LGC Geotechnical, Inc.

January 25, 2021 Project No. 20254-01

Mr. Sunti Kumjim
KNE Real Estate, LLC

Subject: ***Geotechnical Due Diligence Review and Rippability Evaluation for the Proposed Multi-Family Residential Development, Southeast Corner of Whitewood Road and Lee Lane, Murrieta, California***

Introduction

In accordance with your request, LGC Geotechnical, Inc. has performed a geotechnical due diligence review and rippability evaluation for the proposed multi-family residential development located at the southeast corner of Whitewood Road and Lee Lane in the City of Murrieta, California. This report summarizes our findings, conclusions, and preliminary recommendations regarding the bedrock rippability and the future development of the site.

The approximately 18-acre site is bound to the north by Lee Lane, to the east by generally undeveloped residential parcels, to the south by Greenberg Place (road) and to the west by Whitewood Road. See Figure 1 – Site Location Map. The site is currently undeveloped with a primary drainage that transects the central portion of the site and flows from west to east. The primary drainage generally separates the site into two areas (the north and the south) of developable land. Based on our review of the conceptual site plan (Alliance, 2021), the project will generally consist of 44 buildings for multi-family residential units, interior streets, utilities, water quality basins, a dog park, and recreation/clubhouse facilities.

The purpose of our study was to form an opinion of the general geotechnical concerns regarding future development and evaluate the rippability of shallow hard crystalline bedrock present onsite. Specifically, the goal of our field work and analysis was to determine if the onsite bedrock can be excavated by conventional heavy-duty machinery or if blasting may be needed to facilitate excavation. It is our understanding that maximum cuts on the order of 20 feet may be required to achieve pad grades and/or utility installation.

Previous Evaluations

A previous geotechnical evaluation was performed by CHJ, Inc. (2004) in order to characterize subsurface conditions and provide preliminary geotechnical recommendations for design and construction. The previous evaluation included the excavation and logging of six exploratory test pits and select laboratory testing. The previous evaluation has been reviewed as part of our scope of work and the pertinent subsurface and laboratory data has been included in our analysis.

Subsurface Exploration by LGC Geotechnical

LGC Geotechnical recently performed a subsurface exploration which included completing four seismic refraction lines. The four seismic refraction lines (S-1 through S-4) were performed in order to assess the general seismic velocities of the underlying bedrock materials that can be correlated with excavation characteristics (rippability). The seismic refraction lines were strategically placed in areas of the very hard crystalline bedrock present at the site. The seismic refraction line lengths were on the order of approximately 125 feet which resulted in a maximum depth explored of approximately 40 to 45 feet below the existing ground surface.

The approximate locations of the seismic refraction lines are presented on the Preliminary Geotechnical Map (Figure 2) and a separate report summarizing the seismic refraction survey methodology and data is provided in Appendix C.

Please note that the completed seismic refraction lines only characterize the subsurface conditions at the locations they are performed and are placed based on available plans and our understanding of potential future development of the site. If substantial changes the current plans or site layout are made in the future, additional subsurface exploration may be needed.

Geologic Units

Based on our site visit and regional geologic mapping (USGS, 2003), the subject site is generally underlain by hard crystalline bedrock (Gabbro). Additionally, relatively thin surficial deposit present onsite generally include topsoil, colluvium, and alluvium. Brief descriptions of the primary geologic units on the site are presented below.

Surficial Deposits (Not Mapped)

In general, relatively thin surficial deposits (topsoil, colluvium, and alluvium) are present across the site. The topsoil and colluvium are a result of the physical and chemical weathering of the underlying crystalline bedrock. The alluvium is a result of fluvial processes and is present within the primary drainage that transects the site. Based on the previous exploratory test pits and our experience with similar sites, the thickness of these surficial soils varies across the site but are generally less than approximately 2 to 3 feet thick.

Cretaceous Grabbro (Map Symbol – Kgb)

The Cretaceous Gabbro is mainly a crystalline hornblende-gabbro bedrock that is typically brown weathering and medium to very coarse grained (USGS, 2003). However, composition and texture of these rocks vary. Based on our site visit, the gabbro was observed to be gray and coarse grained where encountered. Surface boulders (floaters) were present onsite. The crystalline bedrock is anticipated to be very hard and may be difficult to excavated during future development.

Rippability

In general, the onsite surficial soils (topsoil, colluvium, and alluvium) are anticipated to be easily rippable utilizing conventional heavy-duty earth moving equipment (Caterpillar D9 or equivalent). The excavation difficulty of the gabbro (crystalline bedrock) is highly dependent on the amount of physical and chemical weathering it has been subjected to over time and the amount/spacing of fractures, joints, and/or foliations present. Based on the subsurface data, the crystalline bedrock is generally anticipated to be moderately rippable to non-rippable.

