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Subsurface Exploration Non-Destructive Evaluation

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Via Email 5 Pages +Attachments

Jacobs Engineering Group, Inc.
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Attention: Mr. Paul Davis
Geotechnical Engineer

Re: **Summary Report**
Seismic MASW Shear-Wave Velocity Survey
For Evaluation of Vs 30m at MCAGCC Wastewater Treatment Plant
Twenty Nine Palms, California

INTRODUCTION

This report summarizes the seismic multi-channel analysis of surface waves (MASW), shear-wave velocity survey performed at the referenced site by Advanced Geoscience, Inc. This survey was performed on July 8, 2019 near the location of the proposed waste water treatment plant in Figure 1. The data from this survey was used to prepare one-dimensional (1D) depth profiles of seismic shear-wave velocity layering to evaluate the average shear-wave velocity of the upper 30 meters (“Vs 30m”).

The MASW data was recorded along a single survey line set up at the site designated as Line 1 (Figure 1). Rayleigh-type surface wave data recorded from multiple energy source positions on both ends of the line underwent computer processing using MASW modeling software to generate 1D shear-wave velocity (Vs) profiles. This set of 1D Vs profiles was used to calculate estimates of the Vs 30m.

Seismic refraction data was also recorded from additional energy source points positioned along Line 1. This data underwent refraction tomography processing to prepare a 2D seismic compressional-wave velocity profile for Line 1.

The following sections summarize our field survey procedures and methods of data processing and evaluation. A concluding section discusses the resulting velocity profiles and our overall evaluation of the Vs 30m for the survey area.

FIELD SURVEY

Line 1 was positioned as specified by Jacobs Engineering on the embankment of the existing processing basin shown in Figure 1. This survey line was set up along a straight-line, level traverse with wooden stakes marking the distance stations 0 and 300 feet.

The survey line was set up with 51 geophones spaced 6-feet apart that were connected to a Seistronix EX-6 data recording system. The geophones were 4-Hertz, vertically-aligned velocity transducers commonly used for surface wave and refraction surveys. To improve the data recording the geophones were firmly spike-mounted to the dirt surface. The total recording length for this geophone line was 300 feet.

The following data recording sequence was initiated from an “active” seismic energy source, positioned in-line at locations offset from the first and last geophone positions on Line 1 (at distance stations 0 and 300 feet shown in Figure 1).

1. Energy source points were first generated and recorded using a 60-pound, man-portable weight drop positioned at 12, 18 and 60-feet off the line from the first and last geophone positions. The weight drop was used to make multiple impacts on a metal plate placed on the ground surface. The recordings from three impacts (triggering recording time=0 on the seismograph) were summed together to increase the signal to noise ratio. The separate data recordings at these energy source positions were made using 1.2 second recording time with a sampling rate of 0.5 milliseconds.

2. The energy source point positioned 60-feet from the first and last geophone positions was also used to record multiple impacts with the 60-pound weight drop during a longer time interval. At this longer-offset position a 20-second recording time was manually initiated. During this 20-second time interval 6 to 7 impacts were made to the plate to generate a pattern of multiple Rayleigh wave trains. These recordings were made with 20-second record time with a sampling rate of 2-milliseconds.

To better evaluate the 2D structure of subsurface layering beneath this area additional energy source points were used to record seismic refraction data along Line 1. This data was recorded into the 51-channel geophone line using eleven source points generated with the 60-pound weight drop. The source points started 3-feet off the first geophone position and moved down the line at 30 to 36-foot increments between the geophones, ending 3-feet off the last geophone position. This refraction data was recorded using a 0.5 millisecond record time with a sampling rate of 0.25 milliseconds.

DATA PROCESSING AND EVALUATION

The seismic field records from the active source MASW surveys all showed coherent patterns of higher-amplitude vibrations from in-line surface waves. The refraction data also showed the refracted wave arrivals at all of the geophone positions.

