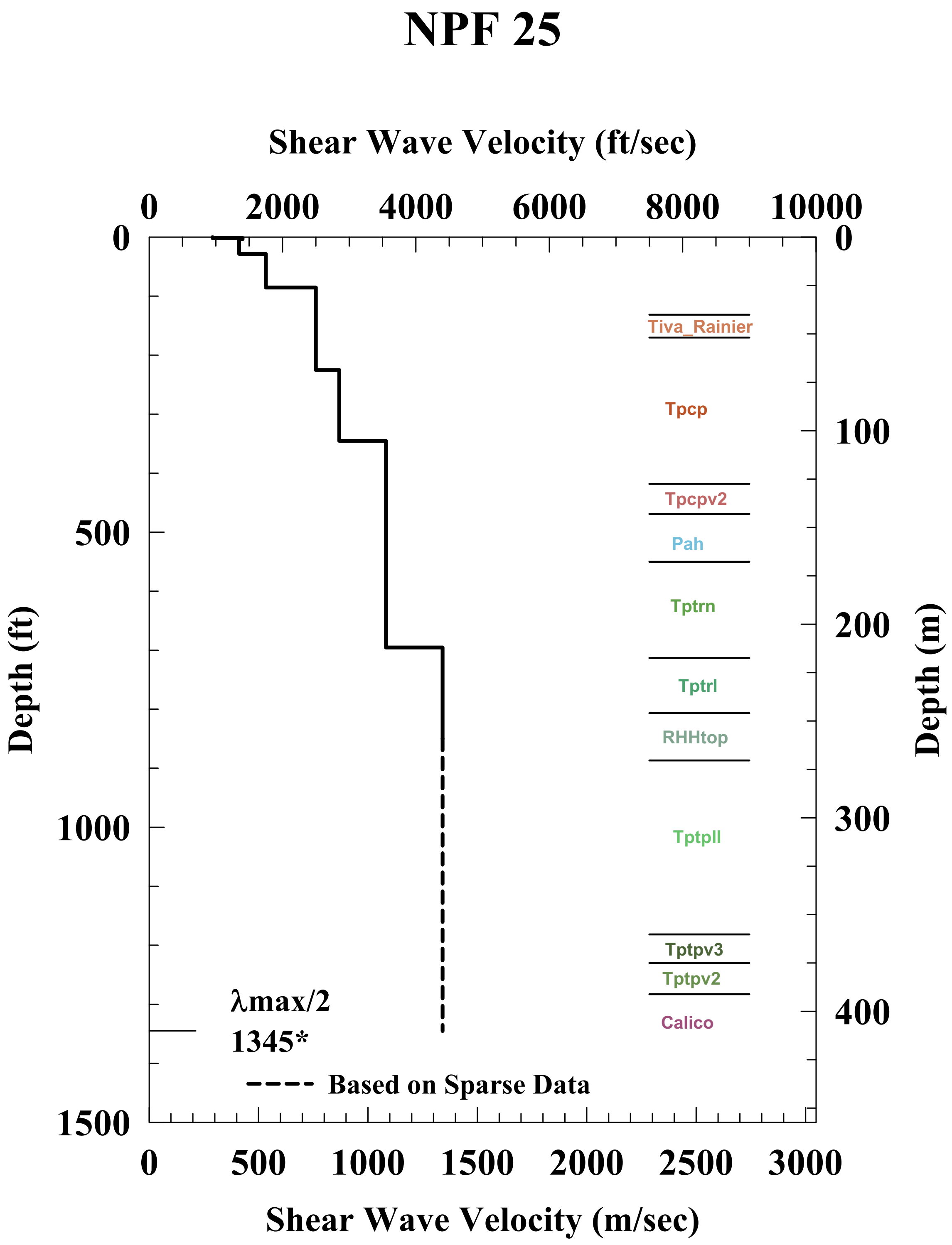
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-41. Experimental and Theoretical Dispersion Curves from NPF 24; Linear Wavelength Axis



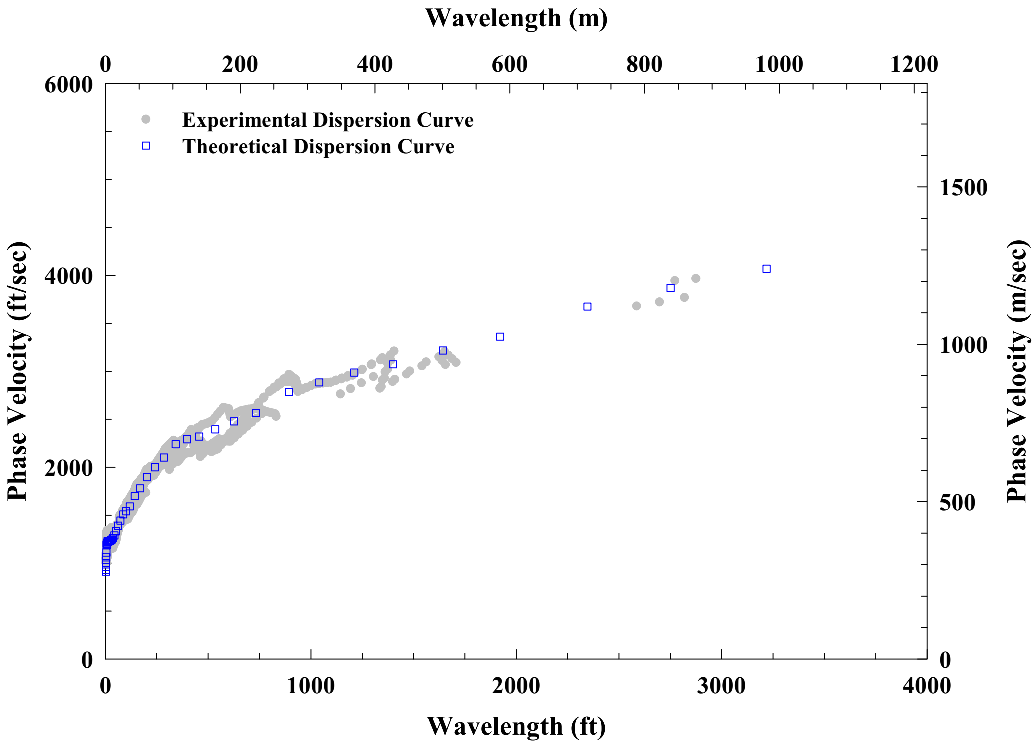
Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-42. Experimental and Theoretical Dispersion Curves from NPF 24; Logarithmic Wavelength Axis



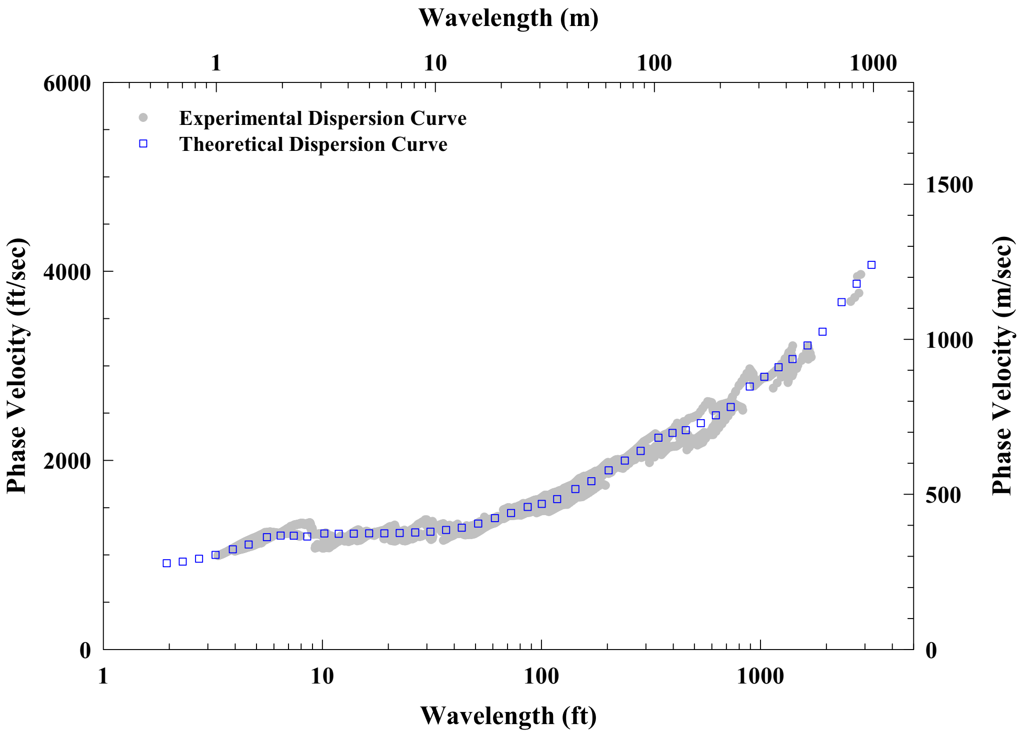
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-43. Shear Wave Velocity Profile Determined at NPF 25



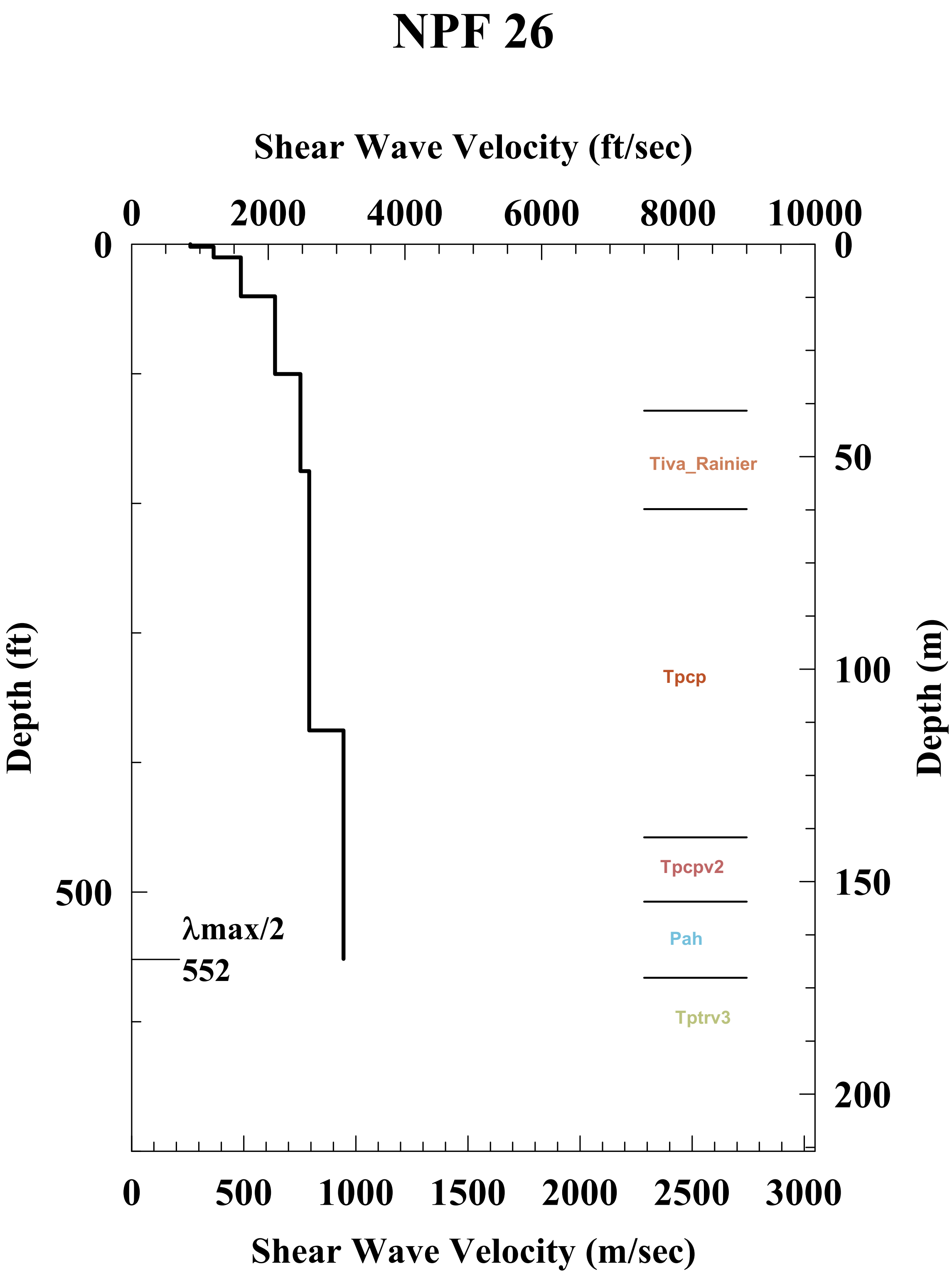
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-44. Experimental and Theoretical Dispersion Curves from NPF 25; Linear Wavelength Axis



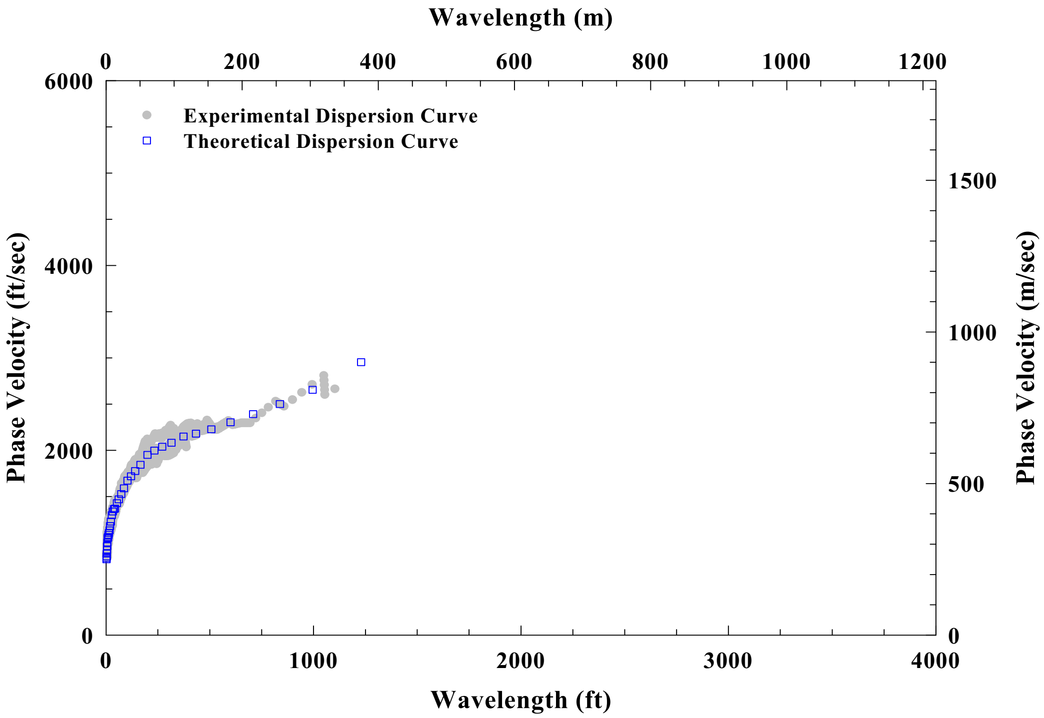
Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-45. Experimental and Theoretical Dispersion Curves from NPF 25; Logarithmic Wavelength Axis



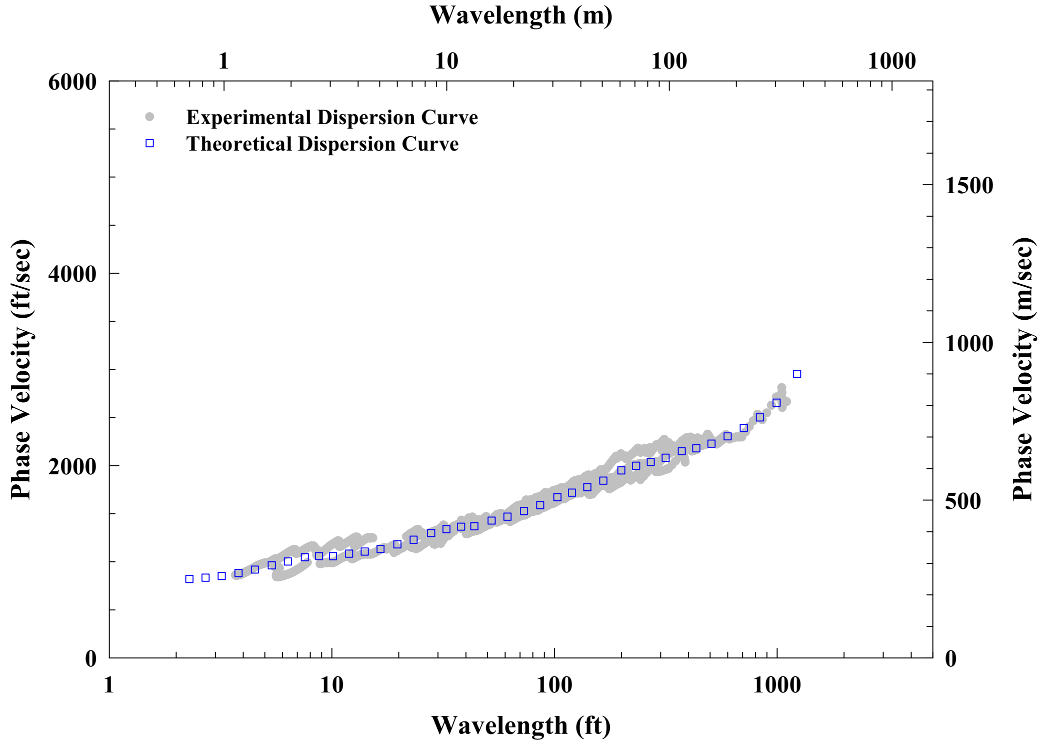
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-46. Shear Wave Velocity Profile Determined at NPF 26



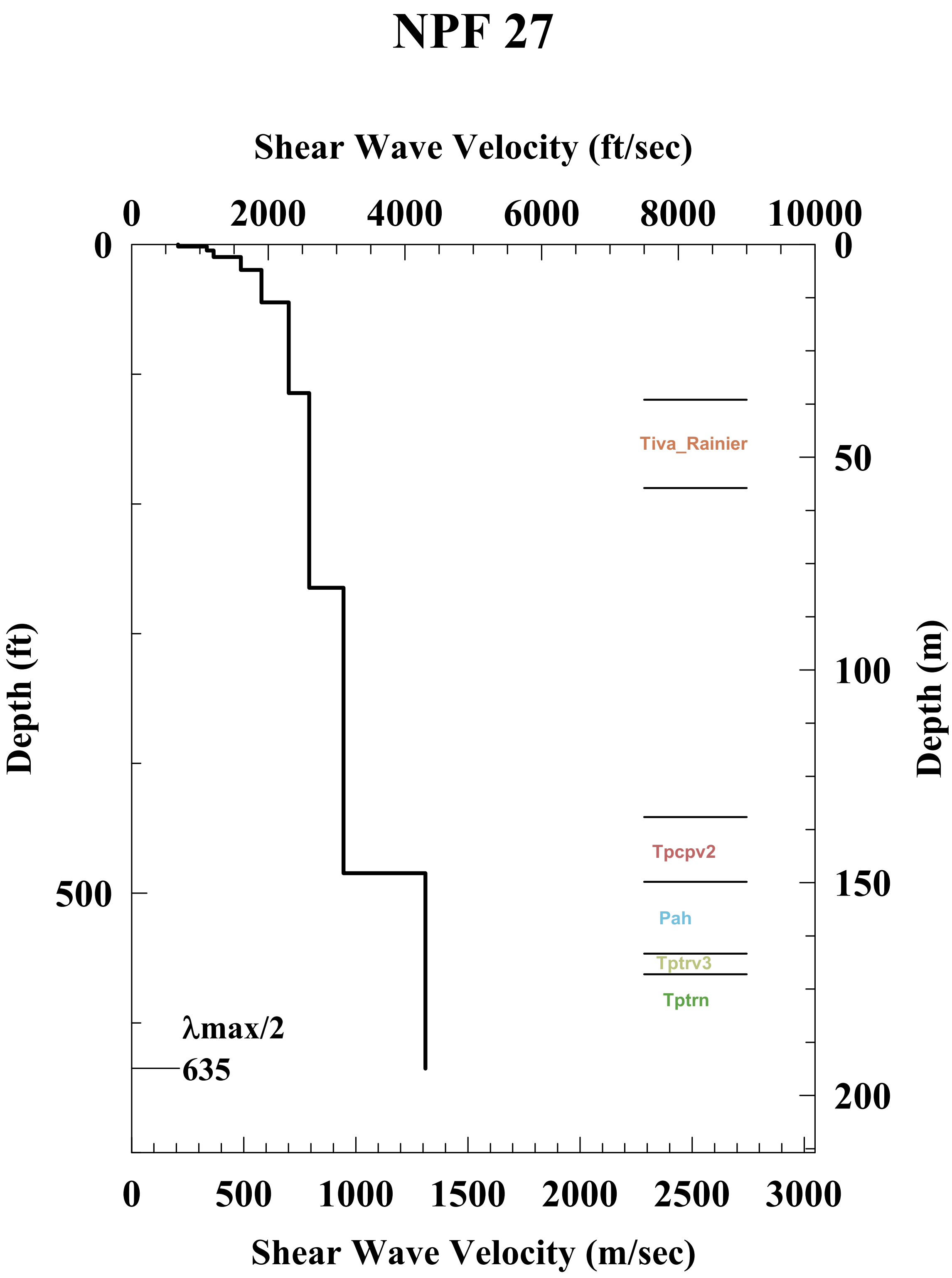
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-47. Experimental and Theoretical Dispersion Curves from NPF 26; Linear Wavelength Axis



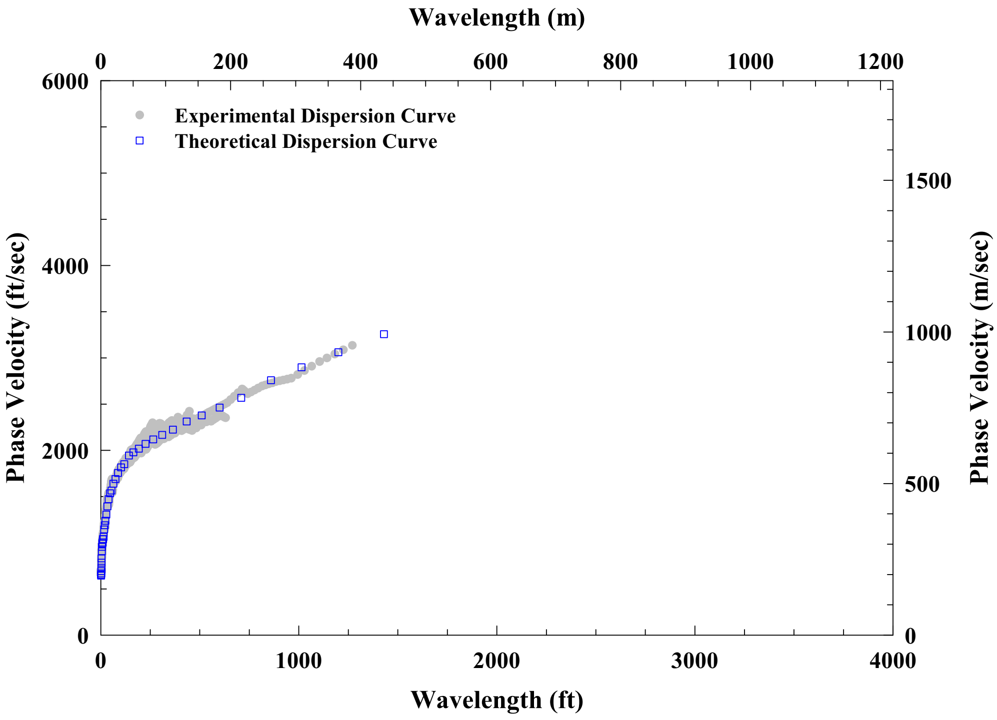
Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-48. Experimental and Theoretical Dispersion Curves from NPF 26; Logarithmic Wavelength Axis



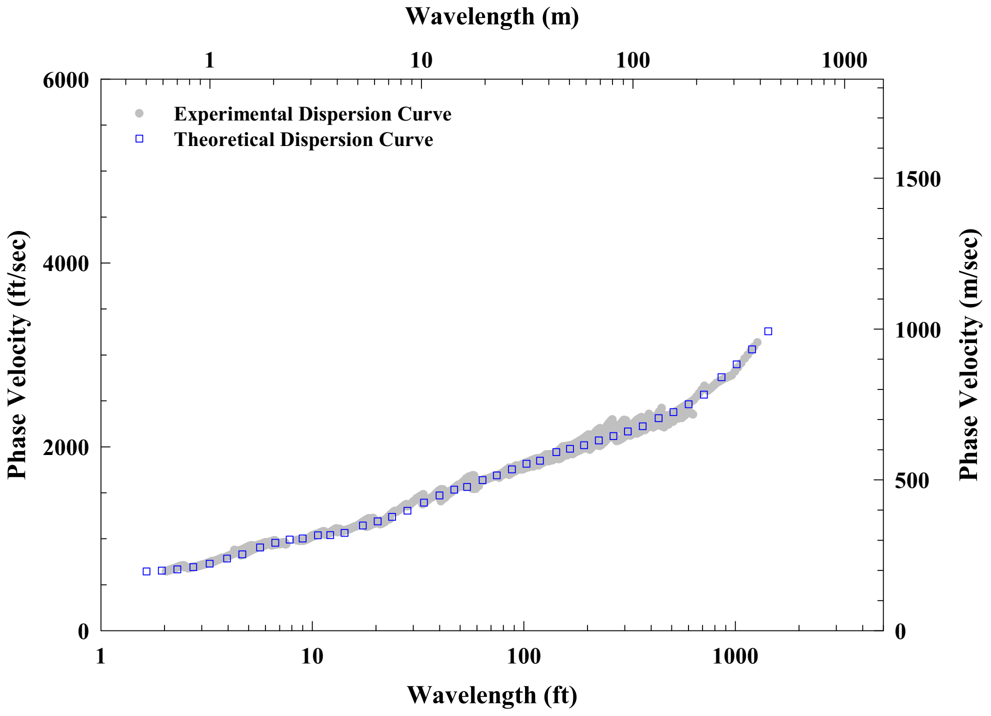
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-49. Shear Wave Velocity Profile Determined at NPF 27



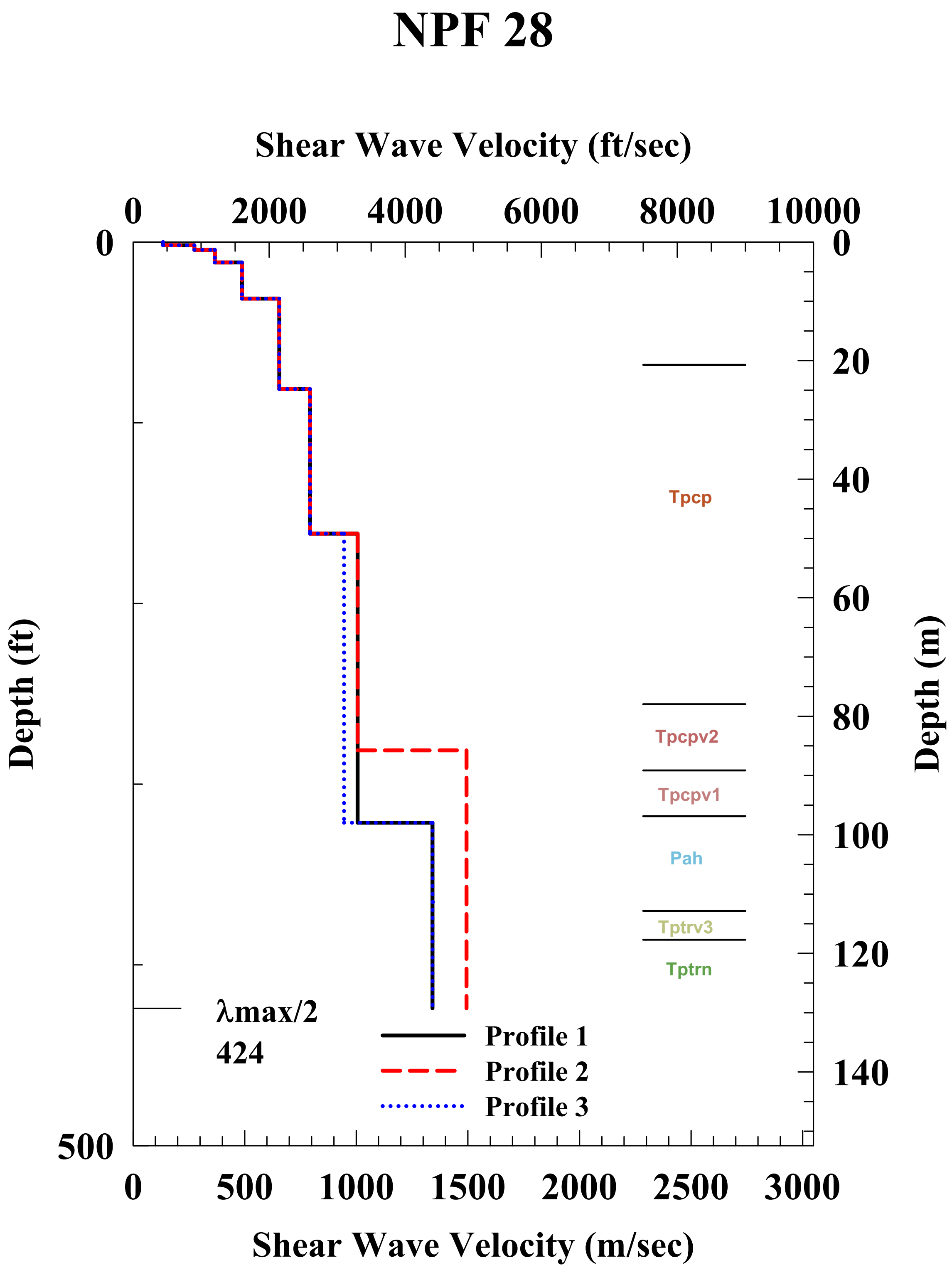
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-50. Experimental and Theoretical Dispersion Curves from NPF 27; Linear Wavelength Axis



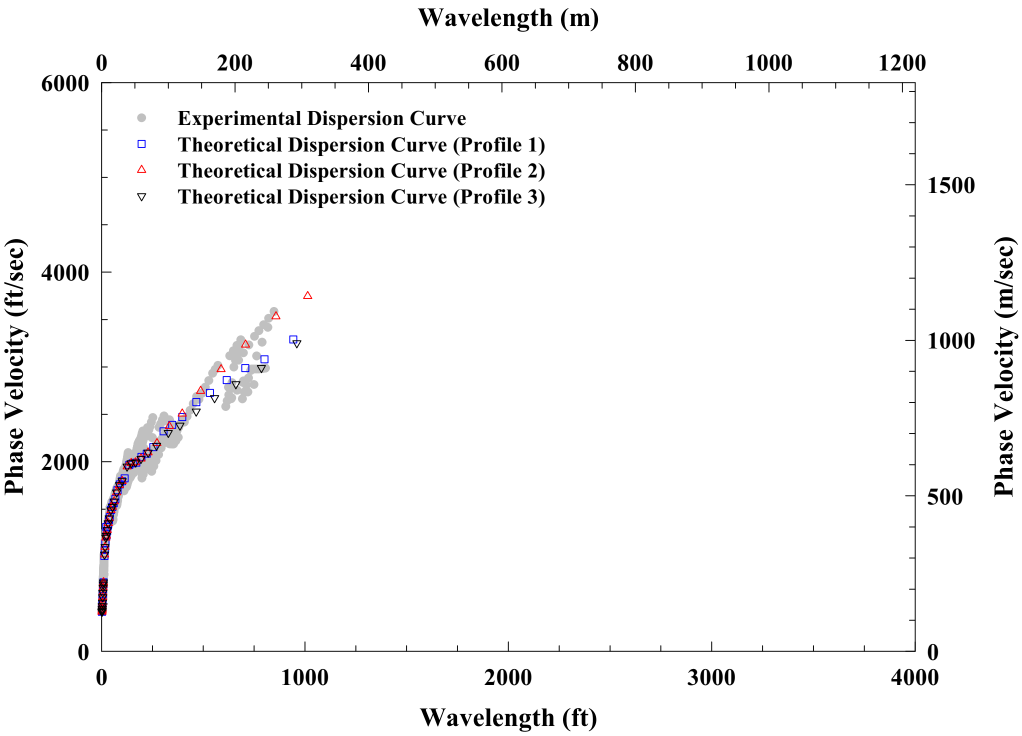
Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-51. Experimental and Theoretical Dispersion Curves from NPF 27; Logarithmic Wavelength Axis



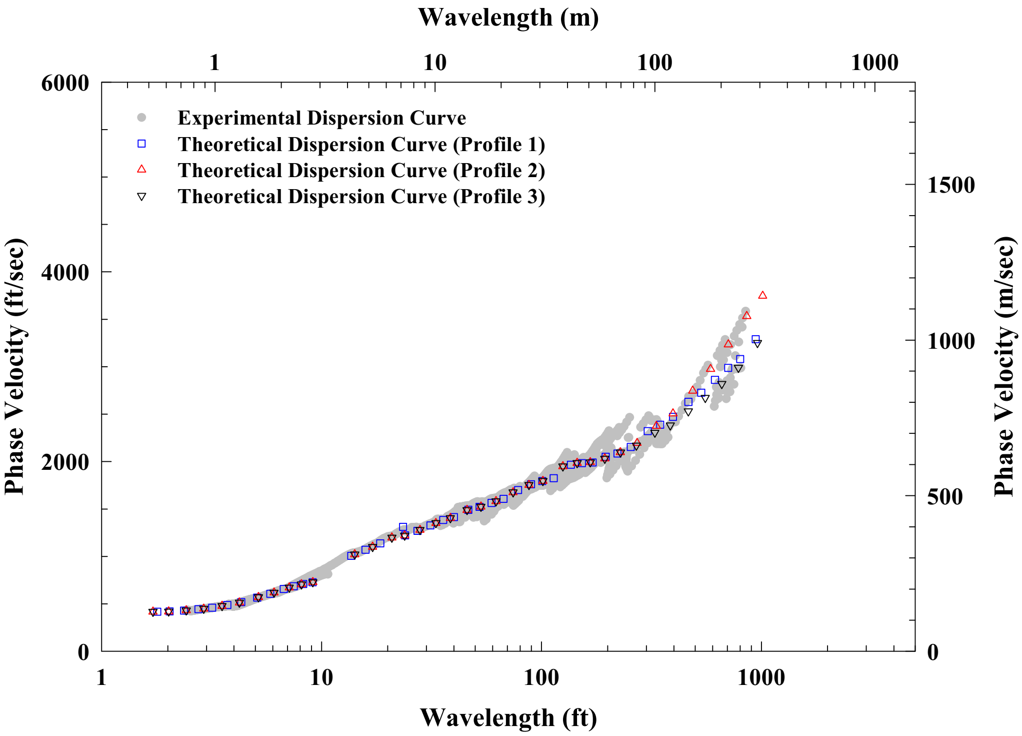
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure IV-52. Shear Wave Velocity Profile Determined at NPF 28



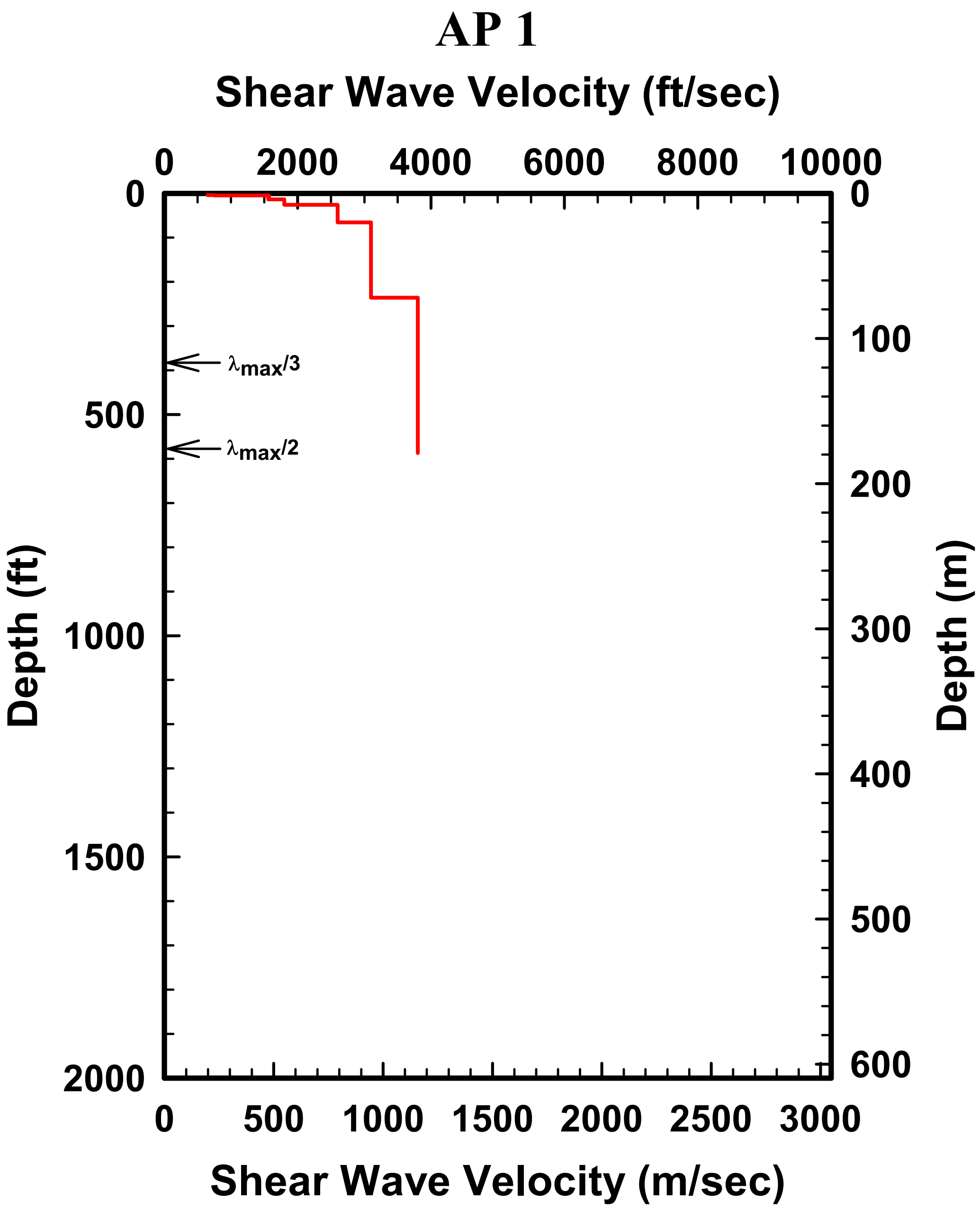
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-53. Experimental and Theoretical Dispersion Curves from NPF 28; Linear Wavelength Axis



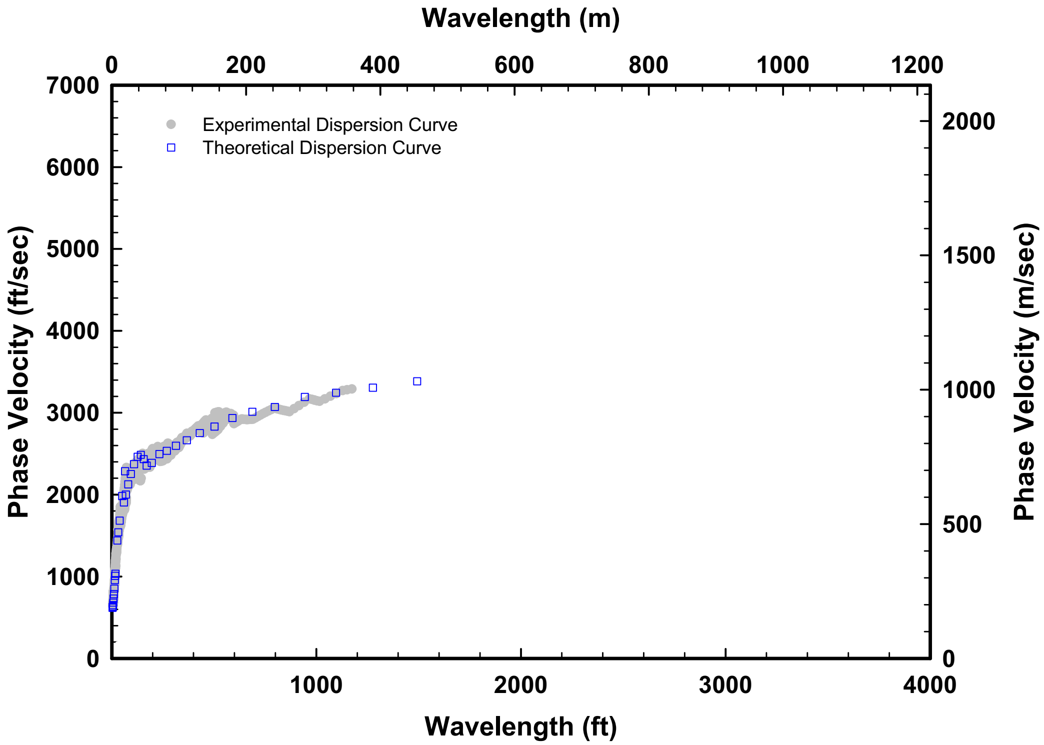
Source: DTN:MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-54. Experimental and Theoretical Dispersion Curves from NPF 28; Logarithmic Wavelength Axis



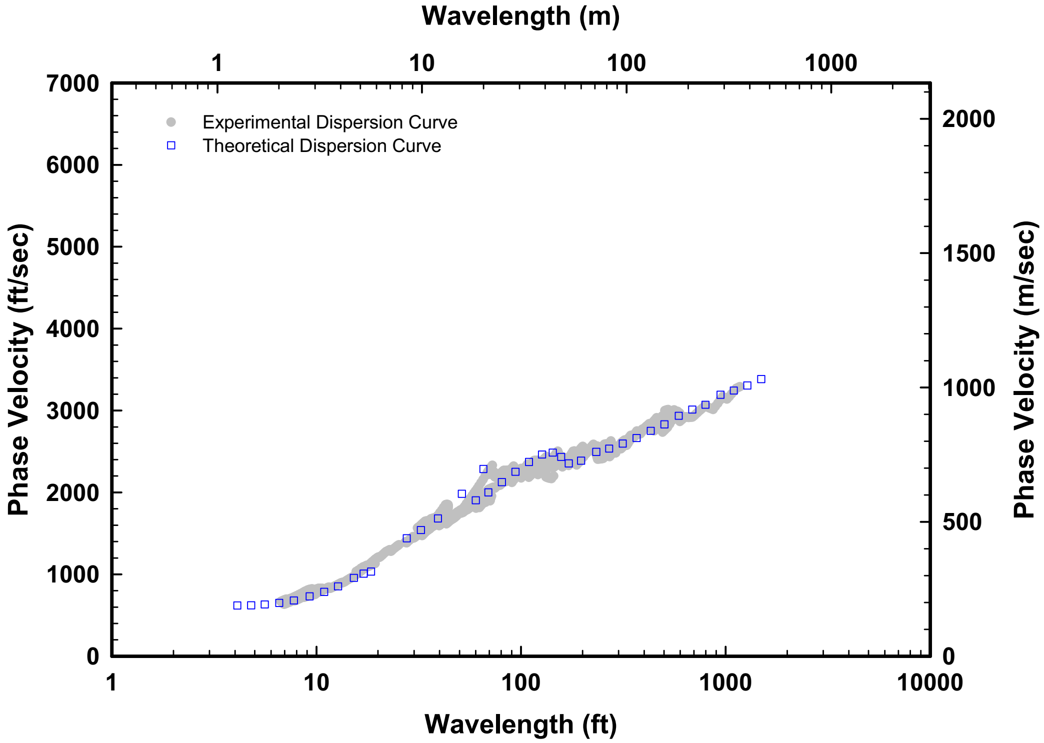
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-55. Shear Wave Velocity Profile Determined at AP 1



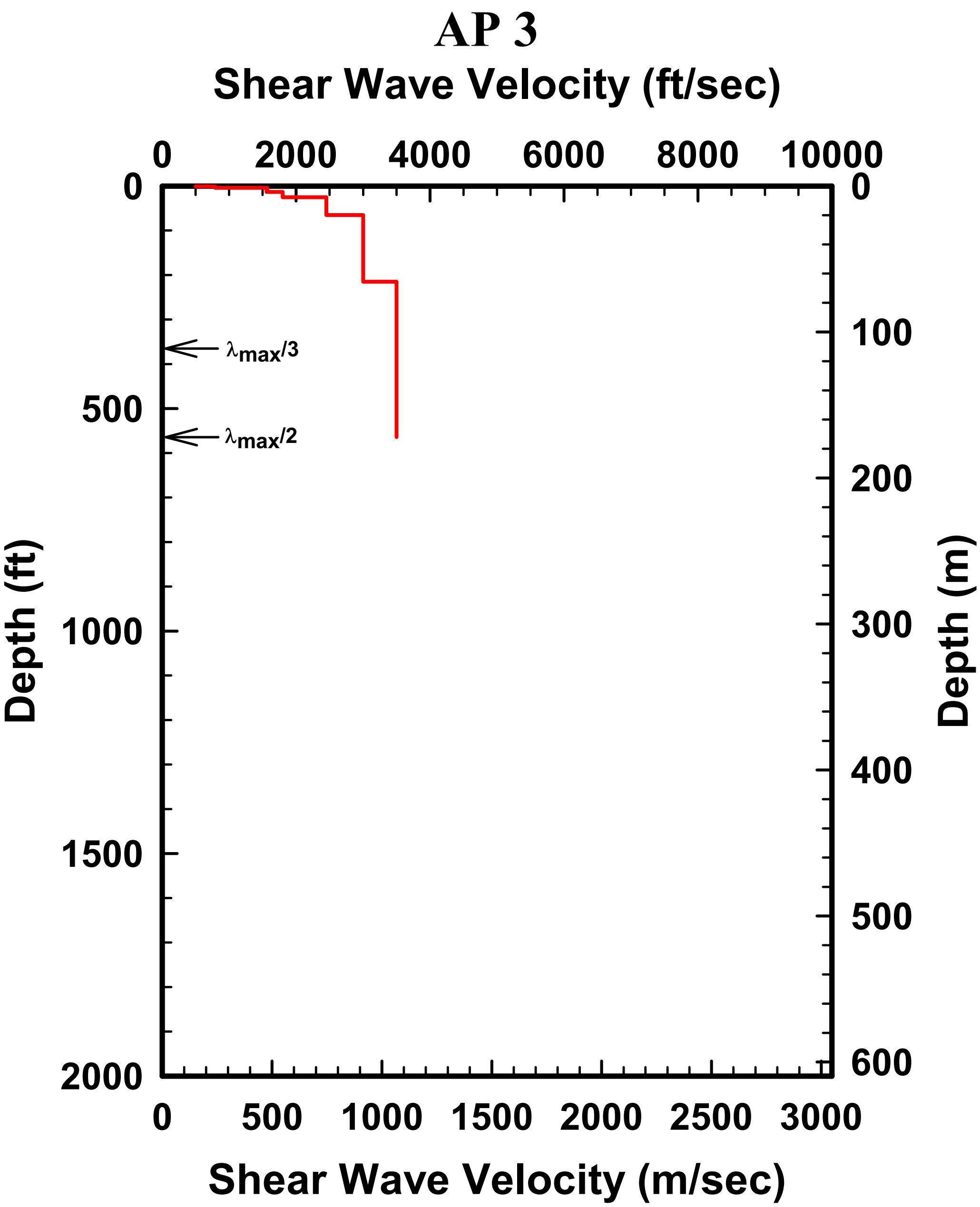
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-56. Experimental and Theoretical Dispersion Curves from AP 1; Linear Wavelength Axis



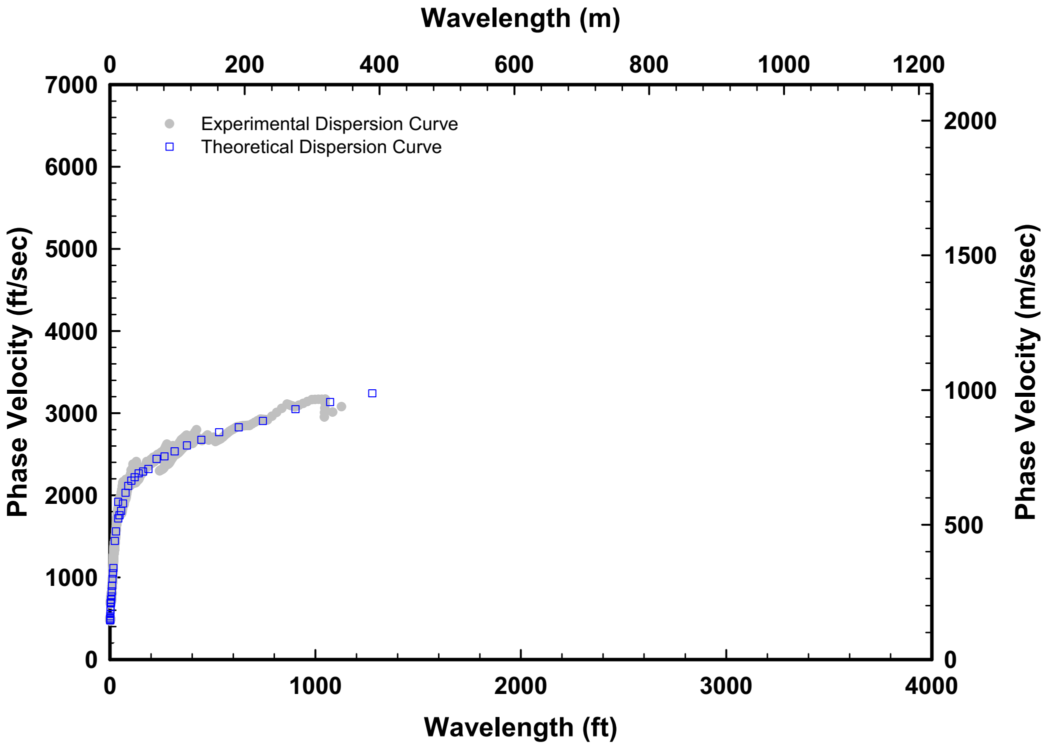
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-57. Experimental and Theoretical Dispersion Curves from AP 1; Logarithmic Wavelength Axis



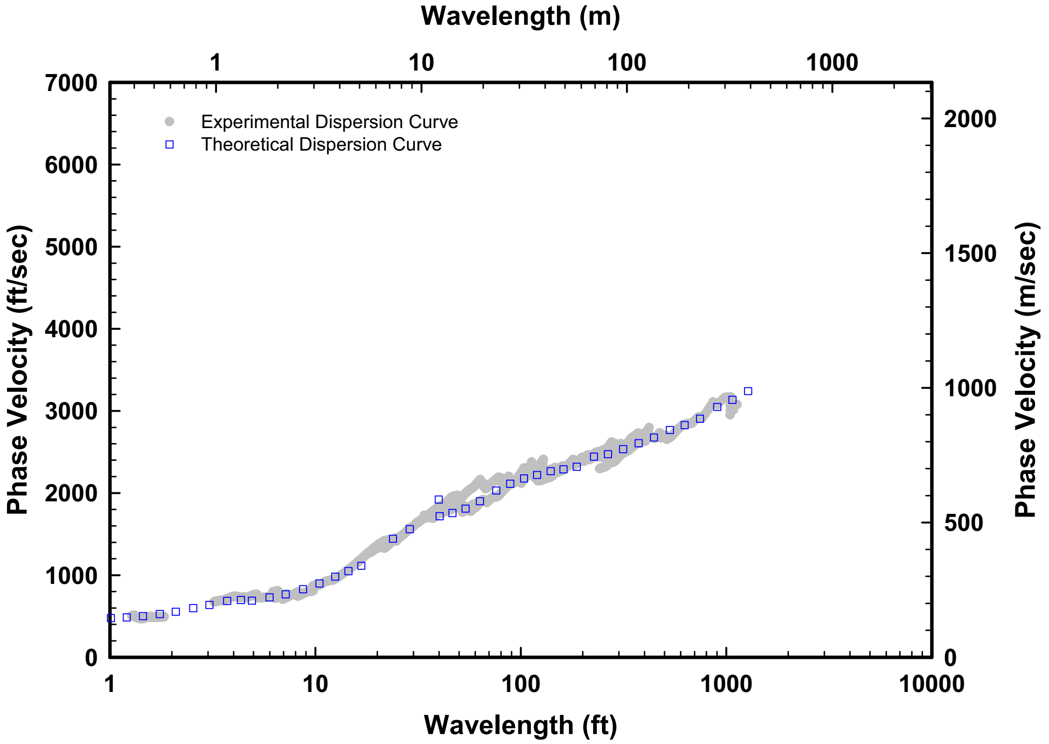
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-58. Shear Wave Velocity Profile Determined at AP 3



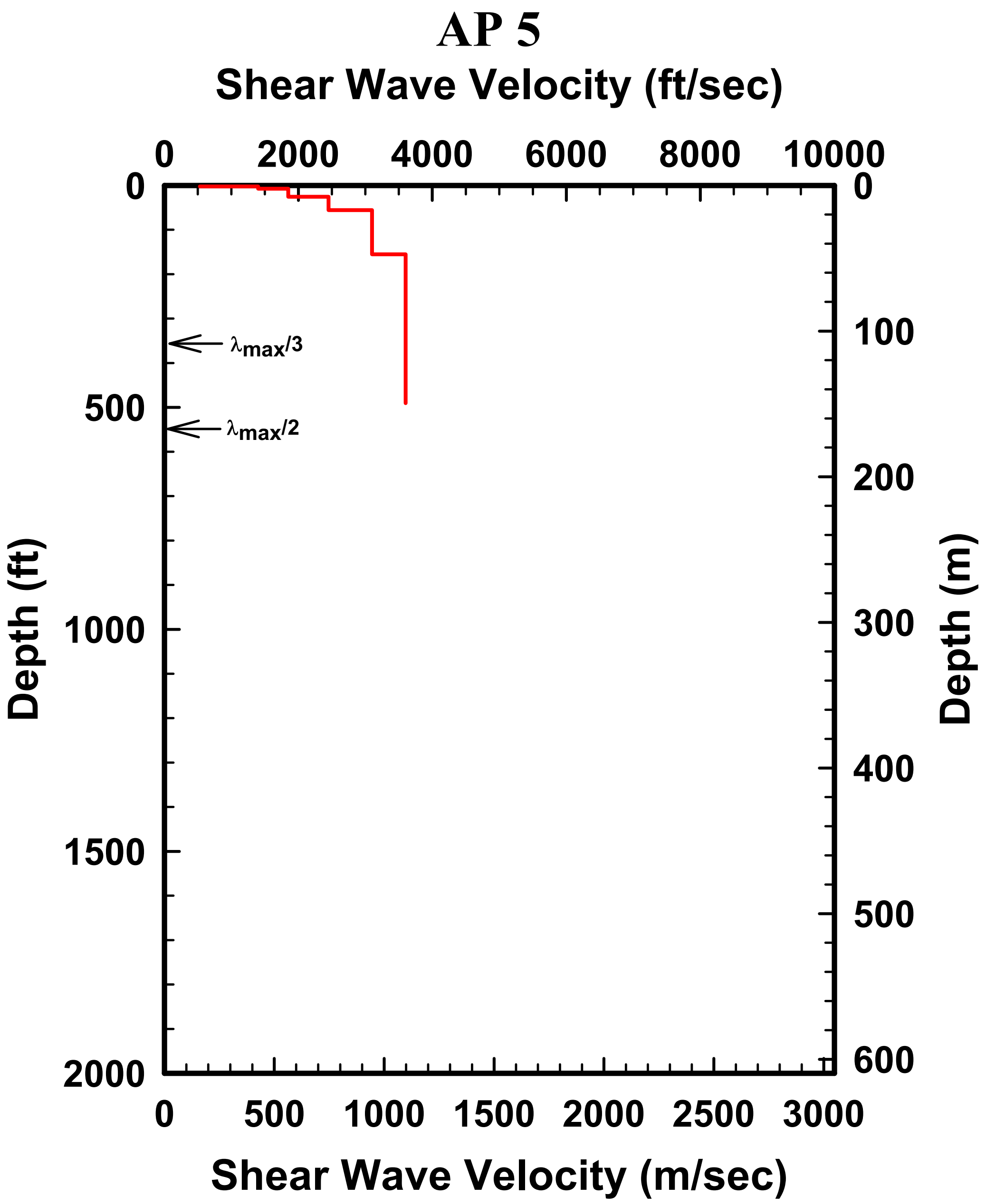
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-59. Experimental and Theoretical Dispersion Curves from AP 3; Linear Wavelength Axis



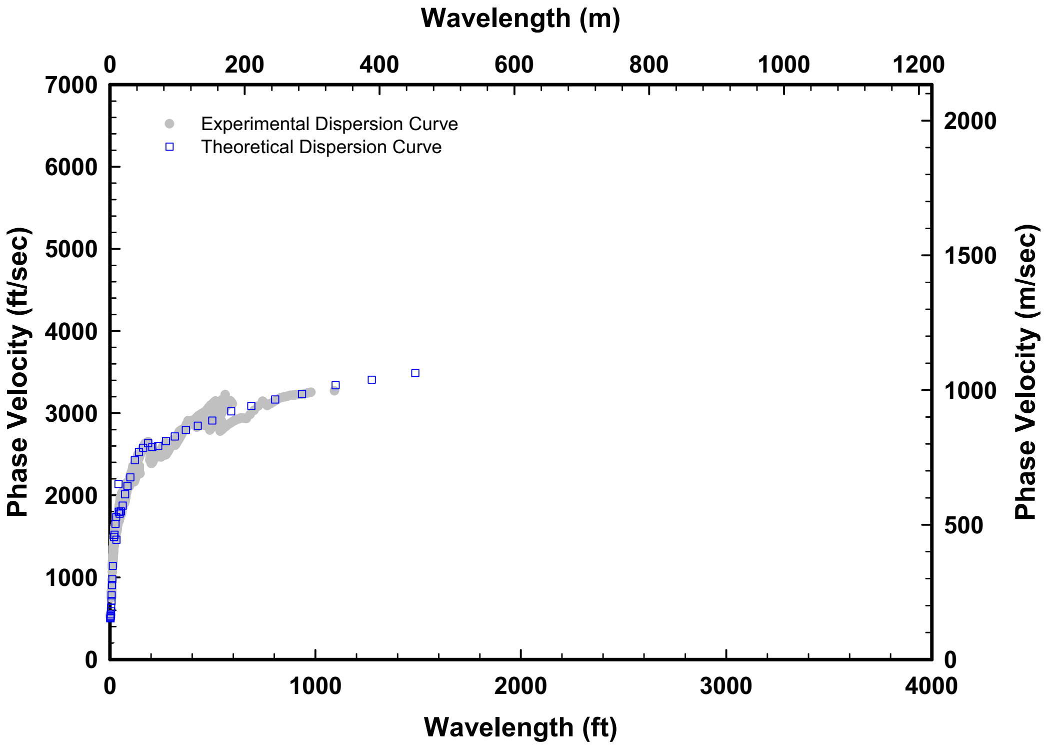
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-60. Experimental and Theoretical Dispersion Curves from AP 3; Logarithmic Wavelength Axis



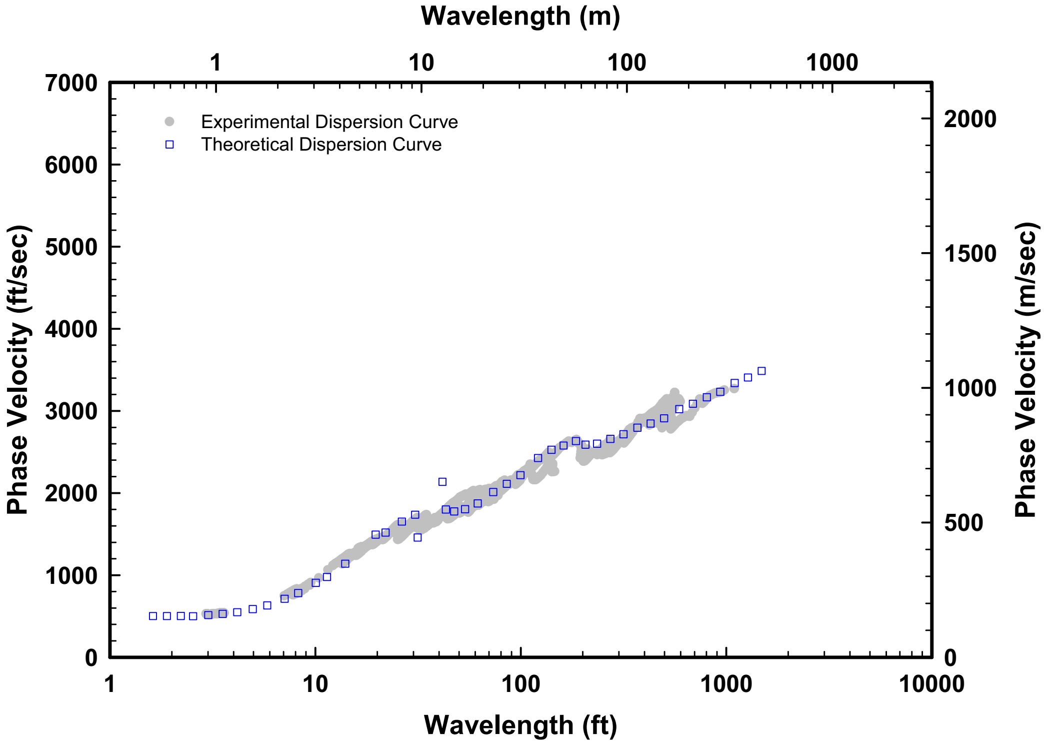
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-61. Shear Wave Velocity Profile Determined at AP 5



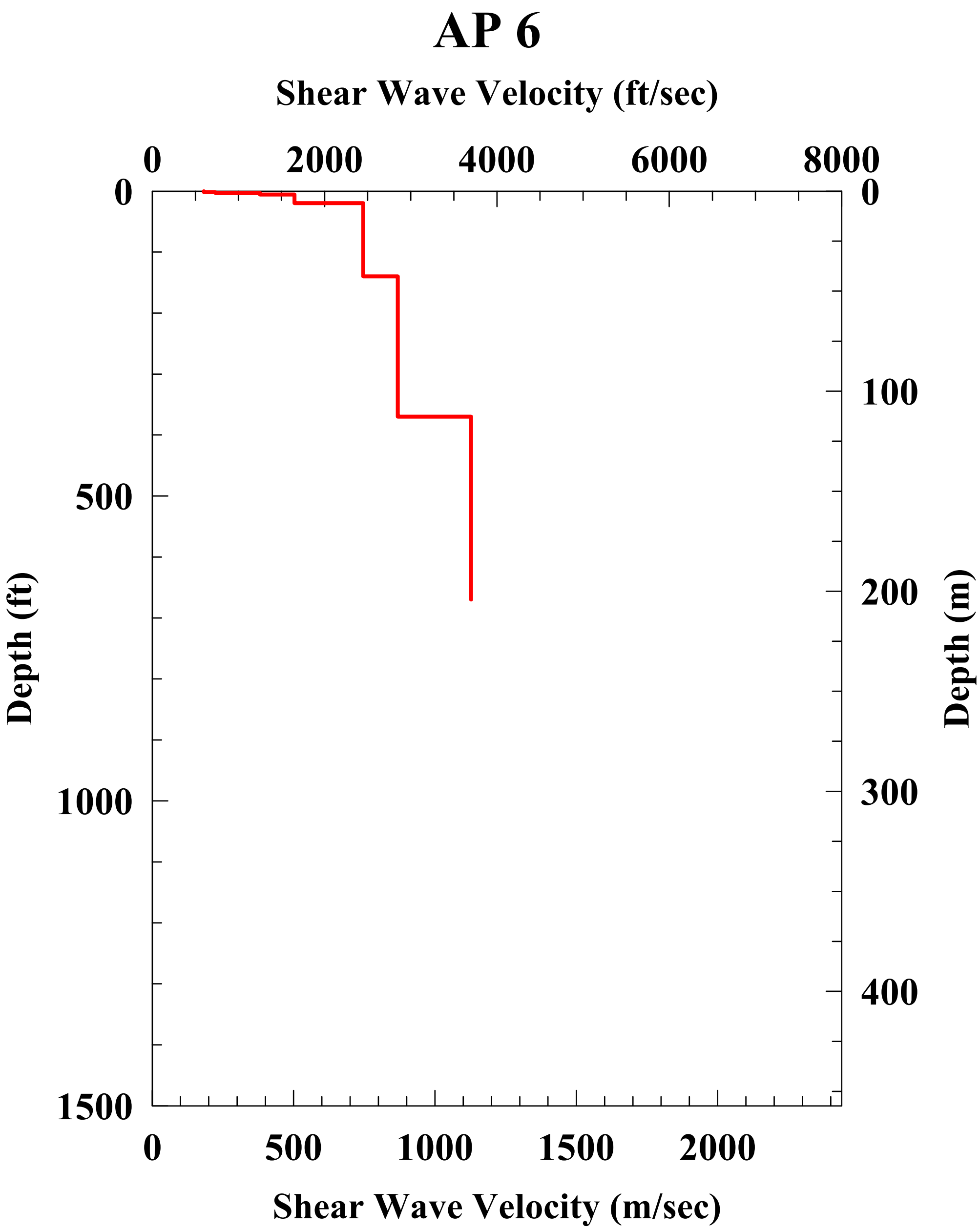
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-62. Experimental and Theoretical Dispersion Curves from AP 5; Linear Wavelength Axis



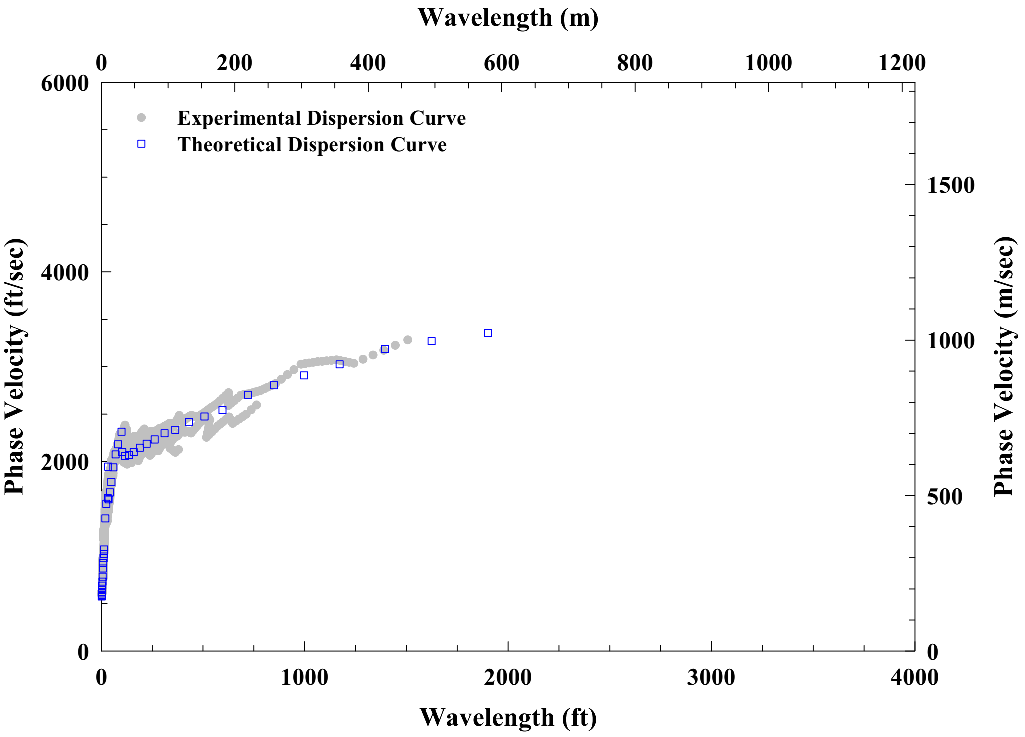
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-63. Experimental and Theoretical Dispersion Curves from AP 5; Logarithmic Wavelength Axis



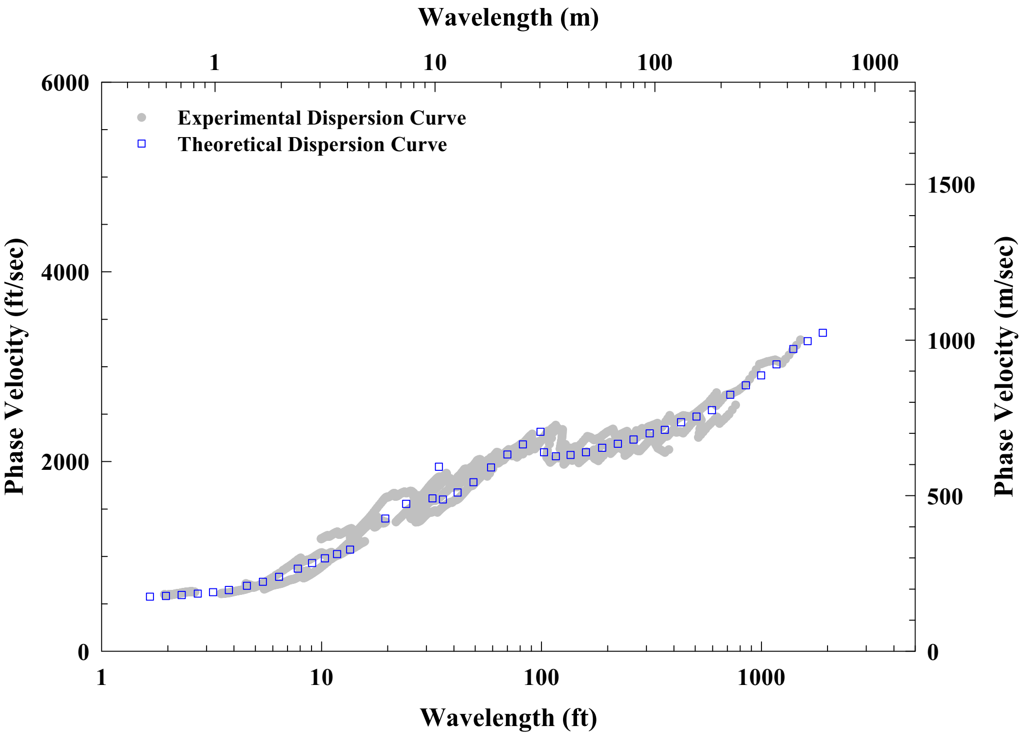
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-64. Shear Wave Velocity Profile Determined at AP 6



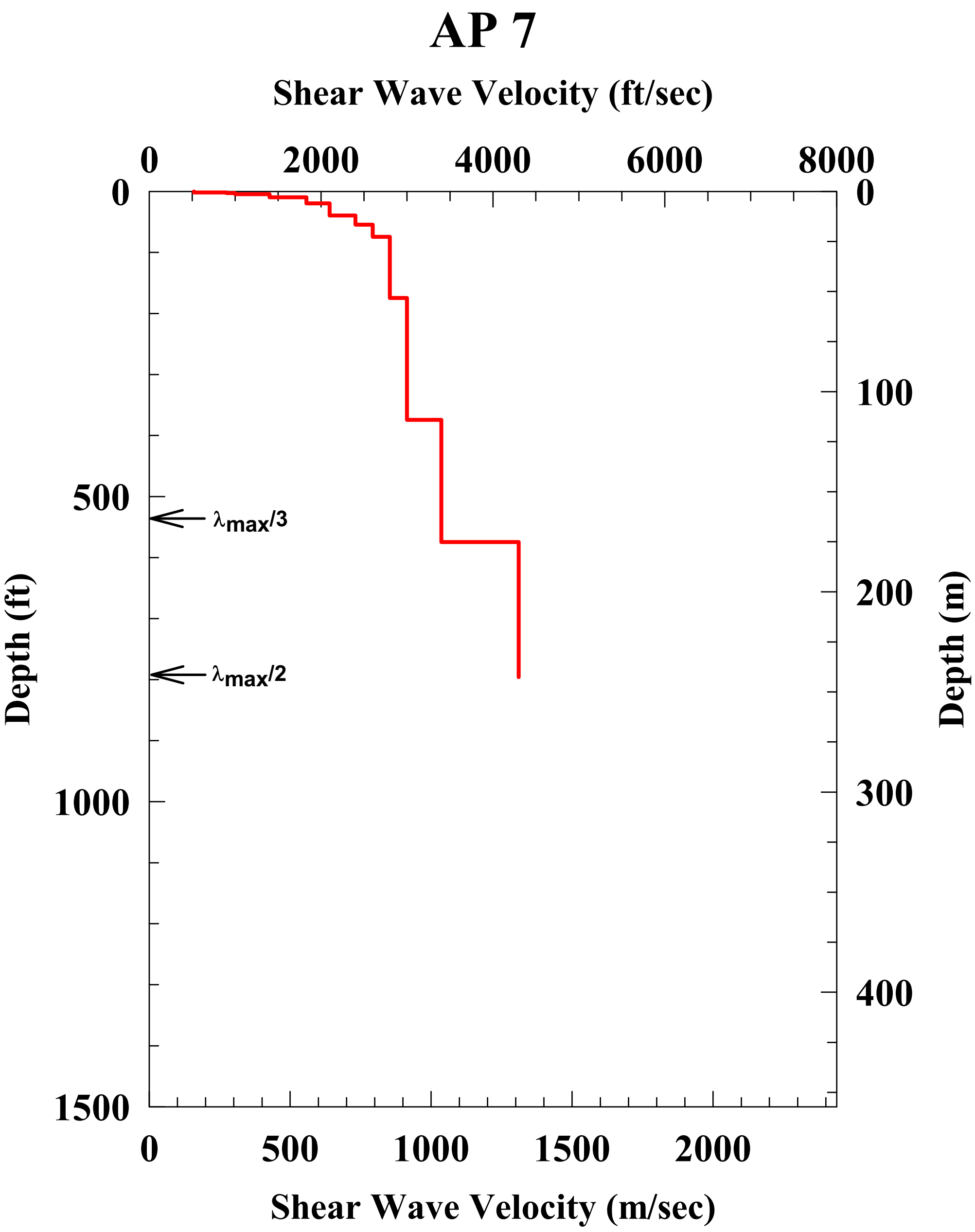
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-65. Experimental and Theoretical Dispersion Curves from AP 6; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-66. Experimental and Theoretical Dispersion Curves from AP 6; Logarithmic Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-67. Shear Wave Velocity Profile Determined at AP 7

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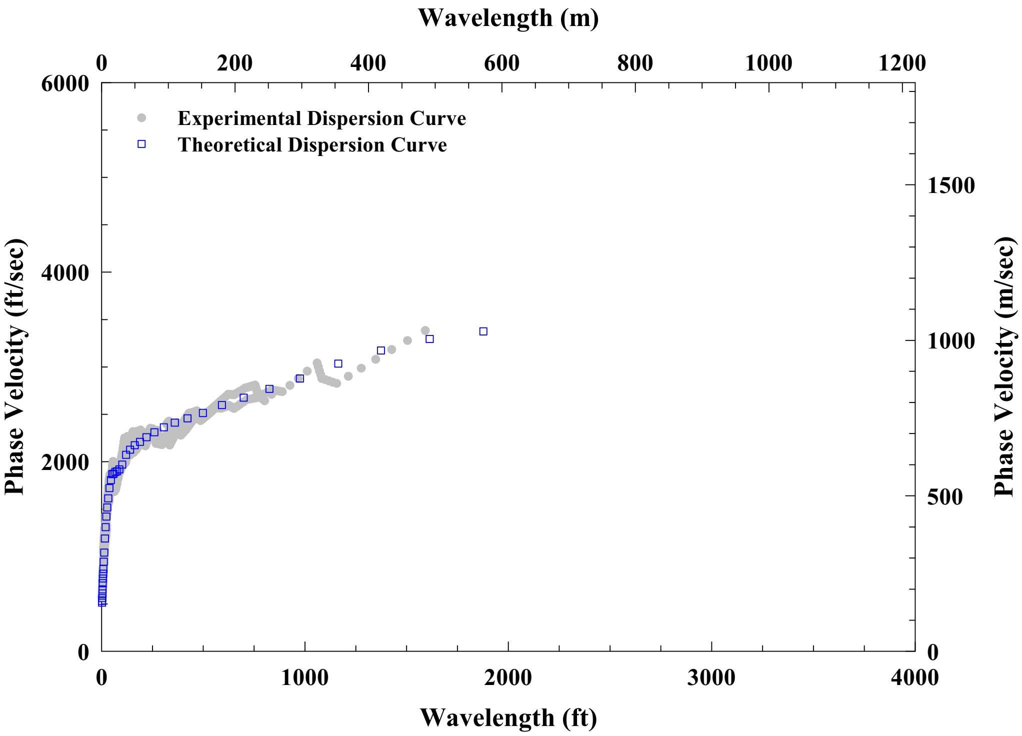
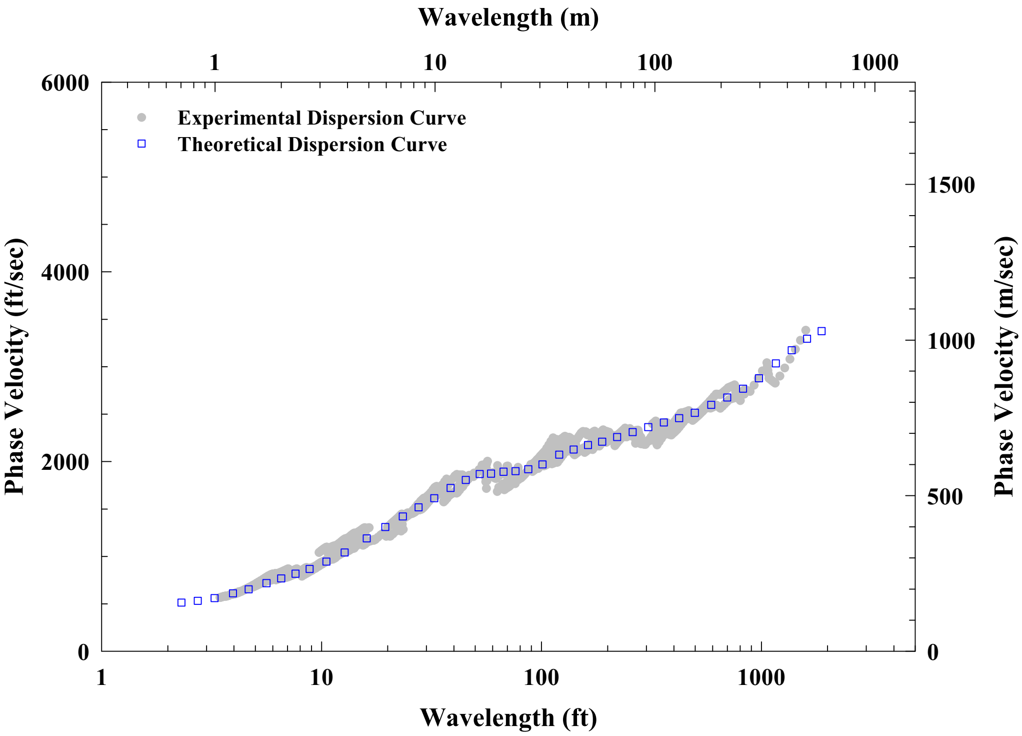


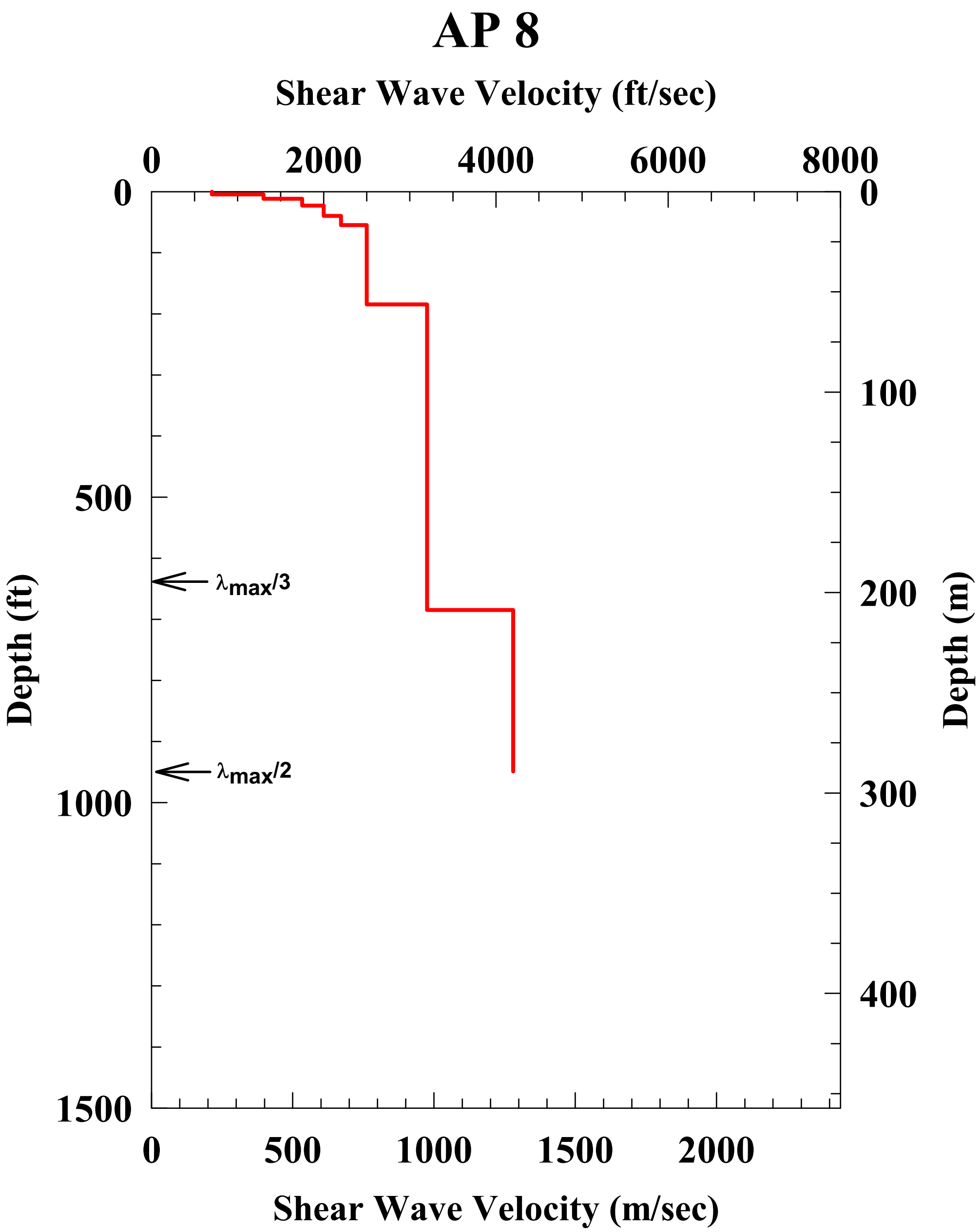
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-68. Experimental and Theoretical Dispersion Curves from AP 7; Linear Wavelength Axis



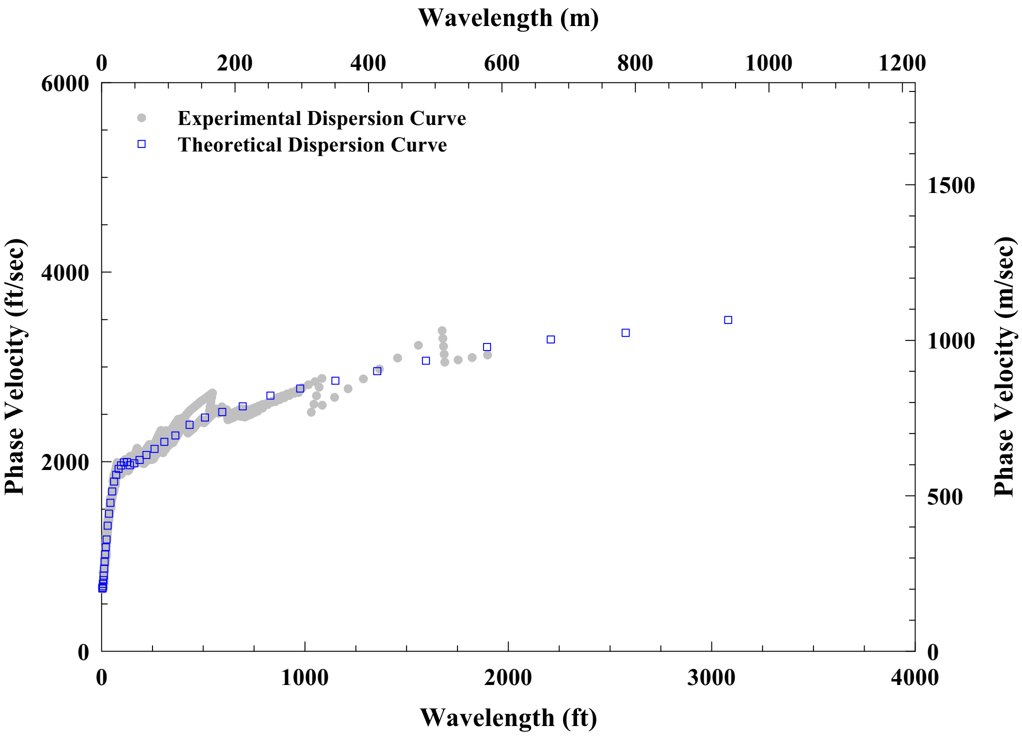
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-69. Experimental and Theoretical Dispersion Curves from AP 7; Logarithmic Wavelength Axis



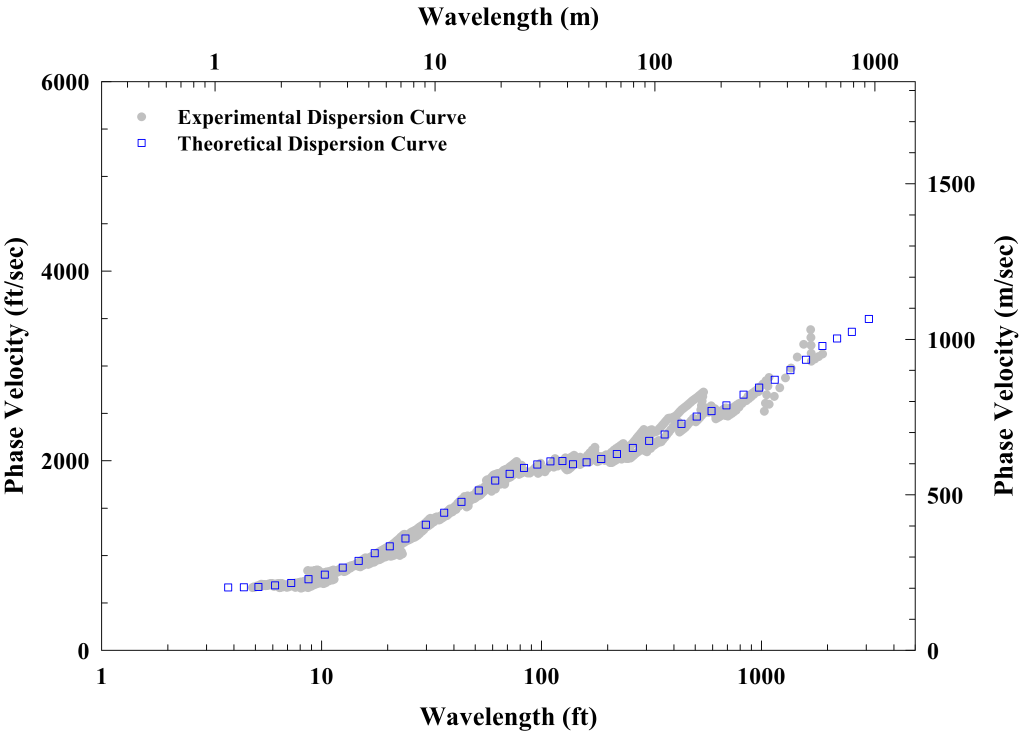
Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-70. Shear Wave Velocity Profile Determined at AP 8



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-71. Experimental and Theoretical Dispersion Curves from AP 8; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS 182125]; Stokoe 2007 [DIRS 183327].

Figure IV-72. Experimental and Theoretical Dispersion Curves from AP 8; Logarithmic Wavelength Axis

ATTACHMENT V

SASW SHEAR WAVE VELOCITY PROFILES FROM AREAS OUTSIDE THE NPF

ATTACHMENT V
SASW SHEAR WAVE VELOCITY PROFILES FROM AREAS OUTSIDE THE NPF

As outlined in Section 6.3.1, in 2004 and 2005, Spectral-Analysis-of-Surface-Wave (SASW) surveys were performed on the surface outside what is considered the North Portal Facilities (NPF) area. These SASW surveys are identified with a "YM" nomenclature. This testing consisted of 25 SASW surveys as listed in Table 6.3-1. This attachment presents the SASW theoretical dispersion curves from experimental dispersion curves and one-dimensional, layered, shear wave velocity (V_S) profiles for the 25 surface sites outside the NPF Area.

The theoretical dispersion curves were developed using WinSASW V. 1.23 (STN: 10588-1.23-00 [DIRS 159433]). The theoretical dispersion curve is fit to the experimental curve through an iterative forward modeling procedure. Tabular data for the theoretical dispersion curves and velocity profiles are contained in DTN: MO0609SASWSTDC.003 [DIRS182125], while plots of the data are presented the scientific notebook supplement accompanying the data package (Stokoe 2007 [DIRS 183327]).

In many cases, multiple arrays were tested at each site. These arrays are numbered as T1, T2, and/or T3… etc. The stratigraphic definitions shown on the plots are included for information purposes only. The stratigraphic information is from DTN: MO0012MWDGFM02.002 [DIRS 153777] queried by the software EarthVision v5.1 (STN: 10174-5.1-00 [DIRS 167994]). The theoretical dispersion curves and shear wave velocity profiles are presented in alphanumeric order beginning on page V-7. Table V-1 shows the as-built survey coordinates for YM SASW points (DTN: MO0701ABSRFLL2.000 [DIRS 182483]).

Table V-1. As-Built Survey Coordinates for SASW YM Sites

Location-Test-Point ID	Coord. Northing	Coord. Easting	Elev.	Scientific Notebook Page	Descriptor
YM 1-T1-N	770463.01	559040.36	4827.48	59	SASW RF 1-NEAR
YM 1-T1-C	769721.10	559150.33	4818.34		SASW RF 1-CENTER
YM 1-T1-F	768215.11	558899.10	4854.12		SASW RF 1-FAR
YM 1-T2-N	771066.44	559021.65	4840.45	115	SASW RF 1A-NEAR
YM 1-T2-C	770331.95	559167.38	4826.17		SASW RF 1A-CENTER
YM 1-T2-F	769589.34	559281.88	4815.68		SASW RF 1A-FAR
YM 2-T1-N	767289.09	558893.50	4857.46	51	SASW RF 2-NEAR
YM 2-T1-C	766539.90	558889.99	4850.32		SASW RF 2-CENTER
YM 2-T1-F	765040.46	558880.32	4851.15		SASW RF 2-FAR
YM 2-T2-N	767291.45	558940.92	4856.01	113	SASW RF 2A-NEAR
YM 2-T2-C	766539.90	558889.99	4850.32		SASW RF 2-CENTER
YM 2-T2-F	765786.90	558922.22	4841.95		SASW RF 2A-FAR
YM 3-T1-N	765182.05	558920.22	4845.35	55	SASW RF 3-NEAR
YM 3-T1-C	764181.80	558952.28	4856.62		SASW RF 3-CENTER
YM 3-T1-F	763200.17	558759.78	4890.21		SASW RF 3-FAR

Table V-1. As-Built Survey Coordinates for SASW YM Sites (Continued)

Location-Test-Point ID	Coord. Northing	Coord. Easting	Elev.	Scientific Notebook Page	Descriptor
YM 3-T2-N	764783.34	558920.45	4851.04	57	SASW RF 3R-NEAR
YM 3-T2-C	764181.80	558952.28	4856.62		SASW RF 3-CENTER
YM 3-T2-F	766280.95	558894.71	4846.18		SASW RF 3R-FAR
YM 3-T3-N	764931.83	558927.68	4849.03	112	SASW RF 3A-NEAR
YM 3-T3-C	*Not Found	*	*		SASW RF 3A-CENTER
YM 3-T3-F	763432.31	558883.68	4874.19		SASW RF 3A-FAR
YM 4-T1-N	762436.40	558595.31	4905.95	53 and 54	SASW RF 4-NEAR
YM 4-T1-C	760814.24	558291.74	4935.68		SASW RF 4-CENTER
YM 4-T1-F	760232.47	558149.83	4940.42		SASW RF 4-FAR
YM 5-T1-N	775656.65	563062.66	4798.92	63	SASW RF 5-NEAR
YM 5-T1-C	775234.27	563327.63	4763.35		SASW RF 5-CENTER
YM 5-T1-F	774325.07	563787.57	4659.30		SASW RF 5-FAR
YM 5-T2-N	776145.79	562811.57	4837.89	118	SASW RF 5A-NEAR
YM 5-T2-C	775543.03	563262.85	4783.02		SASW RF 5A-CENTER
YM 5-T2-F	774846.76	563561.84	4721.90		SASW RF 5A-FAR
YM 6-T1-N	773722.12	563726.81	4622.45	69	SASW RF 6-NEAR
YM 6-T1-C	772769.64	564032.43	4545.92		SASW RF 6-CENTER
YM 6-T1-F	771877.41	564483.36	4450.64		SASW RF 6-FAR
YM 6-T2-N	773577.84	563756.60	4612.37	119	SASW RF 6A-NEAR
YM 6-T2-C	772859.90	563986.59	4555.30		SASW RF 6A-CENTER
YM 6-T2-F	772172.19	564315.46	4483.13		SASW RF 6A-FAR
YM 8-T1-N	772879.41	561459.93	4464.96	71	SASW RF 8-NEAR
YM 8-T1-C	773300.44	561191.37	4493.77		SASW RF 8-CENTER
YM 8-T1-F	774120.93	560619.47	4558.80		SASW RF 8-FAR
YM 10-T1-N	772685.35	561622.01	4445.83	75	SASW RF10-NEAR
YM 10-T1-C	772304.78	561945.67	4415.25		SASW RF 10-CENTER
YM 10-T1-F	771920.88	562263.34	4379.10		SASW RF 10-FAR
YM 10-T2-N	772934.68	561454.54	4467.56	121	SASW RF 10A-NEAR
YM 10-T2-C	772294.03	561847.16	4417.12		SASW RF 10A-CENTER
YM 10-T2-F	771779.95	562410.04	4366.78		SASW RF 10A-FAR
YM 12-T1-N	771979.24	559892.50	4484.35	50	SASW RF 12-NEAR
YM 12-T1-C	771537.59	560208.49	4435.17		SASW RF 12-CENTER
YM 12-T1-F	770897.77	560694.84	4386.09		SASW RF 12-FAR
YM 13-T1-N	770162.65	561505.85	4310.49	47	SASW RF 13-NEAR
YM 13-T1-C	769862.81	562025.44	4272.61		SASW RF 13-CENTER
YM 13-T1-F	769115.52	562969.81	4203.84		SASW RF 13-FAR
YM 13-T2-N	770691.25	560777.76	4369.41	107	SASW RF 13A-NEAR
YM 13-T2-C	770239.01	561377.58	4319.55		SASW RF 13A-CENTER
YM 13-T2-F	769840.07	562017.38	4271.79		SASW RF 13A-FAR
YM 14A-T1-N	766550.95	564694.24	4040.51	43	SASW RF 14A-NEAR
YM 14A-T1-C	766177.06	565161.78	4008.99		SASW RF 14A-CENTER
YM 14A-T1-F	765395.70	566037.21	3954.76		SASW RF 14A-FAR

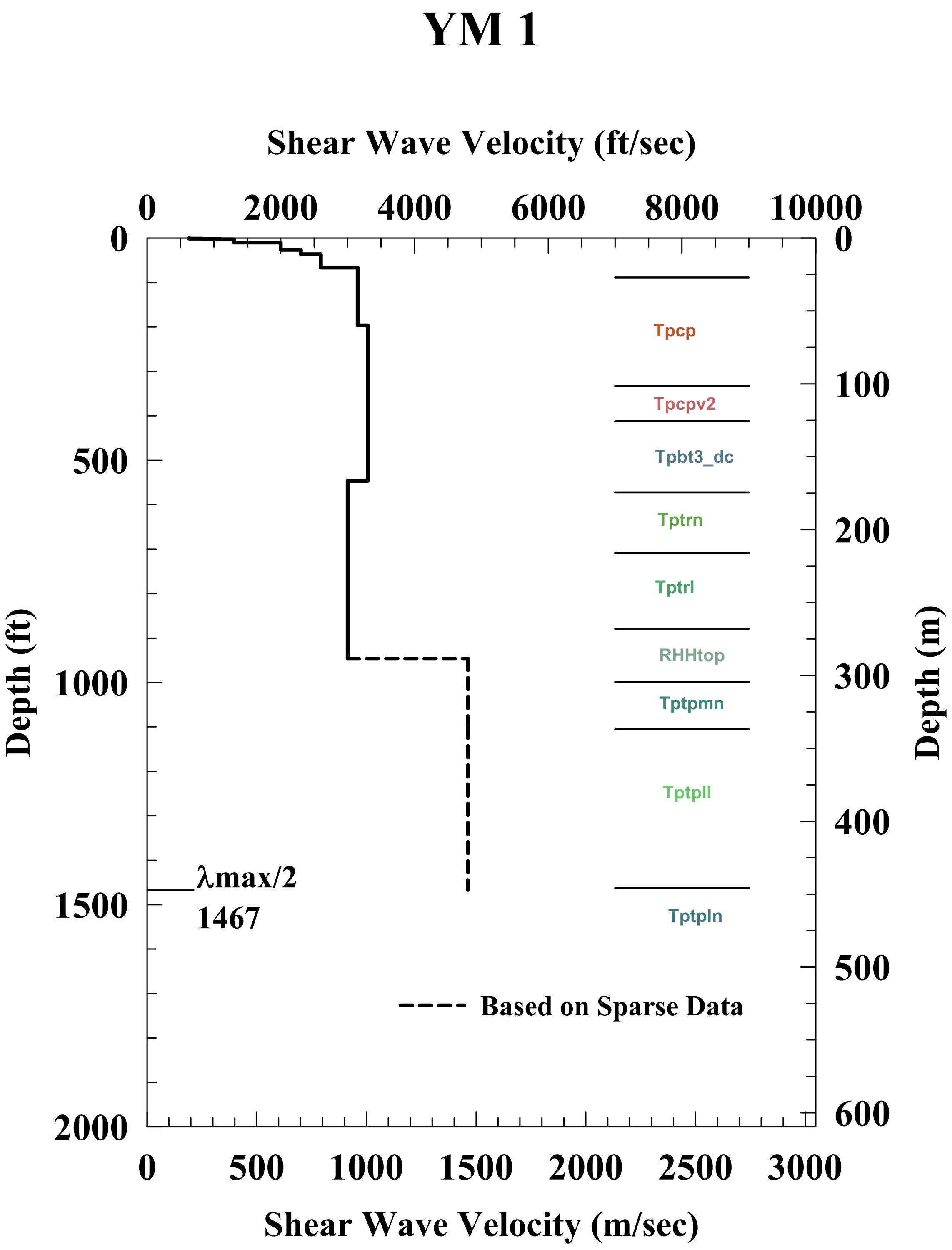
Table V-1. As-Built Survey Coordinates for SASW YM Sites (Continued)

Location-Test-Point ID	Coord. Northing	Coord. Easting	Elev.	Scientific Notebook Page	Descriptor
YM 14A-T2-N	767625.08	564187.59	4100.92	103 and 106	SASW RF 14AA-NEAR
YM 14A-T2-C	767028.79	564644.47	4059.41		SASW RF 14AA-CENTER
YM 14A-T2-F	765947.84	565686.24	3988.82		SASW RF 14AA-FAR
YM 14A-T2-FF	766331.68	564967.35	4023.38		SASW RF 14AAF-FAR
YM 14B-T1-N	767285.65	564133.32	4094.17	45	SASW RF 14B-NEAR
YM 14B-T1-C	767741.05	563891.69	4117.56		SASW RF 14B-CENTER
YM 14B-T1-F	768608.51	563423.39	4165.35		SASW RF 14B-FAR
YM 15A-T1-N	760300.15	565568.17	3954.92	37	SASW RF 15A-NEAR
YM 15A-T1-C	760675.94	564976.81	3997.72		SASW RF 15A-CENTER
YM 15A-T1-F	760932.25	564550.06	4031.31		SASW RF 15A-FAR
YM 15A-T2-N	761919.74	563520.25	4129.34	96	SASW RF 15A2-NEAR
YM 15A-T2-C	761463.77	564116.29	4076.52		SASW RF 15A2-CENTER
YM 15A-T2-F	760549.85	565303.31	3977.66		SASW RF 15A2-FAR
YM 15B-T1-N	760359.95	564572.07	4020.93	39	SASW RF 15B-NEAR
YM 15B-T1-C	760363.38	564870.87	3998.88		SASW RF 15B-CENTER
YM 15B-T1-F	760292.11	565866.01	3941.28		SASW RF 15B-FAR
YM 15B-T2-N	760354.49	564168.08	4055.52	110	SASW RF 15BA-NEAR
YM 15B-T2-C	760332.06	564784.11	4005.71		SASW RF 15BA-CENTER
YM 15B-T2-F	760272.28	565380.70	3967.67		SASW RF 15BA-FAR
YM 16-T1-N	760481.85	563985.82	4075.65	41	SASW RF 16-NEAR
YM 16-T1-C	760817.03	562941.76	4168.07		SASW RF 16-CENTER
YM 16-T1-F	760851.18	562545.69	4199.45		SASW RF 16-FAR
YM 16-T2-N	760719.16	563366.55	4128.75	97	SASW RF 16A-NEAR
YM 16-T2-C	760431.89	563900.43	4076.49		SASW RF 16A-CENTER
YM 16-T2-F	760367.74	565102.59	3984.30		SASW RF 16A-FAR
YM 17-T1-N	778870.20	559890.04	5146.35	62	SASW RF 17-NEAR
YM 17-T1-C	778482.06	560529.59	5093.56		SASW RF 17-CENTER
YM 17-T1-F	777618.19	561789.48	4967.43		SASW RF 17-FAR
YM 17-T2-N	778800.21	559988.78	5138.78	117	SASW RF 17-T2-NEAR
YM 17-T2-C	778380.46	560610.93	5086.37		SASW RF 17-T2-CENTER
YM 17-T2-F	777950.24	561223.02	5025.64		SASW RF 17-T2-FAR
YM 19-T1-N	757219.43	558350.21	4878.02	171	SASW RF 19-T1-NEAR
YM 19-T1-C	757568.00	558314.69	4879.48		SASW RF 19-T1-CENTER
YM 19-T1-F	758263.22	558245.80	4890.42		SASW RF 19-T1-FAR
YM 19-T2-N	757494.83	558344.49	4877.63	171	SASW RF 19-T2-NEAR
YM 19-T2-C	757568.47	558334.43	4878.14		SASW RF 19-T2-CENTER
YM 19-T2-F	757718.62	558315.75	4880.17		SASW RF 19-T2-FAR
YM 20-T1-N	748960.30	574517.74	3411.60	172	SASW RF 20-T1-NEAR
YM 20-T1-C	749713.35	574526.06	3422.65		SASW RF 20-T1-CENTER
YM 20-T1-F	750711.46	574524.91	3457.16		SASW RF 20-T1-FAR

Table V-1. As-Built Survey Coordinates for SASW YM Sites (Continued)

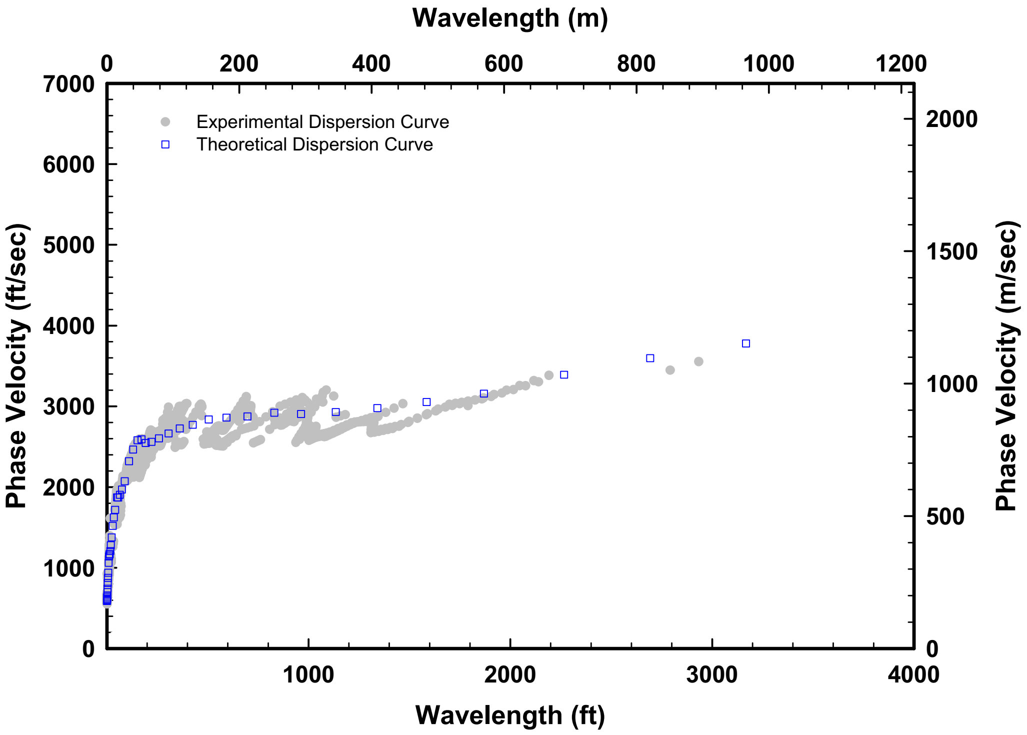
Location-Test-Point ID	**Coord. Northing**	**Coord. Easting**	**Elev.**	**Scientific Notebook Page**	**Descriptor**
YM 20-T2-N	748706.22	574515.31	3402.66	172	SASW RF 20-T2-NEAR
YM 20-T2-C	748830.78	574516.91	3408.09		SASW RF 20-T2-CENTER
YM 20-T2-F	749081.09	574517.61	3405.75		SASW RF 20-T2-FAR
YM 21-T1-N	766048.96	563578.86	4125.32	177	SASW RF 21-T1-NEAR
YM 21-T1-C	766108.57	564024.99	4086.96		SASW RF 21-T1-CENTER
YM 21-T1-F	766239.27	564914.83	4021.50		SASW RF 21-T1-FAR
YM 21-T2-N	766054.74	563679.31	4115.70	179	SASW RF 21-T2-NEAR
YM 21-T2-C	766144.38	564220.86	4076.06		SASW RF 21-T2-CENTER
YM 21-T2-F	766314.04	565307.90	4012.89		SASW RF 21-T2-FAR
YM 22-T1-N	780467.61	565019.35	4292.04	182	SASW RF 22-T1-NEAR
YM 22-T1-C	780202.35	565442.82	4272.58		SASW RF 22-T1-CENTER
YM 22-T1-F	779537.87	566500.71	4212.48		SASW RF 22-T1-FAR
YM 23-T1-N	767833.52	562590.96	4193.93	189	SASW RF 23-T1-NEAR
YM 23-T1-C	767716.94	563178.89	4156.08		SASW RF 23-T1-CENTER
YM 23-T1-F	767483.26	564355.29	4090.56		SASW RF 23-T1-FAR
YM 25-T1-N	744896.58	574361.87	3327.65	201	SASW RF 25-T1-NEAR
YM 25-T1-C	745040.57	573988.36	3340.37		SASW RF 25-T1-CENTER
YM 25-T1-F	745298.07	573338.87	3364.45		SASW RF 25-T1-FAR
YM 26-T1-N	747672.25	568547.43	3569.03	207	SASW RF 26-T1-NEAR
YM 26-T1-C	747375.38	568949.56	3548.83		SASW RF 26-T1-CENTER
YM 26-T1-F	746785.99	569757.26	3507.09		SASW RF 26-T1-FAR

Source: DTN: MO0701ABSRFLL2.000 [DIRS182483].