Estimated average depths, seismic velocity ranges, and rippability classification utilizing heavy-duty equipment (Caterpillar D-9 or equivalent) are presented in Table 1 below. These depth estimates are based on the seismic refraction line data obtained from our recent field work. The rippability classifications and velocity ranges presented below are based on readily available rippability charts (Stephens, 1978 & Caterpillar, 2019) and our local experience with similar nearby projects.

Table 1

Generalized Rippability Summary of Crystalline Bedrock

Rippability Classification	Approximate Seismic Velocity (Feet per Second)	Estimated Average Depth Range (Feet)*
Moderate Rippability	< 4,500	0 - 10
Difficult to Very Difficult Rippability	4,500 to 6,000	10-20
Non-Rippable (Blasting Recommended)	> 6,000	> 20

**From Existing Ground Surface*

In general, it is anticipated that the crystalline bedrock will have a moderate to very difficult rippability classification to an approximate depth of 20 feet below the existing ground surface utilizing conventional heavy-duty earth moving equipment (Caterpillar D9 or equivalent). Localized non-rippable zones or corestones may be present within 20 feet of the existing ground surface and will likely require additional effort (very difficult ripping, breakers, etc.) or larger equipment for excavation. This is evident from the surface boulders present onsite and the tomographic model for S-4. Based on the subsurface data, cuts in the crystalline bedrock greater than approximately 20 feet from the existing ground surface will generally require blasting or other specialized equipment to facilitate excavation.

Based on the geologic characteristics of the onsite bedrock and our local experience, we estimate that a seismic velocity of approximately 6,000 feet per second represents the boundary between a very difficult rippability and non-rippable classification. A seismic velocity of 6,000 feet per second is slightly more conservative than what is presented on the referenced rippability charts, however, it is based on our experience with similar local hard rock grading projects. The approximate depth to non-rippable bedrock, the proposed design profile, and anticipated over-excavation depths have been plotted on the tomography models prepared by Terra Geosciences (2020) and are provided in Appendix B.

Performing blasting at lower seismic velocities (5,000 to 5,500 feet per second) may be determined to be more economical or beneficial for construction scheduling. This is highly dependent on anticipated production rates of the grading contractor based on the equipment used for ripping/excavation. It is recommended that the grading contractor review the provided subsurface data and independently determine the potential non-rippable/blasting depths, lateral extents, quantities, production rates, etc. based on their experience and final project plans. For further details regarding rippability refer to the Seismic Refraction Survey report prepared by Terra Geosciences provided in Appendix C.

Please note that different earthmoving equipment (excavators, smaller dozers, backhoes, etc.) will not correlate exactly with the velocity ranges and rippability classifications presented above. In general, an excavator typically utilized for underground utility installation will generally encounter difficult ripping conditions in materials having a seismic velocity of approximately 4,000 to 4,500 feet per second. Therefore, any future underground utilities proposed in the area of the crystalline bedrock will require over-excavation during rough grading with the larger field equipment. Areas of proposed underground utilities in hard rock conditions are typically over-excavated a minimum depth of 2 feet below the deepest utility during rough grading operations to facilitate installation.

Preliminary Conclusions and Recommendations Regarding Rippability

A summary of our geotechnical conclusions and recommendations regarding bedrock rippability and potential future development are as follows:

- Based on our site visit and regional geologic mapping (USGS, 2003), the subject site is generally underlain by hard crystalline bedrock (Gabbro). Additionally, relatively thin surficial deposit present onsite generally include topsoil, colluvium, and alluvium.
- In general, the onsite surficial soils (topsoil, colluvium, and alluvium) are anticipated to be easily rippable utilizing conventional heavy-duty earth moving equipment (Caterpillar D9 or equivalent).
- In general, it is anticipated that the onsite crystalline bedrock will have a moderate to very difficult rippability classification to an approximate depth of 20 feet below the existing ground surface utilizing conventional heavy-duty earth moving equipment (Caterpillar D9 or equivalent).
- Based on the subsurface data, cuts in the crystalline bedrock greater than approximately 20 feet from the existing ground surface will generally require blasting or other specialized equipment to facilitate excavation.
- Localized non-rippable zones may be present shallower than 20 feet from of the existing ground surface and will likely require additional effort (very difficult ripping, breakers, etc.) or larger equipment for excavation.
- Areas of proposed underground utilities located in hard rock conditions should be over-excavated a minimum depth of 2 feet below the deepest utility during rough grading operations to reduce the potential for future excavation difficulties with smaller machinery (excavators, backhoes, etc.).
- Oversized materials (greater than 8 inches in maximum dimension) should be anticipated to be generated during excavation of the hard crystalline bedrock. These materials will require special handling during grading which may include offsite disposal or crushing/breaking to meet project requirements.