The MASW field records underwent computer processing by Advanced Geoscience using the SurfSeis MASW data processing and modeling software developed by the University of Kansas Geological Survey (www.kgs.ku.edu/software/surfseis). The field records from the various offset energy source positions were first used to generate wave-field amplitude displays of phase velocity versus frequency based on an analysis and summation of active source surface waves traveling in the in-line direction along Line 1. These displays were combined (summed together) for all four energy source recordings and were then used to pick dispersion curves showing our evaluation of the Rayleigh wave (fundamental mode) phase velocity versus frequency variation. The dispersion curves generated were then used to conduct a least-squares inversion to calculate twelve-layer, 1D models of Vs layering for the source positions on the southwest and northeast ends of Line 1. This modeling generated 1D shear-wave profiles to a depth of over 150 feet that simulated a good fit to the picked dispersion curves. Some geologic judgment was used in this processing to keep the number of layers and structure of the models from source points on each end of the line similar. (Copies of the displays generated from this data processing are available in our project files.)

Figure 2 displays the resulting 1D Vs profiles generated for Line 1 from the southwest (SW) and northeast (NE) energy source points (SPs) positioned on each end of the line. Based on our experience with MASW shear-wave velocity profiling, we reference the Line 1 SW profile to a location near station 80 feet and the Line 1 NE profile to a location near station 220 feet, as shown in Figure 1.

The 1D shear-wave velocity profiles generated from each end of the line were used to calculate estimates of the Vs 30m. Two estimates were calculated: one from the southwest end of Line 1, and one from the northeast end of Line 1. These estimates are shown in the table below. Spreadsheets showing these calculations are also included in Appendix A. The calculations were based on the following formula in accordance with the International Building Code (IBC 2000 and later editions) which places a heavier weight on the lower Vs layers (Park, 2013).

$$Vs\ 30m = \sum D_i \,/\, \sum (D_i/Vs_i)$$

For i=1 to Number of Layers to 30 m

D_i = Layer Thickness $\qquad$ Vs_i = Shear-Wave Velocity of Layer

Survey Line	Position of Energy Sources	Calculated Vs 30m From SurfSeis 1D Vs Profile	NEHRP Vs 30m Site Class
Line 1 SW	Offsets Southwest of First Geophone	997 ft/sec	Class D 600 to 1,200 ft/sec (Stiff Soils)
Line 1 NE	Offsets Northeast of Last Geophone	1,007 ft/sec	Class D 600 to 1,200 ft/sec (Stiff Soils)

The refraction data recorded on Line 1 was processed using the RAYFRACT refraction tomography software (www.Rayfract.com) to generate a seismic compressional-wave velocity-depth profile for Line 1. The refraction field records were used to pick first arrival times ("first breaks") for refracted seismic waves traveling in the surface layer and along deeper higher-velocity layers. The travel time data from these first breaks was to conduct refraction tomography imaging of seismic velocity layering in the upper 60 feet. An initial velocity-depth model was first estimated using the Delta TV velocity modeling procedure. This initial model was then refined to produce a closer fit to the first breaks using the Wavepath Eikonal Traveltime (WET) tomographic inversion method with 60 iterations. This best-fit, velocity-depth model was then gridded and color contoured with SURFER (written by Golden Software, Inc.) to show estimated lateral and vertical velocity variations. Figure 3 shows the resulting compressional-wave velocity profile generated for Line 1.

DISCUSION OF RESULTS

The 1D shear-wave velocity profiles generated for the energy source points positioned at each end of Line 1 in Figure 2 compare very well and show similar patterns of velocity layering for the upper 130 feet below ground surface (BGS). These profiles show shear-wave velocity layering ranging between 550 to 1,750 ft/sec for the upper 130 feet BGS which is typical of variable grain-size, valley-fill alluvium in this area. Below 130 feet BGS, the 2,100+ ft/sec velocity layers at 138 to 156 feet BGS probably indicate the upper, weathered surface of the bedrock formation beneath this area.

The shear-wave velocity profiles in Figure 2 show a shallower zone of 1,450+ ft/sec shear wave velocity layering between 28 and 50 feet BGS that appears to be the start of the first layers of courser-grained alluvium. Below this layer, between approximately 55 to 85 feet BGS are lower shear-wave velocity layers (near 1,100 ft/sec) indicating finer-grain deposits. (All other factors being equal, in younger alluvium lower shear-wave velocities indicate less consolidated, more fine-grained silty and clayey deposits.)