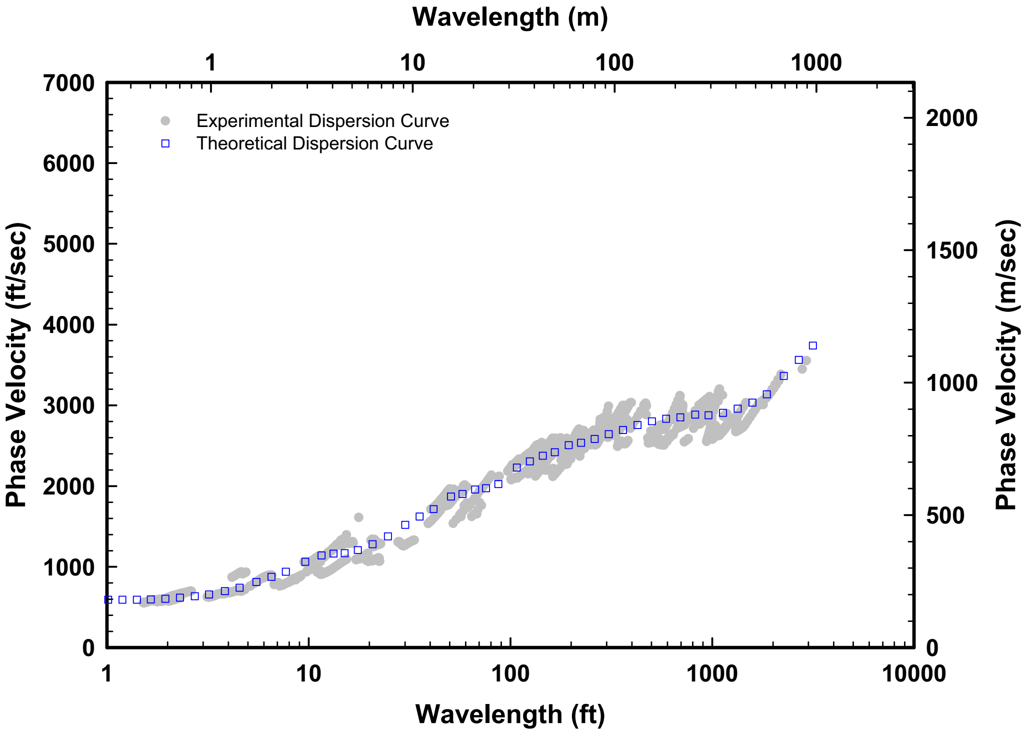
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-1. Shear Wave Velocity Profile Determined at YM 1-T1 and YM 1-T2



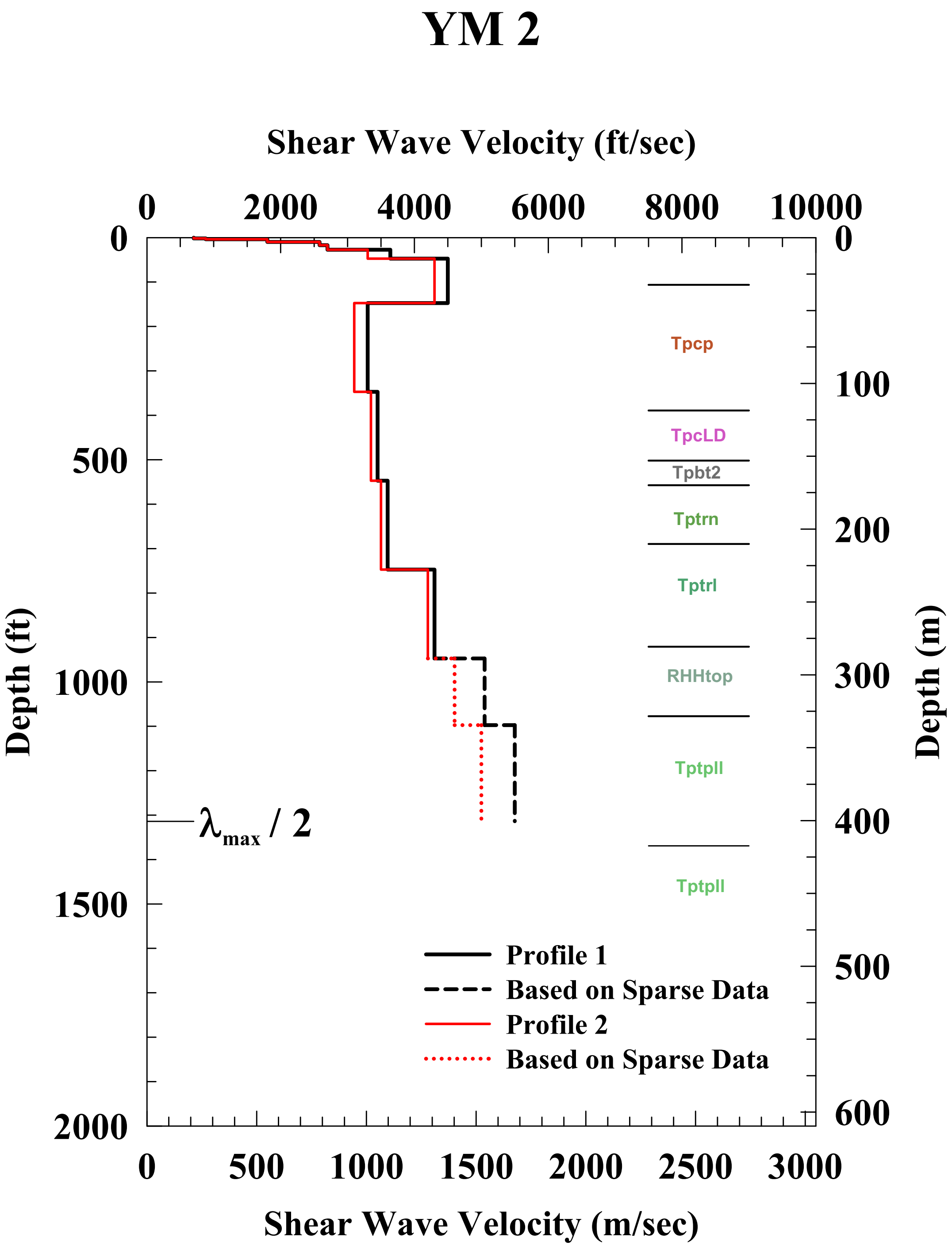
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-2. Experimental and Theoretical Dispersion Curves from YM 1-T1 and YM 1-T2; Linear Wavelength Axis



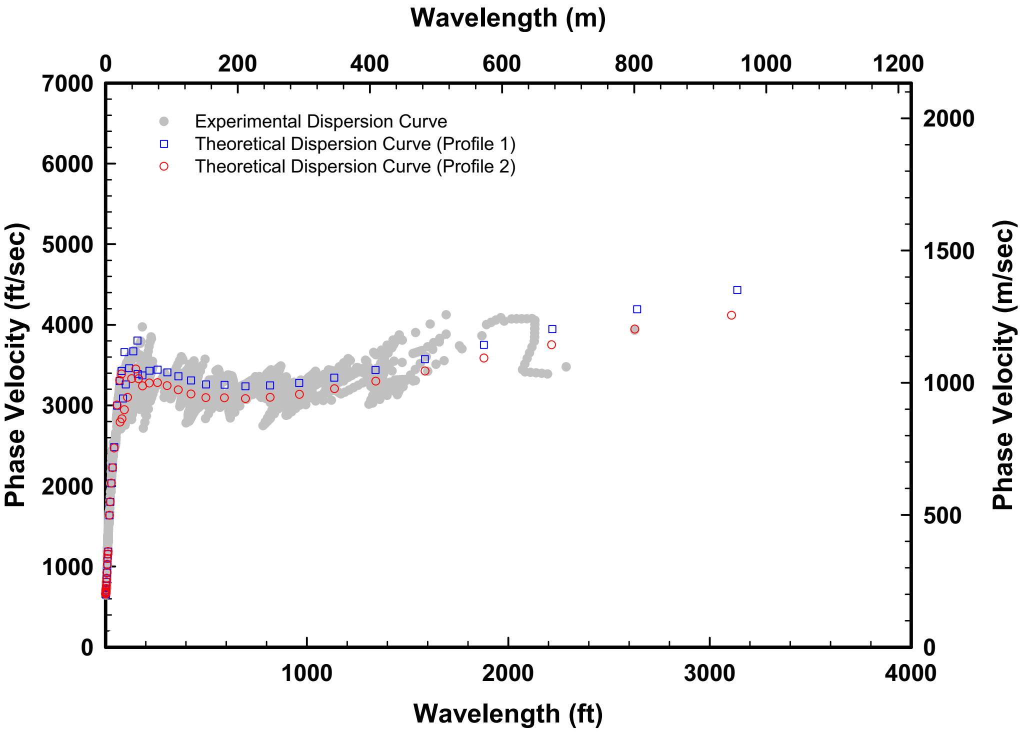
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-3. Experimental and Theoretical Dispersion Curves from YM 1-T1 and YM 1-T2; Logarithmic Wavelength Axis



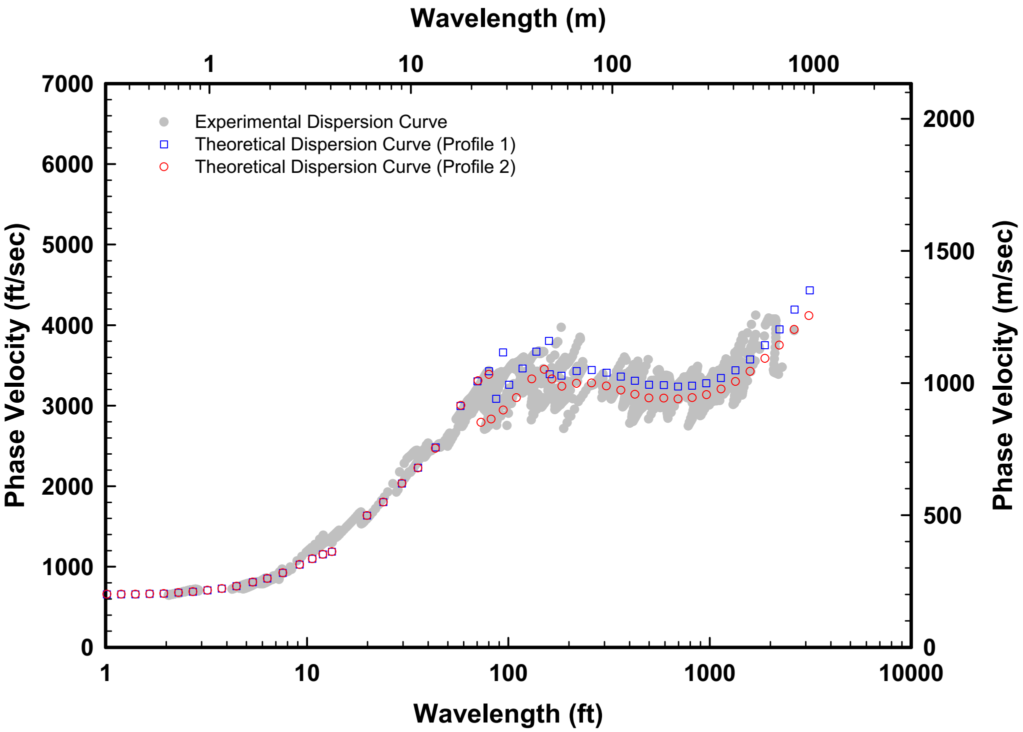
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-4. Shear Wave Velocity Profile Determined at YM 2-T1 and YM 2-T2



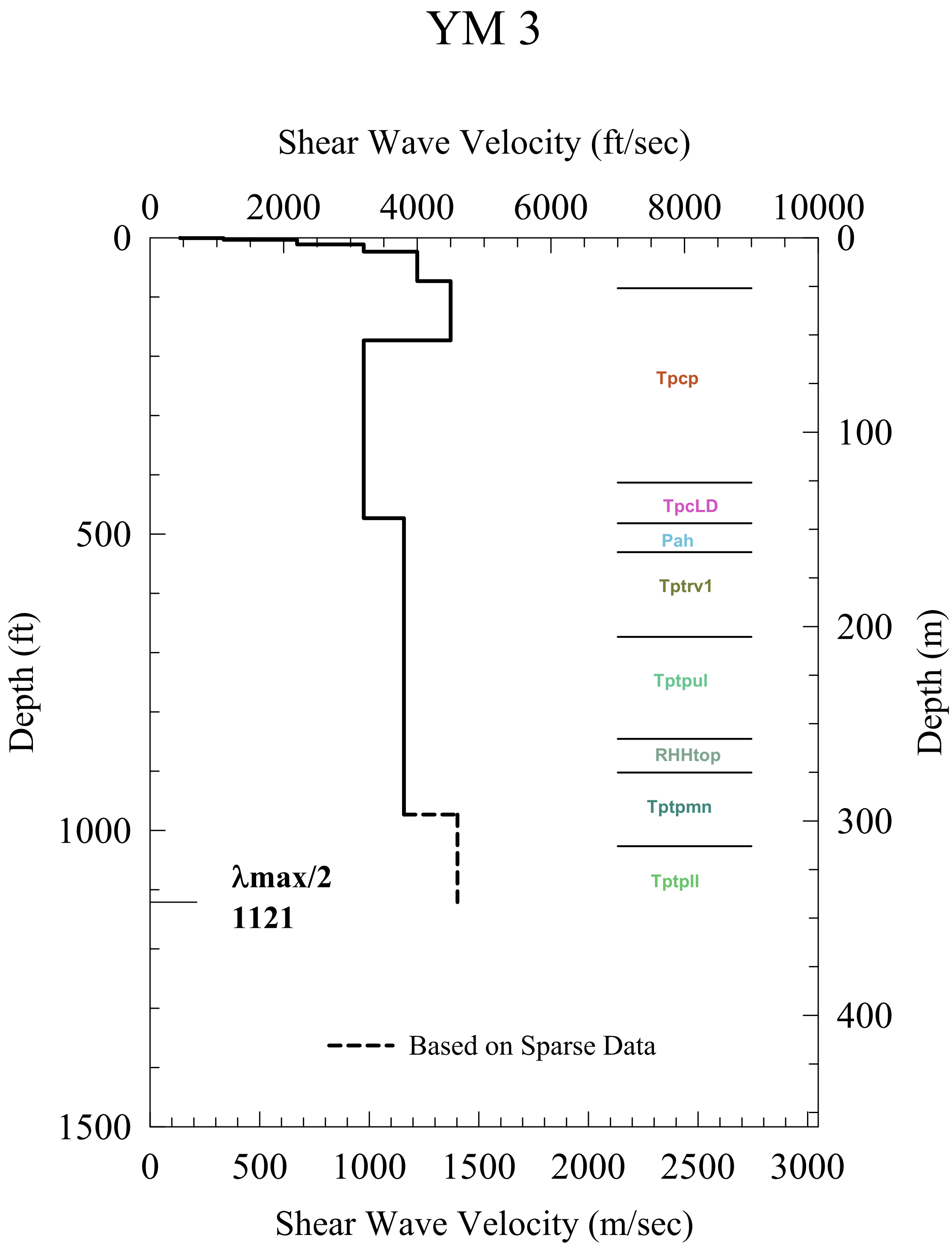
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-5. Experimental and Theoretical Dispersion Curves from YM 2-T1 and YM 2-T2; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

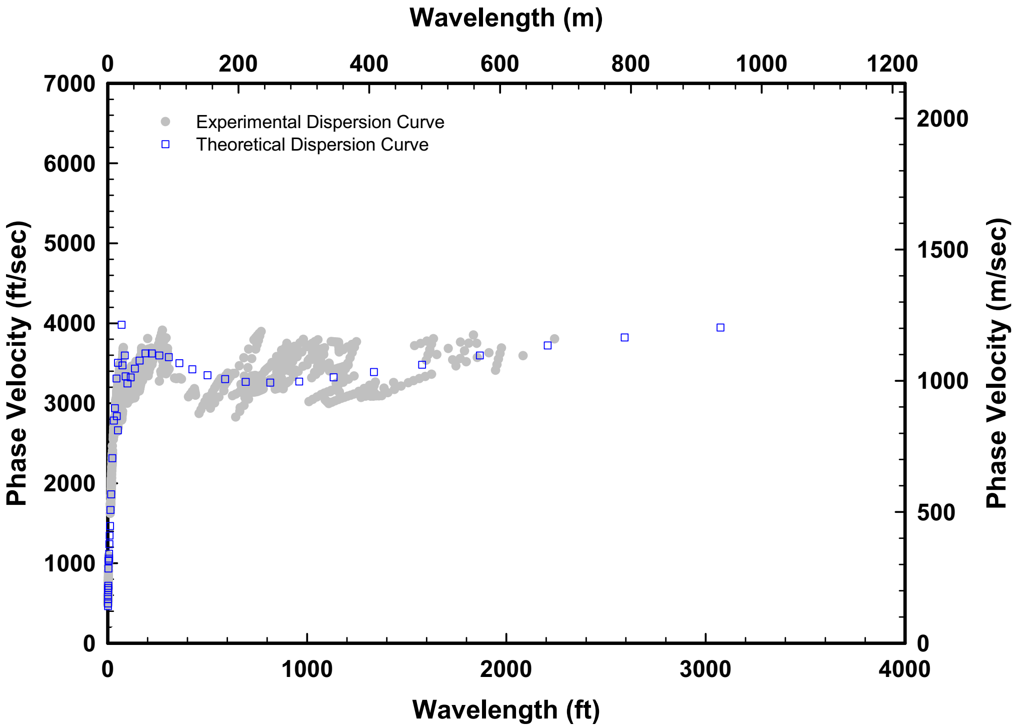
Figure V-6. Experimental and Theoretical Dispersion Curves from YM 2-T1 and YM 2-T2; Logarithmic Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

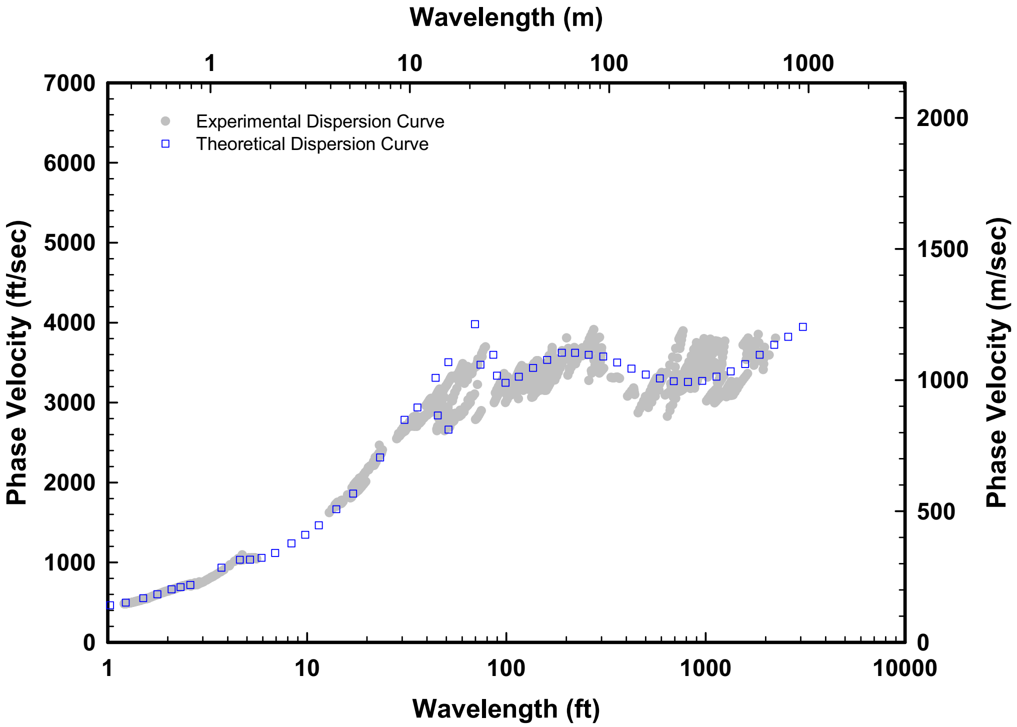
NOTE: YM3 plots in Stokoe 2007 [DIRS 183327] (scientific notebook SN-M&O-SCI-047-V2, Supplement Volume 7 of) showed YM3-T2. YM3-T2 was not included in the data analysis as provided in the DTN: MO0609SASWSTDC.003 [DIRS182125]; therefore, YM3-T2 was removed from the YM3 plots presented in this report.

Figure V-7. Shear Wave Velocity Profile Determined at YM 3-T1 and YM 3-T3



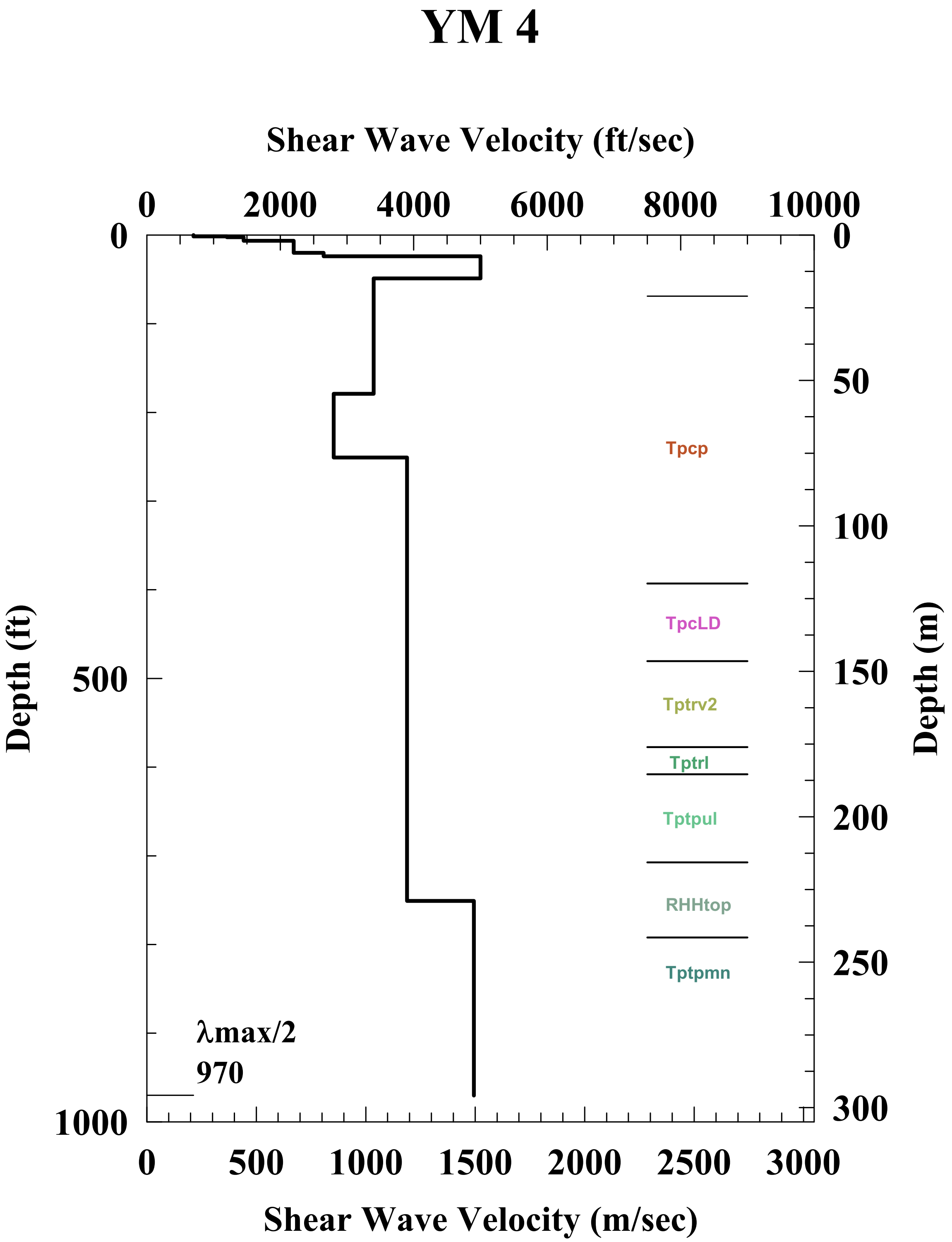
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-8. Experimental and Theoretical Dispersion Curves from YM 3-T1 and YM 3-T3; Linear Wavelength Axis



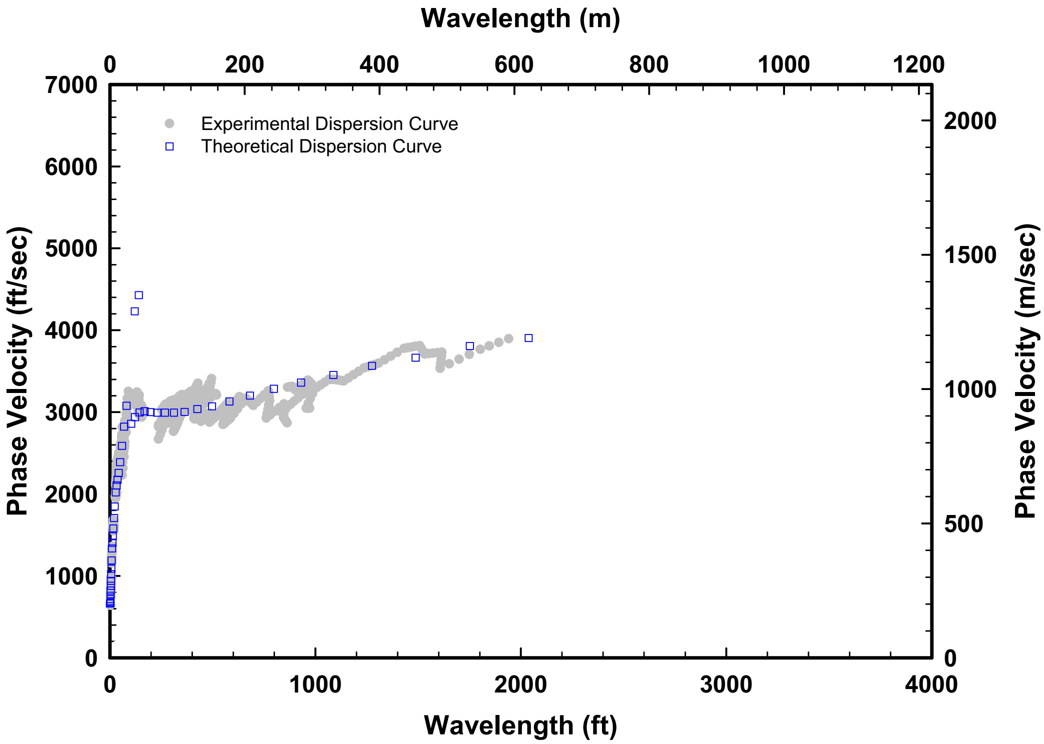
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-9. Experimental and Theoretical Dispersion Curves from YM 3-T1 and YM 3-T3; Logarithmic Wavelength Axis



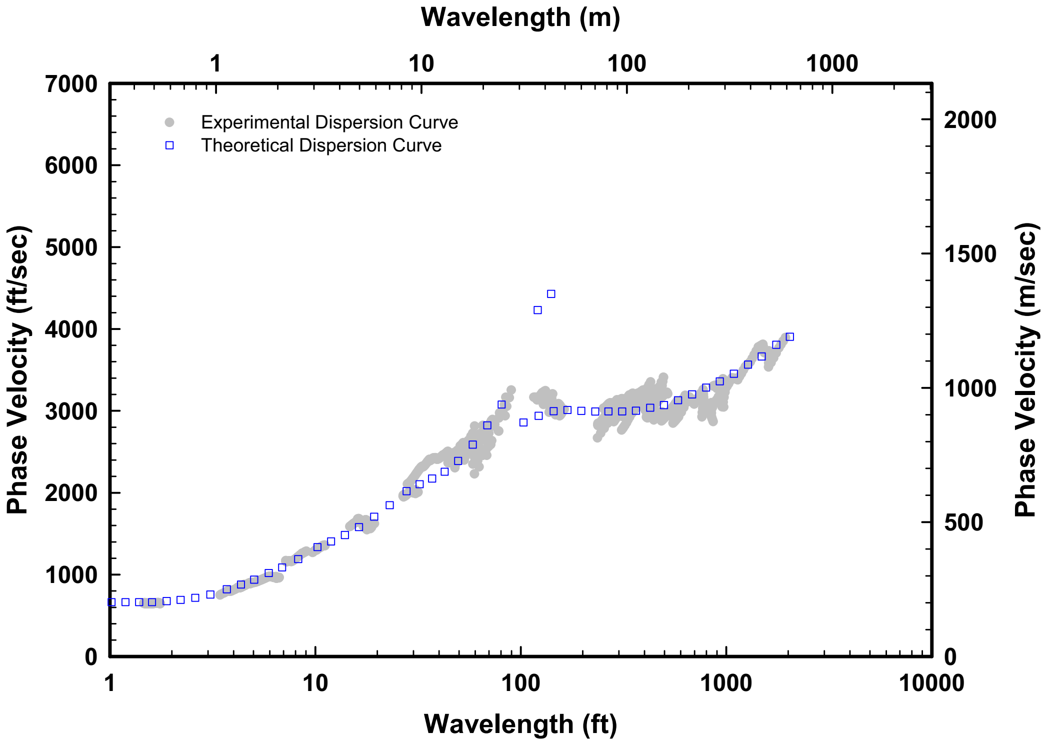
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-10. Shear Wave Velocity Profile Determined at YM 4-T1



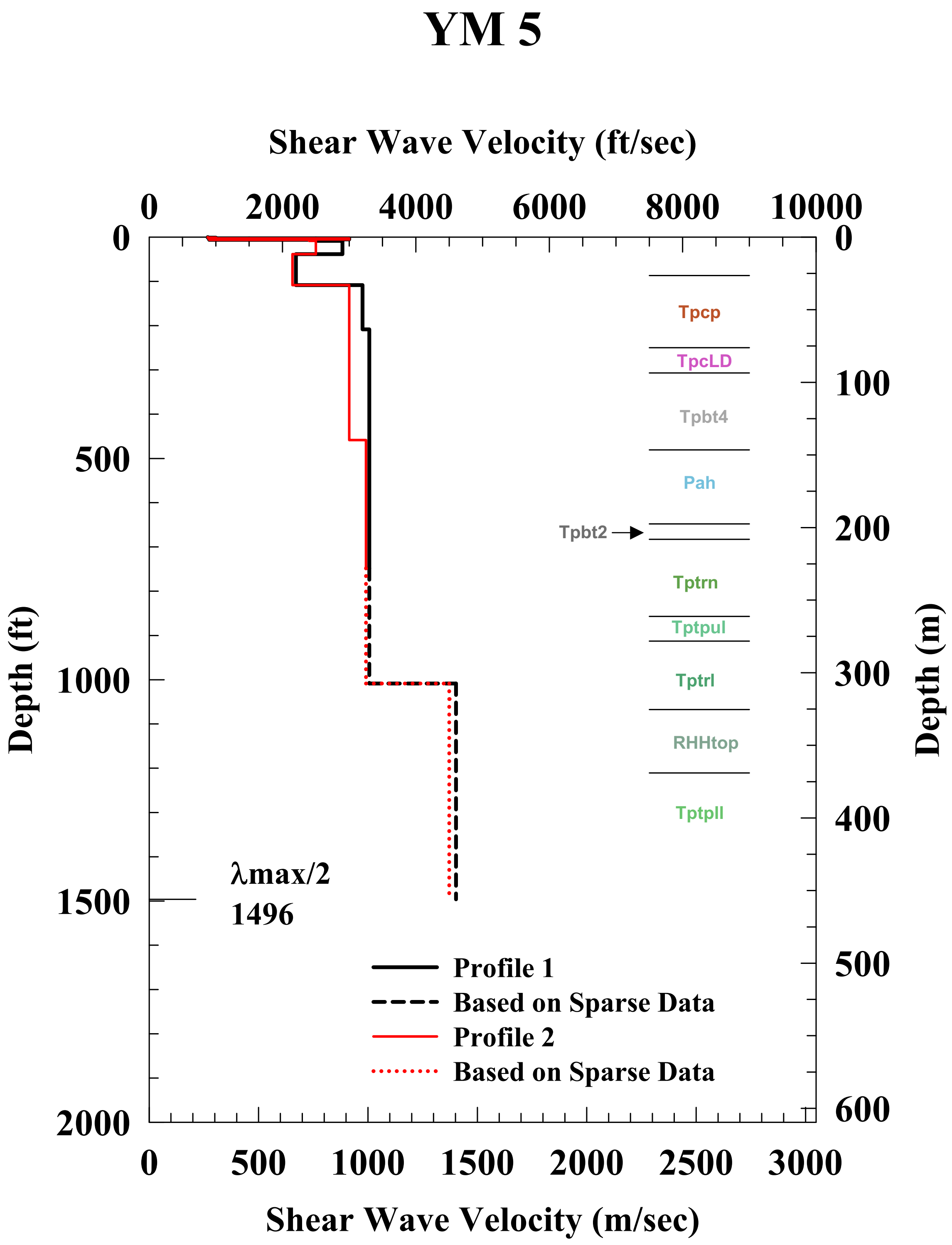
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-11. Experimental and Theoretical Dispersion Curves from YM 4-T1; Linear Wavelength Axis



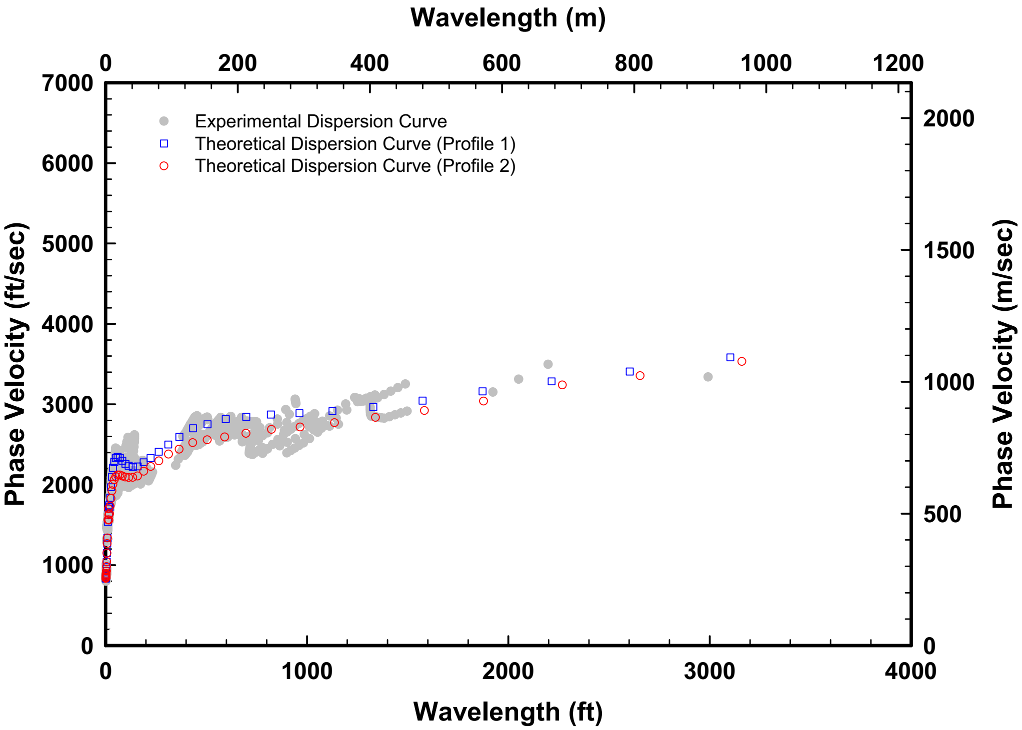
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-12. Experimental and Theoretical Dispersion Curves from YM 4-T1; Logarithmic Wavelength Axis



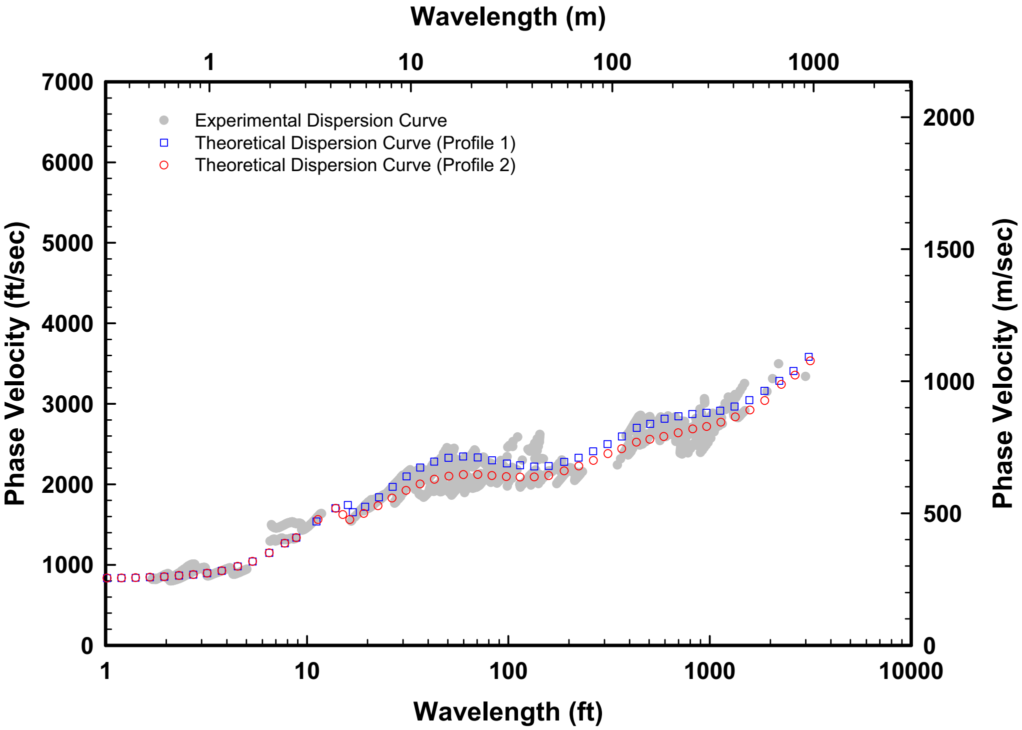
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-13.   Shear Wave Velocity Profile Determined at YM 5-T1 and YM 5-T2



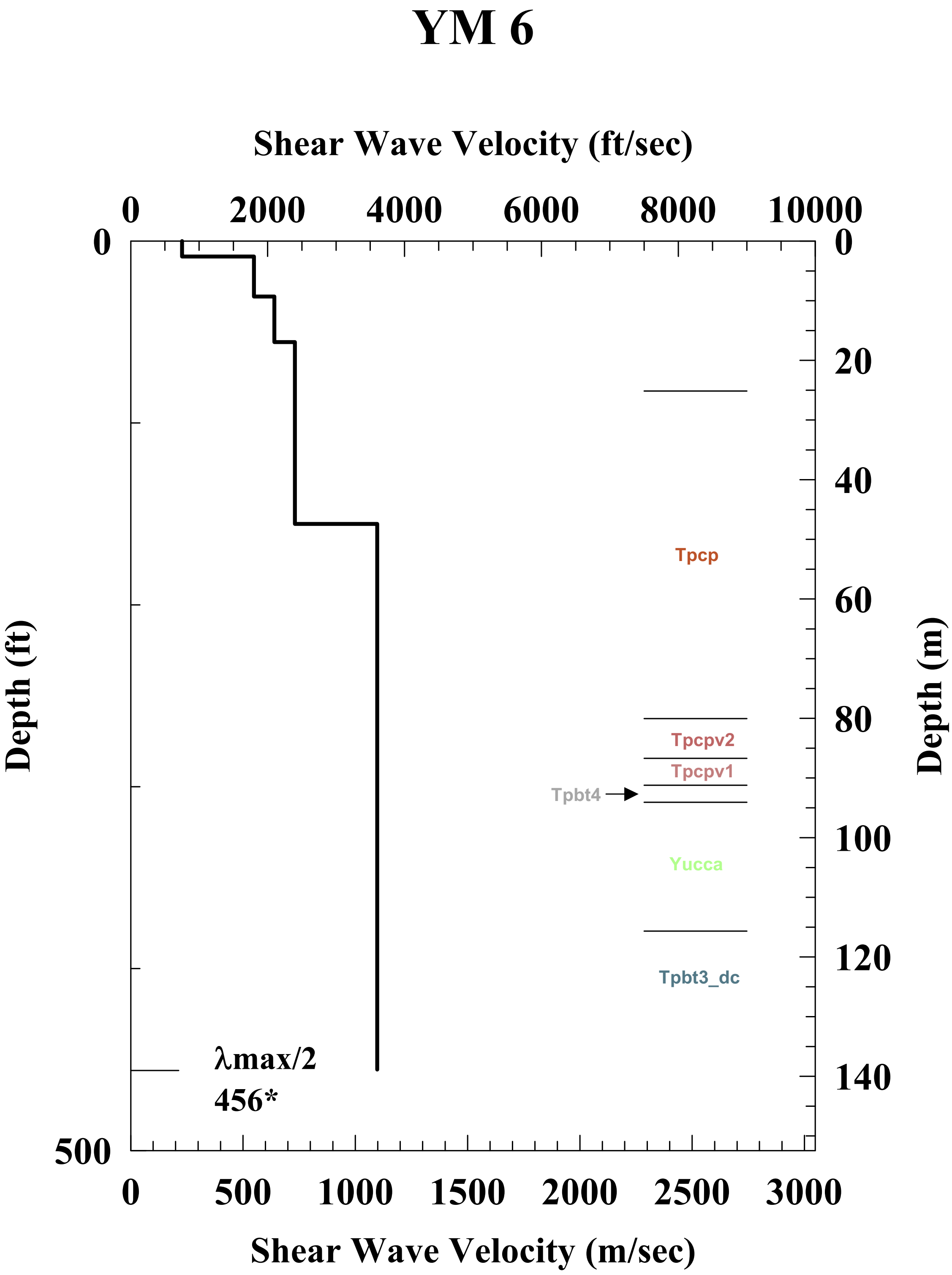
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-14. Experimental and Theoretical Dispersion Curves from YM 5-T1 and YM 5-T2; Linear Wavelength Axis



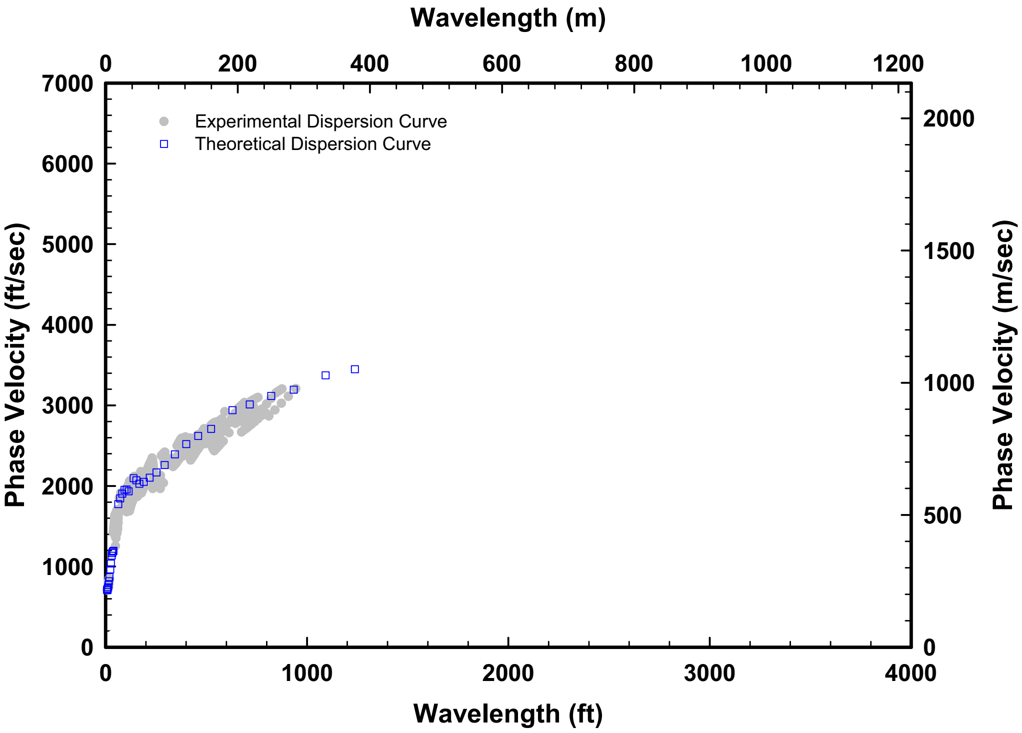
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-15. Experimental and Theoretical Dispersion Curves from YM 5-T1 and YM 5-T2; Logarithmic Wavelength Axis



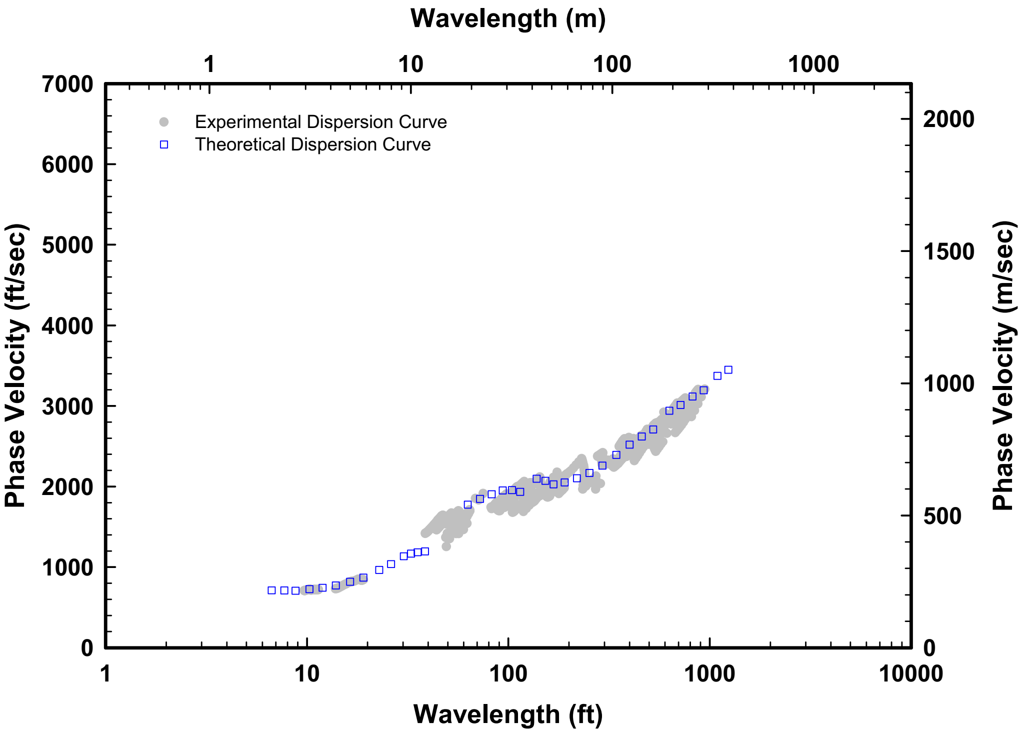
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-16. Shear Wave Velocity Profile Determined at YM 6-T1 and YM 6-T2



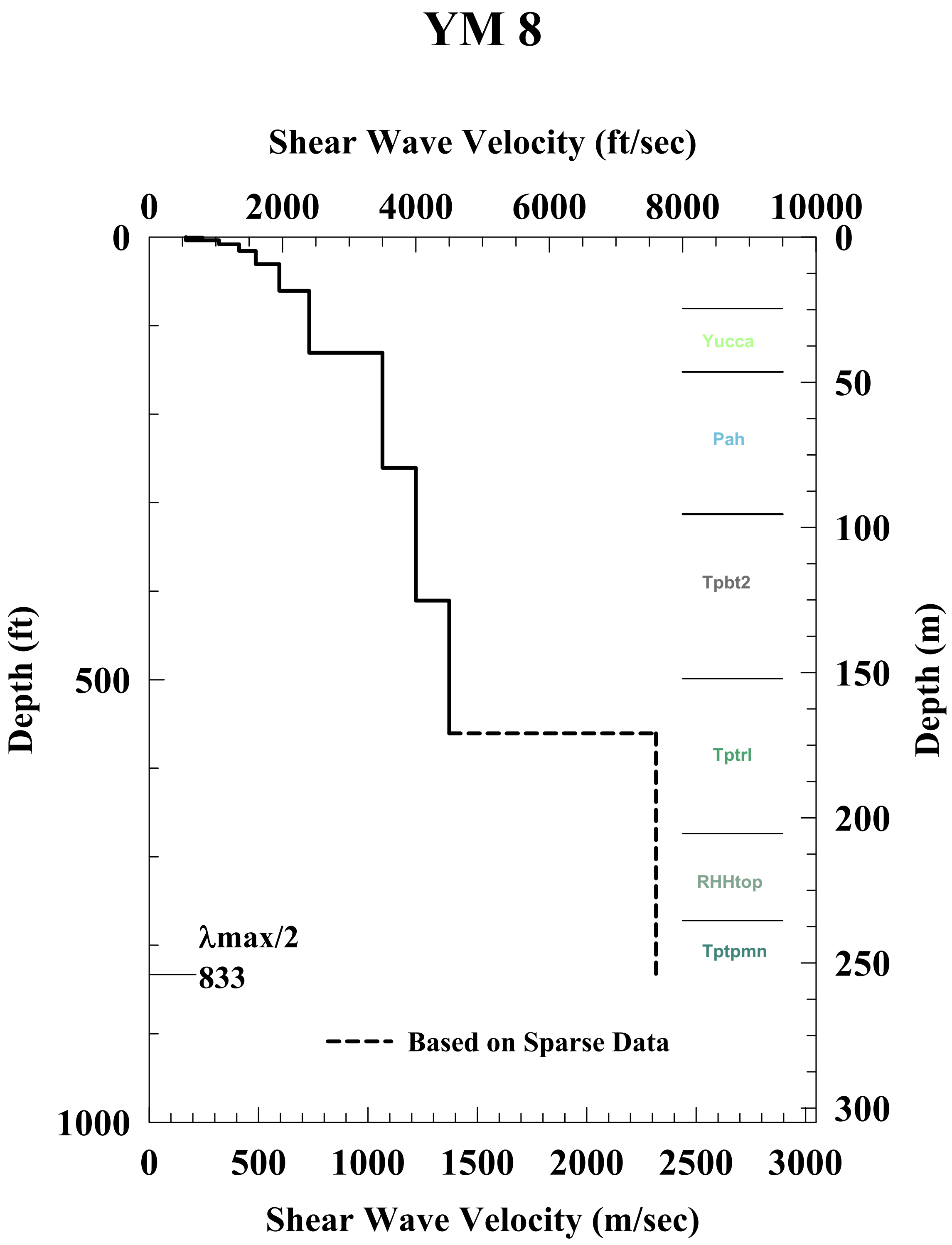
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-17. Experimental and Theoretical Dispersion Curves from YM 6-T1 and YM 6-T2; Linear Wavelength Axis



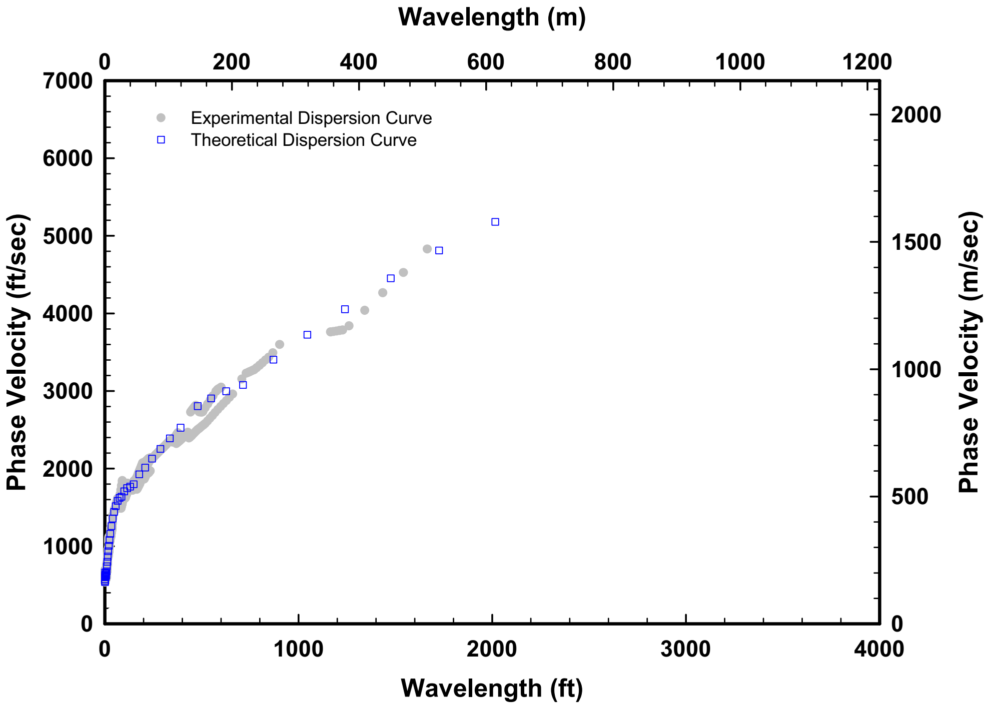
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-18. Experimental and Theoretical Dispersion Curves from YM 6-T1 and YM 6-T2; Logarithmic Wavelength Axis



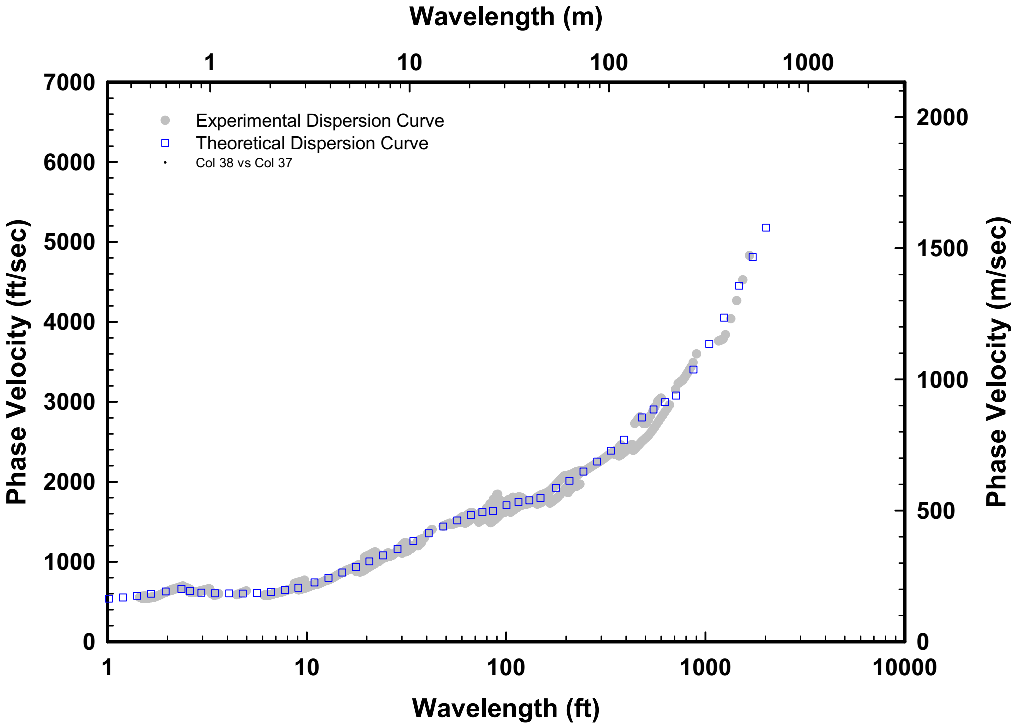
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-19. Shear Wave Velocity Profile Determined at YM 8-T1



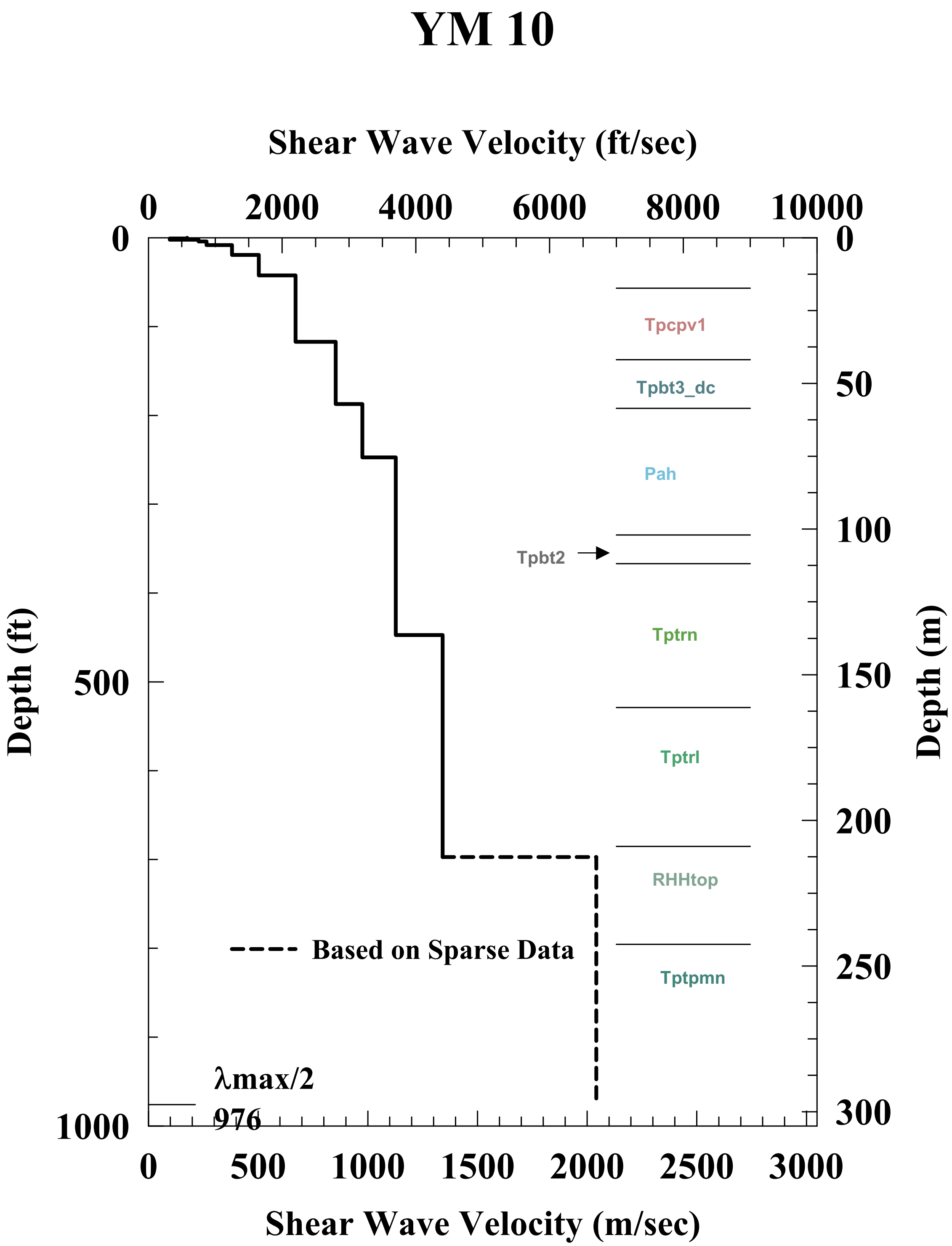
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-20. Experimental and Theoretical Dispersion Curves from YM 8-T1; Linear Wavelength Axis



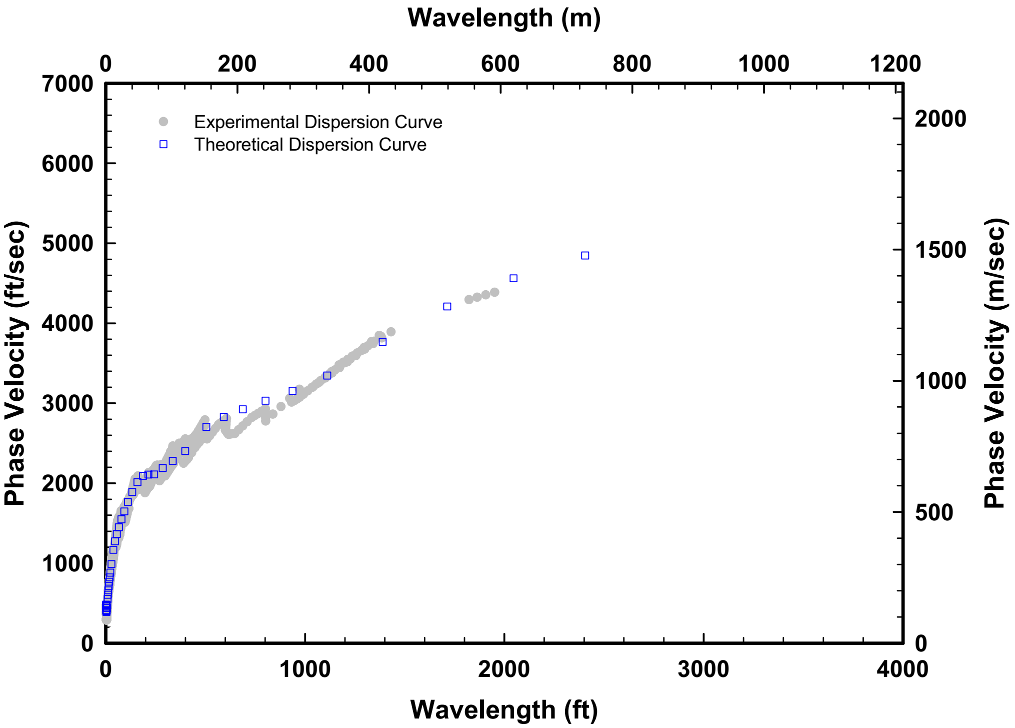
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-21. Experimental and Theoretical Dispersion Curves from YM 8-T1; Logarithmic Wavelength Axis



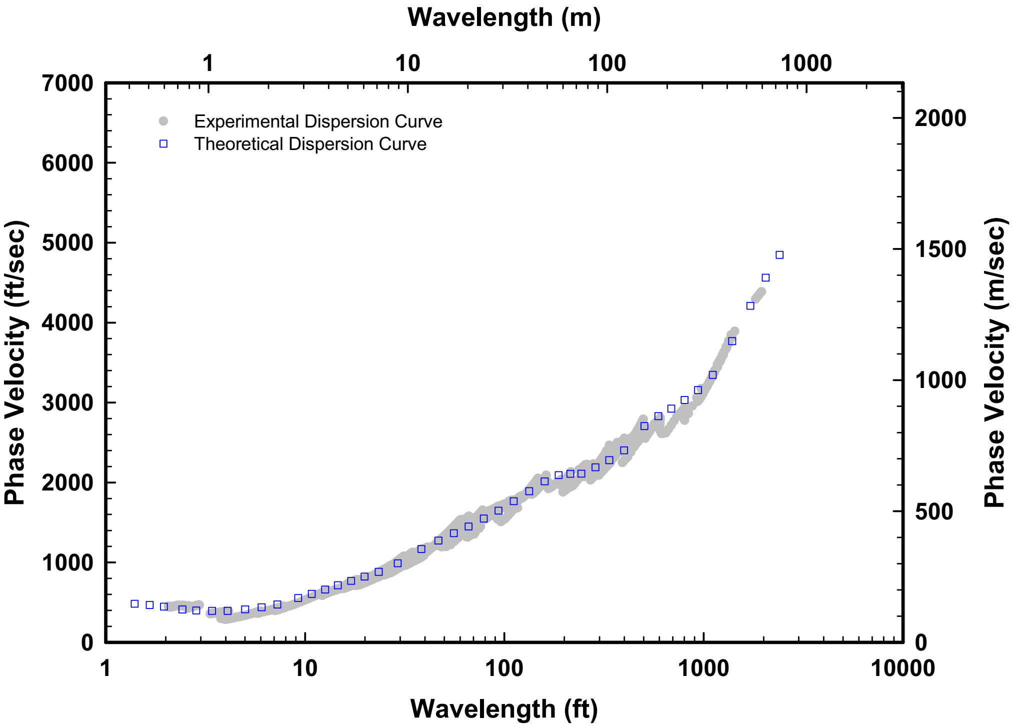
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-22. Shear Wave Velocity Profile Determined at YM 10-T1 and YM 10-T2



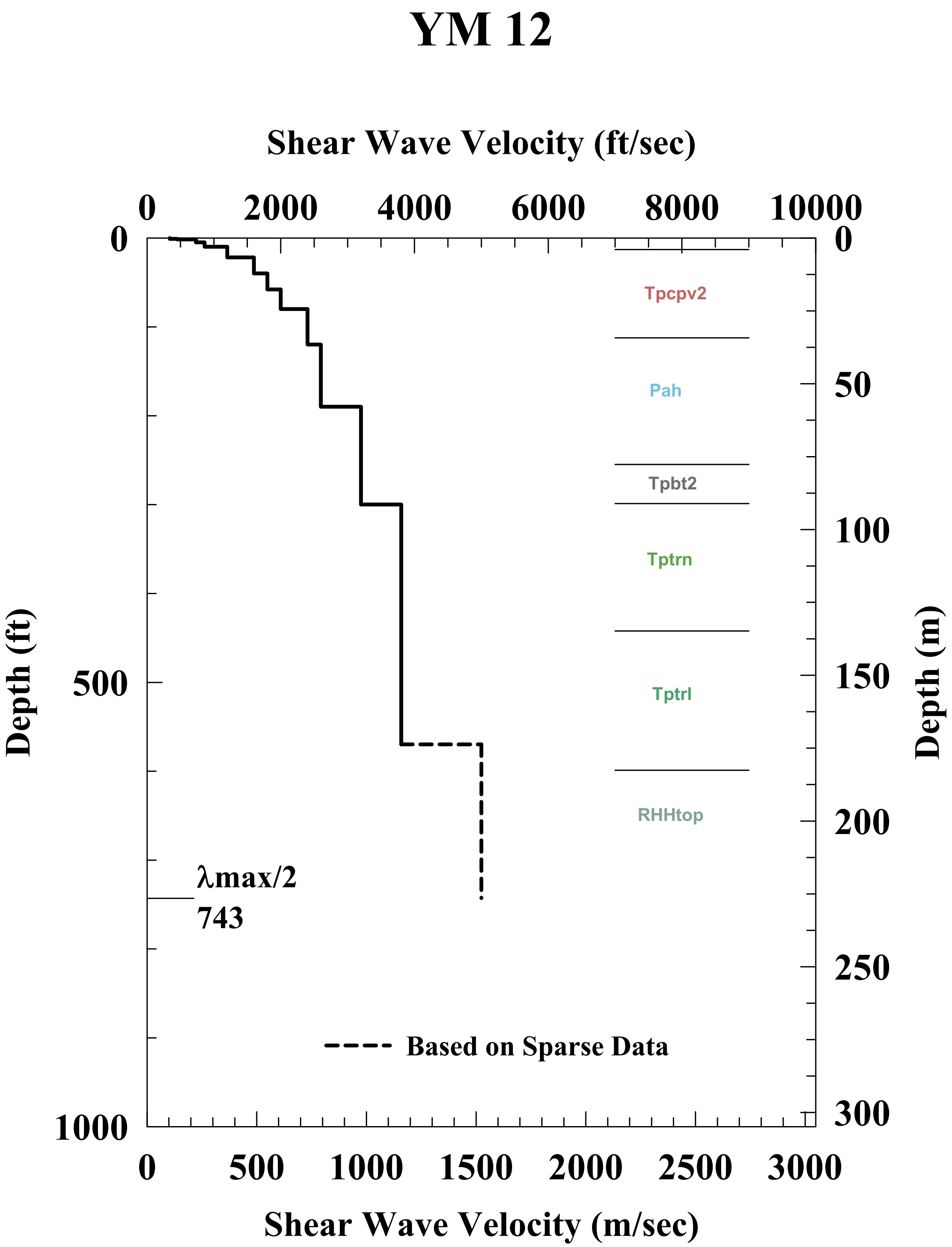
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-23. Experimental and Theoretical Dispersion Curves from YM 10-T1 and YM 10-T2; Linear Wavelength Axis



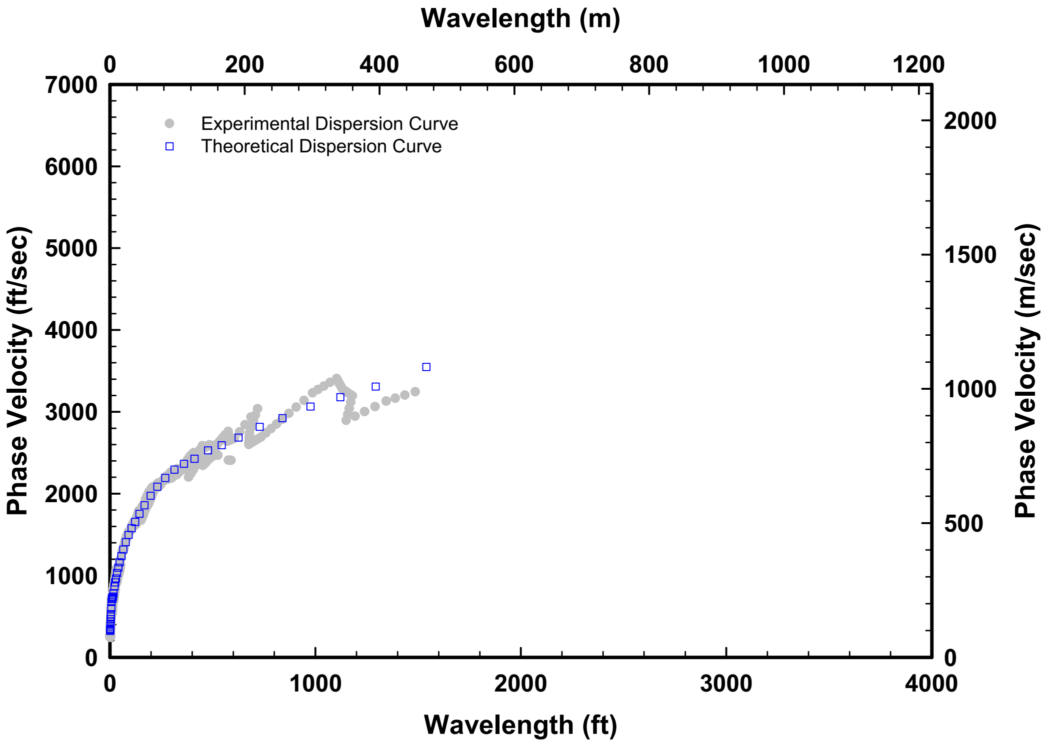
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-24. Experimental and Theoretical Dispersion Curves from YM 10-T1 and YM 10-T2; Logarithmic Wavelength Axis



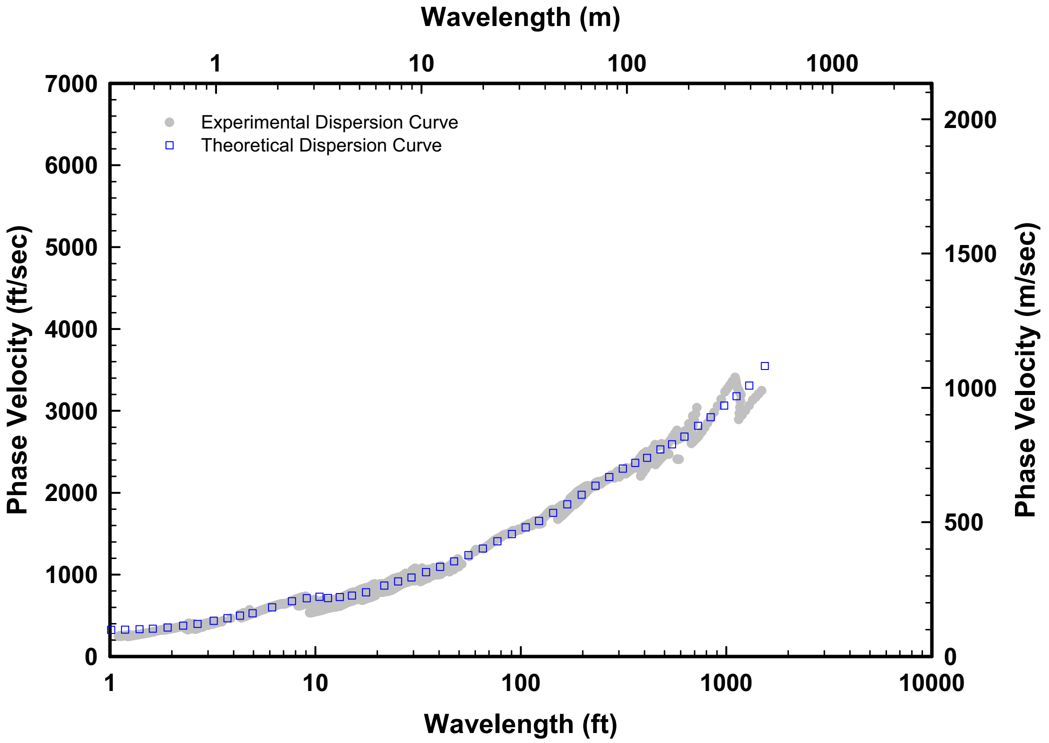
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-25. Shear Wave Velocity Profile Determined at YM 12-T1



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

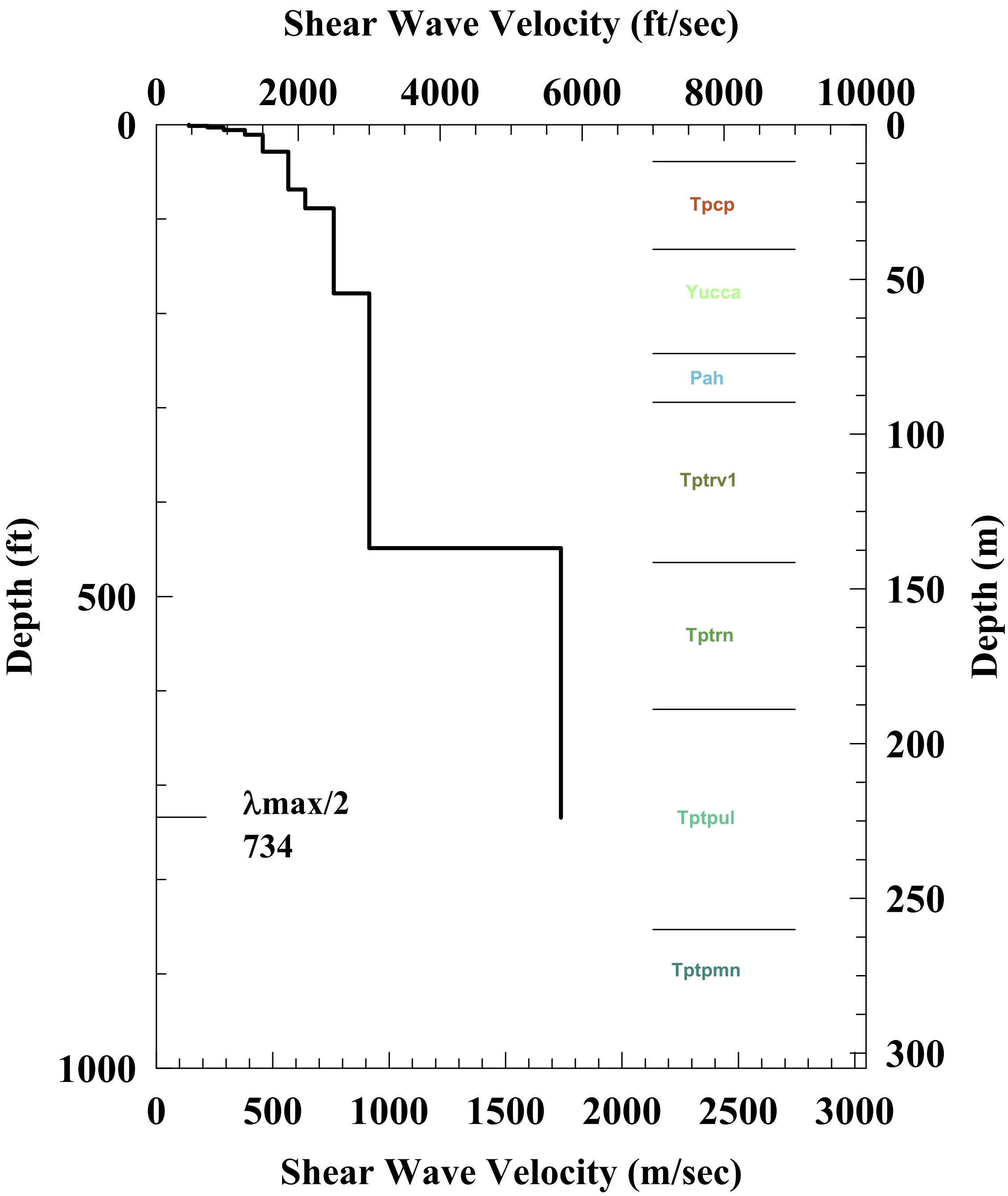
Figure V-26. Experimental and Theoretical Dispersion Curves from YM 12-T1; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

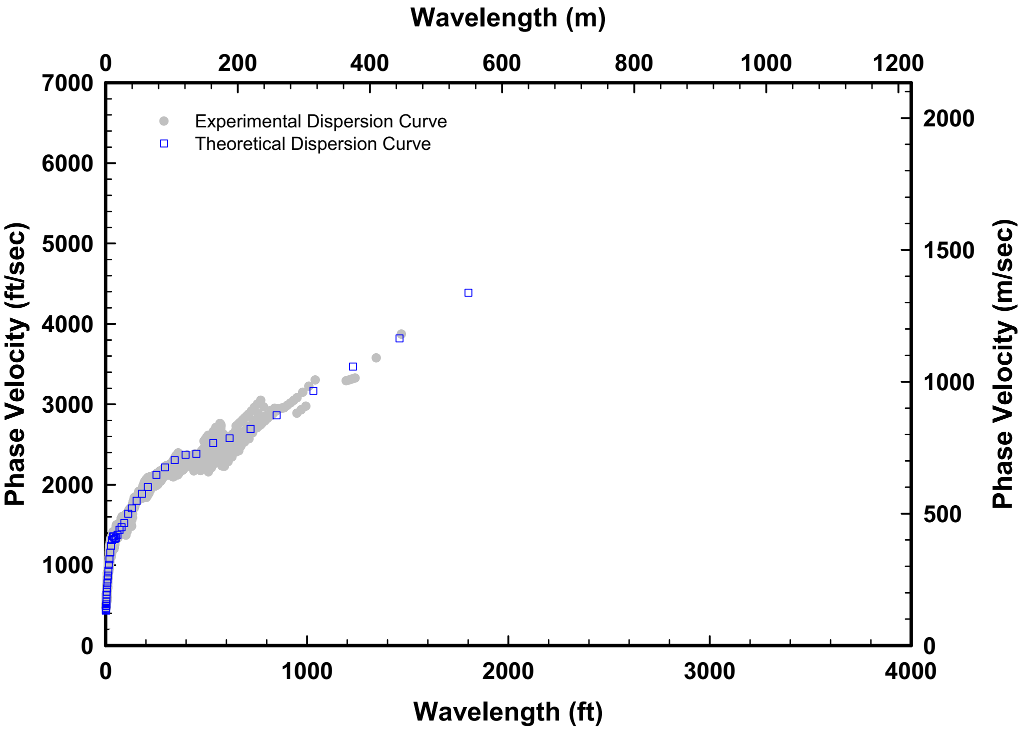
Figure V-27. Experimental and Theoretical Dispersion Curves from YM 12-T1; Logarithmic Wavelength Axis

YM 13



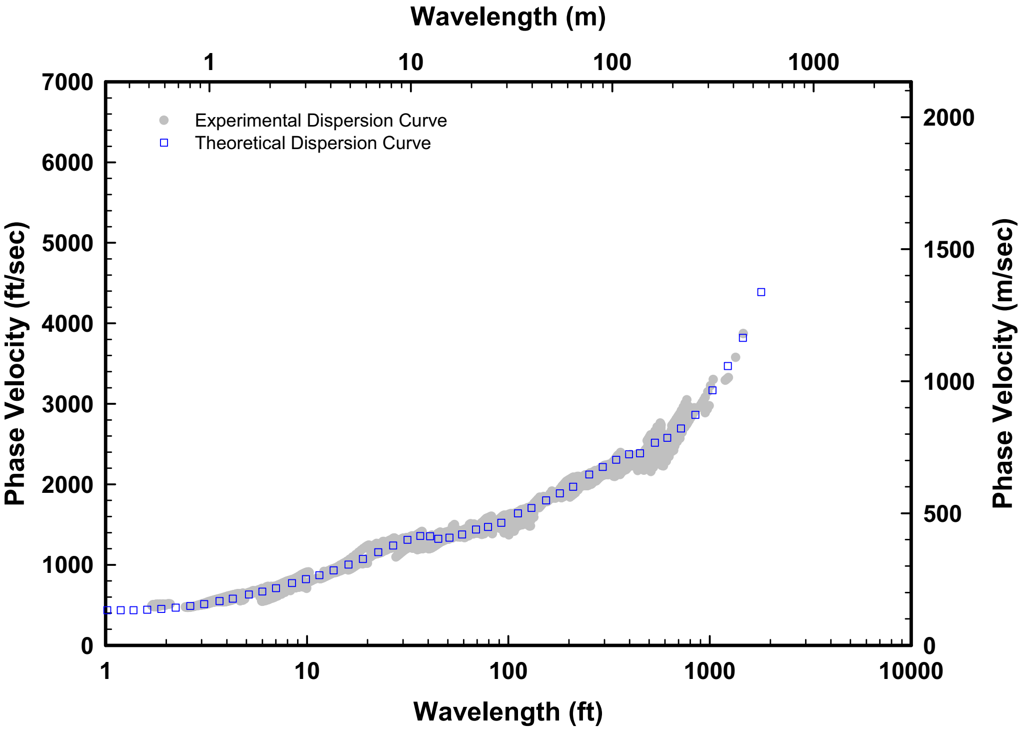
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-28. Shear Wave Velocity Profile Determined at YM 13-T1 and YM 13-T2



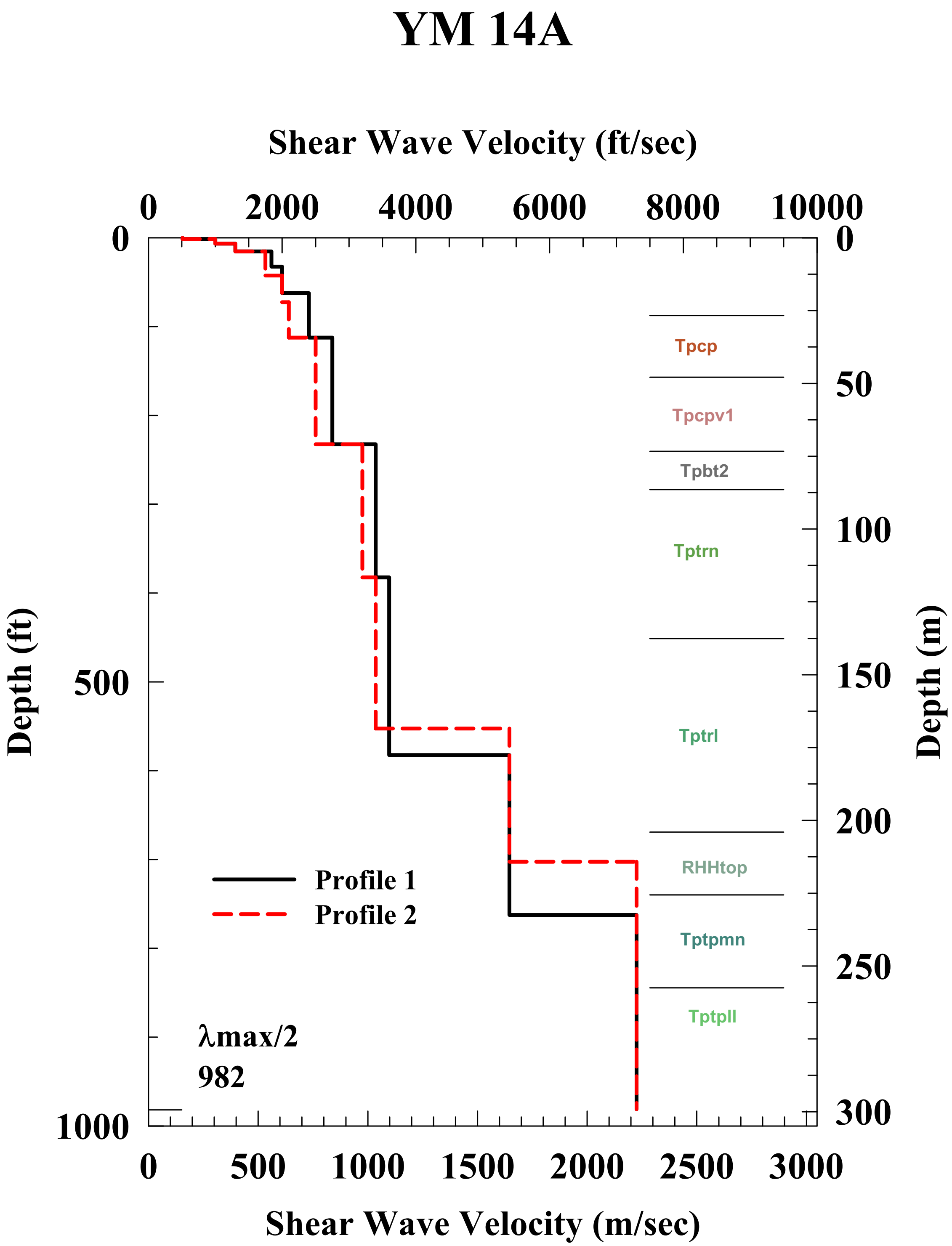
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-29. Experimental and Theoretical Dispersion Curves from YM 13-T1 and YM 13-T2; Linear Wavelength Axis



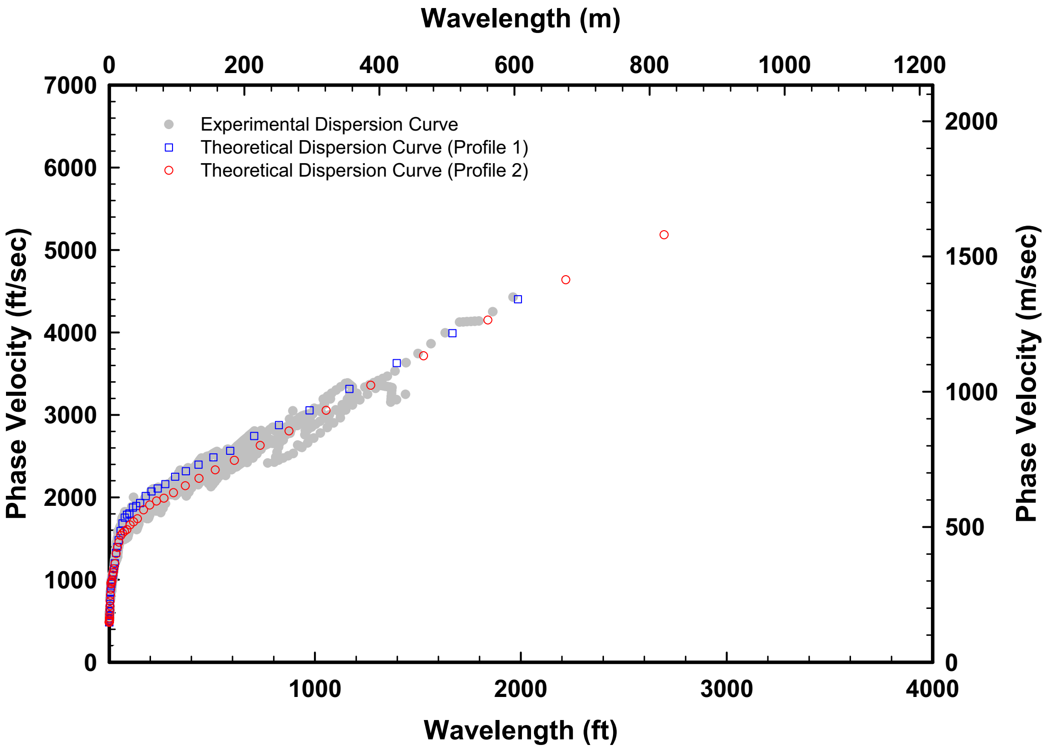
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-30. Experimental and Theoretical Dispersion Curves from YM 13-T1 and YM 13-T2; Logarithmic Wavelength Axis



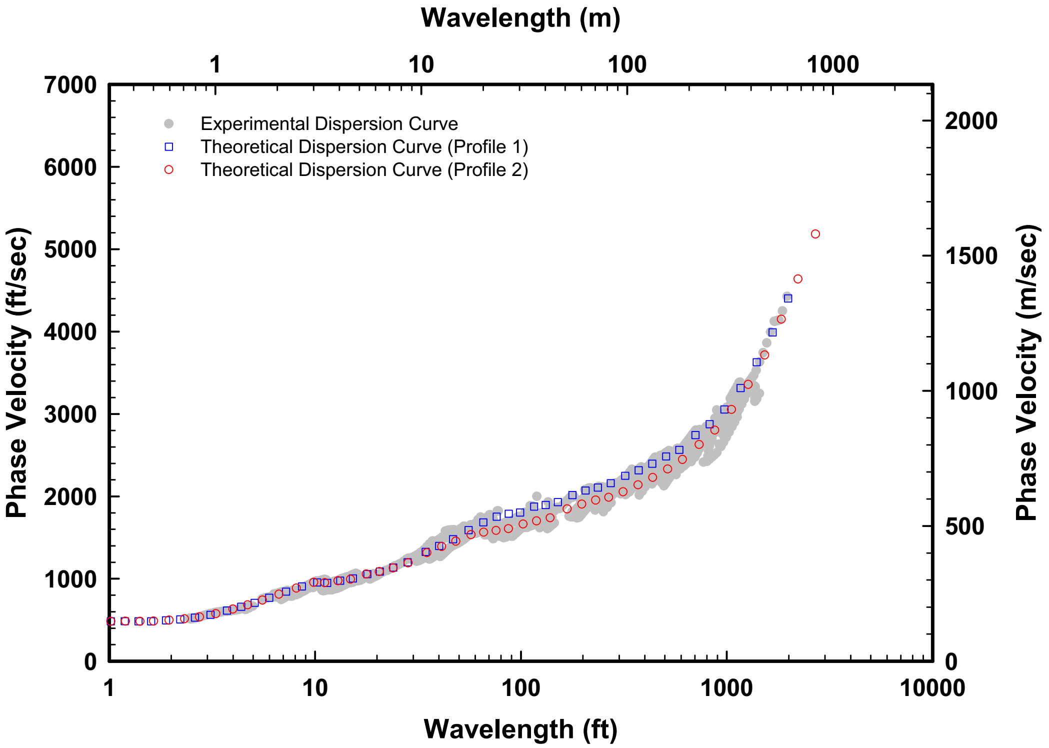
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-31. Shear Wave Velocity Profile Determined at YM 14A-T1 and YM 14A-T2



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

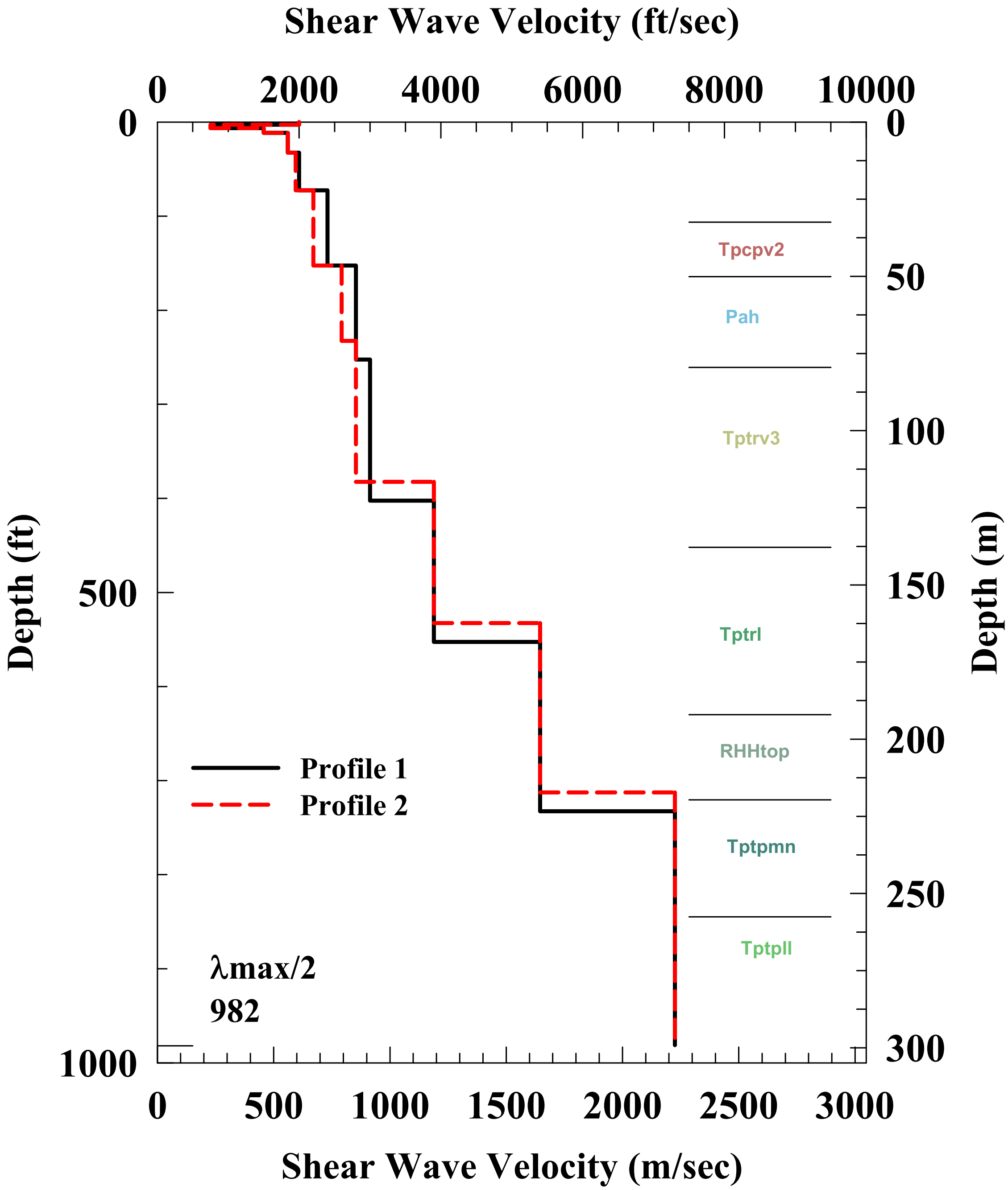
Figure V-32. Experimental and Theoretical Dispersion Curves from YM 14A-T1 and YM 14A-T2; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272]

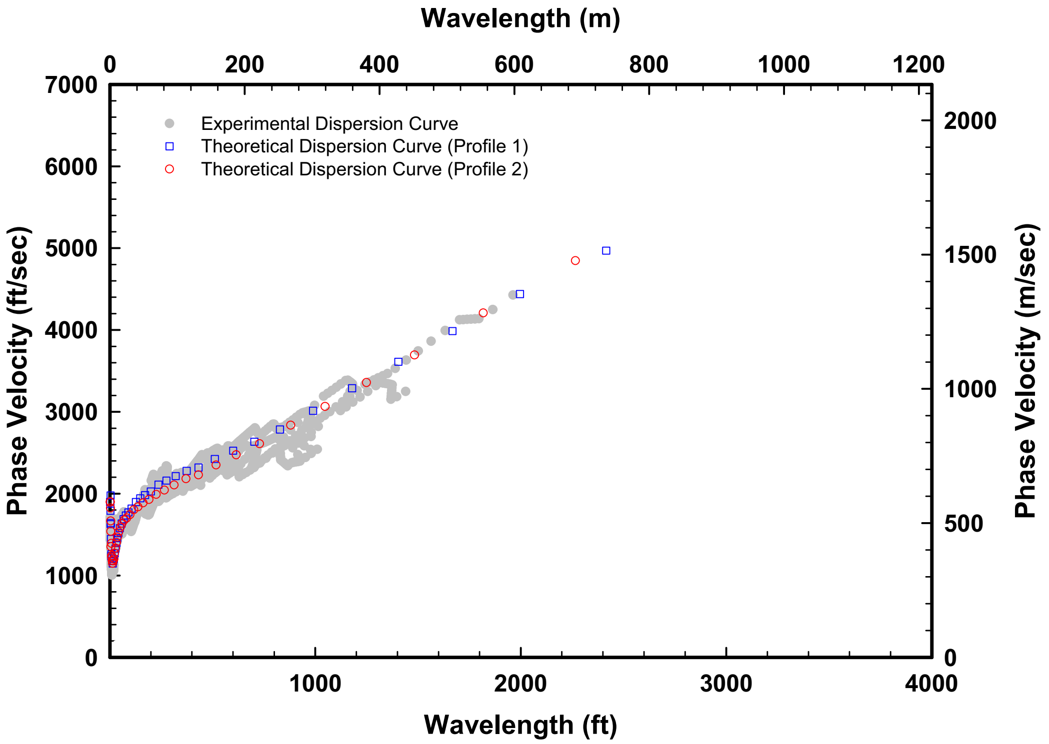
Figure V-33. Experimental and Theoretical Dispersion Curves from YM 14A-T1 and YM 14A-T2; Logarithmic Wavelength Axis

YM 14B



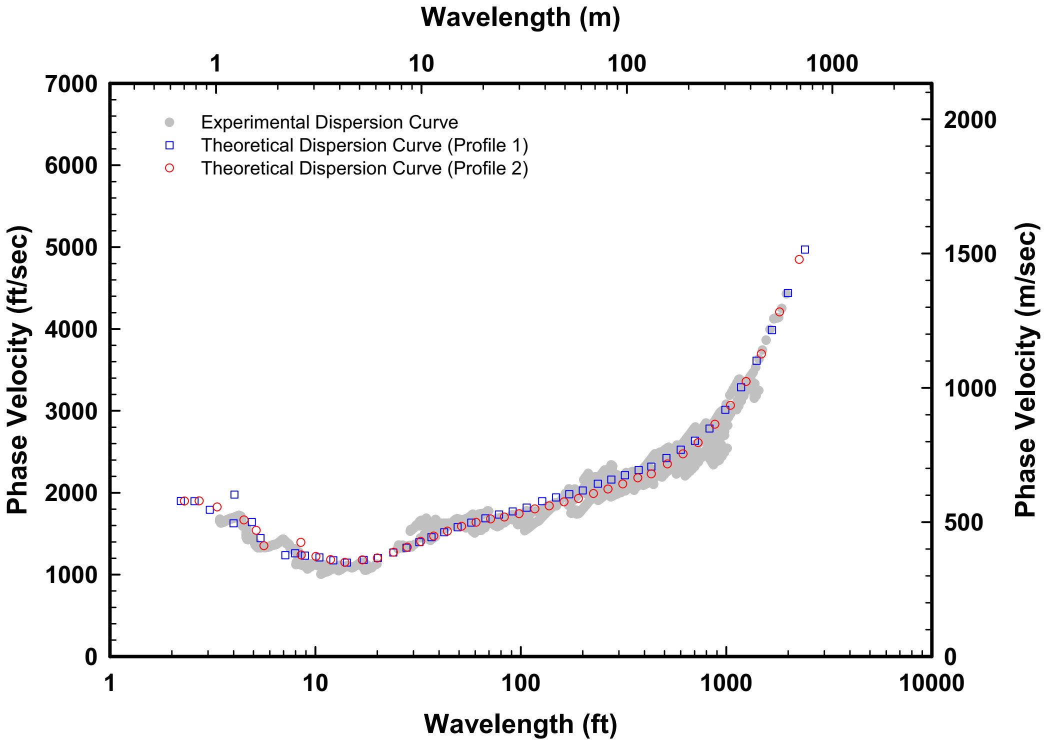
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-34. Shear Wave Velocity Profile Determined at YM 14B-T1



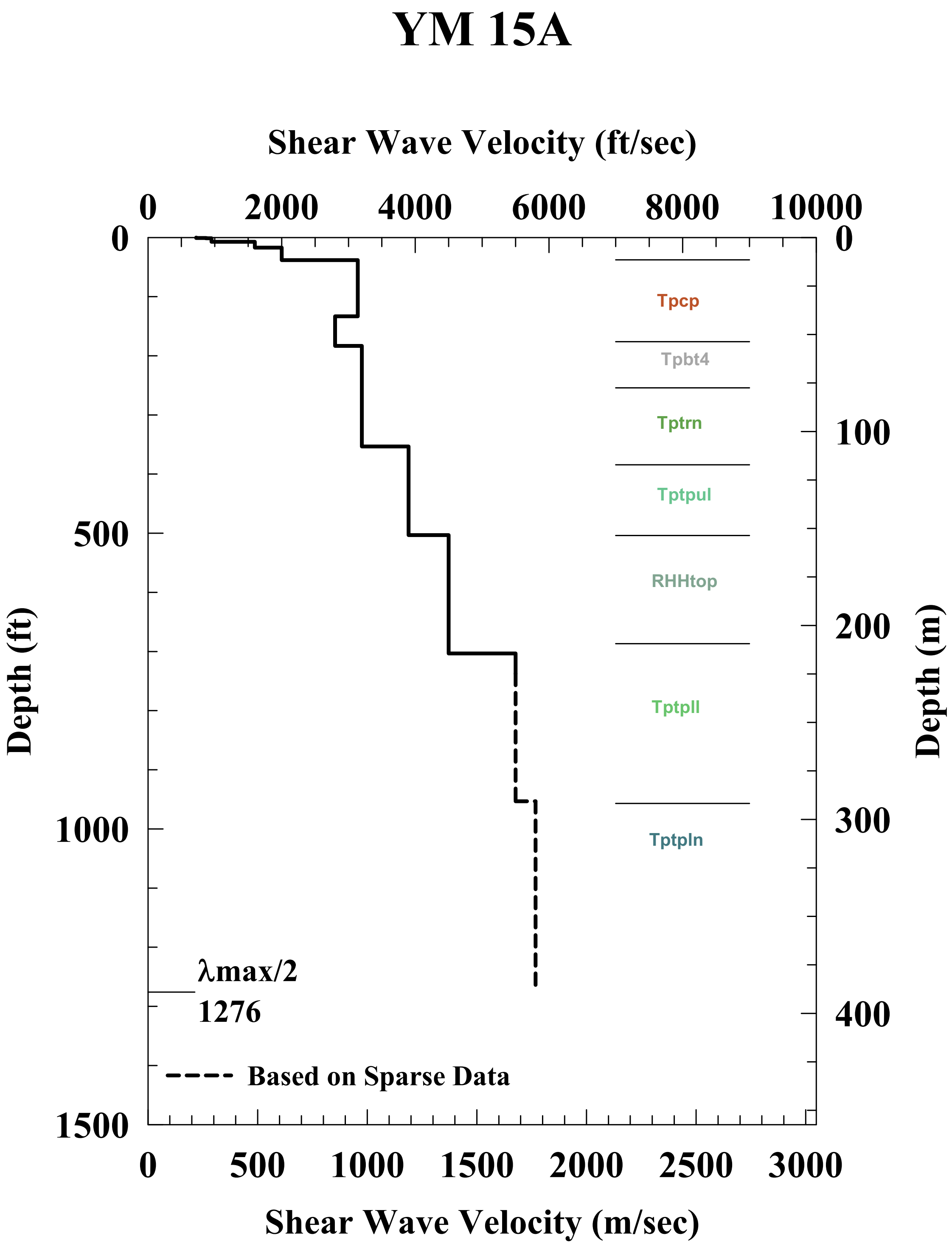
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-35. Experimental and Theoretical Dispersion Curves from YM 14B-T1; Linear Wavelength Axis