Other Geotechnical Findings

Based on our review of the provided geotechnical report, readily available geologic maps and reports, and our knowledge with similar projects, findings, and conclusions regarding other potential geotechnical issues with future development are summarized below.

Faulting

The subject site is not located within a State of California Earthquake Fault Zone (i.e., Alquist-Priolo Earthquake Fault Act Zone) and no active faults are known to cross the site. A fault is considered "Holocene-active" if evidence of surface rupture in Holocene time (the last approximately 11,700 years) is present. The possibility of damage due to ground rupture is considered low since no active faults are known to cross the site. The closest known active fault is the Murrieta Hot Springs Fault located approximately 3 miles south of the subject site.

Landslides

Review of readily available geologic resources and satellite imagery of the surficial conditions at the site do not indicate the presence of landslides on the site or in the immediate vicinity. The potential for landslides or seismically induced landslides to impact the site is considered remote.

Liquefaction

Based on the anticipated as-graded conditions (compacted fill over dense bedrock) and lack of a shallow groundwater (within 50 feet of the ground surface), the potential of liquefaction impacting the site is considered remote.

Subsidence

Based on our review of the Riverside County Geologic Hazards online database (RCIT, 2021), the site is not located in an area considered to be potentially susceptible to subsidence.

Expansive Soils

Based on the results of previous laboratory testing (CHJ, 2004) and our knowledge of similar sites, the majority of the site soils are anticipated to have a "Very Low" expansion potential.

Infiltration

Recent regulatory changes have occurred that mandate that storm water be infiltrated below grade rather than collected in a conventional storm drain system. Based on the County of Riverside Design Handbook for Low Impact Development (RCFC, 2011), bedrock or impermeable surface layers should not be within 5 feet of the proposed infiltration surface and infiltration into artificial fill materials is not accepted. Additionally, purposely infiltrating surface water will result in the localized concentration of groundwater due to the existing geological conditions onsite. This will likely create future seepage/nuisance water issues for onsite slopes and adjacent offsite properties. Based on the geotechnical conditions and provided site development plan, it is our opinion that storm water infiltration at the site is not considered feasible.

Limitations

Our services were performed using the degree of care and skill ordinarily exercised, under similar circumstances, by reputable engineers and geologists practicing in this or similar localities. No other warranty, expressed or implied, is made as to the conclusions and professional advice included in this report. The samples taken and submitted for laboratory testing, the observations made, and the in-situ field testing performed are believed representative of the entire project; however, soil and geologic conditions revealed by excavation may be different than our preliminary findings. If this occurs, the changed conditions must be evaluated by the project soils engineer and geologist and design(s) adjusted as required or alternate design(s) recommended.

The findings of this report are valid as of the present date. However, changes in the conditions of a property can and do occur with the passage of time, whether they be due to natural processes or the works of man on this or adjacent properties. Therefore, the findings, conclusions, and recommendations presented in this report can be relied upon only if LGC Geotechnical has the opportunity to observe the subsurface conditions during grading and construction of the project, in order to confirm that our preliminary findings are representative for the site.

Should you have any questions regarding this letter-report, please do not hesitate to contact our office. We appreciate this opportunity to be of service.

Sincerely,

LGC Geotechnical, Inc.