The seismic refraction velocity profile in Figure 3 also shows evidence of a slightly lower velocity layer beneath the middle of Line 1 extending to a depth of 60 feet BGS. Due to the limited 300-foot length of this refraction survey this lower velocity layer could be deeper and extend below 60 feet BGS which would correlate better with the thickness of the lower shear-wave velocity zone detected on the shear-wave velocity profiles.

The Vs 30m estimates shown in the table above range from 997 to 1,007 ft/sec with an average value reported for the survey area of 1,002 ft/sec. These Vs 30m estimates were compared to the National Earthquake Hazard Reduction Program (NEHRP) seismic site classification which is based on shear-wave velocity ranges. These Vs 30m estimates were within the range of 600 to 1,200 ft/sec for NEHRP Site Class D for “stiff soils” (Park, 2013).

Advanced Geoscience appreciates this opportunity to be of service to Jacobs Engineering and the US Marine Corps. If you have any questions or additional requests concerning this report please contact the undersigned.

Sincerely,

ADVANCED GEOSCIENCE, INC.

Mark G. Olson, PGp, PG
Principal Geophysicist and Geologist

References:

Park, C.B., 2013, MASW for Geotechnical Site Investigation, The Leading Edge, Volume 32, No. 6, Society of Exploration Geophysicists, June, 2013.

Attachments: Figures 1-3
Appendix A- Spreadsheets with Vs 30m Calculations

Google Earth Site Maps Showing Location of
MASW Shear Wave Velocity Survey
At MCAGCC Proposed Wastewater Treatment Plant
Twenty Nine Palms, California

Figure 1
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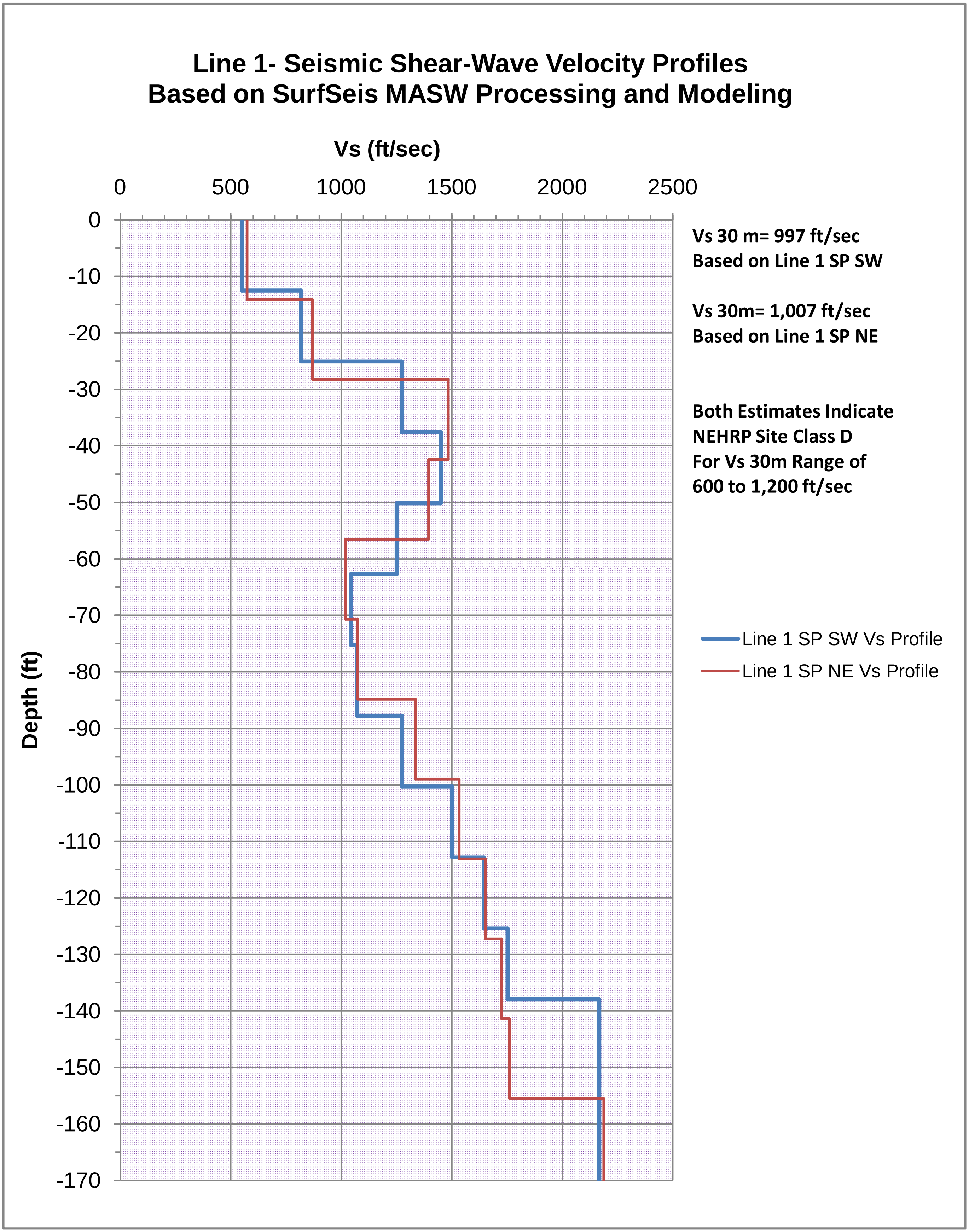