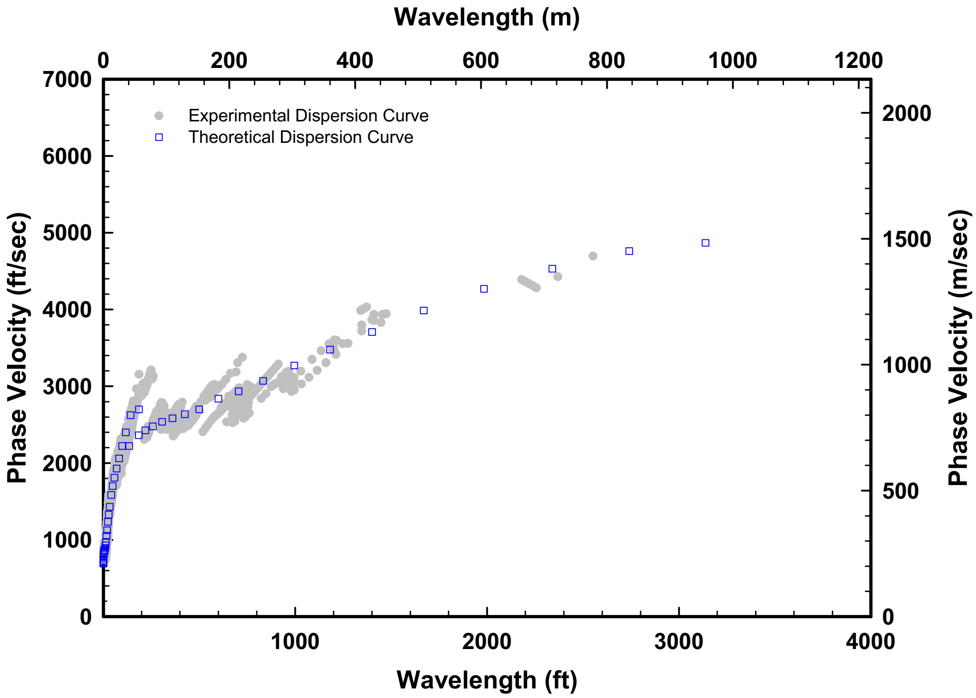
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272]

Figure V-36. Experimental and Theoretical Dispersion Curves from YM 14B-T1; Logarithmic Wavelength Axis



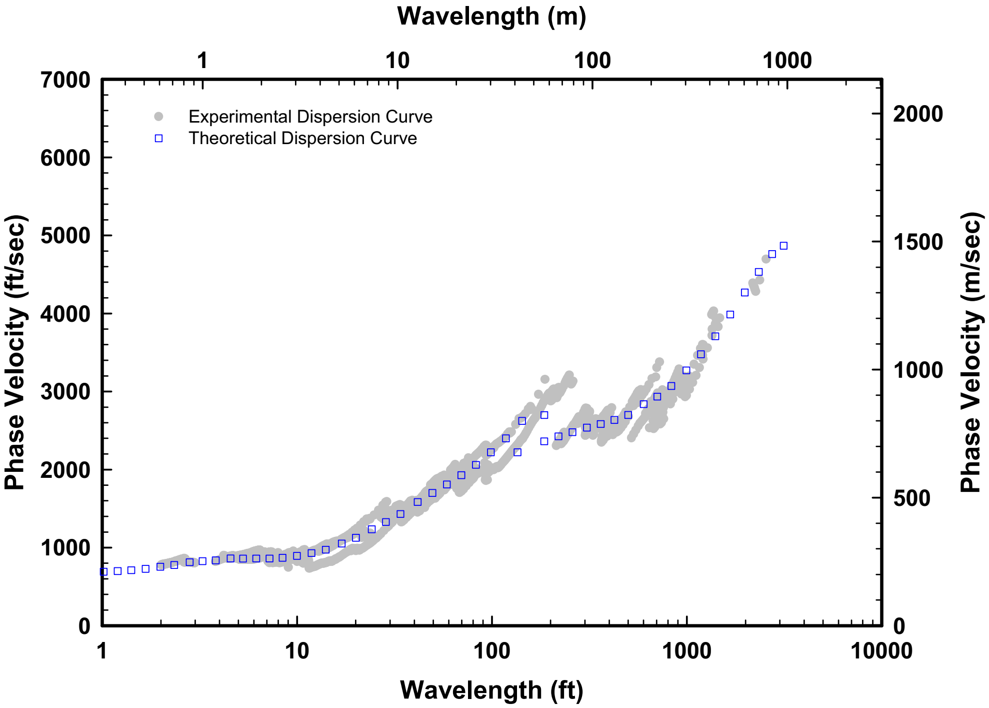
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-37. Shear Wave Velocity Profile Determined at YM 15A-T1 and YM 15A-T2



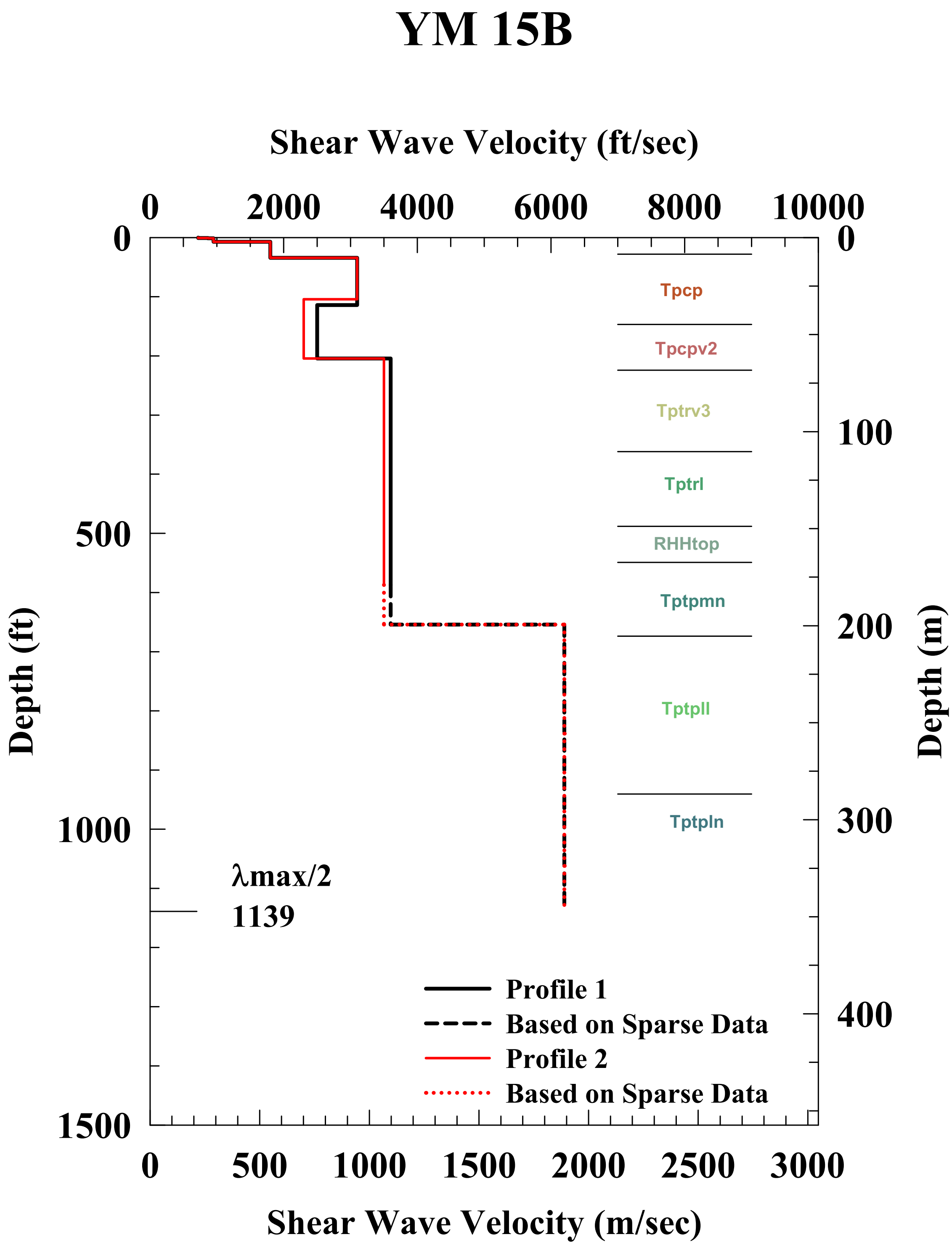
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-38. Experimental and Theoretical Dispersion Curves from YM 15A-T1 and YM 15A-T2; Linear Wavelength Axis



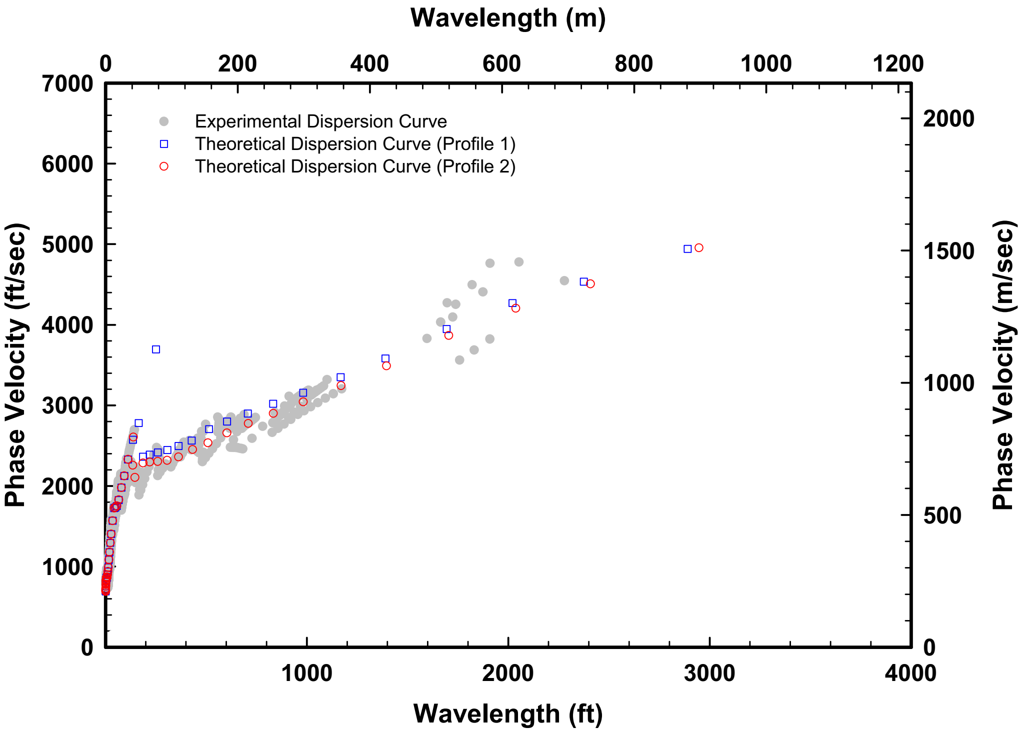
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-39. Experimental and Theoretical Dispersion Curves from YM 15A-T1 and YM 15A-T2; Logarithmic Wavelength Axis



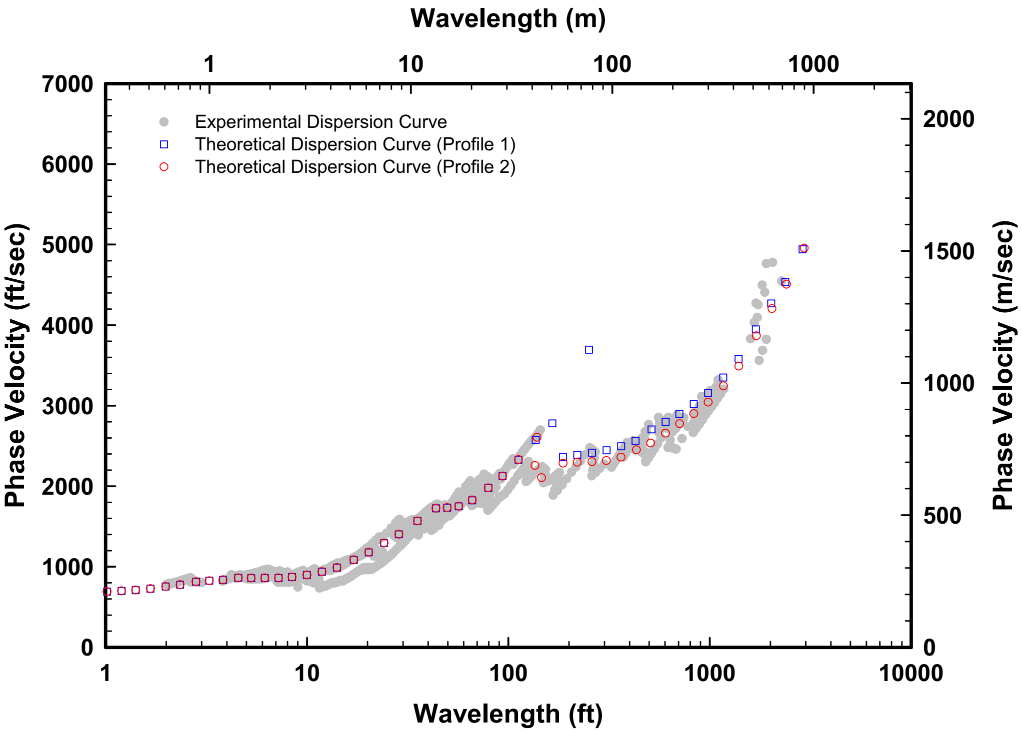
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-40 Shear Wave Velocity Profile Determined at YM 15B-T1 and YM 15B-T2



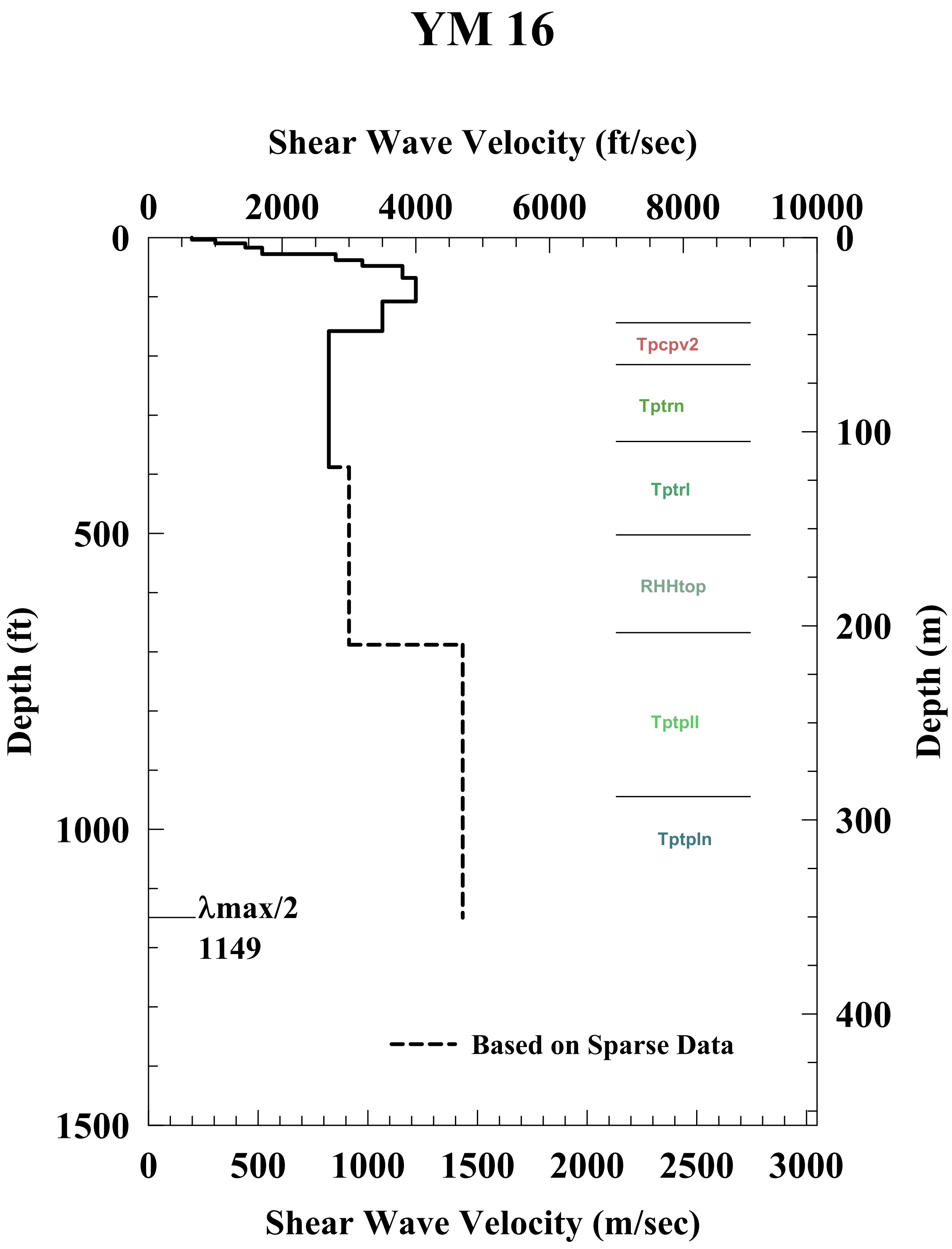
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-41. Experimental and Theoretical Dispersion Curves from YM 15B-T1 and YM 15B-T2; Linear Wavelength Axis



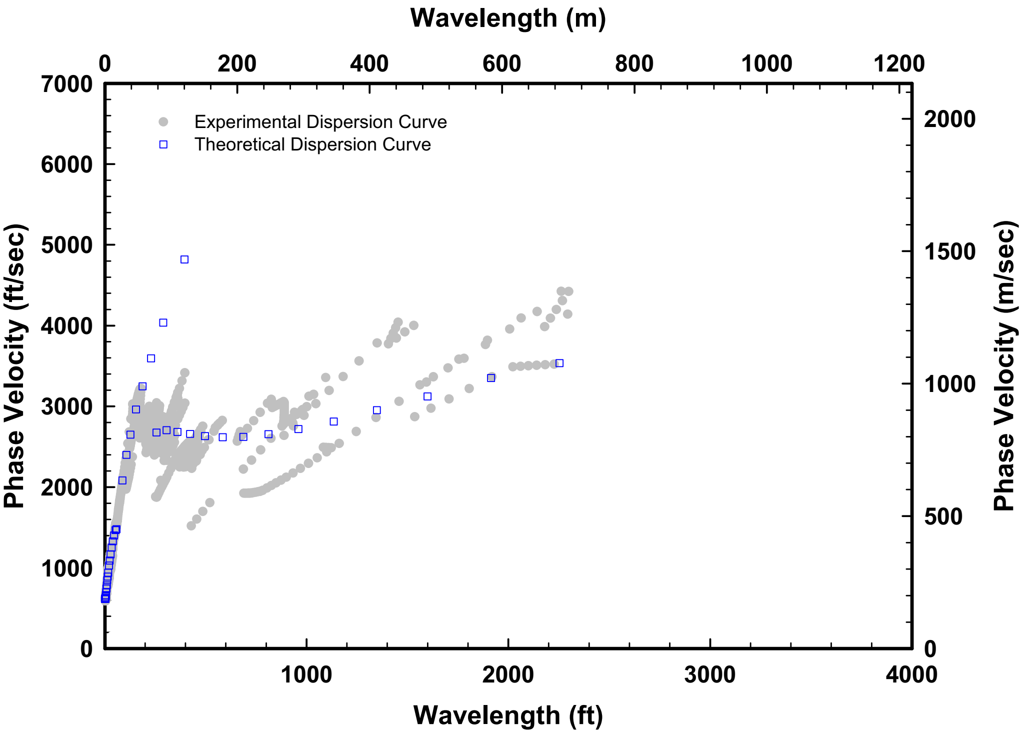
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-42. Experimental and Theoretical Dispersion Curves from YM 15B-T1 and YM 15B-T2; Logarithmic Wavelength Axis



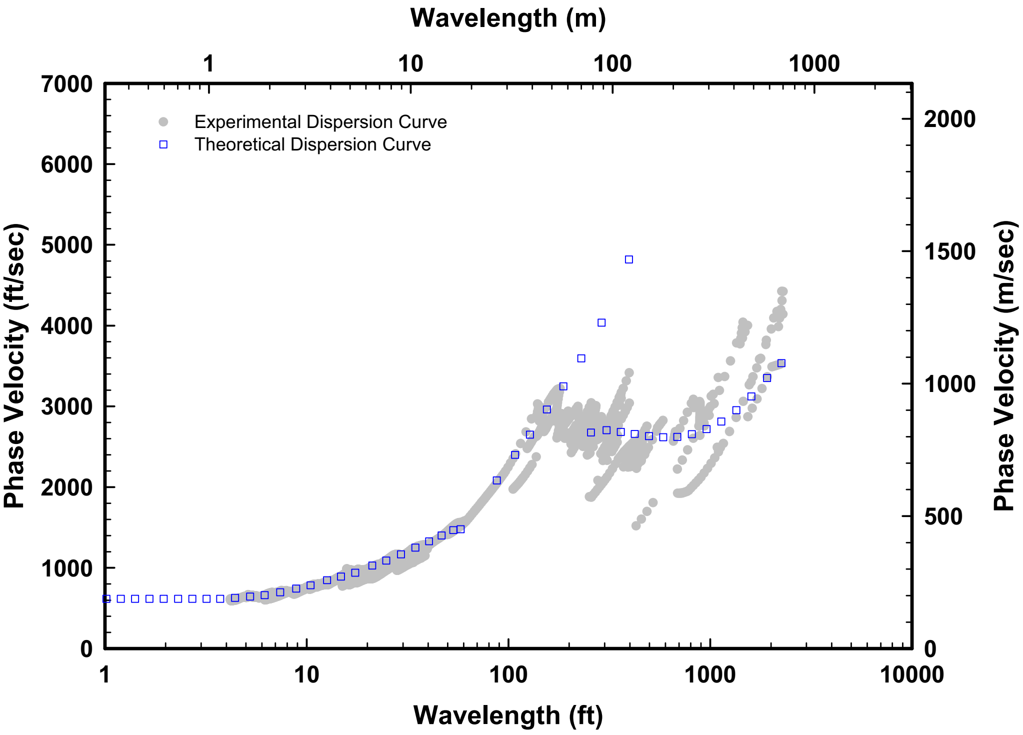
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-43. Shear Wave Velocity Profile Determined at YM 16-T1, YM 16-T2 and YM 16-T3



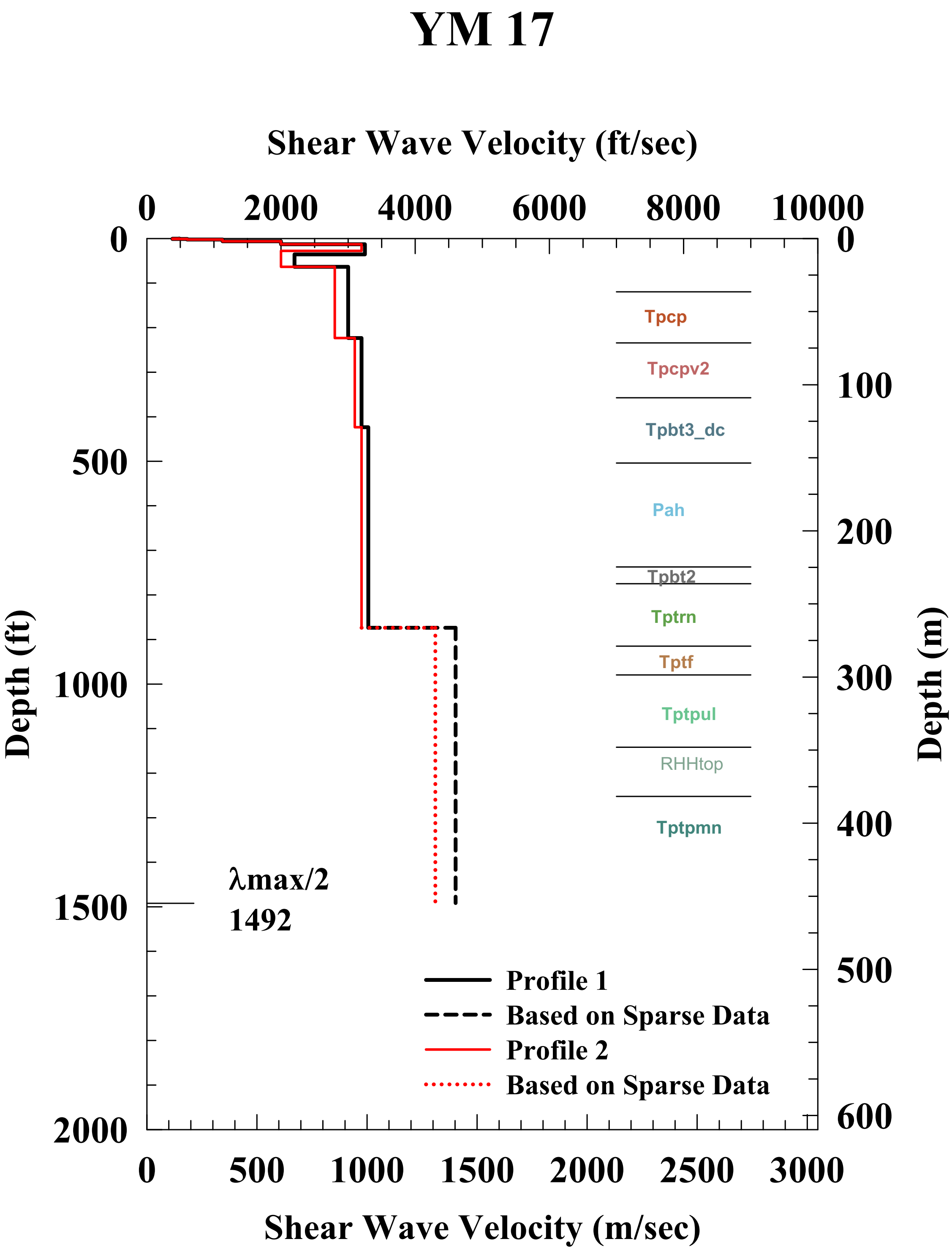
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-44. Experimental and Theoretical Dispersion Curves from YM 16-T1, YM 16-T2 and YM 16-T3; Linear Wavelength Axis



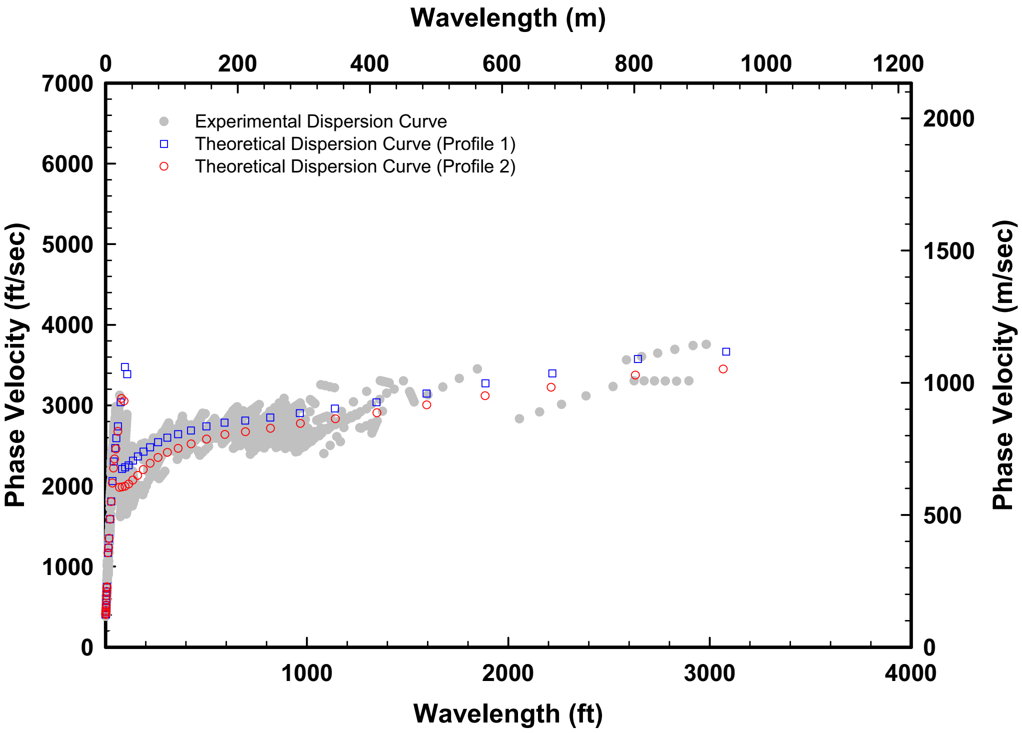
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-45. Experimental and Theoretical Dispersion Curves from YM 16-T1, YM 16-T2 and YM 16-T3; Logarithmic Wavelength Axis



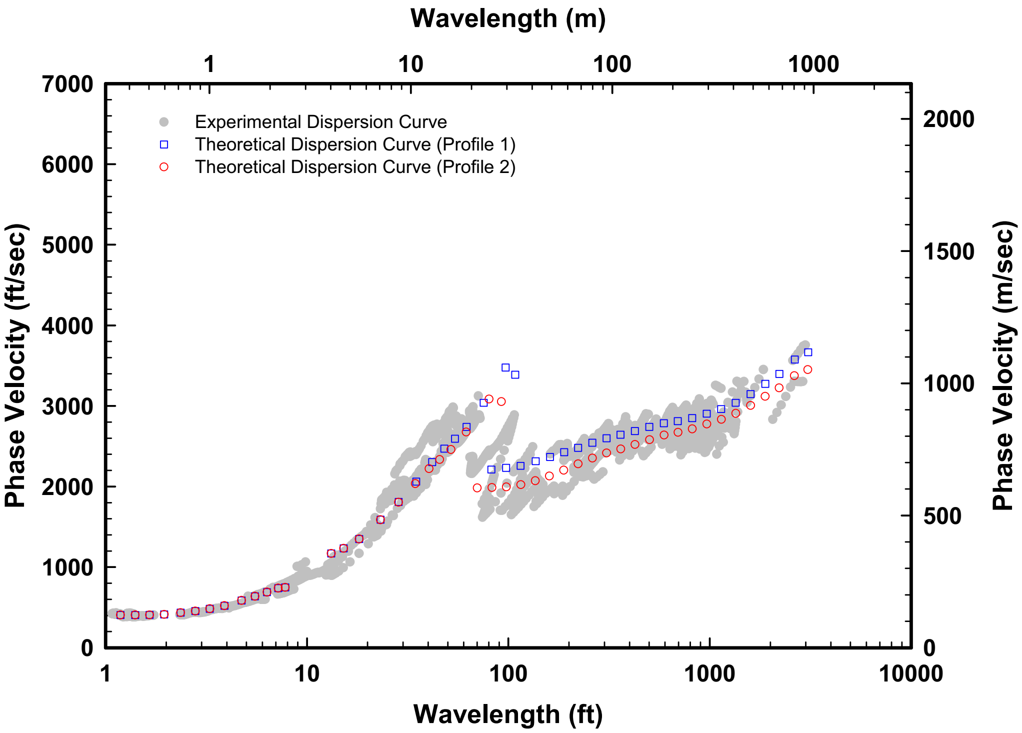
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-46. Shear Wave Velocity Profile Determined at YM 17-T1 and YM 17-T2



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

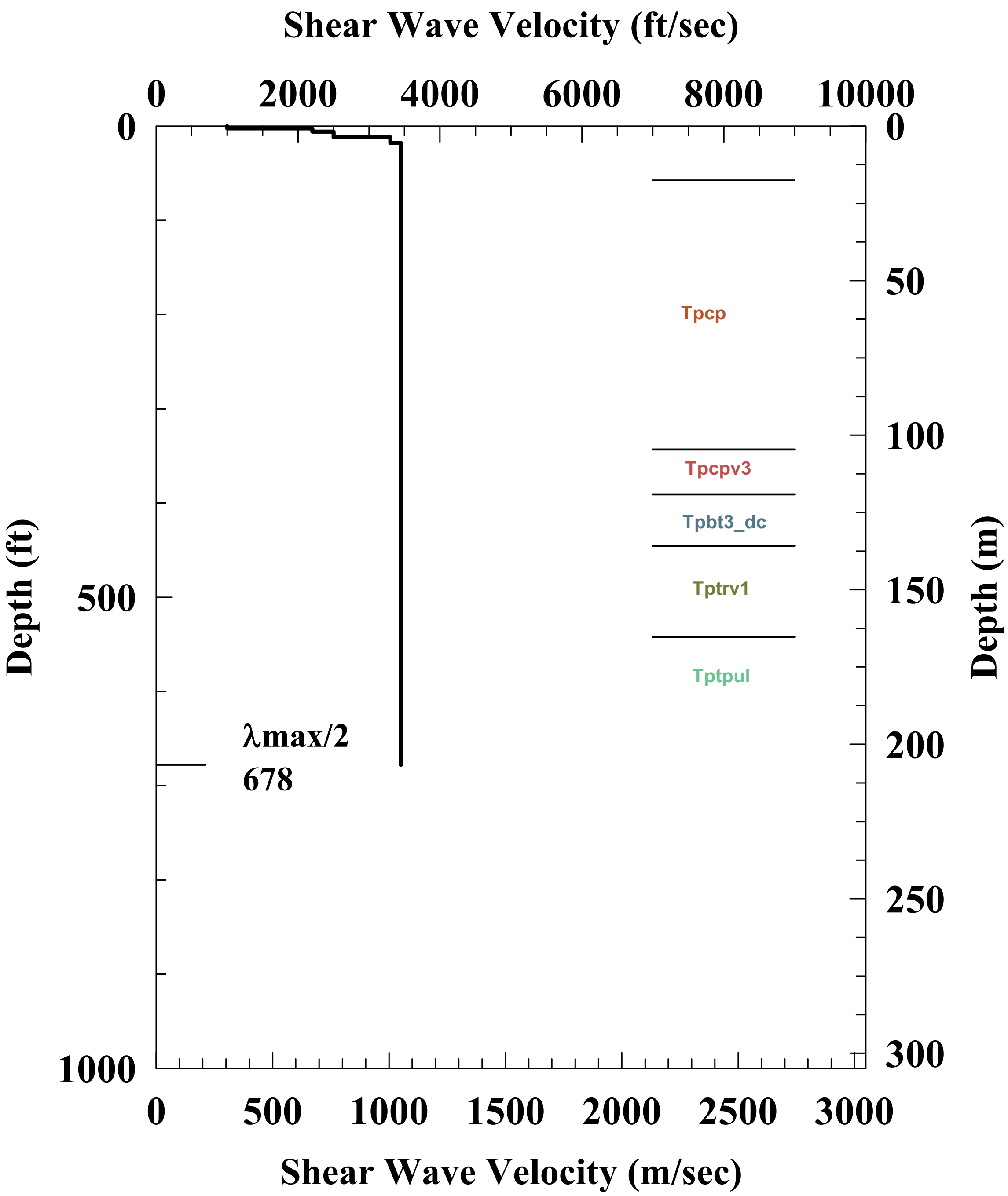
Figure V-47. Experimental and Theoretical Dispersion Curves from YM 17-T1 and YM 17-T2; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

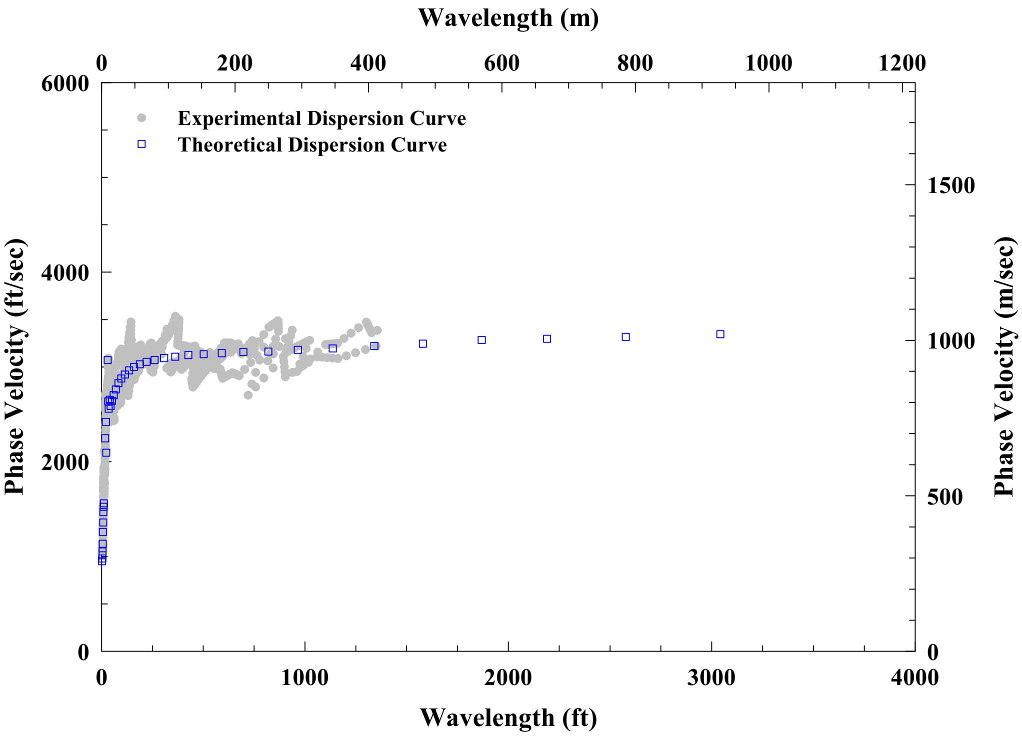
Figure V-48. Experimental and Theoretical Dispersion Curves from YM 17-T1 and YM 17-T2; Logarithmic Wavelength Axis

YM 19



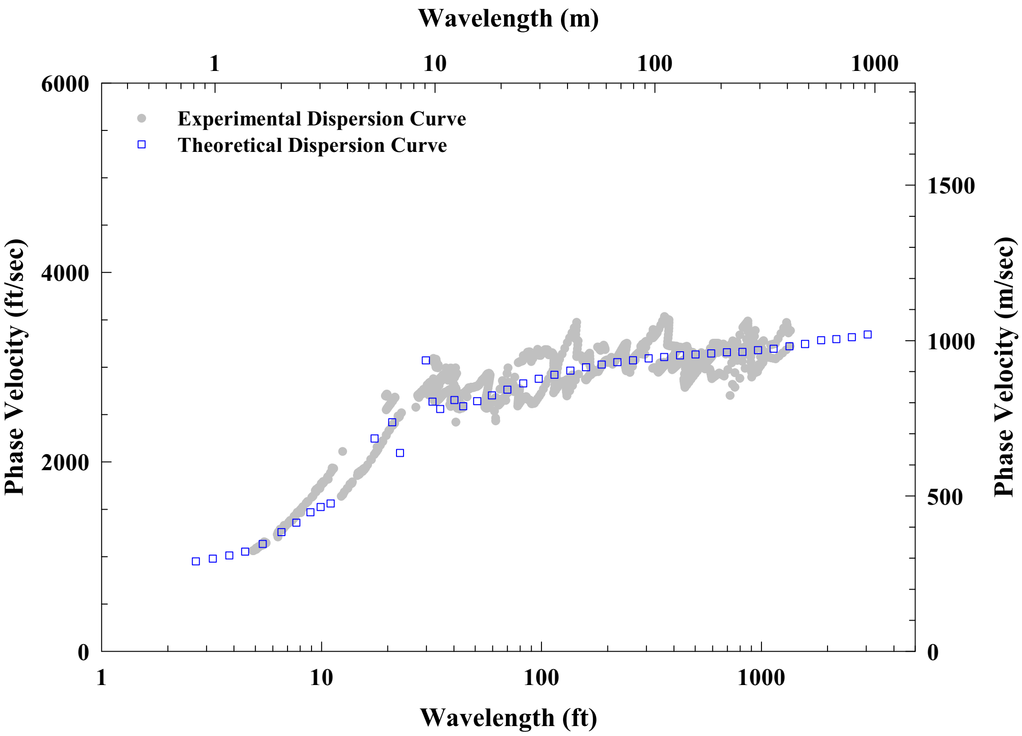
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-49.   Shear Wave Velocity Profile Determined at YM 19



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

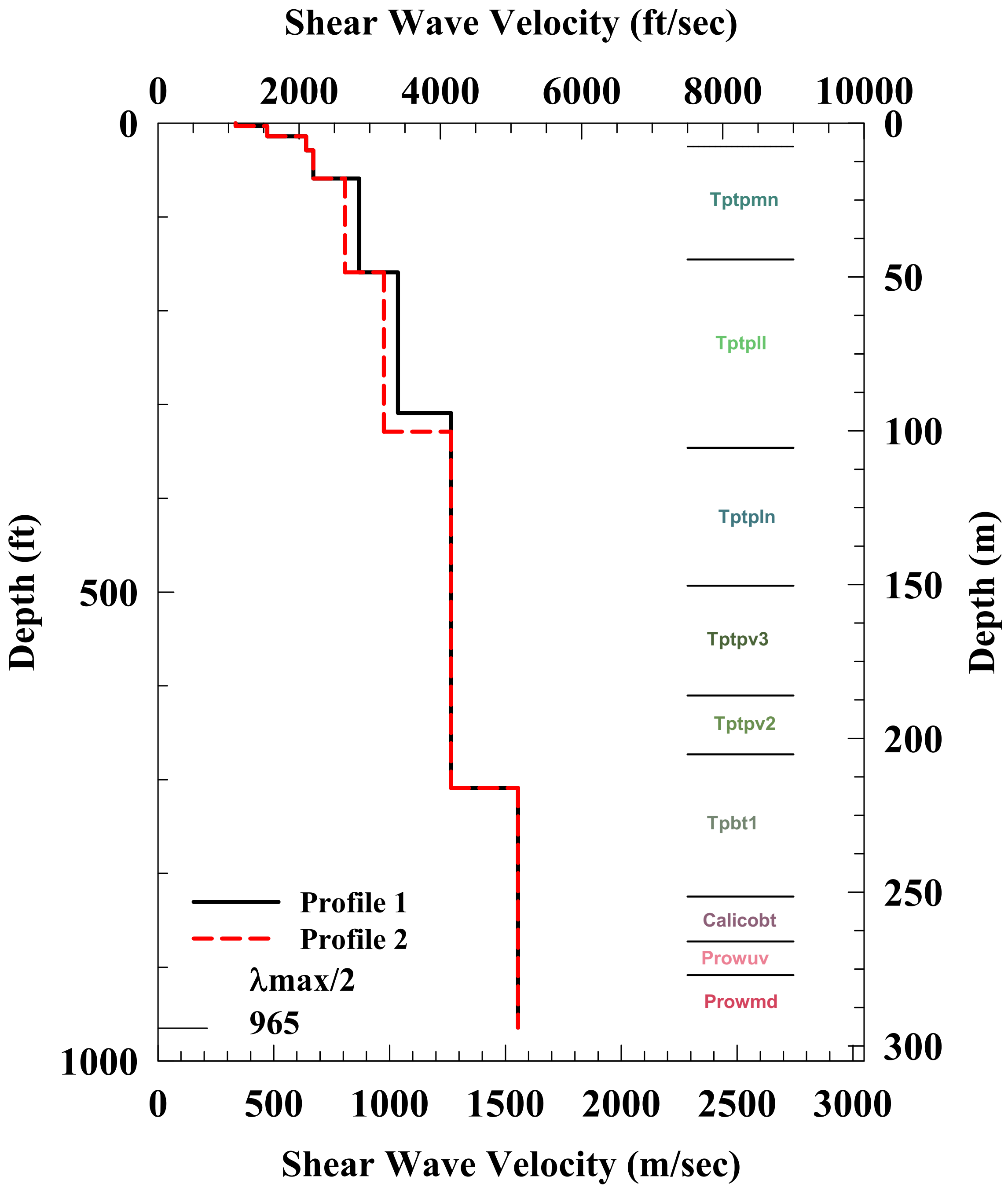
Figure V-50. Experimental and Theoretical Dispersion Curves from YM 19; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

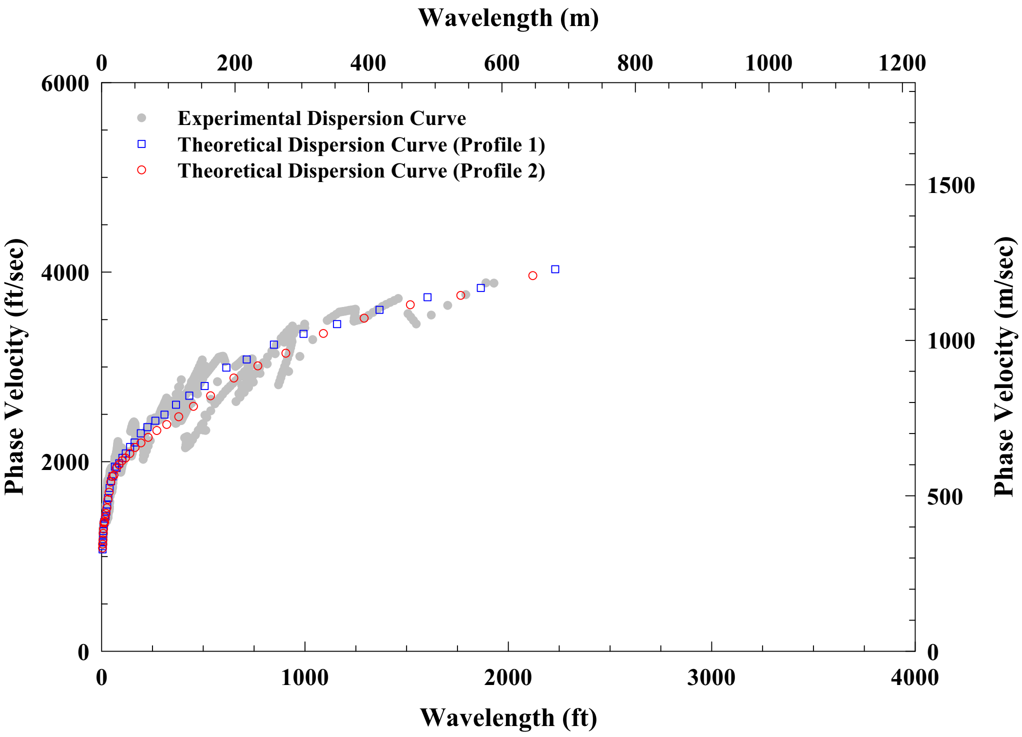
Figure V-51. Experimental and Theoretical Dispersion Curves from YM 19; Logarithmic Wavelength Axis

YM 20



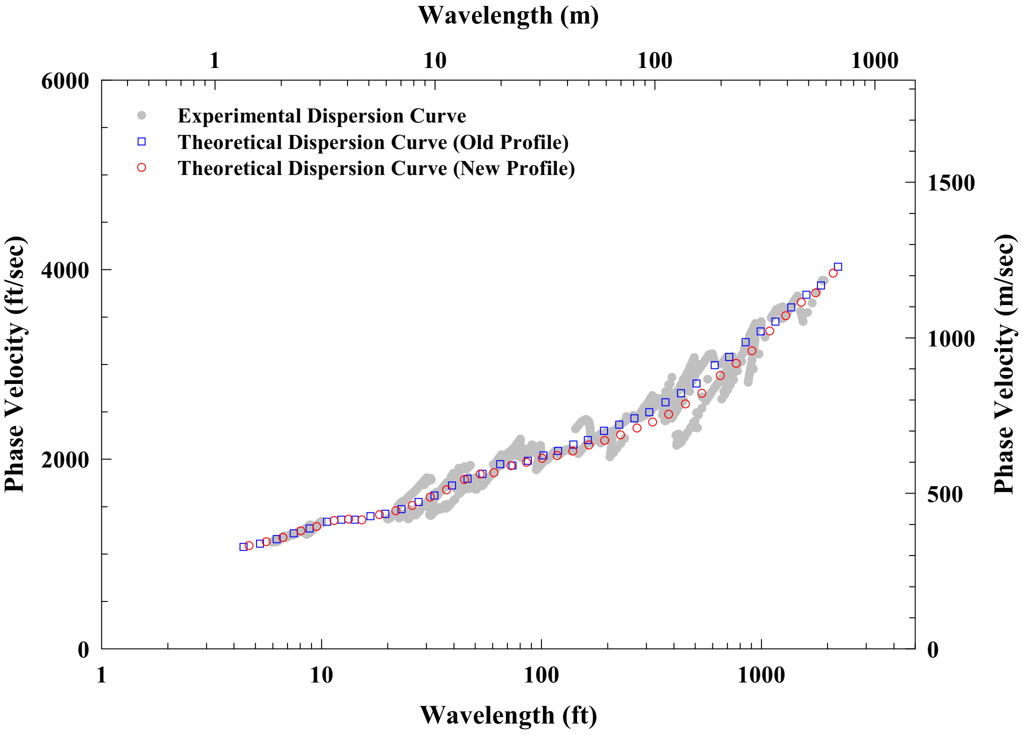
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-52. Shear Wave Velocity Profile Determined at YM 20



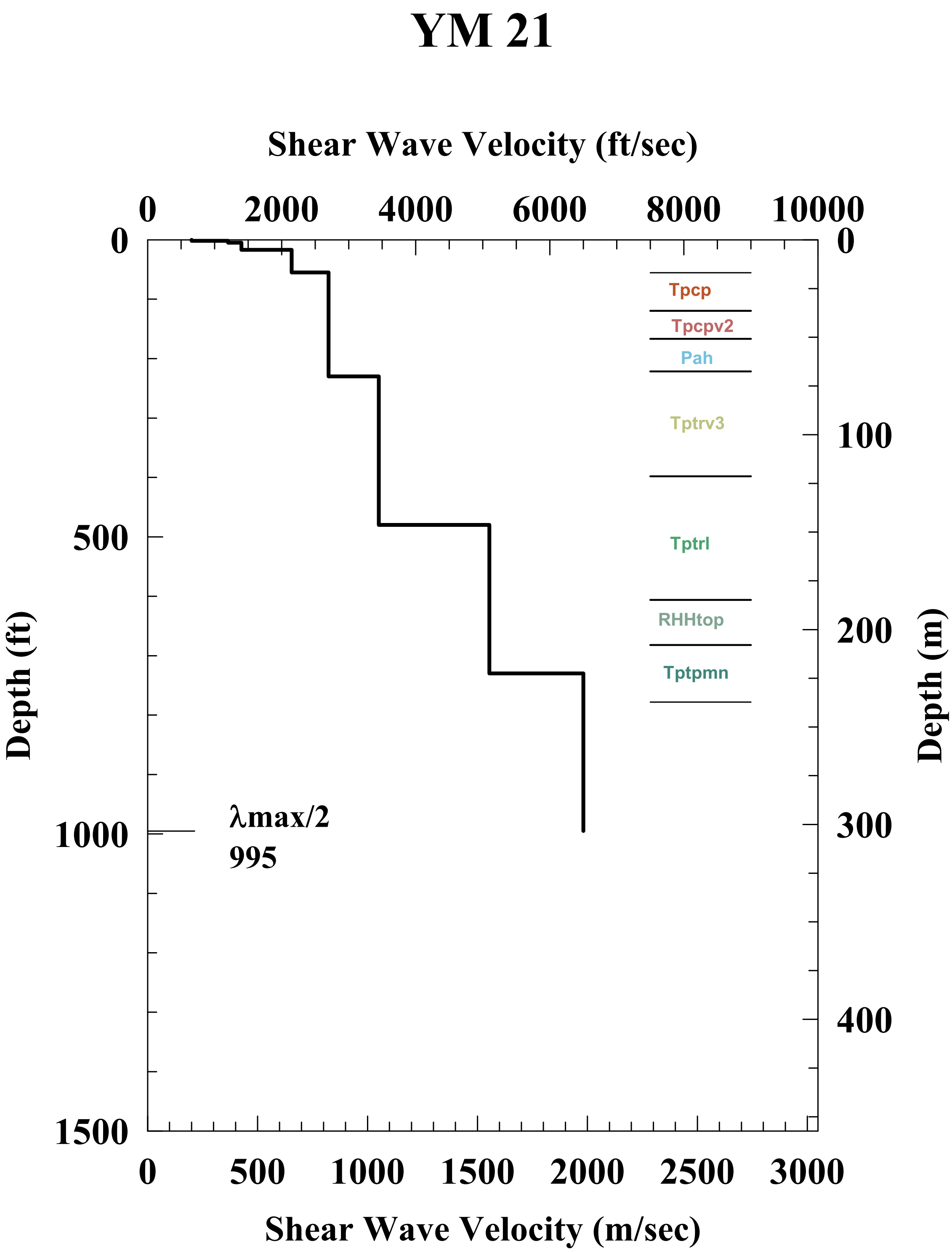
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-53. Experimental and Theoretical Dispersion Curves from YM 20; Linear Wavelength Axis



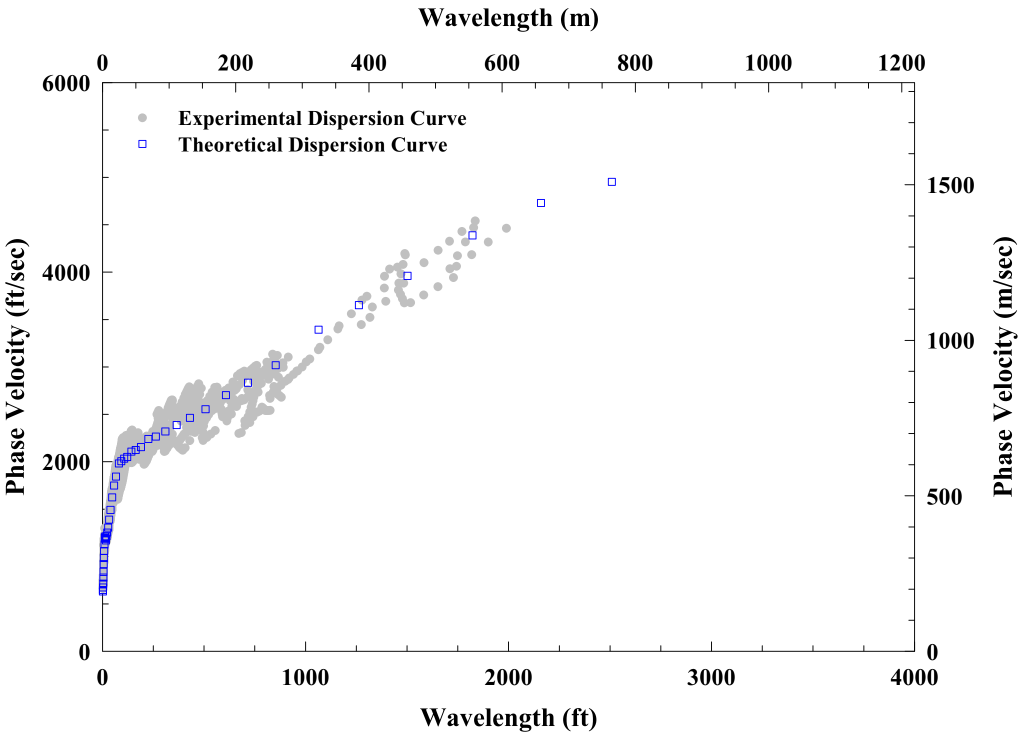
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-54. Experimental and Theoretical Dispersion Curves from YM 20; Logarithmic Wavelength Axis



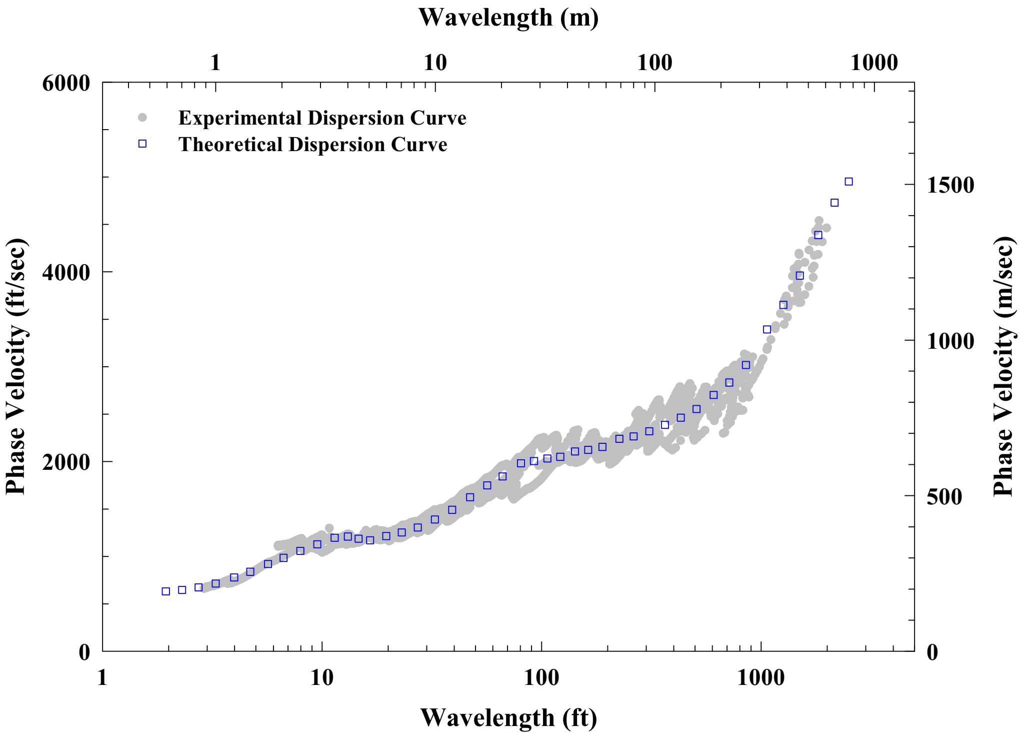
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-55. Shear Wave Velocity Profile Determined at YM 21



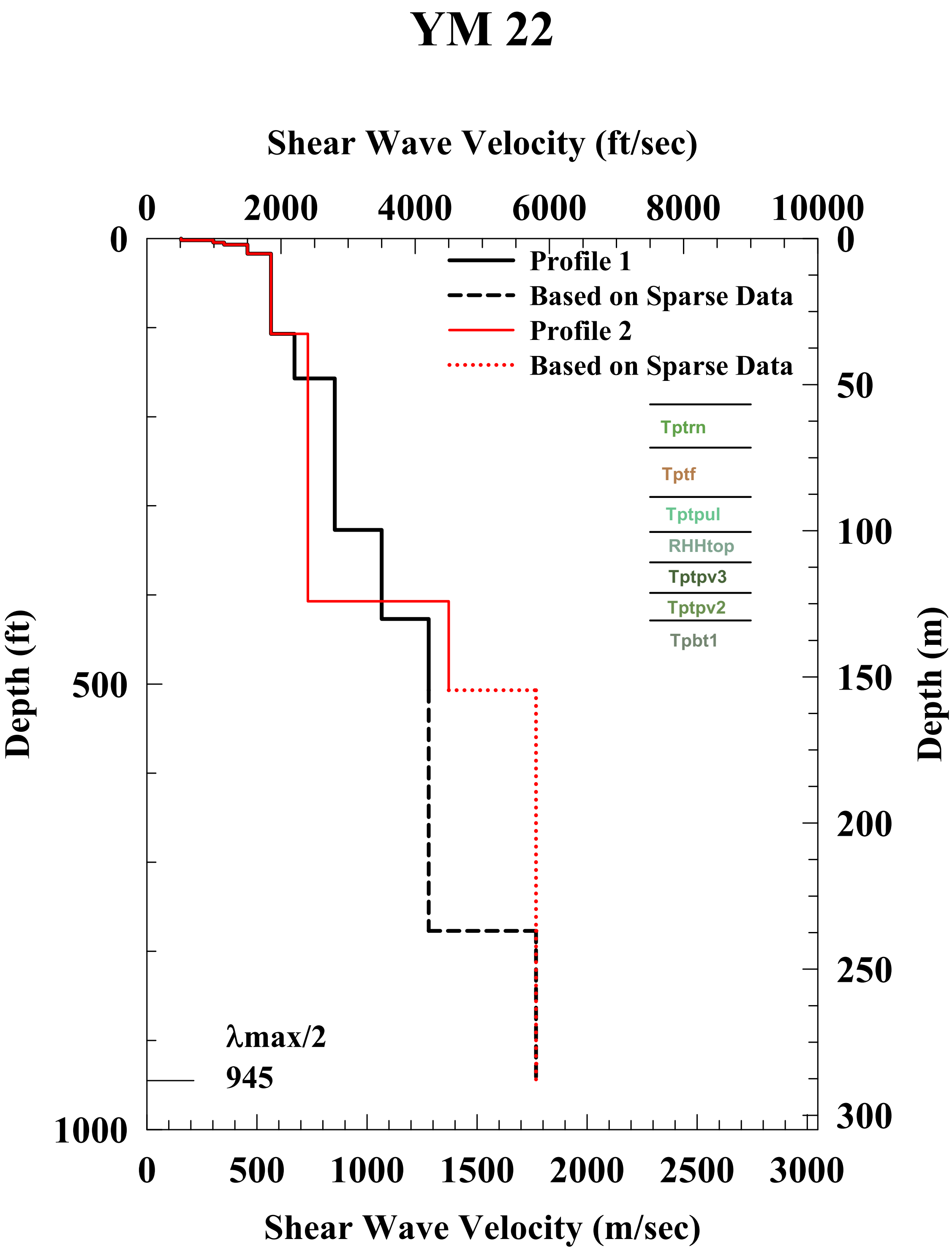
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-56. Experimental and Theoretical Dispersion Curves from YM 21; Linear Wavelength Axis



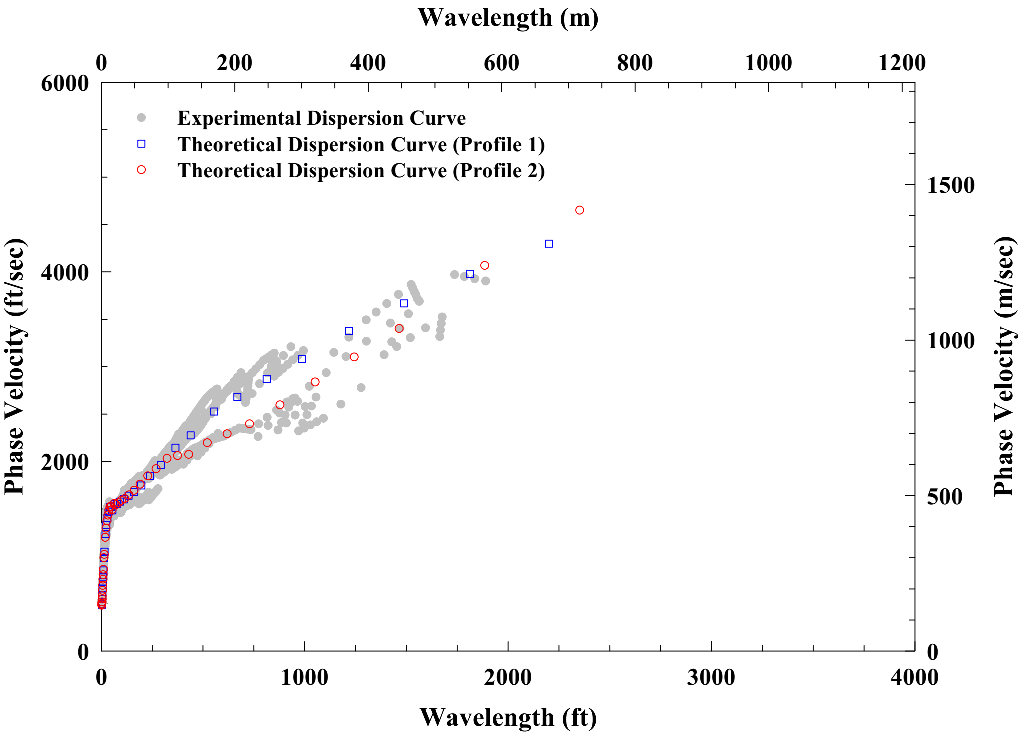
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-57. Experimental and Theoretical Dispersion Curves from YM 21; Logarithmic Wavelength Axis



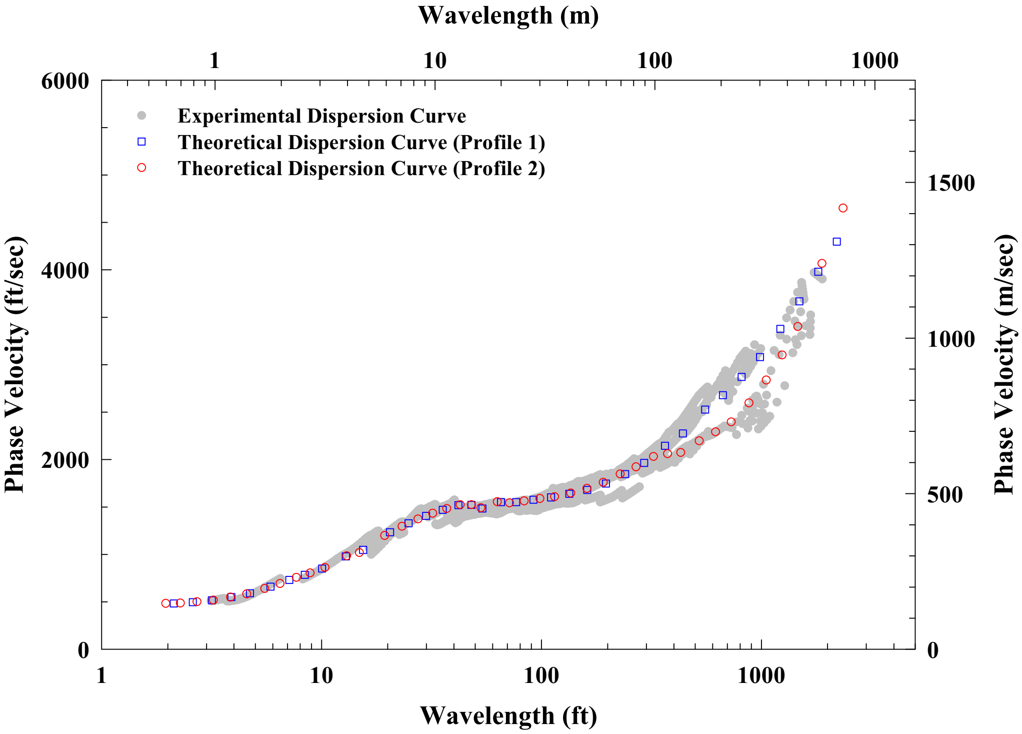
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-58. Shear Wave Velocity Profile Determined at YM 22



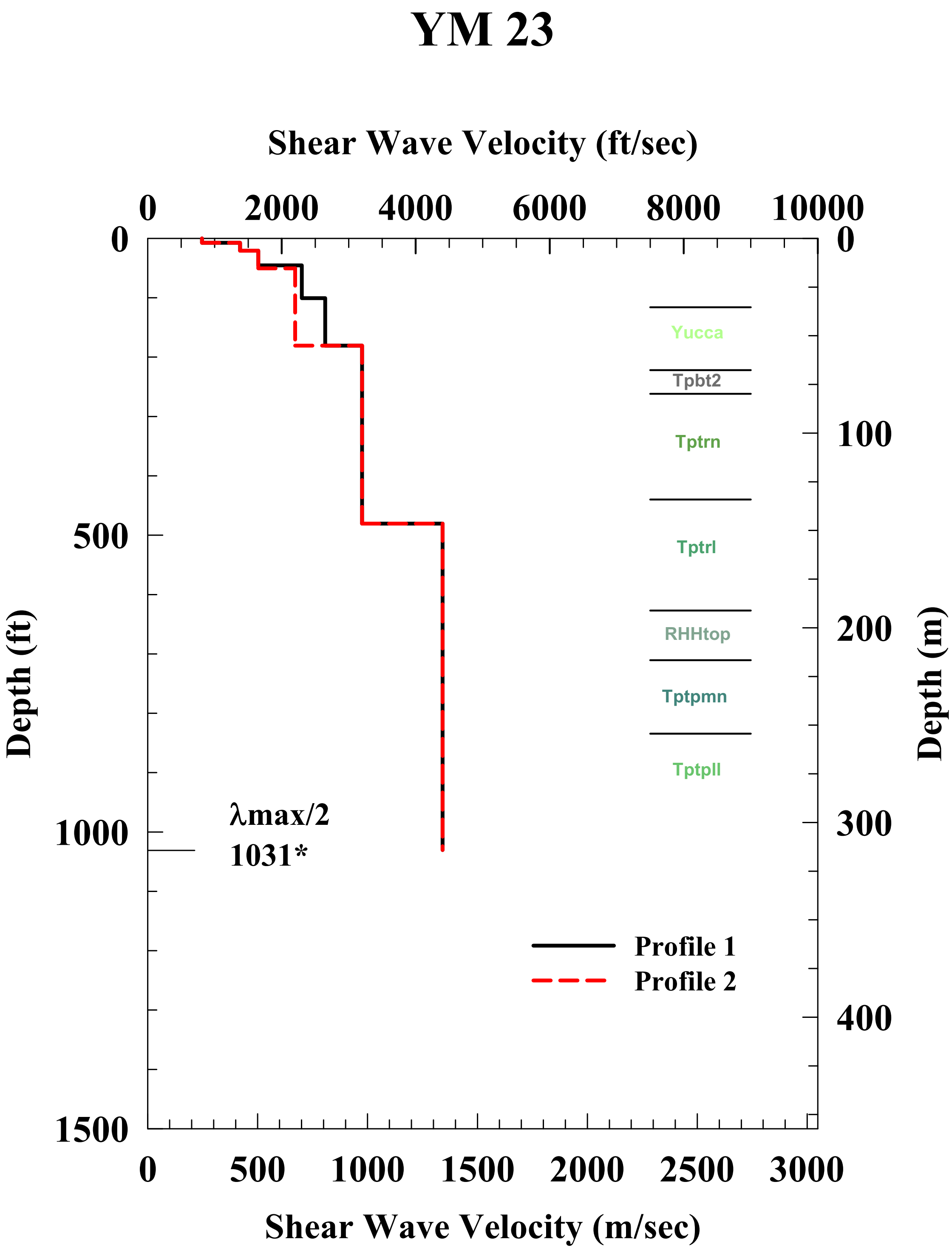
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-59. Experimental and Theoretical Dispersion Curves from YM 22; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

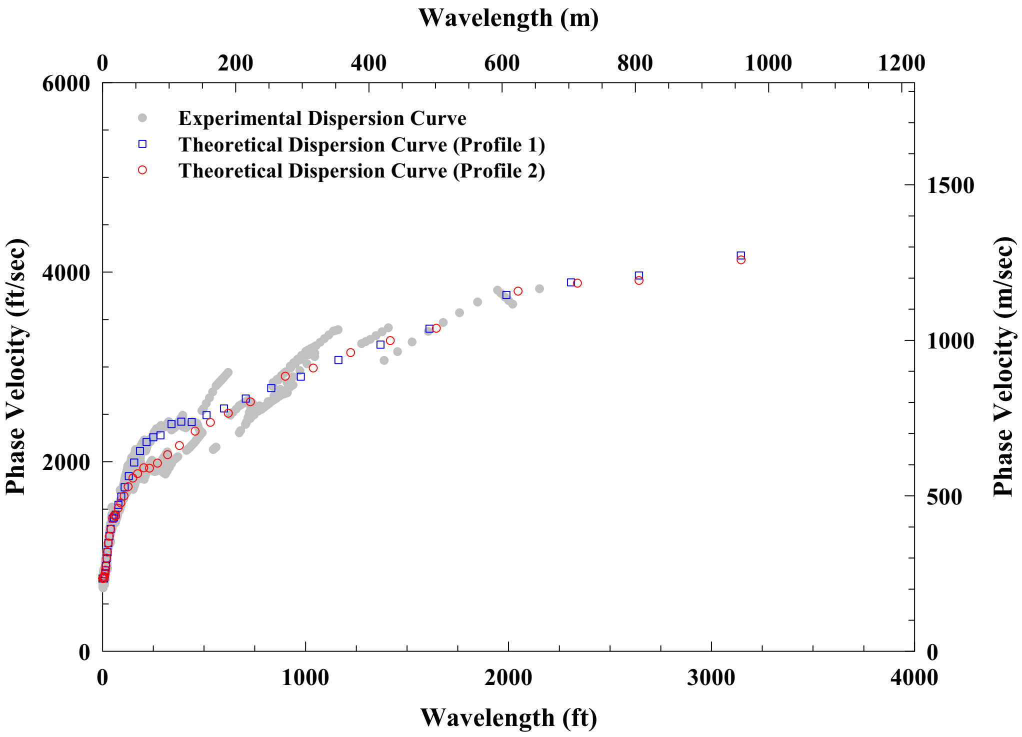
Figure V-60. Experimental and Theoretical Dispersion Curves from YM 22; Logarithmic Wavelength Axis



* Not λ_{max} / 2 because thin layer or profile due to large variation below this depth was removed. See "Developed data" sent to TDMS for details

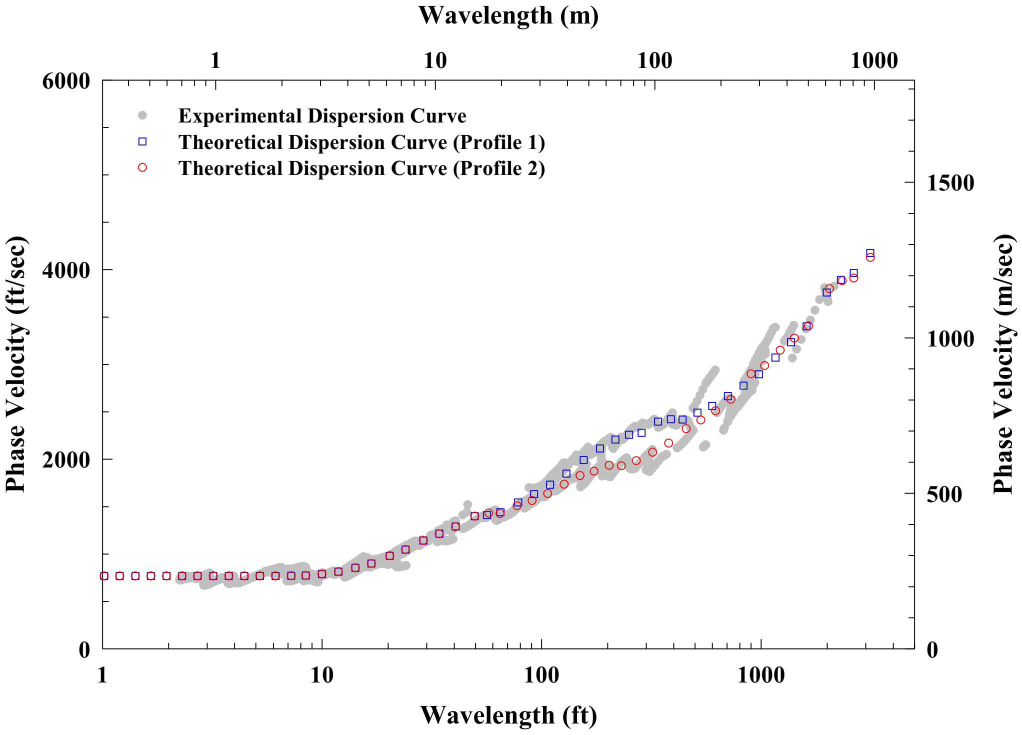
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-61. Shear Wave Velocity Profile Determined at YM 23



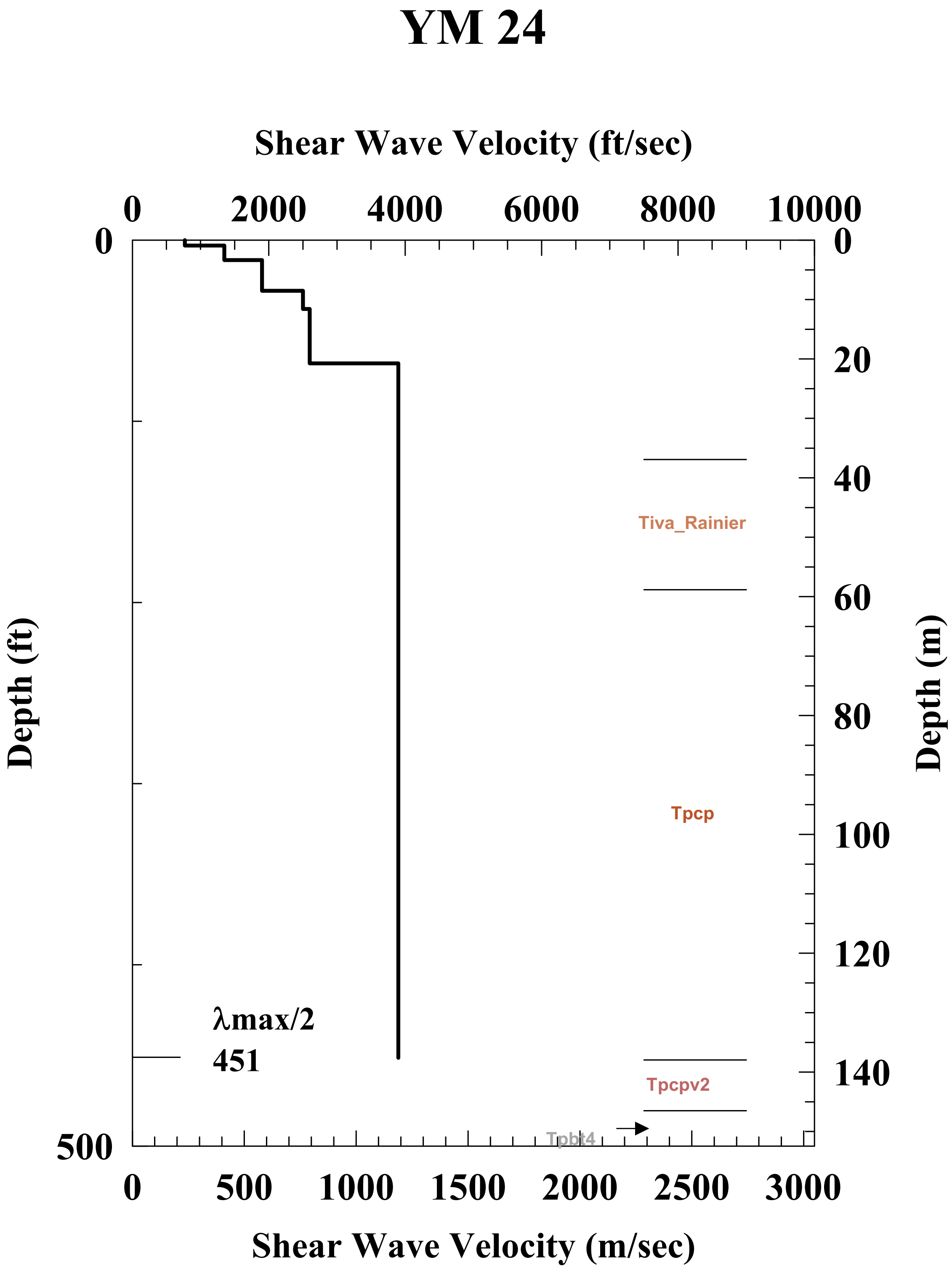
Source:	DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-62.   Experimental and Theoretical Dispersion Curves from YM 23; Linear Wavelength Axis



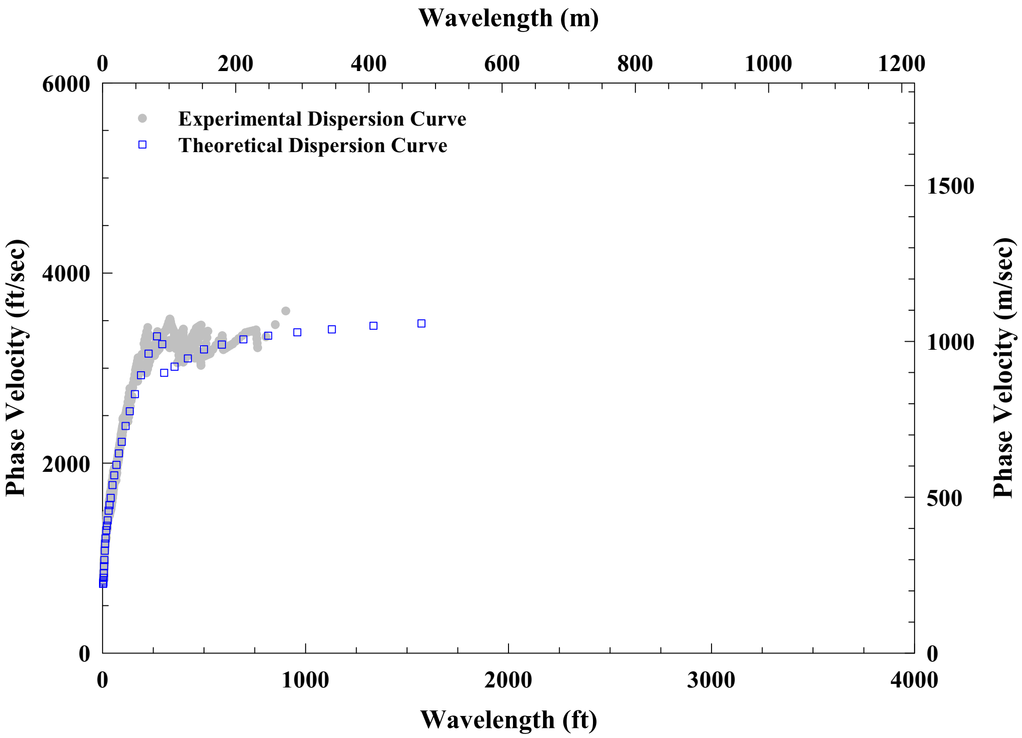
Source:	DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-63.   Experimental and Theoretical Dispersion Curves from YM 23; Logarithmic Wavelength Axis



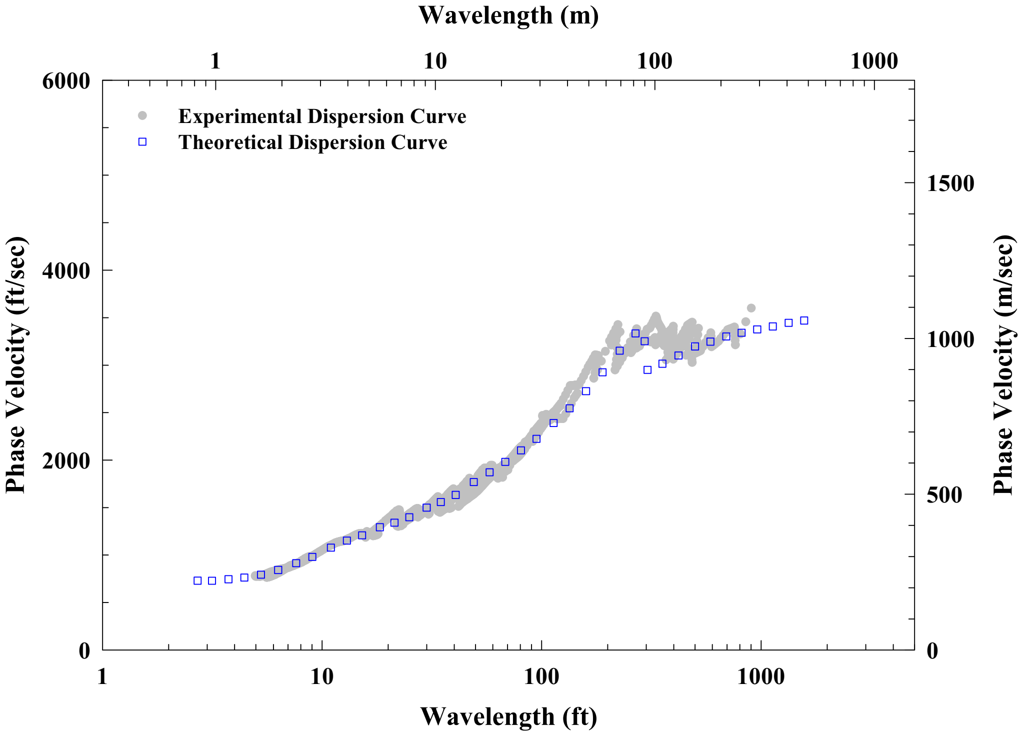
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327]; DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-64. Shear Wave Velocity Profile Determined at YM 24



Source:	DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

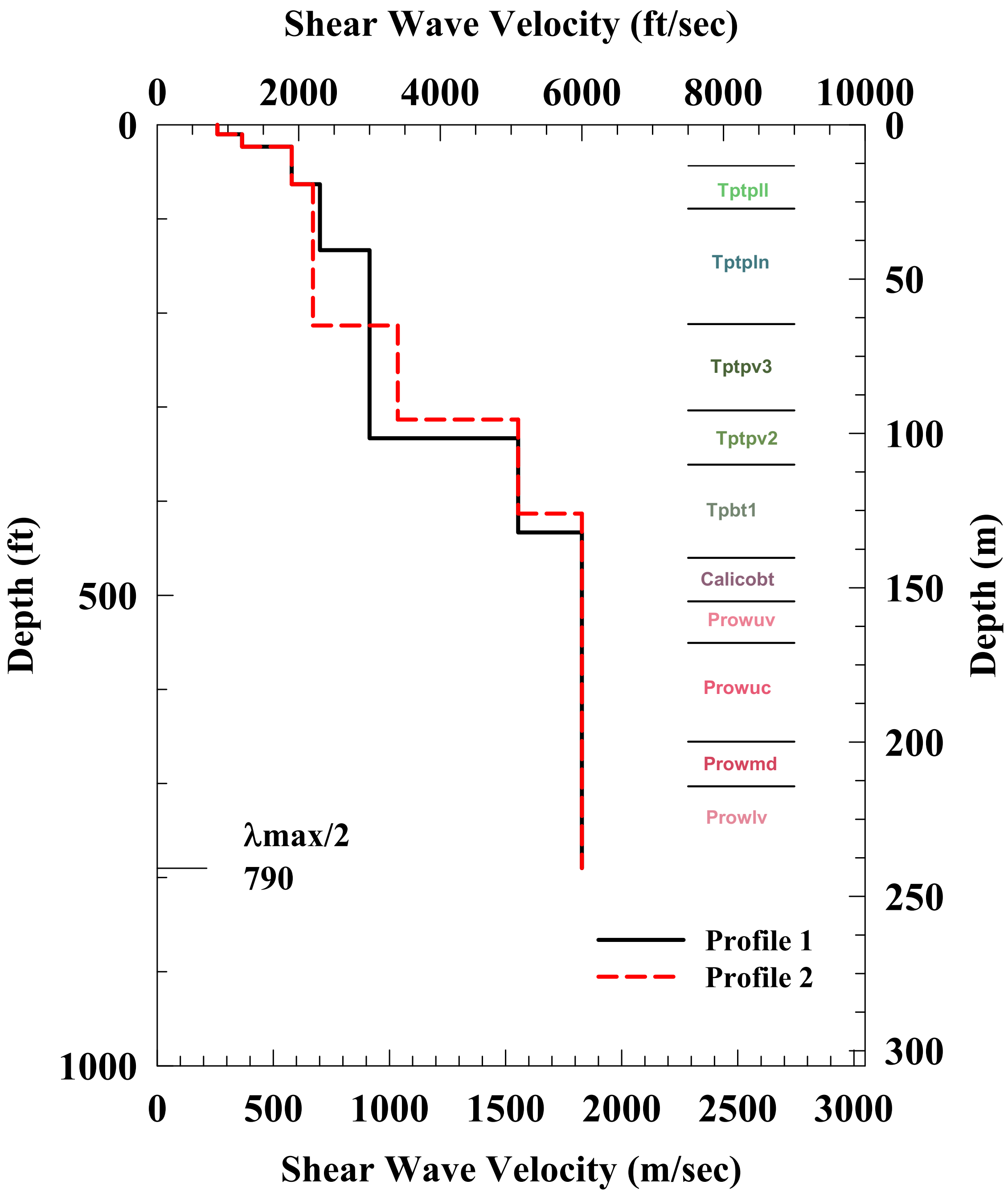
Figure V-65.   Experimental and Theoretical Dispersion Curves from YM 24; Linear Wavelength Axis



Source:	DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

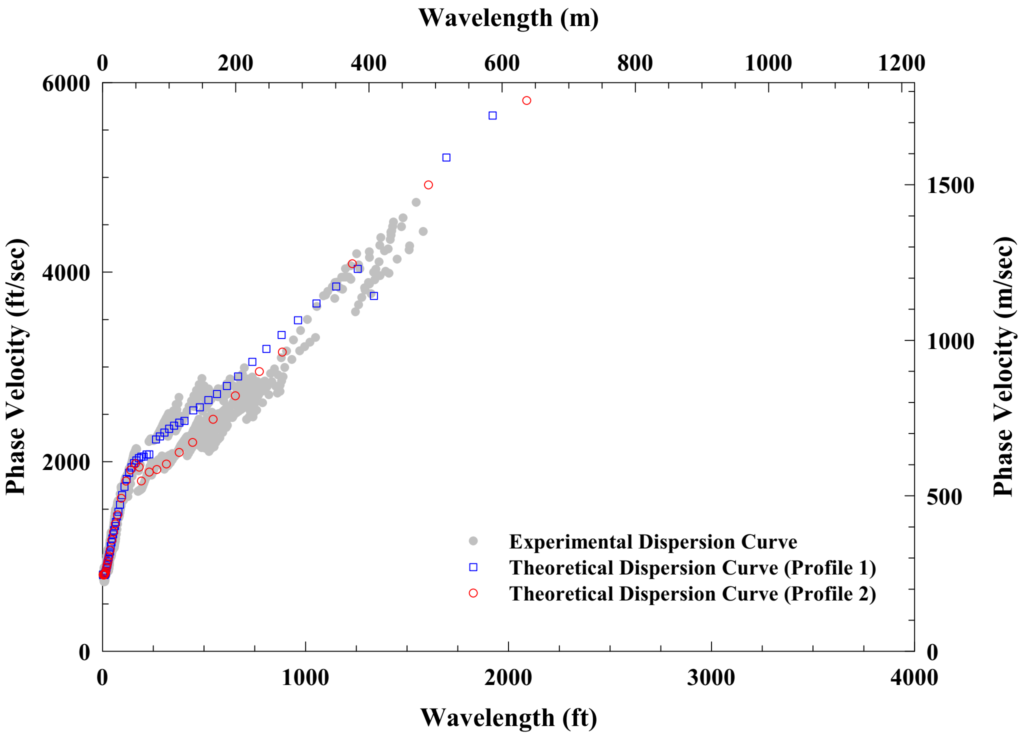
Figure V-66.   Experimental and Theoretical Dispersion Curves from YM 24; Logarithmic Wavelength Axis

YM 25



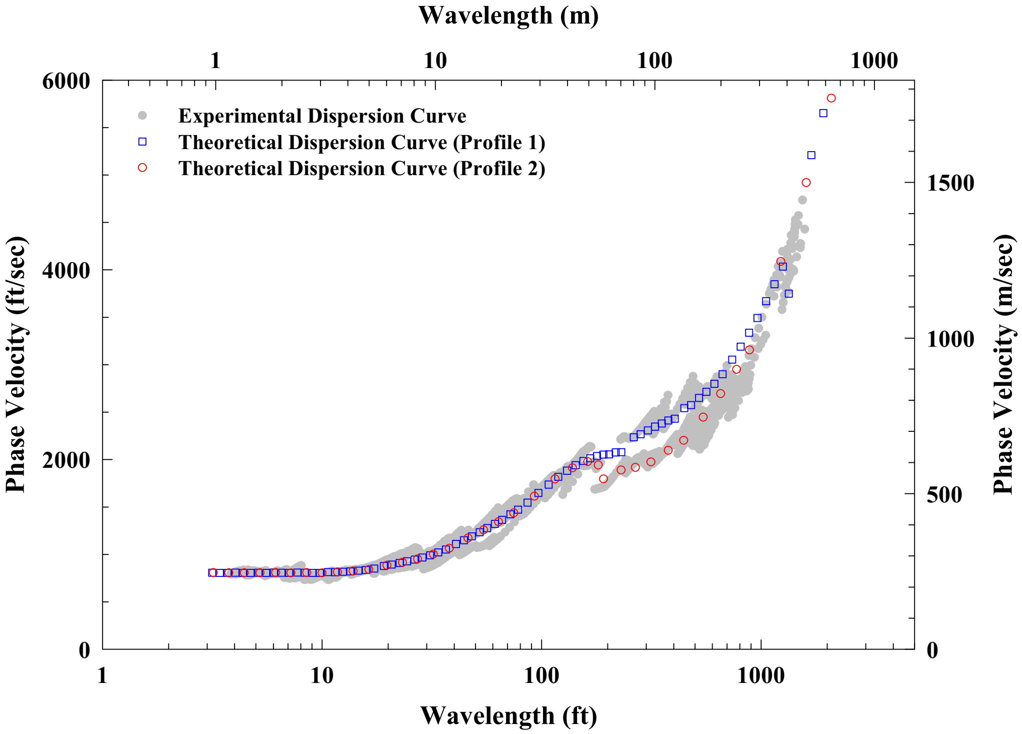
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-67. Shear Wave Velocity Profile Determined at YM 25



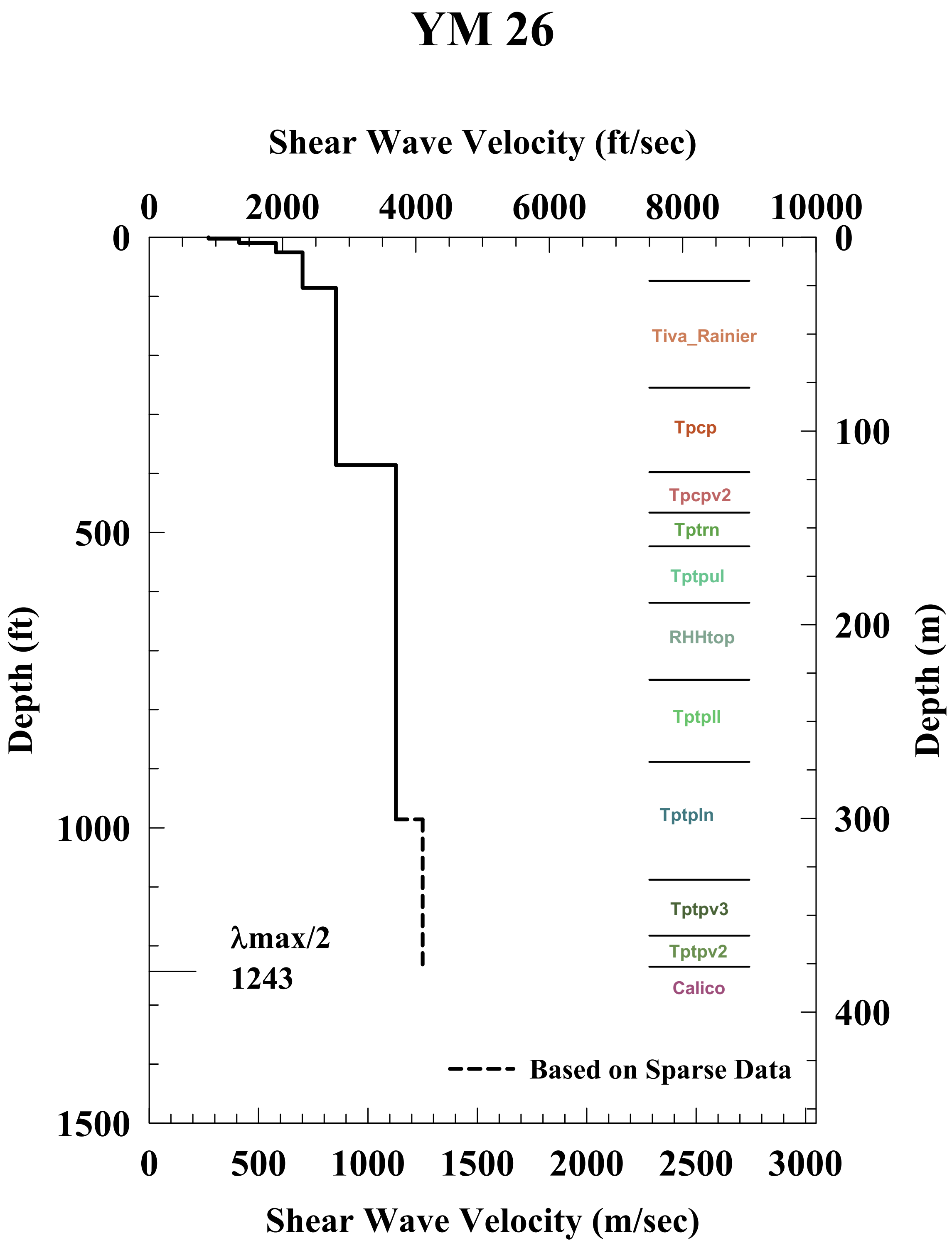
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-68. Experimental and Theoretical Dispersion Curves from YM 25; Linear Wavelength Axis



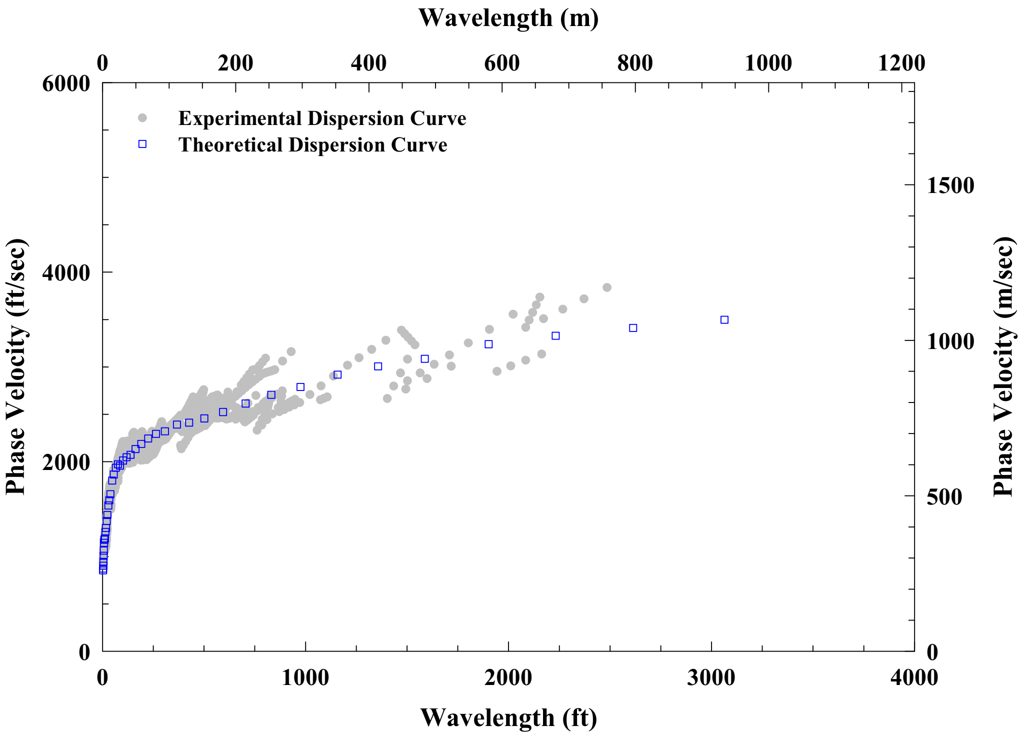
Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-69. Experimental and Theoretical Dispersion Curves from YM 25; Logarithmic Wavelength Axis



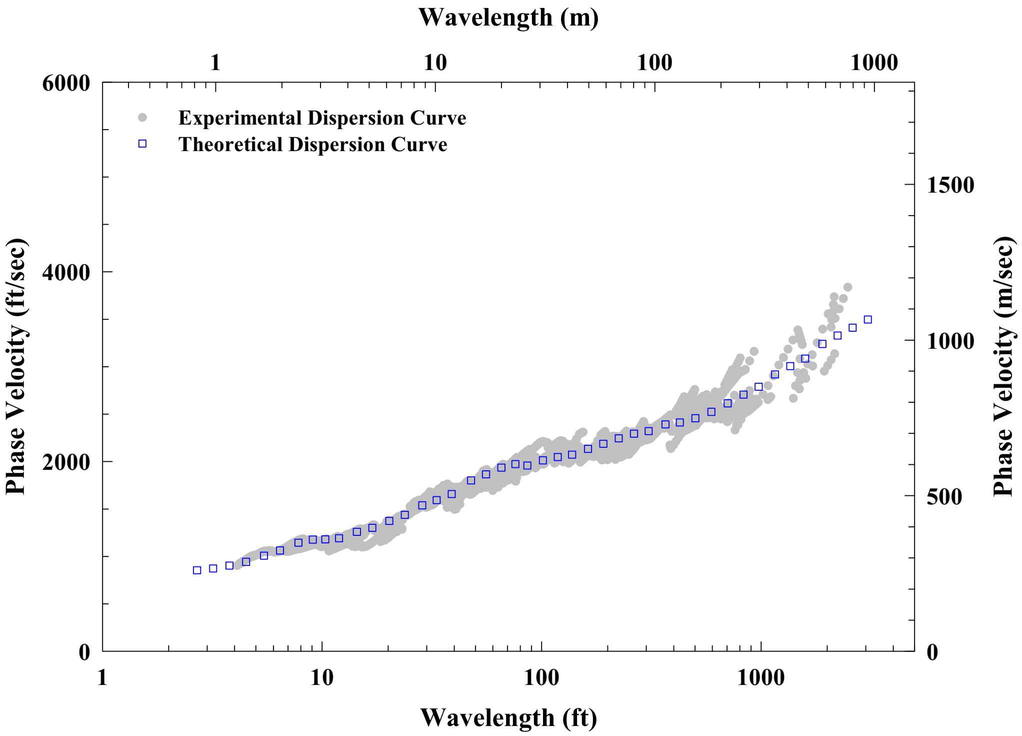
Source: DTN: MO0609SASWSTDC.003 [DIRS18 2125]; Stokoe 2007 [DIRS 183327];
DTN: MO0012MWDGFM02.002 [DIRS 153777].

Figure V-70. Shear Wave Velocity Profile Determined at YM 26



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-71. Experimental and Theoretical Dispersion Curves from YM 26; Linear Wavelength Axis



Source: DTN: MO0609SASWSTDC.003 [DIRS182125]; Stokoe 2007 [DIRS 183272].

Figure V-72. Experimental and Theoretical Dispersion Curves from YM 26; Logarithmic Wavelength Axis

ATTACHMENT VI

SASW SHEAR WAVE VELOCITY PROFILES FROM ESF AND ECRB CROSS-DRIFT

ATTACHMENT VI
SASW SHEAR WAVE VELOCITY PROFILES FROM ESF AND ECRB CROSS-DRIFT

As outlined in Section 6.4.2, in 2004 and 2005, Spectral-Analysis-of-Surface-Wave (SASW) surveys were performed in the Exploratory Studies Facility (ESF) main drift and Enhanced Characterization of Repository Block (ECRB) cross-drift. These SASW surveys are identified with an "ESF" or "ECRB" nomenclature. This testing consisted of 45 SASW surveys as listed in Table 6.4-1. This attachment presents the SASW theoretical dispersion curves from experimental dispersion curves and one-dimensional, layered, shear wave velocity (V_S) profiles for the 45 underground sites located in the ESF and ECRB cross-drift.

The theoretical dispersion curves were developed using WinSASW V. 1.23 (STN: 10588-1.23-00) [DIRS 159433]. The theoretical dispersion curve is fit to the experimental curve through an iterative forward modeling procedure. Tabular data for the theoretical dispersion curves and velocity profiles are contained in DTN: MO0609SASWUTDC.004 [DIRS 183295], while plots of the data are presented in the scientific notebook supplement accompanying the data package (Stokoe 2007 [DIRS 183327]). The theoretical dispersion curves and shear wave velocity profiles are presented in alphanumeric order beginning on page VI-2.

The center points of 29 sites (22 ECRB and 7 ESF) were surveyed and their coordinates are listed in DTN: MO0706SASWPHII.000 [DIRS 183299]. Sites not surveyed prior to the closing of the tunnel are based on a distance measurement using a tape measure to record the distance to the nearest tunnel survey marker. The as-built survey coordinates for the ECRB cross-drift and ESF test locations are provided in Tables VI-1 and VI-2.