Dennis Boratynec, GE 2770
Vice President

REGISTERED PROFESSIONAL ENGINEER
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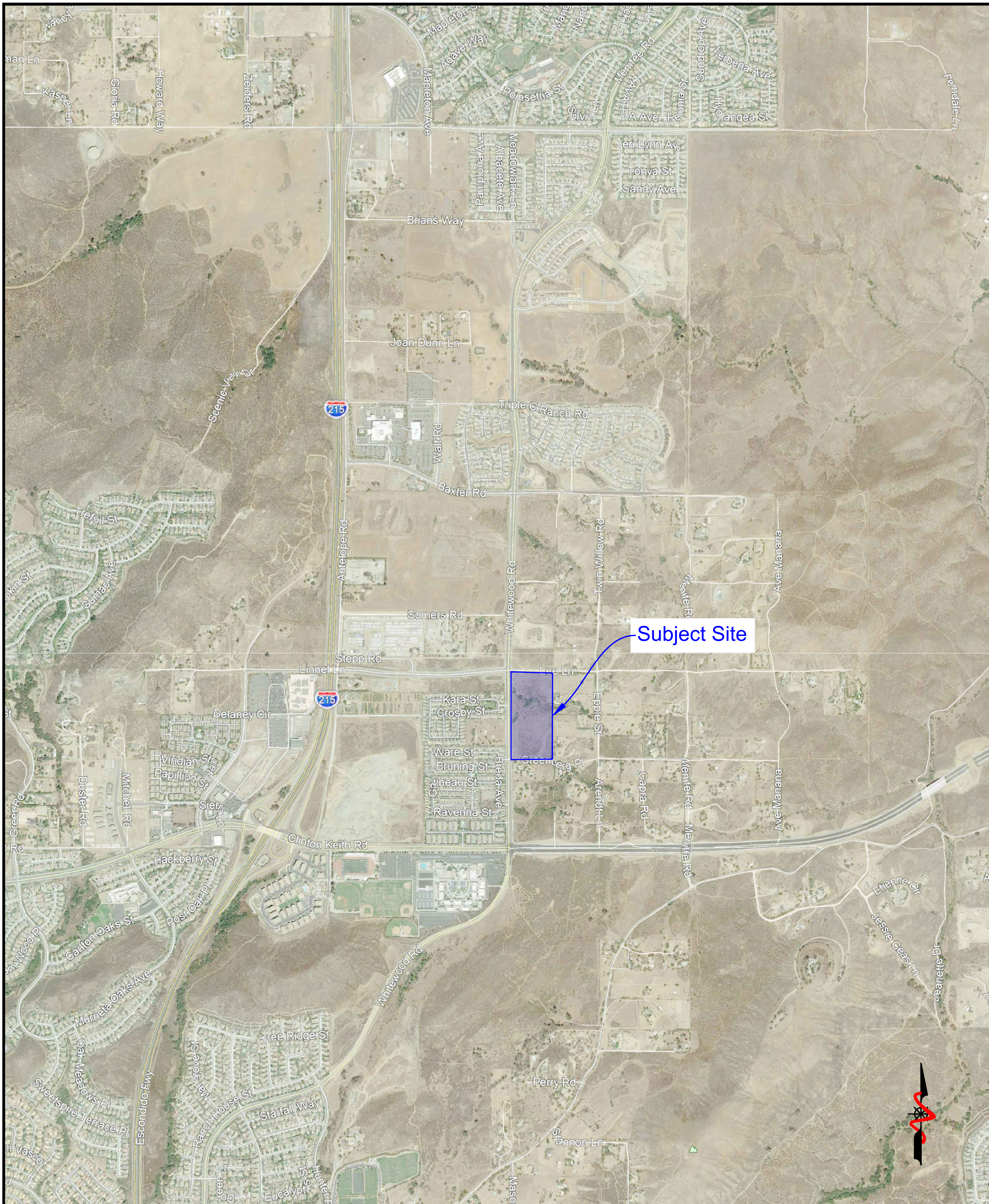
KAD/DJB/amm

Attachments: Figure 1 – Site Location Map
Figure 2 – Preliminary Geotechnical Map
Appendix A – References
Appendix B – Rippability Figures
Appendix C – Subsurface Data by Terra Geosciences for LGC Geotechnical

Distribution: (1) Addressee (electronic copy)



LGC Geotechnical, Inc.

FIGURE 1
Site Location Map

PROJECT NAME	KNE - Murrieta
PROJECT NO.	20254-01
ENG. / GEOL.	DJB / KAD
SCALE	Not to Scale
DATE	January 2021