Figure 2
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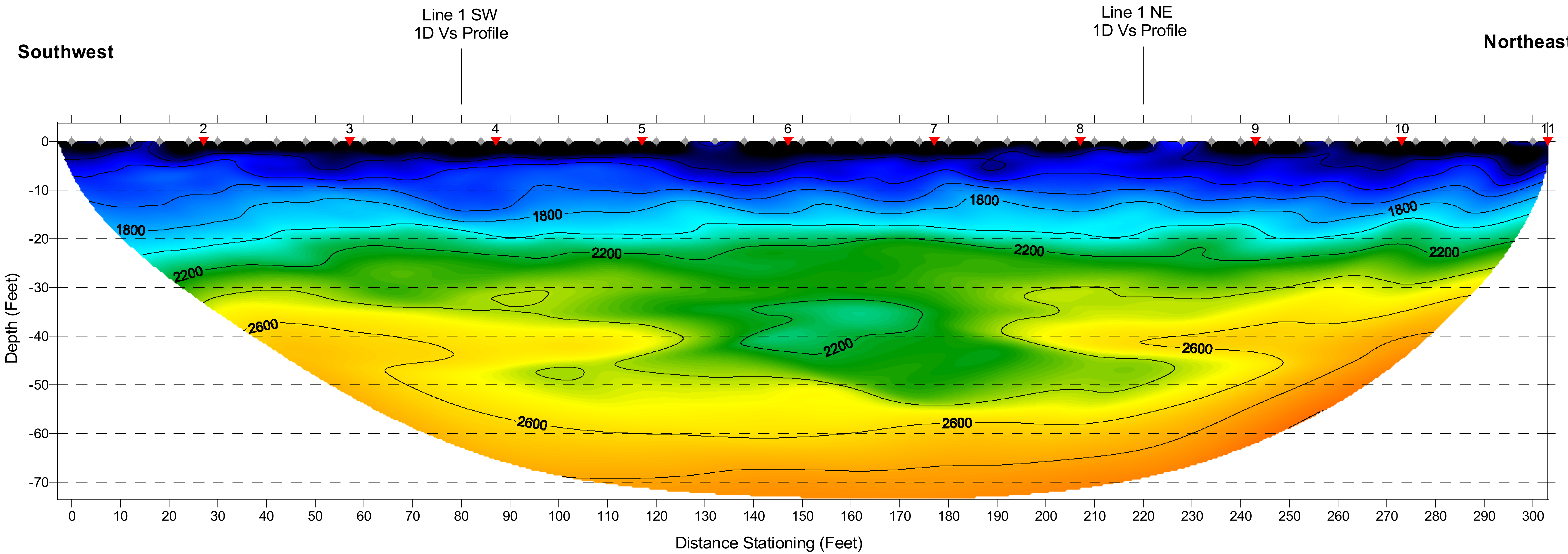
Line 1- Seismic Refraction Velocity Profile