Table VI-1.   As-Built Survey Locations for 22 ECRB Points

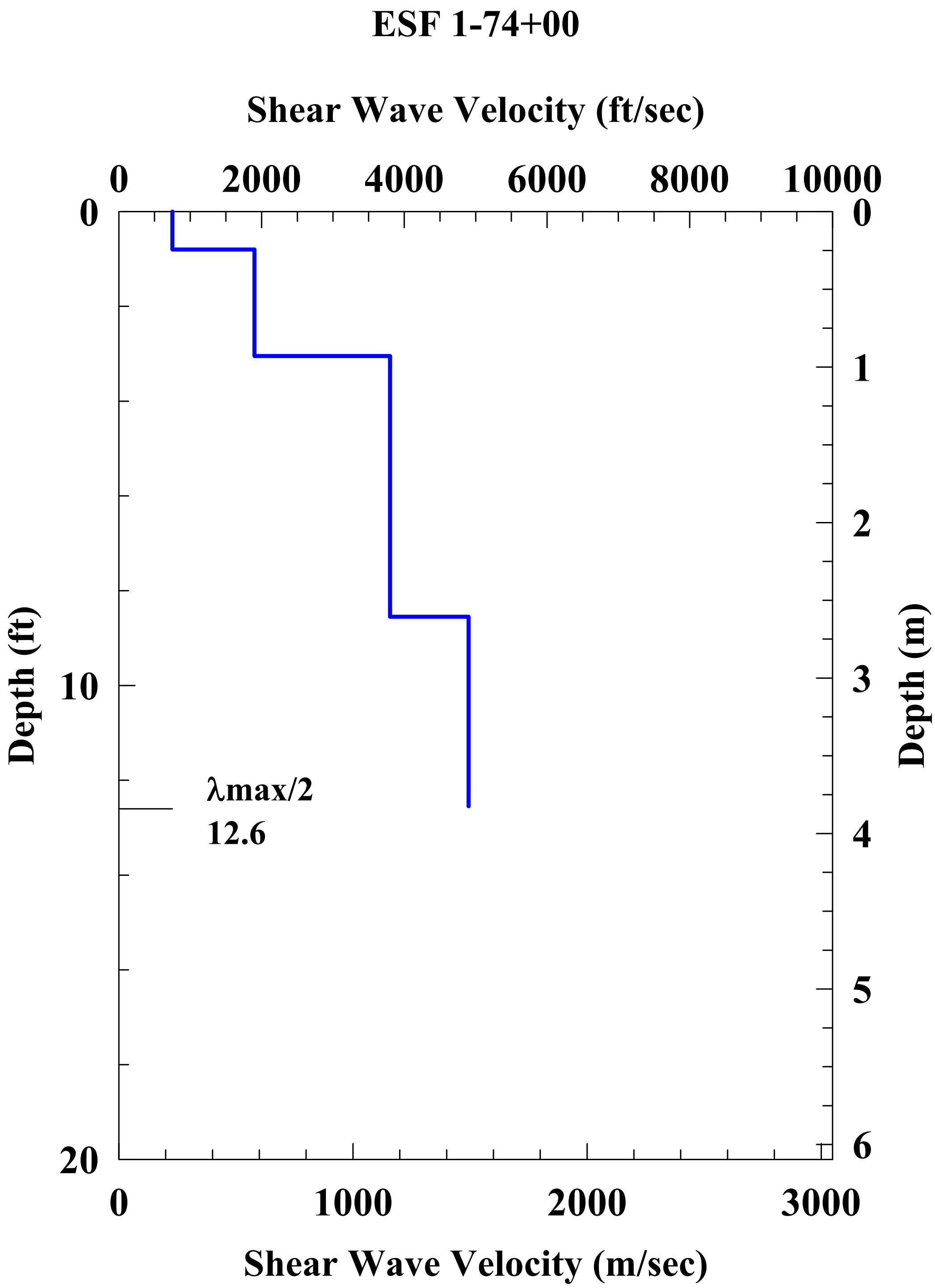
Point ID	Surveyed Station	Coordinate Northing	Coordinate Easting	Elevation	Descriptor	UTA SASW ECRB
STA. 6+59L	6+59.1	23390.53	171387.56	1093.28	TARGET AT STA. 6+59L IN THE ECRB	ECRB-5-06+59
STA. 7+40L	7+41.5	233849.46	171325.37	1094.75	TARGET AT STA. 7+40L IN THE ECRB	ECRB 07+40
STA. 8+14L	8+18.6	233798.90	171267.15	1096.04	TARGET AT STA. 8+15L IN THE ECRB	ECRB 08+15
STA. 9+10L	9+09.8	233739.03	171198.34	1097.59	TARGET AT STA. 9+10L IN THE ECRB	ECRB-4-09+10
STA. 12+20L	12+19.7	233535.74	170964.40	1101.95	TARGET AT STA. 12+20L IN THE ECRB	ECRB-3-12+20
STA. 14+93R	14+99.0	233355.98	170750.60	1105.83	TARGET AT STA. 14+93R IN THE ECRB	ECRB 14+93
STA. 14+94L	14+93.9	233355.83	170757.48	1106.05	TARGET AT STA. 14+94L IN THE ECRB	ECRB 14+94
STA. 15+51L	15+50.7	233318.53	170714.68	1106.96	TARGET AT STA. 15+51L IN THE ECRB	ECRB 15+51
STA. 16+07R	16+08.1	233284.45	170668.30	1107.53	TARGET AT STA. 16+07R IN THE ECRB	ECRB-2-16+07
STA. 16+41L	14+40.5	233259.54	170646.92	1108.09	TARGET AT STA. 16+41L IN THE ECRB	ECRB 16+41
13	18+05.7	233151.21	170522.24	1109.72	TARGET #13 AT STA. 18+05L IN THE ECRB	ECRB 18+02
14	19+19.3	233076.71	170436.45	1110.53	TARGET #14 AT STA. 19+20L IN THE ECRB	ECRB 19+20
15	19+80.9	233036.23	170390.04	1111.21	TARGET #15 AT STA. 19+80L IN THE ECRB	ECRB 19+82
16	20+18.6	233011.61	170361.56	1111.28	TARGET #16 AT STA. 20+19L IN THE ECRB	ECRB 20+19
17	20+70.6	232977.46	170322.27	1111.98	TARGET #17 AT STA. 20+71L IN THE ECRB	ECRB 20+71
18	21+15.4	232948.05	170288.48	1112.25	TARGET #18 AT STA. 21+25L IN THE ECRB	ECRB 21+16
19	21+62.4	232917.18	170253.00	1112.67	TARGET #19 AT STA. 21+62L IN THE ECRB	ECRB 21+63
20	22+30.6	232872.48	170201.50	1113.27	TARGET #20 AT STA. 22+32L IN THE ECRB	ECRB 22+31
21	22+91.4	232832.60	170155.65	1113.85	TARGET #21 AT STA. 22+94l IN THE ECRB	ECRB 22+94
22	23+59.6	232789.20	170102.63	1114.32	TARGET #22 AT STA. 23+55L IN THE ECRB	ECRB 23+60
23	23+95.1	232771.62	170071.54	1114.64	TARGET #23 AT STA. 24+00L IN THE ECRB	ECRB 23+96
24	24+88.6	232742.00	169982.43	1114.93	TARGET #24 AT STA. 24+95L IN THE ECRB	ECRB 24+87

Source: DTN: MO0706SASWPHII.000 [DIRS 183299].

Table VI-2. As-Built Survey Locations for 7 ESF Points

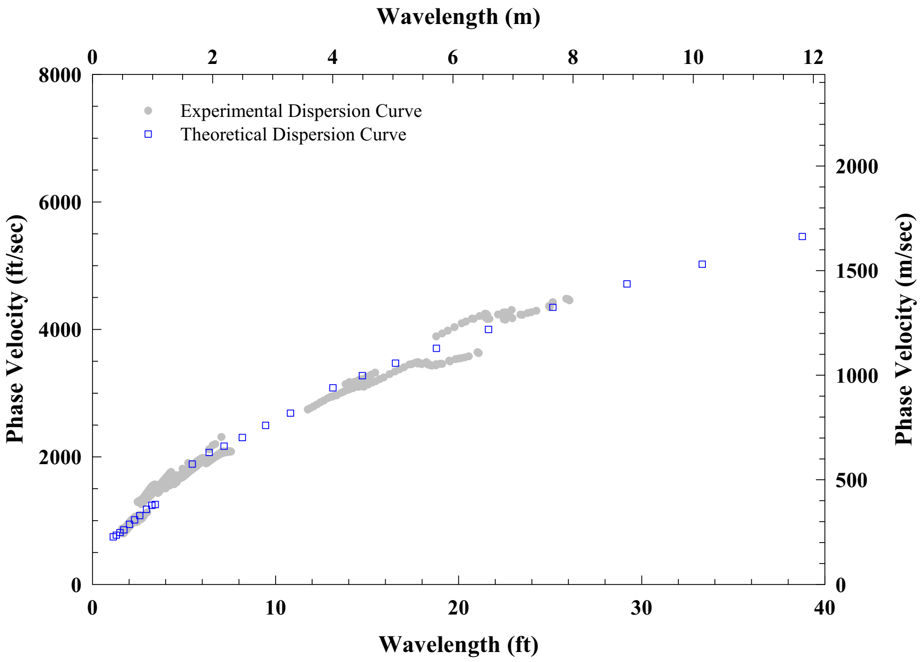
Point ID	Surveyed Station	Coordinate Northing	Coordinate Easting	Elevation	Descriptor	UTA SASW ECRB
STA. 2+12	2+19.6	233388.34	173488.66	1121.99	TARGET AT STA. 2+12R IN THE ESF	ESF 02+12
STA. 2+47	2+46.9	233401.55	173464.83	1121.41	TARGET AT STA. 2+47R IN THE ESF	ESF 02+47
STA. 2+68	2+66.6	233411.09	173447.61	1121.18	TARGET AT STA. 2+68R IN THE ESF	ESF 02+68
STA. 2+82	2+86.0	233420.57	173430.69	1120.92	TARGET AT STA. 2+82R IN THE ESF	ESF 02+82
STA. 3+15	3+15.2	233434.63	173405.08	1120.49	TARGET AT STA. 3+15R IN THE ESF	ESF 03+15
STA. 30+07	30+06.3	233886.22	171299.82	1069.79	TARGET AT STA. 30+07R IN THE ESF	ESF-11-30+06
STA. 31+26	31+26.8	233765.87	171293.37	1071.54	TARGET AT STA. 31+26R IN THE ESF	ESF 31+26

Source: DTN: MO0706SASWPHII.000 [DIRS 183299].



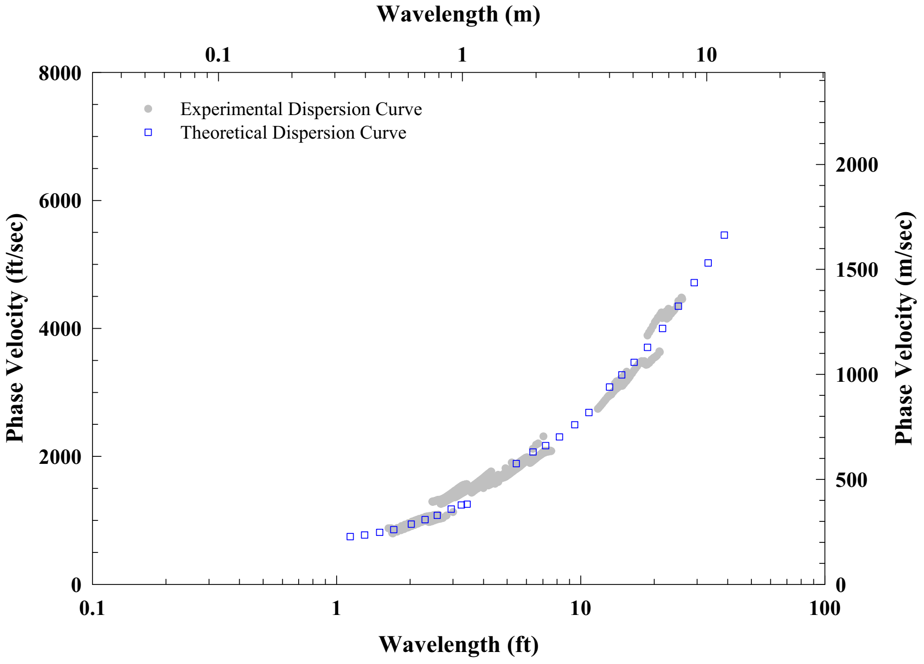
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-1. Shear Wave Velocity Profile Determined at ESF 1-74+00



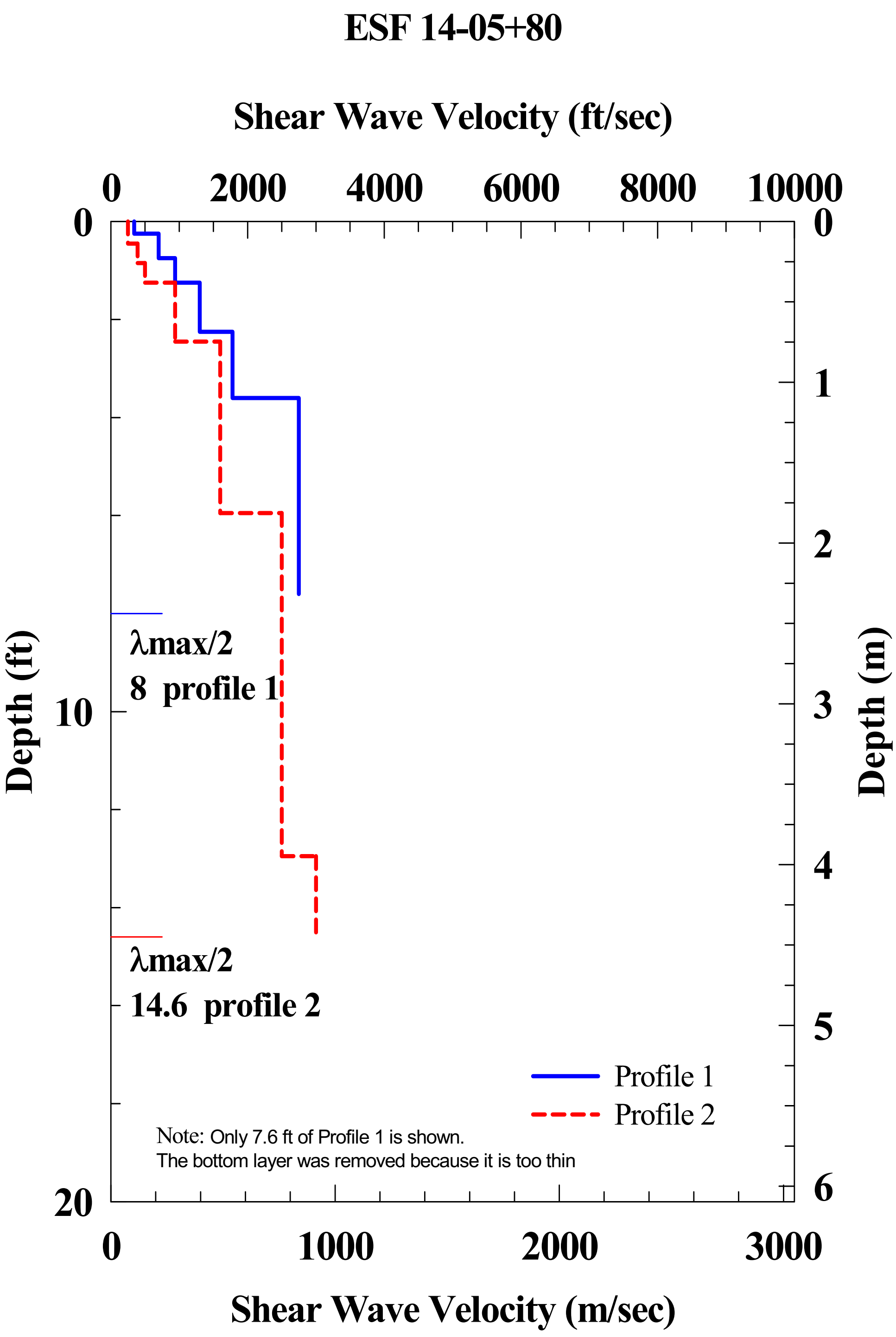
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-2. Experimental and Theoretical Dispersion Curves from ESF 1-74+00; Linear Wavelength Axis



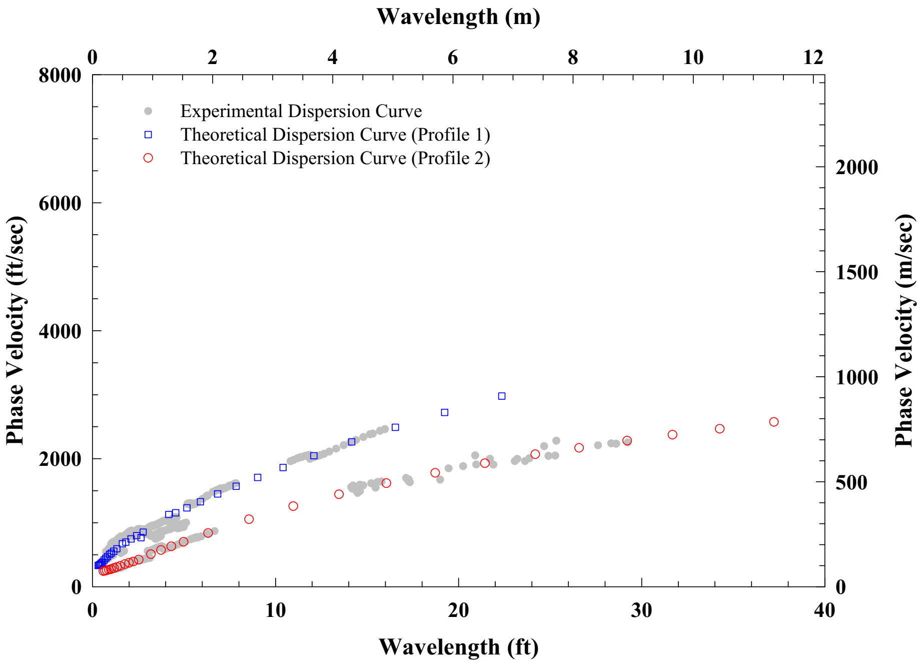
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-3. Experimental and Theoretical Dispersion Curves from ESF 1-74+00; Logarithmic Wavelength Axis



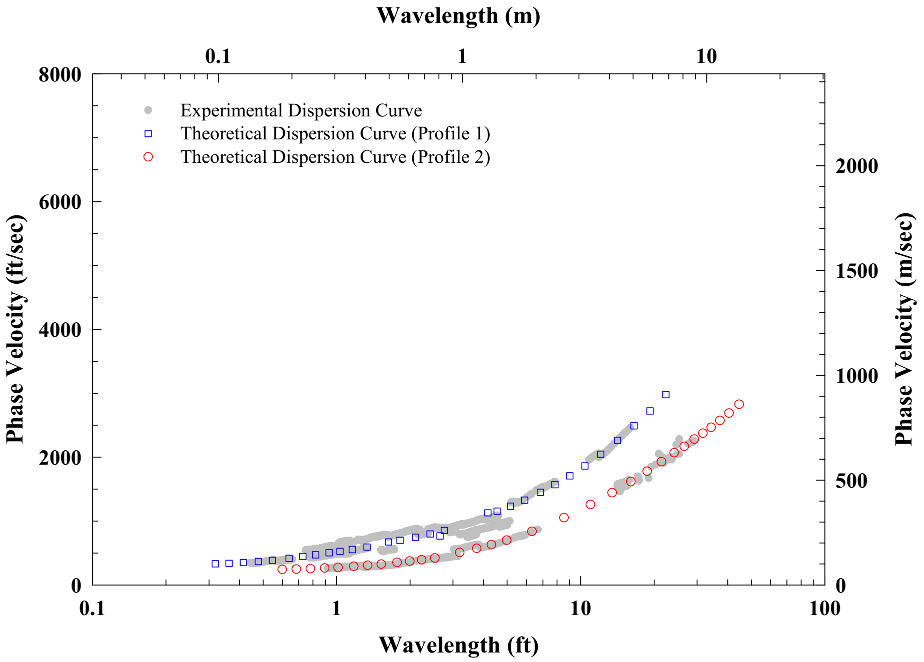
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-4. Shear Wave Velocity Profile Determined at ESF-14-05+80



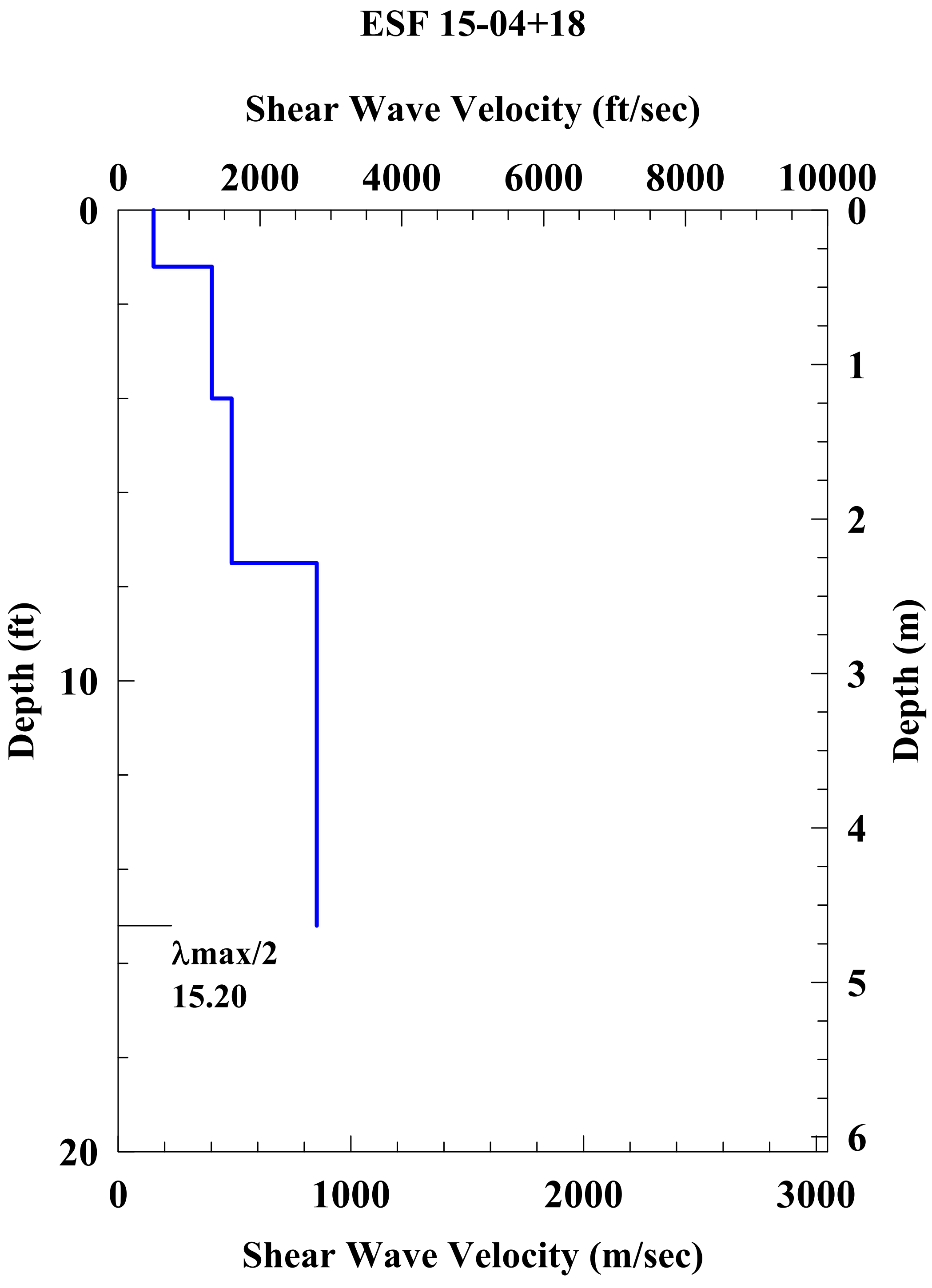
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-5. Experimental and Theoretical Dispersion Curves from ESF-14-05+80; Linear Wavelength Axis



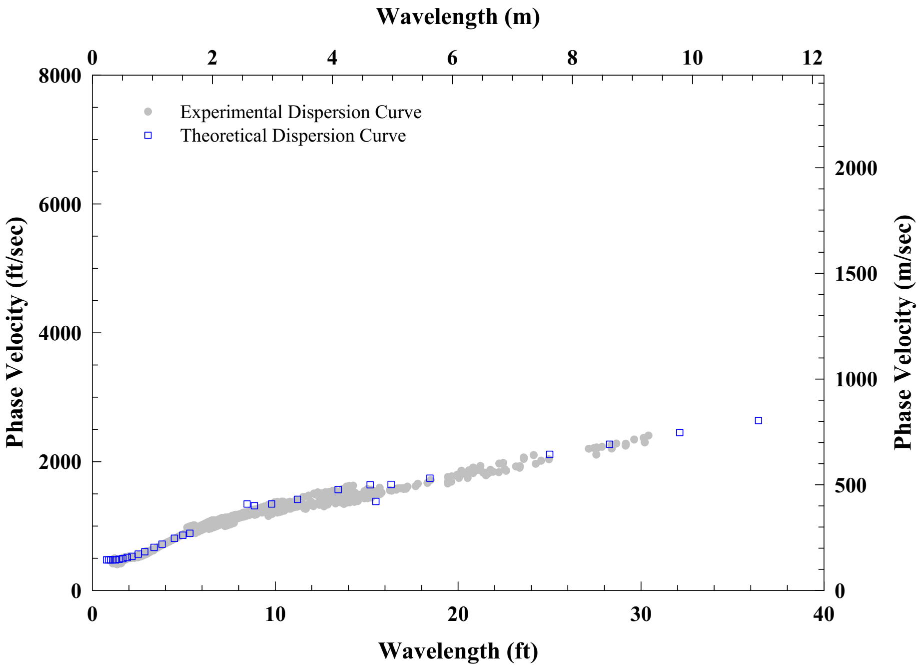
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-6. Experimental and Theoretical Dispersion Curves from ESF-14-05+80; Logarithmic Wavelength Axis



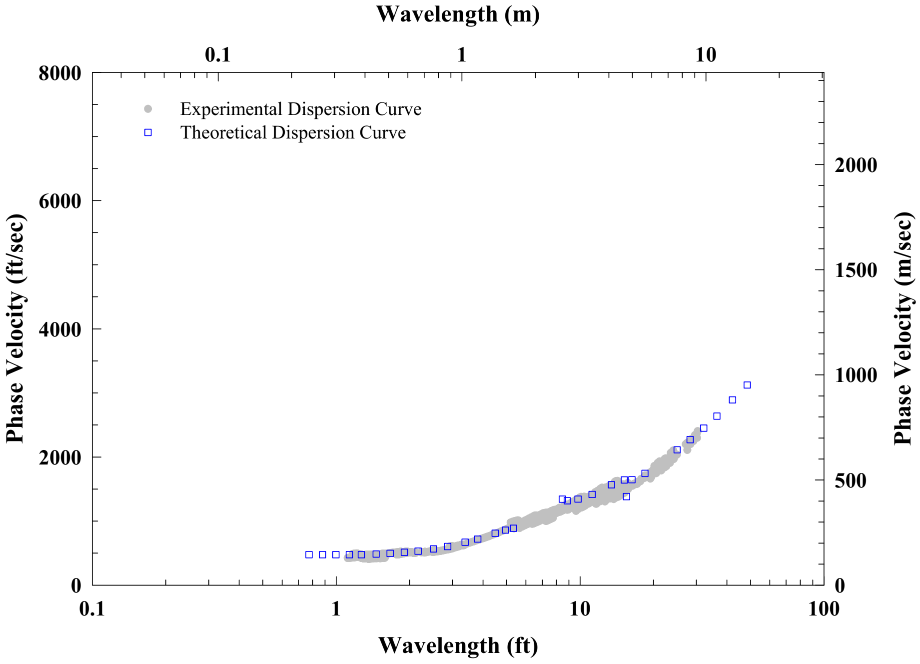
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-7. Shear Wave Velocity Profile Determined at ESF 15-04+18



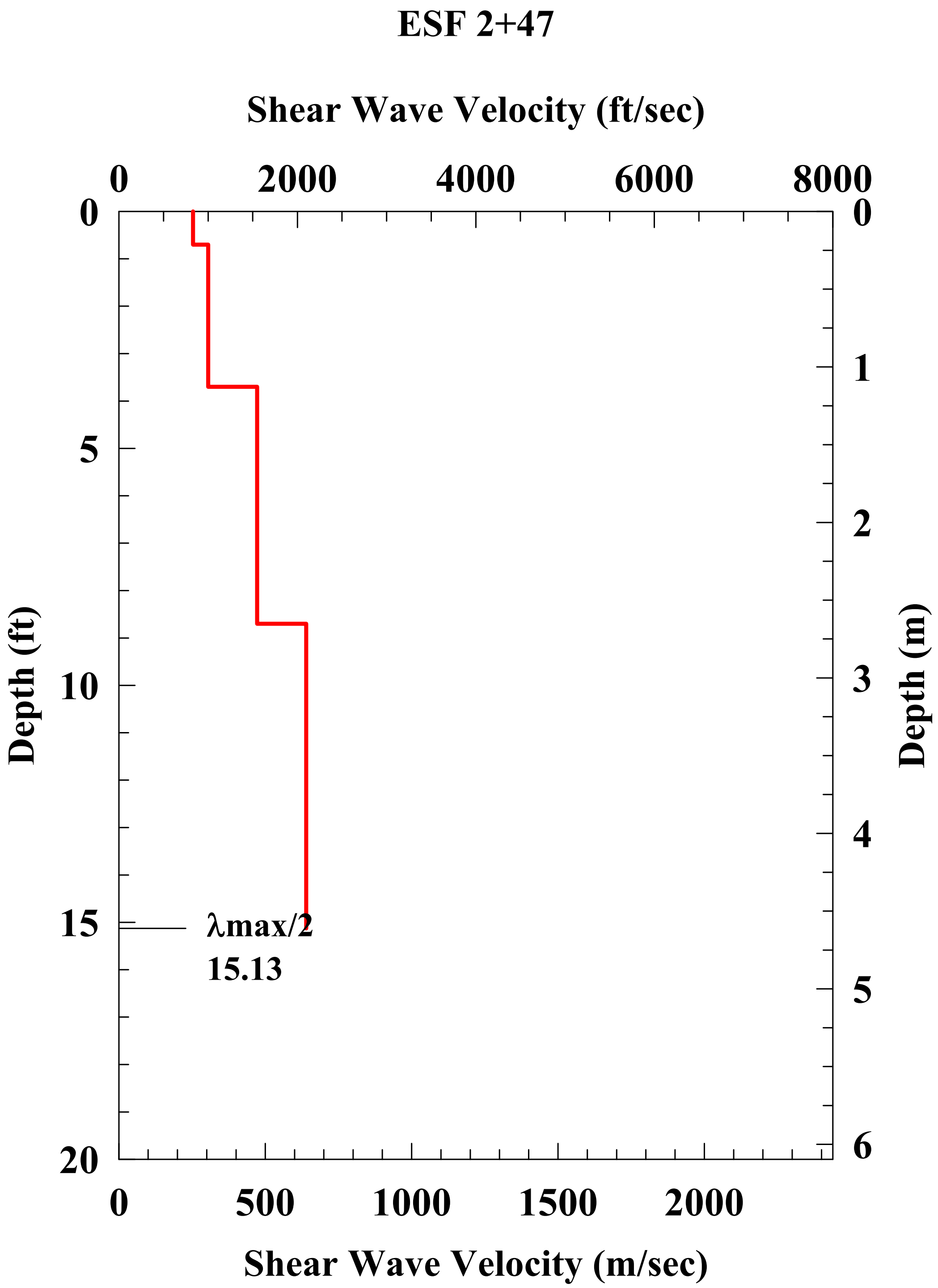
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-8. Experimental and Theoretical Dispersion Curves from ESF 15-04+18; Linear Wavelength Axis



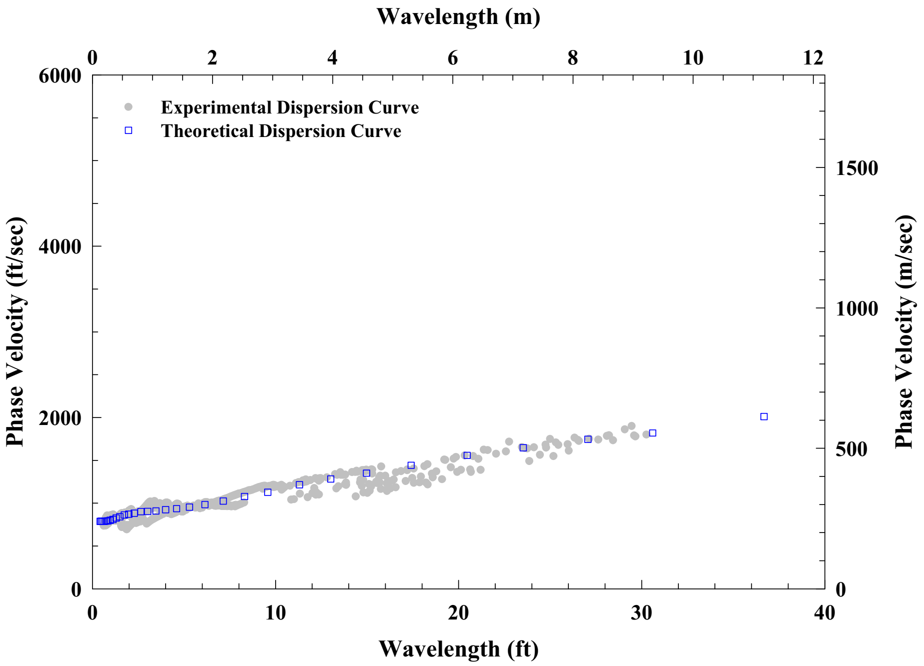
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-9. Experimental and Theoretical Dispersion Curves from ESF 15-04+18; Logarithmic Wavelength Axis



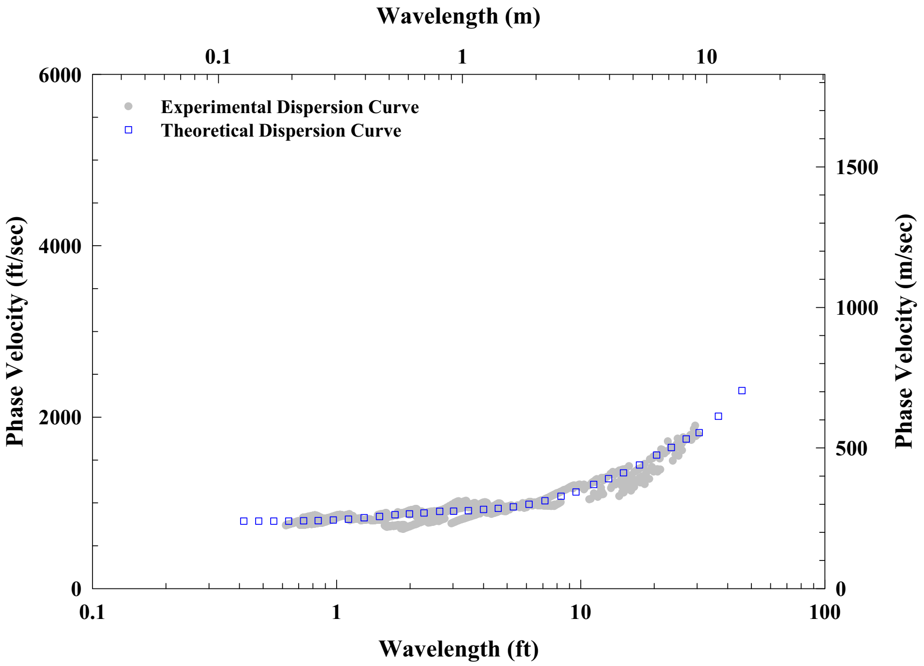
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-10. Shear Wave Velocity Profile Determined at ESF 02+47



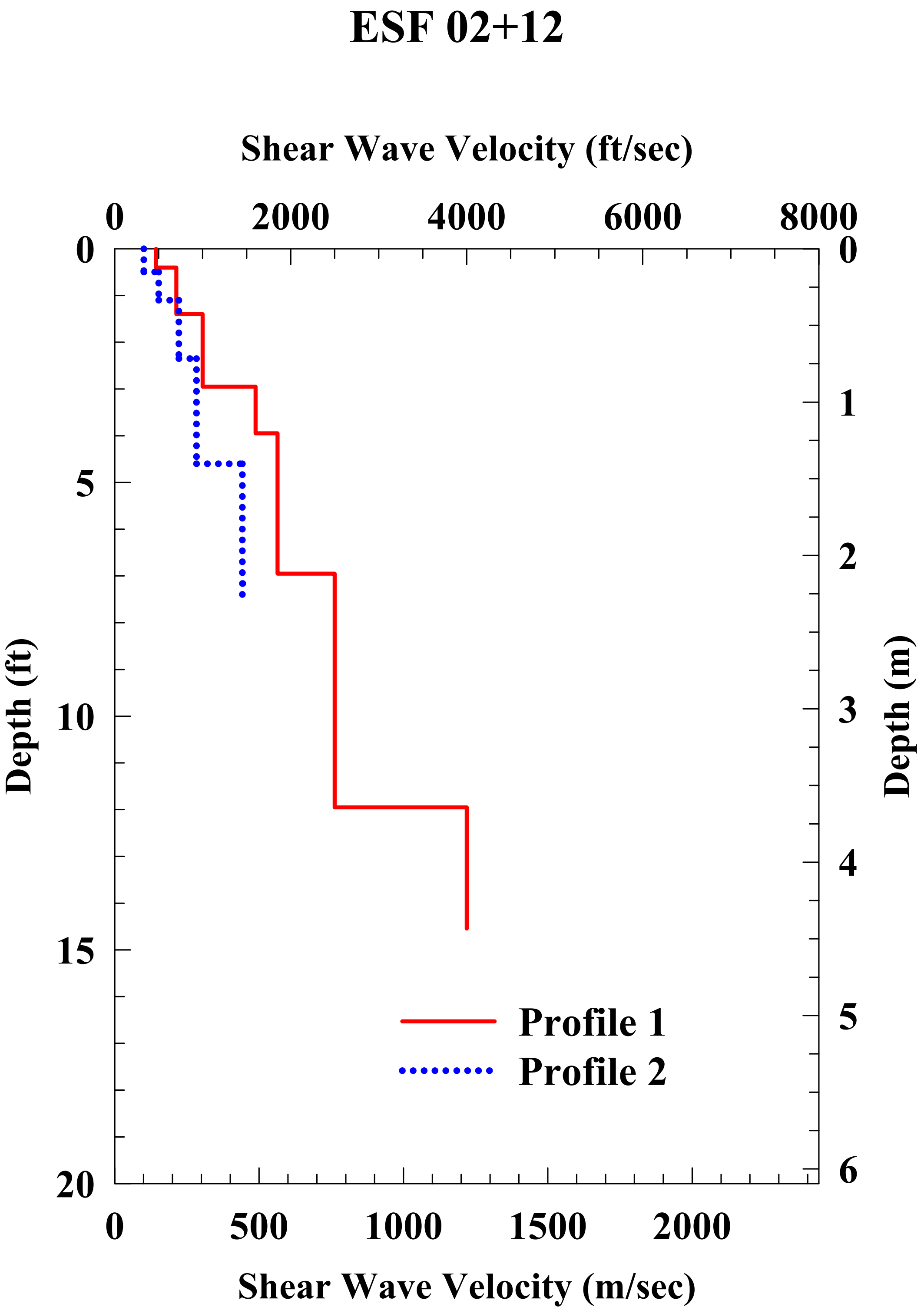
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-11. Experimental and Theoretical Dispersion Curves from ESF 02+47; Linear Wavelength Axis



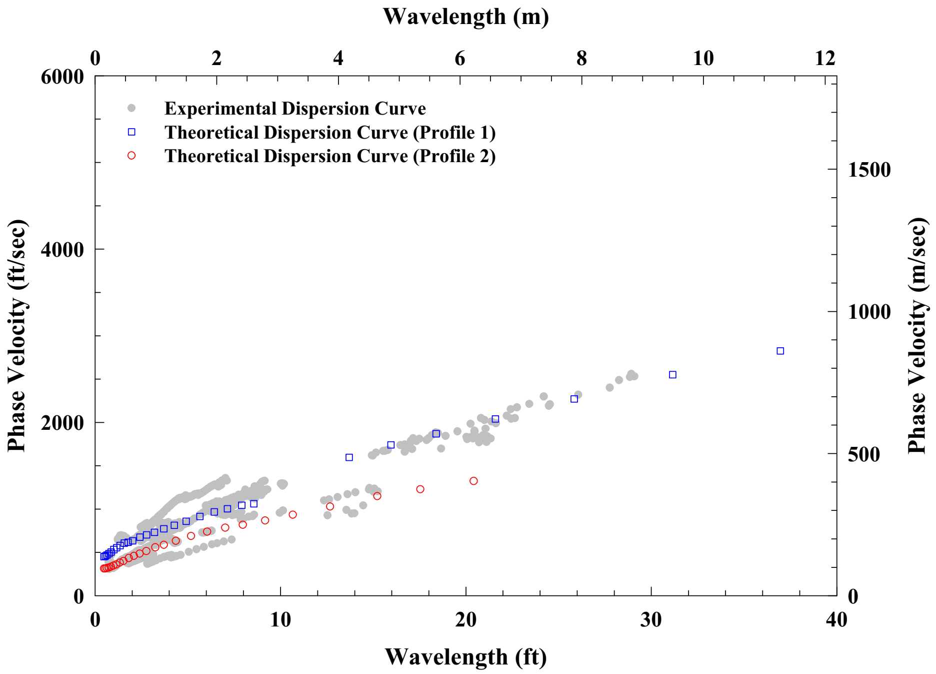
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-12. Experimental and Theoretical Dispersion Curves from ESF 02+47; Logarithmic Wavelength Axis



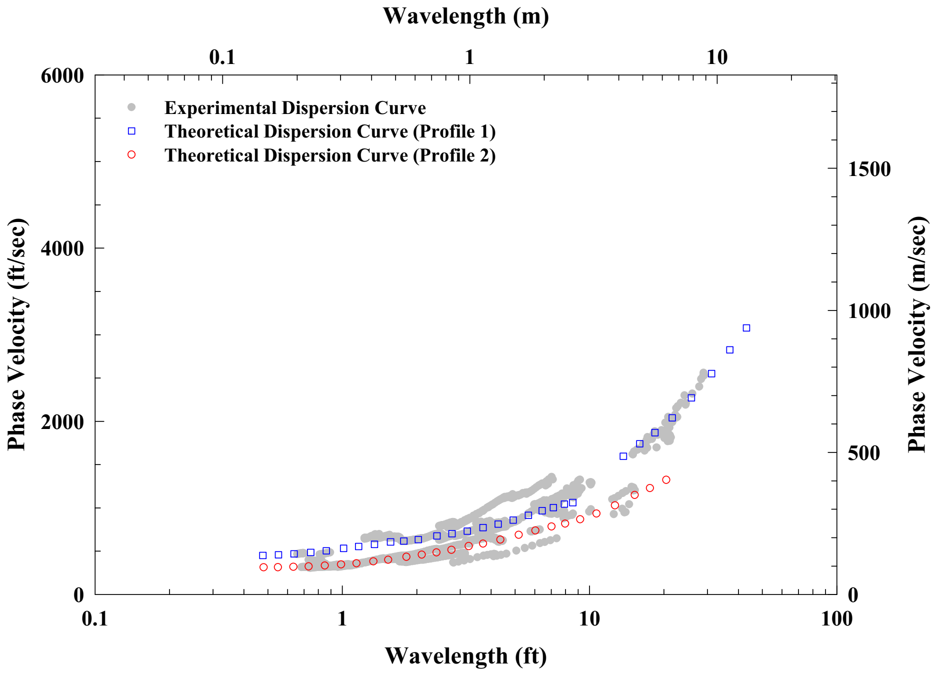
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-13. Shear Wave Velocity Profile Determined at ESF 02+12



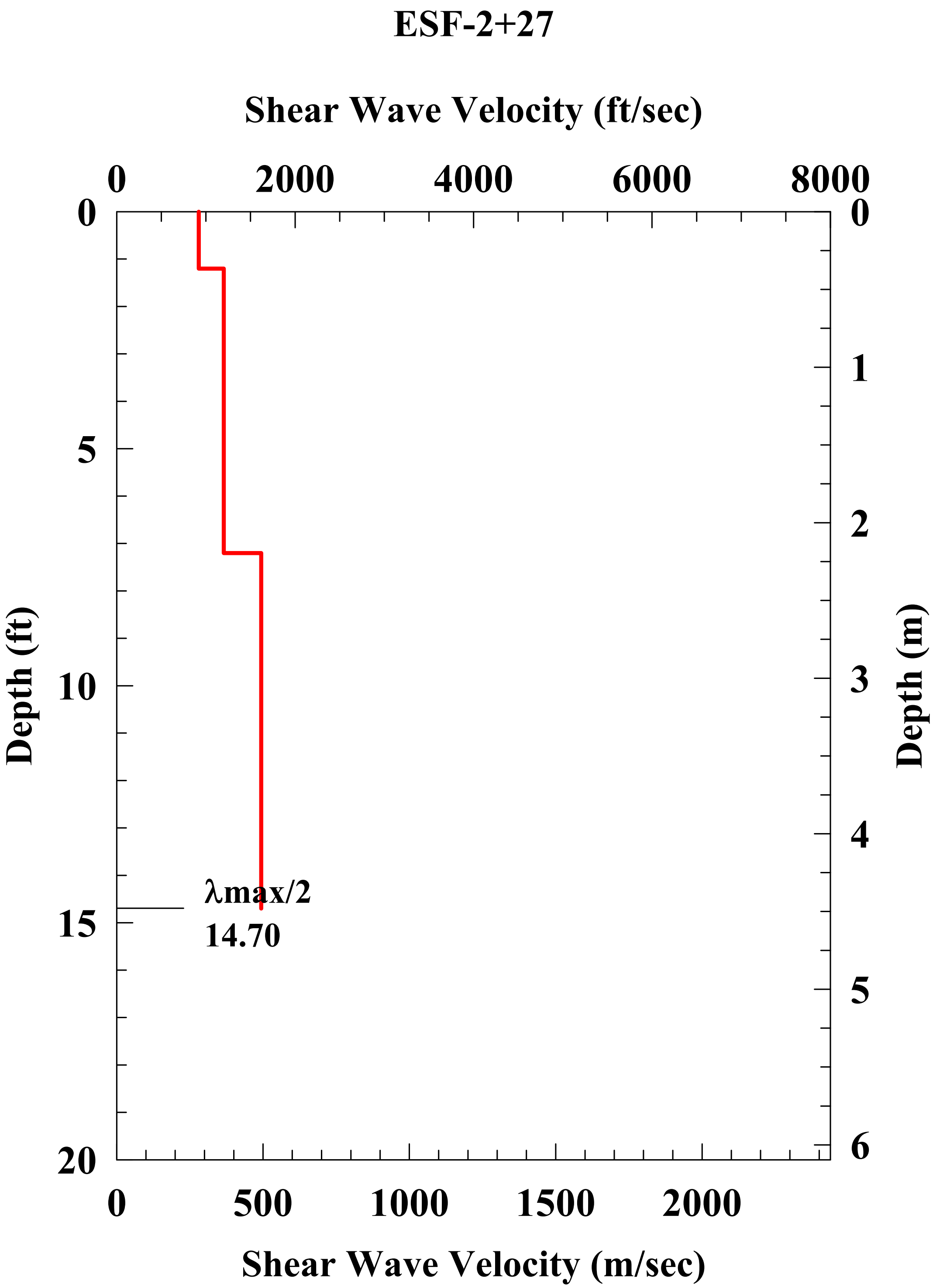
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-14. Experimental and Theoretical Dispersion Curves from ESF 02+12; Linear Wavelength Axis



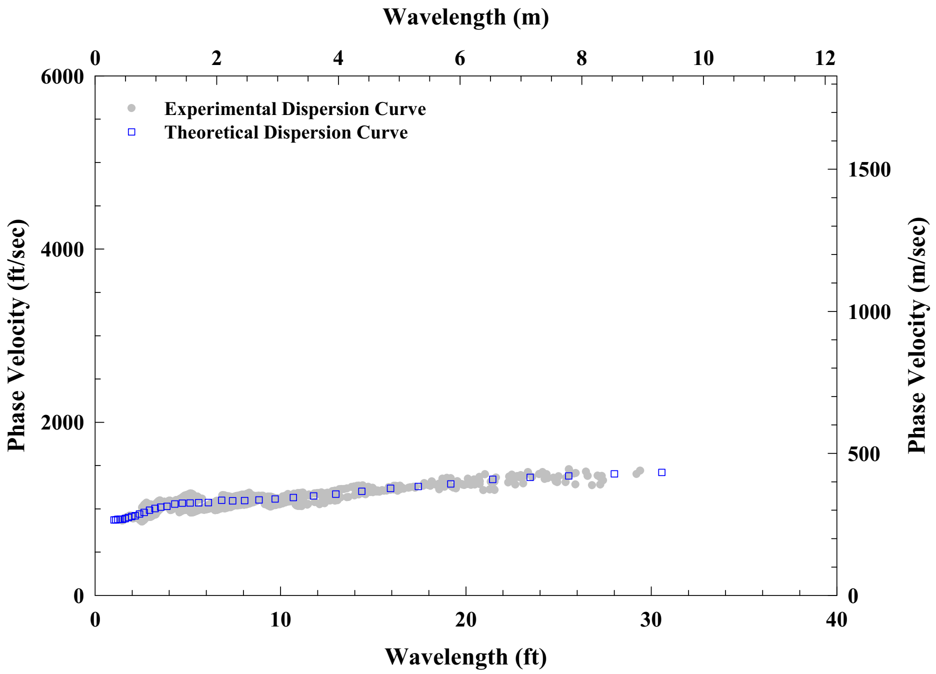
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-15. Experimental and Theoretical Dispersion Curves from ESF 02+12; Logarithmic Wavelength Axis



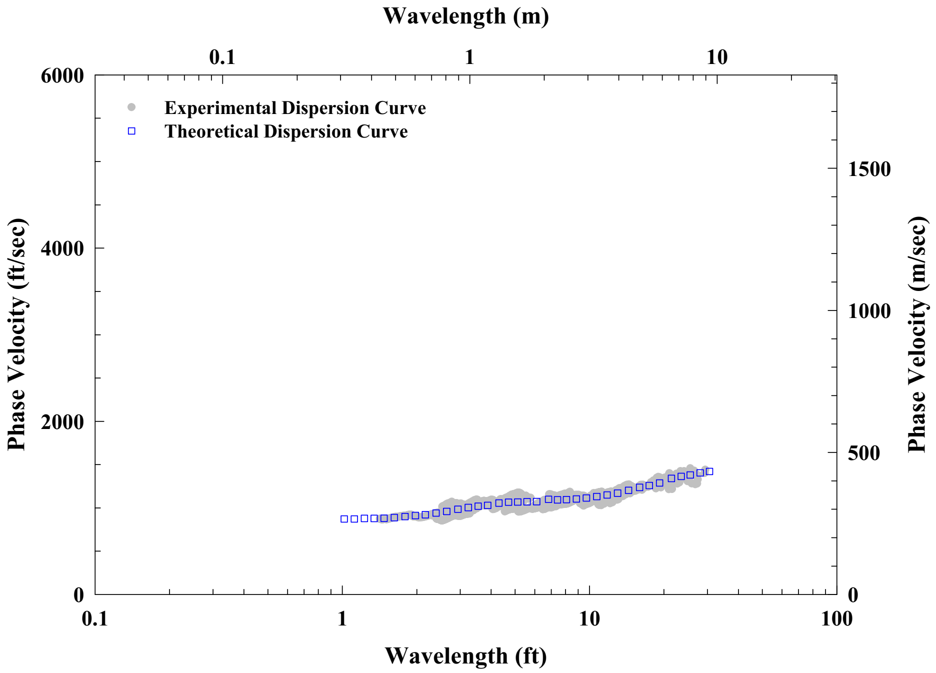
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-16. Shear Wave Velocity Profile Determined at ESF 02+27



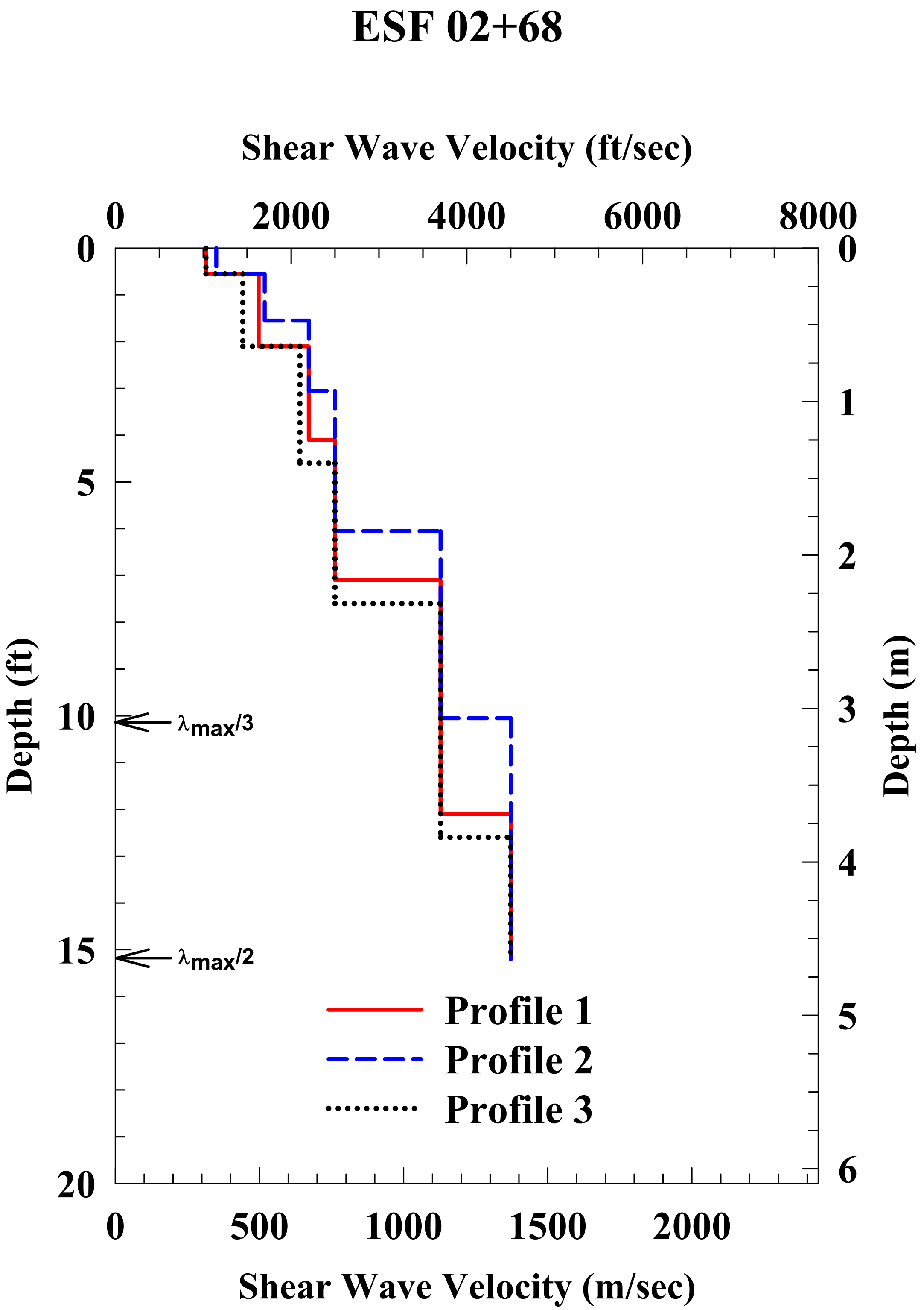
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-17. Experimental and Theoretical Dispersion Curves from ESF 02+27; Linear Wavelength Axis



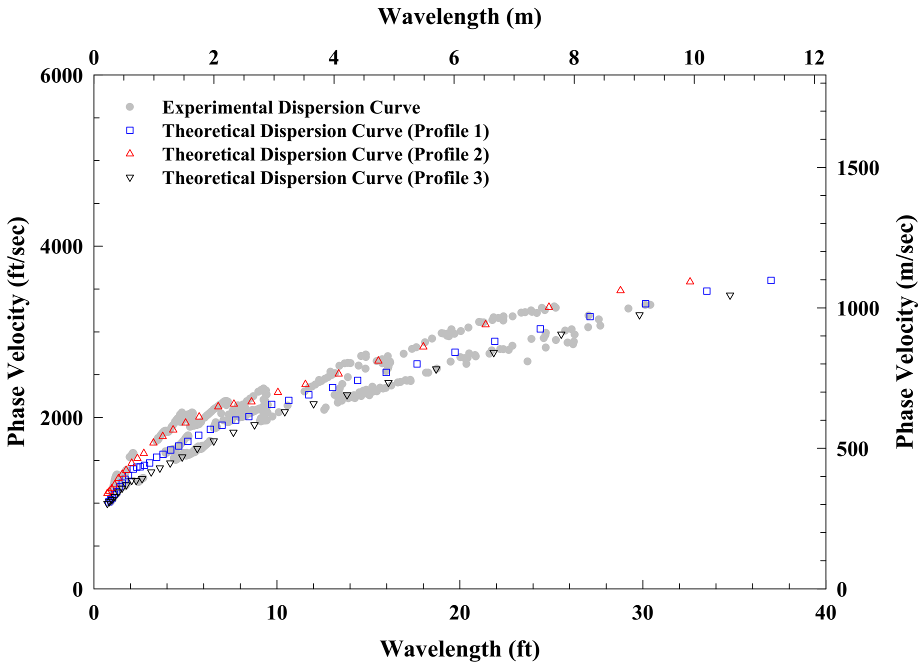
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-18. Experimental and Theoretical Dispersion Curves from ESF 02+27; Logarithmic Wavelength Axis



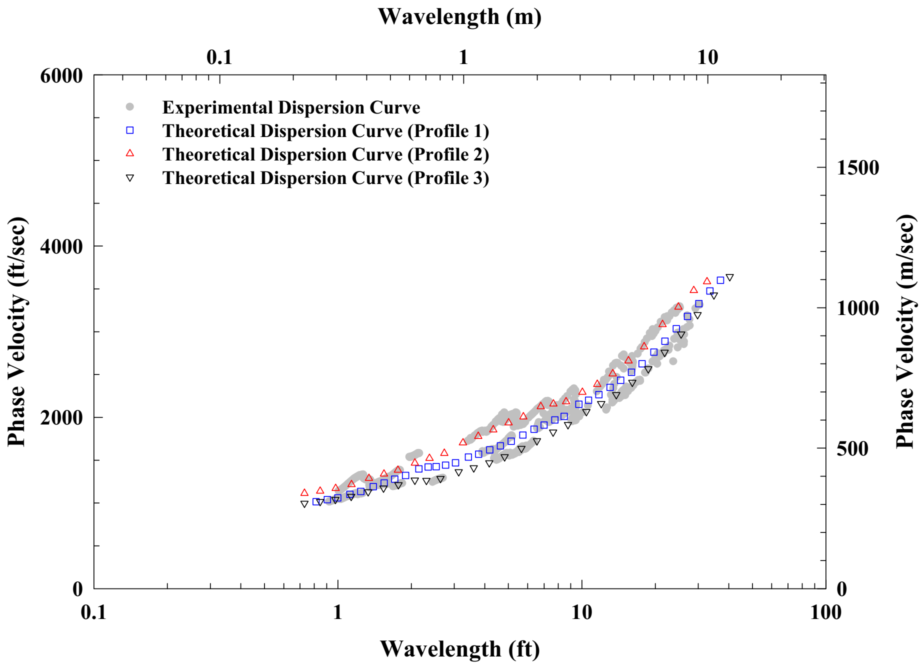
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-19. Shear Wave Velocity Profile Determined at ESF 02+68



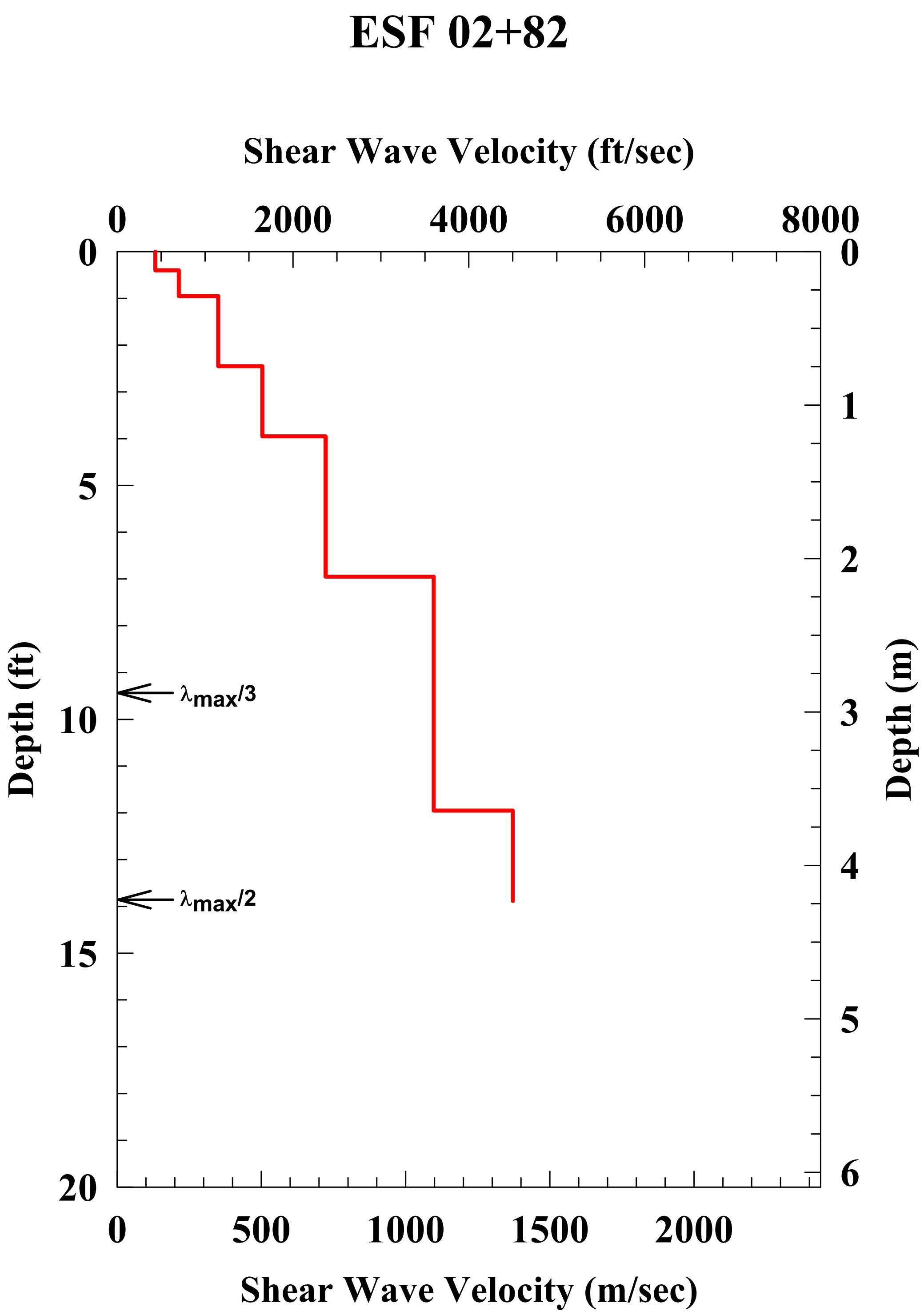
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-20. Experimental and Theoretical Dispersion Curves from ESF 02+68; Linear Wavelength Axis



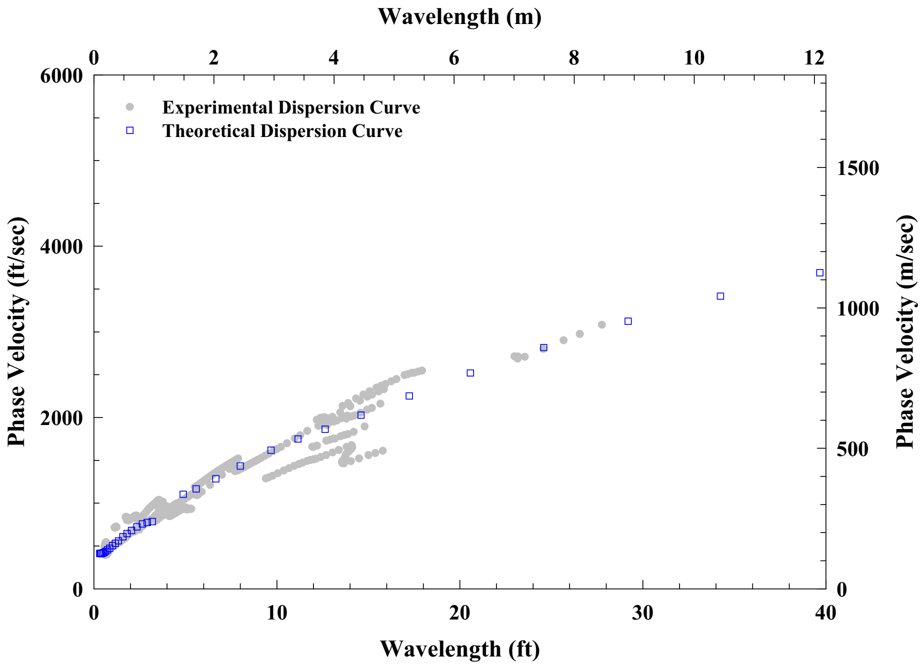
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-21. Experimental and Theoretical Dispersion Curves from ESF 02+68; Logarithmic Wavelength Axis



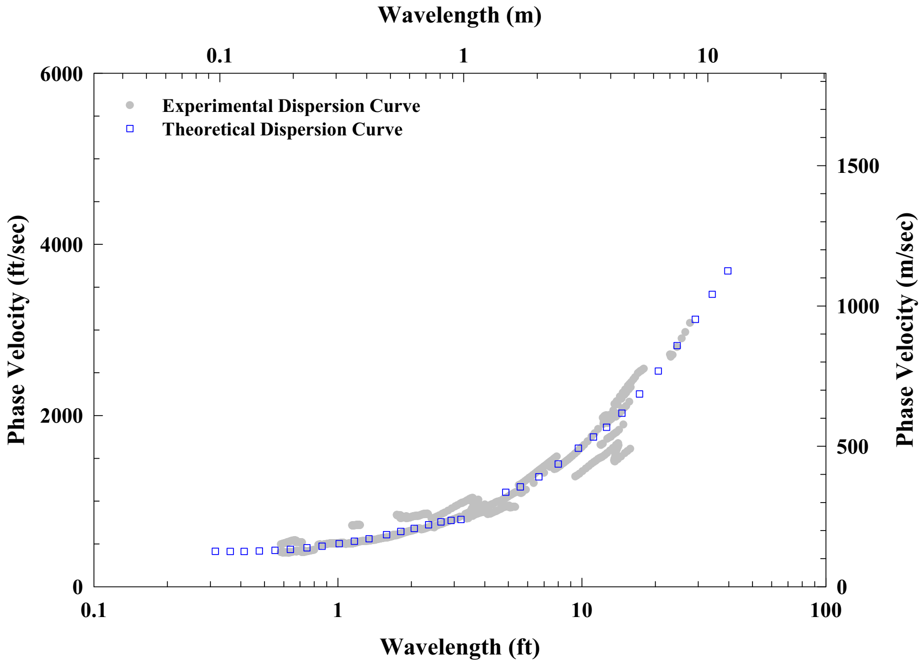
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-22. Shear Wave Velocity Profile Determined at ESF 02+82



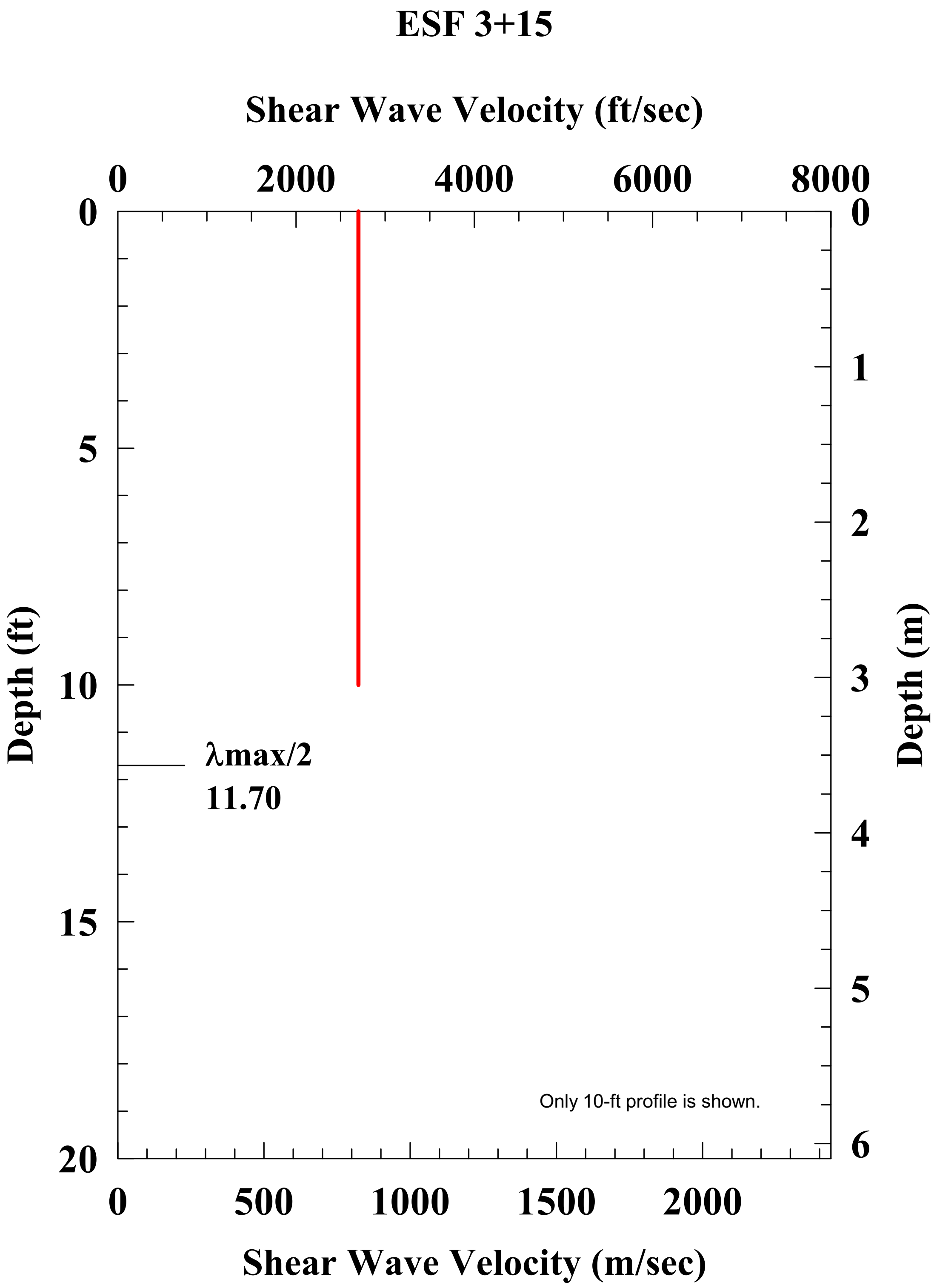
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-23. Experimental and Theoretical Dispersion Curves from ESF 02+82; Linear Wavelength Axis



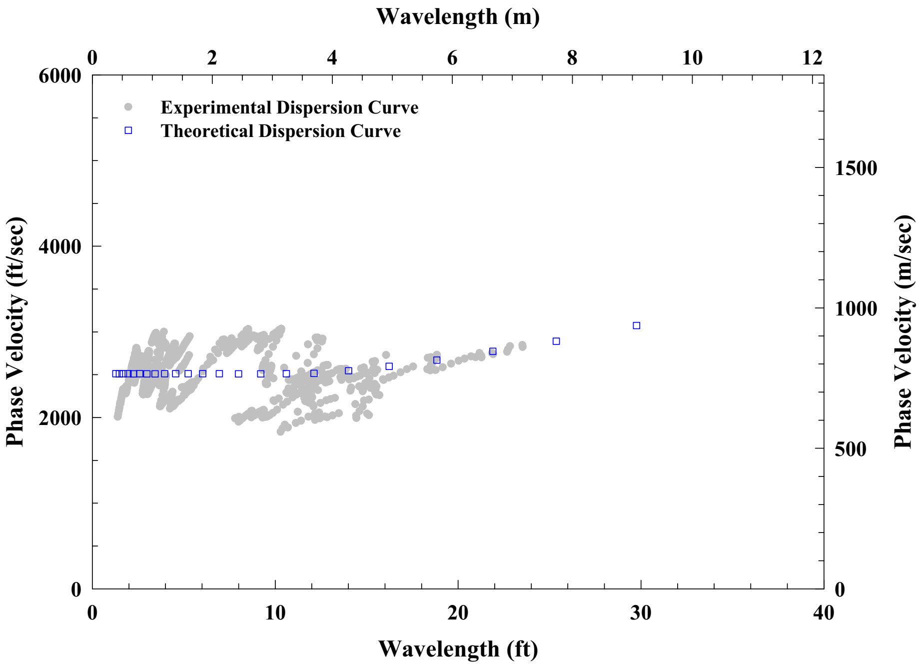
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-24. Experimental and Theoretical Dispersion Curves from ESF 02+82; Logarithmic Wavelength Axis



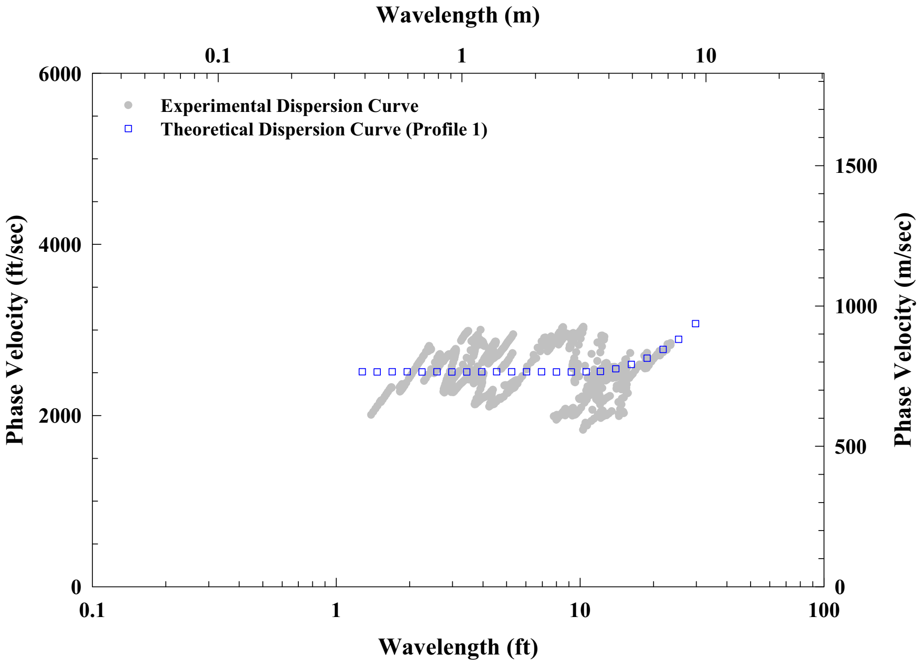
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-25. Shear Wave Velocity Profile Determined at ESF 03+15



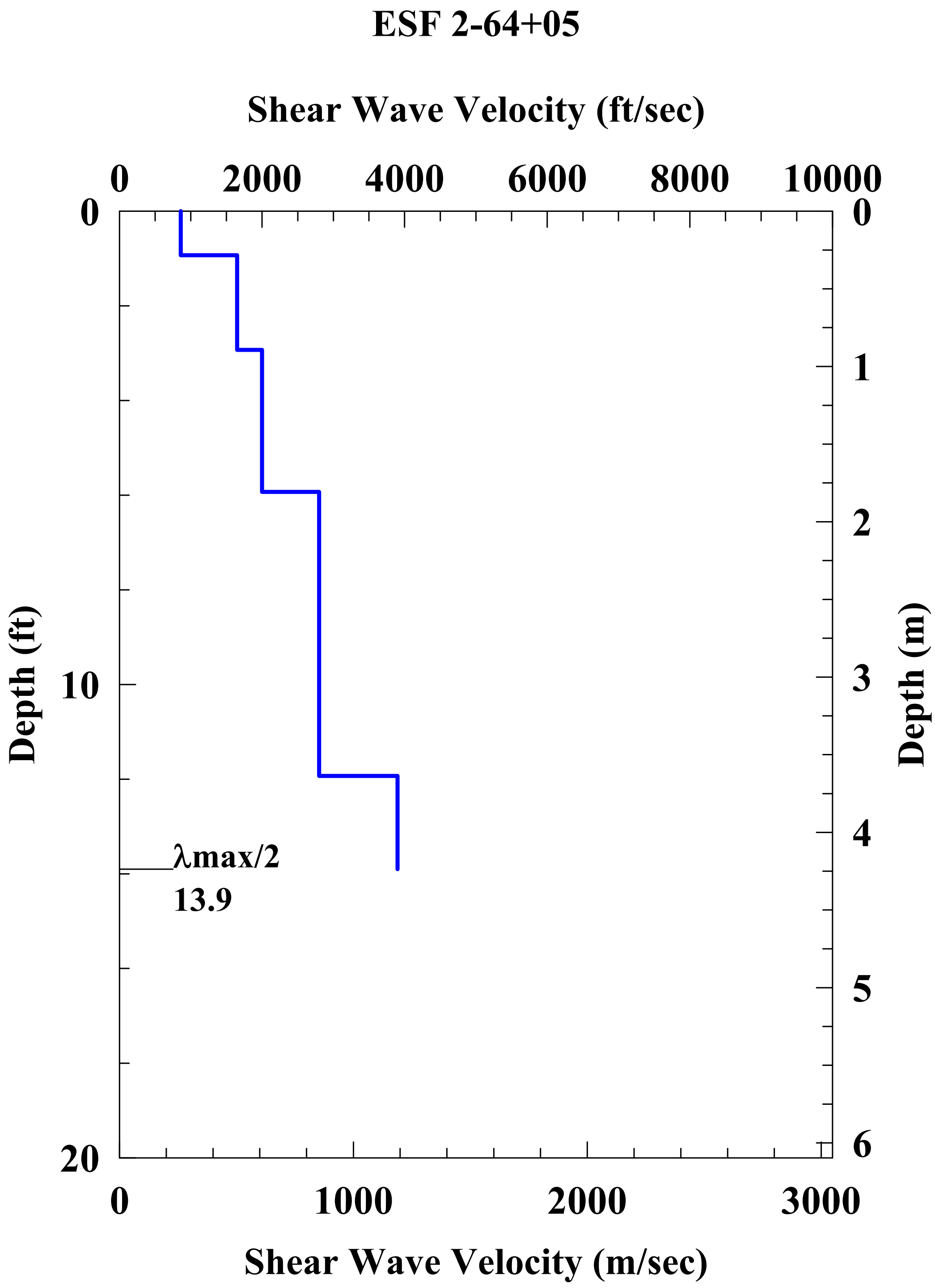
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-26. Experimental and Theoretical Dispersion Curves from ESF 03+15; Linear Wavelength Axis



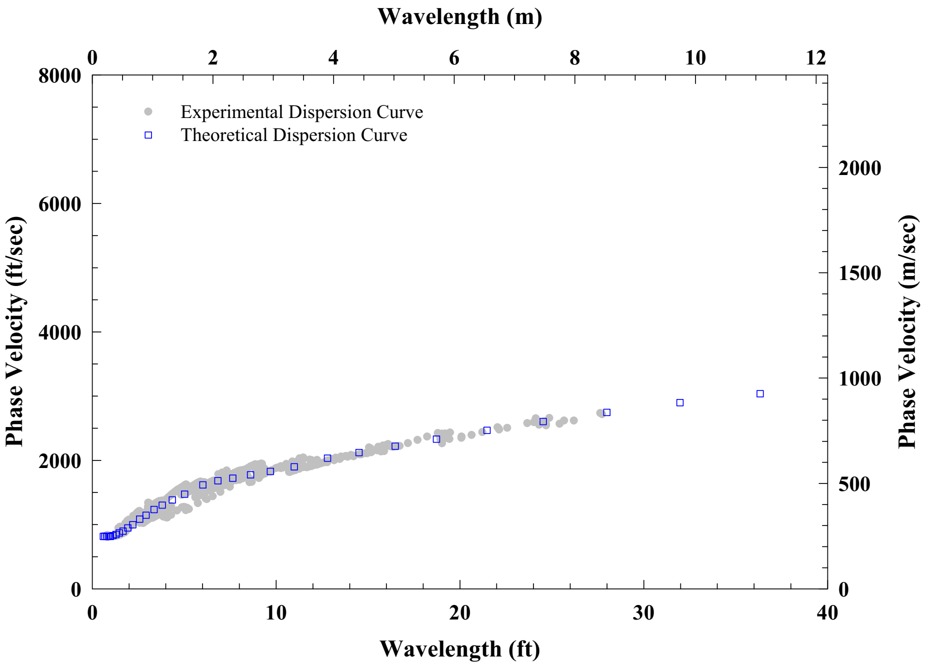
Source: DTN:MO0609SASWUTDC.004 [DIRS 183295; Stokoe 2007 [DIRS 183327].

Figure VI-27. Experimental and Theoretical Dispersion Curves from ESF 03+15; Logarithmic Wavelength Axis



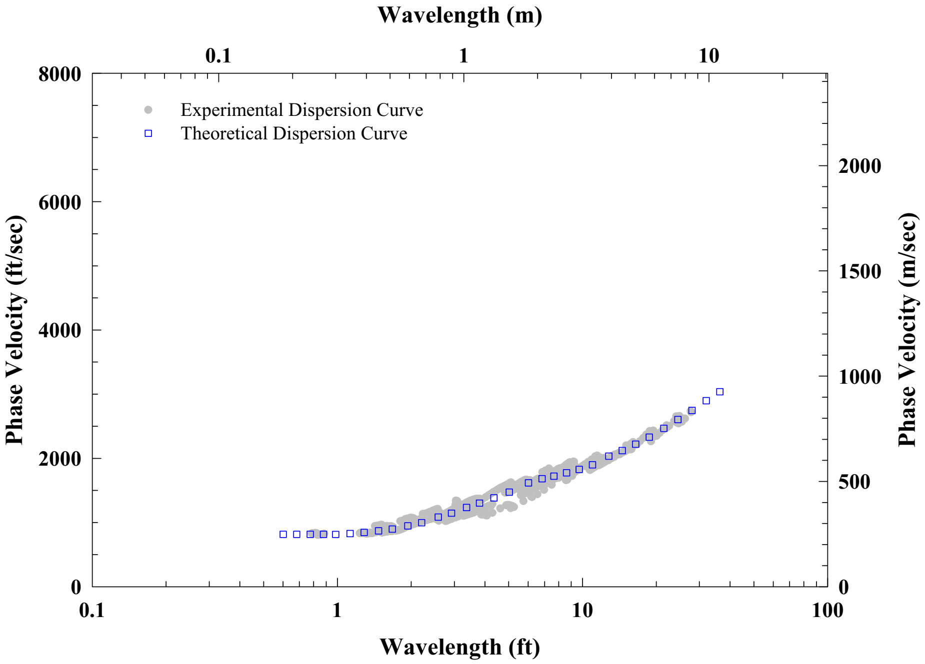
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-28. Shear Wave Velocity Profile Determined at ESF 2-64+05



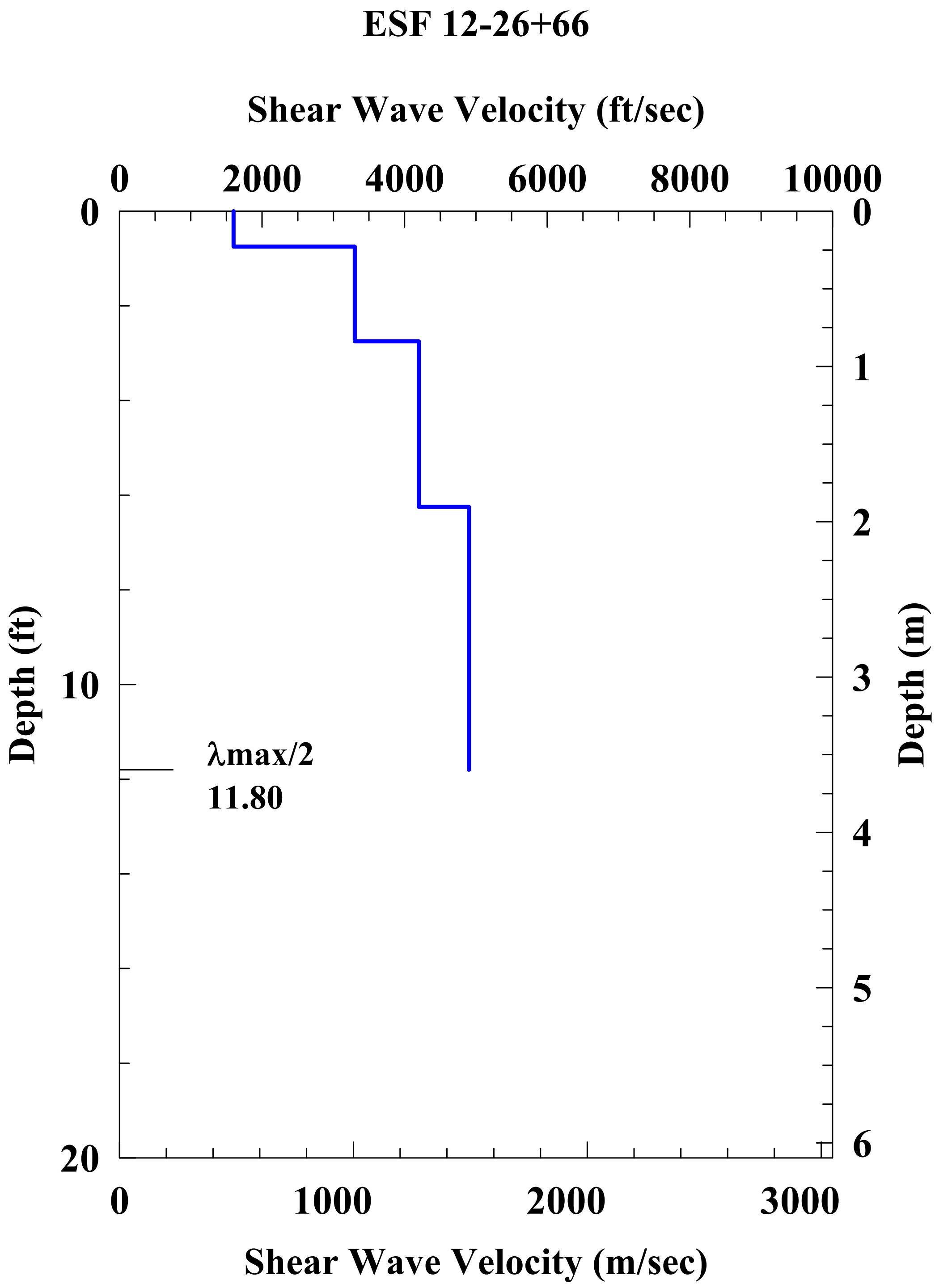
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-29. Experimental and Theoretical Dispersion Curves from ESF 2-64+05; Linear Wavelength Axis



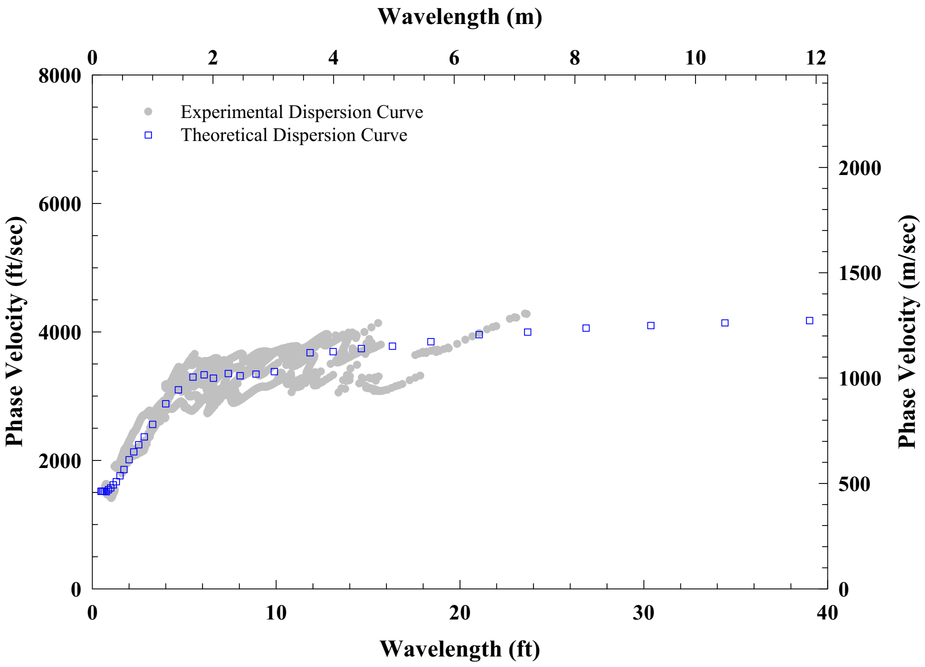
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-30. Experimental and Theoretical Dispersion Curves from ESF 2-64+05; Logarithmic Wavelength Axis



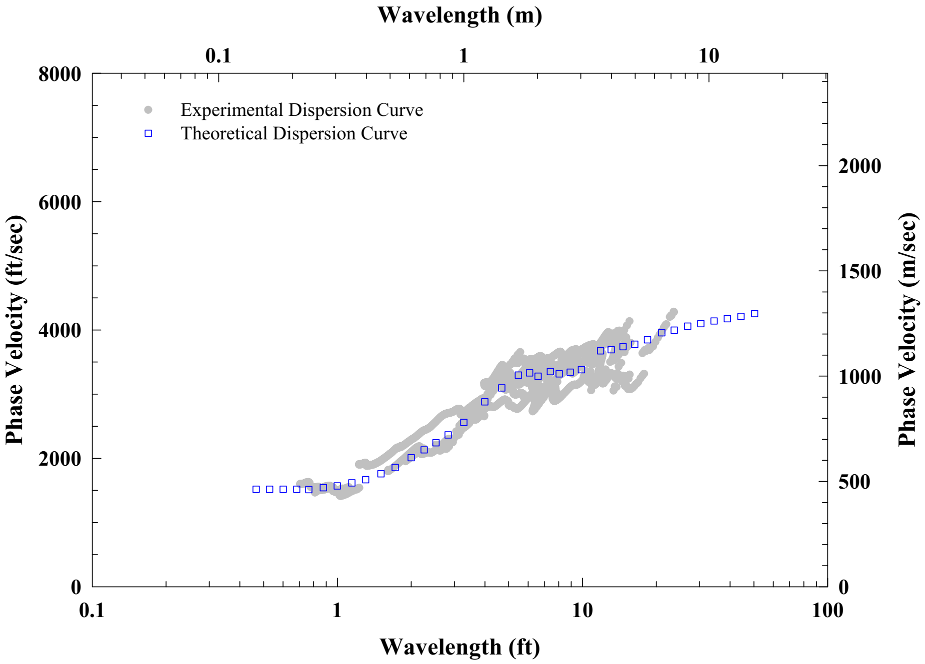
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-31. Shear Wave Velocity Profile Determined at ESF 12-26+66



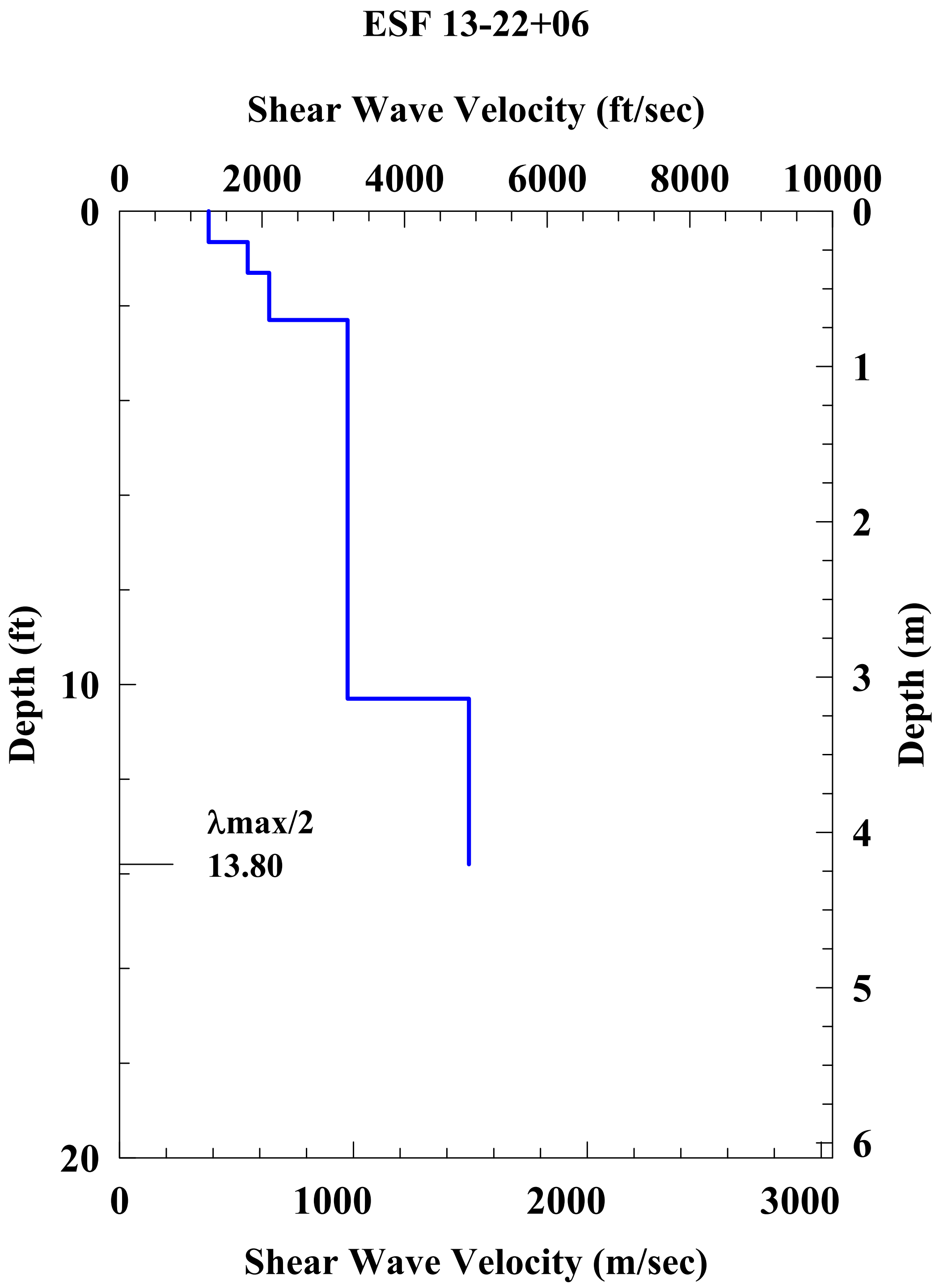
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-32. Experimental and Theoretical Dispersion Curves from ESF 12-26+66; Linear Wavelength Axis



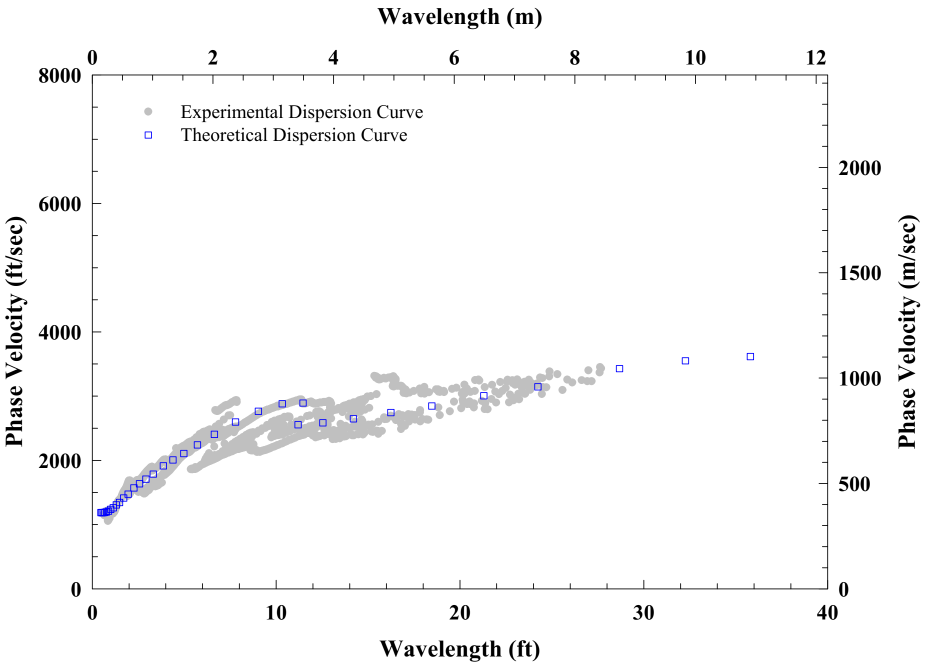
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-33. Experimental and Theoretical Dispersion Curves from ESF 12-26+66; Logarithmic Wavelength Axis



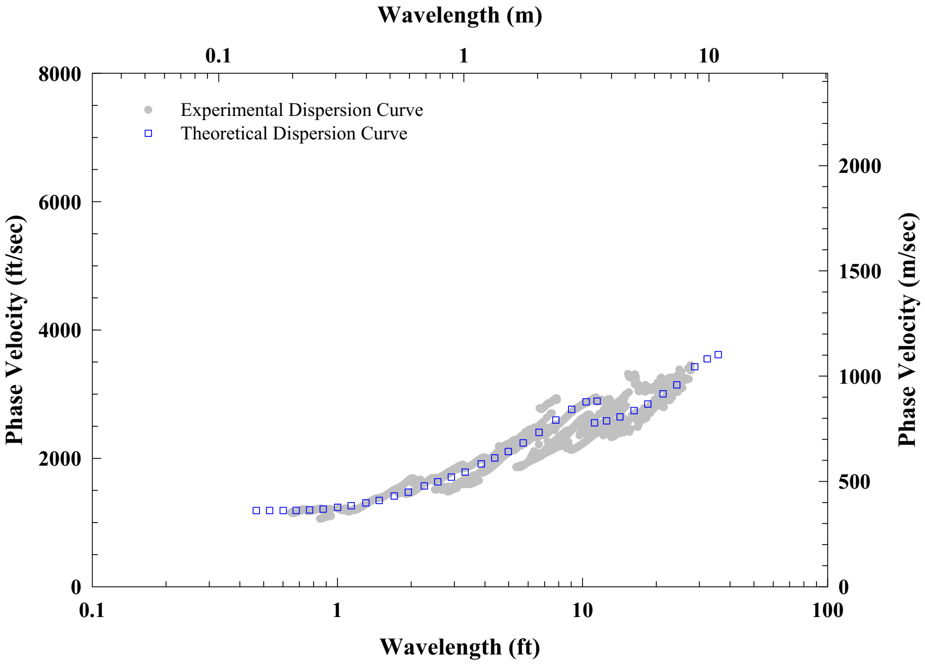
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-34. Shear Wave Velocity Profile Determined at ESF 13-22+06



Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

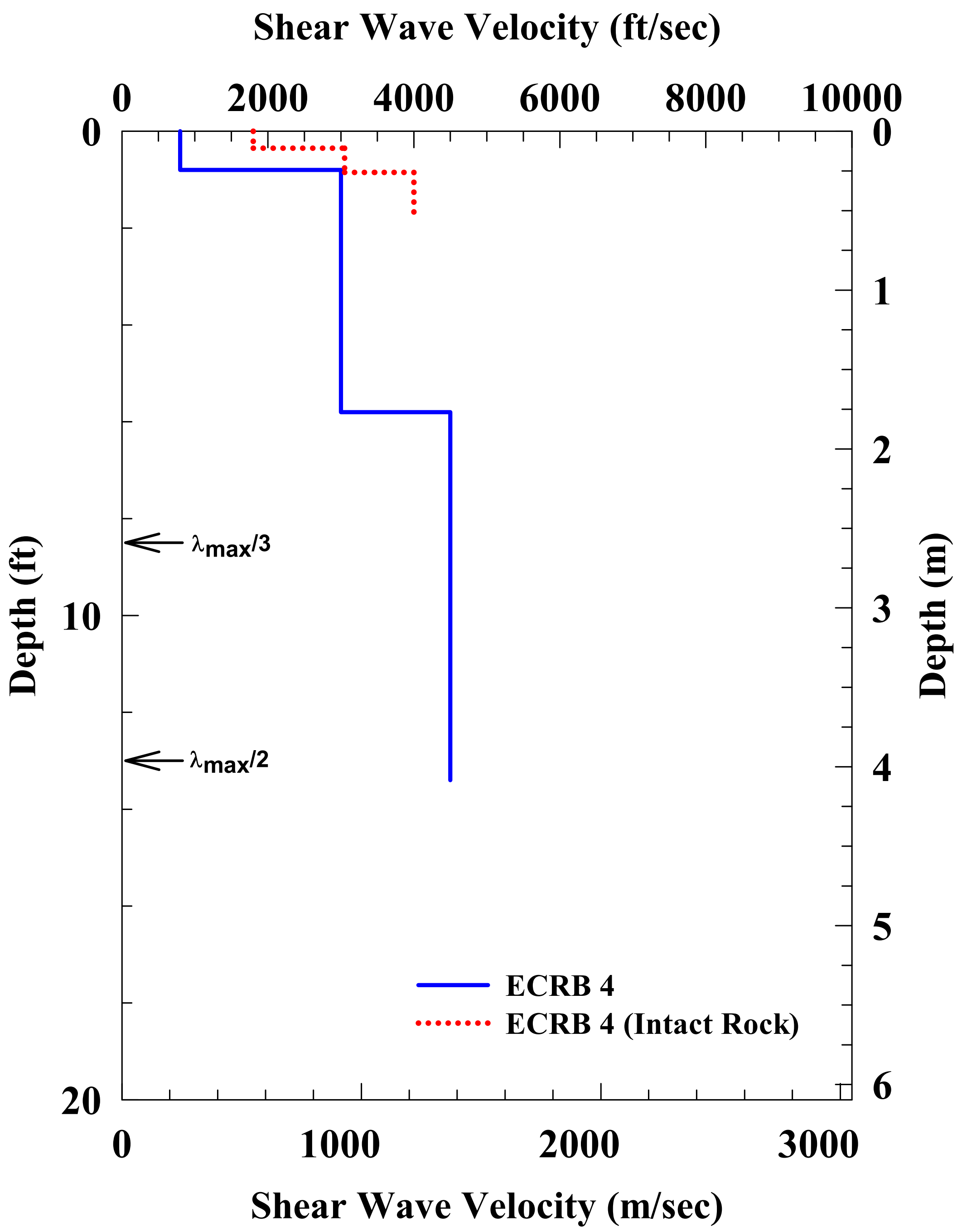
Figure VI-35. Experimental and Theoretical Dispersion Curves from ESF 13-22+06; Linear Wavelength Axis



Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

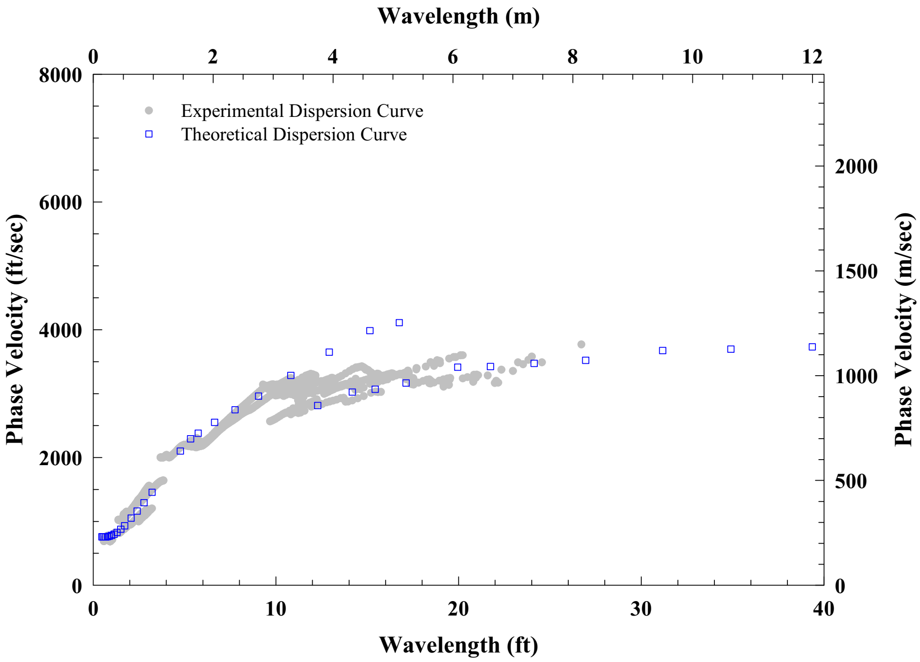
Figure VI-36. Experimental and Theoretical Dispersion Curves from ESF 13-22+06; Logarithmic Wavelength Axis

ECRB-4-09+10



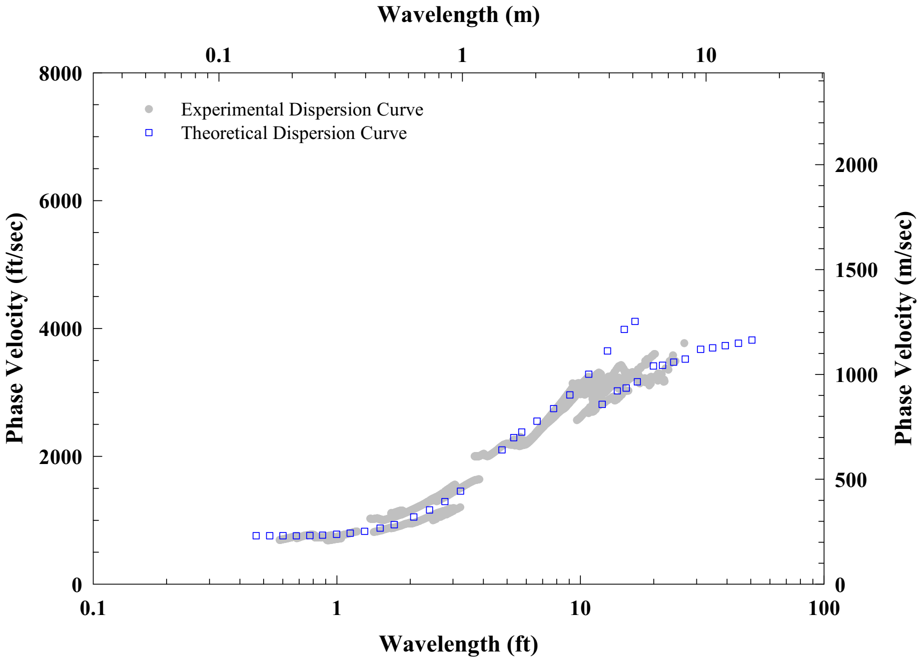
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-37. Shear Wave Velocity Profile Determined at ECRB 4-09+10



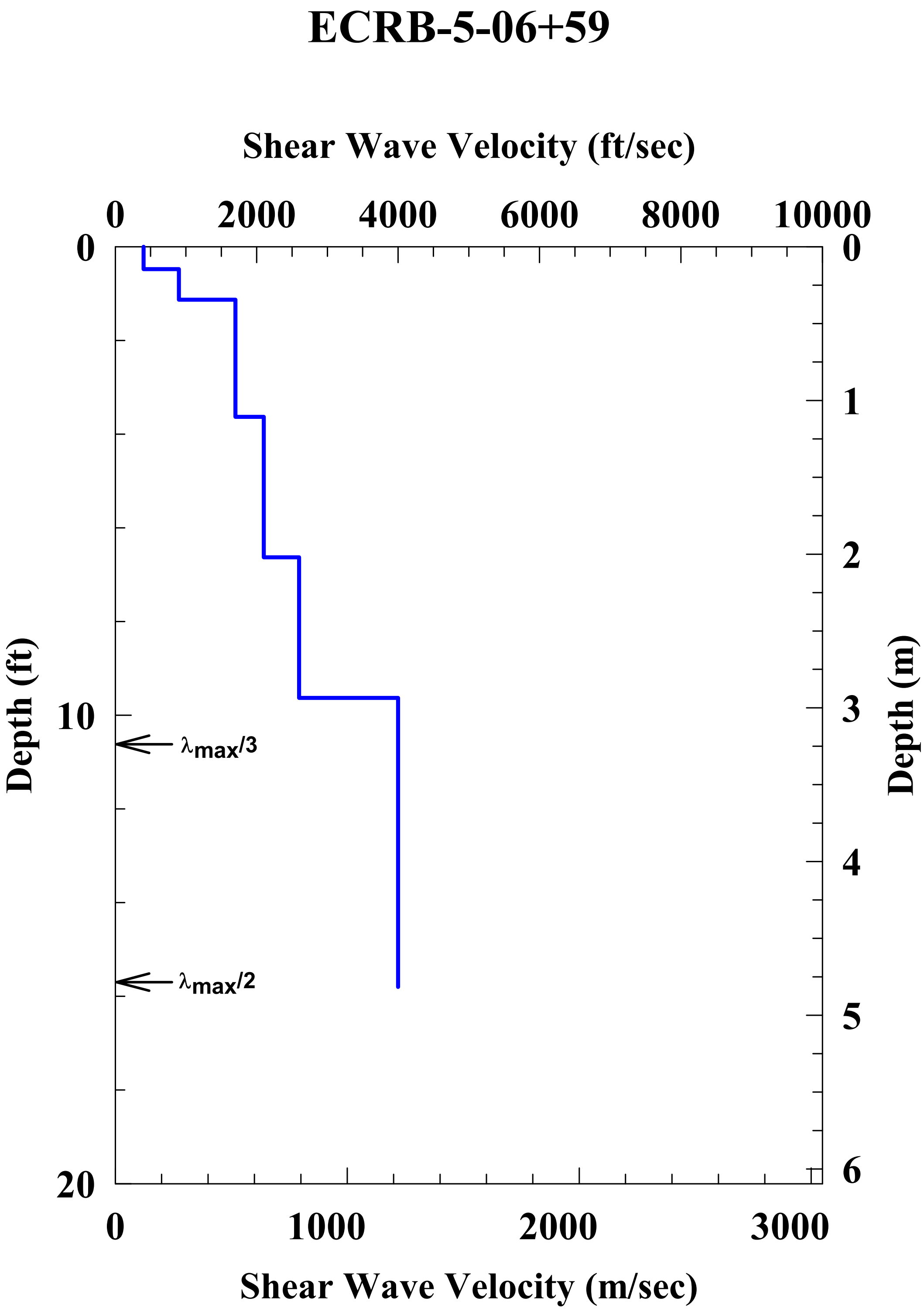
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-38. Experimental and Theoretical Dispersion Curves from ECRB 4-09+10; Linear Wavelength Axis



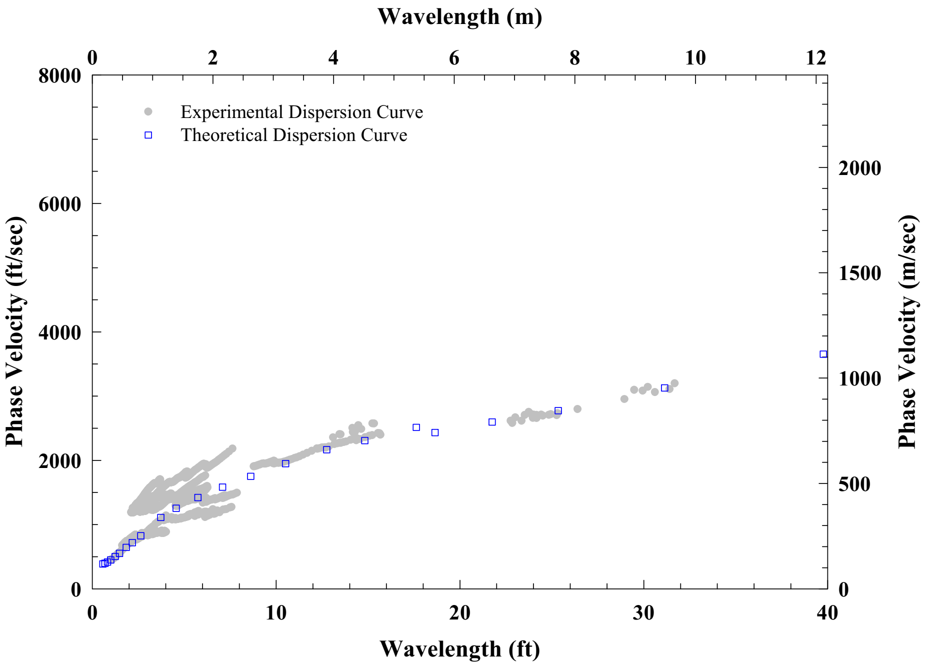
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-39. Experimental and Theoretical Dispersion Curves from ECRB 4-09+10; Logarithmic Wavelength Axis



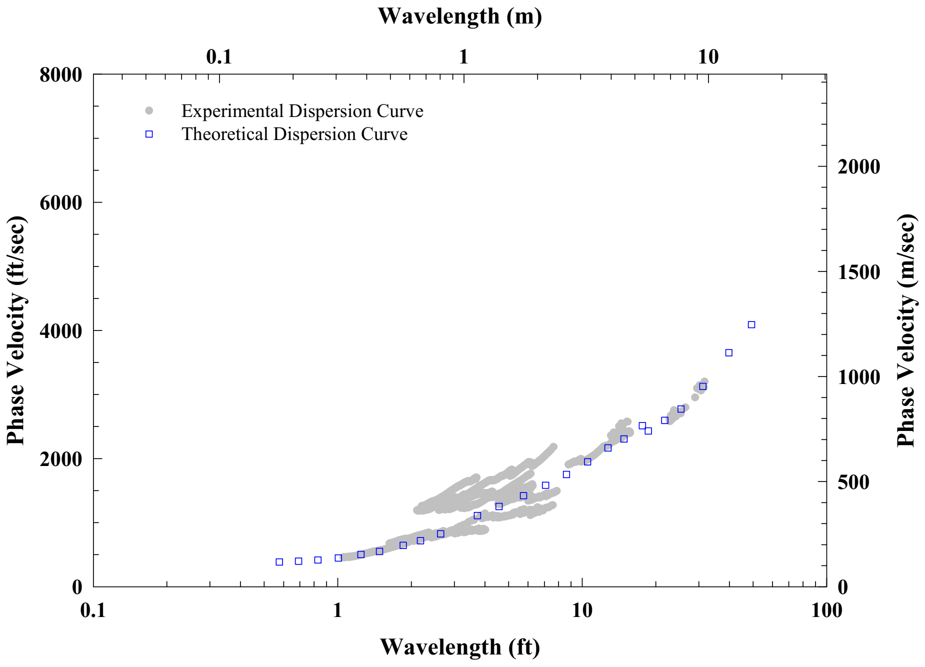
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-40. Shear Wave Velocity Profile Determined at ECRB 5-06+59



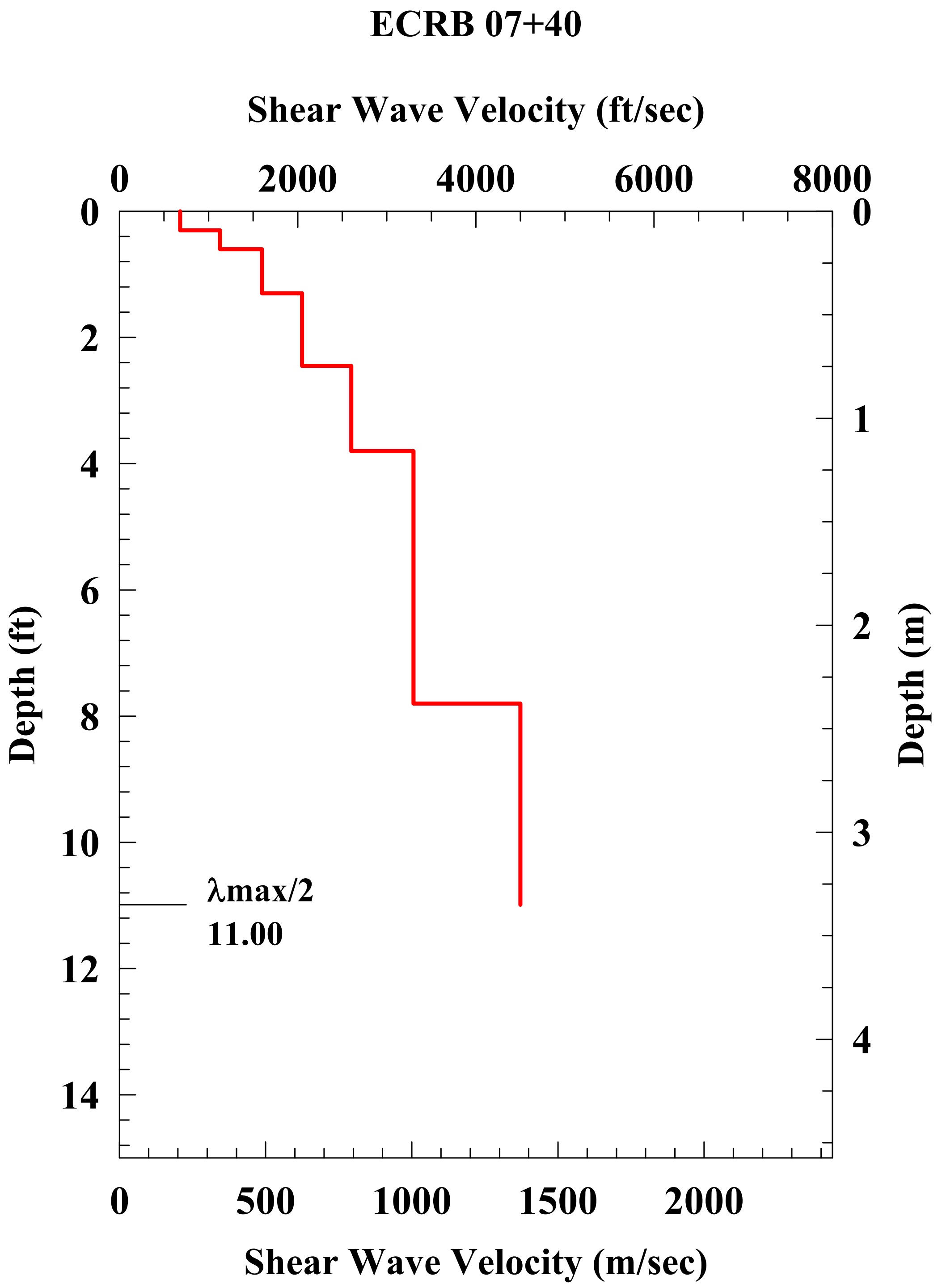
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-41. Experimental and Theoretical Dispersion Curves from ECRB 5-06+59; Linear Wavelength Axis



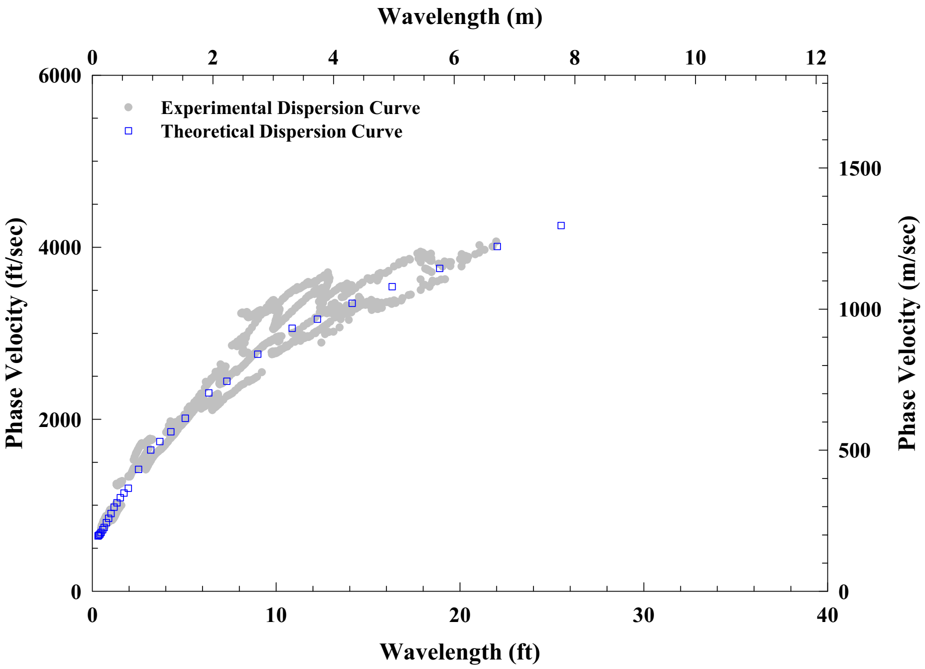
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-42. Experimental and Theoretical Dispersion Curves from ECRB 5-06+59; Logarithmic Wavelength Axis



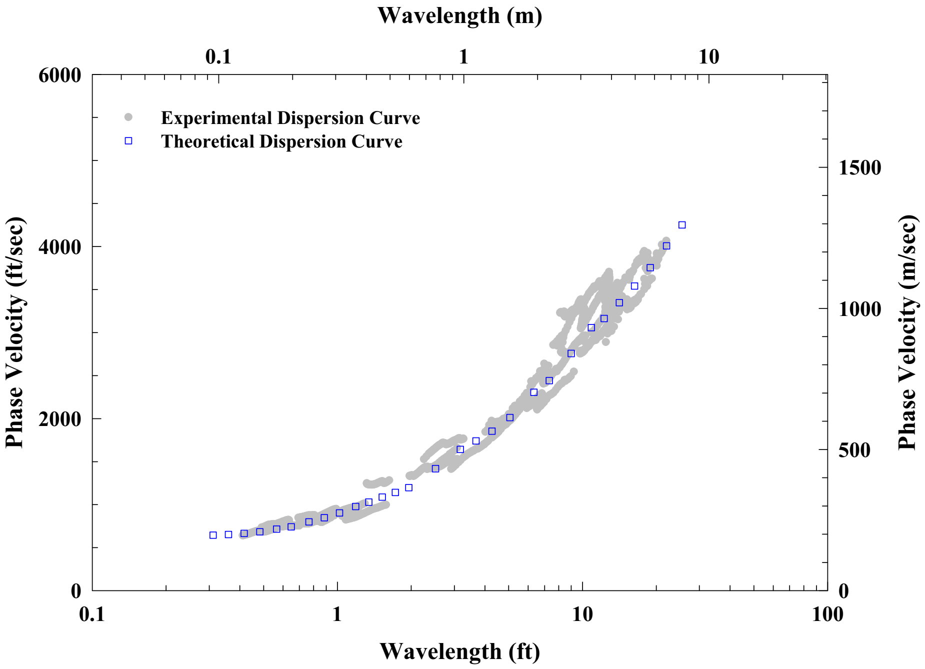
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-43. Shear Wave Velocity Profile Determined at ECRB 07+40



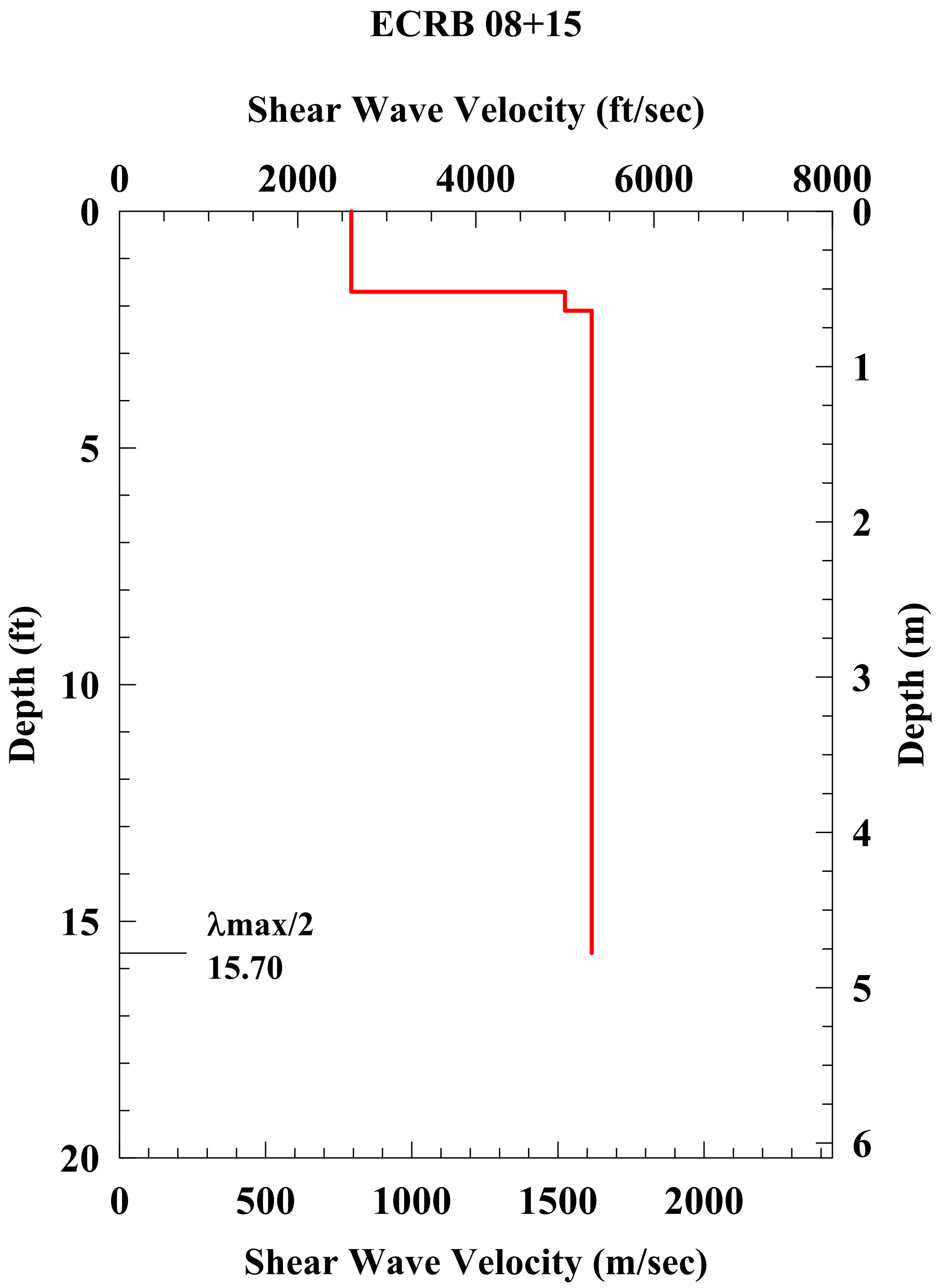
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-44. Experimental and Theoretical Dispersion Curves from ECRB 07+40; Linear Wavelength Axis



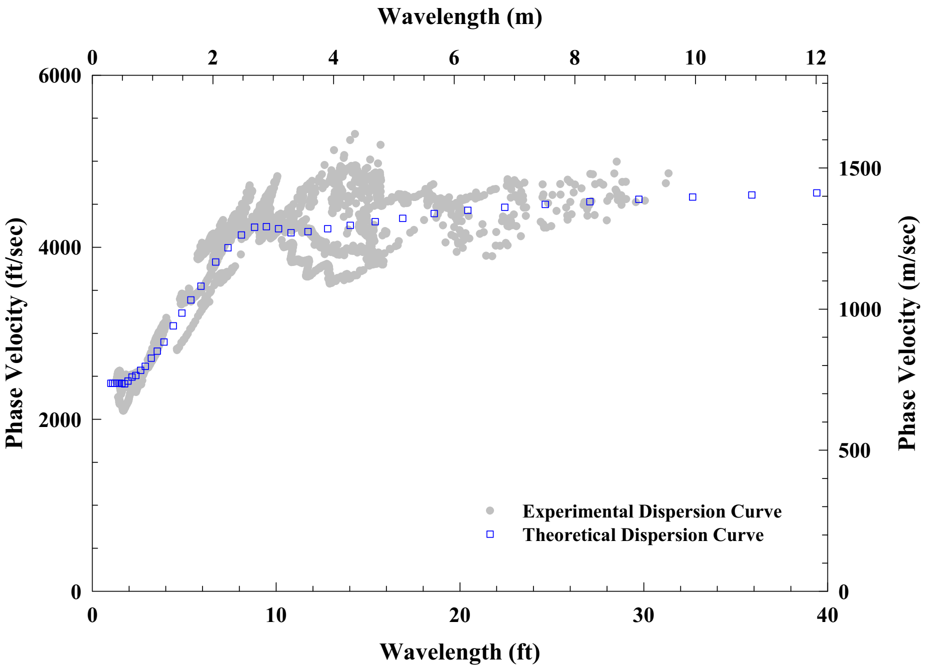
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-45. Experimental and Theoretical Dispersion Curves from ECRB 07+40; Logarithmic Wavelength Axis



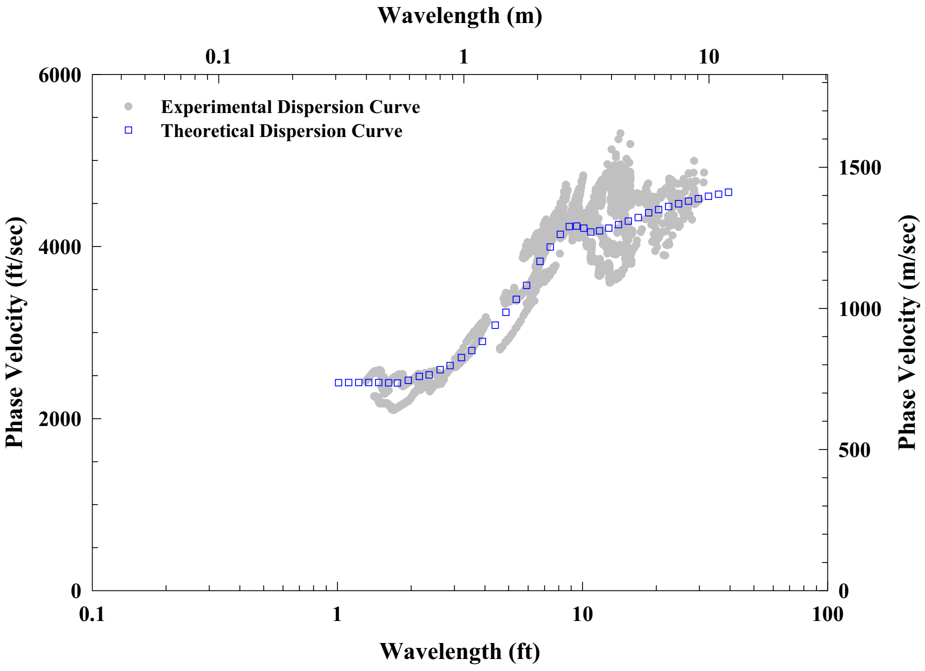
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-46. Shear Wave Velocity Profile Determined at ECRB 08+15



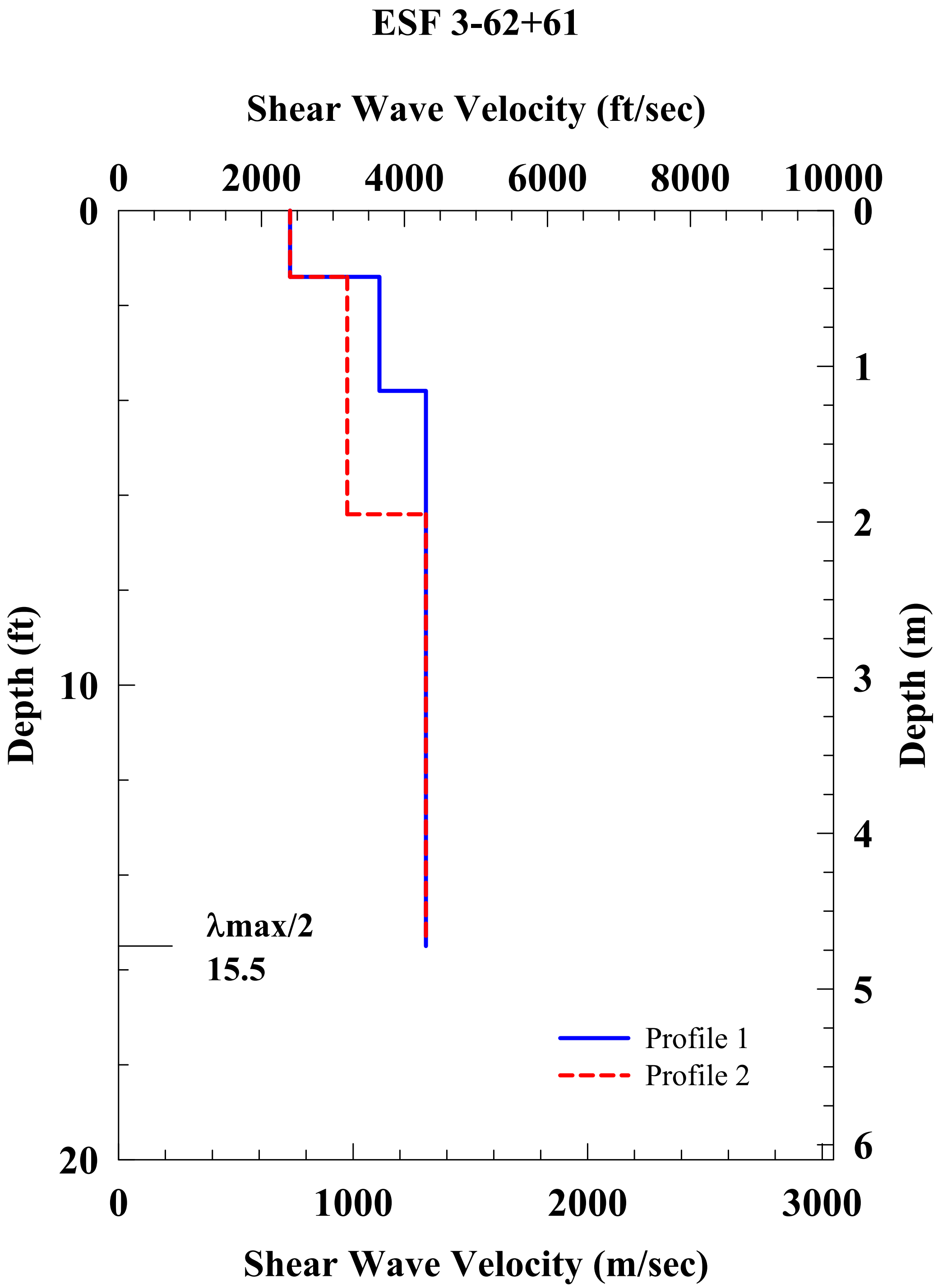
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-47. Experimental and Theoretical Dispersion Curves from ECRB 08+15; Linear Wavelength Axis



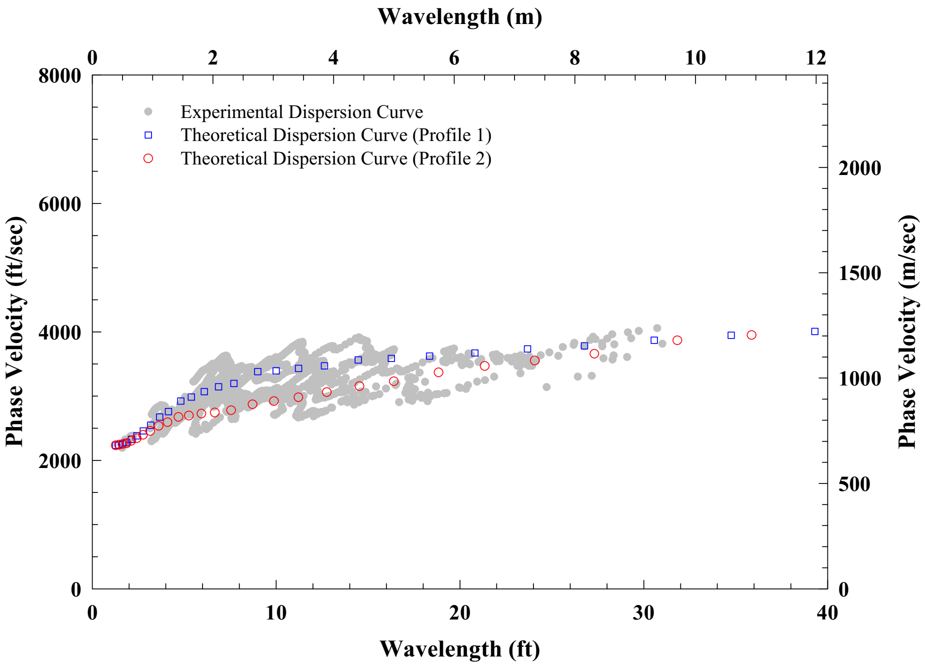
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-48. Experimental and Theoretical Dispersion Curves from ECRB 08+15; Logarithmic Wavelength Axis



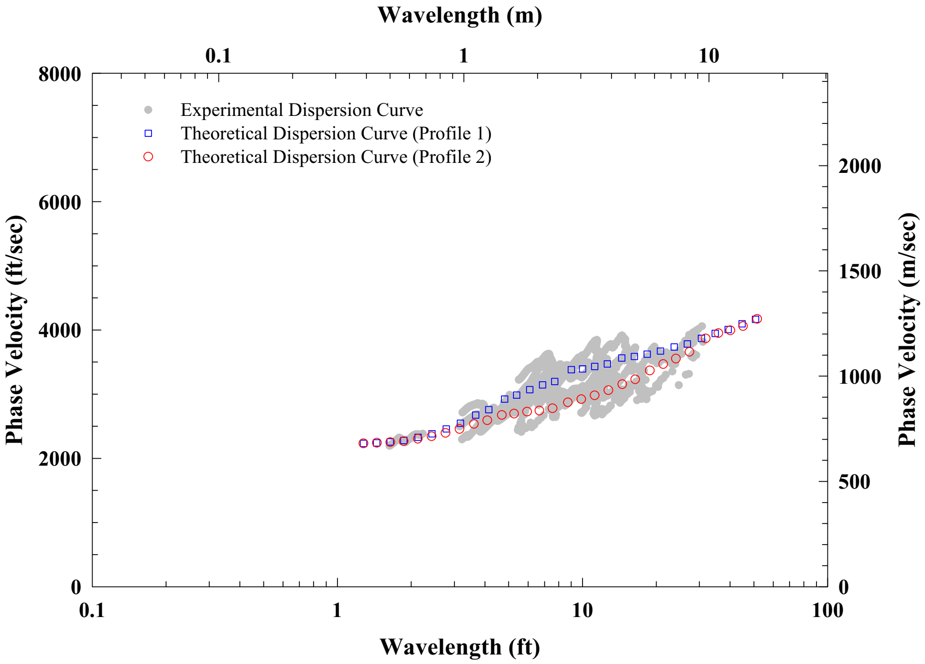
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-49. Shear Wave Velocity Profile Determined at ESF 3-62+61



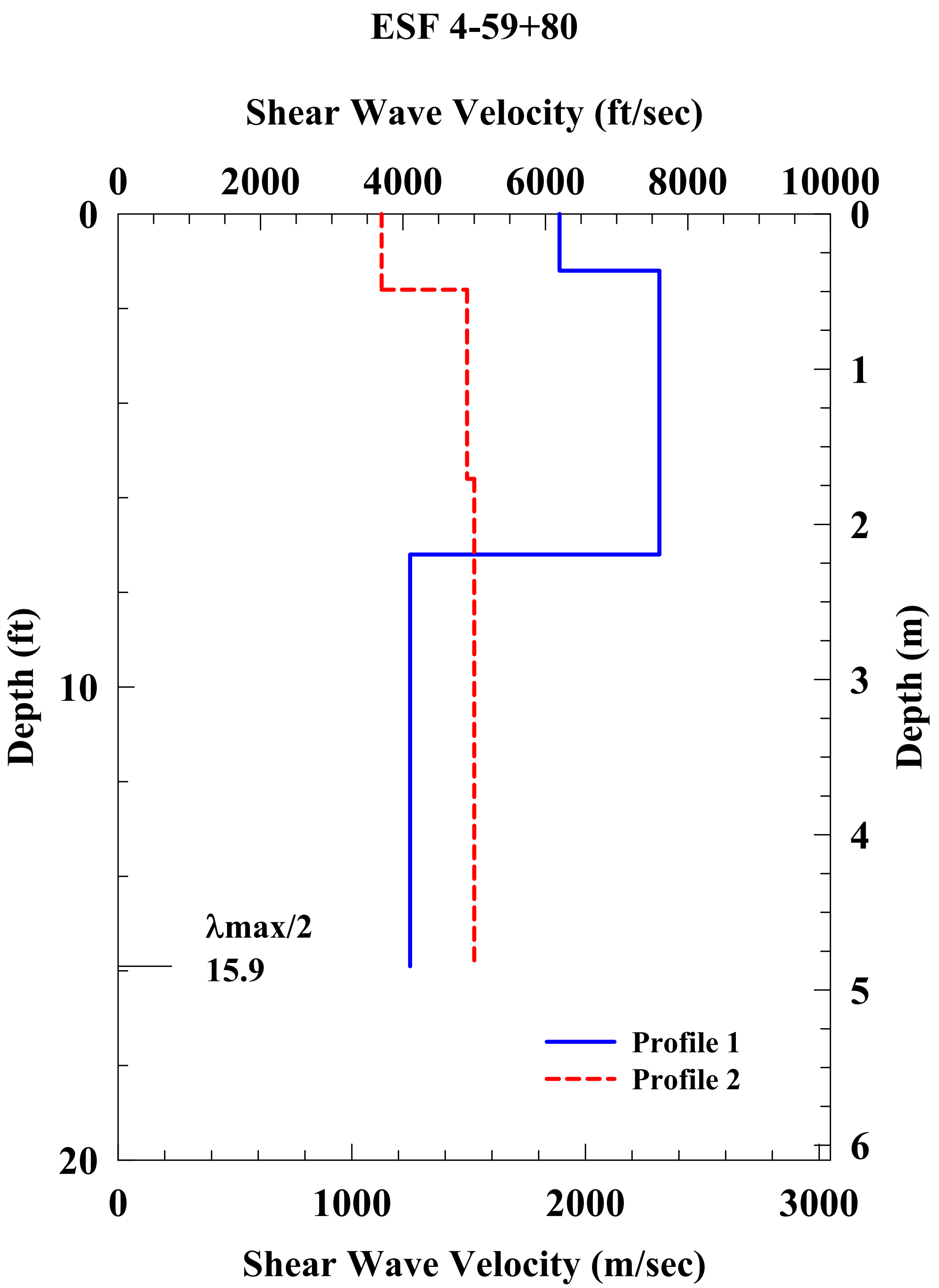
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-50. Experimental and Theoretical Dispersion Curves from ESF 3-62+61; Linear Wavelength Axis



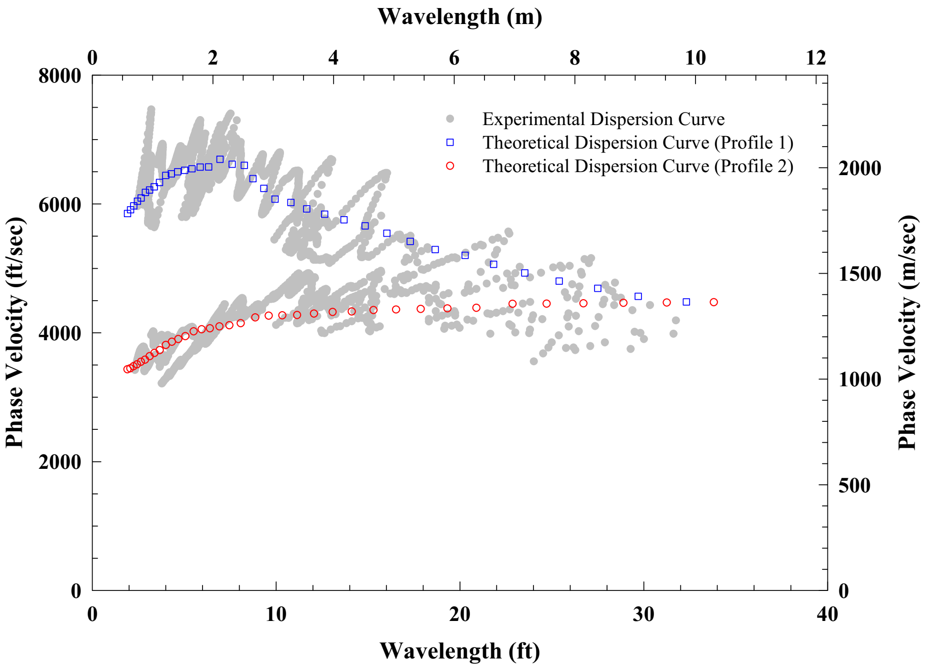
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-51. Experimental and Theoretical Dispersion Curves from ESF 3-62+61; Logarithmic Wavelength Axis



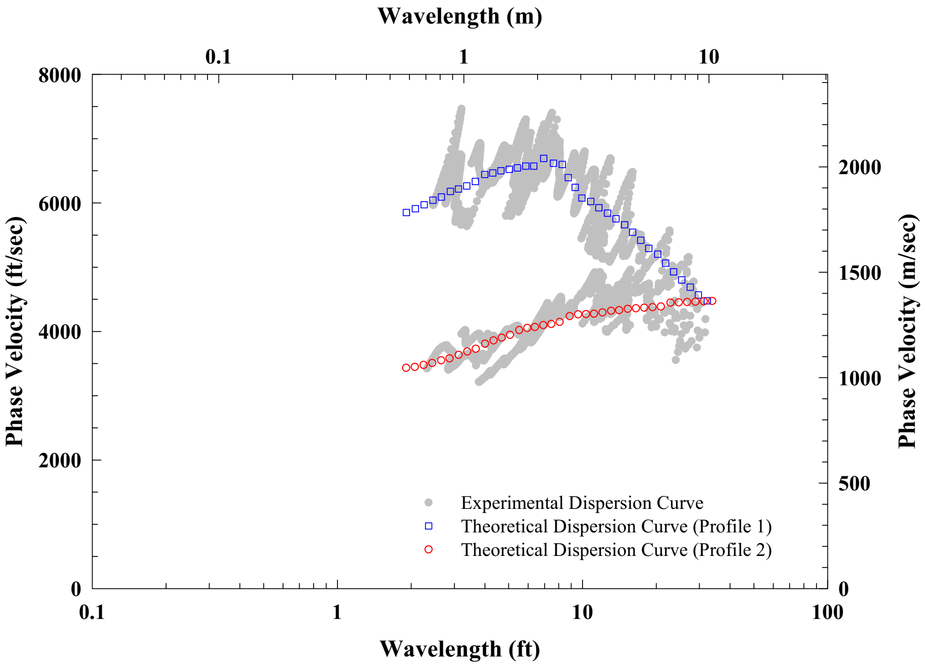
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-52. Shear Wave Velocity Profile Determined at ESF 4-59+80



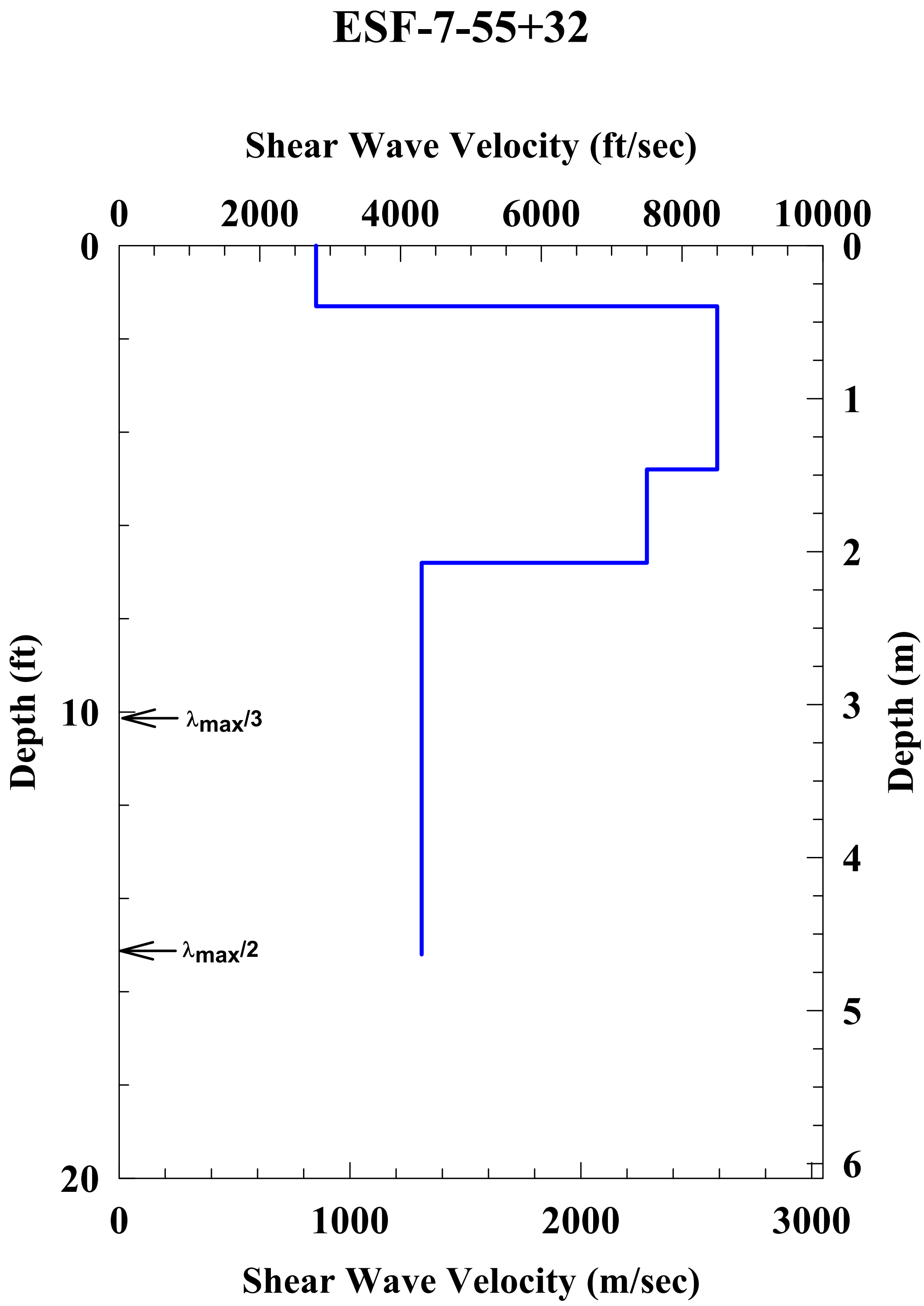
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-53. Experimental and Theoretical Dispersion Curves from ESF 4-59+80; Linear Wavelength Axis



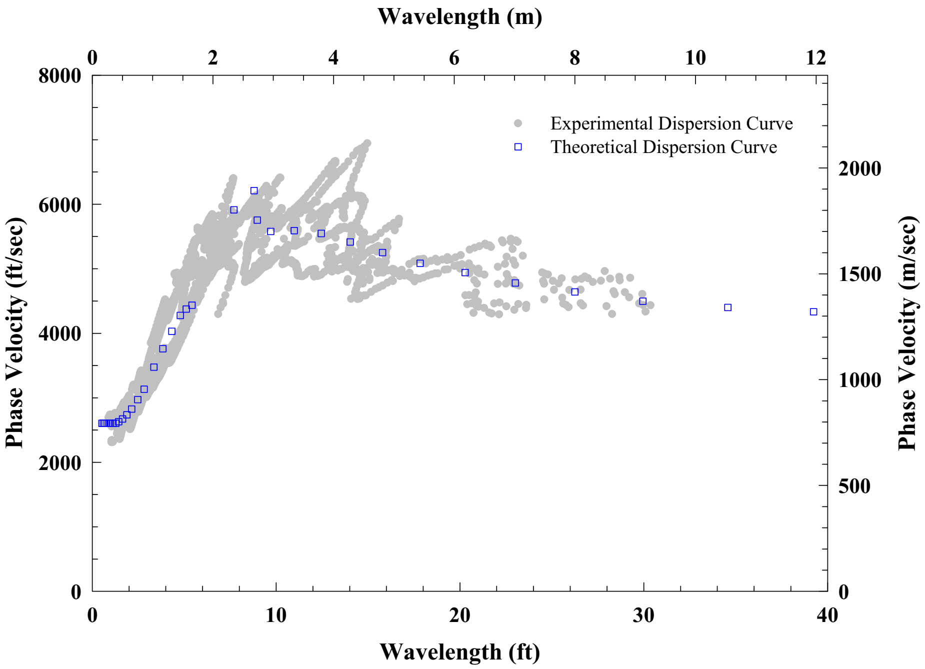
Source: DTN:MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-54. Experimental and Theoretical Dispersion Curves from ESF 4-59+80; Logarithmic Wavelength Axis



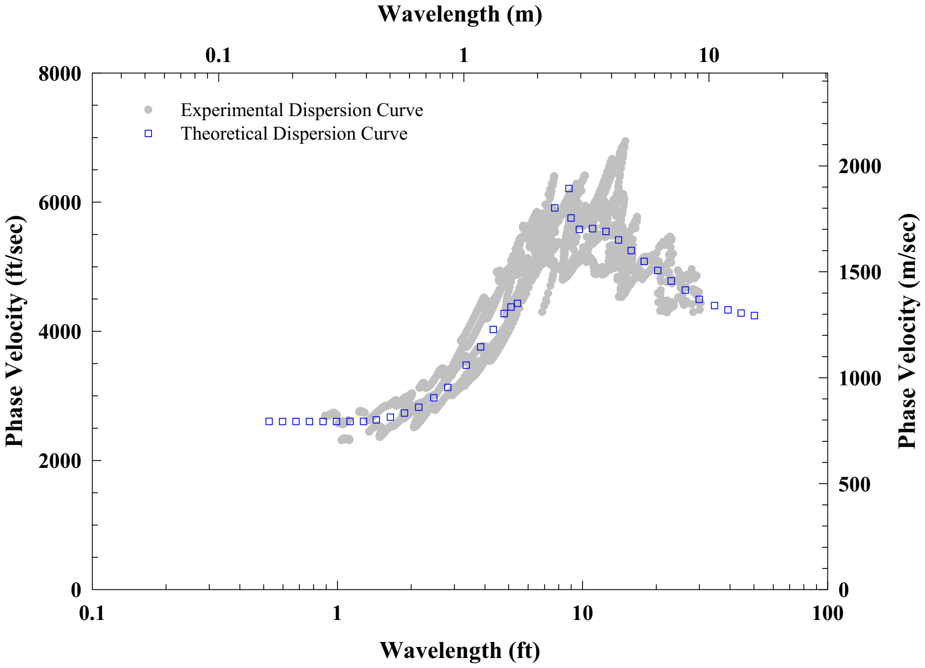
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-55. Shear Wave Velocity Profile Determined at ESF-7-55+32



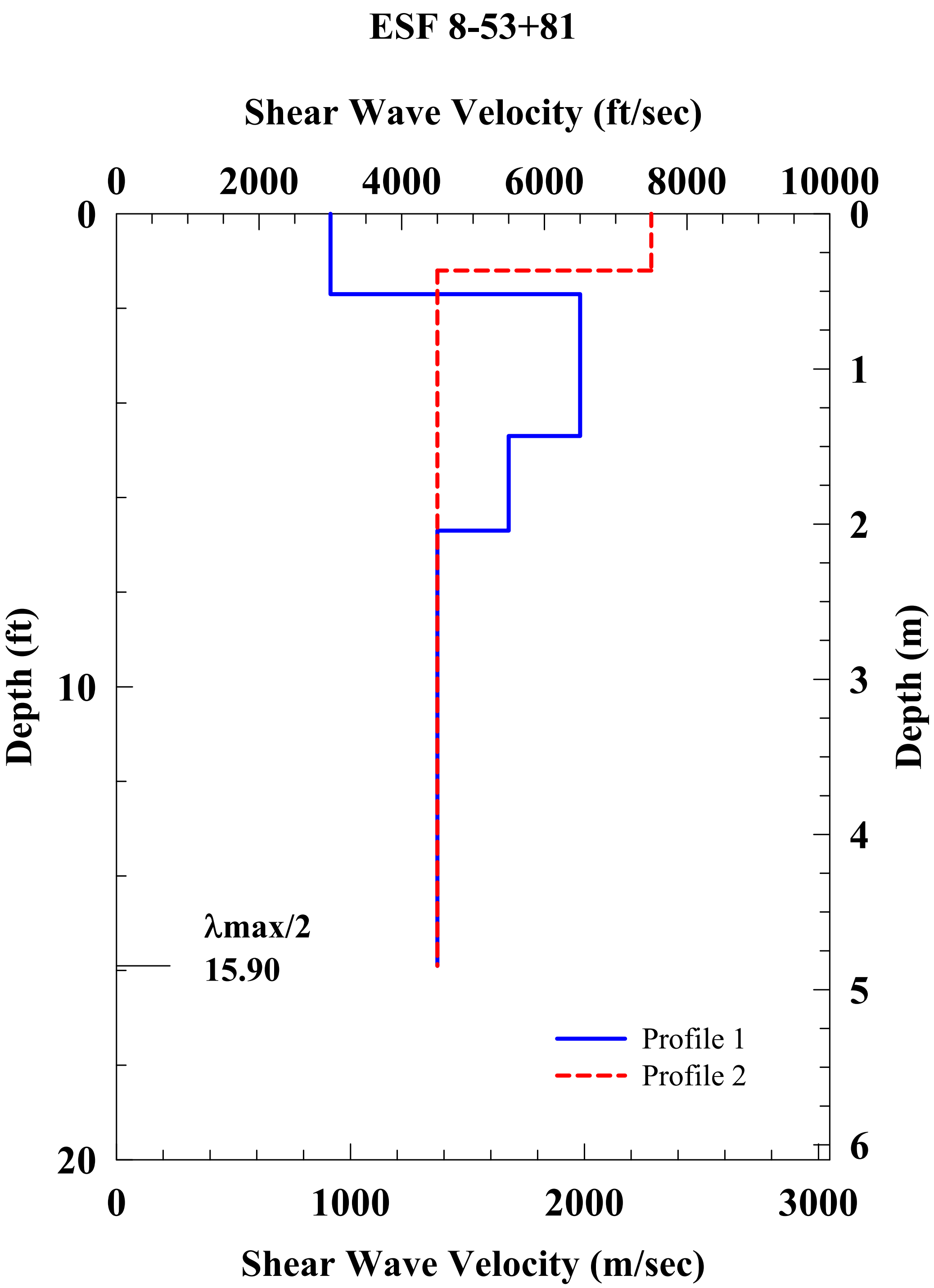
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-56. Experimental and Theoretical Dispersion Curves from ESF-7-55+32; Linear Wavelength Axis



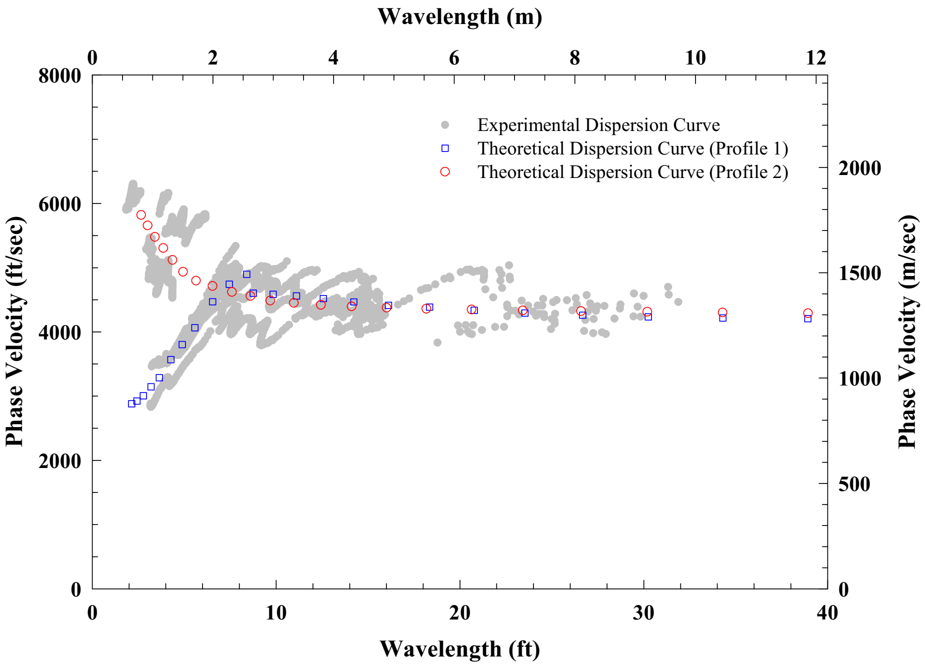
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-57. Experimental and Theoretical Dispersion Curves from ESF-7-55+32; Logarithmic Wavelength Axis



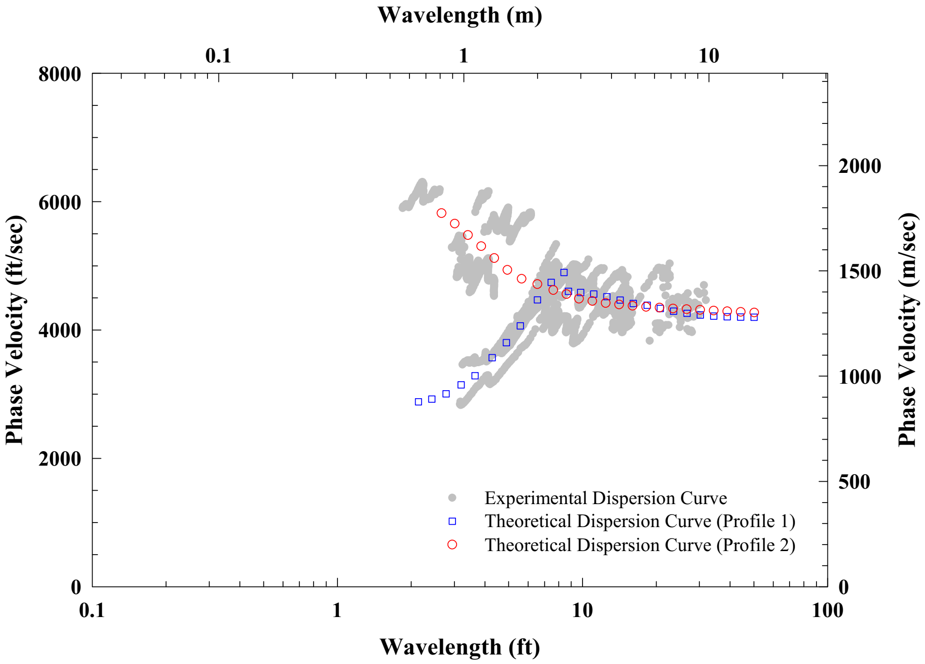
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-58. Shear Wave Velocity Profile Determined at ESF 8-53+31



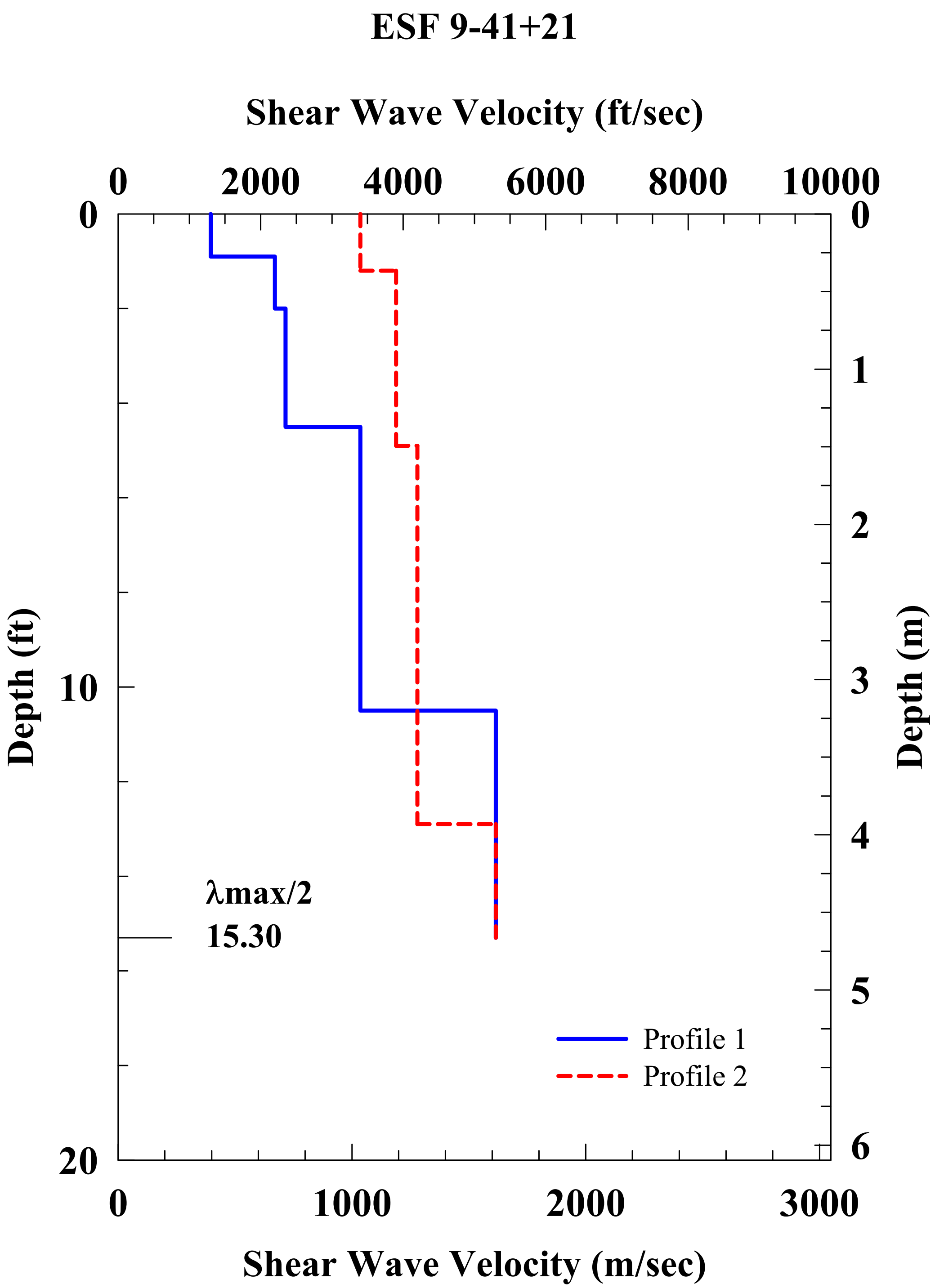
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-59. Experimental and Theoretical Dispersion Curves from ESF 8-53+31; Linear Wavelength Axis



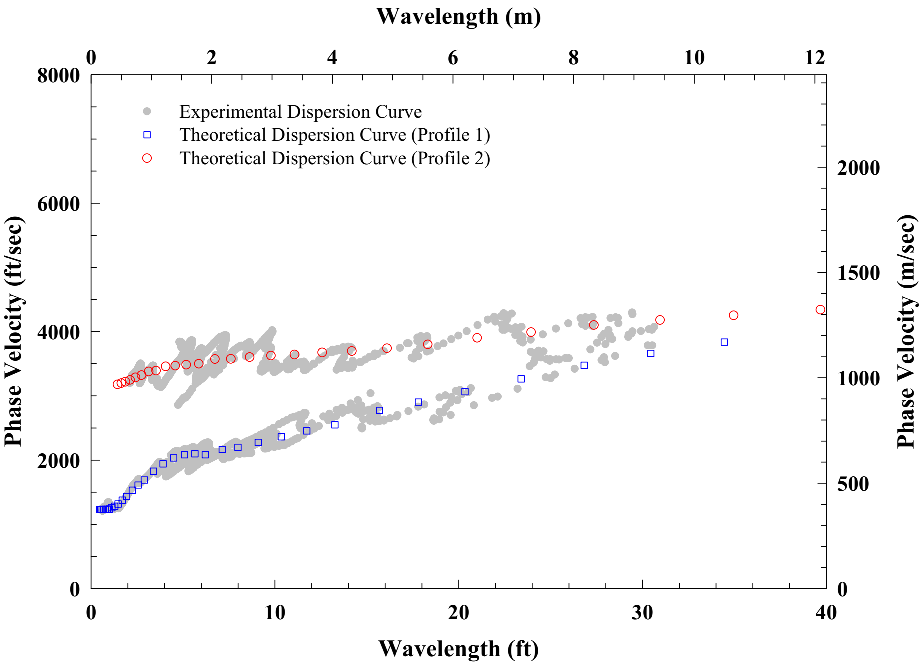
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-60. Experimental and Theoretical Dispersion Curves from ESF 8-53+31; Logarithmic Wavelength Axis



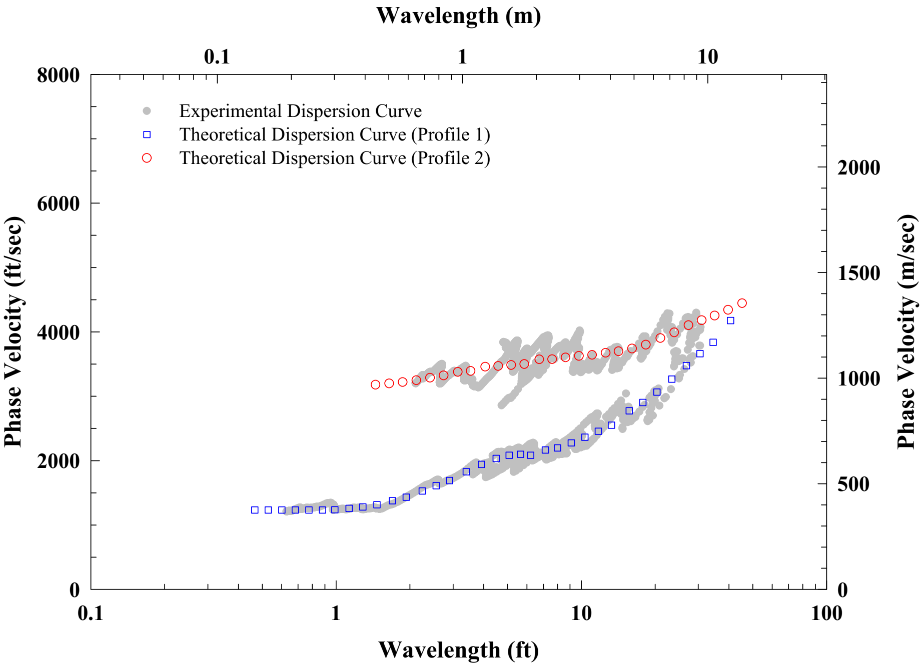
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure IV-61. Shear Wave Velocity Profile Determined at ESF 9-41+21



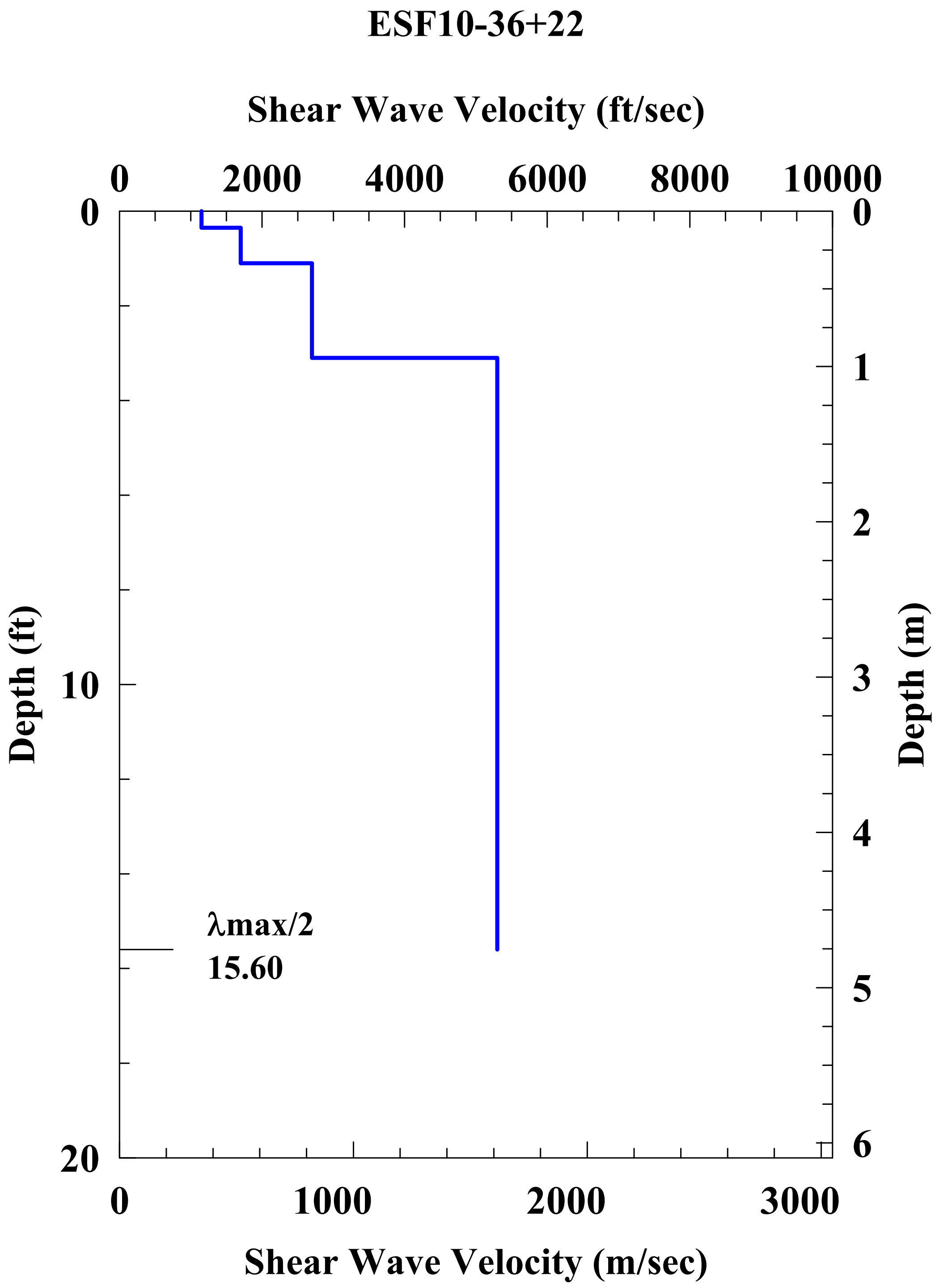
Source: DTN:MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-62. Experimental and Theoretical Dispersion Curves from ESF 9-41+21; Linear Wavelength Axis



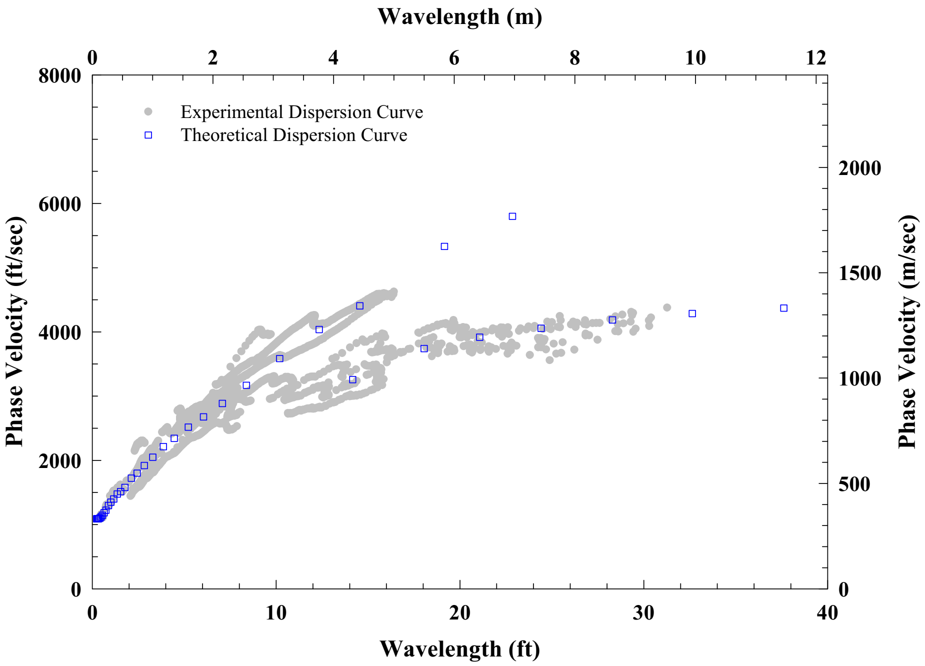
Source: DTN:MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-63. Experimental and Theoretical Dispersion Curves from ESF 9-41+21; Logarithmic Wavelength Axis



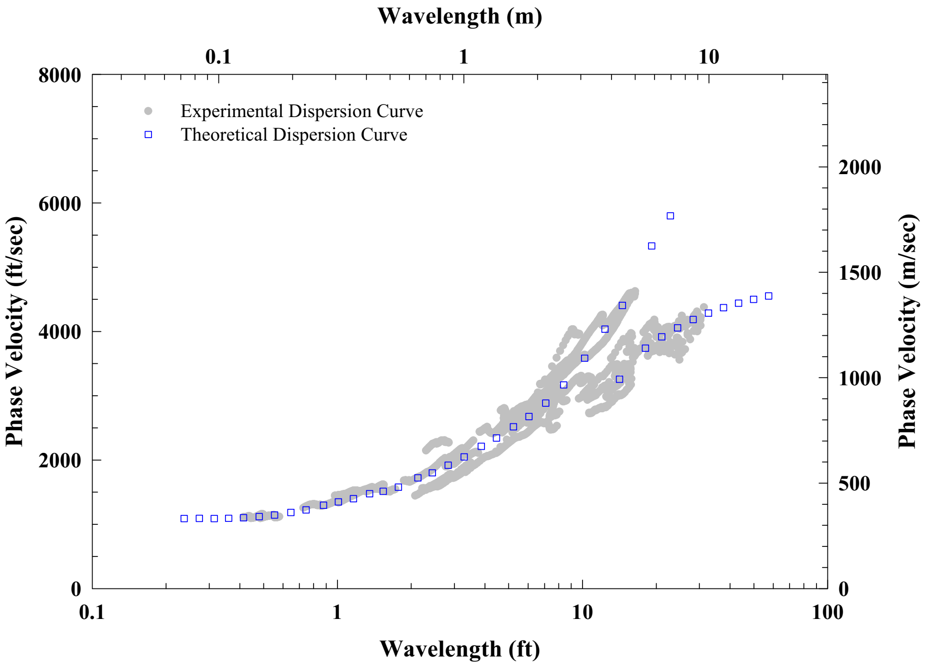
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-64. Shear Wave Velocity Profile Determined at ESF 10-36+22



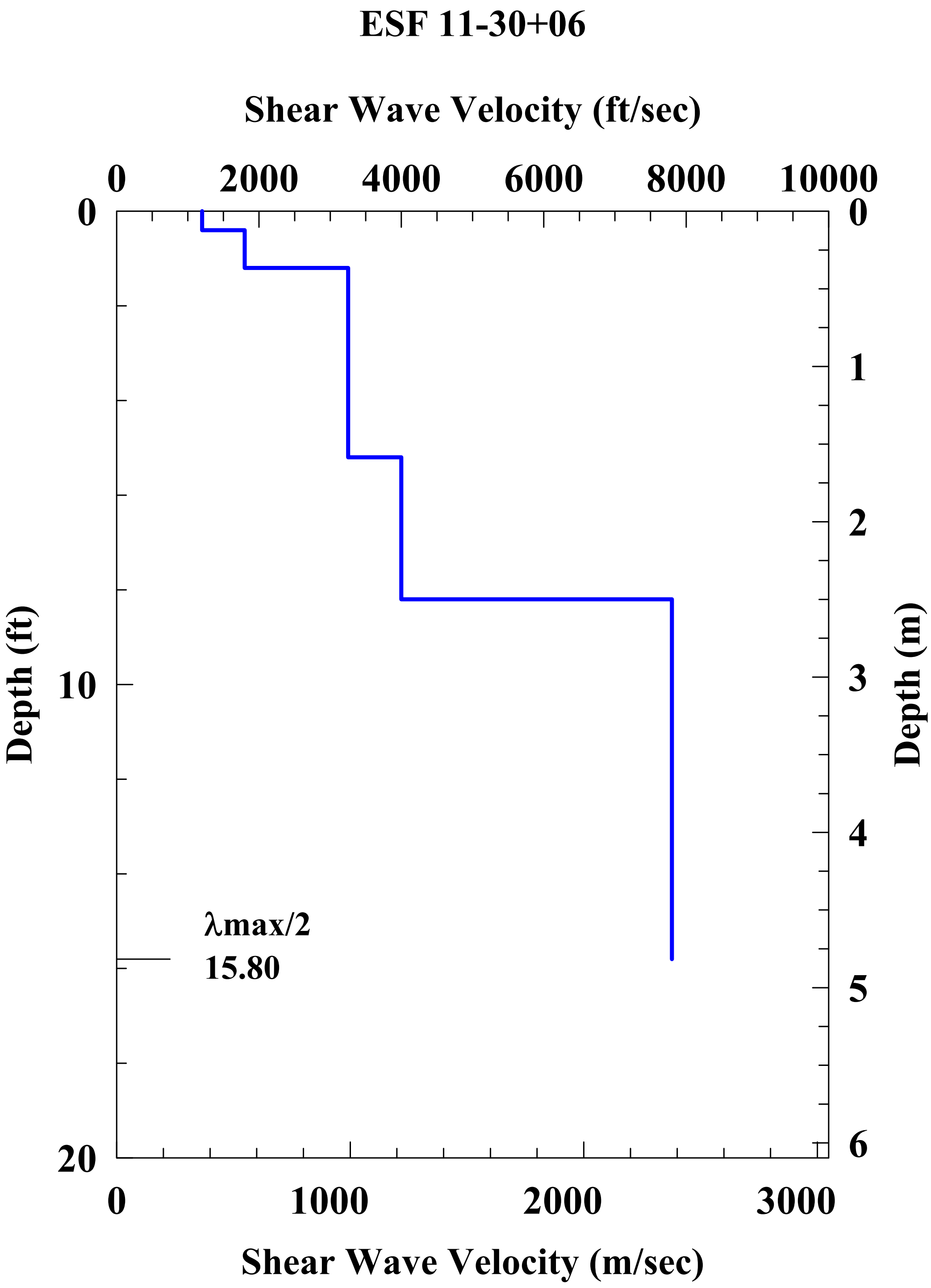
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-65. Experimental and Theoretical Dispersion Curves from ESF 10-36+22; Linear Wavelength Axis



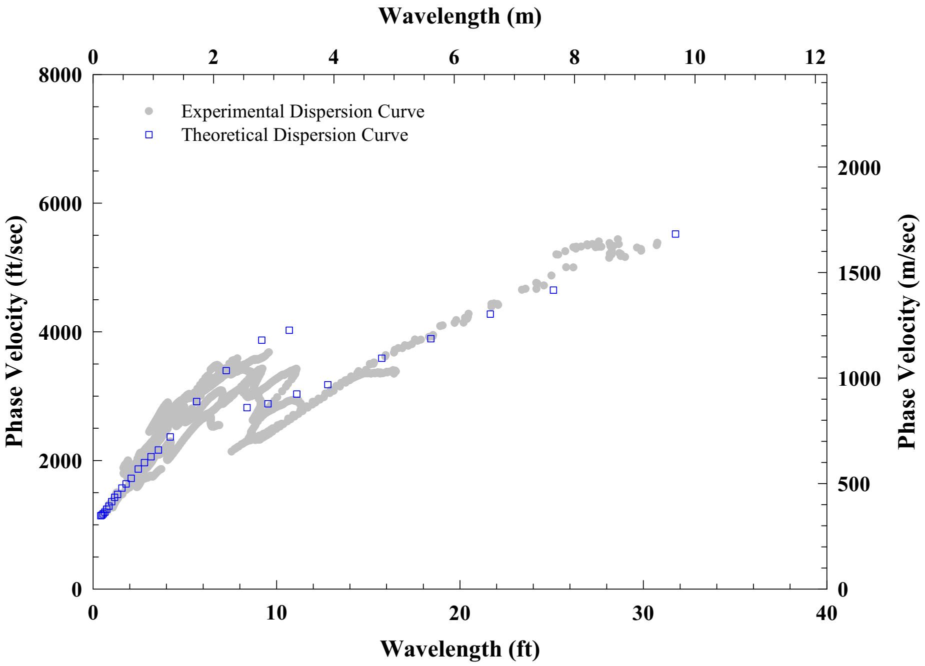
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-66. Experimental and Theoretical Dispersion Curves from ESF 10-36+22; Logarithmic Wavelength Axis



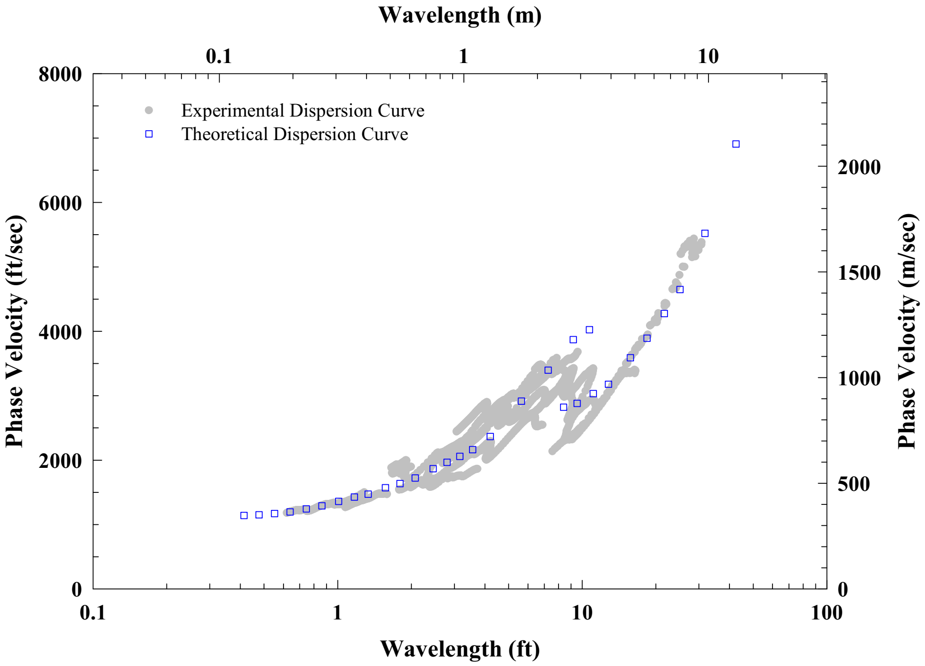
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-67. Shear Wave Velocity Profile Determined at ESF 11-30+06



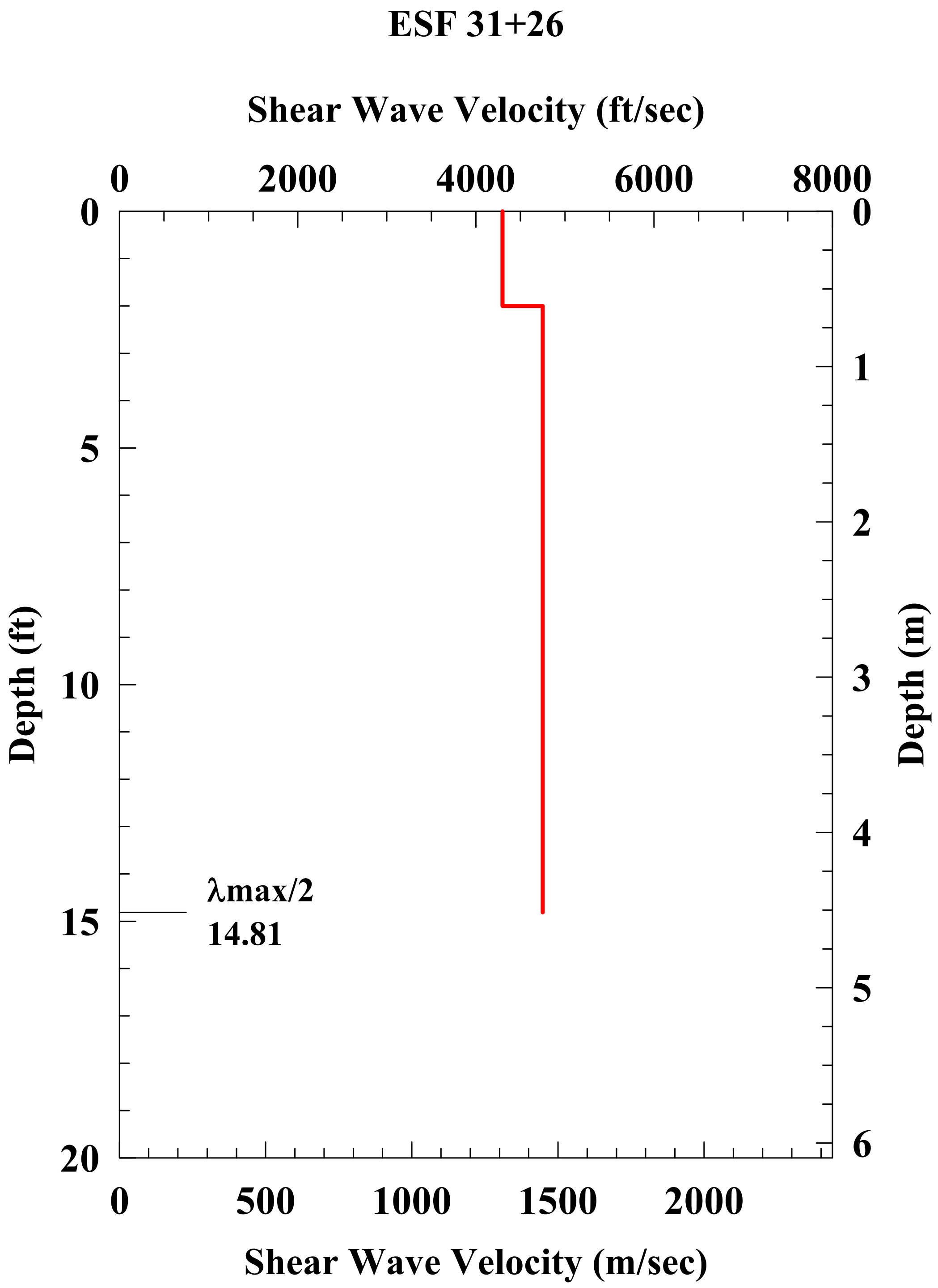
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-68. Experimental and Theoretical Dispersion Curves from ESF 11-30+06; Linear Wavelength Axis



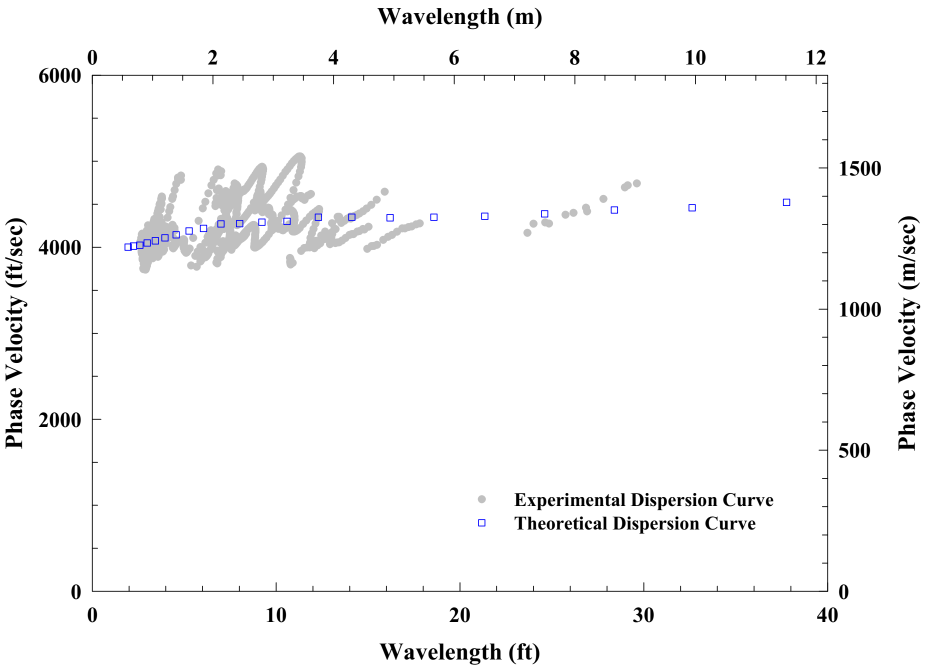
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-69. Experimental and Theoretical Dispersion Curves from ESF 11-30+06; Logarithmic Wavelength Axis



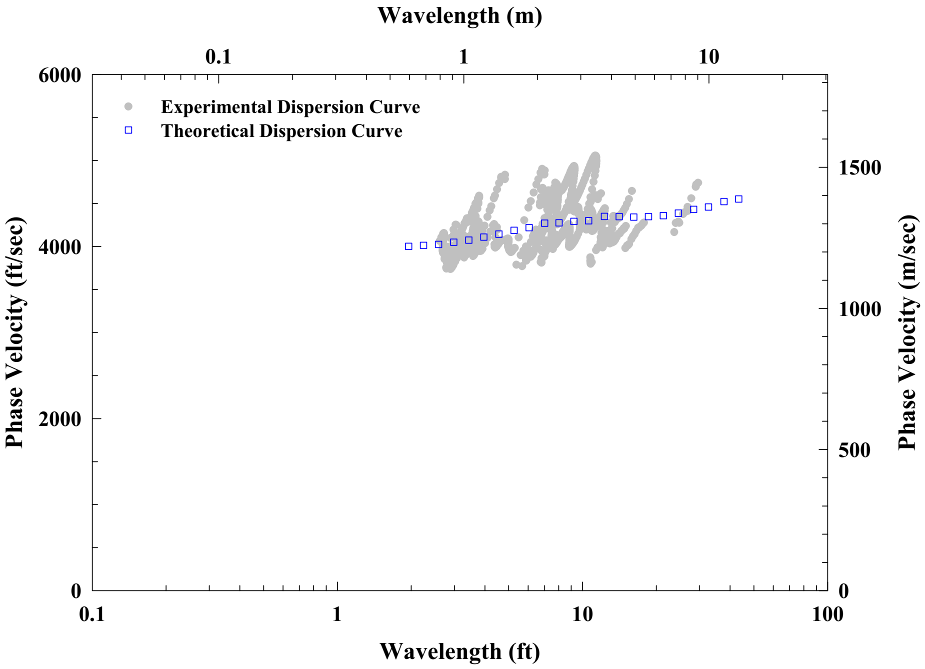
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-70. Shear Wave Velocity Profile Determined at ESF 31+26



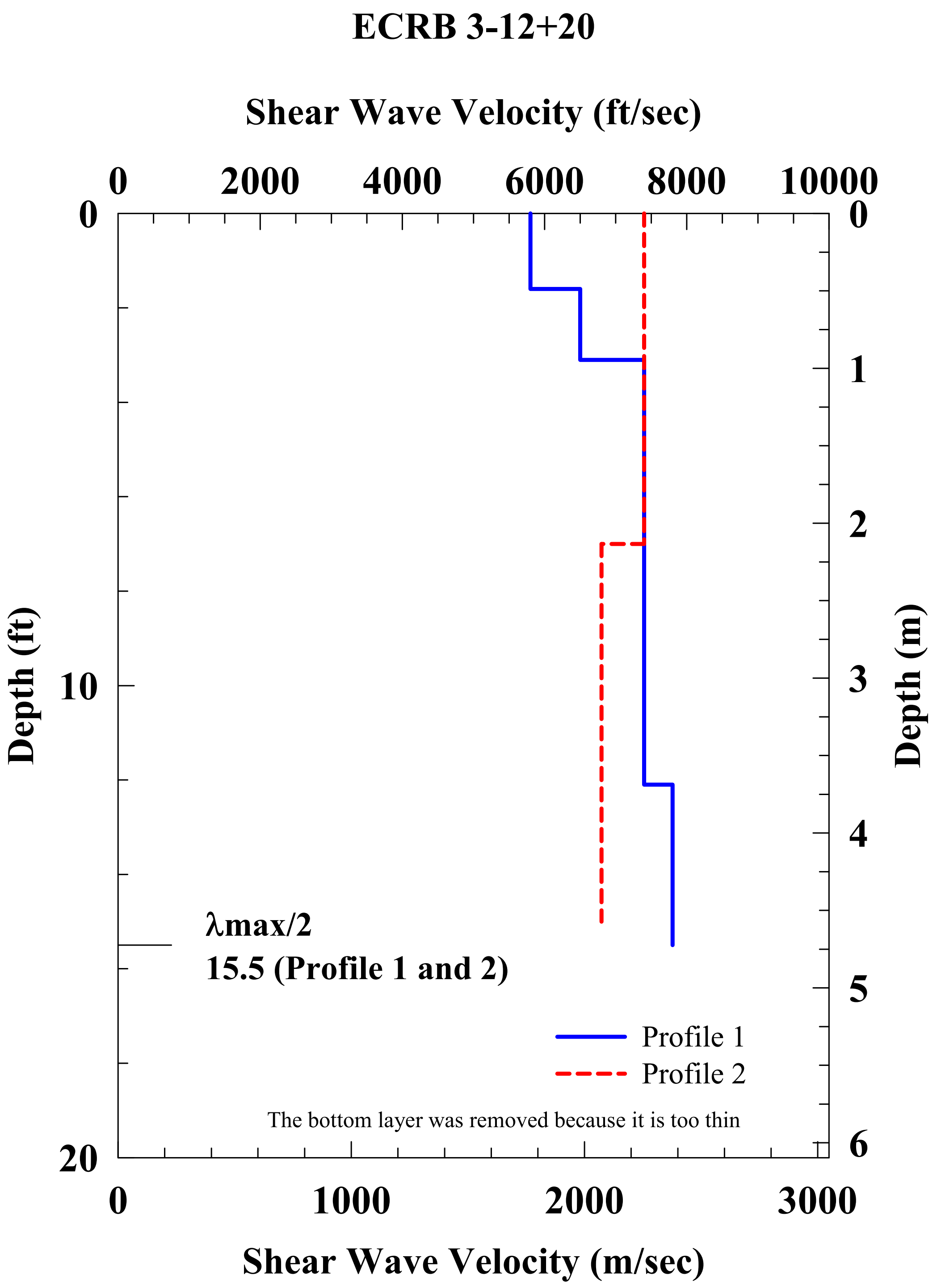
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-71. Experimental and Theoretical Dispersion Curves from ESF 31+26; Linear Wavelength Axis



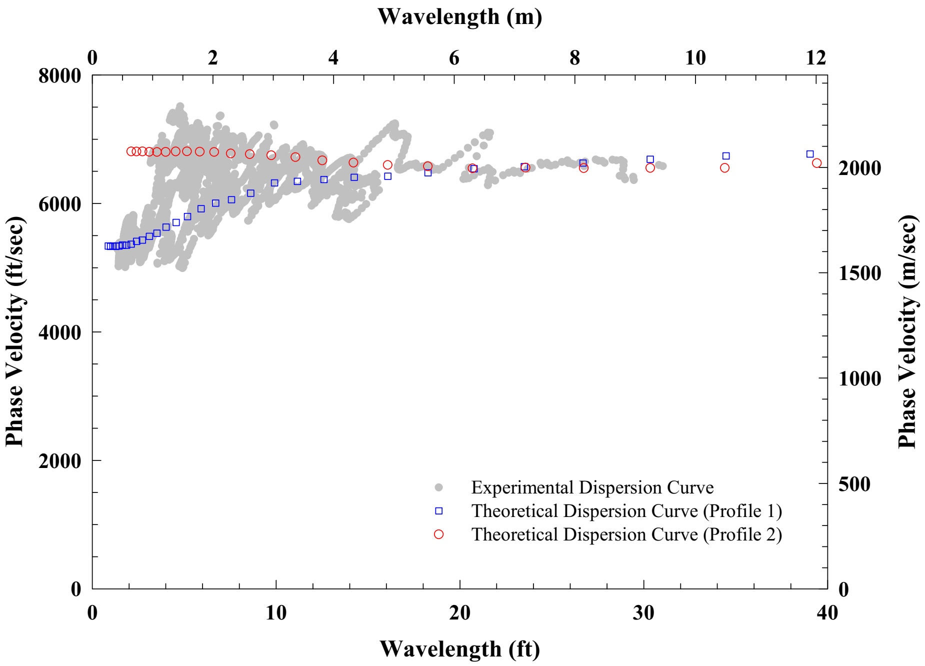
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-72. Experimental and Theoretical Dispersion Curves from ESF 31+26; Logarithmic Wavelength Axis



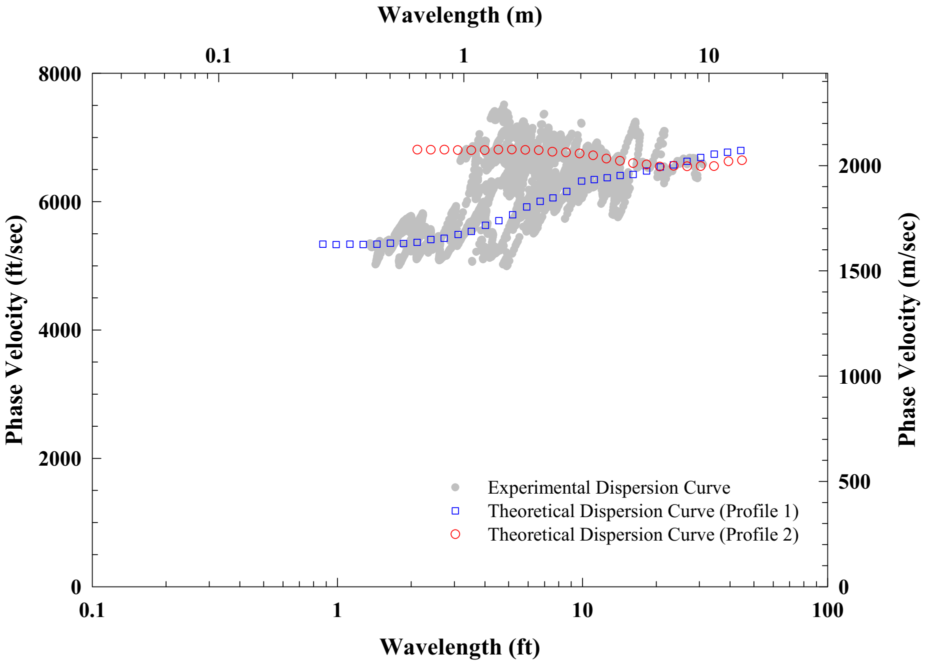
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-73. Shear Wave Velocity Profile Determined at ECRB 3-12+20



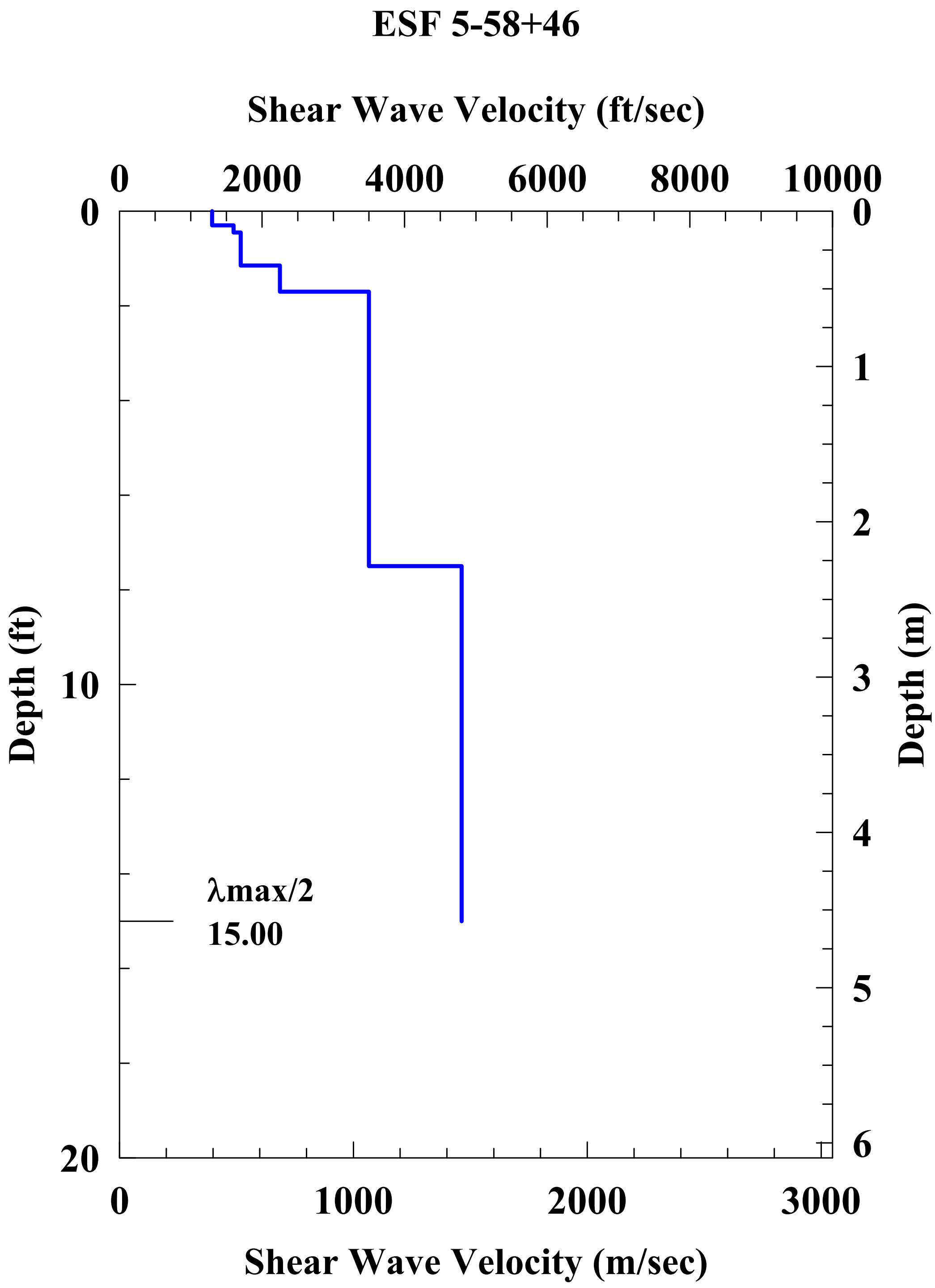
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-74. Experimental and Theoretical Dispersion Curves from ECRB 3-12+20; Linear Wavelength Axis



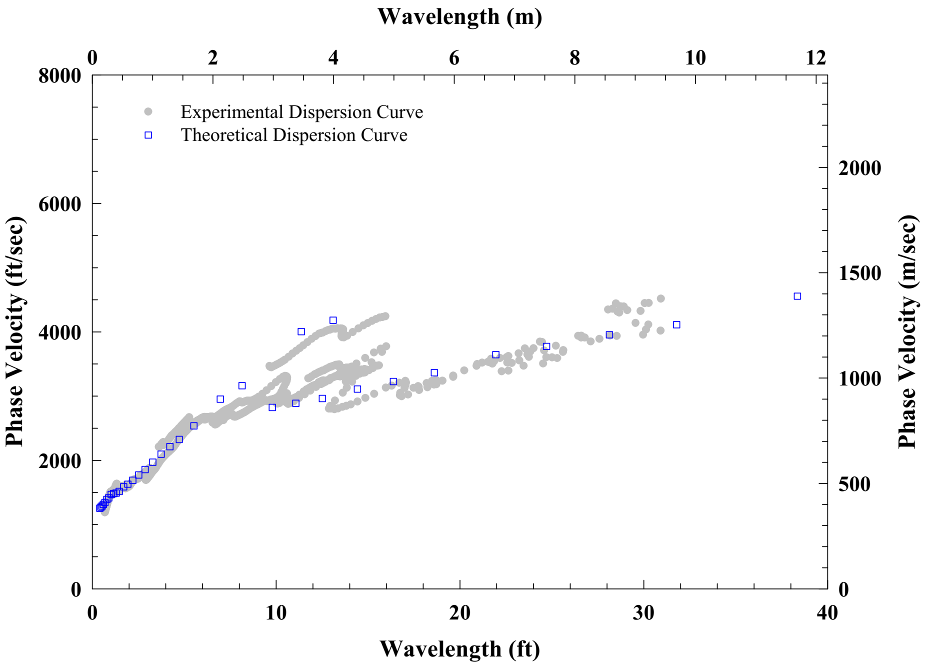
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-75. Experimental and Theoretical Dispersion Curves from ECRB 3-12+20; Logarithmic Wavelength Axis



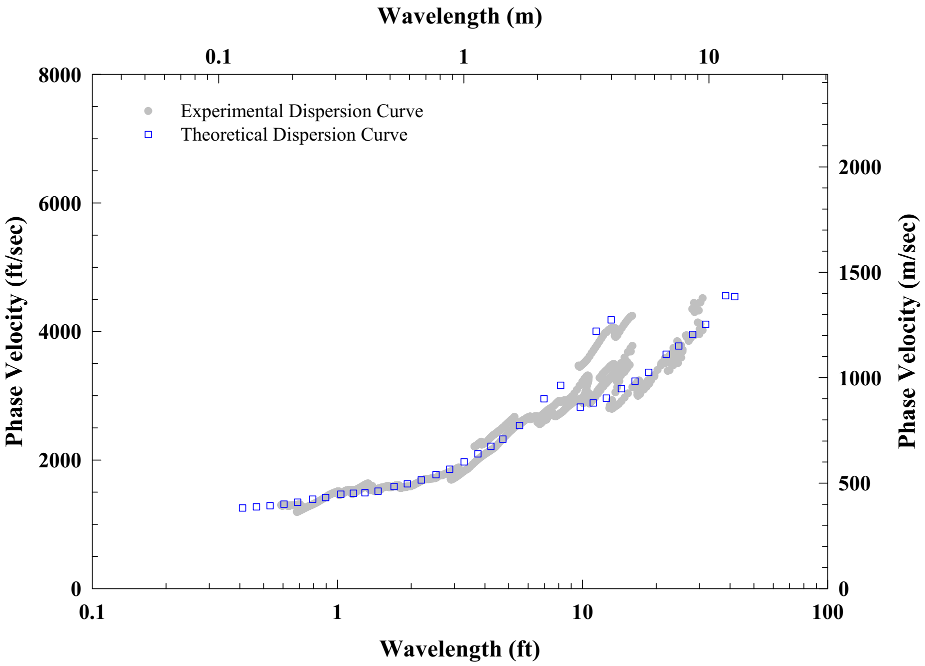
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-76. Shear Wave Velocity Profile Determined at ESF 5-58+46



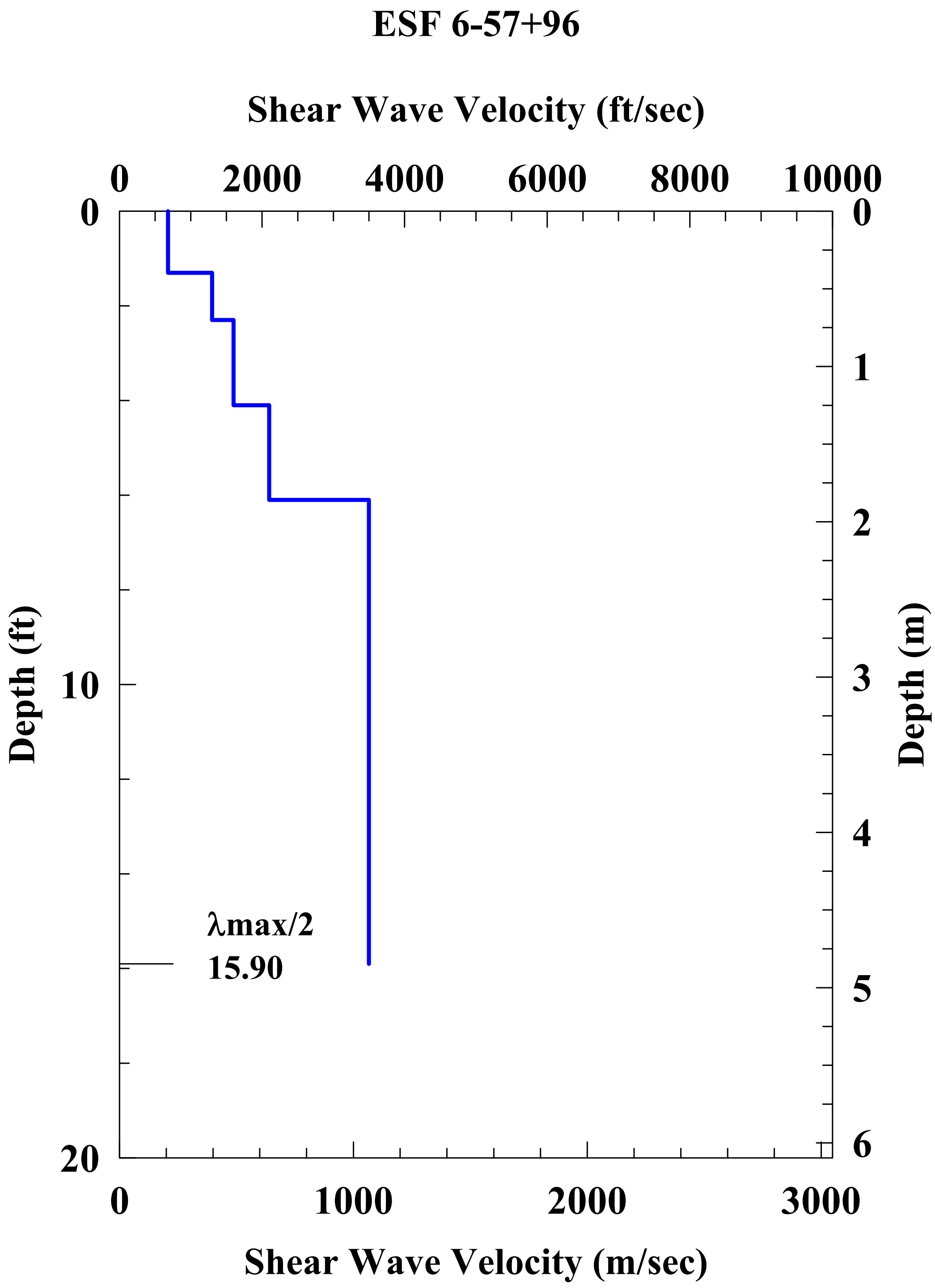
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-77. Experimental and Theoretical Dispersion Curves from ESF 5-58+46; Linear Wavelength Axis