Horizontal and Vertical Scale 1 inch= 20 Feet
Seismic Velocity Contour Interval 200 ft/sec

Refraction Velocity Profile Based on RAYFRACT Tomography
Initial DeltaTV Velocity Model + 50 WET Iterations w/Vmax= 2,500 m/sec

Line 1 Seismic Refraction Compressional-Wave Velocity Profile
For Evaluation of Vs 30m at MCAGCC WTP
Twenty Nine Palms, California

Figure 3
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APPENDIX A

Spreadsheets with Vs 30m Calculations

Twenty Nine Palms MCAGCC WTP Seismic MASW Vs30 m Calculations

Line 1 Energy Source Position on Southwest

1D Shear-Wave Velocity Profile Based on 12-Layer SurfSeis Model

Depth (ft)	Vs (ft/sec)
0	550.559
-12.539	550.559
-12.539	817.822
-25.078	817.822
-25.078	1273.383
-37.617	1273.383
-37.617	1450.256
-50.156	1450.256
-50.156	1251.142
-62.695	1251.142
-62.695	1043.867
-75.234	1043.867
-75.234	1072.791
-87.773	1072.791
-87.773	1275.205
-100.312	1275.205
-100.312	1501.343
-112.851	1501.343
-112.851	1646.329
-125.39	1646.329
-125.39	1752.712
-137.929	1752.712
-137.929	2167.38
-172.411	2167.38

Vs 30m Calculation from 1D Shear Wave Velocity Profile

Depth to Layer Bottom (ft)	Estimated Layer Vs (ft/sec)	Vs Summation Terms to 30 m (98.425 ft) Thickness Di (ft)	Interval Time Di/Vsi (sec)
12.539	550.559	12.539	0.022775
25.078	817.822	12.539	0.015332
37.617	1273.383	12.539	0.009847
50.156	1450.256	12.539	0.008646
62.695	1251.142	12.539	0.010022
75.234	1043.867	12.539	0.012012
87.773	1072.791	12.539	0.011688
100.312	1275.205	10.652	0.008353

Estimated "Vs 30m"= 997.458744 ft/sec

Twenty Nine Palms MCAGCC WTP Seismic MASW Vs30 m Calculations

Line 1 Energy Source Position on Northeast

1D Shear-Wave Velocity Profile Based on 12-Layer SurfSeis Model

Depth (ft)	Vs (ft/sec)
0	573.517
-14.139	573.517
-14.139	870.278
-28.278	870.278
-28.278	1483.8
-42.417	1483.8
-42.417	1395.193
-56.556	1395.193
-56.556	1019.177
-70.695	1019.177
-70.695	1074.459
-84.834	1074.459
-84.834	1335.361
-98.973	1335.361
-98.973	1533.816
-113.112	1533.816
-113.112	1651.864
-127.251	1651.864
-127.251	1726.245
-141.39	1726.245
-141.39	1760.297
-155.529	1760.297
-155.529	2187.126
-194.411	2187.126

Vs 30m Calculation from 1D Shear Wave Velocity Profile

Depth to Layer Bottom (ft)	Estimated Layer Vs (ft/sec)	Vs Summation Terms to 30 m (98.425 ft) Thickness Di (ft)	Interval Time Di/Vsi (sec)
14.139	573.517	14.139	0.024653
28.278	870.278	14.139	0.016247
42.417	1483.8	14.139	0.009529
56.556	1395.193	14.139	0.010134
70.695	1019.177	14.139	0.013873
84.834	1074.459	14.139	0.013159
98.973	1335.361	13.591	0.010178

Estimated "Vs 30m"= 1006.672763 ft/sec

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