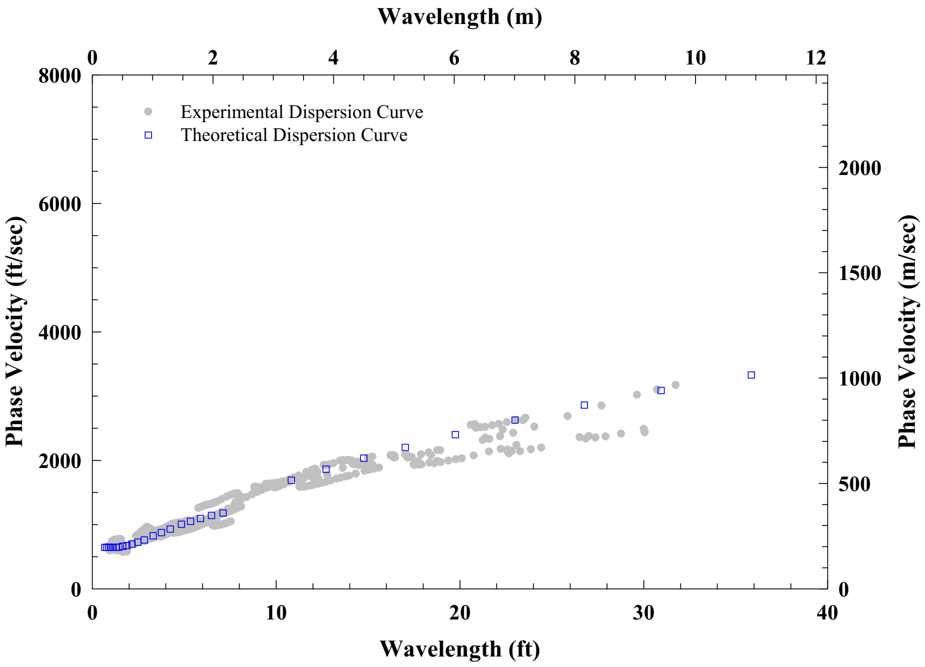
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-78. Experimental and Theoretical Dispersion Curves from ESF 5-58+46; Logarithmic Wavelength Axis



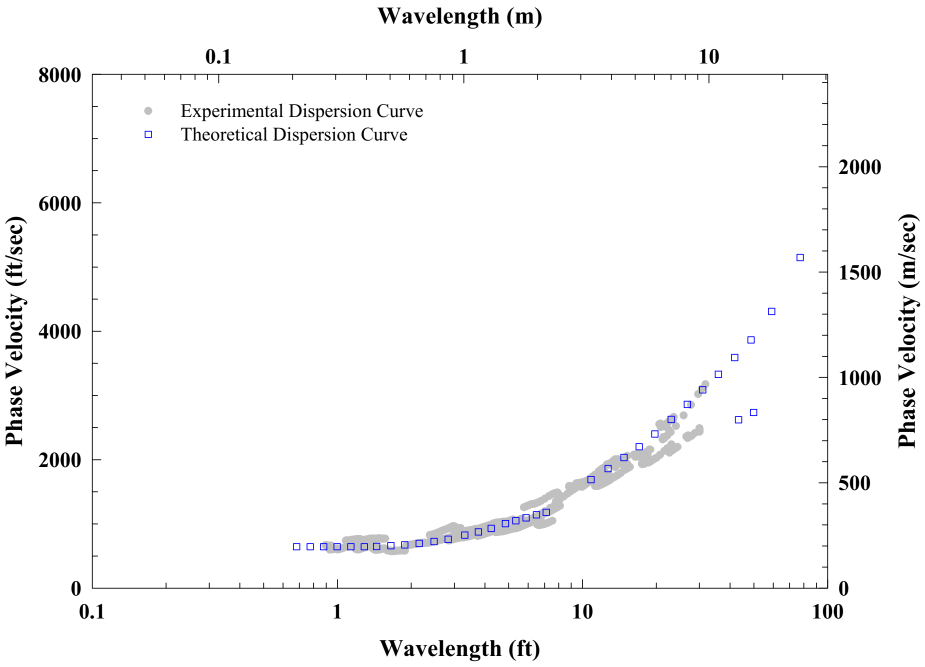
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-79. Shear Wave Velocity Profile Determined at ESF 6-57+96



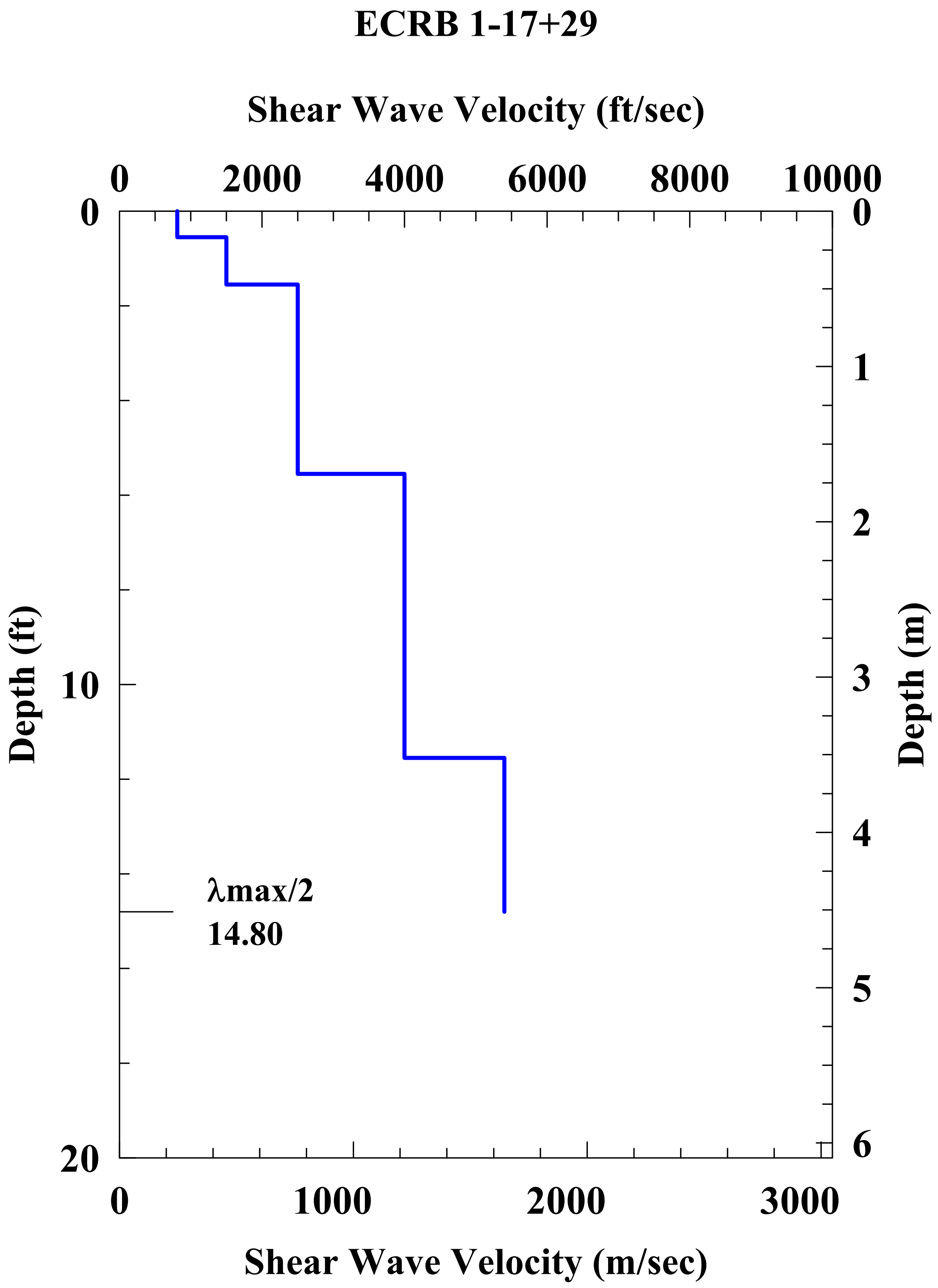
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-80. Experimental and Theoretical Dispersion Curves from ESF 6-57+96; Linear Wavelength Axis



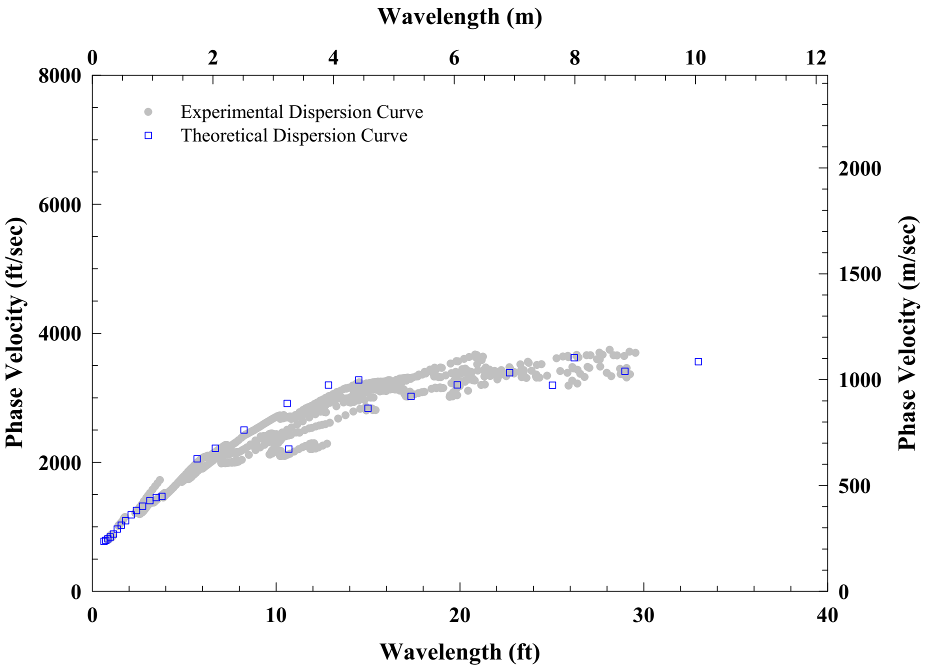
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-81. Experimental and Theoretical Dispersion Curves from ESF 6-57+96; Logarithmic Wavelength Axis



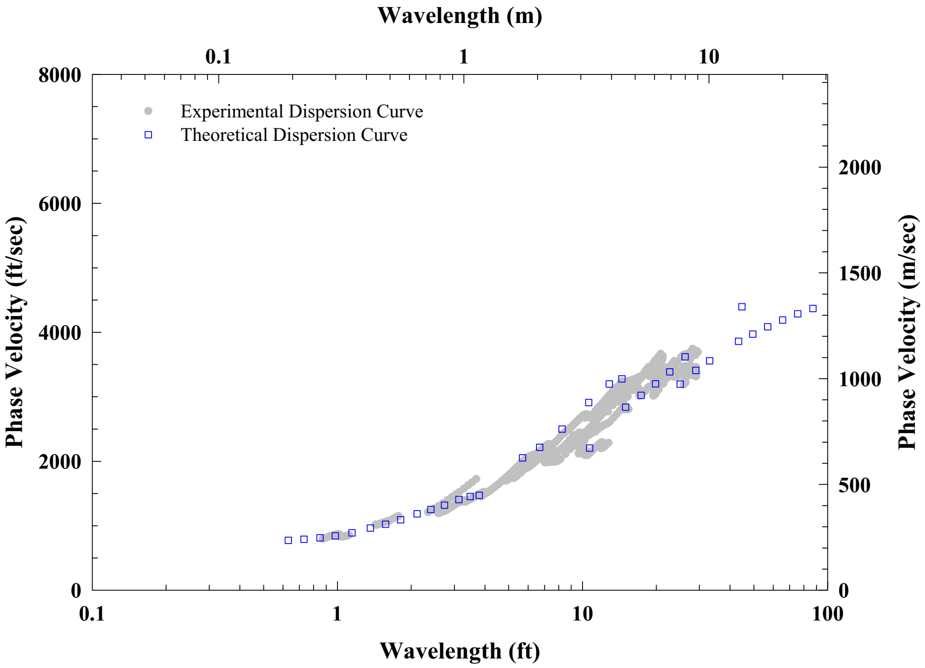
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-82. Shear Wave Velocity Profile Determined at ECRB-1-17+29



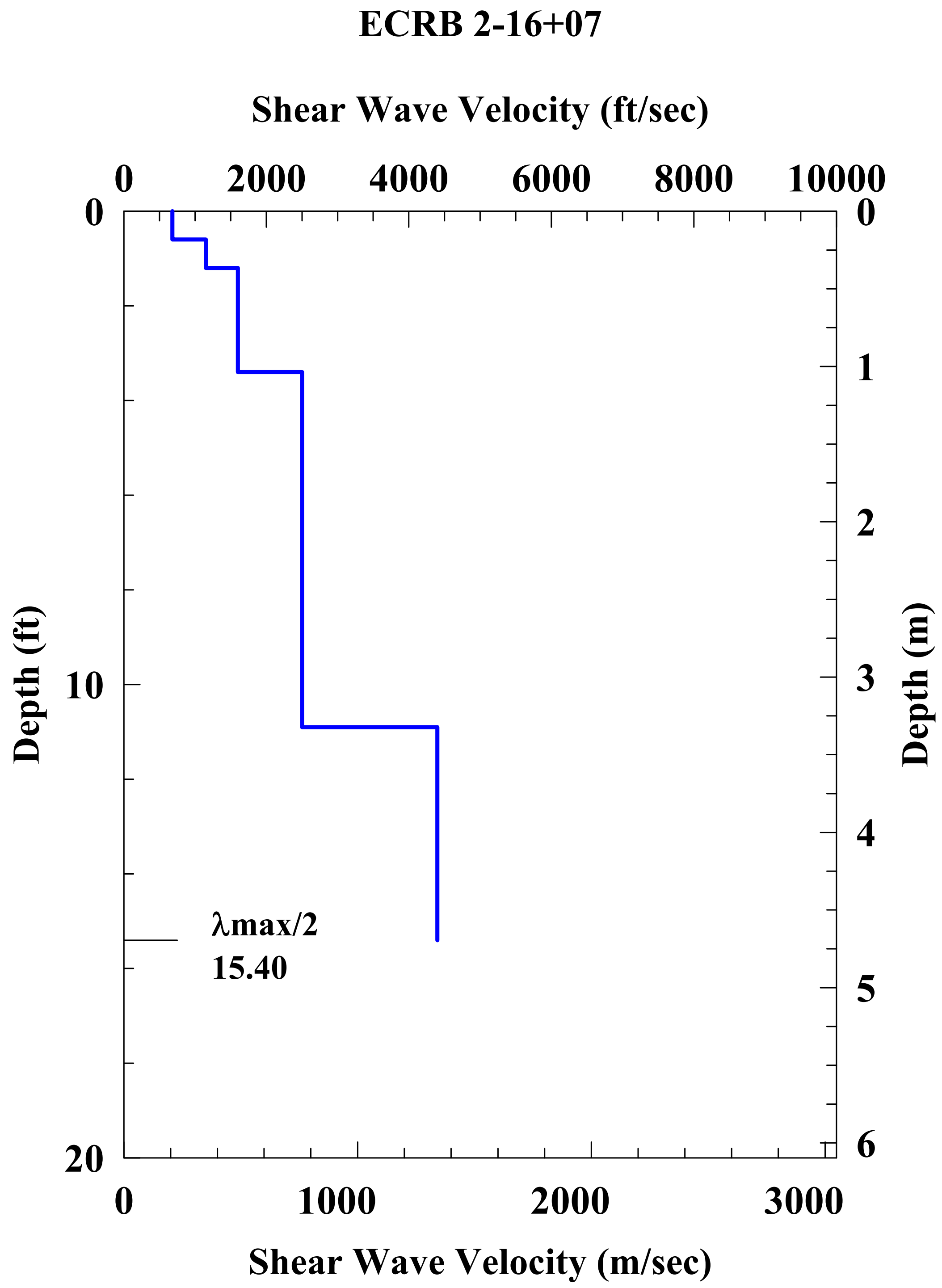
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-83. Experimental and Theoretical Dispersion Curves from ECRB-1-17+29; Linear Wavelength Axis



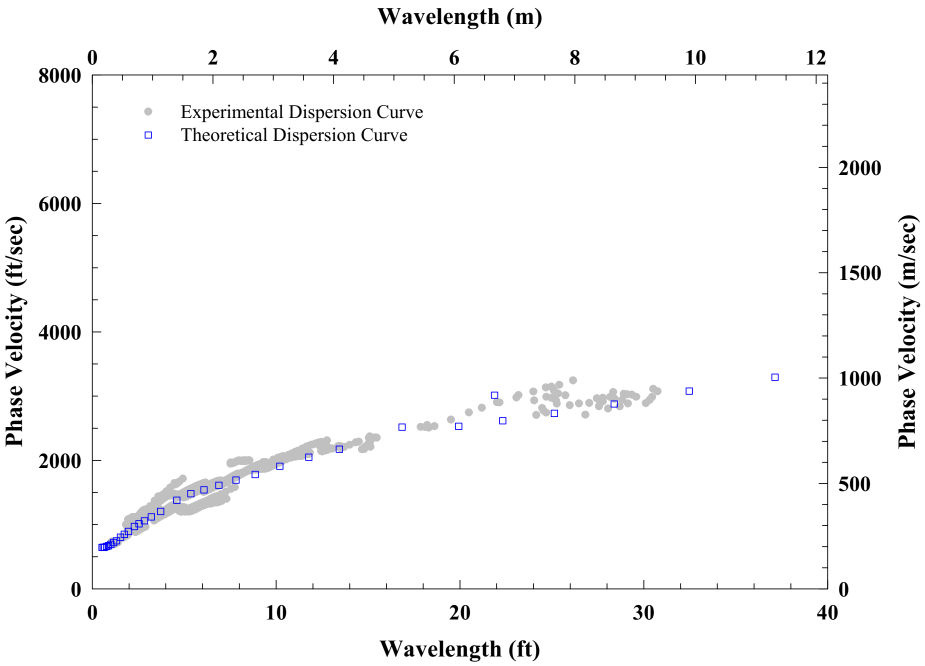
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-84. Experimental and Theoretical Dispersion Curves from ECRB-1-17+29; Logarithmic Wavelength Axis



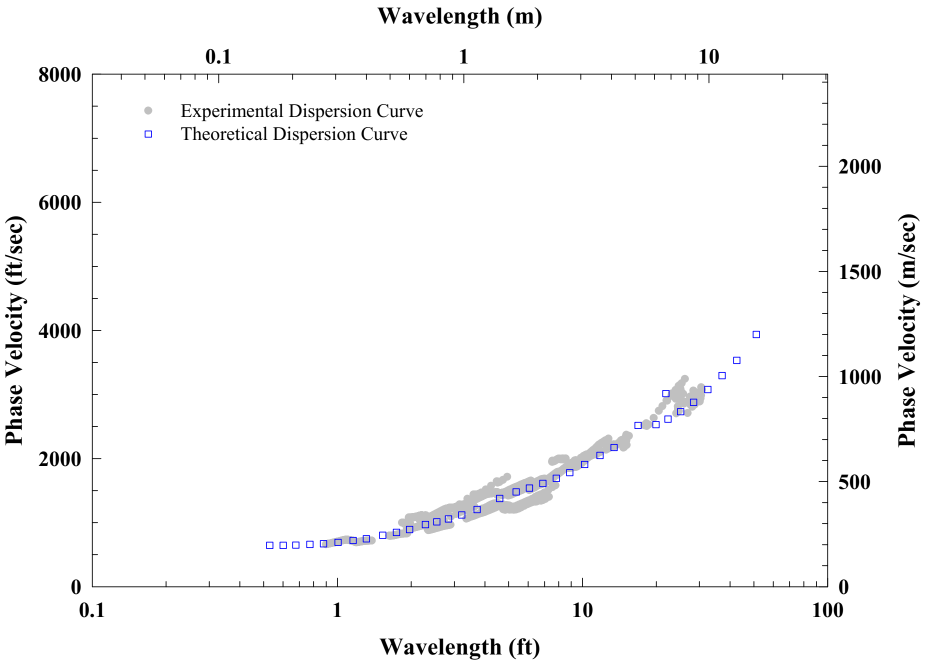
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-85. Shear Wave Velocity Profile Determined at ECRB-2-16+07



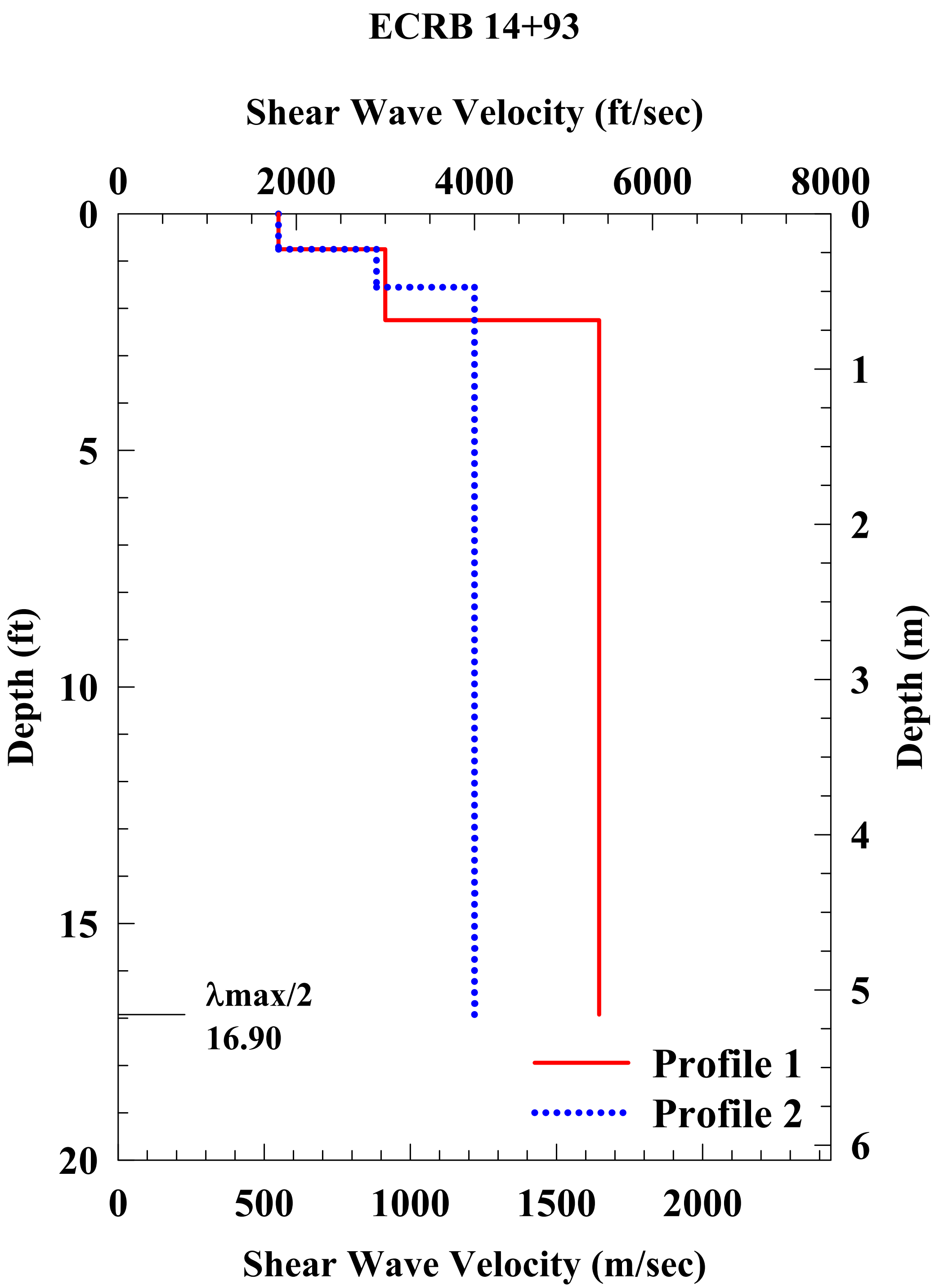
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-86. Experimental and Theoretical Dispersion Curves from ECRB-2-16+07; Linear Wavelength Axis



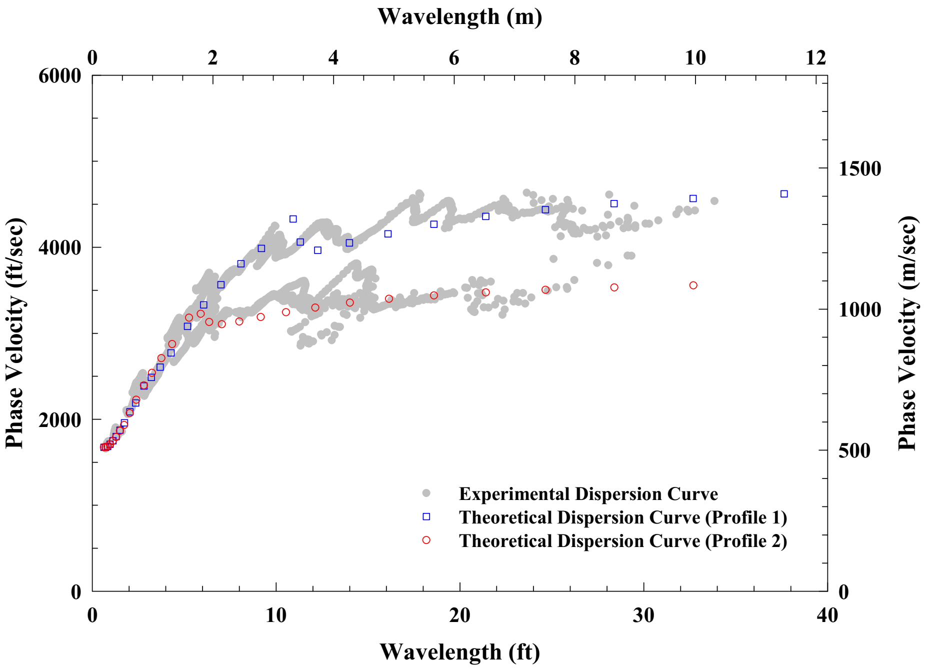
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-87. Experimental and Theoretical Dispersion Curves from ECRB-2-16+07; Logarithmic Wavelength Axis



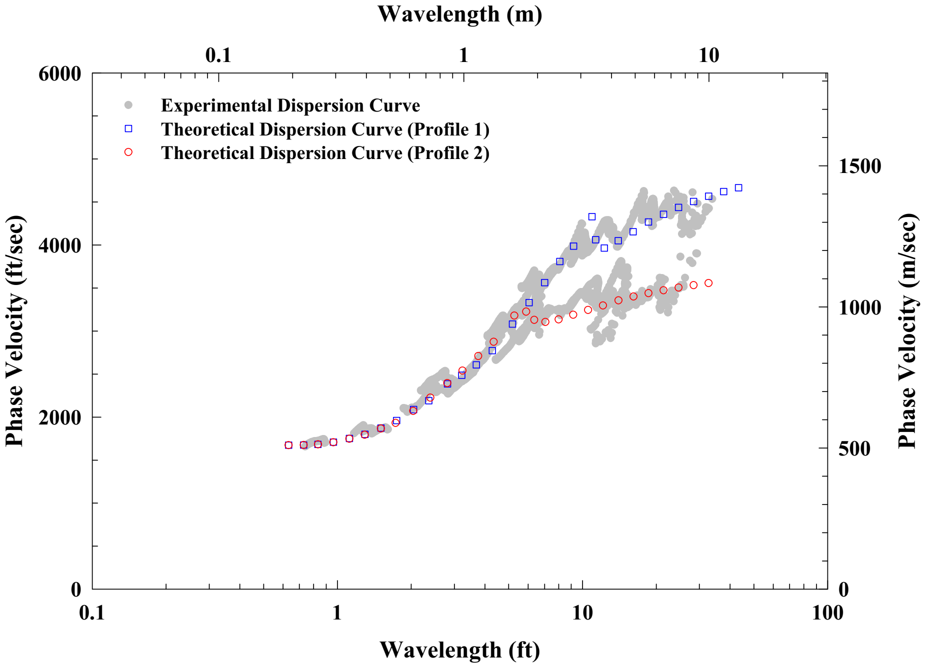
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-88. Shear Wave Velocity Profile Determined at ECRB 14+93



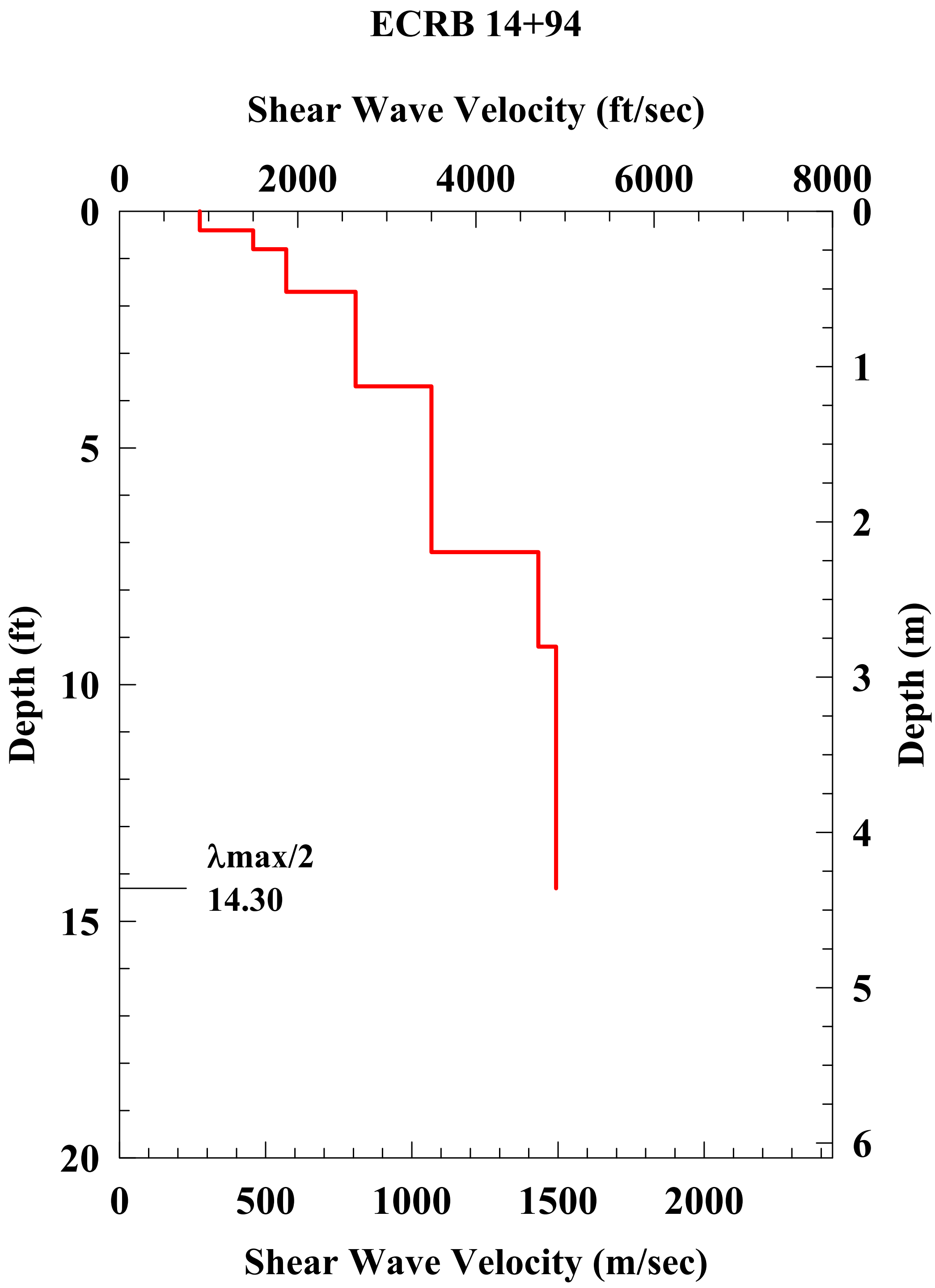
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-89. Experimental and Theoretical Dispersion Curves from ECRB 14+93; Linear Wavelength Axis



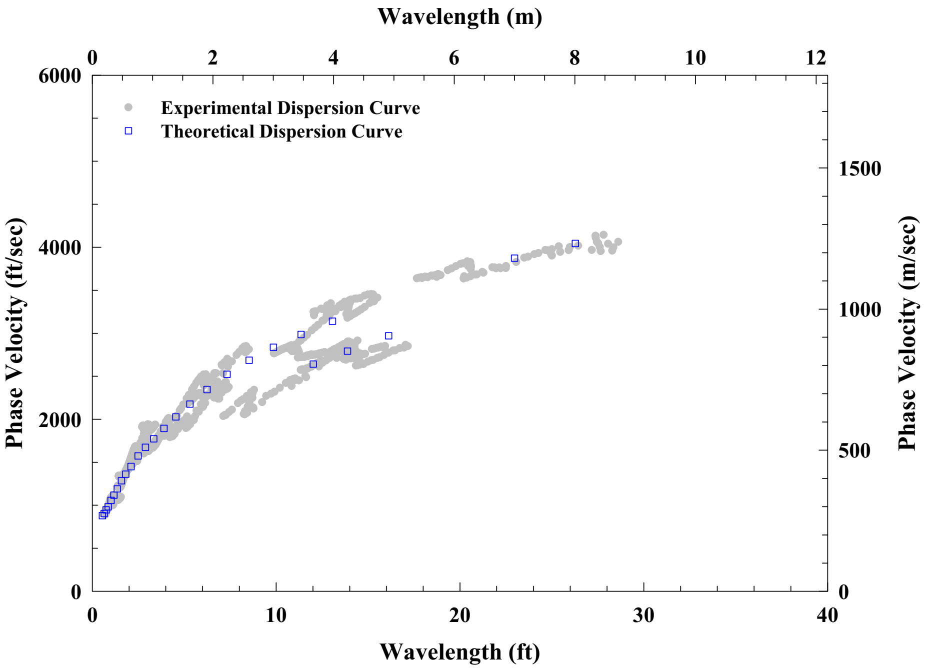
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-90. Experimental and Theoretical Dispersion Curves from ECRB 14+93; Logarithmic Wavelength Axis



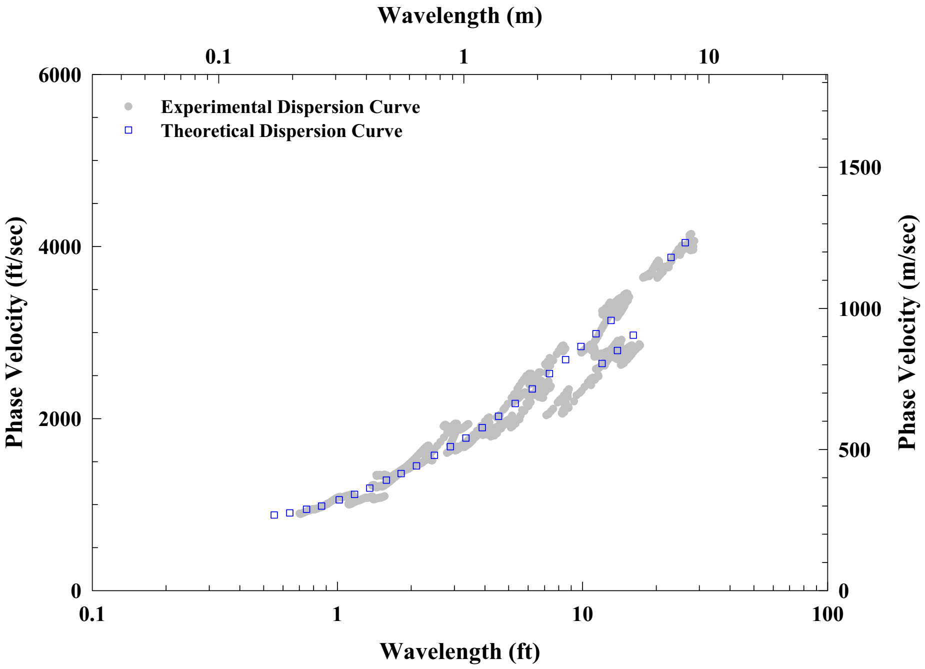
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-91. Shear Wave Velocity Profile Determined at ECRB 14+94



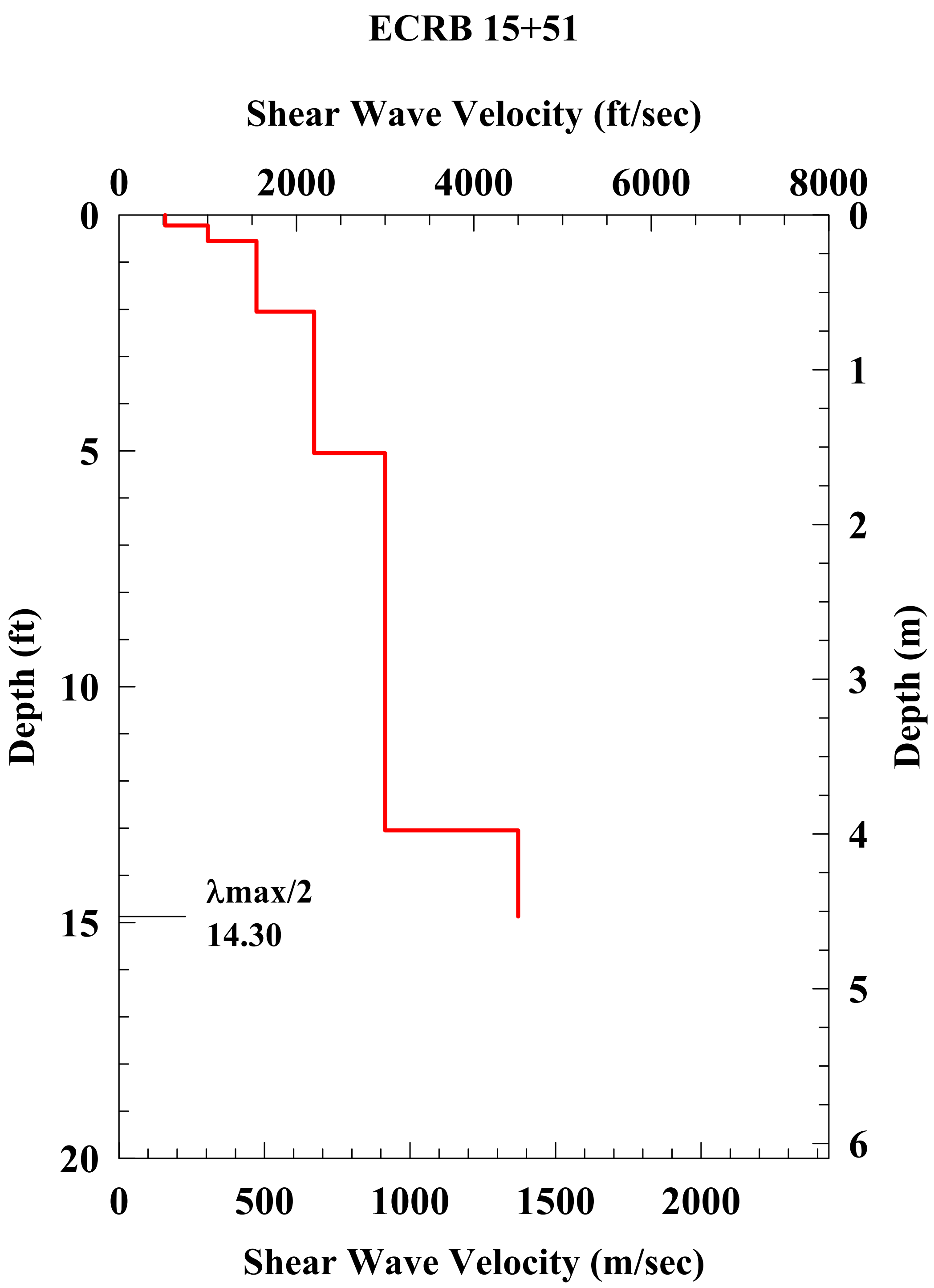
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-92. Experimental and Theoretical Dispersion Curves from ECRB 14+94; Linear Wavelength Axis



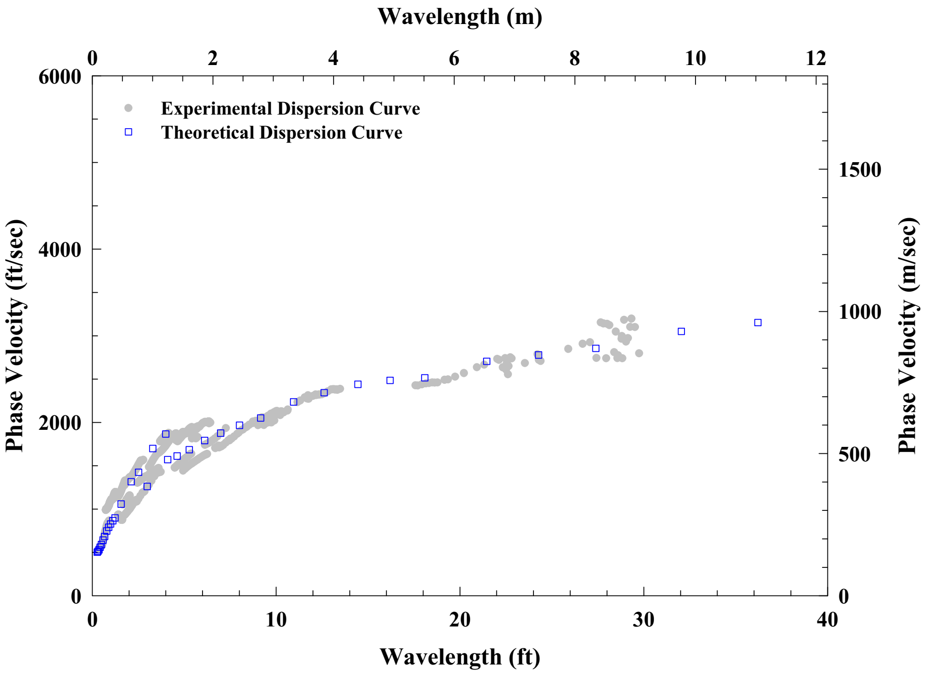
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-93. Experimental and Theoretical Dispersion Curves from ECRB 14+94; Logarithmic Wavelength Axis



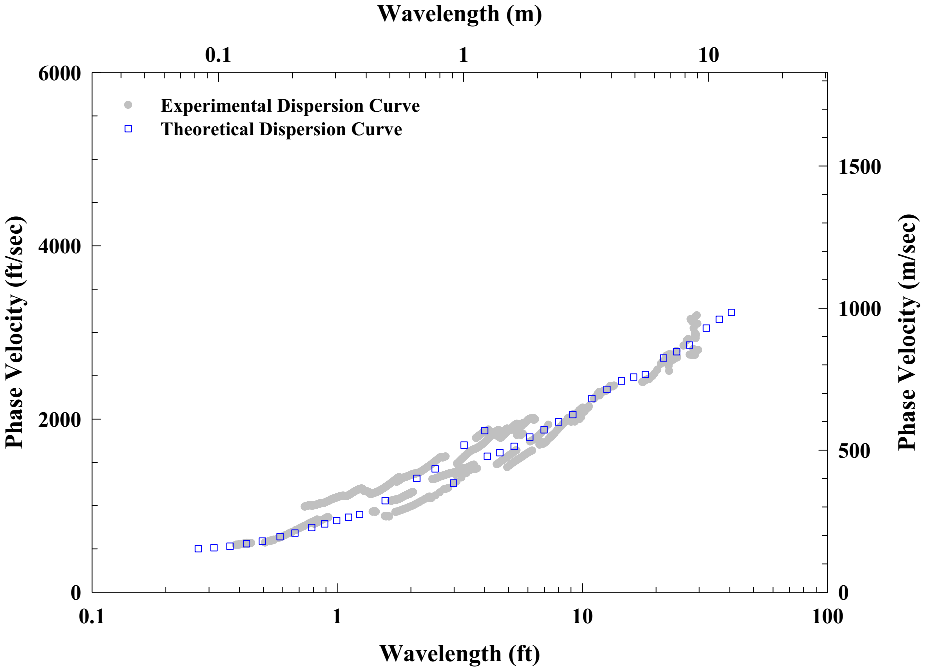
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-94. Shear Wave Velocity Profile Determined at ECRB 15+51



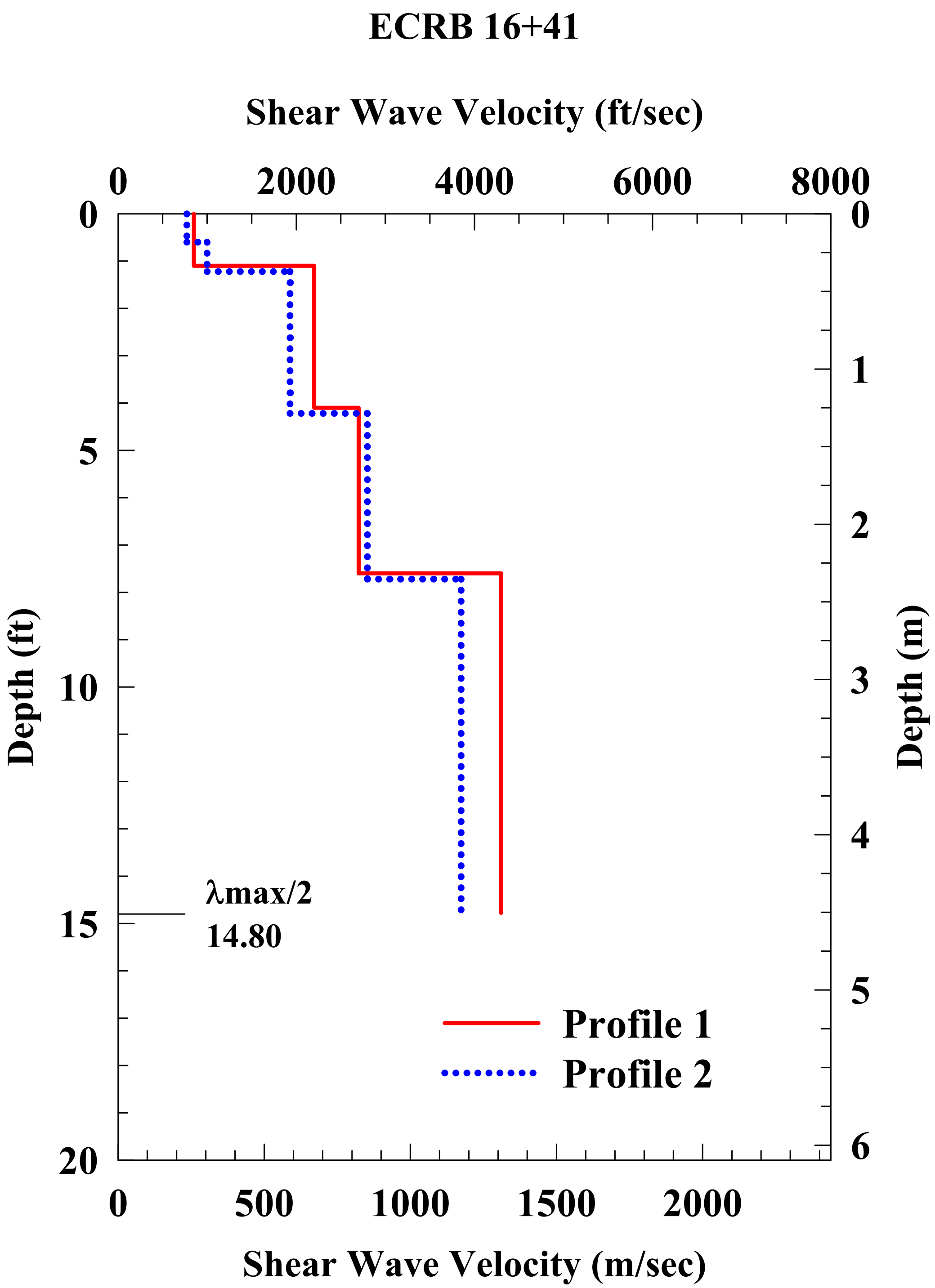
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-95. Experimental and Theoretical Dispersion Curves from ECRB 15+51; Linear Wavelength Axis



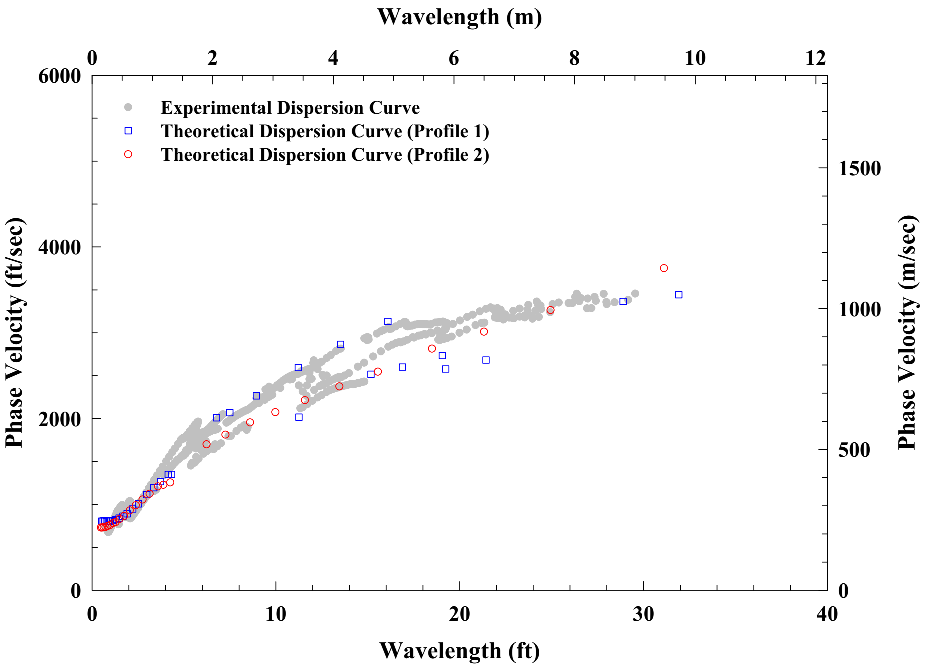
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-96. Experimental and Theoretical Dispersion Curves from ECRB 15+51; Logarithmic Wavelength Axis



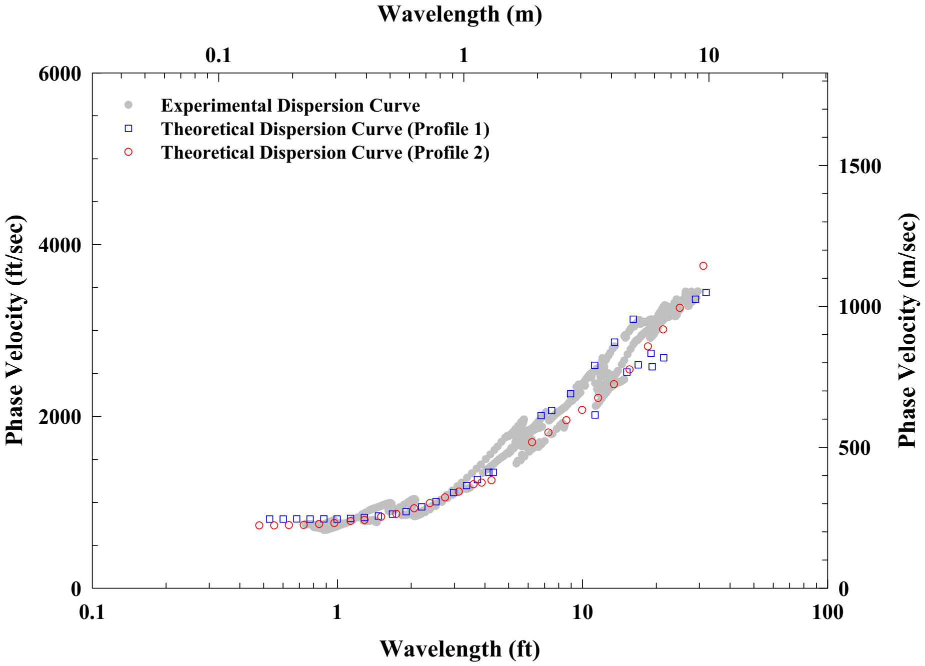
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-97. Shear Wave Velocity Profile Determined at ECRB 16+41



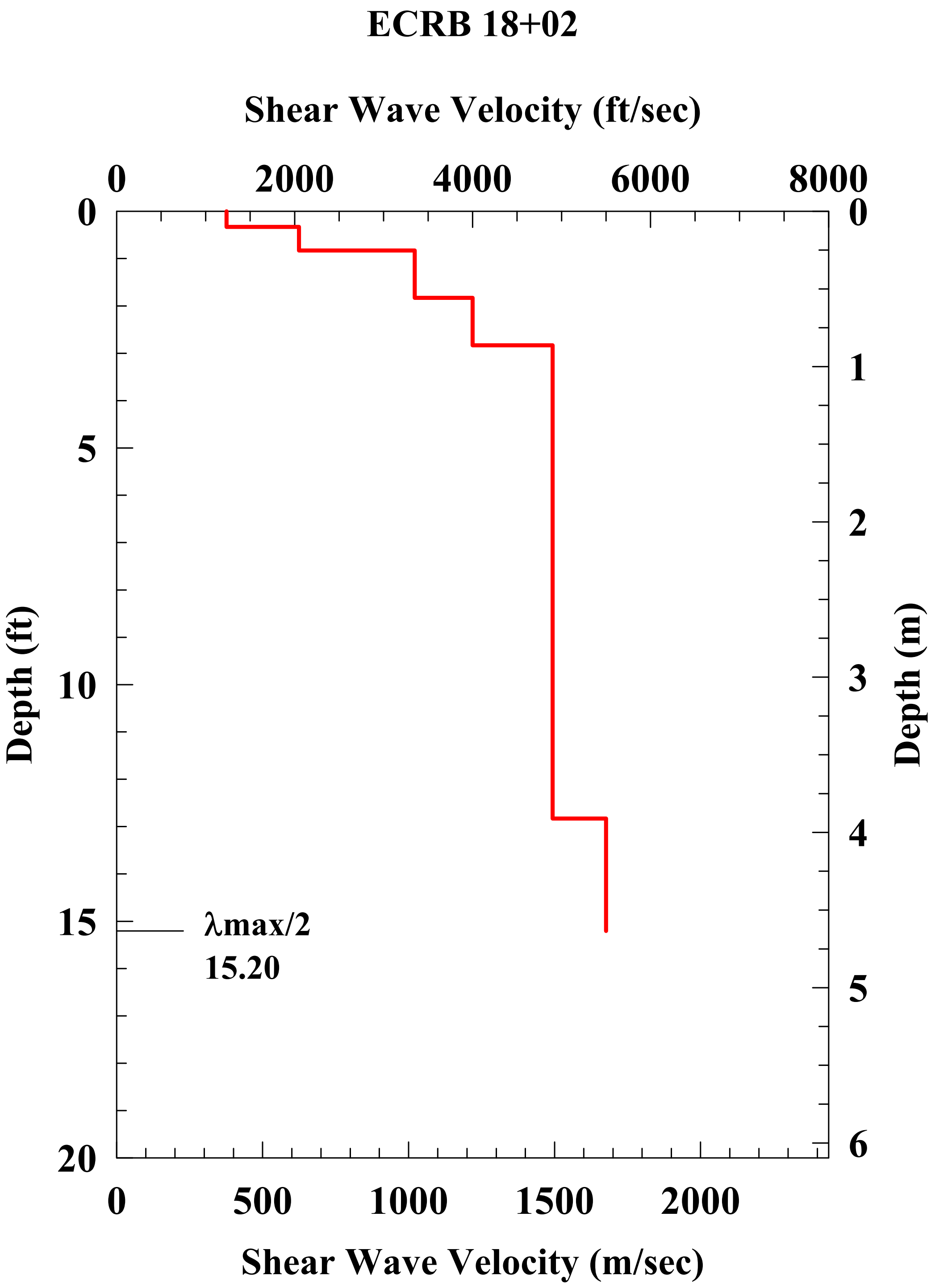
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-98. Experimental and Theoretical Dispersion Curves from ECRB 16+41; Linear Wavelength Axis



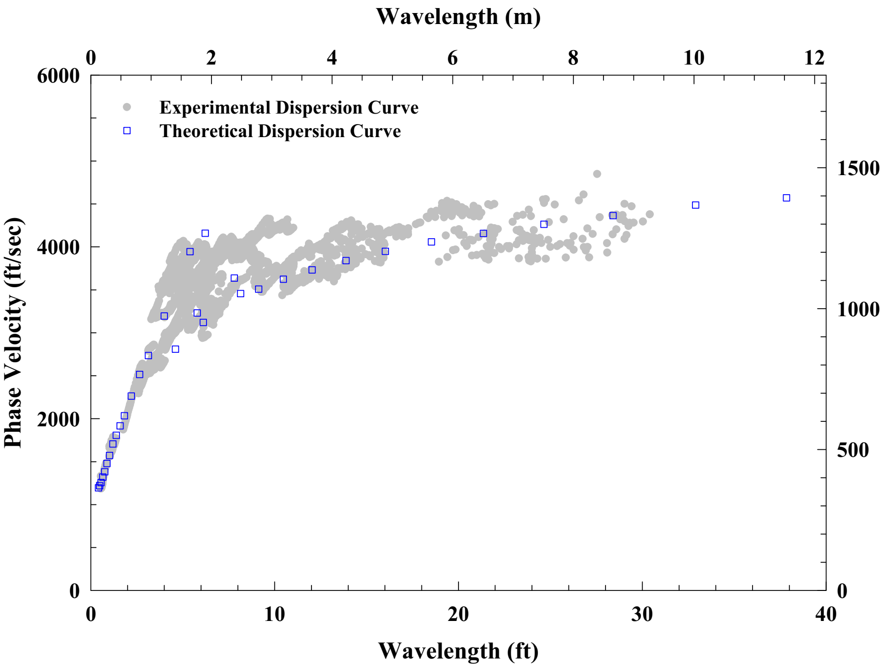
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-99. Experimental and Theoretical Dispersion Curves from ECRB 16+41; Logarithmic Wavelength Axis



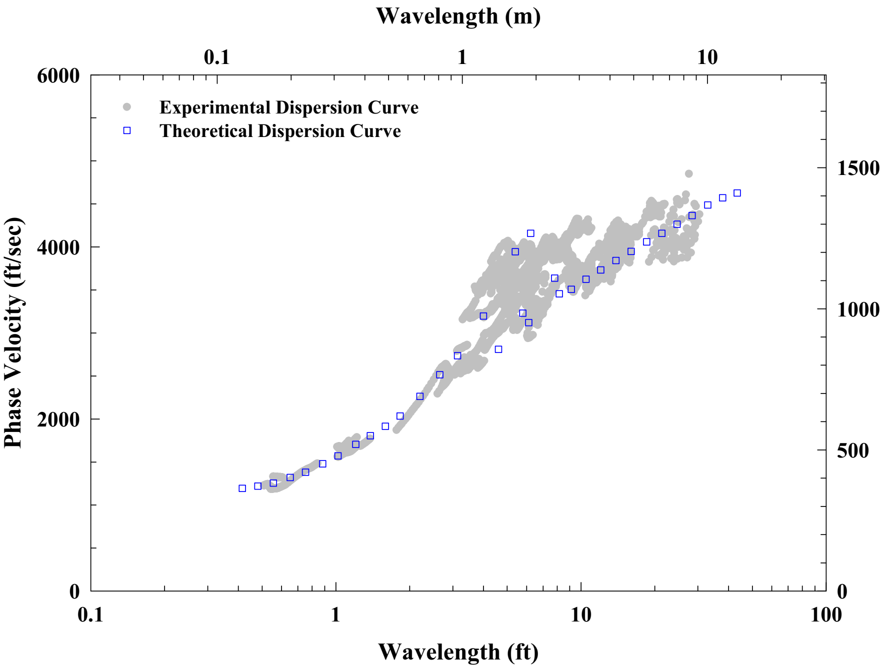
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-100. Shear Wave Velocity Profile Determined at ECRB 18+02



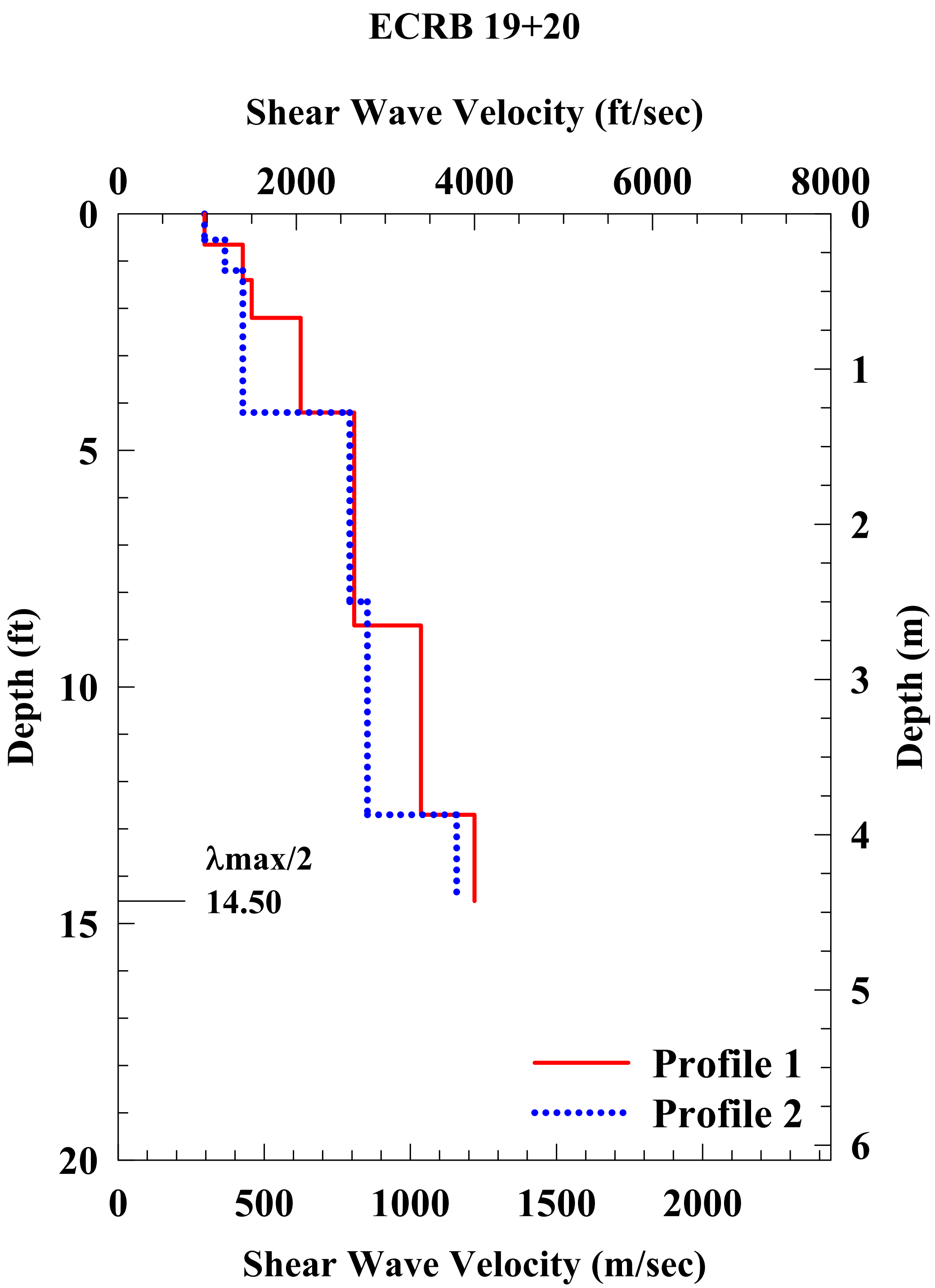
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-101. Experimental and Theoretical Dispersion Curves from ECRB 18+02; Linear Wavelength Axis



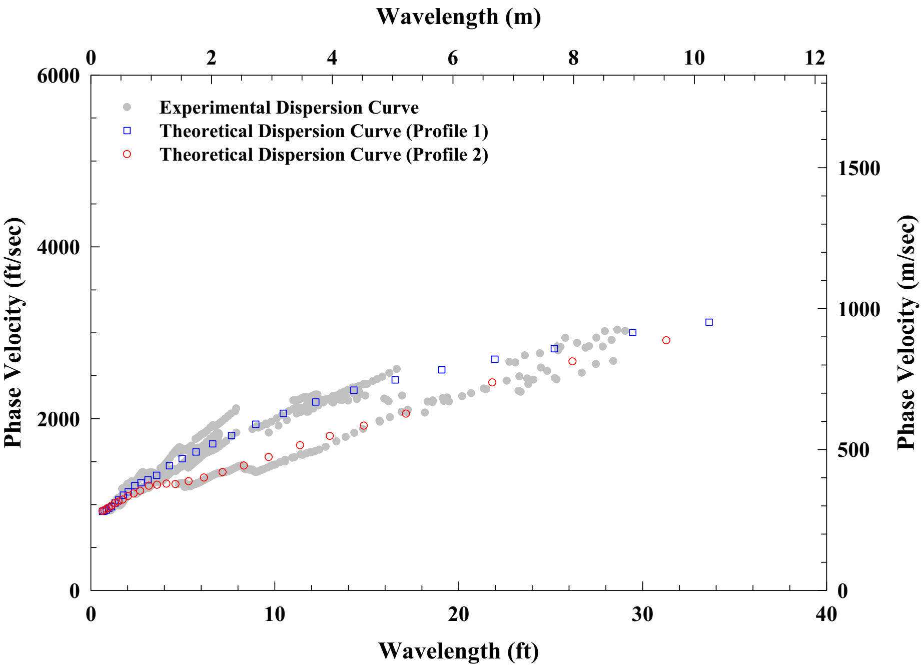
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-102. Experimental and Theoretical Dispersion Curves from ECRB 18+02; Logarithmic Wavelength Axis



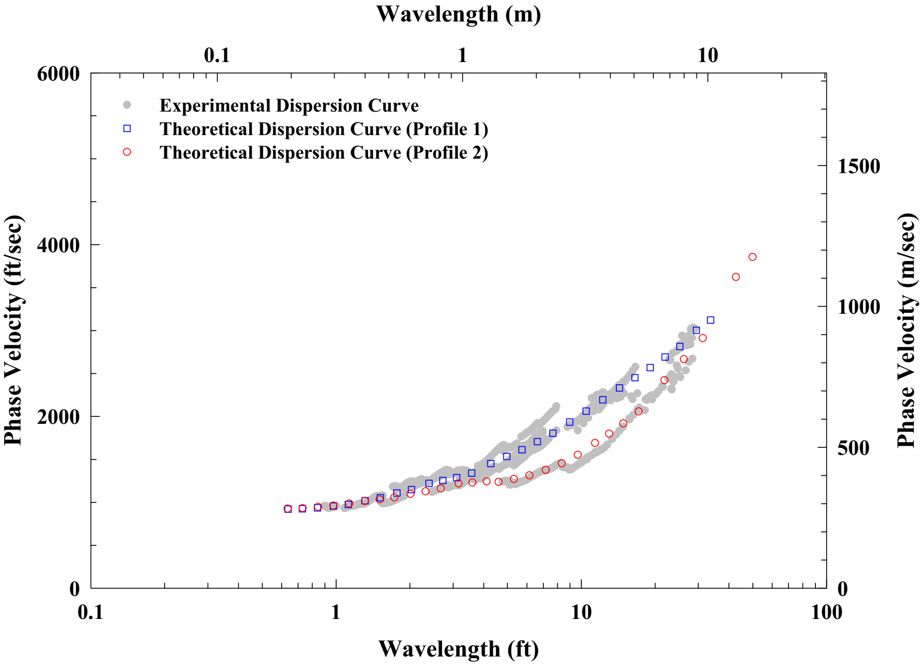
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-103. Shear Wave Velocity Profile Determined at ECRB 19+20



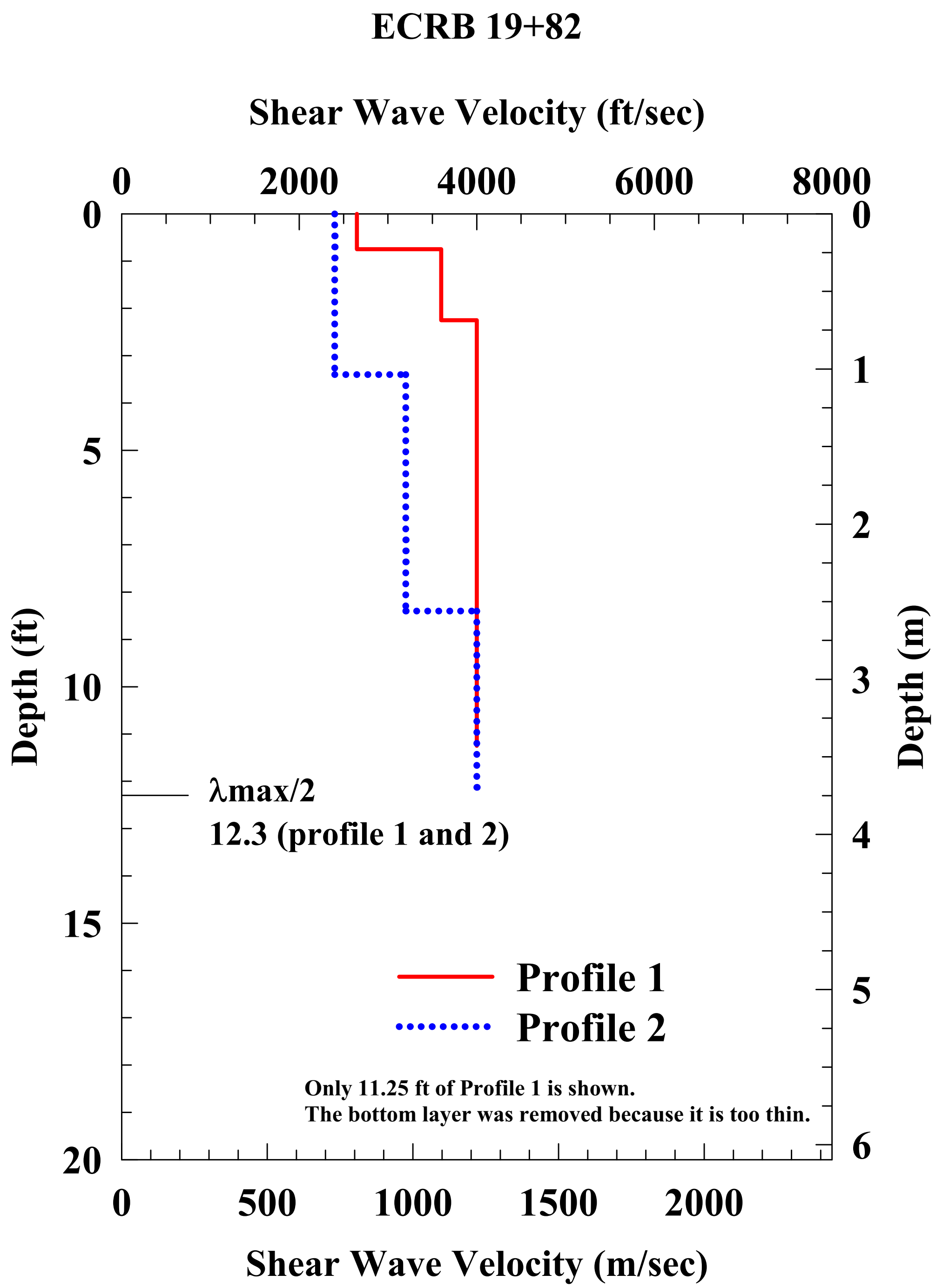
Source:	DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-104. Experimental and Theoretical Dispersion Curves from ECRB 19+20; Linear Wavelength Axis



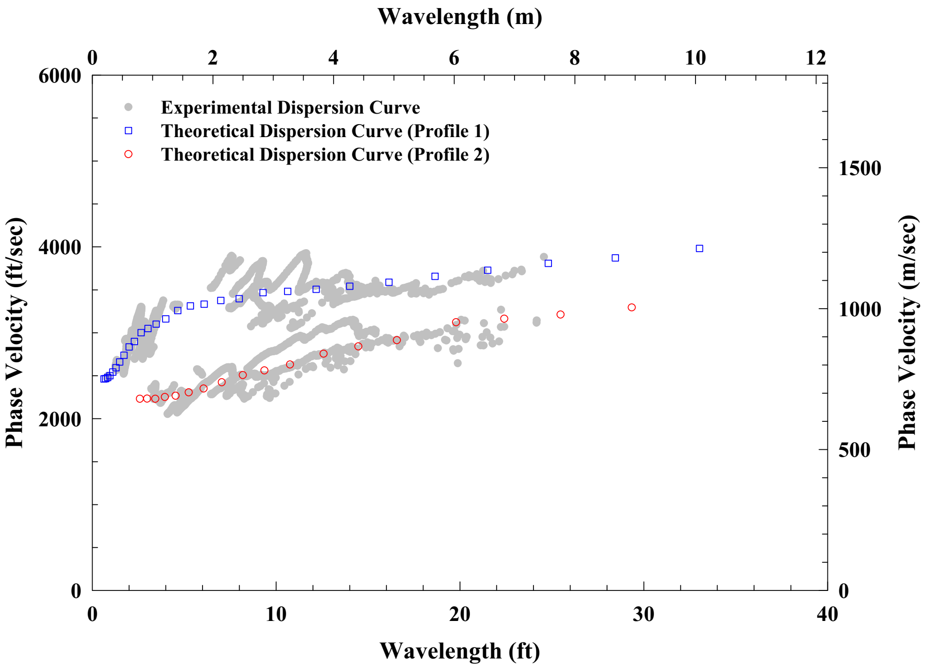
Source:	DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-105. Experimental and Theoretical Dispersion Curves from ECRB 19+20; Logarithmic Wavelength Axis



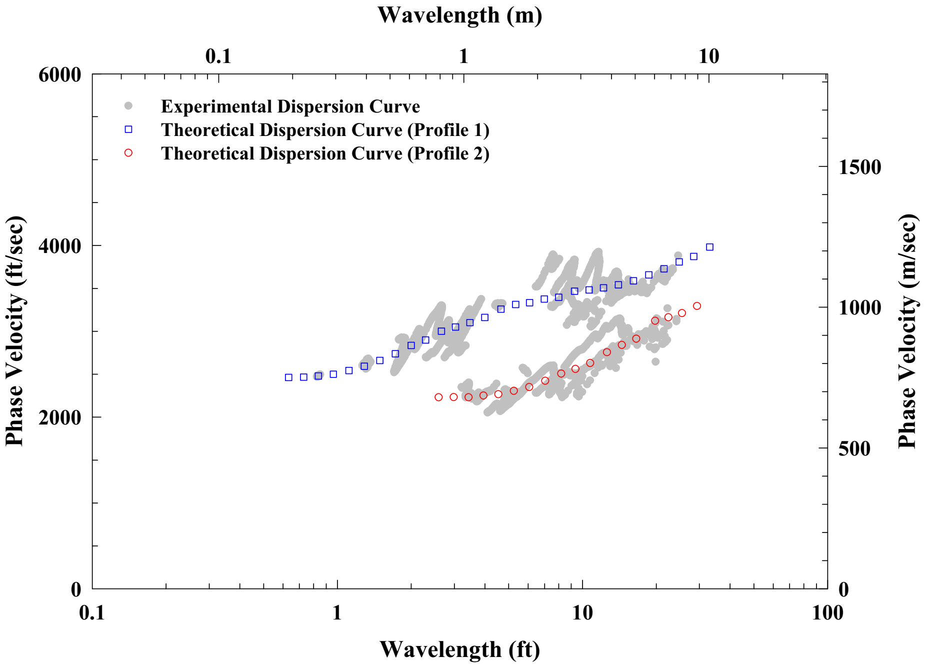
Source:	DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-106.   Shear Wave Velocity Profile Determined at ECRB 19+82



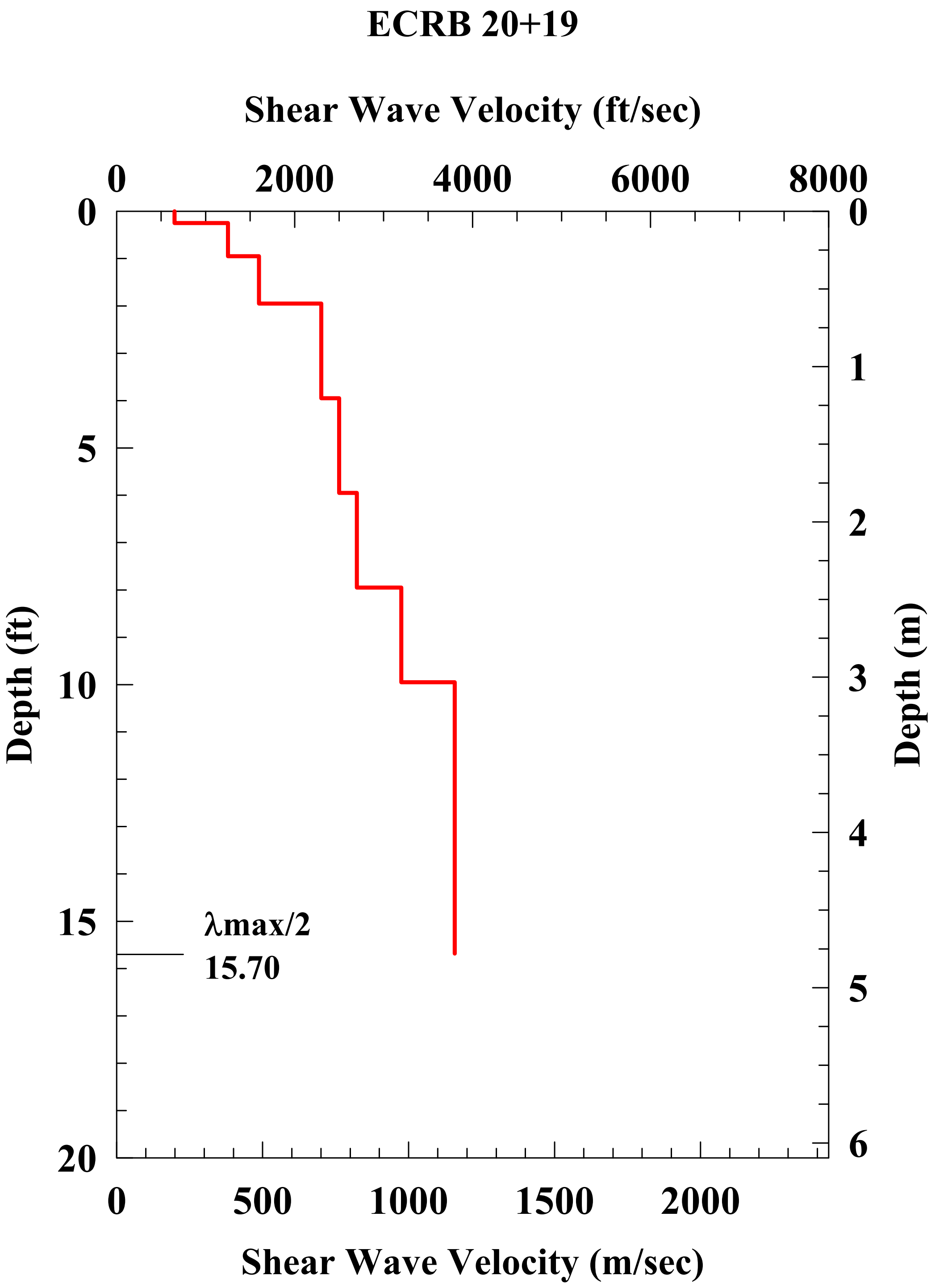
Source: DTN:MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-107. Experimental and Theoretical Dispersion Curves from ECRB 19+82; Linear Wavelength Axis



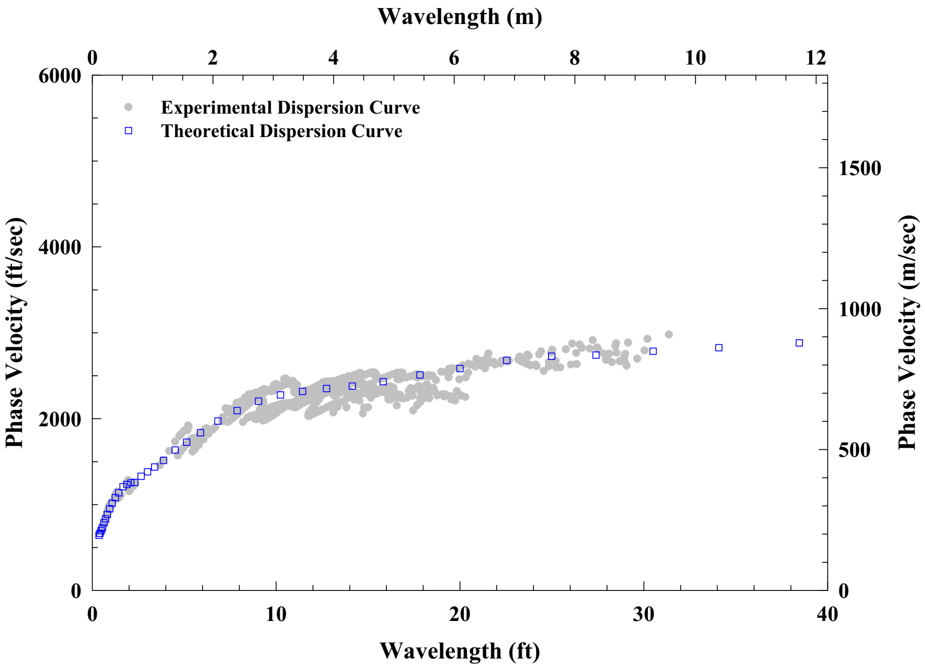
Source: DTN:MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-108. Experimental and Theoretical Dispersion Curves from ECRB 19+82; Logarithmic Wavelength Axis



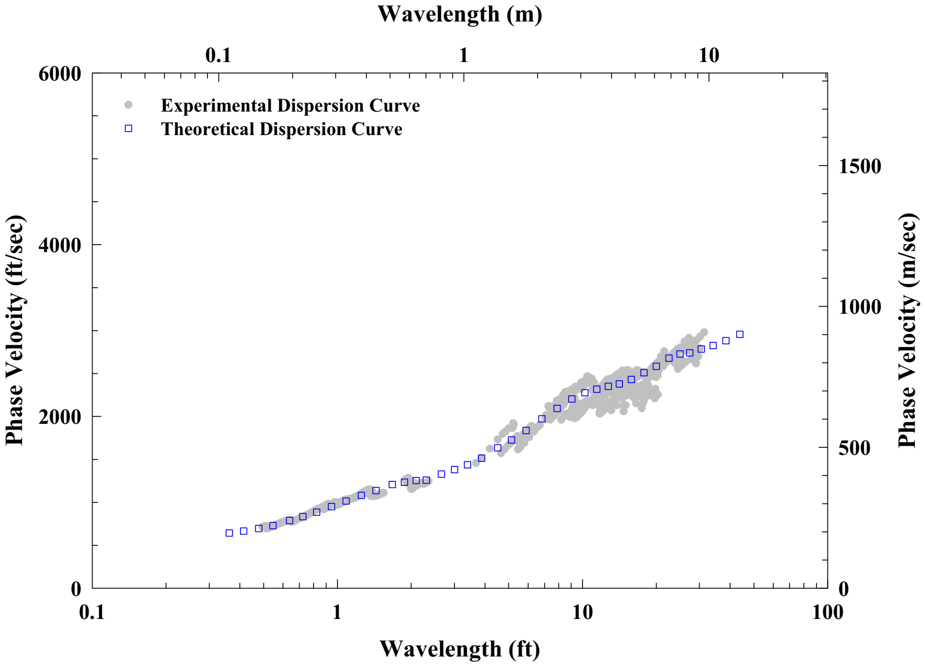
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-109. Shear Wave Velocity Profile Determined at ECRB 20+19



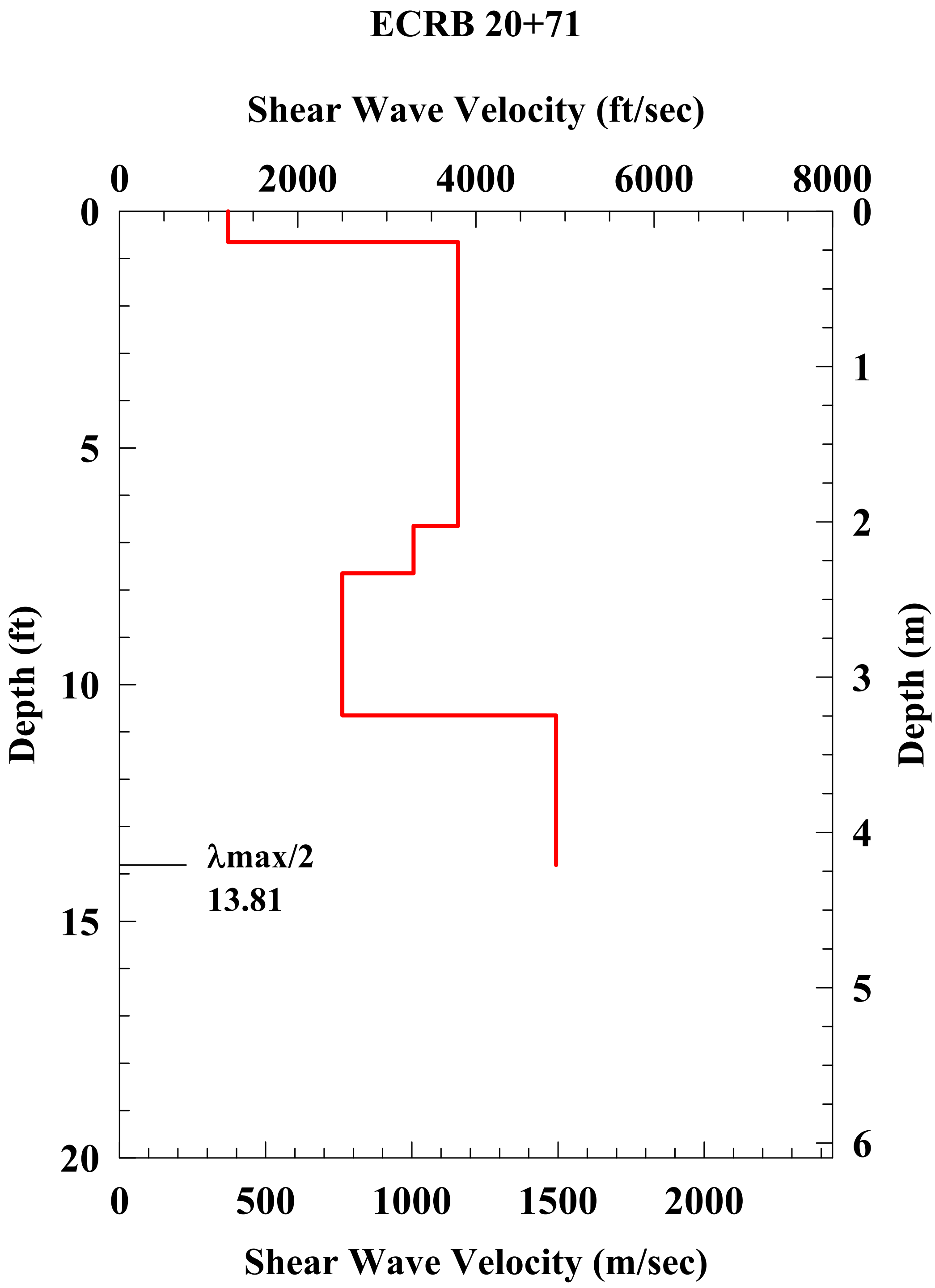
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-110. Experimental and Theoretical Dispersion Curves from ECRB 20+19; Linear Wavelength Axis



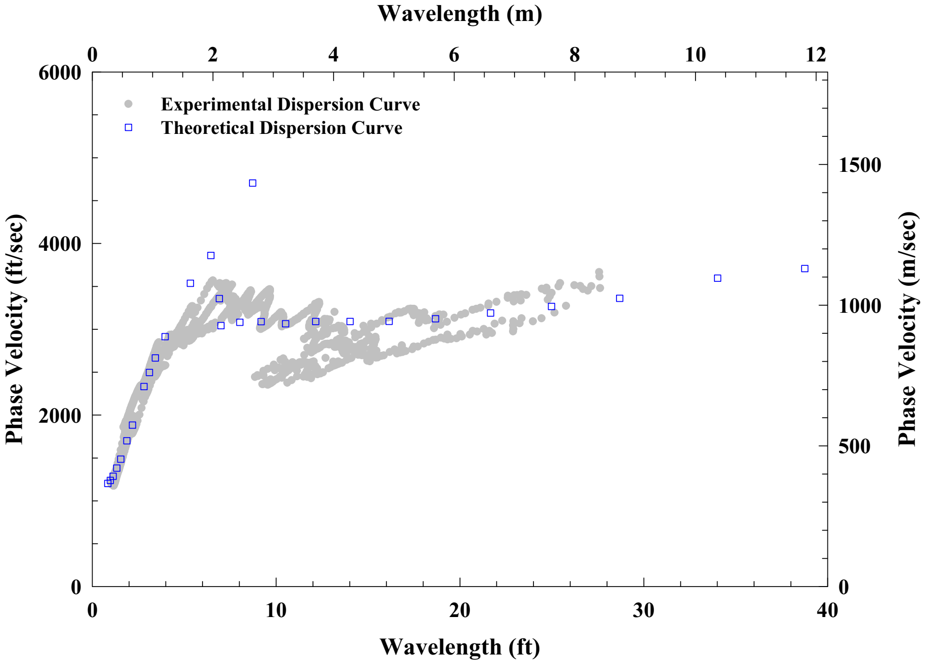
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-111. Experimental and Theoretical Dispersion Curves from ECRB 20+19; Logarithmic Wavelength Axis



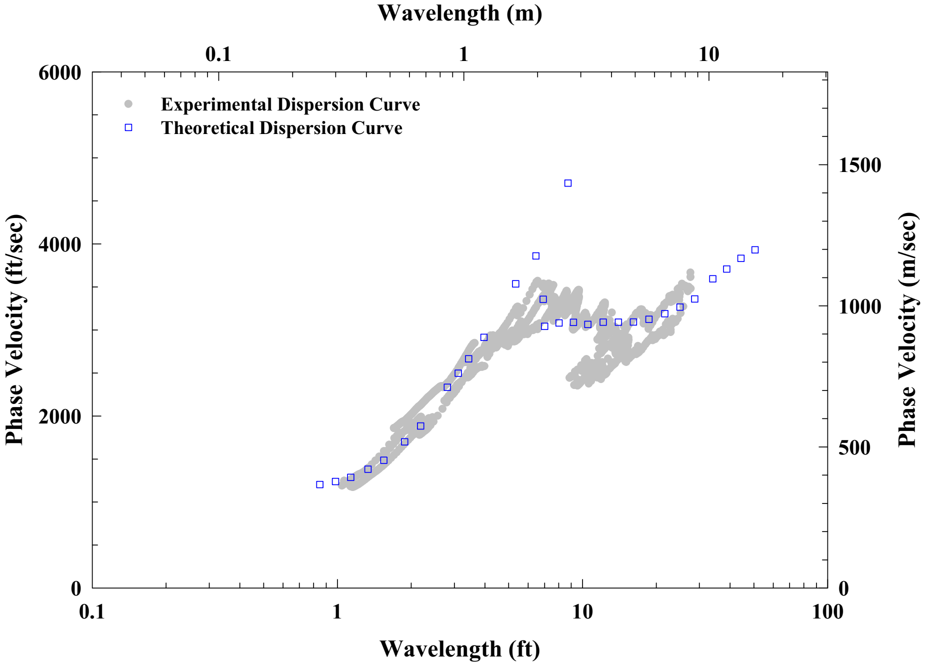
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-112. Shear Wave Velocity Profile Determined at ECRB 20+71



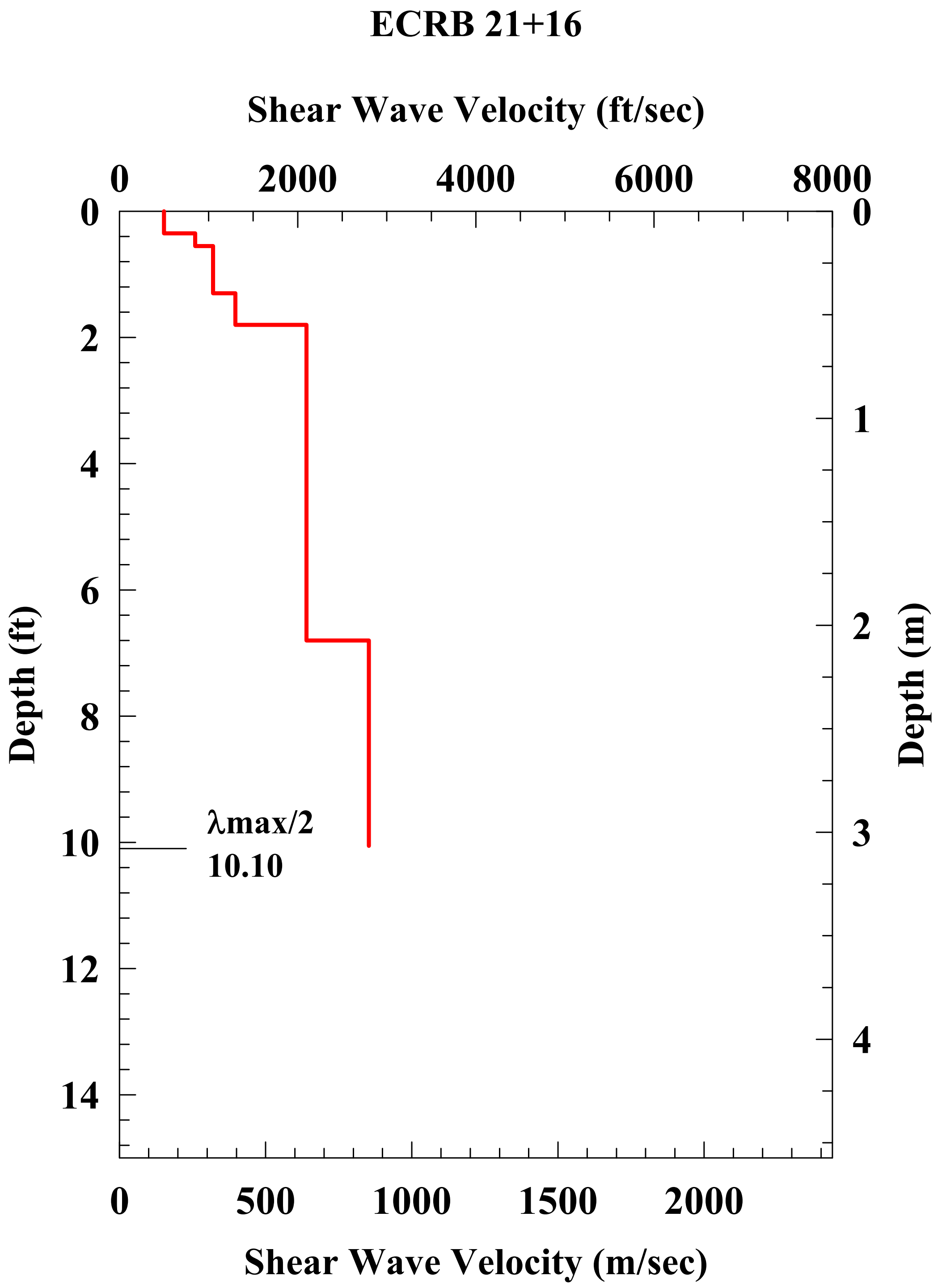
Source: DTN:MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-113. Experimental and Theoretical Dispersion Curves from ECRB 20+71; Linear Wavelength Axis



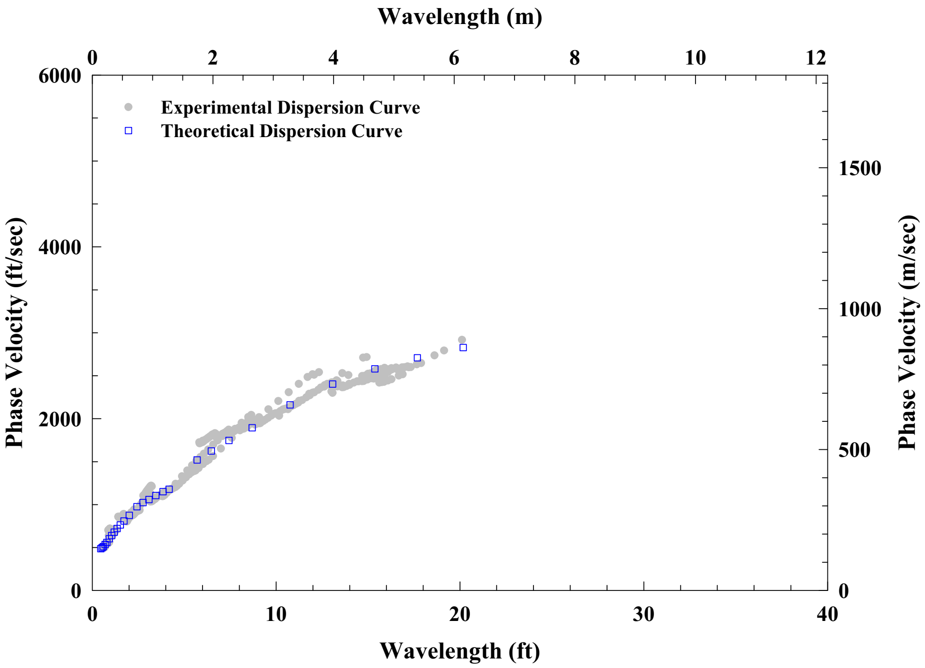
Source: DTN:MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-114. Experimental and Theoretical Dispersion Curves from ECRB 20+71; Logarithmic Wavelength Axis



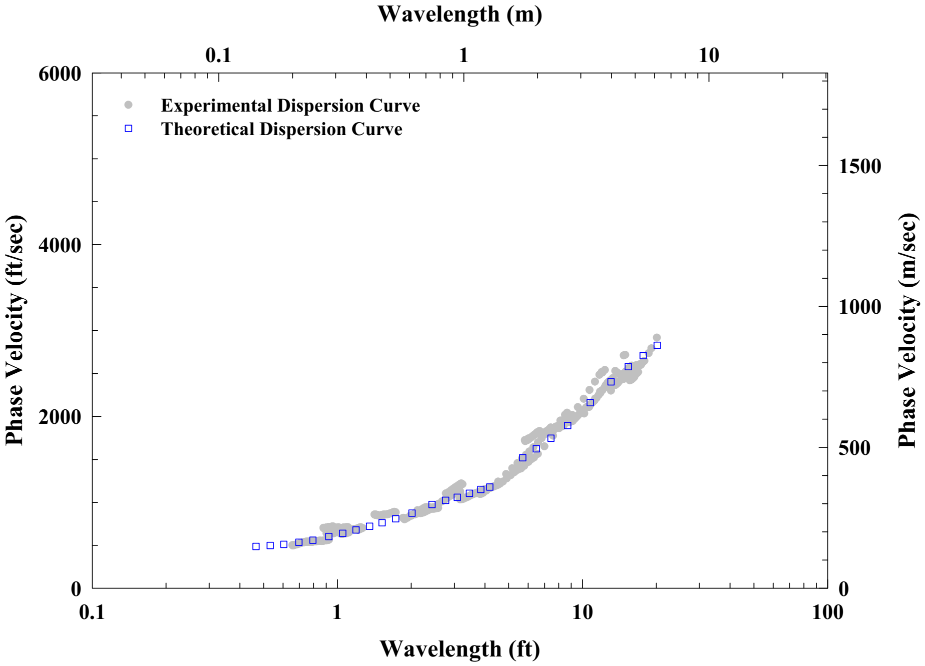
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-115. Shear Wave Velocity Profile Determined at ECRB 21+16



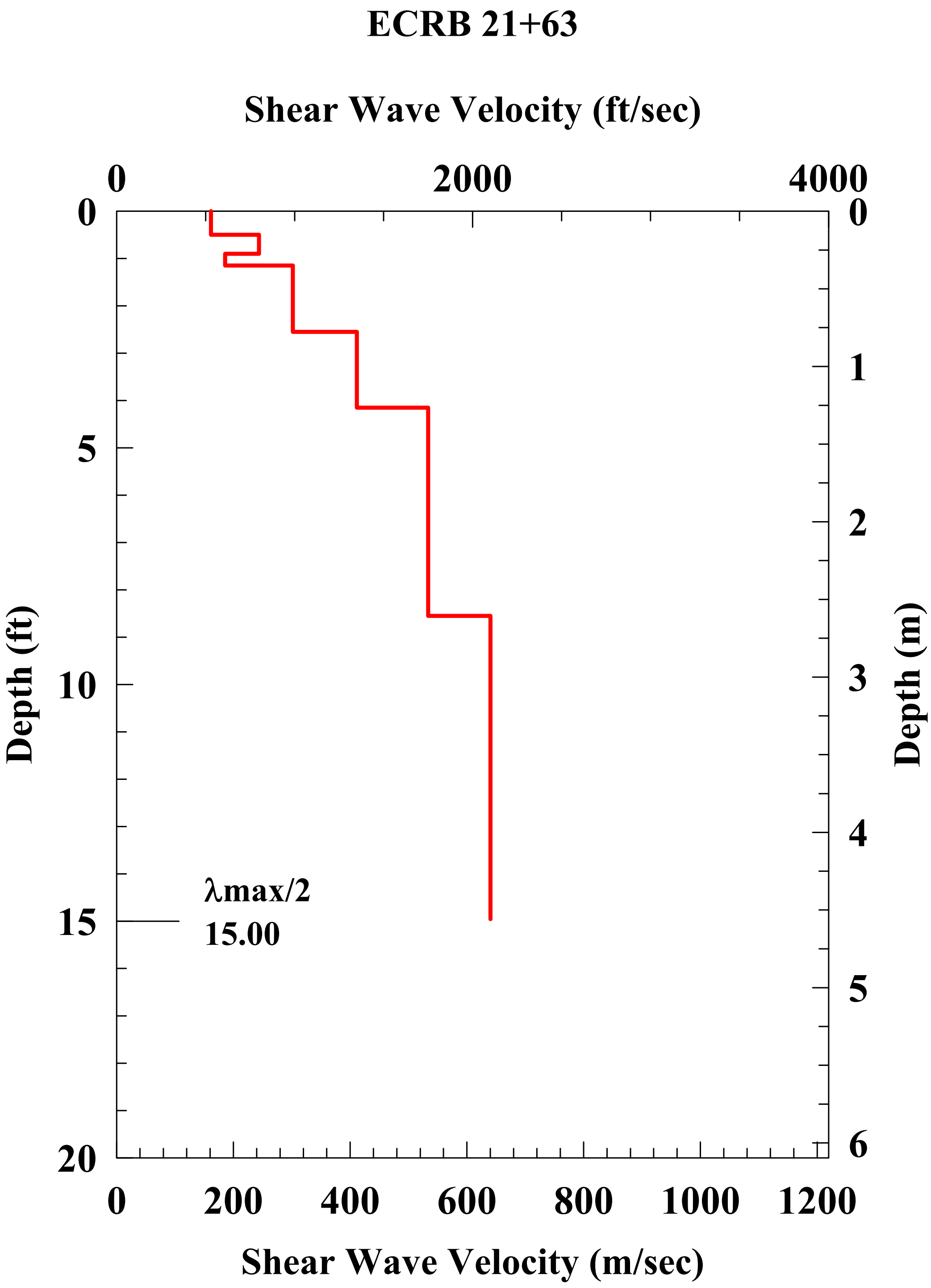
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-116. Experimental and Theoretical Dispersion Curves from ECRB 21+16; Linear Wavelength Axis



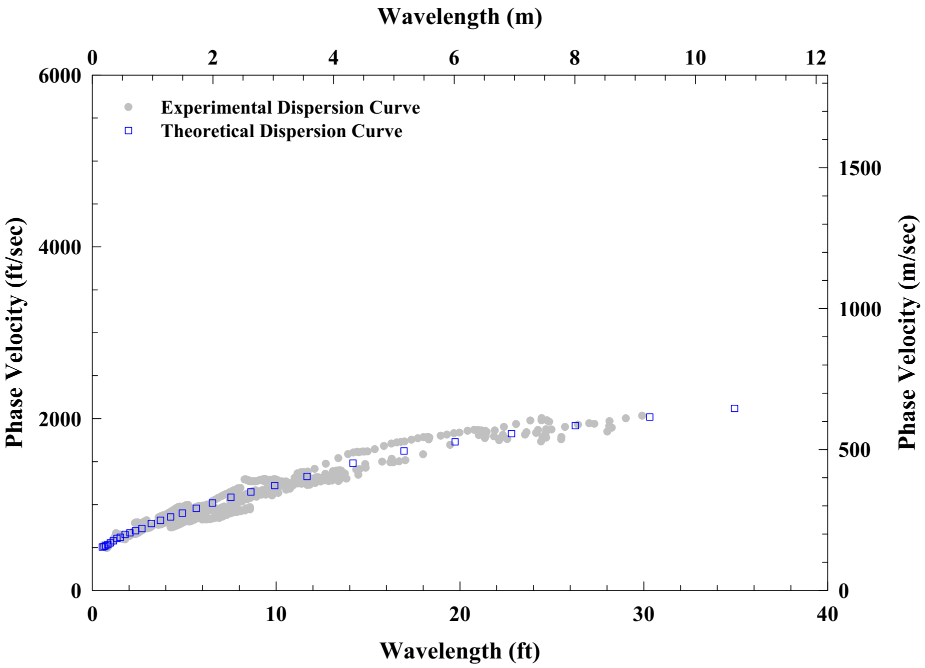
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-117. Experimental and Theoretical Dispersion Curves from ECRB 21+16; Logarithmic Wavelength Axis



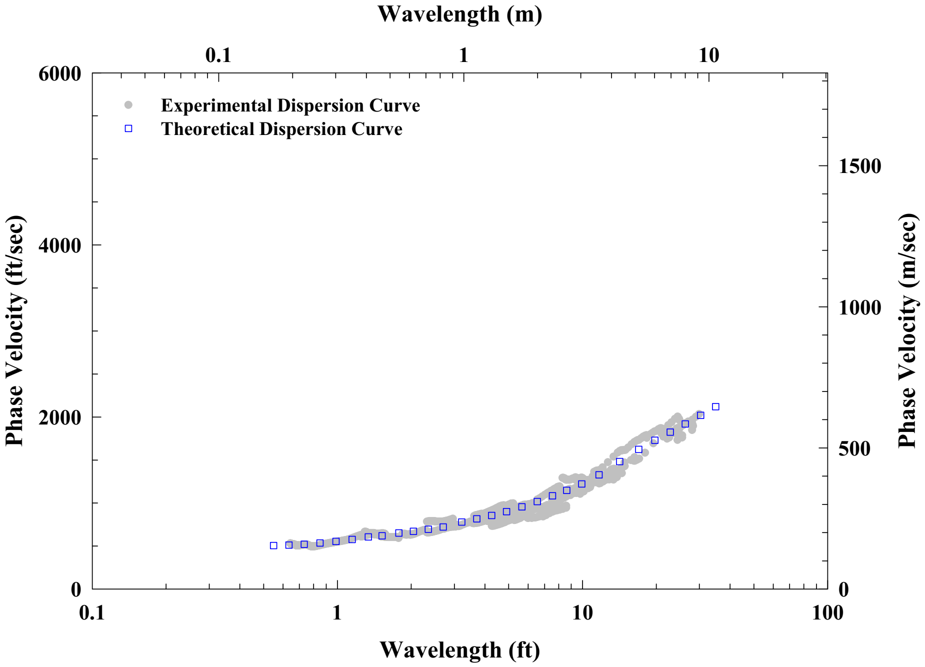
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-118. Shear Wave Velocity Profile Determined at ECRB 21+63



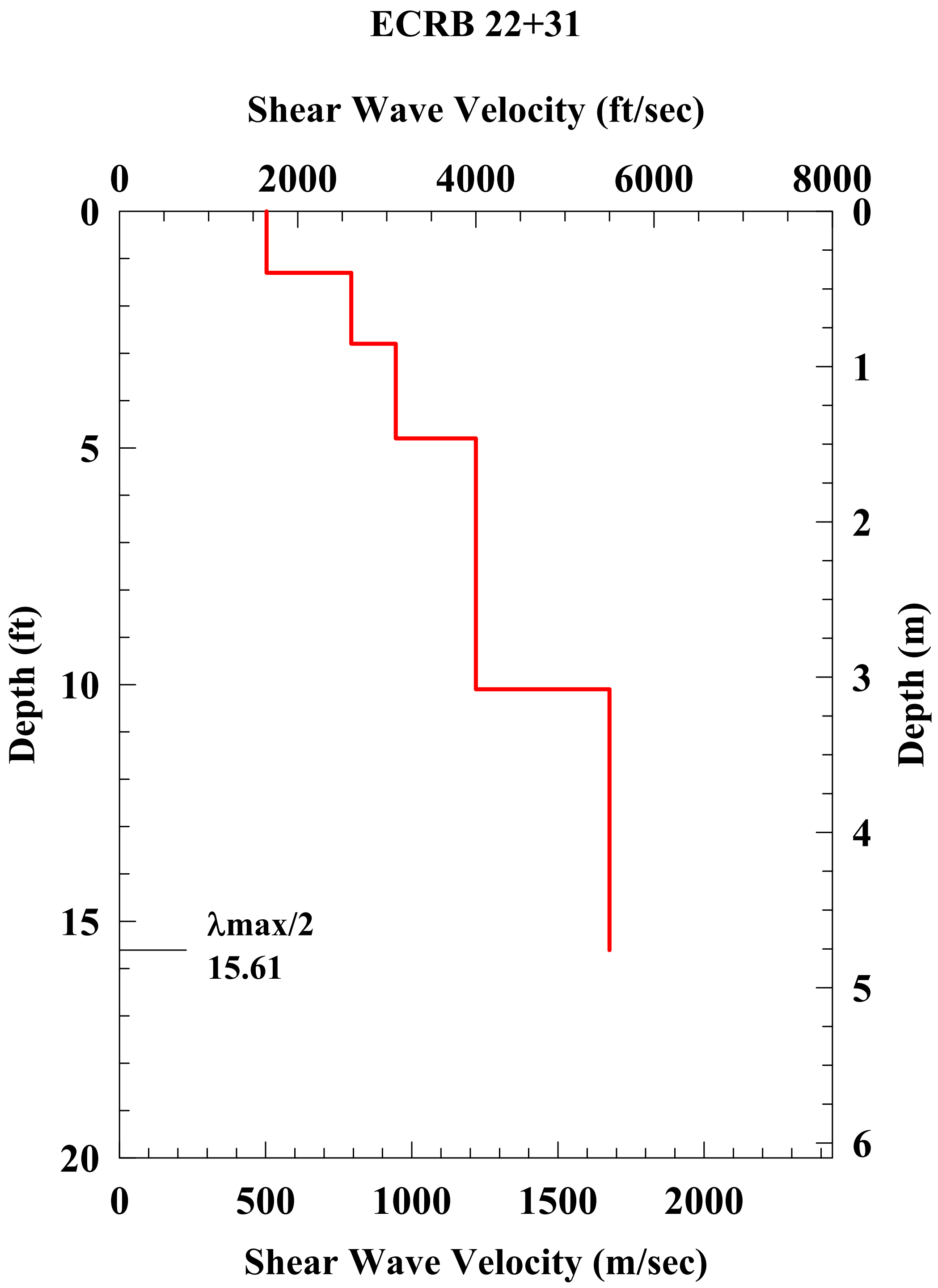
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-119. Experimental and Theoretical Dispersion Curves from ECRB 21+63; Linear Wavelength Axis



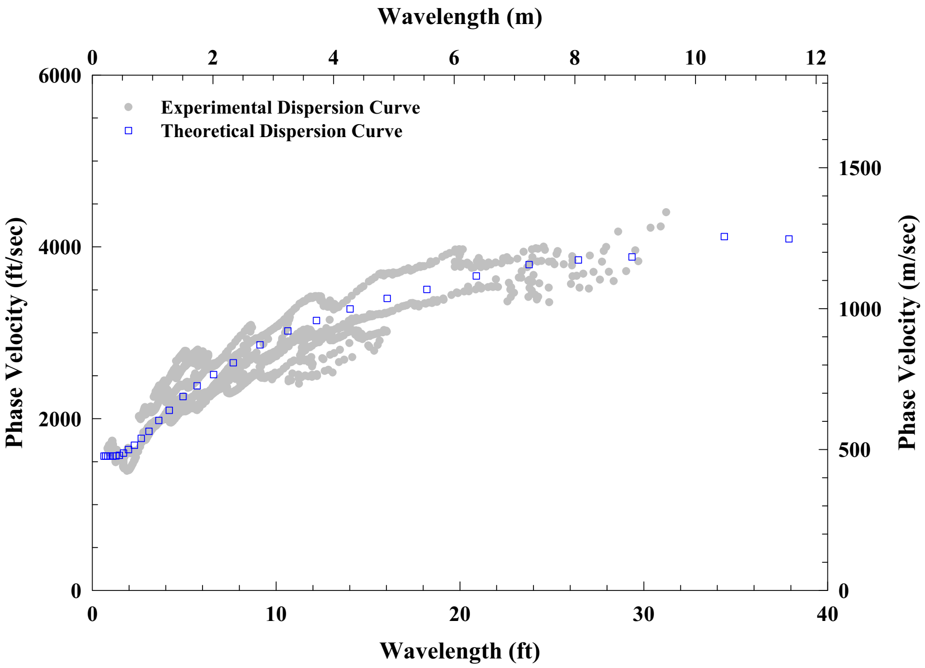
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-120. Experimental and Theoretical Dispersion Curves from ECRB 21+63; Logarithmic Wavelength Axis



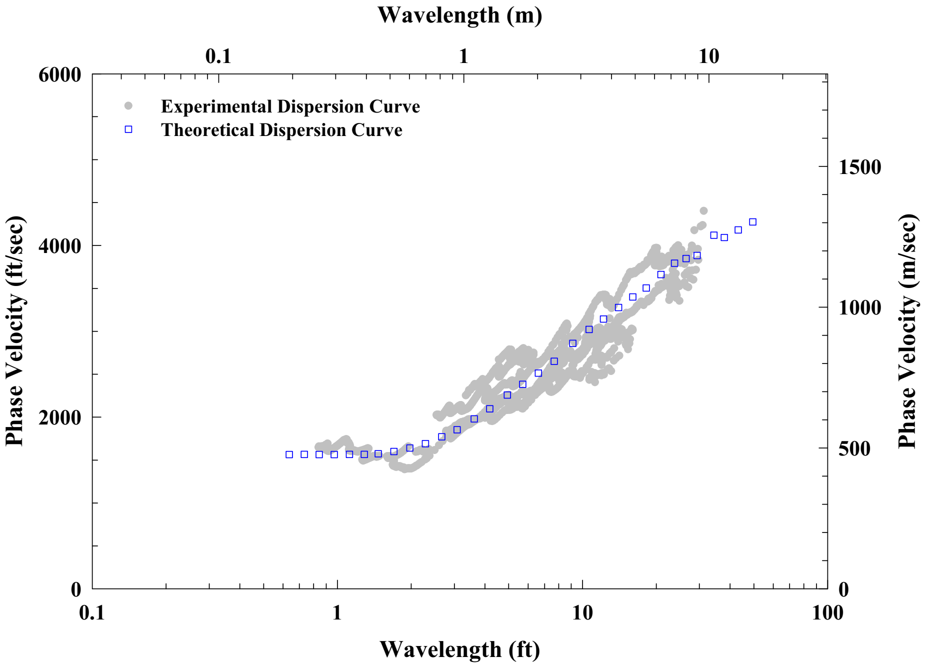
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-121. Shear Wave Velocity Profile Determined at ECRB 22+31



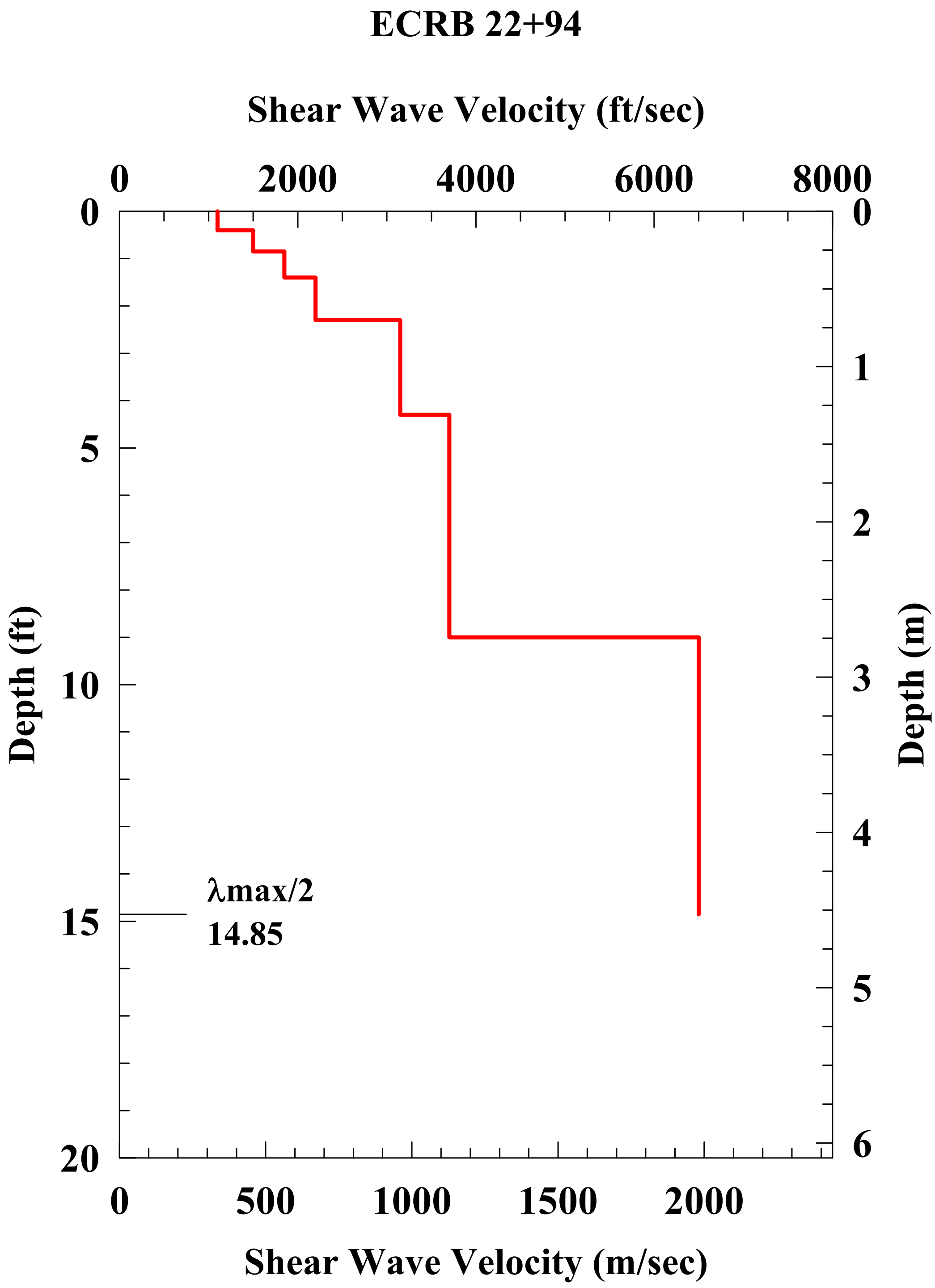
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-122. Experimental and Theoretical Dispersion Curves from ECRB 22+31; Linear Wavelength Axis



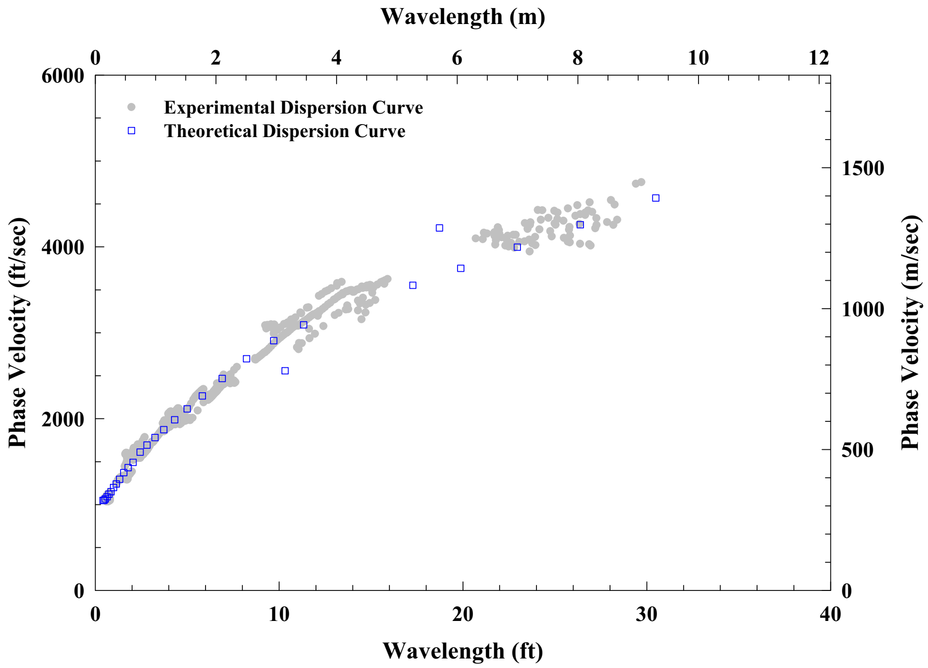
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-123. Experimental and Theoretical Dispersion Curves from ECRB 22+31; Logarithmic Wavelength Axis



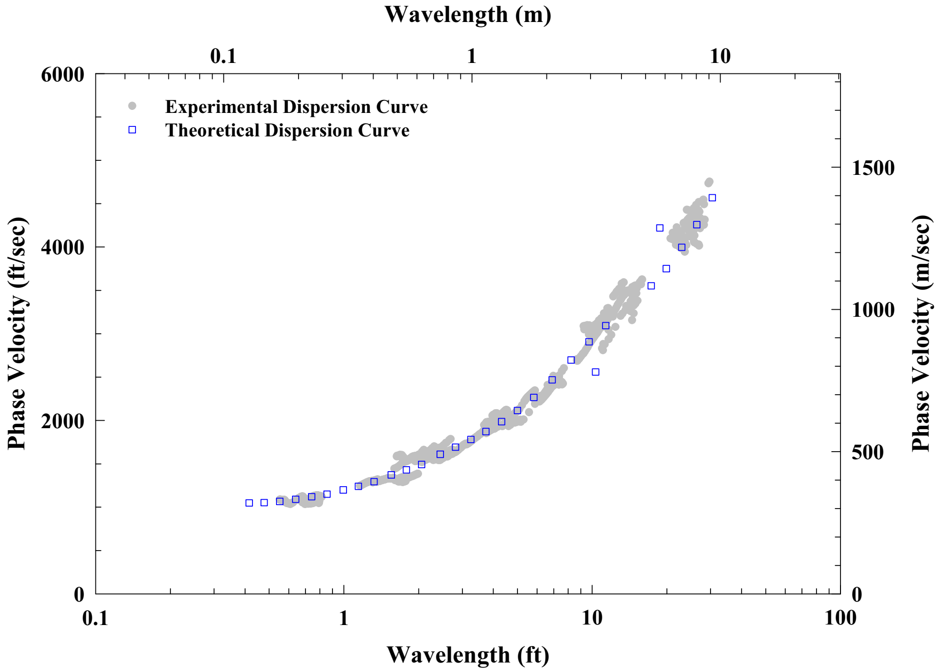
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-124. Shear Wave Velocity Profile Determined at ECRB 22+94



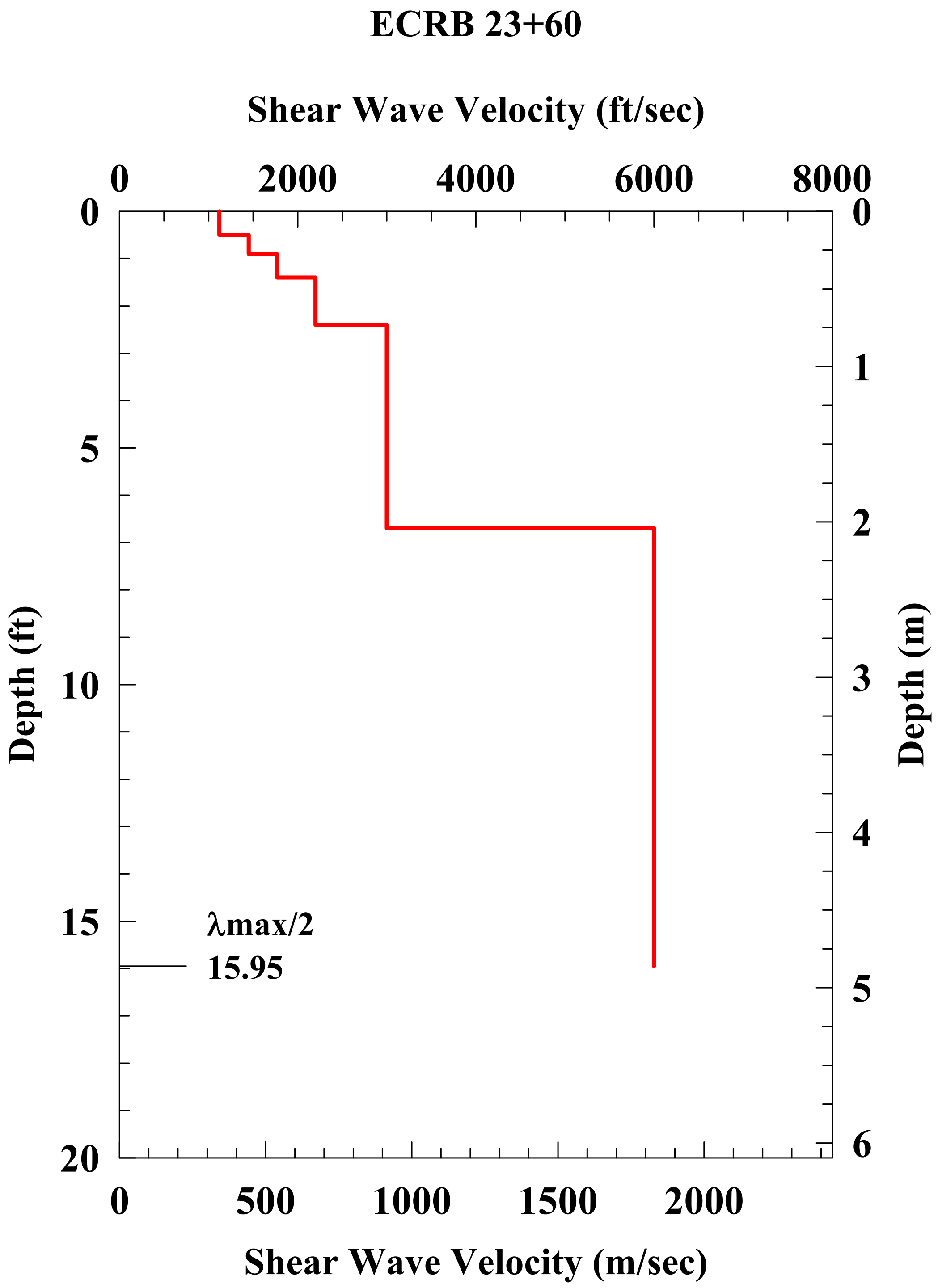
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-125. Experimental and Theoretical Dispersion Curves from ECRB 22+94; Linear Wavelength Axis



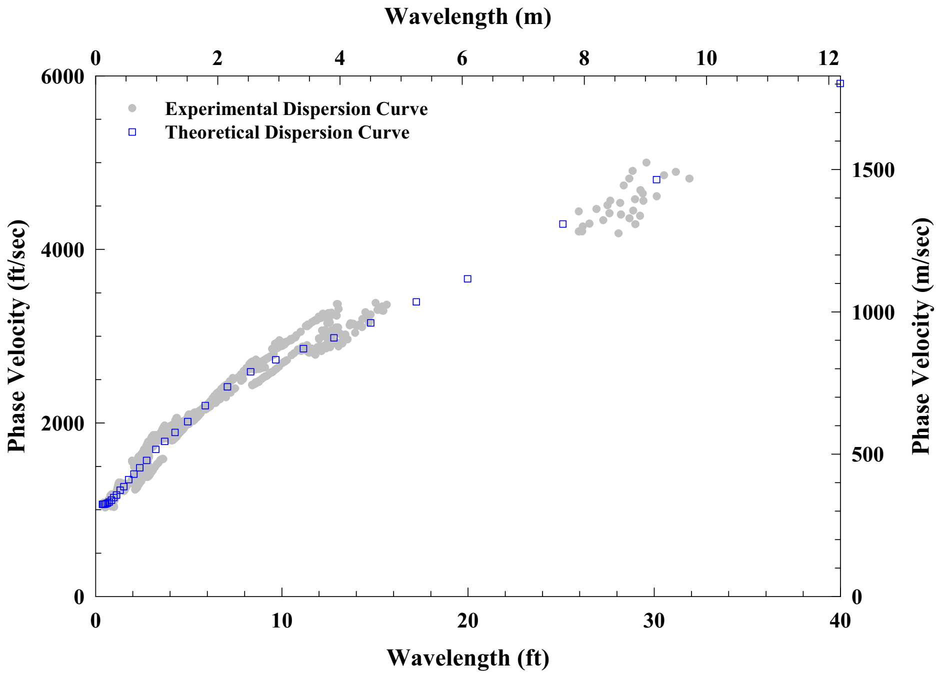
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-126. Experimental and Theoretical Dispersion Curves from ECRB 22+94; Logarithmic Wavelength Axis



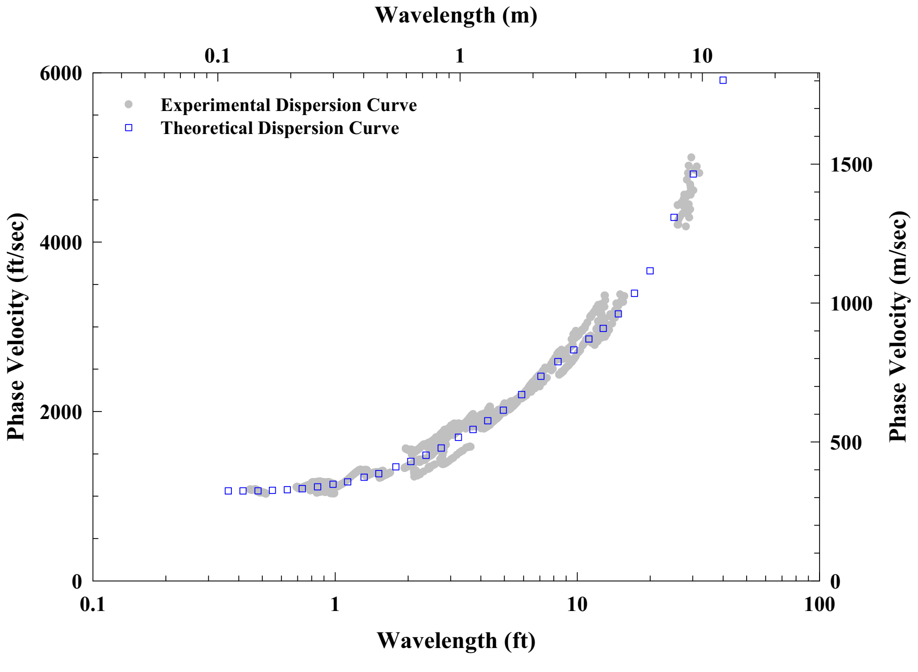
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-127. Shear Wave Velocity Profile Determined at ECRB 23+60



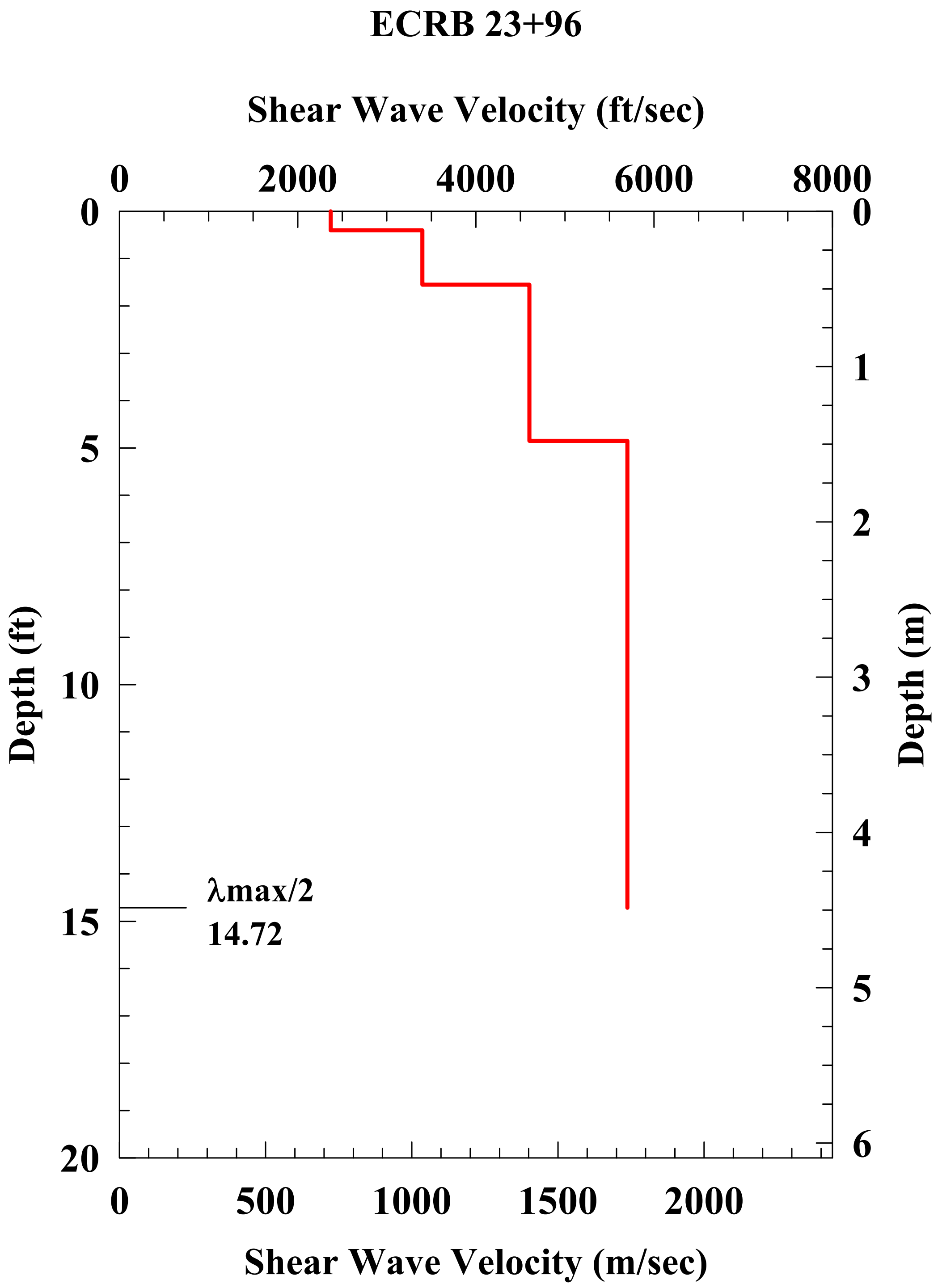
Source:	DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-128. Experimental and Theoretical Dispersion Curves from ECRB 23+60; Linear Wavelength Axis



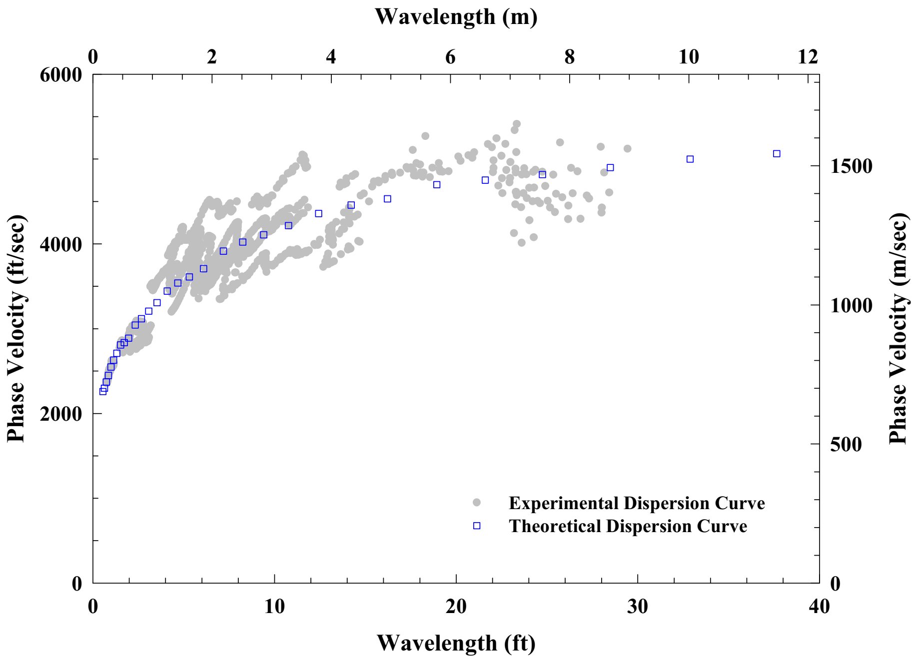
Source:	DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-129. Experimental and Theoretical Dispersion Curves from ECRB 23+60; Logarithmic Wavelength Axis



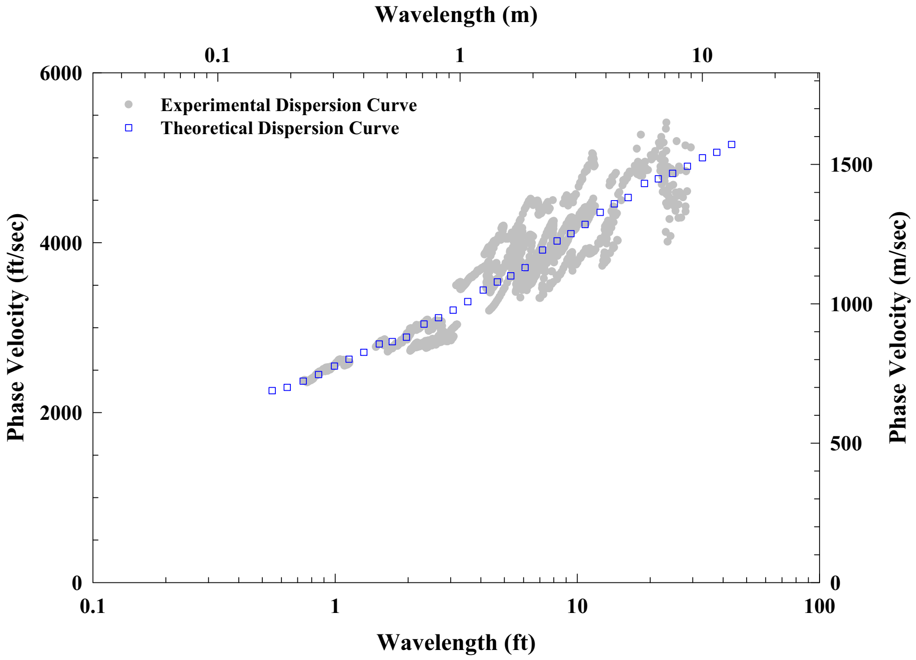
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-130. Shear Wave Velocity Profile Determined at ECRB 23+96



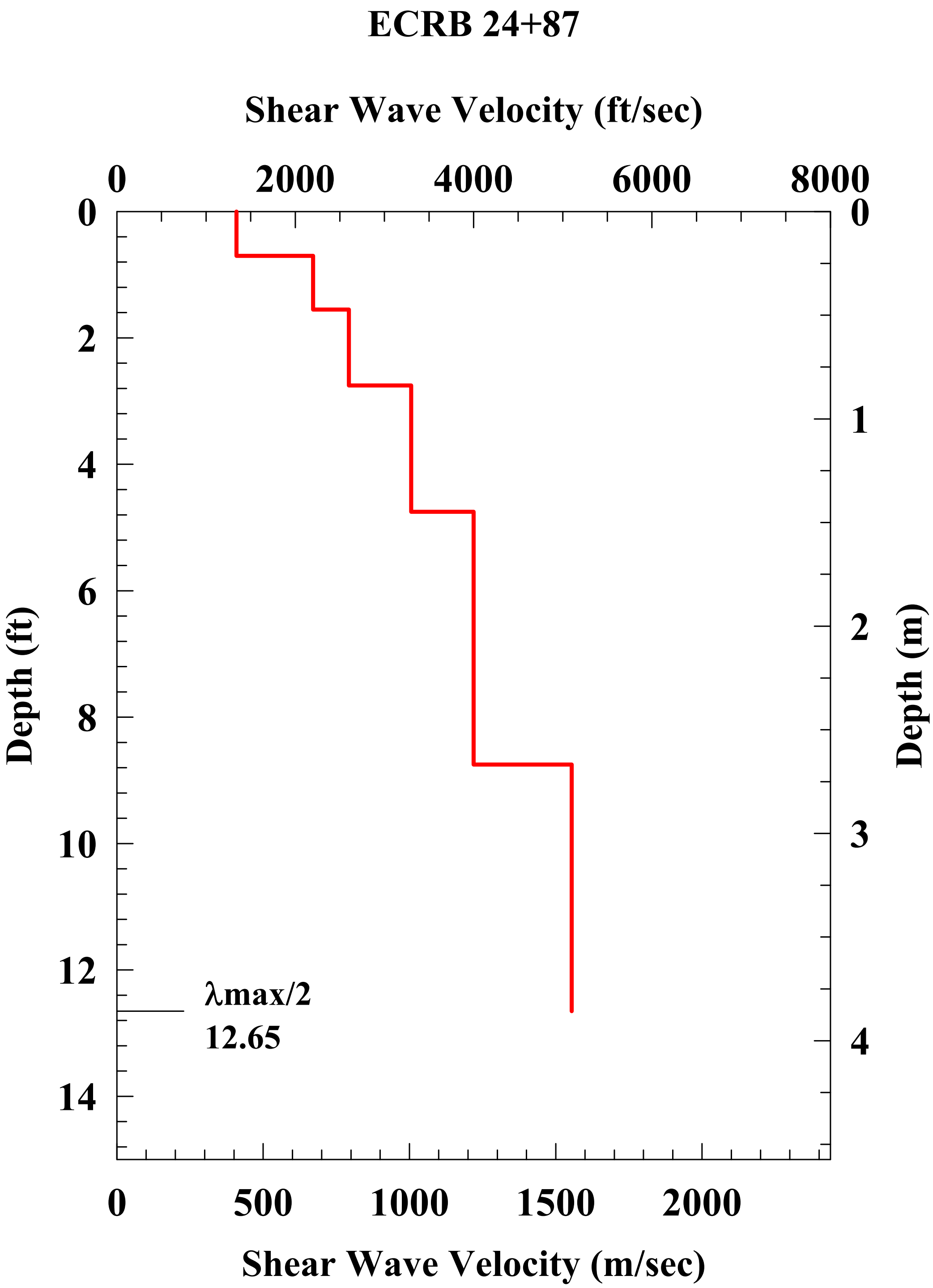
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-131. Experimental and Theoretical Dispersion Curves from ECRB 23+96; Linear Wavelength Axis



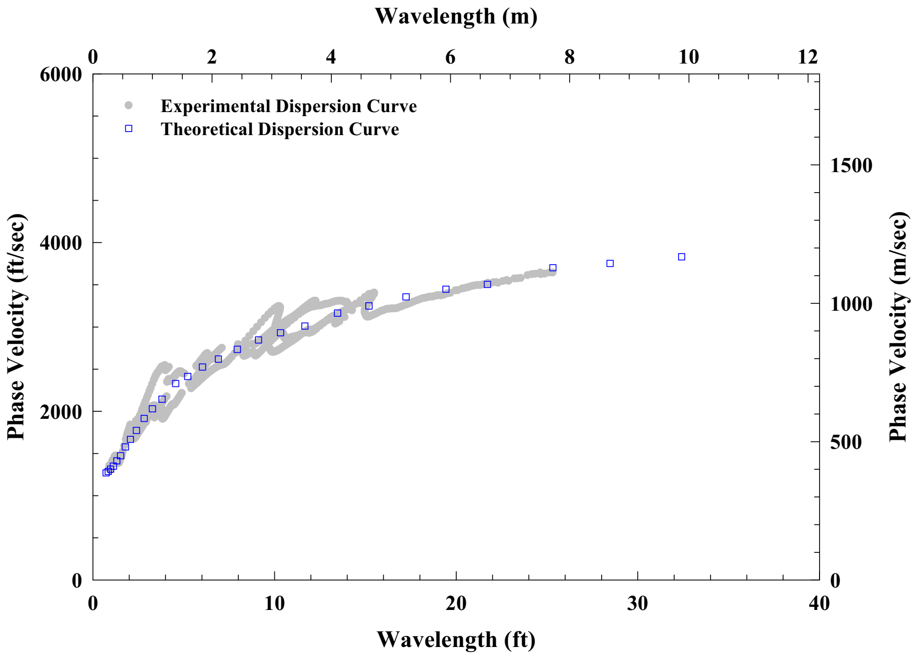
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-132. Experimental and Theoretical Dispersion Curves from ECRB 23+96; Logarithmic Wavelength Axis



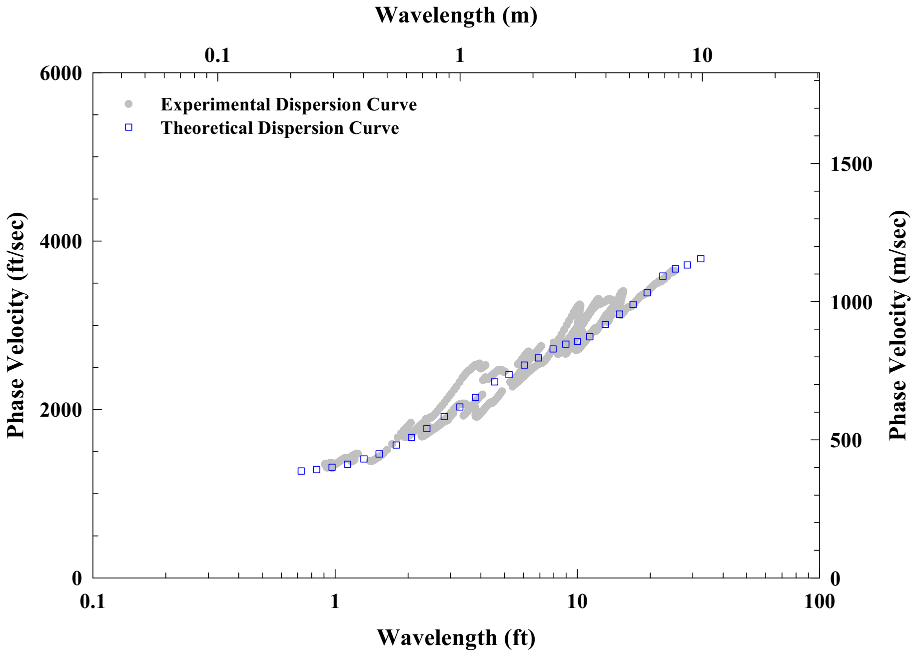
Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-133. Shear Wave Velocity Profile Determined at ECRB 24+87



Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-134. Experimental and Theoretical Dispersion Curves from ECRB 24+87; Linear Wavelength Axis



Source: DTN: MO0609SASWUTDC.004 [DIRS 183295]; Stokoe 2007 [DIRS 183327].

Figure VI-135. Experimental and Theoretical Dispersion Curves from ECRB 24+87; Logarithmic Wavelength Axis

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ATTACHMENT VII

FIXED-FREE TESTING RESULTS

ATTACHMENT VII
FIXED-FREE TESTING RESULTS

Laboratory determination of dynamic material properties employs combined resonant column and torsional shear (RCTS) testing. The RCTS apparatus can be idealized as a fixed-free system. The bottom end of the specimen is fixed against rotation at the base pedestal, and the top end of the specimen is connected to the driving system. The driving system can rotate freely to excite the specimen in cyclic torsion. This type of testing is referred to as a fixed-free dynamic testing. The data contained in this DTN were collected during the period of August 17, 2004, through May 20, 2006, and documented in DTN: MO0707FIXEFREE.005 [DIRS 183329]. This attachment presents the tabular data from DTN: MO0707FIXEFREE.005 [DIRS 183329] beginning on page VII-3.

Table VII-1. Fixed-Free Testing Sample Identification and Sample Origination Location

UT Specimen ID	Stratigraphic Unit	Unit Abbreviation	Parent Borehole	Specimen ID	Depth (ft)	
					Top	Bottom
UTA-42-A (1G)	TOPOPAH SPRING TUFF Crystal-Rich, Lithophysal	Tptrl	USW NRG-7/7A	01025902	482.5	483.1
UTA-42-B (2B-3)	TOPOPAH SPRING TUFF Crystal-Poor, Upper Lithophysal	Tptpul	ESF-HD-TEMP-5	01025905	38.5	39.2
UTA-42-B (2C-2)[1]						
UTA-42-C (3C-2)	TOPOPAH SPRING TUFF Crystal-Poor, Middle Nonlithophysal	Tptpmn	ESF-HD-TEMP-2	01025910	144.7	145.4
UTA-42-C (3K-2)[2]						
UTA-42-D (4C-2)	TOPOPAH SPRING TUFF Crystal-Rich, Nonlithophysal	Tptrn	USW SD-12	01025886	375.7	376.3
UTA-42-E (5C-2)	TOPOPAH SPRING TUFF Crystal-Poor, Lower Lithphysal	Tptpll	UE-25-UZ#16	01025914	866.7	867.3
UTA-42-F (6C-2)	TOPOPAH SPRING TUFF Crystal-Poor, LowerNonlithophysal	Tptpln	UE-25-UZ#16	01025915	950.6	951.3
UTA-42-G (7C-2)	CALICO HILLS	Tac (Devitrified)	USW UZ-14	01025881	1427.2	1428.0
UTA-42-H (8C-2)	CALICO HILLS	Tac (Vitric)	USW SD-12	01025890	1526.6	1527.4
UTA-42-I (9A-2)	TOPOPAH SPRING TUFF Crystal-Poor, Lower Lithphysal	Tptpll	ECRB-SYBT-LA#2	01025913	19.2	19.7
UTA-42-J (10A-2)	TOPOPAH SPRING TUFF Crystal-Poor, Lower Lithphysal	Tptpll	ECRB-SYBT-LA#9	01025912	4.2	4.7
UTA-42-K (11C-1)	TOPOPAH SPRING TUFF Crystal-Poor, Upper Lithophysal	Tptpul	USW UZ-14	01025867	564.1	564.9
UTA-42-L (12C-1)	TOPOPAH SPRING TUFF Crystal-Poor, Upper Lithophysal	Tptpul	USW UZ-14	01025868	577	577.7

Table VII-1. Fixed-Free Testing Sample Identification and Sample Origination Location (Continued)

UT Specimen ID	Stratigraphic Unit	Unit Abbreviation	Parent Borehole	Specimen ID	Depth (ft)	
					Top	Bottom
UTA-42-M (13C-2)	TOPOPAH SPRING TUFF Crystal-Poor, Middle Nonlithophysal	Tptpmn	ESF-HD-TEMP-2	01025908	8.8	9.5
UTA-42-N (14C-2)	TOPOPAH SPRING TUFF Crystal-Poor, Middle Nonlithophysal	Tptpmn	USW UZ-14	01025871	823	823.8
UTA-42-O (15C-3)	TOPOPAH SPRING TUFF Crystal-Poor, Lower Lithphysal	Tptpll	USW UZ-14	01025873	1059	1059.7
UTA-42-P (16C-2)	TOPOPAH SPRING TUFF Crystal-Poor, Lower Lithphysal	Tptpll	ECRB-GTEC-CS2150-01	01025925	0.2	0.8
UTA-42-Q (17C-2)	PROW PASS	Tcp	USW SD-9	01025933	2152.9	2153.6
UTA-42-R (18C-2)	PROW PASS	Tcp	UE-25 UZ#16	01025920	1531.6	1532.3
UTA-42-S (19C-2)	BULLFROG	Tcb	USW SD-7	01025994	2352.8	2353.5
UTA-42-T (20C-2)	TRAM	Tct	USW SD-7	01025989	2623.7	2624.4
UTA-42-U (21C-2)	TRAM	Tct	USW SD-7	01025992	2672.2	2672.9
UTA-42-W(23C)	YUCCA MOUNTAIN TUFF	Tpy	USW SD-9	1026002	135.9	136.4
UTA-42-X(24C)	YUCCA MOUNTAIN TUFF	Tpbt3	USW UZ-7a	01026004	214.2	214.7
UTA-42-Y(25C)	PAH CANYON TUFF	Tpp	USW UZ-7a	1026005	216.2	216.6
UTA-42-AA(27C)	TOPOPAH SPRING TUFF Crystal-Poor, Vitric	Tptpv3	USW UZ-14	1025877	1288.7	1289.2
UTA-42-AB(28E)	PAH CANYON TUFF	Tpbt2	USW SD-9	01026003	248.5	249.0
UTA-42-AC(29C)	CALICO HILLS	Tac (Devitrified)	USW UZ-14	01025884	1518.0	1518.5
UTA-42-AD(30A)	PROW PASS	Tcp	USW SD-7	1026707	1825.8	1826.3
UTA-42-AE(31A)	BULLFROG	Tcb	USW SD-12	1026731	2143.7	2144.1
UTA-42-AF(32A)	BULLFROG	Tcb	USW SD-7	1026713	2560.4	2560.8
UTA-42-AG(33A)	TRAM	Tct	USW SD-7	1026716	2600.0	2600.4

[1] UTA-42-B (2C-2) was cored from specimen UTA-42-B (2B-3).

[2] UTA-42-C (3K-2) was cored from specimen UTA-42-C (3D), which was not tested (see Wong and Stokoe 2007 [DIRS 183328]).

Table VII-2a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Material Damping Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-A (1G)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, g_t**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0.0	157100	7550	6100	0.41	136
50	7200	345	157500	7550	6107	0.37	136
110	15840	759	157780	7564	6111	0.38	136

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-A(1G).xls*.

Table VII-2b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-A (1G); Isotropic Confining Pressure, σ_o = 110 psi (15.8 ksf=759 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.50E-04	158950	1.00	2.45E-04	0.34
4.71E-04	157990	1.00	4.61E-04	0.34
9.06E-04	157990	1.00	8.83E-04	0.41
1.64E-03	156070	0.99	1.58E-03	0.55
2.65E-03	154170	0.97	2.55E-03	0.66
4.57E-03	151310	0.96	4.34E-03	0.84
7.88E-03	147560	0.93	7.36E-03	1.09
1.35E-02	142020	0.90	1.24E-02	1.37
2.36E-02	134790	0.85	2.11E-02	1.86
4.02E-02	126040	0.80	3.50E-02	2.31

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-A(1G).xls*.

Table VII-2c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-A (1G); Isotropic Confining Pressure, σ_o = 110 psi (15.8 ksf = 759 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.04E-03	153600	0.97	0.39	2.04E-03	155400	0.98	0.38
3.12E-03	151100	0.96	0.57	3.12E-03	151100	0.96	0.64
4.53E-03	150300	0.95	0.72	4.52E-03	150700	0.95	0.64

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-A(1G).xls*.

Table VII-3a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-B (2A-1)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	145100	6956	5840	0.74	132
10	1440	69	145100	6956	5842	0.72	132
20	2880	138	145740	6987	5854	0.80	132
40	5760	276	145730	6986	5854	0.80	132

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2A-1).xls*.

Table VII-3b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2A-1); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.09E-05	145760	1.00	1.04E-05	0.74
2.15E-05	145740	1.00	2.05E-05	0.74
4.13E-05	145300	1.00	3.94E-05	0.77
7.67E-05	144490	0.99	7.27E-05	0.87
1.38E-04	143850	0.99	1.30E-04	0.94
2.55E-04	142020	0.97	2.38E-04	1.12

Table VII-3b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2A-1); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa) (Continued)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
4.61E-04	139560	0.96	4.26E-04	1.28
8.18E-04	135900	0.93	7.47E-04	1.51
1.50E-03	131100	0.90	1.35E-03	1.67
2.36E-03	127100	0.87	2.10E-03	1.98

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2A-1).xls*.

Table VII-3c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-B (2A-1); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.76E-04	174000	1.00	0.88	1.81E-04	173000	1.00	0.87
2.77E-04	174000	1.00	0.84	2.72E-04	174000	1.00	0.79
4.37E-04	172300	0.99	0.84	4.26E-04	172700	1.00	0.86

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2A-1).xls*.

Table VII-4a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-B (2A-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	155520	7456	6062	0.61	132
10	1440	69	156730	7514	6071	0.60	132
20	2880	138	156560	7505	6068	0.60	132
40	5760	276	156590	7507	6068	0.60	132
80	11520	552	158570	7602	6105	0.65	132
160	23040	1105	158640	7605	6106	0.69	132

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2A-2).xls*.

Table VII-4b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2A-2); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.16E-05	156760	1.00	1.17E-05	0.60
2.32E-05	156760	1.00	2.34E-05	0.59
4.59E-05	156610	1.00	4.43E-05	0.60
8.94E-05	156600	1.00	8.61E-05	0.64
1.66E-04	155970	1.00	1.59E-04	0.68
3.10E-04	155330	0.99	2.97E-04	0.77
5.50E-04	154030	0.98	5.24E-04	0.79
9.55E-04	151470	0.97	9.61E-04	–
1.69E-03	148920	0.95	1.57E-03	1.16
2.64E-03	145150	0.93	2.41E-03	1.48
4.02E-03	140170	0.89	3.54E-03	2.12

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2A-2).xls*.

Table VII-4c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-B (2A-2); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.41E-04	184000	1.00	0.72	1.42E-04	188000	1.00	0.71
2.69E-04	189000	1.03	0.73	2.61E-04	190000	1.01	0.75
3.86E-04	190000	1.03	0.83	3.76E-04	190000	1.01	0.89

Table VII-4d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2A-2); Isotropic Confining Pressure, σ_o = 160 psi (23.0 ksf=1105 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.07E-05	158840	1.00	1.03E-05	0.69
2.10E-05	158820	1.00	2.02E-05	0.68
4.15E-05	158800	1.00	3.98E-05	0.70
8.21E-05	158140	1.00	7.87E-05	0.72
1.54E-04	157980	0.99	1.48E-04	0.76
2.94E-04	157330	0.99	2.80E-04	0.83
5.42E-04	155370	0.98	5.14E-04	0.84
9.74E-04	152960	0.96	9.17E-04	0.97
1.77E-03	149610	0.94	1.65E-03	1.14

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2A-2).xls*.

Table VII-5a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-B (2A-3)

Isotropic Confining Pressure, σ_o			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, V_S	Low-Amplitude Material Damping Ratio, D_{min}	Estimated Total Unit Weight, gt
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	156834	7519	6078	0.63	132
10	1440	69	157210	7537	6080	0.63	132
20	2880	138	157310	7541	6082	0.62	132
40	5760	276	157240	7538	6080	0.64	132
80	11520	552	158610	7604	6106	0.63	132
160	23040	1105	158660	7606	6106	0.72	132

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2A-3).xls*.

Table VII-5b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2A-3); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.06E-05	157380	1.00	1.01E-05	0.63
2.09E-05	157390	1.00	2.00E-05	0.65
4.13E-05	157380	1.00	3.97E-05	0.64
8.14E-05	157400	1.00	7.82E-05	0.65
1.55E-04	156750	1.00	1.49E-04	0.66
3.02E-04	156740	1.00	2.89E-04	0.69
5.70E-04	155460	0.99	5.44E-04	0.74
1.03E-03	154650	0.98	9.76E-04	0.83
1.77E-03	152230	0.97	1.66E-03	1.03
2.66E-03	148900	0.95	2.46E-03	1.28

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2A-3).xls*.

Table VII-5c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-B (2A-3); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.22E-04	191000	1.00	0.57	1.22E-04	191000	1.00	0.55
2.40E-04	191000	1.00	0.74	2.34E-04	191000	1.00	0.76
3.83E-04	188700	0.99	0.65	3.87E-04	188500	0.99	0.61

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2A-3).xls*.

Table VII-5d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2A-3); Isotropic Confining Pressure, σ_o = 160 psi (23.0 ksf=1105 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
9.59E-06	158680	1.00	9.20E-06	0.66
1.90E-05	158670	1.00	1.82E-05	0.68
3.79E-05	158820	1.00	3.63E-05	0.67
7.50E-05	158670	1.00	7.19E-05	0.69
1.41E-04	158020	1.00	1.35E-04	0.70
2.78E-04	158010	1.00	2.66E-04	0.72
5.36E-04	157340	0.99	5.11E-04	0.78
1.00E-03	156200	0.98	9.49E-04	0.87
1.86E-03	153590	0.97	1.75E-03	0.99
2.89E-03	150930	0.95	2.68E-03	1.26

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2A-3).xls*.

Table VII-5e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-B (2A-3); Isotropic Confining Pressure, σ_o = 160 psi (23.0 ksf=1105 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.41E-04	184000	1.00	0.72	1.42E-04	188000	1.00	0.71
2.69E-04	189000	1.03	0.73	2.61E-04	190000	1.01	0.75
3.86E-04	190000	1.03	0.83	3.76E-04	190000	1.01	0.89

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file Table_UTA-42-B(2A-3).xls.

Table VII-6a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2B-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.50E-04	158950	1.00	2.45E-04	0.34
4.71E-04	157990	1.00	4.61E-04	0.34
9.06E-04	157990	1.00	8.83E-04	0.41
1.64E-03	156070	0.99	1.58E-03	0.55
2.65E-03	154170	0.97	2.55E-03	0.66
4.57E-03	151310	0.96	4.34E-03	0.84
7.88E-03	147560	0.93	7.36E-03	1.09
1.35E-02	142020	0.90	1.24E-02	1.37
2.36E-02	134790	0.85	2.11E-02	1.86
4.02E-02	126040	0.80	3.50E-02	2.31

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-1).xls*.

Table VII-7a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-B (2B-2)

Isotropic Confining Pressure, σ_o			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, V_S	Low-Amplitude Material Damping Ratio, D_{min}	Estimated Total Unit Weight, gt
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	136080	6524	5693	0.81	130
10	1440	69	137920	6612	5731	0.83	130
20	2880	138	138550	6642	5744	0.84	130
40	5760	276	139840	6704	5770	0.83	130
80	11520	552	141230	6771	5798	0.85	130
160	23040	1105	143030	6857	5833	0.92	130

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-2).xls*.

Table VII-7b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2B-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
2.17E-05	136050	1.00	2.07E-05	0.75
4.30E-05	135560	1.00	4.10E-05	0.75
8.53E-05	135460	1.00	8.14E-05	0.76
1.62E-04	135440	1.00	1.55E-04	0.78
3.15E-04	134840	0.99	3.00E-04	0.79
6.11E-04	134320	0.99	5.80E-04	0.84
1.16E-03	133590	0.98	1.09E-03	0.91
2.19E-03	131760	0.97	2.06E-03	1.03
3.68E-03	129490	0.95	3.42E-03	1.21
6.08E-03	126510	0.93	5.53E-03	1.56

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-2).xls*.

Table VII-7c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2B-2); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.04E-05	139820	1.00	9.85E-06	0.85
2.05E-05	139840	1.00	1.94E-05	0.83
4.06E-05	139830	1.00	3.86E-05	0.83
8.06E-05	139820	1.00	7.65E-05	0.84
1.53E-04	139860	1.00	1.45E-04	0.87
2.99E-04	139200	1.00	2.83E-04	0.88
5.78E-04	139230	1.00	5.46E-04	0.91
1.11E-03	137970	0.99	1.04E-03	0.98
2.10E-03	136260	0.97	1.97E-03	1.11
3.63E-03	134300	0.96	3.36E-03	1.26

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-2).xls*.

Table VII-7d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-B (2B-2); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.54E-04	163000	1.00	1.81	1.46E-04	163000	1.00	1.80
3.53E-04	162000	0.99	1.65	3.48E-04	162000	0.99	1.71
4.52E-04	161000	0.99	1.79	4.47E-04	161000	0.99	1.82

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-2).xls*.

Table VII-7e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2B-2); Isotropic Confining Pressure, σ_o = 160 psi (5.8 ksf=1105 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.04E-05	139820	1.00	9.85E-06	0.85
2.05E-05	139840	1.00	1.94E-05	0.83
4.06E-05	139830	1.00	3.86E-05	0.83
8.06E-05	139820	1.00	7.65E-05	0.84
1.53E-04	139860	1.00	1.45E-04	0.87
2.99E-04	139200	1.00	2.83E-04	0.88
5.78E-04	139230	1.00	5.46E-04	0.91
1.11E-03	137970	0.99	1.04E-03	0.98
2.10E-03	136260	0.97	1.97E-03	1.11
3.63E-03	134300	0.96	3.36E-03	1.26

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-2).xls*.

Table VII-7f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-B (2B-2); Isotropic Confining Pressure, σ_o = 160 psi (5.8 ksf=1105 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.54E-04	163000	1.00	1.81	1.46E-04	163000	1.00	1.80
3.53E-04	162000	0.99	1.65	3.48E-04	162000	0.99	1.71
4.52E-04	161000	0.99	1.79	4.47E-04	161000	0.99	1.82

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-2).xls*.

Table VII-8a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-B (2B-3)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	136320	6535	5743	0.84	130
10	1440	69	138580	6643	5745	0.84	130
20	2880	138	138600	6644	5745	0.83	130
40	5760	276	139890	6706	5771	0.85	130
80	11520	552	142410	6827	5823	0.81	130
160	23040	1105	144340	6920	5861	0.82	130

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-3).xls*.

Table VII-8b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2B-3); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.11E-05	139870	1.00	1.06E-05	0.87
2.19E-05	139880	1.00	2.08E-05	0.85
4.34E-05	139890	1.00	4.12E-05	0.86
8.59E-05	139880	1.00	8.16E-05	0.87
1.63E-04	139270	1.00	1.54E-04	0.90
3.19E-04	139260	1.00	3.02E-04	0.95
6.17E-04	138030	0.99	5.83E-04	1.03
1.16E-03	136790	0.98	1.09E-03	1.00
2.20E-03	134940	0.96	2.05E-03	1.12
3.72E-03	133100	0.95	3.44E-03	1.24

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-3).xls*.

Table VII-8c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-B (2B-3); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.40E-04	167000	1.00	0.66	1.40E-04	167000	1.00	0.64
2.39E-04	168000	1.01	1.02	2.39E-04	168000	1.01	0.95
4.26E-04	163700	0.98	1.20	4.37E-04	163800	0.98	1.21

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-3).xls.*

Table VII-8d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2B-3); Isotropic Confining Pressure, σ_o = 160 psi (5.8 ksf=1105 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.08E-05	143740	1.00	1.03E-05	0.84
2.14E-05	143740	1.00	2.03E-05	0.82
4.26E-05	143720	1.00	4.05E-05	0.82
8.45E-05	143610	1.00	8.04E-05	0.84
1.61E-04	143760	1.00	1.53E-04	0.86
3.15E-04	143110	1.00	2.99E-04	0.88
6.13E-04	142500	0.99	5.80E-04	0.93
1.17E-03	141240	0.98	1.10E-03	0.95
2.27E-03	140010	0.97	2.13E-03	1.05
3.94E-03	137980	0.96	3.67E-03	1.15

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-3).xls*.

Table VII-8e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-B (2B-3); Isotropic Confining Pressure, σ_o = 160 psi (5.8 ksf=1105 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.35E-04	172000	1.00	0.81	1.35E-04	172000	1.00	0.76
2.29E-04	171000	0.99	1.23	2.29E-04	171000	0.99	1.26
4.31E-04	169000	0.98	1.39	4.37E-04	169000	0.98	1.39

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2B-3).xls*.

Table VII-9a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
8.16E-05	280390	1.00	8.14E-05	0.28
1.63E-04	280100	1.00	1.62E-04	0.25
3.23E-04	280190	1.00	3.20E-04	0.26
6.32E-04	277930	0.99	6.26E-04	0.28
1.33E-03	277960	0.99	1.32E-03	0.24
2.43E-03	277710	0.99	2.40E-03	0.24
4.53E-03	277690	0.99	4.47E-03	0.31
8.39E-03	275240	0.98	8.25E-03	0.26
1.44E-02	273020	0.97	1.41E-02	0.35

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2C-1).xls*.

Table VII-10a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-B (2C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	280330	13439	7985	0.24	141
10	1440	69	280340	13439	7988	0.20	141
20	2880	138	280390	13442	7988	0.18	141
40	5760	276	280440	13444	7988	0.19	141
80	11520	552	280260	13436	7984	0.19	141
160	23040	1105	280650	13454	7986	0.19	141

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2C-2).xls*.

Table VII-10b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2C-2); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
3.50E-05	280280	1.00	3.55E-05	0.23
6.98E-05	280290	1.00	6.95E-05	0.21
1.40E-04	280290	1.00	1.38E-04	0.20
2.78E-04	280320	1.00	2.75E-04	0.21
5.44E-04	280570	1.00	5.38E-04	0.25
1.10E-03	280300	1.00	1.08E-03	0.22
1.91E-03	280370	1.00	1.88E-03	0.23
3.87E-03	277720	0.99	3.81E-03	0.25
7.36E-03	277810	0.99	7.24E-03	0.28
1.39E-02	275360	0.98	1.36E-02	0.35
2.32E-02	272860	0.97	2.25E-02	0.46
3.46E-02	270670	0.97	3.33E-02	0.61
5.57E-02	263010	0.94	5.31E-02	0.77

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2C-2).xls*.

Table VII-10c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-B (2C-2); Isotropic Confining Pressure, σ_o = 40 psi (5.8 ksf=276 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
7.15E-04	283000	1.00	0.42	7.19E-04	284000	1.00	0.47
9.95E-04	281000	0.99	0.34	9.98E-04	281000	0.99	0.37
2.34E-03	281400	0.99	0.34	2.31E-03	281000	0.99	0.31

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2C-2).xls*.

Table VII-10d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-B (2C-2); Isotropic Confining Pressure, σ_o = 160 psi (5.8 ksf=1105 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
3.31E-05	280820	1.00	3.27E-05	0.21
6.61E-05	280770	1.00	6.52E-05	0.22
1.32E-04	280770	1.00	1.31E-04	0.21
2.66E-04	280770	1.00	2.63E-04	0.20
5.59E-04	280780	1.00	5.52E-04	0.21
1.09E-03	280780	1.00	1.08E-03	0.21
1.91E-03	280750	1.00	1.88E-03	0.23
3.86E-03	278060	0.99	3.80E-03	0.25
7.30E-03	278320	0.99	7.18E-03	0.27
1.40E-02	275590	0.98	1.37E-02	0.33
2.40E-02	273070	0.97	2.34E-02	0.42
3.99E-02	268390	0.96	3.86E-02	0.55

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2C-2).xls*.

Table VII-10e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-B (2C-2); Isotropic Confining Pressure, σ_o = 160 psi (5.8 ksf=1105 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
7.29E-04	283200	1.00	0.33	7.24E-04	282400	1.00	0.34
1.06E-03	281800	1.00	0.29	1.06E-03	281300	1.00	0.25
2.32E-03	281100	0.99	0.41	2.32E-03	281500	1.00	0.35

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-B(2C-2).xls*.

Table VII-11a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-C(3C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.27E-05	229080	1.00	1.22E-05	0.56
2.55E-05	229110	1.00	2.46E-05	0.55
5.12E-05	228870	1.00	4.95E-05	0.55
1.03E-04	228900	1.00	9.96E-05	0.54
1.98E-04	228910	1.00	1.91E-04	0.55
3.91E-04	228910	1.00	3.77E-04	0.56
7.55E-04	227960	1.00	7.29E-04	0.57
1.45E-03	226960	0.99	1.40E-03	0.58
2.56E-03	225960	0.99	2.45E-03	0.65

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3C-1).xls*.

Table VII-12a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-C (3C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	231200	11084	7200	0.53	144
36	5184	249	232290	11136	7205	0.53	144
72	10368	497	233320	11185	7220	0.52	144
144	20736	994	233380	11188	7220	0.54	144
288	41472	1988	234590	11246	7236	0.51	144
450	64800	3106	234870	11260	7238	0.52	144

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3C-2).xls*.

Table VII-12b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-C (3C-2); Isotropic Confining Pressure, σ_o = 144 psi (20.7 ksf=993 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.24E-05	233440	1.00	1.20E-05	0.56
2.50E-05	233440	1.00	2.42E-05	0.55
5.04E-05	233450	1.00	4.88E-05	0.54
1.02E-04	233460	1.00	9.83E-05	0.53
1.96E-04	233460	1.00	1.89E-04	0.52
3.92E-04	233460	1.00	3.80E-04	0.52
7.75E-04	233230	1.00	7.50E-04	0.54
1.54E-03	232490	1.00	1.49E-03	0.57
2.72E-03	231250	0.99	2.62E-03	0.62
4.50E-03	229290	0.98	4.30E-03	0.74

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3C-2).xls*.

Table VII-12c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-C (3C-2); Isotropic Confining Pressure, σ_o = 144 psi (20.7 ksf=993 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.66E-04	259000	1.00	1.19	1.60E-04	260000	1.00	1.17
2.43E-04	256100	0.99	1.39	2.47E-04	261000	1.00	1.29
4.08E-04	254500	0.98	1.28	4.08E-04	258000	0.99	1.29

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3C-2).xls*.

Table VII-12d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-C (3C-2); Isotropic Confining Pressure, σ_o = 450 psi (64.8 ksf=3103 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.28E-05	234750	1.00	1.24E-05	0.55
2.60E-05	234750	1.00	2.52E-05	0.51
5.27E-05	234780	1.00	5.10E-05	0.50
1.07E-04	234780	1.00	1.04E-04	0.50
2.04E-04	234770	1.00	1.98E-04	0.50
4.08E-04	234720	1.00	3.96E-04	0.50
8.00E-04	233800	1.00	7.75E-04	0.54
1.56E-03	232800	0.99	1.50E-03	0.60
2.86E-03	231560	0.99	2.75E-03	0.60
5.20E-03	229580	0.98	4.90E-03	0.96

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3C-2).xls*.

Table VII-12e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-C (3C-2); Isotropic Confining Pressure, σ_o = 450 psi (64.8 ksf=3103 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.62E-04	253000	1.00	0.73	1.61E-04	252000	1.00	0.79
2.25E-04	252000	1.00	0.91	2.18E-04	251000	1.00	0.93
3.15E-04	250000	0.99	0.94	3.15E-04	251000	1.00	0.92

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3C-2).xls*.

Table VII-13a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-C (3K-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
4.15E-05	322040	1.00	4.05E-05	0.52
8.21E-05	322070	1.00	7.98E-05	0.51
1.65E-04	322120	1.00	1.60E-04	0.51
3.29E-04	322130	1.00	3.19E-04	0.51
6.76E-04	322150	1.00	6.56E-04	0.52
1.25E-03	322170	1.00	1.21E-03	0.52
2.46E-03	322160	1.00	2.38E-03	0.53
4.63E-03	322170	1.00	4.48E-03	0.62
8.45E-03	319350	0.99	8.13E-03	0.62
1.41E-02	316230	0.98	1.36E-02	0.66

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file *Table_UTA-42-C(3K-1).xls*.

Table VII-14a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-C (3K-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	322490	15460	8405	0.47	147
37	5328	255	322370	15454	8402	0.35	147
74	10656	511	325310	15595	8439	0.34	147
148	21312	1022	325380	15599	8440	0.34	147
296	42624	2043	325650	15612	8440	0.34	147
450	64800	3106	325680	15613	8437	0.40	147

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3K-2).xls*.

Table VII-14b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-C (3K-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
4.18E-05	322460	0.99	4.06E-05	0.56
8.31E-05	325030	1.00	8.07E-05	0.53
1.65E-04	324940	1.00	1.61E-04	0.53
3.31E-04	325040	1.00	3.21E-04	0.53
6.77E-04	325060	1.00	6.57E-04	0.54
1.26E-03	324760	1.00	1.23E-03	0.53
2.49E-03	322250	0.99	2.42E-03	0.55
4.96E-03	322240	0.99	4.81E-03	0.55
9.31E-03	321880	0.99	8.99E-03	0.57
1.53E-02	319170	0.98	1.47E-02	0.65

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3K-2).xls*.

Table VII-14c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-C (3K-2); Isotropic Confining Pressure, σ_o = 148 psi (21.3 ksf=1020 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
4.88E-05	325280	1.00	4.95E-05	0.43
9.72E-05	325320	1.00	9.66E-05	0.40
1.94E-04	325360	1.00	1.90E-04	0.40
3.89E-04	325410	1.00	3.81E-04	0.40
8.02E-04	325490	1.00	7.83E-04	0.41
1.48E-03	325530	1.00	1.44E-03	0.41
2.91E-03	325510	1.00	2.84E-03	0.43
5.73E-03	325190	1.00	5.58E-03	0.41
1.04E-02	322250	0.99	1.01E-02	0.45
1.68E-02	319610	0.98	1.62E-02	0.52
2.50E-02	317050	0.97	2.40E-02	0.68
3.92E-02	311440	0.96	3.73E-02	0.83

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3K-2).xls*.

Table VII-14d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-C (3K-2); Isotropic Confining Pressure, σ_o = 148 psi (21.3 ksf=1020 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
8.11E-04	313000	1.00	1.02	8.19E-04	314000	1.00	0.98
1.46E-03	315300	1.01	1.09	1.46E-03	315700	1.01	1.10
2.23E-03	313000	1.00	1.16	2.23E-03	314000	1.00	1.12

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3K-2).xls*.

Table VII-14e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-C (3K-2); Isotropic Confining Pressure, σ_o = 450 psi (64.8 ksf=3103 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
4.68E-05	325710	1.00	4.58E-05	0.43
9.37E-05	325780	1.00	9.13E-05	0.42
1.88E-04	325820	1.00	1.84E-04	0.42
3.76E-04	325770	1.00	3.67E-04	0.42
7.74E-04	325750	1.00	7.57E-04	0.43
1.43E-03	325800	1.00	1.40E-03	0.42
2.85E-03	325840	1.00	2.78E-03	0.43
5.59E-03	325450	1.00	5.45E-03	0.46
1.04E-02	325790	1.00	1.01E-02	0.57
1.83E-02	323040	0.99	1.77E-02	0.57
2.90E-02	320090	0.98	2.79E-02	0.65
5.75E-02	308710	0.95	5.39E-02	1.07

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3K-2).xls*.

Table VII-14f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-C (3K-2); Isotropic Confining Pressure, σ_o = 450 psi (64.8 ksf=3103 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
7.92E-04	323000	1.00	1.01	7.92E-04	323000	1.00	1.04
9.94E-04	323000	1.00	0.92	1.00E-03	322000	1.00	0.98
1.42E-03	322000	1.00	1.01	1.43E-03	323000	1.00	1.08

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-C(3K-2).xls*.

Table VII-15a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-D (4C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.49E-05	160820	1.00	1.46E-05	0.40
2.99E-05	160830	1.00	2.93E-05	0.38
5.89E-05	159940	1.00	5.77E-05	0.40
1.19E-04	160700	1.00	1.16E-04	0.38
2.47E-04	159960	1.00	2.42E-04	0.38
4.48E-04	159830	1.00	4.38E-04	0.40
8.45E-04	158920	0.99	8.25E-04	0.47
1.54E-03	158040	0.98	1.50E-03	0.44
2.74E-03	156430	0.97	2.65E-03	0.54

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-D(4C-1).xls*.

Table VII-16a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-D (4C-2)

Isotropic Confining Pressure, σ_o			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, V_S	Low-Amplitude Material Damping Ratio, D_{min}	Estimated Total Unit Weight, gt
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	159100	7627	5945	0.43	145
96	13824	663	168220	8064	6113	0.35	145
190	27360	1312	168270	8067	6112	0.34	145
378	54432	2609	169300	8116	6129	0.33	145
450	64800	3106	169230	8113	6127	0.32	145

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-D(4C-2).xls*.

Table VII-16b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-D (4C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.28E-05	159080	1.00	1.25E-05	0.46
2.56E-05	159090	1.00	2.50E-05	0.43
5.10E-05	159090	1.00	4.98E-05	0.42
1.01E-04	159110	1.00	9.88E-05	0.43
2.08E-04	159110	1.00	2.03E-04	0.43
3.78E-04	159100	1.00	3.68E-04	0.45
7.10E-04	158230	0.99	6.90E-04	0.52
1.32E-03	157360	0.99	1.28E-03	0.51
2.43E-03	156470	0.98	2.35E-03	0.59
4.36E-03	154770	0.97	4.18E-03	0.67

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-D(4C-2).xls*.

Table VII-16c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-D (4C-2); Isotropic Confining Pressure, σ_o = 378 psi (54.4 ksf=2606 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.55E-05	169420	1.00	1.52E-05	0.32
3.12E-05	169250	1.00	3.05E-05	0.34
6.21E-05	169250	1.00	6.09E-05	0.33
1.24E-04	169260	1.00	1.21E-04	0.33
2.51E-04	169240	1.00	2.46E-04	0.34
4.47E-04	169260	1.00	4.38E-04	0.35
8.87E-04	168340	0.99	8.68E-04	0.36
1.65E-03	167410	0.99	1.61E-03	0.40
2.94E-03	166670	0.98	2.85E-03	0.49
4.91E-03	165600	0.98	4.73E-03	0.59
8.45E-03	162840	0.96	8.14E-03	0.59

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-D(4C-2).xls*.

Table VII-16d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-D (4C-2); Isotropic Confining Pressure, σ_o = 378 psi (54.4 ksf=2606 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.54E-04	160000	1.00	1.02	2.58E-04	161000	1.00	0.98
3.67E-04	160000	1.00	1.09	3.60E-04	161000	1.00	1.10
6.74E-04	160500	1.00	1.16	6.74E-04	160500	1.00	1.12

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-D(4C-2).xls*.

Table VII-16e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-D (4C-2); Isotropic Confining Pressure, σ_o = 450 psi (64.8 ksf=3103 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.52E-05	169430	1.00	1.49E-05	0.33
3.04E-05	169270	1.00	2.98E-05	0.33
6.02E-05	169450	1.00	5.90E-05	0.33
1.20E-04	169440	1.00	1.18E-04	0.33
2.45E-04	169440	1.00	2.40E-04	0.34
4.35E-04	169430	1.00	4.26E-04	0.34
8.84E-04	168480	0.99	8.65E-04	0.36
1.71E-03	167560	0.99	1.67E-03	0.38
3.01E-03	166480	0.98	2.91E-03	0.57
5.51E-03	164640	0.97	5.34E-03	0.50
8.98E-03	163730	0.97	8.65E-03	0.59
1.46E-02	161150	0.95	1.39E-02	0.78

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-D(4C-2).xls*.

Table VII-16f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-D (4C-2); Isotropic Confining Pressure, σ_o = 450 psi (64.8 ksf=3103 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.50E-04	168000	1.00	0.86	2.48E-04	168000	1.00	0.87
3.50E-04	168000	1.00	0.89	3.50E-04	168000	1.00	0.89
6.36E-04	167500	1.00	0.98	6.40E-04	167300	1.00	1.01

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-D(4C-2).xls*.

Table VII-17a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-E (5C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.69E-05	194970	1.00	1.63E-05	0.53
3.35E-05	194790	1.00	3.24E-05	0.53
6.68E-05	194980	1.00	6.46E-05	0.53
1.32E-04	194990	1.00	1.27E-04	0.54
2.49E-04	194830	1.00	2.40E-04	0.56
4.93E-04	193990	1.00	4.75E-04	0.58
9.46E-04	193290	0.99	9.11E-04	0.61
1.80E-03	192450	0.99	1.73E-03	0.63
3.17E-03	190780	0.98	3.03E-03	0.72
5.23E-03	188900	0.97	4.98E-03	0.81

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-E(5C-1).xls*.

Table VII-18a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-E (5C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	195820	9388	6758	0.52	138
25	3600	172	196680	9429	6771	0.50	138
50	7200	345	196530	9422	6768	0.49	138
100	14400	690	196560	9423	6767	0.49	138
200	28800	1379	197630	9474	6784	0.50	138
400	57600	2758	198010	9493	6786	0.51	138

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-E(5C-2).xls*.

Table VII-18b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-E (5C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.62E-05	195620	1.00	1.57E-05	0.54
3.25E-05	195830	1.00	3.14E-05	0.52
6.47E-05	195860	1.00	6.25E-05	0.52
1.34E-04	195670	1.00	1.29E-04	0.54
2.45E-04	195710	1.00	2.36E-04	0.54
4.76E-04	195640	1.00	4.60E-04	0.57
9.40E-04	194830	1.00	9.05E-04	0.61
1.82E-03	194030	0.99	1.75E-03	0.63
3.36E-03	192290	0.98	3.22E-03	0.70
5.42E-03	190660	0.97	5.15E-03	0.80

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-E(5C-2).xls*.

Table VII-18c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-E (5C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.64E-05	195950	1.00	1.60E-05	0.48
3.29E-05	195950	1.00	3.19E-05	0.48
6.56E-05	196590	1.00	6.36E-05	0.50
1.35E-04	195950	1.00	1.31E-04	0.48
2.49E-04	196010	1.00	2.41E-04	0.50
4.85E-04	196040	1.00	4.70E-04	0.52
9.31E-04	195170	1.00	8.99E-04	0.55
1.76E-03	194330	0.99	1.69E-03	0.60
3.09E-03	192460	0.98	2.97E-03	0.63
5.09E-03	191650	0.98	4.87E-03	0.74
8.91E-03	189310	0.97	8.46E-03	0.85
1.34E-02	186550	0.95	1.25E-02	1.03

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-E(5C-2).xls*.

Table VII-18d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-E (5C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
3.20E-04	208000	1.00	0.55	3.23E-04	206000	1.00	0.62
3.96E-04	209000	1.00	0.54	3.95E-04	209000	1.01	0.50
5.18E-04	208000	1.00	0.49	5.11E-04	208000	1.01	0.58

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-E(5C-2).xls*.

Table VII-18e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-E (5C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.59E-05	197920	1.00	1.55E-05	0.51
3.18E-05	198250	1.00	3.08E-05	0.51
6.34E-05	198010	1.00	6.15E-05	0.51
1.31E-04	198010	1.00	1.27E-04	0.53
2.38E-04	198010	1.00	2.30E-04	0.51
4.67E-04	197100	0.99	4.52E-04	0.51
9.15E-04	197200	1.00	8.86E-04	0.53
1.79E-03	195650	0.99	1.73E-03	0.55
3.34E-03	194640	0.98	3.21E-03	0.65
5.53E-03	192870	0.97	5.29E-03	0.72
9.80E-03	190380	0.96	9.30E-03	0.84
1.37E-02	187840	0.95	1.28E-02	0.99

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-E(5C-2).xls*.

Table VII-18f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-E (5C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.03E-04	204000	1.00	0.35	2.01E-04	207000	1.00	0.37
3.25E-04	204000	1.00	0.35	3.20E-04	204000	0.99	0.43
4.03E-04	203000	1.00	0.40	4.03E-04	203000	0.98	0.40
5.30E-04	204000	1.00	0.30	5.28E-04	205000	0.99	0.32

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-E(5C-2).xls*.

Table VII-19a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-F (6C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.10E-05	288320	1.00	1.06E-05	0.59
2.20E-05	288310	1.00	2.12E-05	0.58
4.38E-05	288370	1.00	4.23E-05	0.58
9.04E-05	288350	1.00	8.72E-05	0.58
1.66E-04	287130	1.00	1.60E-04	0.58
3.31E-04	287140	1.00	3.19E-04	0.58
6.57E-04	287100	1.00	6.33E-04	0.58
1.28E-03	285900	0.99	1.23E-03	0.62
2.31E-03	285890	0.99	2.22E-03	0.67
3.76E-03	283420	0.98	3.59E-03	0.75

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-E(5C-2).xls*.

Table VII-20a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-F (6C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	289530	13880	7971	0.55	147
25	3600	172	289450	13876	7974	0.54	147
50	7200	345	289500	13879	7974	0.54	147
100	14400	690	289830	13894	7978	0.52	147
200	28800	1379	290980	13949	7992	0.51	147
400	57600	2758	291200	13960	7992	0.49	147

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-F(6C-2).xls*.

Table VII-20b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-F (6C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.11E-05	289570	1.00	1.07E-05	0.56
2.22E-05	289300	1.00	2.14E-05	0.56
4.42E-05	289310	1.00	4.27E-05	0.56
9.14E-05	289590	1.00	8.83E-05	0.55
1.68E-04	289310	1.00	1.63E-04	0.56
3.30E-04	289640	1.00	3.19E-04	0.57
6.53E-04	288370	1.00	6.30E-04	0.58
1.28E-03	288100	1.00	1.24E-03	0.59
2.33E-03	286850	0.99	2.24E-03	0.64
3.98E-03	285610	0.99	3.81E-03	0.70
7.12E-03	283420	0.98	6.77E-03	0.82

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-F(6C-2).xls*.

Table VII-20c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-F (6C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.21E-05	289640	1.00	1.22E-05	0.51
1.21E-05	289690	1.00	1.18E-05	0.51
2.41E-05		289370	2.33E-05	0.52
4.81E-05		289380	4.66E-05	0.51
1.00E-04	289670	1.00	9.70E-05	0.51
1.84E-04	289390	1.00	1.78E-04	0.52
3.64E-04	289400	1.00	3.53E-04	0.52
7.08E-04	289710	1.00	6.85E-04	0.52
1.40E-03	288170	1.00	1.36E-03	0.53
2.57E-03	287220	0.99	2.47E-03	0.61
4.35E-03	285990	0.99	4.18E-03	0.64
7.45E-03	283550	0.98	7.10E-03	0.78
1.00E-02	280810	0.97	9.44E-03	0.92

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-F(6C-2).xls.*

Table VII-20d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-F (6C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.24E-05	291330	1.00	1.20E-05	0.50
2.48E-05	291270	1.00	2.40E-05	0.50
4.94E-05	291300	1.00	4.79E-05	0.49
1.03E-04	291040	1.00	9.98E-05	0.50
1.88E-04	291040	1.00	1.83E-04	0.50
3.70E-04	291040	1.00	3.59E-04	0.51
7.32E-04	290050	1.00	7.09E-04	0.52
1.43E-03	289790	0.99	1.38E-03	0.53
2.60E-03	288560	0.99	2.51E-03	0.60
4.24E-03	286040	0.98	4.08E-03	0.65
9.04E-03	282370	0.97	8.59E-03	0.84
1.03E-02	281400	0.97	9.73E-03	0.90

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-F(6C-2).xls.*

Table VII-21a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-G (7C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
4.28E-05	73528	1.00	4.21E-05	0.27
8.62E-05	73529	1.00	8.48E-05	0.27
1.75E-04	73525	1.00	1.72E-04	0.28
3.36E-04	73540	1.00	3.30E-04	0.30
6.63E-04	72944	0.99	6.49E-04	0.35
1.15E-03	72351	0.98	1.12E-03	0.38
2.15E-03	71761	0.98	2.09E-03	0.44

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-G(7C-1).xls*.

Table VII-22a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-G (7C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	80235	3846	5078	0.37	103
25	3600	172	80253	3847	5079	0.36	103
50	7200	345	80265	3848	5079	0.36	103
100	14400	690	80278	3848	5079	0.35	103

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-G(7C-2).xls*.

Table VII-22b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-G (7C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
3.44E-05	80234	1.00	3.37E-05	0.34
6.81E-05	80237	1.00	6.66E-05	0.36
1.35E-04	80247	1.00	1.32E-04	0.36
2.65E-04	80240	1.00	2.58E-04	0.37
5.28E-04	79619	0.99	5.15E-04	0.38
9.79E-04	79559	0.99	9.54E-04	0.41
1.84E-03	79003	0.98	1.79E-03	0.45
3.53E-03	78307	0.98	3.42E-03	0.48

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-G(7C-2).xls*.

Table VII-22c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-G (7C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
3.63E-05	80278	1.00	3.56E-05	0.35
7.19E-05	80295	1.00	7.04E-05	0.34
1.44E-04	80300	1.00	1.41E-04	0.34
2.86E-04	80217	1.00	2.80E-04	0.35
5.75E-04	80219	1.00	5.63E-04	0.34
1.01E-03	79590	0.99	9.88E-04	0.37
1.97E-03	79594	0.99	1.92E-03	0.41
3.52E-03	79051	0.99	3.42E-03	0.48
6.53E-03	77746	0.97	6.30E-03	0.58
1.16E-02	76599	0.95	1.11E-02	0.74
1.89E-02	74774	0.93	1.79E-02	0.89
2.93E-02	72306	0.90	2.74E-02	1.07
4.12E-02	70541	0.88	3.81E-02	1.30

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-G(7C-2).xls*.

Table VII-22d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-G (7C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle** [5]			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
3.90E-04	84600	1.00	0.76	3.89E-04	84400	1.00	0.76
7.75E-04	84600	1.00	0.85	7.77E-04	84700	1.00	0.79
9.70E-04	84400	1.00	0.83	9.80E-04	84500	1.00	0.87
1.27E-03	84200	1.00	0.84	1.27E-03	84200	1.00	0.86

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-G(7C-2).xls.*

Table VII-23a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-H (8C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
2.89E-05	98516	1.00	2.85E-05	0.32
5.77E-05	98421	1.00	5.66E-05	0.31
1.13E-04	98521	1.00	1.11E-04	0.32
2.27E-04	98422	1.00	2.23E-04	0.31
4.60E-04	98427	1.00	4.51E-04	0.32
8.25E-04	98436	1.00	8.11E-04	0.27
1.59E-03	98054	1.00	1.56E-03	0.31
3.12E-03	97757	0.99	3.05E-03	0.35
5.72E-03	97010	0.99	5.58E-03	0.40
9.44E-03	96136	0.98	9.18E-03	0.44

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file *Table_UTA-42-H(8C-1).xls*.

Table VII-24a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-H (8C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	102350	4907	5929	0.28	94
25	3600	172	102400	4909	5931	0.27	94
50	7200	345	102400	4909	5930	0.26	94
100	14400	690	102430	4910	5931	0.25	94
200	28800	1379	102470	4912	5931	0.24	94
400	57600	2758	102440	4911	5929	0.24	94

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-H(8C-2).xls*.

Table VII-24b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-H (8C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.82E-05	102460	1.00	2.78E-05	0.31
5.48E-05	102370	1.00	5.38E-05	0.28
1.11E-04	102480	1.00	1.09E-04	0.28
2.18E-04	102380	1.00	2.15E-04	0.28
4.51E-04	102370	1.00	4.43E-04	0.27
8.37E-04	102370	1.00	8.23E-04	0.29
1.65E-03	102390	1.00	1.62E-03	0.30
3.23E-03	102370	1.00	3.17E-03	0.30
6.10E-03	101610	0.99	5.96E-03	0.36
9.82E-03	100820	0.98	9.58E-03	0.41

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-H(8C-2).xls*.

Table VII-24c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-H (8C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
3.00E-05	102440	1.00	2.96E-05	0.21
5.84E-05	102350	1.00	5.75E-05	0.24
1.19E-04	102460	1.00	1.17E-04	0.24
2.39E-04	102470	1.00	2.35E-04	0.25
4.83E-04	102360	1.00	4.76E-04	0.25
9.01E-04	102360	1.00	8.87E-04	0.25
1.78E-03	102470	1.00	1.75E-03	0.26
3.47E-03	102370	1.00	3.41E-03	0.27
6.50E-03	101690	0.99	6.37E-03	0.32
1.05E-02	100910	0.99	1.02E-02	0.41
1.49E-02	100120	0.98	1.45E-02	0.48
2.30E-02	98582	0.96	2.22E-02	0.61

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-H(8C-2).xls*.

Table VII-24d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-H (8C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
3.11E-04	106000	1.00	0.19	3.13E-04	106000	1.00	0.35
4.53E-04	106000	1.00	0.33	4.57E-04	105000	0.99	0.30
7.58E-04	106000	1.00	0.35	7.52E-04	106000	1.00	0.27
9.65E-04	107000	1.01	0.34	9.68E-04	106000	1.00	0.36

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-H(8C-2).xls*.

Table VII-24e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-H (8C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
3.02E-05	102510	1.00	2.97E-05	0.24
5.96E-05	102510	1.00	5.88E-05	0.23
1.19E-04	102520	1.00	1.17E-04	0.24
2.37E-04	102530	1.00	2.33E-04	0.24
4.88E-04	102430	1.00	4.81E-04	0.24
8.70E-04	102530	1.00	8.56E-04	0.25
1.67E-03	101750	0.99	1.64E-03	0.26
3.53E-03	101750	0.99	3.47E-03	0.27
6.32E-03	101760	0.99	6.20E-03	0.30
1.14E-02	100860	0.98	1.11E-02	0.37
1.75E-02	100180	0.98	1.70E-02	0.46
2.55E-02	98632	0.96	2.45E-02	0.63

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-H(8C-2).xls*.

Table VII-24f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-H (8C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.83E-04	114000	1.00	0.28	2.84E-04	113000	1.00	0.24
4.86E-04	114000	1.00	0.28	4.87E-04	114000	1.01	0.24
6.96E-04	114000	1.00	0.25	6.95E-04	114000	1.01	0.25
9.02E-04	115000	1.01	0.26	9.02E-04	114000	1.01	0.26

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file *Table_UTA-42-H(8C-2).xls.*

Table VII-25a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-I (9A-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.12E-05	134690	1.00	1.07E-05	0.85
2.24E-05	134580	1.00	2.14E-05	0.84
4.45E-05	134710	1.00	4.22E-05	0.85
8.87E-05	134570	1.00	8.42E-05	0.86
1.68E-04	134590	1.00	1.59E-04	0.85
3.29E-04	133930	1.00	3.12E-04	0.88
6.32E-04	133240	0.99	5.96E-04	0.94
1.22E-03	131920	0.98	1.15E-03	1.02
2.23E-03	129920	0.97	2.08E-03	1.18

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-I(9A-1).xls*.

Table VII-26a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-I (9A-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	140030	6713	5767	0.84	136
25	3600	172	141410	6779	5795	0.81	136
50	7200	345	141440	6781	5795	0.78	136
100	14400	690	141560	6786	5797	0.75	136
200	28800	1379	142950	6853	5823	0.68	136
400	57600	2758	145220	6962	5866	0.68	136

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-I(9A-2).xls*.

Table VII-26b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-I (9A-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G^1, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average ^{2} Shearing Strain, %**	**Material Damping Ratio^3, D, %**
1.07E-05	140020	1.00	1.02E-05	0.85
2.14E-05	140170	1.00	2.04E-05	0.84
4.25E-05	140020	1.00	4.04E-05	0.84
8.48E-05	140170	1.00	8.06E-05	0.85
1.73E-04	140020	1.00	1.64E-04	0.82
3.17E-04	140020	1.00	3.00E-04	0.86
6.19E-04	139350	0.99	5.86E-04	0.88
1.21E-03	137930	0.98	1.14E-03	0.98
2.24E-03	135930	0.97	2.09E-03	1.11
3.69E-03	133740	0.95	3.41E-03	1.30

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-I(9A-2).xls*.

Table VII-26c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-I (9A-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.16E-05	141630	1.00	1.11E-05	0.75
2.32E-05	142170	1.00	2.22E-05	0.74
4.61E-05	142170	1.00	4.41E-05	0.75
9.15E-05	141480	1.00	8.75E-05	0.76
1.74E-04	141480	1.00	1.67E-04	0.77
3.45E-04	141630	1.00	3.29E-04	0.75
6.74E-04	140800	0.99	6.42E-04	0.78
1.29E-03	140100	0.99	1.23E-03	0.83
2.36E-03	138180	0.97	2.22E-03	0.98
3.91E-03	136020	0.96	3.64E-03	1.17
6.48E-03	131930	0.93	5.93E-03	1.44

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-I(9A-2).xls*.

Table VII-26d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-I (9A-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.29E-04	142000	1.00	2.37	2.30E-04	146000	1.00	2.18
3.77E-04	143000	1.01	2.41	3.86E-04	146000	1.00	2.20
4.92E-04	143000	1.01	2.41	4.86E-04	146000	1.00	2.23

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-I(9A-2).xls*.

Table VII-26e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-I (9A-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.20E-05	145230	1.00	1.15E-05	0.67
2.38E-05	145230	1.00	2.29E-05	0.66
4.75E-05	145380	1.00	4.56E-05	0.66
9.46E-05	145230	1.00	9.09E-05	0.67
1.80E-04	145370	1.00	1.73E-04	0.68
3.52E-04	145220	1.00	3.38E-04	0.71
6.88E-04	144530	0.99	6.58E-04	0.75
1.33E-03	143830	0.99	1.27E-03	0.79
2.45E-03	141730	0.98	2.32E-03	0.87
4.11E-03	140360	0.97	3.86E-03	1.00
6.64E-03	136930	0.94	6.12E-03	1.31
9.09E-03	133540	0.92	8.23E-03	1.64

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-I(9A-2).xls*.

Table VII-26f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-I (9A-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.07E-04	149000	1.00	1.63	1.05E-04	148000	1.00	1.65
2.28E-04	149000	1.00	1.67	2.24E-04	146000	0.99	1.66
3.72E-04	152000	1.02	1.73	3.78E-04	150000	1.01	1.62
4.67E-04	151000	1.01	1.63	4.97E-04	151300	1.02	1.86

[1] Gmax is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/Gmax = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-I(9A-2).xls*.

Table VII-27a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-J (10A-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.41E-05	123600	1.00	1.34E-05	0.83
2.76E-05	123610	1.00	2.63E-05	0.85
5.37E-05	122940	0.99	5.10E-05	0.86
1.03E-04	121960	0.99	9.68E-05	0.95
1.89E-04	120860	0.98	1.77E-04	1.05
3.59E-04	118690	0.96	3.35E-04	1.13

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-J(10A-1).xls.*

Table VII-28a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-J (10A-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	117340	5625	5228	0.85	138
25	3600	173	121670	5833	5323	0.87	138
50	7200	345	123870	5938	5370	0.87	138
100	14400	690	123810	5935	5367	0.87	138
200	28800	1381	125650	6024	5405	0.87	138
400	57600	2761	128570	6164	5440	0.86	138

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-J(10A-2).xls*.

Table VII-28b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-J (10A-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.17E-05	117360	1.00	1.11E-05	0.85
2.31E-05	117350	1.00	2.19E-05	0.85
4.51E-05	117340	1.00	4.29E-05	0.89
8.82E-05	116830	1.00	8.36E-05	0.88
1.64E-04	116300	0.99	1.55E-04	0.93
3.10E-04	114730	0.98	2.91E-04	1.03
5.83E-04	113680	0.97	5.44E-04	1.12
1.05E-03	111600	0.95	9.67E-04	1.31

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-J(10A-2).xls*.

Table VII-28c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-J (10A-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.02E-05	123820	1.00	9.69E-06	0.86
2.01E-05	123800	1.00	1.90E-05	0.87
3.93E-05	123350	1.00	3.73E-05	0.89
7.64E-05	122820	0.99	7.23E-05	0.89
1.38E-04	121750	0.98	1.30E-04	0.94
2.71E-04	120660	0.97	2.55E-04	1.01
5.18E-04	119050	0.96	4.83E-04	1.12
9.63E-04	117460	0.95	8.92E-04	1.26
1.82E-03	114840	0.93	1.67E-03	1.41

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-J(10A-2).xls*.

Table VII-28d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-J (10A-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.97E-04	97560	1.00	0.46	1.97E-04	97450	1.00	0.43
3.59E-04	92610	0.95	0.48	3.59E-04	92350	0.95	0.44
7.81E-04	92160	0.94	0.67	7.81E-04	92190	0.95	0.70

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-J(10A-2).xls*.

Table VII-28e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-J (10A-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
8.99E-06	128570	1.00	8.52E-06	0.87
1.74E-05	128690	1.00	1.66E-05	0.86
3.45E-05	128130	1.00	3.27E-05	0.87
6.78E-05	127990	0.99	6.42E-05	0.87
1.23E-04	127580	0.99	1.16E-04	0.89
2.36E-04	126480	0.98	2.22E-04	0.96
4.66E-04	125380	0.97	4.36E-04	1.06
8.84E-04	123600	0.96	8.21E-04	1.21
1.64E-03	120880	0.94	1.51E-03	1.39

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-J(10A-2).xls*.

Table VII-28f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-J (10A-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.79E-04	97160	1.00	0.59	1.79E-04	97270	1.00	0.59
3.47E-04	94290	0.97	0.48	3.53E-04	94180	0.97	0.43
7.40E-04	94430	0.97	0.47	7.58E-04	94000	0.97	0.48

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-J(10A-2).xls*.

Table VII-29a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-K (11C-1); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
5.53E-06	223300	1.00	5.34E-06	0.58
1.06E-05	222620	1.00	1.02E-05	0.59
2.10E-05	223290	1.00	2.02E-05	0.60
4.15E-05	223510	1.00	4.00E-05	0.59
8.26E-05	222700	1.00	7.96E-05	0.60
1.55E-04	223340	1.00	1.49E-04	0.63
3.05E-04	222490	1.00	2.94E-04	0.63
6.04E-04	222450	1.00	5.80E-04	0.67
1.16E-03	221030	0.99	1.11E-03	0.71
2.08E-03	219150	0.98	1.98E-03	0.78
3.10E-03	216630	0.97	2.93E-03	0.87
4.58E-03	213250	0.96	4.24E-03	1.26

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-K(11C-1).xls*.

Table VII-29b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-K (11C-1); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.97E-04	261000	0.99	0.39	1.91E-04	263000	1.00	0.38
3.76E-04	264900	1.00	0.38	3.59E-04	264200	1.00	0.38

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-K(11C-1).xls*.

Table VII-30a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-L (12C-1); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
8.59E-06	196020	1.00	8.37E-06	0.48
1.70E-05	196000	1.00	1.66E-05	0.46
3.39E-05	196020	1.00	3.30E-05	0.45
6.84E-05	196170	1.00	6.65E-05	0.45
1.41E-04	196180	1.00	1.37E-04	0.44
2.56E-04	196200	1.00	2.49E-04	0.45
4.99E-04	196010	1.00	4.85E-04	0.47
9.61E-04	195110	1.00	9.32E-04	0.49
1.79E-03	194390	0.99	1.73E-03	0.56
3.10E-03	192420	0.98	2.98E-03	0.66
4.72E-03	190640	0.97	4.49E-03	0.82

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-L(12C-1).xls*.

Table VII-30b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-L (12C-1); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.15E-04	222000	1.00	0.40	2.20E-04	221000	1.00	0.35
3.70E-04	219000	0.99	0.42	3.62E-04	222000	1.00	0.47
4.75E-04	221000	1.00	0.41	4.75E-04	223000	1.01	0.43

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-L(12C-1).xls*.

Table VII-31a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-M (13C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.38E-05	252170	1.00	1.35E-05	0.52
2.73E-05	252220	1.00	2.65E-05	0.52
5.41E-05	252270	1.00	5.25E-05	0.52
1.10E-04	252250	1.00	1.07E-04	0.52
2.03E-04	251000	1.00	1.97E-04	0.52
4.01E-04	250960	1.00	3.87E-04	0.54
7.62E-04	250990	1.00	7.35E-04	0.58
1.45E-03	248480	0.99	1.40E-03	0.61
2.50E-03	247220	0.98	2.39E-03	0.77
3.65E-03	243260	0.96	3.44E-03	0.96

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-M(13C-1).xls*.

Table VII-32a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-M (13C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	253610	12158	7532	0.52	144
25	3600	172	255100	12229	7554	0.50	144
50	7200	345	253820	12168	7536	0.46	144
100	14400	690	253520	12154	7532	0.43	144
200	28800	1379	253340	12145	7531	0.39	144
400	57600	2758	253020	12130	7530	0.31	144

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-M(13C-2).xls*.

Table VII-32b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-M (13C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average[2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.29E-05	253630	1.00	1.25E-05	0.53
2.59E-05	253900	1.00	2.52E-05	0.51
5.13E-05	253630	1.00	4.97E-05	0.52
1.03E-04	253630	1.00	9.95E-05	0.52
1.96E-04	253900	1.00	1.90E-04	0.52
3.84E-04	253900	1.00	3.72E-04	0.53
7.33E-04	252620	1.00	7.08E-04	0.56
1.40E-03	252420	1.00	1.35E-03	0.61
2.45E-03	251420	0.99	2.35E-03	0.72
3.66E-03	247610	0.98	3.46E-03	0.93

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-M(13C-2).xls*.

Table VII-32c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-M (13C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average[2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.47E-05	253800	1.00	1.43E-05	0.43
2.93E-05	253800	1.00	2.85E-05	0.42
5.85E-05	254070	1.00	5.70E-05	0.43
1.21E-04	253790	1.00	1.18E-04	0.43
2.23E-04	253790	1.00	2.17E-04	0.43
4.33E-04	253790	1.00	4.22E-04	0.45
8.31E-04	252520	0.99	8.07E-04	0.47
1.62E-03	252520	0.99	1.57E-03	0.51
2.79E-03	250030	0.98	2.69E-03	0.60
4.59E-03	248770	0.98	4.34E-03	0.84
6.85E-03	244970	0.96	6.43E-03	1.03

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-M(13C-2).xls*.

Table VII-32d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-M (13C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.50E-04	316000	1.00	0.24	1.54E-04	315000	1.00	0.37
2.55E-04	314000	0.99	0.24	2.57E-04	316000	1.00	0.26
3.31E-04	313000	0.99	0.30	3.24E-04	317000	1.01	0.23

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-M(13C-2).xls*.

Table VII-32e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-M (13C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average[2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.85E-05	254150	1.00	1.82E-05	0.31
3.66E-05	254430	1.00	3.59E-05	0.33
7.23E-05	254420	1.00	7.09E-05	0.33
1.50E-04	254160	1.00	1.48E-04	0.32
2.71E-04	254160	1.00	2.66E-04	0.31
5.21E-04	252880	0.99	5.11E-04	0.32
1.03E-03	252880	0.99	1.01E-03	0.35
1.90E-03	251670	0.99	1.85E-03	0.40
3.18E-03	250390	0.98	3.08E-03	0.52
4.76E-03	249120	0.98	4.56E-03	0.69
5.73E-03	247850	0.98	5.46E-03	0.77
7.51E-03	245330	0.97	7.10E-03	0.92
1.00E-02	241630	0.95	9.39E-03	1.06

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-M(13C-2).xls*.

Table VII-32f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-M (13C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.59E-04	312000	1.00	0.21	1.56E-04	311000	1.00	0.31
2.58E-04	310000	0.99	0.27	2.58E-04	309000	0.99	0.27
3.36E-04	310000	0.99	0.31	3.37E-04	308000	0.99	0.24

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-M(13C-2).xls*.

Table VII-33a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-N (14C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
8.45E-06	259510	1.00	8.03E-06	0.82
1.67E-05	259540	1.00	1.59E-05	0.83
3.34E-05	259580	1.00	3.17E-05	0.82
6.63E-05	259290	1.00	6.30E-05	0.82
1.27E-04	259590	1.00	1.21E-04	0.83
2.52E-04	259340	1.00	2.40E-04	0.84
4.94E-04	258490	1.00	4.69E-04	0.85
9.59E-04	258470	1.00	9.09E-04	0.88
1.85E-03	257440	0.99	1.75E-03	0.94
3.12E-03	255250	0.98	2.93E-03	1.01
5.14E-03	252000	0.97	4.77E-03	1.22

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-N(14C-1).xls*.

Table VII-34a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-N (14C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	262810	12599	7667	0.79	145
25	3600	172	264000	12656	7684	0.80	145
50	7200	345	264030	12658	7684	0.81	145
100	14400	690	264100	12661	7685	0.80	145
200	28800	1379	264180	12665	7683	0.80	145
400	57600	2758	264260	12669	7681	0.71	145

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-N(14C-2).xls*.

Table VII-34b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-N (14C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G^1, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average ^{2} Shearing Strain, %**	**Material Damping Ratio^3, D, %**
8.79E-06	262810	1.00	8.39E-06	0.83
1.75E-05	262810	1.00	1.66E-05	0.80
3.48E-05	262870	1.00	3.32E-05	0.79
6.93E-05	262530	1.00	6.60E-05	0.80
1.32E-04	262530	1.00	1.26E-04	0.81
2.62E-04	262530	1.00	2.50E-04	0.81
5.15E-04	261780	1.00	4.90E-04	0.81
1.00E-03	261710	1.00	9.54E-04	0.84
1.93E-03	260620	0.99	1.83E-03	0.88
3.29E-03	258160	0.98	3.10E-03	0.99
5.47E-03	255180	0.97	5.09E-03	1.17
7.32E-03	251690	0.96	6.71E-03	1.43

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-N(14C-2).xls*.

Table VII-34c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-N (14C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
8.57E-06	264090	1.00	8.21E-06	0.83
1.70E-05	264090	1.00	1.62E-05	0.80
3.40E-05	263810	1.00	3.24E-05	0.79
6.78E-05	264090	1.00	6.46E-05	0.80
1.30E-04	263810	1.00	1.24E-04	0.81
2.58E-04	263810	1.00	2.45E-04	0.81
5.07E-04	263900	1.00	4.83E-04	0.81
9.81E-04	262710	1.00	9.32E-04	0.84
1.86E-03	261890	0.99	1.76E-03	0.91
3.17E-03	259450	0.98	2.98E-03	1.00
5.55E-03	256440	0.97	5.17E-03	1.14

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-N(14C-2).xls*.

Table VII-34d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-N (14C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.00E-04	254000	1.00	3.03	1.98E-04	256000	1.00	3.04
3.24E-04	257000	1.01	3.04	3.26E-04	255000	1.00	3.08
4.23E-04	257000	1.01	3.06	4.23E-04	258000	1.01	3.08

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-N(14C-2).xls*.

Table VII-34e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-N (14C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
9.16E-06	263220	1.00	8.77E-06	0.69
1.82E-05	264320	1.00	1.75E-05	0.71
3.62E-05	264320	1.00	3.47E-05	0.71
7.25E-05	264090	1.00	6.95E-05	0.70
1.38E-04	264230	1.00	1.32E-04	0.69
2.72E-04	263190	1.00	2.60E-04	0.71
5.39E-04	263120	1.00	5.15E-04	0.72
1.02E-03	262120	0.99	9.77E-04	0.76
1.93E-03	261090	0.99	1.83E-03	0.83
3.25E-03	258700	0.98	3.07E-03	0.91
5.64E-03	256730	0.97	5.29E-03	1.07
7.70E-03	253350	0.96	7.11E-03	1.31

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: Table_UTA-42-N(14C-2).xls.

Table VII-34f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-N (14C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
9.41E-05	260000	1.00	2.34	9.62E-05	265000	1.00	2.07
1.87E-04	269000	1.03	2.10	1.79E-04	267000	1.01	2.29
3.17E-04	265000	1.02	2.24	3.11E-04	267000	1.01	2.23
4.07E-04	268000	1.03	2.28	4.01E-04	268000	1.01	2.23

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: Table_UTA-42-N(14C-2).xls.

Table VII-35a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-O (15C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.38E-05	182760	1.00	1.34E-05	0.42
2.74E-05	181920	1.00	2.67E-05	0.41
5.16E-05	181720	1.00	5.03E-05	0.41
9.57E-05	180660	0.99	9.30E-05	0.47
1.76E-04	178730	0.98	1.70E-04	0.55
3.06E-04	176650	0.97	2.94E-04	0.65

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-O(15C-1).xls.*

Table VII-36a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-O (15C-2); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.11E-05	188210	1.00	1.11E-05	0.48
2.15E-05	188030	1.00	2.15E-05	0.48
4.15E-05	187130	0.99	4.04E-05	0.43
7.78E-05	186940	0.99	7.56E-05	0.48
1.50E-04	184820	0.98	1.45E-04	0.56
2.55E-04	183960	0.98	2.46E-04	0.62
4.68E-04	180610	0.96	4.48E-04	0.70

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-O(15C-2).xls*.

Table VII-37a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-O (15C-3)

Isotropic Confining Pressure, σ_o			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, V_S	Low-Amplitude Material Damping Ratio, D_{min}	Estimated Total Unit Weight, gt
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	197780	9482	6668	0.58	143
25	3600	173	196860	9437	6652	0.59	143
50	7200	345	196860	9437	6652	0.58	143
100	14400	690	196920	9440	6653	0.58	143
200	28800	1381	196940	9441	6653	0.54	143
400	57600	2761	196960	9442	6652	0.57	143

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-O(15C-3).xls*.

Table VII-37b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-O (15C-3); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
9.11E-06	197950	1.00	8.81E-06	0.55
1.73E-05	196840	0.99	1.67E-05	0.55
3.47E-05	196640	0.99	3.35E-05	0.59
6.86E-05	196840	0.99	6.62E-05	0.58
1.38E-04	195730	0.99	1.33E-04	0.62
2.41E-04	194650	0.98	2.32E-04	0.66
4.60E-04	192470	0.97	4.40E-04	0.73
8.70E-04	190300	0.96	8.29E-04	0.79

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-O(15C-3).xls*.

Table VII-37c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-O (15C-3); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
9.16E-06	196870	1.00	8.85E-06	0.55
1.76E-05	196880	1.00	1.70E-05	0.56
3.50E-05	196700	1.00	3.38E-05	0.55
6.80E-05	196690	1.00	6.56E-05	0.58
1.36E-04	195790	0.99	1.30E-04	0.62
2.37E-04	193610	0.98	2.27E-04	0.69
4.50E-04	192510	0.98	4.30E-04	0.74
8.64E-04	190190	0.97	8.23E-04	0.79

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-O(15C-3).xls*.

Table VII-37d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-O (15C-3); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.38E-04	204600	1.01	0.49	1.38E-04	200700	0.99	0.52
2.63E-04	201400	0.99	0.65	2.56E-04	205600	1.01	0.62
5.50E-04	199800	0.98	0.69	5.50E-04	196400	0.97	0.55

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-O(15C-3).xls*.

Table VII-37e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-O (15C-3); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2761 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
8.77E-06	197890	1.00	8.48E-06	0.55
1.73E-05	196800	1.00	1.67E-05	0.58
3.49E-05	196990	1.00	3.37E-05	0.55
6.67E-05	196990	1.00	6.44E-05	0.58
1.32E-04	195690	0.99	1.27E-04	0.62
2.33E-04	193710	0.98	2.23E-04	0.68
4.39E-04	192450	0.98	4.19E-04	0.75
8.42E-04	190470	0.97	8.02E-04	0.80
1.59E-03	187230	0.95	1.50E-03	0.90
2.84E-03	183870	0.93	2.68E-03	0.95
4.71E-03	180690	0.92	4.40E-03	1.10
8.22E-03	175610	0.89	7.52E-03	1.44
9.75E-03	174600	0.89	8.82E-03	1.65

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-O(15C-3).xls*.

Table VII-37f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-O (15C-3); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2761 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.24E-04	203100	1.00	0.48	1.24E-04	206800	1.01	0.57
2.52E-04	203300	1.00	0.35	2.49E-04	203200	0.99	0.57
5.36E-04	201600	0.99	0.60	5.32E-04	200300	0.98	0.68

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-O(15C-3).xls*.

Table VII-38a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-P (16C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.06E-05	191130	1.00	1.03E-05	0.43
2.10E-05	191150	1.00	2.05E-05	0.41
4.19E-05	191170	1.00	4.07E-05	0.42
8.31E-05	191350	1.00	8.10E-05	0.43
1.69E-04	191320	1.00	1.64E-04	0.42
3.04E-04	190430	1.00	2.96E-04	0.46
6.02E-04	190420	1.00	5.85E-04	0.46
1.15E-03	189540	0.99	1.11E-03	0.50
2.22E-03	188590	0.99	2.15E-03	0.54
4.05E-03	186780	0.98	3.89E-03	0.65

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-P(16C-1).xls*.

Table VII-39a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-P (16C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G^1, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average ^{2} Shearing Strain, %**	**Material Damping Ratio^3, D, %**
1.99E-05	193060	1.00	1.94E-05	0.43
3.99E-05	192320	1.00	3.89E-05	0.44
7.87E-05	192140	1.00	7.65E-05	0.45
1.65E-04	192320	1.00	1.60E-04	0.44
3.02E-04	192140	1.00	2.93E-04	0.44
5.92E-04	192140	1.00	5.75E-04	0.46
1.14E-03	191220	0.99	1.10E-03	0.49
2.19E-03	190480	0.99	2.11E-03	0.53
3.96E-03	188620	0.98	3.81E-03	0.60
5.95E-03	185990	0.97	5.66E-03	0.80

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-P(16C-2).xls*.

Table VII-39b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-P (16C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G^1, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average ^{2} Shearing Strain, %**	**Material Damping Ratio^3, D, %**
2.03E-05	193260	1.00	1.98E-05	0.43
4.10E-05	193090	1.00	4.01E-05	0.41
8.07E-05	192290	1.00	7.86E-05	0.43
1.66E-04	192340	1.00	1.62E-04	0.43
3.05E-04	192160	1.00	2.97E-04	0.43
6.01E-04	192340	1.00	5.85E-04	0.43
1.14E-03	191250	0.99	1.11E-03	0.47
2.19E-03	190500	0.99	2.12E-03	0.51
3.92E-03	189410	0.98	3.78E-03	0.59
6.56E-03	187760	0.97	6.30E-03	0.67
9.86E-03	184190	0.95	9.29E-03	0.96

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-P(16C-2).xls*.

Table VII-39c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-P (16C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.13E-04	224000	1.00	0.24	1.14E-04	223000	1.00	0.23
3.60E-04	223000	1.00	0.25	3.54E-04	224000	1.00	0.25
4.65E-04	225000	1.00	0.26	4.62E-04	225000	1.01	0.24

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-P(16C-2).xls*.

Table VII-39d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-P (16C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.96E-05	192570	1.00	1.91E-05	0.42
3.89E-05	192570	1.00	3.80E-05	0.40
7.77E-05	192630	1.00	7.59E-05	0.40
1.60E-04	192570	1.00	1.56E-04	0.41
2.93E-04	192630	1.00	2.86E-04	0.39
5.73E-04	192620	1.00	5.59E-04	0.42
1.08E-03	191640	1.00	1.05E-03	0.46
2.06E-03	190780	0.99	2.00E-03	0.49
3.76E-03	189700	0.99	3.63E-03	0.58
6.24E-03	187870	0.98	5.97E-03	0.71
9.68E-03	185290	0.96	9.13E-03	0.94
1.42E-02	181730	0.94	1.32E-02	1.14

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-P(16C-2).xls*.

Table VII-39e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-P (16C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.10E-04	225000	1.00	0.27	2.18E-04	224000	1.00	0.26
3.58E-04	224000	1.00	0.28	3.60E-04	223000	1.00	0.26
4.66E-04	225000	1.00	0.27	4.65E-04	225000	1.00	0.27

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-P(16C-2).xls*.

Table VII-40a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-Q (17C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.24E-05	105230	1.00	2.18E-05	0.51
4.37E-05	105310	1.00	4.24E-05	0.53
8.53E-05	105290	1.00	8.27E-05	0.51
1.66E-04	105210	1.00	1.61E-04	0.51
3.44E-04	104410	0.99	3.33E-04	0.52
6.10E-04	104420	0.99	5.89E-04	0.56
1.18E-03	103720	0.98	1.14E-03	0.59
2.25E-03	102930	0.98	2.16E-03	0.64
4.29E-03	101240	0.96	4.11E-03	0.70

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Q(17C-1).xls.*

Table VII-41a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-Q (17C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	115050	5515	5815	0.54	110
25	3600	172	115910	5557	5836	0.51	110
50	7200	345	116020	5562	5838	0.47	110
100	14400	690	116880	5603	5860	0.45	110
200	28800	1379	116890	5604	5857	0.44	110
400	57600	2758	116870	5603	5857	0.41	110

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Q(17C-2).xls*.

Table VII-41b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-Q (17C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.97E-05	115170	1.00	1.91E-05	0.54
3.87E-05	115160	1.00	3.75E-05	0.53
7.64E-05	115060	1.00	7.40E-05	0.55
1.54E-04	115160	1.00	1.49E-04	0.53
3.15E-04	115170	1.00	3.05E-04	0.54
5.79E-04	115070	1.00	5.61E-04	0.55
1.12E-03	115170	1.00	1.08E-03	0.53
2.17E-03	114340	0.99	2.10E-03	0.56
4.11E-03	113500	0.99	3.96E-03	0.59
7.32E-03	112560	0.98	7.02E-03	0.66
1.19E-02	111730	0.97	1.14E-02	0.75

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Q(17C-2).xls*.

Table VII-41c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-Q (17C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
2.22E-05	116780	1.00	2.16E-05	0.45
4.34E-05	116790	1.00	4.23E-05	0.44
8.66E-05	116790	1.00	8.44E-05	0.44
1.72E-04	116790	1.00	1.68E-04	0.45
3.50E-04	116790	1.00	3.41E-04	0.42
6.34E-04	116050	0.99	6.17E-04	0.42
1.26E-03	115960	0.99	1.22E-03	0.44
2.48E-03	116040	0.99	2.41E-03	0.46
4.77E-03	115100	0.99	4.62E-03	0.50
8.65E-03	114270	0.98	8.35E-03	0.57
1.38E-02	113430	0.97	1.32E-02	0.68
2.34E-02	110940	0.95	2.22E-02	0.83

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Q(17C-2).xls*.

Table VII-41d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-Q (17C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
4.48E-04	115000	1.00	0.53	4.42E-04	115000	1.00	0.55
9.54E-04	115000	1.00	0.54	9.40E-04	116000	1.01	0.57

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Q(17C-2).xls*.

Table VII-41e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-Q (17C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
2.31E-05	116970	1.00	2.25E-05	0.42
4.52E-05	116870	1.00	4.41E-05	0.42
9.03E-05	116860	1.00	8.81E-05	0.42
1.81E-04	116970	1.00	1.77E-04	0.41
3.71E-04	116860	1.00	3.62E-04	0.42
6.84E-04	116860	1.00	6.67E-04	0.43
1.31E-03	116970	1.00	1.28E-03	0.41
2.57E-03	116020	0.99	2.50E-03	0.43
4.88E-03	116040	0.99	4.74E-03	0.46
9.13E-03	114460	0.98	8.82E-03	0.56
1.52E-02	113520	0.97	1.47E-02	0.63
2.52E-02	111950	0.96	2.40E-02	0.81
3.61E-02	109460	0.94	3.40E-02	0.99

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Q(17C-2).xls*.

Table VII-41f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-Q (17C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.18E-04	116000	1.00	0.57	2.16E-04	117000	1.00	0.52
9.50E-04	115000	0.99	0.54	9.45E-04	115000	0.98	0.57

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Q(17C-2).xls*.

Table VII-42a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-R (18C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.49E-05	107930	1.00	2.45E-05	0.27
4.97E-05	107920	1.00	4.88E-05	0.29
9.67E-05	107240	1.00	9.50E-05	0.28
1.96E-04	107920	1.00	1.92E-04	0.28
4.01E-04	107250	1.00	3.94E-04	0.30
7.47E-04	107250	1.00	7.33E-04	0.31
1.45E-03	107240	1.00	1.42E-03	0.33
2.72E-03	106380	0.99	2.66E-03	0.37
4.93E-03	105710	0.98	4.79E-03	0.45
8.44E-03	104170	0.97	8.16E-03	0.56

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-R(18C-1).xls*.

Table VII-43a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-R (18C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	117590	5637	5652	0.38	119
25	3600	173	117490	5632	5650	0.39	119
50	7200	345	118440	5678	5672	0.40	119
100	14400	690	118360	5674	5669	0.34	119
200	28800	1381	119230	5716	5689	0.32	119
400	57600	2761	120190	5762	5709	0.32	119

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-R(18C-2).xls*.

Table VII-43b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-R (18C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G^1, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average ^{2} Shearing Strain, %**	**Material Damping Ratio^3, D, %**
2.05E-05	117470	1.00	2.01E-05	0.36
4.09E-05	117480	1.00	4.00E-05	0.36
8.14E-05	117480	1.00	7.96E-05	0.36
1.62E-04	117480	1.00	1.59E-04	0.37
3.32E-04	117470	1.00	3.25E-04	0.38
6.12E-04	117480	1.00	5.98E-04	0.37
1.19E-03	117480	1.00	1.16E-03	0.39
2.31E-03	116670	0.99	2.25E-03	0.41
4.31E-03	115870	0.99	4.19E-03	0.46
7.74E-03	115060	0.98	7.48E-03	0.54
1.25E-02	113470	0.97	1.20E-02	0.66

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-R(18C-2).xls*.

Table VII-43c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-R (18C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.23E-05	118270	1.00	2.18E-05	0.30
4.50E-05	118380	1.00	4.41E-05	0.31
8.91E-05	118370	1.00	8.74E-05	0.31
1.78E-04	118380	1.00	1.75E-04	0.32
3.62E-04	118250	1.00	3.55E-04	0.33
6.70E-04	118390	1.00	6.57E-04	0.32
1.29E-03	118380	1.00	1.26E-03	0.34
2.46E-03	117550	0.99	2.40E-03	0.37
2.54E-03	117580	0.99	2.48E-03	0.36
4.65E-03	116760	0.99	4.53E-03	0.42
8.06E-03	115960	0.98	7.81E-03	0.52
1.31E-02	114210	0.97	1.26E-02	0.63

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-R(18C-2).xls*.

Table VII-43d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-R (18C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.23E-04	123000	1.00	0.36	2.26E-04	123000	1.00	0.33
4.12E-04	123400	1.00	0.39	4.12E-04	123000	1.00	0.42
8.50E-04	123000	1.00	0.45	8.50E-04	123000	1.00	0.48

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-R(18C-2).xls*.

Table VII-43e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-R (18C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.17E-05	120980	1.00	2.12E-05	0.31
4.30E-05	120980	1.00	4.22E-05	0.30
8.56E-05	120980	1.00	8.40E-05	0.31
1.71E-04	120990	1.00	1.68E-04	0.30
3.49E-04	120980	1.00	3.42E-04	0.30
6.62E-04	120270	0.99	6.50E-04	0.31
1.31E-03	120180	0.99	1.29E-03	0.31
2.57E-03	120270	0.99	2.51E-03	0.36
4.76E-03	119460	0.99	4.64E-03	0.39
8.18E-03	118540	0.98	7.93E-03	0.48
1.31E-02	116910	0.97	1.26E-02	0.61
2.02E-02	114470	0.95	1.93E-02	0.79
2.84E-02	112090	0.93	2.66E-02	1.02

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-R(18C-2).xls*.

Table VII-43f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-R (18C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.07E-04	125000	1.00	0.48	2.04E-04	125000	1.00	0.56
4.00E-04	126000	1.01	0.41	3.88E-04	125000	1.00	0.42
8.43E-04	124200	0.99	0.45	8.43E-04	124200	0.99	0.40

[1] Gmax is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/Gmax = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-R(18C-2).xls*.

Table VII-44a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-S (19C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.43E-05	248010	1.00	1.39E-05	0.51
2.82E-05	247980	1.00	2.73E-05	0.52
5.51E-05	248040	1.00	5.33E-05	0.52
1.08E-04	246780	1.00	1.04E-04	0.55
1.97E-04	245630	0.99	1.90E-04	0.57
3.81E-04	244370	0.99	3.67E-04	0.61
6.68E-04	241970	0.98	6.40E-04	0.70
1.16E-03	238370	0.96	1.10E-03	0.84

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-S(19C-1).xls*.

Table VII-45a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-S (19C-2)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	252910	12124	7396	0.43	149
25	3600	173	254140	12183	7413	0.44	149
50	7200	345	254170	12185	7413	0.42	149
100	14400	690	254210	12187	7413	0.44	149
200	28800	1381	256800	12311	7450	0.45	149
400	57600	2761	258230	12379	7467	0.45	149

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-S(19C-2).xls.*

Table VII-45b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-S (19C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.59E-05	252840	1.00	1.55E-05	0.38
3.15E-05	252860	1.00	3.07E-05	0.41
6.19E-05	252890	1.00	6.03E-05	0.43
1.23E-04	252850	1.00	1.20E-04	0.45
2.22E-04	251370	0.99	2.16E-04	0.44
4.09E-04	250400	0.99	3.96E-04	0.52
7.07E-04	247970	0.98	6.80E-04	0.63
1.20E-03	244330	0.97	1.14E-03	0.78

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-S(19C-2).xls*.

Table VII-45c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-S (19C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.57E-05	254270	1.00	1.53E-05	0.44
3.10E-05	254270	1.00	3.02E-05	0.43
6.07E-05	254260	1.00	5.91E-05	0.42
1.22E-04	253060	1.00	1.19E-04	0.45
2.20E-04	253070	1.00	2.13E-04	0.48
4.12E-04	251560	0.99	3.99E-04	0.52
7.12E-04	249370	0.98	6.84E-04	0.63
1.21E-03	245710	0.97	1.15E-03	0.75
1.87E-03	242110	0.95	1.76E-03	1.00

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-S(19C-2).xls*.

Table VII-45d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-S (19C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.06E-04	271500	1.00	0.50	1.06E-04	271800	1.00	0.43
1.91E-04	272100	1.00	0.49	1.91E-04	272100	1.00	0.41
3.92E-04	268300	0.99	0.45	3.92E-04	268100	0.99	0.47

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-S(19C-2).xls*.

Table VII-45e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-S (19C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.53E-05	258280	1.00	1.49E-05	0.42
3.00E-05	258280	1.00	2.92E-05	0.42
5.87E-05	257020	1.00	5.72E-05	0.43
1.22E-04	257020	1.00	1.19E-04	0.38
2.17E-04	255810	0.99	2.10E-04	0.46
4.11E-04	254570	0.99	3.98E-04	0.53
7.15E-04	252100	0.98	6.87E-04	0.63
1.21E-03	248410	0.96	1.16E-03	0.74
1.93E-03	245980	0.95	1.82E-03	0.93
2.95E-03	241140	0.93	2.75E-03	1.16

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-S(19C-2).xls*.

Table VII-45f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-S (19C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
9.48E-05	273000	1.00	0.51	9.35E-05	277000	1.00	0.45
1.91E-04	272100	1.00	0.52	1.88E-04	270200	0.98	0.60
3.92E-04	275600	1.01	0.43	3.92E-04	275400	0.99	0.46

[1] Gmax is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/Gmax = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-S(19C-2).xls*.

Table VII-46a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-T (20C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.63E-05	98404	1.00	2.56E-05	0.47
5.10E-05	98416	1.00	4.96E-05	0.47
1.01E-04	98495	1.00	9.79E-05	0.47
1.98E-04	98499	1.00	1.92E-04	0.46
3.99E-04	98406	1.00	3.87E-04	0.48
7.06E-04	97654	0.99	6.84E-04	0.49
1.18E-03	97661	0.99	1.14E-03	0.51
1.60E-03	97669	0.99	1.55E-03	0.55
2.60E-03	96915	0.98	2.51E-03	0.59
4.89E-03	96165	0.98	4.70E-03	0.63
8.39E-03	95422	0.97	8.01E-03	0.75

[1] Gmax is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/Gmax = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-T(20C-1).xls*.

Table VII-47a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-T (20C-2)

Isotropic Confining Pressure, σ_o			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, V_S	Low-Amplitude Material Damping Ratio, D_{min}	Estimated Total Unit Weight, gt
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	102240	4901	5456	0.45	111
25	3600	172	102220	4900	5455	0.43	111
50	7200	345	102340	4906	5458	0.41	111
100	14400	690	102350	4907	5458	0.40	111
200	28800	1379	102380	4908	5458	0.39	111
400	57600	2758	102410	4910	5458	0.37	111

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-T(20C-2).xls*.

Table VII-47b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-T (20C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
2.59E-05	102240	1.00	2.52E-05	0.46
5.01E-05	102240	1.00	4.88E-05	0.45
9.93E-05	102240	1.00	9.67E-05	0.44
1.98E-04	102240	1.00	1.93E-04	0.45
4.07E-04	102130	1.00	3.96E-04	0.43
7.32E-04	102170	1.00	7.12E-04	0.45
1.40E-03	101490	0.99	1.36E-03	0.46
2.73E-03	101490	0.99	2.65E-03	0.50
5.17E-03	100710	0.99	4.98E-03	0.58
8.76E-03	99190	0.97	8.40E-03	0.68
1.37E-02	98420	0.96	1.30E-02	0.82

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-T(20C-2).xls*.

Table VII-47c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-T (20C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.83E-05	102350	1.00	2.77E-05	0.42
5.50E-05	102350	1.00	5.37E-05	0.40
1.07E-04	102280	1.00	1.05E-04	0.41
2.15E-04	102280	1.00	2.10E-04	0.41
4.44E-04	102280	1.00	4.33E-04	0.42
8.15E-04	102280	1.00	7.95E-04	0.42
1.54E-03	102280	1.00	1.51E-03	0.41
2.99E-03	101490	0.99	2.91E-03	0.45
5.52E-03	100820	0.99	5.34E-03	0.52
9.52E-03	99220	0.97	9.16E-03	0.63
1.51E-02	98490	0.96	1.44E-02	0.76

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-T(20C-2).xls*.

Table VII-47d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-T (20C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.25E-04	112000	1.00	0.46	2.21E-04	112000	1.00	0.46
4.48E-04	112000	1.00	0.48	4.51E-04	112000	1.00	0.46
9.72E-04	112000	1.00	0.38	9.71E-04	112000	1.00	0.39

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-T(20C-2).xls*.

Table VII-47e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-T (20C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
2.98E-05	103090	1.00	2.93E-05	0.39
5.63E-05	102410	1.00	5.52E-05	0.40
1.14E-04	103090	1.00	1.12E-04	0.37
2.26E-04	102410	1.00	2.21E-04	0.38
4.72E-04	102410	1.00	4.63E-04	0.38
8.68E-04	102300	0.99	8.51E-04	0.38
1.68E-03	102410	1.00	1.64E-03	0.36
3.34E-03	101660	0.99	3.25E-03	0.40
5.87E-03	100880	0.98	5.69E-03	0.49
9.78E-03	99360	0.97	9.42E-03	0.61
1.59E-02	98510	0.96	1.52E-02	0.73
2.51E-02	97010	0.94	2.36E-02	0.97

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-T(20C-2).xls*.

Table VII-47f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-T (20C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
2.25E-04	111000	1.00	0.29	2.31E-04	112000	1.00	0.28
4.49E-04	111000	1.00	0.44	4.49E-04	112000	1.00	0.45
9.79E-04	111000	1.00	0.39	9.74E-04	112000	1.00	0.39

[1] Gmax is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/Gmax = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-T(20C-2).xls*.

Table VII-48a. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-U (21C-1); Isotropic Confining Pressure, σ_o = 0 psi (0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
4.01E-05	82704	1.00	3.94E-05	0.34
7.73E-05	82708	1.00	7.59E-05	0.31
1.54E-04	82636	1.00	1.51E-04	0.31
3.01E-04	82641	1.00	2.95E-04	0.33
5.93E-04	82639	1.00	5.81E-04	0.32
1.07E-03	82011	0.99	1.05E-03	0.33
2.00E-03	81931	0.99	1.95E-03	0.38
3.70E-03	81245	0.98	3.60E-03	0.43
5.95E-03	80552	0.97	5.75E-03	0.55
9.61E-03	79175	0.96	9.20E-03	0.71

[1] Gmax is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/Gmax = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-U(21C-1).xls*.

Table VII-49a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-U (21C-2)

Isotropic Confining Pressure, σ_o			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, V_S	Low-Amplitude Material Damping Ratio, D_{min}	Estimated Total Unit Weight, gt
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	84060	4030	5115	0.36	103
25	3600	172	84068	4030	5115	0.34	103
50	7200	345	84074	4030	5115	0.35	103
100	14400	690	84086	4031	5116	0.37	103
200	28800	1379	84764	4064	5135	0.35	103
400	57600	2758	84904	4070	5137	0.38	103

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-U(21C-2).xls*.

Table VII-49b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-U (21C-2); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
3.55E-05	84027	1.00	3.49E-05	0.40
7.05E-05	84027	1.00	6.91E-05	0.37
1.41E-04	84027	1.00	1.39E-04	0.35
2.83E-04	84060	1.00	2.77E-04	0.35
5.83E-04	84060	1.00	5.72E-04	0.37
1.05E-03	84060	1.00	1.02E-03	0.39
1.91E-03	84060	1.00	1.87E-03	0.37
3.68E-03	83339	0.99	3.58E-03	0.44
6.14E-03	82653	0.98	5.94E-03	0.54
9.94E-03	81257	0.97	9.51E-03	0.71
1.42E-02	79874	0.95	1.33E-02	0.98

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-U(21C-2).xls*.

Table VII-49c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-U (21C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
3.61E-05	84709	1.01	3.55E-05	0.37
7.07E-05	84084	1.00	6.94E-05	0.37
1.42E-04	84118	1.00	1.40E-04	0.35
2.85E-04	84116	1.00	2.80E-04	0.35
5.90E-04	84120	1.00	5.79E-04	0.36
1.06E-03	84120	1.00	1.04E-03	0.38
1.94E-03	84116	1.00	1.89E-03	0.37
3.71E-03	83331	0.99	3.62E-03	0.44
6.03E-03	82611	0.98	5.82E-03	0.55
1.01E-02	81248	0.96	9.73E-03	0.65
1.57E-02	79930	0.95	1.47E-02	0.98

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-U(21C-2).xls*.

Table VII-49d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-U (21C-2); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
5.26E-04	93700	1.00	0.39	5.34E-04	93400	1.00	0.47
9.02E-04	92300	0.99	0.41	8.97E-04	92900	0.99	0.46
1.18E-03	92900	0.99	0.42	1.18E-03	92700	0.99	0.39

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-U(21C-2).xls*.

Table VII-49e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-U (21C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
3.52E-05	84906	1.00	3.47E-05	0.35
7.04E-05	84805	1.00	6.90E-05	0.35
1.38E-04	84904	1.00	1.35E-04	0.37
2.72E-04	84904	1.00	2.66E-04	0.33
5.55E-04	84904	1.00	5.43E-04	0.34
9.82E-04	84904	1.00	9.61E-04	0.35
1.91E-03	84080	0.99	1.86E-03	0.37
3.55E-03	83358	0.98	3.46E-03	0.42
5.94E-03	82672	0.97	5.74E-03	0.57
9.79E-03	81276	0.96	9.39E-03	0.67
1.58E-02	79955	0.94	1.49E-02	0.95

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-U(21C-2).xls*.

Table VII-49f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-U (21C-2); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
5.32E-04	93400	1.00	0.45	5.29E-04	93000	1.00	0.48
8.83E-04	93100	1.00	0.42	8.83E-04	93000	1.00	0.41
1.16E-03	93300	1.00	0.43	1.16E-03	93600	1.01	0.47

[1] Gmax is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/Gmax = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-U(21C-2).xls*.

Table VII-50a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-W (23C)

Isotropic Confining Pressure, σ_o			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, V_S	Low-Amplitude Material Damping Ratio, D_{min}	Estimated Total Unit Weight, gt
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	49938	2394	4208	0.68	91
21	3024	145	50947	2442	4250	0.68	91
41	5904	283	51016	2446	4253	0.67	91
82	11808	566	51149	2452	4258	0.66	91
164	23616	1132	49777	2386	4200	0.69	91
328	47232	2264	50548	2423	4230	0.71	91

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-W(23C).xls*.

Table VII-50b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-W (23C); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
2.03E-05	50028	1.00	1.95E-05	0.67
4.03E-05	50025	1.00	3.86E-05	0.66
7.68E-05	49809	1.00	7.37E-05	0.66
1.49E-04	49593	0.99	1.42E-04	0.68
2.86E-04	49042	0.98	2.73E-04	0.78

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-W(23C).xls*.

Table VII-50c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-W (23C); Isotropic Confining Pressure, σ_o = 82 psi (11.8 ksf=565 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
2.08E-05	51170	1.00	2.00E-05	0.63
3.93E-05	51069	1.00	3.78E-05	0.63
7.53E-05	50845	1.00	7.24E-05	0.63
1.47E-04	50632	0.99	1.41E-04	0.73
2.80E-04	50087	0.98	2.67E-04	0.79
5.44E-04	49272	0.96	5.14E-04	0.90
9.50E-04	48193	0.94	8.91E-04	1.05
1.78E-03	46868	0.92	1.65E-03	1.23
3.44E-03	46072	0.90	3.16E-03	1.38
6.39E-03	44517	0.87	5.76E-03	1.74

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-W(23C).xls*.

Table VII-50d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-W (23C); Isotropic Confining Pressure, σ_o = 82 psi (11.8 ksf=565 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.33E-04	50200	1.00	3.94	1.31E-04	50300	1.00	3.96
2.51E-04	50200	1.00	3.95	2.49E-04	50100	1.00	3.94
4.96E-04	50200	1.00	3.95	4.92E-04	50100	1.00	3.94
1.01E-03	49000	0.98	4.13	1.01E-03	49300	0.98	4.17
2.26E-03	47300	0.94	4.51	2.24E-03	47900	0.95	4.52

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-W(23C).xls*.

Table VII-50e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-W (23C); Isotropic Confining Pressure, σ_o = 328 psi (47.2 ksf=2262 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.98E-05	50977	1.00	1.91E-05	0.62
3.72E-05	50749	1.00	3.57E-05	0.66
7.09E-05	50537	0.99	6.77E-05	0.75
1.35E-04	50207	0.99	1.29E-04	0.77
2.49E-04	49662	0.97	2.35E-04	0.92
4.85E-04	48572	0.95	4.54E-04	1.07
8.53E-04	47505	0.93	7.93E-04	1.19
1.62E-03	46185	0.91	1.49E-03	1.37
3.13E-03	44882	0.88	2.85E-03	1.55
5.91E-03	43854	0.86	5.24E-03	1.99

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-W(23C).xls.*

Table VII-50f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-W (23C); Isotropic Confining Pressure, σ_o = 328 psi (47.2 ksf=2262 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.31E-04	50100	1.00	3.96	1.35E-04	50100	1.00	3.95
2.46E-04	50200	1.00	3.93	2.44E-04	50200	1.00	3.98
5.00E-04	49500	0.99	3.94	4.94E-04	49800	0.99	3.98
1.03E-03	48300	0.96	3.99	1.02E-03	48800	0.97	3.95
2.29E-03	46800	0.93	4.23	2.28E-03	46800	0.93	4.20

[1] Gmax is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/Gmax = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-W(23C).xls.*

Table VII-51a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-X (24C)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	27204	1304	3296	0.75	81
32	4608	220	28701	1376	3384	0.73	81
65	9360	449	29943	1435	3456	0.74	81
130	18720	897	32241	1546	3584	0.73	81
260	37440	1793	36391	1745	3803	0.70	81
400	57600	2758	38355	1839	3901	0.68	81

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-X(24C).xls*.

Table VII-51b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-X (24C); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G^1, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average ^{2} Shearing Strain, %**	**Material Damping Ratio^3, D, %**
3.69E-05	27163	1.00	3.55E-05	0.66
7.08E-05	27165	1.00	6.82E-05	0.66
1.38E-04	27167	1.00	1.34E-04	0.65
2.74E-04	27082	1.00	2.64E-04	0.66
5.26E-04	26878	0.99	5.04E-04	0.69
8.84E-04	26671	0.98	8.45E-04	0.74

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-X(24C).xls*.

Table VII-51c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-X (24C); Isotropic Confining Pressure, σ_o = 130 psi (18.7 ksf=896 kPa)

Peak Shearing Strain, %	**Shear Modulus, G^1, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average ^{2} Shearing Strain, %**	**Material Damping Ratio^3, D, %**
5.52E-05	32942	1.00	5.27E-05	0.75
1.08E-04	32946	1.00	1.04E-04	0.71
2.15E-04	32942	1.00	2.06E-04	0.71
4.26E-04	32946	1.00	4.09E-04	0.72
8.37E-04	32949	1.00	8.01E-04	0.71
1.56E-03	32724	0.99	1.49E-03	0.75
2.86E-03	32497	0.99	2.71E-03	0.87
5.13E-03	32047	0.97	4.81E-03	1.04
8.78E-03	31153	0.95	8.11E-03	1.30

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-X(24C).xls*.

Table VII-51d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-X (24C); Isotropic Confining Pressure, σ_o = 130 psi (18.7 ksf=896 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
2.07E-04	33400	1.00	1.95	2.02E-04	33300	1.00	1.95
3.86E-04	33100	0.99	1.93	3.82E-04	33300	1.00	1.97
7.48E-04	33200	0.99	2.02	7.64E-04	33300	1.00	1.95
1.51E-03	33300	1.00	2.17	1.51E-03	33200	1.00	2.13
3.28E-03	33000	0.99	2.34	3.28E-03	33000	0.99	2.23

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-X(24C).xls*.

Table VII-51e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-X (24C); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
5.04E-05	38759	1.00	4.88E-05	0.69
9.83E-05	38751	1.00	9.46E-05	0.66
1.96E-04	38852	1.00	1.89E-04	0.65
3.92E-04	38811	1.00	3.76E-04	0.65
7.80E-04	38761	1.00	7.50E-04	0.67
1.49E-03	38714	1.00	1.43E-03	0.69
2.88E-03	38665	1.00	2.76E-03	0.68
5.48E-03	38370	0.99	5.24E-03	0.72
1.02E-02	38324	0.99	9.62E-03	0.86
1.83E-02	37294	0.96	1.72E-02	1.00
3.03E-02	36281	0.94	2.82E-02	1.22
5.03E-02	34812	0.90	4.55E-02	1.66

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-X(24C).xls*.

Table VII-51f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-X (24C); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle** [5]			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
3.21E-04	40400	1.00	1.46	3.20E-04	40400	1.00	1.44
6.27E-04	40600	1.00	1.49	6.29E-04	40400	1.00	1.45
1.25E-03	40500	1.00	1.43	1.25E-03	40500	1.00	1.47
2.73E-03	40500	1.00	1.50	2.72E-03	40600	1.00	1.44

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-X(24C).xls*.

Table VII-52a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-Y (25C)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	40246	1929	4141	0.35	76
32	4608	220	40259	1930	4141	0.35	76
65	9360	449	40373	1935	4146	0.36	76
130	18720	897	40543	1944	4154	0.37	76
260	37440	1793	41102	1970	4181	0.38	76
400	57600	2758	41340	1982	4191	0.40	76

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Y(25C).xls*.

Table VII-52b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-Y (25C); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
3.81E-05	40210	1.00	3.74E-05	0.39
7.38E-05	40209	1.00	7.23E-05	0.35
1.47E-04	40213	1.00	1.45E-04	0.33
2.93E-04	40173	1.00	2.88E-04	0.34
5.79E-04	40123	1.00	5.68E-04	0.36
1.19E-03	40104	1.00	1.17E-03	0.35
2.20E-03	40074	1.00	2.16E-03	0.33
4.23E-03	39979	0.99	4.13E-03	0.38
7.85E-03	39446	0.98	7.64E-03	0.45
1.43E-02	38964	0.97	1.38E-02	0.55

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Y(25C).xls*.

Table VII-52c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-Y (25C); Isotropic Confining Pressure, σ_o = 130 psi (18.7 ksf=896 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
3.49E-05	40577	1.00	3.44E-05	0.41
6.92E-05	40580	1.00	6.79E-05	0.37
1.38E-04	40683	1.00	1.36E-04	0.36
2.77E-04	40686	1.00	2.70E-04	0.36
5.49E-04	40687	1.00	5.36E-04	0.37
1.12E-03	40685	1.00	1.09E-03	0.37
2.03E-03	40443	1.00	1.98E-03	0.39
3.98E-03	40441	1.00	3.88E-03	0.40
7.18E-03	40442	1.00	6.98E-03	0.45
1.29E-02	39949	0.98	1.24E-02	0.58
2.37E-02	38970	0.96	2.26E-02	0.71
3.92E-02	38004	0.94	3.71E-02	0.90

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Y(25C).xls*.

Table VII-52d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-Y (25C); Isotropic Confining Pressure, σ_o = 130 psi (18.7 ksf=896 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.60E-04	42800	1.000	1.10	1.58E-04	42700	1.000	1.11
3.00E-04	42800	1.000	1.04	2.94E-04	42700	1.000	1.06
5.88E-04	42800	1.000	1.09	5.86E-04	42800	1.002	1.05
1.17E-03	42700	0.998	1.10	1.17E-03	43000	1.007	1.09
2.54E-03	42900	1.002	1.12	2.52E-03	43100	1.009	1.04

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Y(25C).xls*.

Table VII-52e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-Y (25C); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G^1, ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
3.37E-05	41465	1.00	3.33E-05	0.45
6.72E-05	41470	1.00	6.57E-05	0.39
1.33E-04	41527	1.00	1.30E-04	0.39
2.65E-04	41533	1.00	2.59E-04	0.38
5.30E-04	41482	1.00	5.17E-04	0.39
1.09E-03	41431	1.00	1.06E-03	0.40
2.01E-03	41382	1.00	1.97E-03	0.41
3.91E-03	41331	1.00	3.81E-03	0.41
7.46E-03	41281	1.00	7.24E-03	0.49
1.36E-02	40737	0.98	1.31E-02	0.53
2.42E-02	40189	0.97	2.33E-02	0.63
3.93E-02	39647	0.96	3.73E-02	0.83
5.95E-02	38142	0.92	5.54E-02	1.15
8.43E-02	36665	0.88	7.72E-02	1.45

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Y(25C).xls*.

Table VII-52f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-Y (25C); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.53E-04	43600	1.00	0.97	1.59E-04	43900	1.00	0.96
2.90E-04	43700	1.00	0.96	2.89E-04	43700	1.00	0.98
5.83E-04	43700	1.00	0.95	5.83E-04	43700	1.00	0.94
1.16E-03	43700	1.00	0.98	1.15E-03	43800	1.00	0.97
2.50E-03	43800	1.00	0.96	2.50E-03	43700	1.00	0.96

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-Y(25C).xls*.

Table VII-53a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-AA (27C)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	124450	5966	5264	1.18	145
25	3600	173	125300	6007	5281	1.21	145
50	7200	345	125300	6007	5281	1.20	145
100	14400	690	125300	6007	5281	1.28	145
200	28800	1381	127790	6126	5333	1.32	145
400	57600	2761	133770	6413	5457	1.43	145

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AA(27C).xls*.

Table VII-53b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AA (27C); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
9.38E-06	124460	1.00	8.80E-06	1.05
1.73E-05	124580	1.00	1.62E-05	1.00
3.44E-05	123670	0.99	3.22E-05	1.08
6.77E-05	123660	0.99	6.32E-05	1.12
1.30E-04	122040	0.98	1.21E-04	1.23

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AA(27C).xls*.

Table VII-53c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AA (27C); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
8.50E-06	125320	1.00	7.92E-06	1.16
1.60E-05	125310	1.00	1.48E-05	1.20
3.12E-05	125320	1.00	2.89E-05	1.25
6.13E-05	125340	1.00	5.67E-05	1.26
1.18E-04	123690	0.99	1.08E-04	1.35
2.16E-04	121940	0.97	1.98E-04	1.45
3.43E-04	119640	0.96	3.11E-04	1.61

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AA(27C).xls*.

Table VII-53d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AA (27C); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
3.25E-05	109000	1.01	8.43	3.16E-05	109000	1.01	8.44
1.16E-04	108000	1.00	8.38	1.16E-04	108000	1.00	8.35
2.31E-04	108000	1.00	8.41	2.33E-04	108000	1.00	8.39
4.67E-04	106000	0.98	8.80	4.71E-04	106000	0.98	8.95

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AA(27C).xls*.

Table VII-53e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AA (27C); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
7.69E-06	138860	1.00	7.15E-06	1.19
1.48E-05	138860	1.00	1.37E-05	1.24
2.89E-05	138860	1.00	2.69E-05	1.19
5.67E-05	137870	1.00	5.23E-05	1.33
1.11E-04	137130	0.99	1.02E-04	1.36
2.05E-04	136150	0.98	1.88E-04	1.43
3.78E-04	132750	0.96	3.44E-04	1.56
6.91E-04	129400	0.93	6.18E-04	1.85
1.20E-03	124560	0.90	1.04E-03	2.28
2.26E-03	115720	0.84	1.93E-03	2.63
3.93E-03	109480	0.79	3.23E-03	3.35

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AA(27C).xls*.

Table VII-53f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AA (27C); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle** [5]			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
5.95E-05	117000	1.01	7.21	5.77E-05	116000	1.00	7.13
1.06E-04	116000	1.00	7.11	1.05E-04	116000	1.00	7.12
2.13E-04	116000	1.00	7.42	2.16E-04	117000	1.01	7.49
4.36E-04	114000	0.98	7.75	4.34E-04	115000	0.99	7.78
9.83E-04	109000	0.94	8.48	9.82E-04	109000	0.94	8.52

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AA(27C).xls*.

Table VII-54a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-AB (28E)

Isotropic Confining Pressure, σ_o			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, V_S	Low-Amplitude Material Damping Ratio, D_{min}	Estimated Total Unit Weight, gt
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	8362	401	2064	0.87	63
38	5472	261	13921	667	2660	0.77	63
75	10800	518	15747	755	2826	0.76	63
150	21600	1035	18074	866	3025	0.75	63
300	43200	2069	20857	1000	3245	0.75	63
400	57600	2758	21563	1034	3299	0.74	63

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AB(28E).xls*.

Table VII-54b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AB (28E); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
9.05E-05	8386	1.00	8.74E-05	0.76
1.72E-04	8164	0.97	1.64E-04	0.76
3.23E-04	7981	0.95	3.07E-04	0.81
6.14E-04	7765	0.93	5.77E-04	1.03
1.15E-03	7424	0.89	1.07E-03	1.20

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AB(28E).xls*.

Table VII-54c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AB (28E); Isotropic Confining Pressure, σ_o = 150 psi (21.6 ksf=1034 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
5.86E-05	18142	1.00	5.59E-05	0.74
9.70E-05	18209	1.00	9.35E-05	0.68
1.92E-04	18211	1.00	1.85E-04	0.63
3.82E-04	18190	1.00	3.67E-04	0.64
7.52E-04	18158	1.00	7.23E-04	0.64
1.44E-03	18125	1.00	1.38E-03	0.69
2.59E-03	17929	0.99	2.47E-03	0.78
4.61E-03	17569	0.97	4.34E-03	0.98
8.09E-03	17052	0.94	7.48E-03	1.28
1.39E-02	16387	0.90	1.26E-02	1.65

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AB(28E).xls*.

Table VII-54d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AB (28E); Isotropic Confining Pressure, σ_o = 150 psi (21.6 ksf=1034 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.81E-04	18600	1.00	3.45	1.79E-04	18700	1.00	3.39
3.55E-04	18600	1.00	3.30	3.59E-04	18700	1.00	3.46
6.62E-04	18700	1.01	3.45	6.69E-04	18700	1.00	3.39
1.35E-03	18500	0.99	3.41	1.35E-03	18400	0.98	3.46
2.73E-03	18200	0.98	3.62	2.73E-03	18200	0.97	3.73
6.04E-03	17700	0.95	4.23	6.01E-03	17700	0.95	4.19

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AB(28E).xls*.

Table VII-54e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AB (28E); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
4.15E-05	21742	1.00	4.01E-05	0.56
8.85E-05	21747	1.00	8.53E-05	0.60
1.67E-04	21746	1.00	1.60E-04	0.63
3.14E-04	21747	1.00	3.02E-04	0.66
6.45E-04	21747	1.00	6.20E-04	0.63
1.27E-03	21725	1.00	1.22E-03	0.67
2.36E-03	21694	1.00	2.26E-03	0.73
4.52E-03	21477	0.99	4.32E-03	0.74
8.25E-03	21261	0.98	7.82E-03	0.86
1.44E-02	20865	0.96	1.35E-02	1.10
2.46E-02	19783	0.91	2.26E-02	1.39
3.62E-02	19082	0.88	3.22E-02	1.94
5.62E-02	17406	0.80	4.75E-02	2.84

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AB(28E).xls*.

Table VII-54f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AB (28E); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.47E-04	22800	1.00	3.24	1.42E-04	22900	1.00	3.17
2.90E-04	22800	1.00	3.26	2.93E-04	22700	0.99	3.24
5.49E-04	22800	1.00	3.33	5.50E-04	22800	1.00	3.21
1.09E-03	22900	1.00	3.18	1.09E-03	23000	1.00	3.28
2.19E-03	22800	1.00	3.30	2.18E-03	22800	1.00	3.30
4.78E-03	22500	0.99	3.46	4.77E-03	22600	0.99	3.53

[1] Gmax is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/Gmax = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AB(28E).xls*.

Table VII-55a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-AC (29C)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	104750	5022	5561	0.58	109
25	3600	173	105590	5062	5582	0.53	109
50	7200	345	105620	5063	5583	0.52	109
100	14400	690	106480	5105	5605	0.51	109
200	28800	1381	107210	5140	5623	0.48	109
400	57600	2761	108210	5188	5646	0.50	109

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AC(29C).xls*.

Table VII-55b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AC (29C); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
8.97E-06	104750	1.00	8.68E-06	0.52
1.75E-05	104770	1.00	1.69E-05	0.52
3.49E-05	104760	1.00	3.37E-05	0.57
6.99E-05	104860	1.00	6.74E-05	0.56
1.39E-04	104750	1.00	1.34E-04	0.57
2.87E-04	104760	1.00	2.77E-04	0.56
5.23E-04	104860	1.00	5.05E-04	0.58
1.01E-03	104750	1.00	9.75E-04	0.59
2.01E-03	103980	0.99	1.94E-03	0.62
3.90E-03	103220	0.99	3.74E-03	0.67

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AC(29C).xls*.

Table VII-55c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AC (29C); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
9.22E-06	105620	1.00	8.97E-06	0.44
1.85E-05	105670	1.00	1.80E-05	0.44
3.59E-05	105660	1.00	3.48E-05	0.51
7.18E-05	105660	1.00	6.96E-05	0.50
1.44E-04	105610	1.00	1.40E-04	0.51
2.98E-04	105660	1.00	2.88E-04	0.51
5.48E-04	105580	1.00	5.31E-04	0.51
1.10E-03	105670	1.00	1.07E-03	0.53
2.12E-03	105570	1.00	2.05E-03	0.56
4.13E-03	104780	0.99	3.98E-03	0.60
7.54E-03	104000	0.98	7.23E-03	0.69
1.42E-02	101760	0.96	1.35E-02	0.83

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AC(29C).xls*.

Table VII-55d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AC (29C); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.12E-04	113000	1.00	2.90	1.13E-04	113000	1.00	2.95
2.16E-04	113000	1.00	2.91	2.16E-04	113000	1.00	2.95
4.27E-04	113000	1.00	2.93	4.24E-04	113000	1.00	2.93
9.20E-04	112000	0.99	2.91	9.10E-04	113000	1.00	2.91

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AC(29C).xls*.

Table VII-55e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AC (29C); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G^1, ksf	Normalized Shear Modulus, G/G_{max}	Average ^{2} Shearing Strain, %	Material Damping Ratio^3, D, %
9.87E-06	108950	1.00	9.62E-06	0.41
1.93E-05	108240	1.00	1.88E-05	0.44
3.80E-05	108940	1.00	3.69E-05	0.45
7.67E-05	108240	1.00	7.46E-05	0.45
1.50E-04	108140	1.00	1.46E-04	0.45
3.15E-04	108180	1.00	3.06E-04	0.46
5.84E-04	108220	1.00	5.68E-04	0.46
1.16E-03	108120	1.00	1.12E-03	0.47
2.30E-03	108110	1.00	2.23E-03	0.47
4.39E-03	107430	0.99	4.25E-03	0.50
8.16E-03	106540	0.98	7.88E-03	0.57
1.39E-02	105840	0.98	1.33E-02	0.70
1.99E-02	103380	0.95	1.88E-02	0.93

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AC(29C).xls*.

Table VII-55f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AC (29C); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle ^{4}				Tenth Cycle ^{5}			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.38E-05	117000	1.00	2.21	5.18E-05	117000	0.99	2.26
9.90E-05	117000	1.00	2.21	1.03E-04	118000	1.00	2.21
2.05E-04	117000	1.00	2.31	2.06E-04	117000	0.99	2.25
4.07E-04	118000	1.01	2.28	4.08E-04	118000	1.00	2.21
8.83E-04	118000	1.01	2.25	8.62E-04	118000	1.00	2.22

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AC(29C).xls*.

Table VII-56a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-AD (30A)

Isotropic Confining Pressure, σ_o			Low-Amplitude Shear Modulus, G_{max}		Low-Amplitude Shear Wave Velocity, V_S	Low-Amplitude Material Damping Ratio, D_{min}	Estimated Total Unit Weight, gt
(psi)	(psf)	(kPa)	(ksf)	(MPa)	(fps)	(%)	(pcf)
0	0	0	205480	9851	6804	1.16	143
25	3600	172	207630	9954	6839	0.98	143
50	7200	345	207520	9948	6837	0.99	143
100	14400	690	208940	10017	6859	1.14	143
200	28800	1379	215710	10341	6968	1.09	143
400	57600	2758	224170	10747	7099	0.97	143

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AD(30A).xls*.

Table VII-56b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AD (30A); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.18E-05	205250	1.00	1.10E-05	1.15
1.95E-05	205490	1.00	1.82E-05	1.14
3.87E-05	205440	1.00	3.61E-05	1.14
7.70E-05	205240	1.00	7.18E-05	1.15
1.49E-04	205270	1.00	1.39E-04	1.16
2.95E-04	204370	1.00	2.75E-04	1.16
5.67E-04	201050	0.98	5.26E-04	1.25
1.05E-03	197760	0.96	9.67E-04	1.41

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AD(30A).xls*.

Table VII-56c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AD (30A); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.08E-05	208870	1.00	1.01E-05	1.13
1.95E-05	208870	1.00	1.82E-05	1.12
3.86E-05	208870	1.00	3.60E-05	1.13
7.64E-05	208880	1.00	7.12E-05	1.15
1.46E-04	208650	1.00	1.37E-04	1.11
2.96E-04	207520	0.99	2.76E-04	1.14
5.81E-04	205300	0.98	5.41E-04	1.18
1.07E-03	202190	0.97	9.90E-04	1.33
1.97E-03	197800	0.95	1.79E-03	1.61
3.37E-03	191120	0.92	2.99E-03	1.96

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AD(30A).xls*.

Table VII-56d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AD (30A); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
7.04E-05	183000	1.00	7.74	7.12E-05	183000	1.00	7.73
1.35E-04	183000	1.00	7.77	1.30E-04	183000	1.00	7.78
2.78E-04	178000	0.97	7.76	2.75E-04	180000	0.98	7.72
6.01E-04	179000	0.98	8.07	6.00E-04	179000	0.98	8.06

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AD(30A).xls*.

Table VII-56e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AD (30A); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
1.21E-05	224110	1.00	1.14E-05	0.98
2.01E-05	224050	1.00	1.90E-05	0.95
4.01E-05	223830	1.00	3.79E-05	0.94
7.96E-05	224060	1.00	7.52E-05	0.94
1.54E-04	222900	1.00	1.45E-04	0.95
3.04E-04	222920	1.00	2.87E-04	0.95
5.95E-04	221740	0.99	5.60E-04	0.99
1.12E-03	219420	0.98	1.05E-03	1.07
2.10E-03	216000	0.96	1.95E-03	1.26
3.57E-03	210340	0.94	3.26E-03	1.50
5.61E-03	202480	0.90	4.97E-03	2.00

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AD(30A).xls*.

Table VII-56f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AD (30A); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
6.69E-05	187000	1.00	7.35	6.64E-05	189000	1.00	7.40
1.34E-04	187000	1.00	7.38	1.33E-04	188000	0.99	7.37
2.69E-04	188000	1.01	7.36	2.67E-04	189000	1.00	7.36
5.78E-04	188000	1.01	7.66	5.74E-04	188000	0.99	7.69

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AD(30A).xls*.

Table VII-57a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-AE (31A)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	108500	5201	5401	0.79	120
25	3600	173	108590	5206	5403	0.77	120
50	7200	345	108490	5201	5400	0.77	120
100	14400	690	109250	5237	5418	0.74	120
200	28800	1381	110110	5279	5438	0.73	120
400	57600	2761	111600	5350	5471	0.73	120

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AE(31A).xls*.

Table VII-57b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AE (31A); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
7.55E-06	108500	1.00	7.22E-06	0.74
1.33E-05	108520	1.00	1.27E-05	0.74
2.68E-05	108530	1.00	2.56E-05	0.75
5.25E-05	108510	1.00	5.01E-05	0.76
1.04E-04	108510	1.00	9.97E-05	0.76
2.08E-04	108510	1.00	1.99E-04	0.75
3.95E-04	108530	1.00	3.77E-04	0.76
7.73E-04	107800	0.99	7.37E-04	0.78
1.57E-03	107100	0.99	1.49E-03	0.82
2.93E-03	106380	0.98	2.77E-03	0.89

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AE(31A).xls*.

Table VII-57c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AE (31A); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
7.76E-06	109300	1.00	7.44E-06	0.67
1.44E-05	109300	1.00	1.38E-05	0.61
2.79E-05	109270	1.00	2.67E-05	0.67
5.61E-05	109290	1.00	5.38E-05	0.67
1.12E-04	109300	1.00	1.07E-04	0.69
2.22E-04	109280	1.00	2.13E-04	0.68
4.19E-04	109300	1.00	4.02E-04	0.69
8.33E-04	108590	0.99	7.97E-04	0.71
1.61E-03	108590	0.99	1.54E-03	0.74
3.09E-03	107150	0.98	2.94E-03	0.81
5.62E-03	105700	0.97	5.29E-03	0.97
9.18E-03	104280	0.95	8.54E-03	1.19

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AE(31A).xls*.

Table VII-57d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AE (31A); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.99E-05	114000	1.00	3.48	5.63E-05	114000	1.00	3.45
2.12E-04	114000	1.00	3.57	2.10E-04	114000	1.00	3.54
4.32E-04	113000	0.99	3.42	4.32E-04	113000	0.99	3.44
9.22E-04	114000	1.00	3.48	9.10E-04	114000	1.00	3.47

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AE(31A).xls*.

Table VII-57e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AE (31A); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
7.60E-06	111700	1.00	7.30E-06	0.65
1.45E-05	111700	1.00	1.39E-05	0.63
2.82E-05	111680	1.00	2.71E-05	0.67
5.59E-05	111690	1.00	5.36E-05	0.66
1.11E-04	111700	1.00	1.06E-04	0.65
2.29E-04	111700	1.00	2.20E-04	0.66
4.25E-04	111710	1.00	4.07E-04	0.66
8.37E-04	111710	1.00	8.03E-04	0.67
1.63E-03	111700	1.00	1.56E-03	0.68
3.20E-03	110850	0.99	3.05E-03	0.73
5.90E-03	109520	0.98	5.60E-03	0.84
9.60E-03	108070	0.97	9.01E-03	1.03
1.85E-02	102380	0.92	1.66E-02	1.82

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AE(31A).xls*.

Table VII-57f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AE (31A); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
5.90E-05	116000	1.00	3.10	6.01E-05	116000	1.00	3.16
2.10E-04	116000	1.00	3.12	2.06E-04	116000	1.00	3.16
4.18E-04	115000	0.99	3.15	4.23E-04	116000	1.00	3.17
8.98E-04	116000	1.00	3.15	8.97E-04	117000	1.01	3.18

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AE(31A).xls*.

Table VII-58a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-AF (32A)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	78986	3786.6	4912	0.68	105
25	3600	172	80230	3846.2	4950	0.69	105
50	7200	345	81546	3909.3	4990	0.68	105
100	14400	690	82855	3972.0	5029	0.67	105
200	28800	1379	84206	4036.8	5068	0.67	105
400	57600	2758	84916	4070.8	5088	0.68	105

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AF(32A).xls*.

Table VII-58b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AF (32A); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.33E-05	78996	1.00	2.25E-05	0.69
4.65E-05	78993	1.00	4.47E-05	0.67
9.27E-05	79077	1.00	8.92E-05	0.66
1.83E-04	78998	1.00	1.76E-04	0.65
3.73E-04	79006	1.00	3.58E-04	0.67
6.68E-04	78387	0.99	6.41E-04	0.68
1.33E-03	78362	0.99	1.27E-03	0.71
2.55E-03	77758	0.98	2.44E-03	0.75
4.62E-03	77139	0.98	4.38E-03	0.86

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AF(32A).xls*.

Table VII-58c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AF (32A); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.20E-05	82808	1.00	2.11E-05	0.67
4.30E-05	82811	1.00	4.14E-05	0.68
8.61E-05	82819	1.00	8.26E-05	0.67
1.71E-04	82812	1.00	1.65E-04	0.67
3.41E-04	82801	1.00	3.27E-04	0.67
6.43E-04	82900	1.00	6.17E-04	0.67
1.25E-03	82823	1.00	1.20E-03	0.68
2.46E-03	82166	0.99	2.36E-03	0.72
4.59E-03	80898	0.98	4.38E-03	0.78
6.94E-03	79639	0.96	6.47E-03	1.15
9.81E-03	77135	0.93	8.92E-03	1.58

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AF(32A).xls*.

Table VII-58d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AF (32A); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.56E-04	81300	1.00	2.34	1.56E-04	81200	1.00	2.30
3.04E-04	82420	1.01	2.32	3.04E-04	82420	1.02	2.32
6.15E-04	81100	1.00	2.31	6.17E-04	81300	1.00	2.31
1.34E-03	80900	1.00	2.41	1.34E-03	80900	1.00	2.45

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AF(32A).xls*.

Table VII-58e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AF (32A); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
2.14E-05	84912	1.00	2.06E-05	0.64
4.12E-05	84906	1.00	3.96E-05	0.64
8.26E-05	84909	1.00	7.93E-05	0.66
1.64E-04	84906	1.00	1.57E-04	0.68
3.26E-04	84902	1.00	3.12E-04	0.68
6.20E-04	84910	1.00	5.94E-04	0.69
1.23E-03	84257	0.99	1.18E-03	0.69
2.43E-03	84263	0.99	2.33E-03	0.72
4.59E-03	83621	0.99	4.38E-03	0.79
7.18E-03	81683	0.96	6.71E-03	1.09
1.07E-02	79779	0.94	9.76E-03	1.55
1.53E-02	76658	0.90	1.34E-02	2.21
2.22E-02	72997	0.86	1.87E-02	2.90

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AF(32A).xls*.

Table VII-58f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AF (32A); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				**Tenth Cycle [5]**			
Peak Shearing Strain, %	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**	**Peak Shearing Strain, %**	**Shear Modulus, G, ksf**	**Normalized Shear Modulus, G/G_{max}**	**Material Damping Ratio, D, %**
1.52E-04	83200	1.00	2.14	1.56E-04	83100	1.00	2.12
3.02E-04	82700	0.99	2.14	3.03E-04	82900	1.00	2.16
6.04E-04	83000	1.00	2.12	6.04E-04	82800	1.00	2.14
1.30E-03	83300	1.00	2.31	1.29E-03	83500	1.00	2.32

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AF(32A).xls*.

Table VII-59a. Variation in Low-Amplitude Shear Wave Velocity, Low-Amplitude Shear Modulus, Low-Amplitude Ratio, and Estimated Total Unit Weight with Isotropic Confining Pressure from RC Tests of Specimen UTA-42-AG (33A)

Isotropic Confining Pressure, σ_o			**Low-Amplitude Shear Modulus, G_{max}**		**Low-Amplitude Shear Wave Velocity, V_S**	**Low-Amplitude Material Damping Ratio, D_{min}**	**Estimated Total Unit Weight, gt**
(psi)	**(psf)**	**(kPa)**	**(ksf)**	**(MPa)**	**(fps)**	**(%)**	**(pcf)**
0	0	0	74223	3558	4660	0.81	120
25	3600	173	82209	3941	4904	0.73	120
50	7200	345	83495	4003	4942	0.73	120
100	14400	690	84169	4035	4961	0.72	120
200	28800	1381	84860	4068	4980	0.72	120
400	57600	2761	84984	4074	4980	0.74	120

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AG(33A).xls*.

Table VII-59b. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AG (33A); Isotropic Confining Pressure, σ_o = 0 psi (0.0 ksf=0 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.11E-05	74213	1.00	1.06E-05	0.74
2.05E-05	74197	1.00	1.96E-05	0.74
3.90E-05	74265	1.00	3.72E-05	0.74
7.39E-05	73674	0.99	7.01E-05	0.84
1.40E-04	73083	0.99	1.33E-04	0.90

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AG(33A).xls*.

Table VII-59c. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AG (33A); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

Peak Shearing Strain, %	**Shear Modulus, G[1], ksf**	**Normalized Shear Modulus, G/G_{max}**	**Average [2] Shearing Strain, %**	**Material Damping Ratio[3], D, %**
1.02E-05	84176	1.00	9.84E-06	0.65
1.97E-05	84180	1.00	1.90E-05	0.65
3.92E-05	84172	1.00	3.77E-05	0.65
7.78E-05	84185	1.00	7.47E-05	0.65
1.56E-04	84107	1.00	1.50E-04	0.65
3.19E-04	84185	1.00	3.06E-04	0.67
5.89E-04	84105	1.00	5.65E-04	0.66
1.17E-03	83548	0.99	1.12E-03	0.68
2.29E-03	83461	0.99	2.19E-03	0.71
4.41E-03	82845	0.98	4.21E-03	0.74
8.25E-03	82209	0.98	7.83E-03	0.83
1.40E-02	80960	0.96	1.32E-02	0.95

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AG(33A).xls*.

Table VII-59d. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AG (33A); Isotropic Confining Pressure, σ_o = 100 psi (14.4 ksf=690 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
1.94E-04	85700	1.00	2.98	1.93E-04	85700	1.00	2.95
2.75E-04	85900	1.00	2.95	2.79E-04	85800	1.00	2.99
5.66E-04	85600	1.00	2.96	5.60E-04	85700	1.00	3.00
1.21E-03	85600	1.00	3.00	1.21E-03	85900	1.00	2.96

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AG(33A).xls*.

Table VII-59e. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from RC Tests of Specimen UTA-42-AG (33A); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

Peak Shearing Strain, %	Shear Modulus, G[1], ksf	Normalized Shear Modulus, G/G_{max}	Average [2] Shearing Strain, %	Material Damping Ratio[3], D, %
9.85E-06	85601	1.00	9.46E-06	0.65
1.95E-05	85613	1.00	1.87E-05	0.66
3.85E-05	85602	1.00	3.70E-05	0.66
7.69E-05	85602	1.00	7.39E-05	0.66
1.54E-04	85605	1.00	1.48E-04	0.65
3.20E-04	85595	1.00	3.07E-04	0.64
5.86E-04	85603	1.00	5.63E-04	0.66
1.16E-03	85607	1.00	1.11E-03	0.66
2.29E-03	84957	0.99	2.20E-03	0.66
4.62E-03	84885	0.99	4.43E-03	0.67
8.69E-03	84892	0.99	8.31E-03	0.74
1.51E-02	83704	0.98	1.44E-02	0.84
2.40E-02	82428	0.96	2.25E-02	1.08
3.12E-02	80552	0.94	2.89E-02	1.25

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_UTA-42-AG(33A).xls*.

Table VII-59f. Variation in Shear Modulus, Normalized Shear Modulus, and Material Damping Ratio with Shearing Strain from TS Tests of Specimen UTA-42-AG (33A); Isotropic Confining Pressure, σ_o = 400 psi (57.6 ksf=2758 kPa)

First Cycle [4]				Tenth Cycle [5]			
Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %	Peak Shearing Strain, %	Shear Modulus, G, ksf	Normalized Shear Modulus, G/G_{max}	Material Damping Ratio, D, %
8.80E-05	87000	0.99	2.44	8.74E-05	87000	0.99	2.42
1.50E-04	87800	1.00	2.43	1.48E-04	87800	1.00	2.40
2.78E-04	87500	1.00	2.41	2.72E-04	87800	1.00	2.47
5.62E-04	87400	1.00	2.41	5.60E-04	87900	1.00	2.41
1.18E-03	87800	1.00	2.48	1.18E-03	87600	1.00	2.47

[1] G_{max} is taken as the average of the first few values of G in the strain range where G varies insignificantly (generally less than 0.5 %) and G/G_{max} = 1.00.

[2] When using the free vibration decay curve, the shearing strain is the average shearing strain from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the shearing strain is the same as the peak shearing strain.

[3] When using the free vibration decay curve, the material damping ratio is the average material damping ratio from the first three cycles of the free vibration decay curve. When using the half-power bandwidth method, the material damping ratio is the single value measured from the width of the fundamental-mode resonance curve.

[4] The first or second cycle in the ten loading cycles.

[5] The ninth or tenth cycle in the ten loading cycles.

Source: DTN: MO0707FIXEFREE.005 [DIRS 183329], file: *Table_ UTA-42-AG(33A).xls.*

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ATTACHMENT VIII

FREE-FREE TESTING RESULTS

ATTACHMENT VIII
FREE-FREE TESTING RESULTS

As outlined in Section 6.5.3, Free-Free testing is a laboratory testing method incorporated into the geotechnical investigations during the period of 2004 through 2006. This method is described as an unconfined, Free-Free, resonant column (URC) test that can be used to evaluate the stiffnesses and material damping ratios of soil and rock specimens at small strains. The measurements in both shear and compression can be performed on the same specimen, which provides valuable comparisons with the measurements from the laboratory combined Resonant Column and Torsional Shear (RCTS) tests, the field Spectral-Analysis-of-Surface-Waves (SASW), and downhole seismic testing. Because this laboratory testing method was not performed during 2000 and 2001, a detailed discussion on the test methodology is contained in Section 6.5.3.1.

A subset the specimens were tested in a method scoping mode during the period of August 17, 2004, through December 1, 2004. These specimens include: FR1, FR2, FR3, FR4, FR5, FR6, and FR7. During this period calibrated M&TE was not used and these specimens are included as un-Q. They are included for completeness. Data from these scoping tests were submitted to the TDMS as Non-Q (DTN: MO0709FREEFRUQ.007 [DIRS 183292]). All other specimens listed in Table 4 were tested during the period of December 11, 2004, through May 7, 2006, and these data were submitted to the TDMS as Q data (DTN: MO0707FREEFREE.006 [DIRS 183287]). The non-Q specimens are identified in Tables VIII-1 and VIII-2.

Table VIII-1. Free-Free Small Strain Laboratory Test Data Consisting of Total Unit Weight, Average[1] Wave Velocities and Moduli Determined from Small-Strain, Free-Free, Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement

Sample ID	Total Unit Weight, γ_t, pcf	Low Amplitude Constrained Compression Wave Velocity, V_P, fps	Low Amplitude Unconstrained Compression Wave Velocity, V_C, fps	Low Amplitude Shear Wave Velocity, V_S, fps	Low Amplitude Constrained Modulus, M_{max}, from V_P, psf	Low Amplitude Unconstrained Modulus, E_{max}, from V_C, psf	Low Amplitude Shear Modulus, G_{max}, from V_S, psf
FR1[2]	132	7317	7131	3686	2.19E+08	2.08E+08	5.55E+07
FR2[2]	137	12870	10880	6998	7.03E+08	5.02E+08	2.08E+08
FR3[2]	144	13914	13551	8756	8.66E+08	8.21E+08	3.43E+08
FR4[2]	140	11351	10986	6663	5.58E+08	5.23E+08	1.92E+08
FR5[2]	132	11348	8985	6526	5.26E+08	3.30E+08	1.74E+08
FR6[2]	145	14449	13984	9163	9.40E+08	8.81E+08	3.78E+08
FR7[2]	100	8324	7291	4787	2.14E+08	1.64E+08	7.08E+07
FR8	91	9708	9044	5901	2.66E+08	2.31E+08	9.82E+07
FR9	127	7629	5551	3367	2.29E+08	1.21E+08	4.46E+07
FR10	129	9648	8852	5807	3.72E+08	3.13E+08	1.35E+08
FR11	132	9995	9515	6257	4.08E+08	3.70E+08	1.60E+08
FR12	136	10909	10010	6440	5.03E+08	4.23E+08	1.75E+08
FR13	138	10638	10020	6637	4.83E+08	4.29E+08	1.88E+08
FR14	132	11117	10951	7248	5.05E+08	4.90E+08	2.15E+08
FR15	122	9027	7197	3973	3.09E+08	1.96E+08	5.99E+07
FR16	134	11970	9246	5817	5.97E+08	3.56E+08	1.41E+08
FR17	119	9624	8999	5852	3.41E+08	2.99E+08	1.26E+08
FR18	142	11812	9922	6303	6.13E+08	4.33E+08	1.75E+08
FR19	109	9167	6917	4067	2.83E+08	1.61E+08	5.58E+07
FR20	113	10397	8220	5038	3.78E+08	2.37E+08	8.88E+07
FR21	118	10269	8715	5299	3.85E+08	2.78E+08	1.03E+08
FR22	118	10499	8996	5507	4.05E+08	2.98E+08	1.12E+08
FR23	134	12577	11459	7319	6.58E+08	5.46E+08	2.23E+08
FR24	135	12626	11872	7321	6.69E+08	5.91E+08	2.25E+08
FR25	133	12759	12307	7620	6.73E+08	6.26E+08	2.40E+08
FR26	143	13798	13097	8595	8.46E+08	7.62E+08	3.28E+08
FR27	141	13171	12918	8682	7.57E+08	7.29E+08	3.29E+08
FR28	140	13104	12990	8724	7.46E+08	7.33E+08	3.31E+08
FR29	142	13178	12948	8766	7.65E+08	7.38E+08	3.38E+08
FR30	142	13399	13256	8830	7.94E+08	7.77E+08	3.45E+08
FR31	143	13756	13507	8928	8.38E+08	8.08E+08	3.53E+08
FR32	143	13689	13497	8958	8.31E+08	8.08E+08	3.56E+08
FR33	139	11734	9190	6103	5.93E+08	3.64E+08	1.61E+08
FR34	133	9824	9706	6539	4.00E+08	3.90E+08	1.77E+08
FR35	135	8783	6322	4164	3.24E+08	1.68E+08	7.27E+07
FR36	143	12065	10537	6112	6.45E+08	4.92E+08	1.66E+08

Table VIII-1. Free-Free Small Strain Laboratory Test Data Consisting of Total Unit Weight, Average [1] Wave Velocities and Moduli Determined from Small-Strain, Free-Free, Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement (Continued)

Sample ID	Total Unit Weight, γ_t, pcf	Low Amplitude Constrained Compression Wave Velocity, V_P, fps	Low Amplitude Unconstrained Compression Wave Velocity, V_C, fps	Low Amplitude Shear Wave Velocity, V_S, fps	Low Amplitude Constrained Modulus, M_{max}, from V_P, psf	Low Amplitude Unconstrained Modulus, E_{max}, from V_C, psf	Low Amplitude Shear Modulus, G_{max}, from V_S, psf
FR37	125	10463	10462	6862	4.26E+08	4.26E+08	1.83E+08
FR38	127	12329	12151	7110	6.01E+08	5.84E+08	2.00E+08
FR39	140	12239	11699	7482	6.49E+08	5.93E+08	2.43E+08
FR40	146	13879	12773	7373	8.73E+08	7.39E+08	2.46E+08
FR41	144	13290	12395	7983	7.89E+08	6.87E+08	2.85E+08
FR42	146	14112	13572	8652	9.02E+08	8.35E+08	3.39E+08
FR43	145	12968	12876	8760	7.59E+08	7.48E+08	3.46E+08
FR44	149	14105	13817	9003	8.95E+08	8.59E+08	3.65E+08
FR45	144	14300	13915	9110	9.11E+08	8.63E+08	3.70E+08
FR46	144	14605	14164	9222	9.54E+08	8.97E+08	3.80E+08
FR47	130	12376	11410	7019	6.18E+08	5.25E+08	1.99E+08
FR48	131	11475	10962	7037	5.36E+08	4.89E+08	2.02E+08
FR49	133	12757	12131	7451	6.70E+08	6.06E+08	2.29E+08
FR50	101	6061	4739	2932	1.15E+08	7.02E+07	2.69E+07
FR51	103	6428	6137	4143	1.33E+08	1.21E+08	5.51E+07
FR52	98	6753	6417	4218	1.38E+08	1.25E+08	5.40E+07
FR53	110	9727	9254	5983	3.22E+08	2.91E+08	1.22E+08
FR54	86	4157	3737	1885	4.63E+07	3.75E+07	9.53E+06
FR55	88	8107	7675	5016	1.79E+08	1.60E+08	6.84E+07
FR56	91	8506	8009	5317	2.03E+08	1.80E+08	7.94E+07
FR57	88	8699	8426	5589	2.08E+08	1.95E+08	8.58E+07
FR58	102	7192	6444	4117	1.64E+08	1.32E+08	5.38E+07
FR59	112	6951	6554	4174	1.67E+08	1.49E+08	6.03E+07
FR60	105	7455	7022	4413	1.82E+08	1.61E+08	6.37E+07
FR61	107	7602	6986	4433	1.92E+08	1.62E+08	6.52E+07
FR62	111	7222	6988	4513	1.80E+08	1.68E+08	7.03E+07
FR63	113	8616	8399	5600	2.61E+08	2.48E+08	1.10E+08
FR64	111	9494	8969	5660	3.12E+08	2.78E+08	1.11E+08
FR65	118	9172	8936	5732	3.09E+08	2.93E+08	1.21E+08
FR66	109	9368	9103	6014	2.96E+08	2.80E+08	1.22E+08
FR67	122	10073	9942	6717	3.85E+08	3.75E+08	1.71E+08
FR68	102	7986	7597	5087	2.02E+08	1.82E+08	8.18E+07
FR69	123	9083	8713	5762	3.14E+08	2.89E+08	1.26E+08
FR70	136	11807	10631	6858	5.90E+08	4.78E+08	1.99E+08
FR71	139	12753	12222	7674	7.03E+08	6.45E+08	2.54E+08
FR72	148	13384	12922	8557	8.21E+08	7.65E+08	3.36E+08
FR73	106	8727	8089	5065	2.50E+08	2.15E+08	8.42E+07

Table VIII-1. Free-Free Small Strain Laboratory Test Data Consisting of Total Unit Weight, Average [1] Wave Velocities and Moduli Determined from Small-Strain, Free-Free, Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement (Continued)

Sample ID	Total Unit Weight, γ_t, pcf	Low Amplitude Constrained Compression Wave Velocity, V_P, fps	Low Amplitude Unconstrained Compression Wave Velocity, V_C, fps	Low Amplitude Shear Wave Velocity, V_S, fps	Low Amplitude Constrained Modulus, M_{max}, from V_P, psf	Low Amplitude Unconstrained Modulus, E_{max}, from V_C, psf	Low Amplitude Shear Modulus, G_{max}, from V_S, psf
FR74	100	9073	8221	5190	2.55E+08	2.10E+08	8.35E+07
FR75	102	8541	8123	5191	2.32E+08	2.10E+08	8.56E+07
FR76	110	9136	8661	5670	2.84E+08	2.56E+08	1.10E+08
FR77	81	3398	2497	1259	2.89E+07	1.56E+07	3.96E+06
FR78	95	8575	8245	5388	2.17E+08	2.01E+08	8.58E+07
FR79	87	6683	5636	3618	1.21E+08	8.62E+07	3.55E+07
FR80	83	6629	5737	3719	1.13E+08	8.47E+07	3.56E+07
FR81	109	6079	5371	3430	1.25E+08	9.73E+07	3.97E+07
FR82	113	8512	7080	4413	2.54E+08	1.75E+08	6.82E+07
FR83	118	8901	8672	5844	2.91E+08	2.76E+08	1.25E+08
FR84	121	5582	4057	2415	1.17E+08	6.18E+07	2.19E+07
FR85	127	11972	10035	5911	5.65E+08	3.97E+08	1.38E+08
FR86	144	12597	12569	8739	7.10E+08	7.07E+08	3.42E+08
FR87	146	14356	13870	8974	9.34E+08	8.72E+08	3.65E+08
FR88	122	9844	7103	4260	3.66E+08	1.91E+08	6.85E+07
FR89	132	11307	8367	5026	5.24E+08	2.87E+08	1.04E+08
FR90	146	13920	13126	8438	8.76E+08	7.78E+08	3.22E+08
FR91	143	14457	14193	9416	9.31E+08	8.97E+08	3.95E+08
FR92	89	8460	8039	5273	1.98E+08	1.78E+08	7.67E+07
FR93	103	5256	4839	3249	8.85E+07	7.50E+07	3.38E+07
FR94	90	7024	6860	4595	1.37E+08	1.31E+08	5.88E+07
FR95	86	5582	4882	3087	8.27E+07	6.33E+07	2.53E+07
FR96	81	6600	5608	3519	1.09E+08	7.86E+07	3.09E+07
FR97 [3]	118	9393	N/A[3]	N/A[3]	3.24E+08	N/A[3]	N/A[3]
FR98	69	5277	4825	3004	5.98E+07	5.00E+07	1.94E+07
FR99	73	7244	6453	4163	1.19E+08	9.43E+07	3.92E+07
FR100	65	3911	3281	2069	3.10E+07	2.18E+07	8.68E+06
FR101	66	4289	4011	2579	3.79E+07	3.31E+07	1.37E+07
FR102	142	6019	3623	2231	1.60E+08	5.79E+07	2.20E+07
FR103	95	7911	7523	4457	1.84E+08	1.67E+08	5.85E+07
FR104	97	7168	6514	4050	1.55E+08	1.28E+08	4.94E+07
FR105	79	4896	3985	2753	5.89E+07	3.90E+07	1.86E+07
FR106	77	5559	5519	3821	7.36E+07	7.25E+07	3.48E+07
FR107	141	11292	9045	6324	5.57E+08	3.57E+08	1.75E+08
FR108	95	2998	2553	1770	2.65E+07	1.92E+07	9.25E+06
FR109	139	13290	12718	8147	7.61E+08	6.97E+08	2.86E+08
FR110	103	8154	7592	4714	2.13E+08	1.84E+08	7.10E+07

Table VIII-1. Free-Free Small Strain Laboratory Test Data Consisting of Total Unit Weight, Average [1] Wave Velocities and Moduli Determined from Small-Strain, Free-Free, Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement (Continued)

Sample ID	Total Unit Weight, γ_t, pcf	Low Amplitude Constrained Compression Wave Velocity, V_P, fps	Low Amplitude Unconstrained Compression Wave Velocity, V_C, fps	Low Amplitude Shear Wave Velocity, V_S, fps	Low Amplitude Constrained Modulus, M_{max}, from V_P, psf	Low Amplitude Unconstrained Modulus, E_{max}, from V_C, psf	Low Amplitude Shear Modulus, G_{max}, from V_S, psf
FR111	113	7808	7358	4740	2.13E+08	1.89E+08	7.86E+07
FR112	120	8837	8635	5198	2.91E+08	2.78E+08	1.01E+08
FR113	130	11244	10666	6920	5.12E+08	4.61E+08	1.94E+08
FR114	142	11943	11695	7756	6.30E+08	6.05E+08	2.66E+08
FR115	134	10621	9717	5997	4.67E+08	3.91E+08	1.49E+08
FR116	104	7426	7244	4764	1.78E+08	1.70E+08	7.34E+07
FR117	124	10653	10344	6644	4.36E+08	4.11E+08	1.70E+08
FR118	122	10402	8533	4944	4.11E+08	2.77E+08	9.28E+07
FR119	108	8627	7926	5434	2.49E+08	2.10E+08	9.87E+07
FR120	114	8052	8004	5475	2.29E+08	2.26E+08	1.06E+08
FR121	116	9204	9049	6080	3.05E+08	2.95E+08	1.33E+08
FR122	143	12682	12361	8130	7.13E+08	6.77E+08	2.93E+08
FR123	147	13678	13213	8636	8.51E+08	7.94E+08	3.39E+08
FR124	136	12351	11813	7645	6.45E+08	5.90E+08	2.47E+08
FR125	121	8058	5149	3560	2.44E+08	9.97E+07	4.76E+07
FR126	117	7685	3849	2605	2.15E+08	5.40E+07	2.47E+07
FR127	104	7829	5142	3239	1.98E+08	8.52E+07	3.38E+07
FR128	118	11031	10609	6805	4.44E+08	4.11E+08	1.69E+08
FR129	130	11289	10895	7047	5.14E+08	4.78E+08	2.00E+08
FR130	109	8235	7118	4457	2.30E+08	1.72E+08	6.72E+07
FR131	112	11583	9572	5960	3.23E+06	2.20E+06	8.55E+05
FR132	144	14548	14043	9127	6.56E+06	6.11E+06	2.58E+06
FR133	143	10025	7974	5210	2.45E+06	1.55E+06	6.62E+05
FR134	104	11595	7767	5141	3.01E+06	1.35E+06	5.91E+05
FR135	109	10505	7376	5080	2.59E+06	1.28E+06	6.06E+05
UTA-42-C(3C-1)	144	13925	13127	8402	8.69E+08	7.72E+08	3.16E+08
UTA-42-C(3C-1) w/ Venthole	144	13484	13120	8474	8.15E+08	7.71E+08	3.22E+08
UTA-42-D(4C-1)	144	11788	11235	6683	6.21E+08	5.64E+08	2.00E+08
UTA-42-D(4C-1) w/ Venthole	144	11788	11309	6811	6.21E+08	5.71E+08	2.07E+08
UTA-42-E(5C-1)	138	12463	11596	7755	6.65E+08	5.76E+08	2.58E+08
UTA-42-E(5C-1) w/ Venthole	138	12333	11390	7737	6.52E+08	5.56E+08	2.56E+08

Table VIII-1. Free-Free Small Strain Laboratory Test Data Consisting of Total Unit Weight, Average[1] Wave Velocities and Moduli Determined from Small-Strain, Free-Free, Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement (Continued)

Sample ID	**Total Unit Weight, γ_t, pcf**	**Low Amplitude Constrained Compression Wave Velocity, V_P, fps**	**Low Amplitude Unconstrained Compression Wave Velocity, V_C, fps**	**Low Amplitude Shear Wave Velocity, V_S, fps**	**Low Amplitude Constrained Modulus, M_{max}, from V_P, psf**	**Low Amplitude Unconstrained Modulus, E_{max}, from V_C, psf**	**Low Amplitude Shear Modulus, G_{max}, from V_S, psf**
UTA-42-F(6C-1)	147	14228	13867	9154	9.21E+08	8.75E+08	3.81E+08
UTA-42-F(6C-1) w/ Venthole	147	14279	13889	9148	9.28E+08	8.78E+08	3.81E+08
UTA-42-G(7C-1)	103	8107	7624	4835	2.10E+08	1.86E+08	7.46E+07
UTA-42-H(8C-1)	94	9656	9102	5966	2.72E+08	2.41E+08	1.04E+08
UTA-42-I(9A-1)	136	10649	10140	6573	4.77E+08	4.33E+08	1.82E+08
UTA-42-J(10A-1)	138	11563	9257	5725	5.72E+08	3.66E+08	1.40E+08
UTA-42-K(11C-1)	139	12977	11714	7968	7.28E+08	5.93E+08	2.74E+08
UTA-42-L(12C-1)	139	11924	10720	7443	6.12E+08	4.95E+08	2.38E+08
UTA-42-M(13C-1)	144	13120	13080	8442	7.69E+08	7.64E+08	3.18E+08
UTA-42-N(14C-1)	145	13394	13363	8675	8.05E+08	8.01E+08	3.38E+08
UTA-42-O(15C-1)	143	12317	11733	6912	6.74E+08	6.12E+08	2.12E+08
UTA-42-P(16C-1)	138	12495	11521	7293	6.70E+08	5.70E+08	2.28E+08
UTA-42-Q(17C-1)	110	8910	8229	5706	2.70E+08	2.30E+08	1.11E+08
UTA-42-R(18C-1)	118	8994	8696	5634	2.97E+08	2.78E+08	1.17E+08
UTA-42-S(19C-1)	149	13636	13092	8485	8.59E+08	7.92E+08	3.33E+08
UTA-42-T(20C-1)	111	8715	7815	5307	2.61E+08	2.10E+08	9.66E+07
UTA-42-U(21C-1)	111	8412	8069	5298	2.27E+08	2.09E+08	9.01E+07
UTA-42-V(22C-1)	137	11321	7498	4301	5.46E+08	2.39E+08	7.88E+07
UTA-42-W(23C)	91	6913	6251	4370	1.35E+08	1.10E+08	5.38E+07
UTA-42-X(24C)	81	5259	4668	3126	6.92E+07	5.45E+07	2.45E+07
UTA-42-Y(25C)	76	6500	5778	3820	9.91E+07	7.83E+07	3.42E+07

Table VIII-1. Free-Free Small Strain Laboratory Test Data Consisting of Total Unit Weight, Average [1] Wave Velocities and Moduli Determined from Small-Strain, Free-Free, Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement (Continued)

Sample ID	Total Unit Weight, γ_t, pcf	Low Amplitude Constrained Compression Wave Velocity, V_P, fps	Low Amplitude Unconstrained Compression Wave Velocity, V_C, fps	Low Amplitude Shear Wave Velocity, V_S, fps	Low Amplitude Constrained Modulus, M_{max}, from V_P, psf	Low Amplitude Unconstrained Modulus, E_{max}, from V_C, psf	Low Amplitude Shear Modulus, G_{max}, from V_S, psf
UTA-42-AA(27C)	145	8924	8037	5579	3.58E+08	2.90E+08	1.40E+08
UTA-42-AB(28A)	64	3869	3113	1903	2.96E+07	1.92E+07	7.17E+06
UTA-42-AB(28B)	67	3484	3107	1967	2.52E+07	2.01E+07	8.04E+06
UTA-42-AB(28C)	62	3245	1750	1116	2.02E+07	5.88E+06	2.39E+06
UTA-42-AB(28E)	63	3564	2894	1819	2.52E+07	1.66E+07	6.56E+06
UTA-42-AC(29C)	109	8777	8589	5798	2.61E+08	2.50E+08	1.14E+08
UTA-42-AD(30A)	143	11761	11566	7564	6.08E+08	5.88E+08	2.51E+08
UTA-42-AE(31A)	117	8870	8657	5890	2.85E+08	2.72E+08	1.26E+08
UTA-42-AF(32A)	105	7909	7581	5051	2.05E+08	1.88E+08	8.34E+07
UTA-42-AG(33A)	145	8117	6840	4528	1.56E+06	1.60E+08	7.00E+07

Source: DTNs: MO0707FREEFREE.006 [DIRS 1832 87] and MO0709FREEFRUQ.007[DIRS 183292].

NOTES: [1] Averaged from three measurements.

[2] During this period, calibrated M&TE was not used and these specimens are un-Q (DTN: MO0709FREEFRUQ.007).

[3] Only constrained compression wave velocity (Vp) could be obtained since the specimen broke when the accelerometer used in the measurement was being detached from specimen FR97.

Table VIII-2. Free-Free Laboratory Test Data Consisting of Average[1] Material Damping Ratio Values and Poisson’s Ratio Values Determined from Small-Strain, Free- Free Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement

Sample ID	**Low Amplitude Material Damping Ratio in Unconstrained Compression, $D_{C,min}$, %**	**Low Amplitude Material Damping Ratio in Shear, $D_{S, min}$, %**	**Low Amplitude Poisson's Ratio, ν_{MG}, from the Relationship of M_{max} and G_{max}[3]**	**Low Amplitude Poisson's Ratio, ν_{EG}, from the Relationship of E_{max} and G_{max}[4]**	**Low Amplitude Poisson's Ratio, ν_{ME}, from the Relationship of M_{max} and E_{max}[5]**
FR1[2]	0.95	1.33	0.33	0.87	0.15
FR2[2]	0.45	0.49	0.29	0.21	0.31
FR3[2]	0.15	0.37	0.17	0.20	0.15
FR4[2]	0.25	0.24	0.24	0.36	0.16
FR5[2]	0.26	0.39	0.25	-0.05	0.35
FR6[2]	0.14	0.18	0.16	0.16	0.16
FR7[2]	0.48	0.52	0.25	0.16	0.29
FR8	0.39	0.42	0.21	0.17	0.23
FR9	0.66	1.90	0.38	0.36	0.38
FR10	0.44	0.37	0.22	0.16	0.24
FR11	0.29	0.31	0.18	0.16	0.19
FR12	0.33	0.33	0.23	0.21	0.24
FR13	0.43	0.43	0.18	0.14	0.21
FR14	0.16	0.30	0.13	0.14	0.11
FR15	0.35	0.59	0.38	0.64	0.35
FR16	0.57	0.41	0.35	0.26	0.36
FR17	0.84	0.80	0.21	0.18	0.22
FR18	0.76	0.74	0.30	0.24	0.32
FR19	0.79	1.49	0.38	0.45	0.37
FR20	0.64	1.10	0.35	0.33	0.35
FR21	0.49	0.72	0.32	0.35	0.31
FR22	0.40	0.85	0.31	0.33	0.30
FR23	0.30	0.52	0.24	0.23	0.25
FR24	0.47	2.11	0.25	0.31	0.21
FR25	0.39	0.48	0.22	0.30	0.17
FR26	0.22	0.30	0.18	0.16	0.20
FR27	0.41	0.28	0.12	0.11	0.13
FR28	0.20	0.22	0.10	0.11	0.09
FR29	0.19	0.22	0.10	0.09	0.12
FR30	0.24	0.24	0.12	0.13	0.10
FR31	0.18	0.19	0.14	0.14	0.13
FR32	0.27	0.17	0.13	0.13	0.11
FR33	0.75	0.78	0.31	0.13	0.35
FR34	0.42	0.38	0.10	0.10	0.10
FR35	1.57	0.85	0.36	0.15	0.38
FR36	0.49	0.73	0.33	0.49	0.29

Table VIII-2. Free-Free Laboratory Test Data Consisting of Average [1] Material Damping Ratio Values and Poisson's Ratio Values Determined from Small-Strain, Free- Free Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement (Continued)

Sample ID	**Low Amplitude Material Damping Ratio in Unconstrained Compression, $D_{C,min}$, %**	**Low Amplitude Material Damping Ratio in Shear, $D_{S,\ min}$, %**	**Low Amplitude Poisson's Ratio, ν_{MG}, from the Relationship of M_{max} and G_{max}[3]**	**Low Amplitude Poisson's Ratio, ν_{EG}, from the Relationship of E_{max} and G_{max}[4]**	**Low Amplitude Poisson's Ratio, ν_{ME}, from the Relationship of M_{max} and E_{max}[5]**
FR37	0.86	1.29	0.12	0.16	0.01
FR38	0.56	0.58	0.25	0.46	0.11
FR39	0.37	0.41	0.20	0.22	0.19
FR40	0.46	0.93	0.30	0.50	0.24
FR41	0.29	0.29	0.22	0.21	0.22
FR42	0.27	0.22	0.20	0.23	0.18
FR43	0.38	0.31	0.08	0.08	0.08
FR44	0.28	0.19	0.16	0.18	0.13
FR45	0.18	0.21	0.16	0.17	0.15
FR46	0.22	0.17	0.17	0.18	0.16
FR47	0.42	0.34	0.26	0.32	0.24
FR48	0.21	0.41	0.20	0.21	0.19
FR49	0.29	0.30	0.24	0.33	0.20
FR50	2.19	2.05	0.35	0.31	0.35
FR51	0.46	0.55	0.14	0.10	0.19
FR52	0.69	0.51	0.18	0.16	0.20
FR53	0.48	0.45	0.20	0.20	0.20
FR54	1.88	6.36	0.37	0.97	0.27
FR55	0.49	0.88	0.19	0.17	0.20
FR56	0.61	0.49	0.18	0.13	0.21
FR57	0.44	0.54	0.15	0.14	0.16
FR58	0.67	0.68	0.26	0.22	0.27
FR59	0.56	0.72	0.22	0.23	0.21
FR60	0.44	0.60	0.23	0.27	0.21
FR61	0.55	0.55	0.24	0.24	0.24
FR62	0.37	0.42	0.18	0.20	0.16
FR63	0.27	0.25	0.13	0.12	0.15
FR64	0.55	0.66	0.22	0.26	0.21
FR65	0.41	0.73	0.18	0.21	0.15
FR66	0.51	0.71	0.15	0.15	0.15
FR67	0.29	0.60	0.10	0.10	0.11
FR68	0.33	0.36	0.16	0.12	0.20
FR69	0.47	0.65	0.16	0.14	0.18
FR70	0.57	0.81	0.25	0.20	0.26
FR71	0.30	0.54	0.22	0.27	0.18

Table VIII-2. Free-Free Laboratory Test Data Consisting of Average [1] Material Damping Ratio Values and Poisson's Ratio Values Determined from Small-Strain, Free- Free Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement (Continued)

Sample ID	Low Amplitude Material Damping Ratio in Unconstrained Compression, $D_{C,min}$, %	Low Amplitude Material Damping Ratio in Shear, $D_{S,\ min}$, %	Low Amplitude Poisson's Ratio, ν_{MG}, from the Relationship of M_{max} and G_{max}[3]	Low Amplitude Poisson's Ratio, ν_{EG}, from the Relationship of E_{max} and G_{max}[4]	Low Amplitude Poisson's Ratio, ν_{ME}, from the Relationship of M_{max} and E_{max}[5]
FR72	0.39	0.30	0.15	0.14	0.17
FR73	0.63	2.68	0.25	0.28	0.23
FR74	0.38	0.67	0.26	0.25	0.26
FR75	0.36	0.60	0.21	0.22	0.20
FR76	0.76	0.76	0.19	0.17	0.20
FR77	7.59	6.35	0.42	0.97	0.38
FR78	0.14	0.42	0.17	0.17	0.18
FR79	0.85	1.05	0.29	0.21	0.31
FR80	0.90	1.48	0.27	0.19	0.30
FR81	0.96	1.03	0.27	0.23	0.28
FR82	0.54	2.09	0.32	0.29	0.32
FR83	0.39	0.39	0.12	0.10	0.15
FR84	1.68	3.52	0.38	0.41	0.38
FR85	1.05	0.80	0.34	0.44	0.32
FR86	0.40	0.34	0.04	0.03	0.05
FR87	0.19	0.20	0.18	0.19	0.17
FR88	0.21	0.36	0.38	0.39	0.38
FR89	0.90	2.78	0.38	0.39	0.38
FR90	0.16	0.21	0.21	0.21	0.21
FR91	0.12	0.16	0.13	0.14	0.13
FR92	0.43	0.73	0.18	0.16	0.20
FR93	0.47	0.72	0.19	0.11	0.24
FR94	0.50	0.73	0.13	0.11	0.14
FR95	1.10	1.35	0.28	0.25	0.29
FR96	0.65	0.77	0.30	0.27	0.31
FR97 [6]	N/A[6]	N/A[6]	N/A[6]	N/A[6]	N/A[6]
FR98	0.56	0.82	0.26	0.29	0.25
FR99	0.37	0.49	0.25	0.20	0.27
FR100	2.55	5.33	0.31	0.26	0.32
FR101	0.69	0.75	0.22	0.21	0.22
FR102	2.96	3.66	0.42	0.32	0.43
FR103	1.24	2.37	0.27	0.42	0.20
FR104	0.85	0.99	0.27	0.29	0.25
FR105	1.88	2.29	0.27	0.05	0.33
FR106	0.68	0.82	0.05	0.04	0.08

Table VIII-2. Free-Free Laboratory Test Data Consisting of Average[1] Material Damping Ratio Values and Poisson's Ratio Values Determined from Small-Strain, Free- Free Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement (Continued)

Sample ID	**Low Amplitude Material Damping Ratio in Unconstrained Compression, $D_{C,min}$, %**	**Low Amplitude Material Damping Ratio in Shear, $D_{S,\ min}$, %**	**Low Amplitude Poisson's Ratio, ν_{MG}, from the Relationship of M_{max} and G_{max}[3]**	**Low Amplitude Poisson's Ratio, ν_{EG}, from the Relationship of E_{max} and G_{max}[4]**	**Low Amplitude Poisson's Ratio, ν_{ME}, from the Relationship of M_{max} and E_{max}[5]**
FR107	3.07	1.91	0.27	0.02	0.34
FR108	3.70	3.66	0.23	0.04	0.31
FR109	0.33	1.14	0.20	0.22	0.19
FR110	0.33	0.48	0.25	0.30	0.23
FR111	0.47	0.49	0.21	0.20	0.21
FR112	0.55	0.69	0.24	0.38	0.14
FR113	0.25	0.33	0.20	0.19	0.20
FR114	0.38	0.38	0.14	0.14	0.13
FR115	0.71	0.69	0.27	0.31	0.25
FR116	0.63	0.58	0.15	0.16	0.14
FR117	0.34	0.44	0.18	0.21	0.16
FR118	0.70	0.72	0.35	0.49	0.33
FR119	0.54	0.53	0.17	0.06	0.24
FR120	0.75	0.86	0.07	0.07	0.07
FR121	0.63	0.65	0.11	0.11	0.12
FR122	0.32	0.31	0.15	0.16	0.15
FR123	0.24	1.18	0.17	0.17	0.17
FR124	0.26	0.34	0.19	0.19	0.19
FR125	2.39	3.00	0.38	0.05	0.42
FR126	2.79	6.52	0.44	0.09	0.45
FR127	0.93	1.82	0.40	0.26	0.41
FR128	0.54	0.51	0.19	0.22	0.18
FR129	0.58	0.69	0.18	0.20	0.17
FR130	1.98	2.08	0.29	0.28	0.30
FR131	0.34	0.30	0.32	0.29	0.33
FR132	0.09	0.08	0.18	0.18	0.17
FR133	1.25	1.53	0.32	0.17	0.35
FR134	1.05	1.24	0.38	0.14	0.40
FR135	0.68	1.03	0.35	0.05	0.39
UTA-42-C(3C-1)	0.38	0.40	0.21	0.22	0.21
UTA-42-C(3C-1) w/ Venthole	0.36	0.45	0.17	0.20	0.15
UTA-42-D(4C-1)	0.57	0.32	0.26	0.41	0.19
UTA-42-D(4C-1) w/ Venthole	0.28	0.35	0.25	0.38	0.18
UTA-42-E(5C-1)	0.67	0.90	0.18	0.12	0.23

Table VIII-2. Free-Free Laboratory Test Data Consisting of Average [1] Material Damping Ratio Values and Poisson's Ratio Values Determined from Small-Strain, Free- Free Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement (Continued)

Sample ID	Low Amplitude Material Damping Ratio in Unconstrained Compression, $D_{C,min}$, %	Low Amplitude Material Damping Ratio in Shear, $D_{S,\ min}$, %	Low Amplitude Poisson's Ratio, ν_{MG}, from the Relationship of M_{max} and G_{max}[3]	Low Amplitude Poisson's Ratio, ν_{EG}, from the Relationship of E_{max} and G_{max}[4]	Low Amplitude Poisson's Ratio, ν_{ME}, from the Relationship of M_{max} and E_{max}[5]
UTA-42-E(5C-1) w/ Venthole	0.96	0.88	0.18	0.08	0.24
UTA-42-F(6C-1)	0.36	0.36	0.15	0.15	0.15
UTA-42-F(6C-1) w/ Venthole	0.44	0.31	0.15	0.15	0.15
UTA-42-G(7C-1)	1.01	0.80	0.22	0.24	0.21
UTA-42-G(8C-1)	0.75	0.69	0.19	0.16	0.21
UTA-42-I(9A-1)	0.87	0.53	0.19	0.19	0.19
UTA-42-J(10A-1)	0.99	0.74	0.34	0.31	0.34
UTA-42-K(11C-1)	0.72	0.86	0.20	0.08	0.26
UTA-42-L(12C-1)	1.12	1.20	0.18	0.04	0.27
UTA-42-M(13C-1)	0.66	0.83	0.15	0.20	0.05
UTA-42-N(14C-1)	0.63	0.83	0.14	0.19	0.05
UTA-42-O(15C-1)	0.91	1.02	0.27	0.44	0.19
UTA-42-P(16C-1)	0.57	1.12	0.24	0.25	0.24
UTA-42-Q(17C-1)	0.91	0.91	0.15	0.04	0.24
UTA-42-R(18C-1)	0.71	0.97	0.18	0.19	0.16
UTA-42-S(19C-1)	0.35	0.43	0.18	0.19	0.18
UTA-42-T(20C-1)	0.81	0.72	0.21	0.08	0.27
UTA-42-U(21C-1)	0.65	0.59	0.17	0.16	0.18
UTA-42-V(22C-1)	0.75	0.89	0.42	0.52	0.41
UTA-42-W(23C)	3.50	1.12	0.17	0.02	0.26
UTA-42-X(24C)	1.79	1.75	0.23	0.11	0.28
UTA-42-Y(25C)	1.87	1.26	0.24	0.14	0.28
UTA-42-AA(27C)	1.39	2.97	0.18	0.04	0.26
UTA-42-AB(28A)	2.72	1.94	0.34	0.34	0.34
UTA-42-AB(28B)	4.56	4.51	0.27	0.25	0.27
UTA-42-AB(28C)	4.39	5.55	0.43	0.23	0.44
UTA-42-AB(28E)	3.86	4.23	0.27	0.32	0.34
UTA-42-AC(29C)	1.40	0.67	0.11	0.10	0.14
UTA-42-AD(30A)	0.59	0.58	0.15	0.17	0.12
UTA-42-AE(31A)	0.86	1.02	0.11	0.08	0.14

Table VIII-2. Free-Free Laboratory Test Data Consisting of Average [1] Material Damping Ratio Values and Poisson's Ratio Values Determined from Small-Strain, Free- Free Torsional and Longitudinal Resonant Measurements and Direct-Travel-Time Measurements without Confinement (Continued)

Sample ID	**Low Amplitude Material Damping Ratio in Unconstrained Compression, $D_{C,min}$, %**	**Low Amplitude Material Damping Ratio in Shear, $D_{S,\ min}$, %**	**Low Amplitude Poisson's Ratio, ν_{MG}, from the Relationship of M_{max} and G_{max}[3]**	**Low Amplitude Poisson's Ratio, ν_{EG}, from the Relationship of E_{max} and G_{max}[4]**	**Low Amplitude Poisson's Ratio, ν_{ME}, from the Relationship of M_{max} and E_{max}[5]**
UTA-42-AF(32A)	1.06	1.02	0.16	0.13	0.18
UTA-42-AG(33A)	3.73	1.90	0.27	0.14	0.32

Source: DTNs: MO0707FREEFREE.006 [DIRS 183287] and MO0709FREEFRUQ.007[DIRS 183292].

NOTES:

[1] Averaged from three measurements.

[2] During this period, calibrated M&TE was not used and these specimens are un-Q (DTN: MO0709FREEFRUQ.007).

[3] $$\nu_{MG} = \frac{M_{max} - 2G_{max}}{2(M_{max} - G_{max})}$$

[4] $$\nu_{EG} = \frac{E_{max} - 2G_{max}}{2G_{max}}$$

[5] $$\nu_{ME} = \frac{1}{4M_{max}}\left(-M_{max} + E_{max} + \sqrt{9M_{max}{}^{2} - 10M_{max}E_{max} + E_{max}{}^{2}}\right)$$

[6] Only constrained compression wave velocity (V_p) could be obtained since the specimen broke when the accelerometer used in the measurement was being detached from Specimen FR97.

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