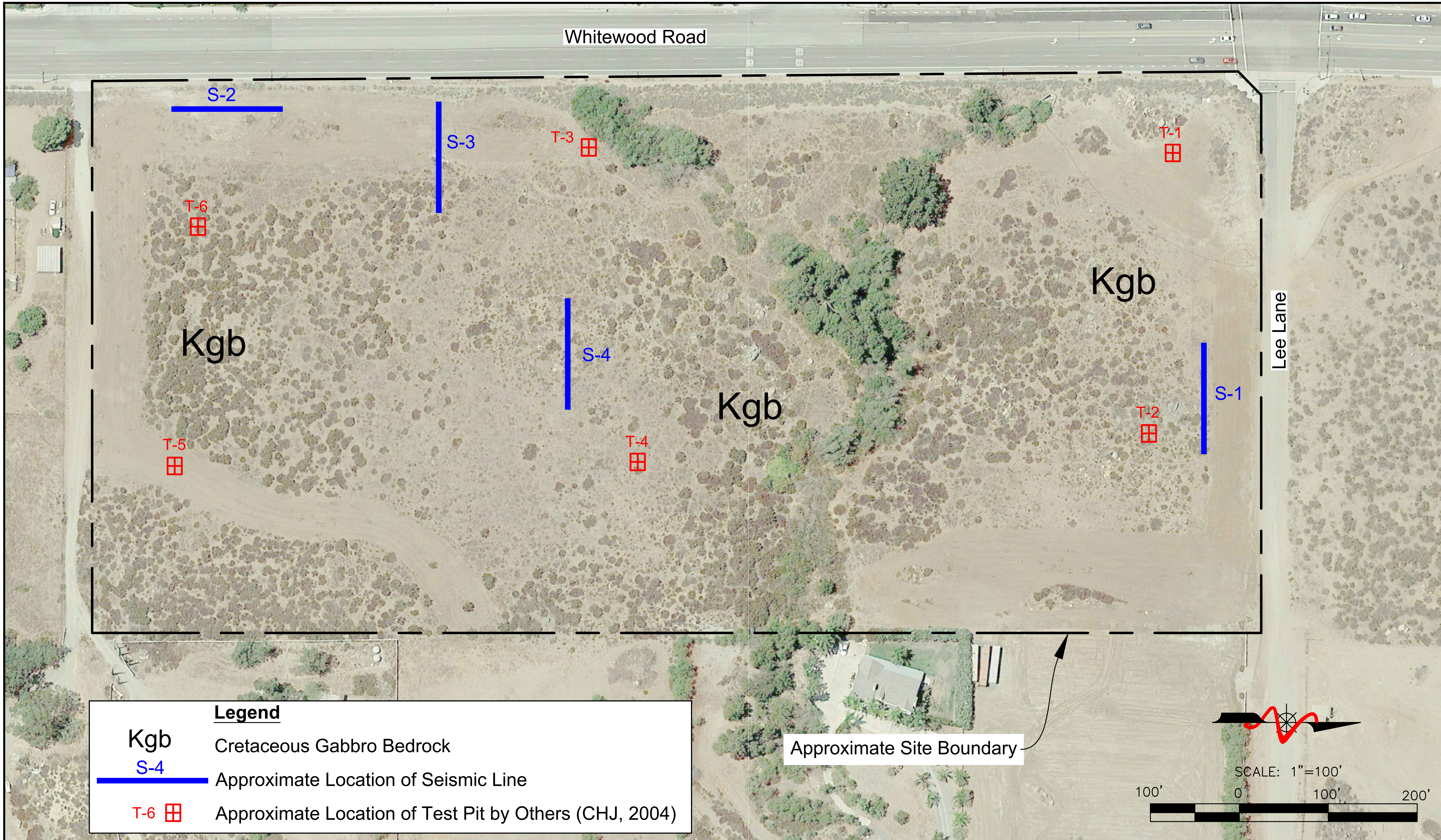


FIGURE 2
Preliminary Geotechnical Map

PROJECT NAME	KNE - Murrieta
PROJECT NO.	20254-01
ENG. / GEOL.	DJB / KAD
SCALE	1" = 100'
DATE	January 2021

Appendix A
References

Appendix A

References

Alliance Land Planning & Engineering, 2021, Murrieta Whitewood Site Development Plan, dated January 18, 2021.

Caterpillar, Inc., 2019, D-9R Ripper Performance Chart, Caterpillar Performance Handbook, 49th Edition.

CHJ, Inc., 2004, Geotechnical Investigation Tentative Tract No. 31998, Southeast corner of Lee Land and Meadowlark Lane, Murrieta, California, Job No. 04390-3, dated April 29, 2004.

Stephens, E., 1978, Calculating Earthwork Factors Using Seismic Velocities, California Department of Transportation Report No. FHWA-CA-TL-78-23.

Riverside County Integrated Technologies (RCIT), 2017, Interactive Geographic Information Services, Website Address: http://gis.rivcoit.org/

Terra Geosciences, 2021, Seismic Refraction Survey, KNE – Murrieta Project, Southeast of Whitewood Road and Lee Land, City of Murrieta, California, Project No. 213566-1, dated January 12, 2021.

United States Geological Survey (USGS), 2003, Preliminary Geologic Map of the Murrieta 7.5' Quadrangle, Version 1.0, by M.P. Kennedy and D.M. Morton, Open-File Report 03-189.

Appendix B
Rippability Figures

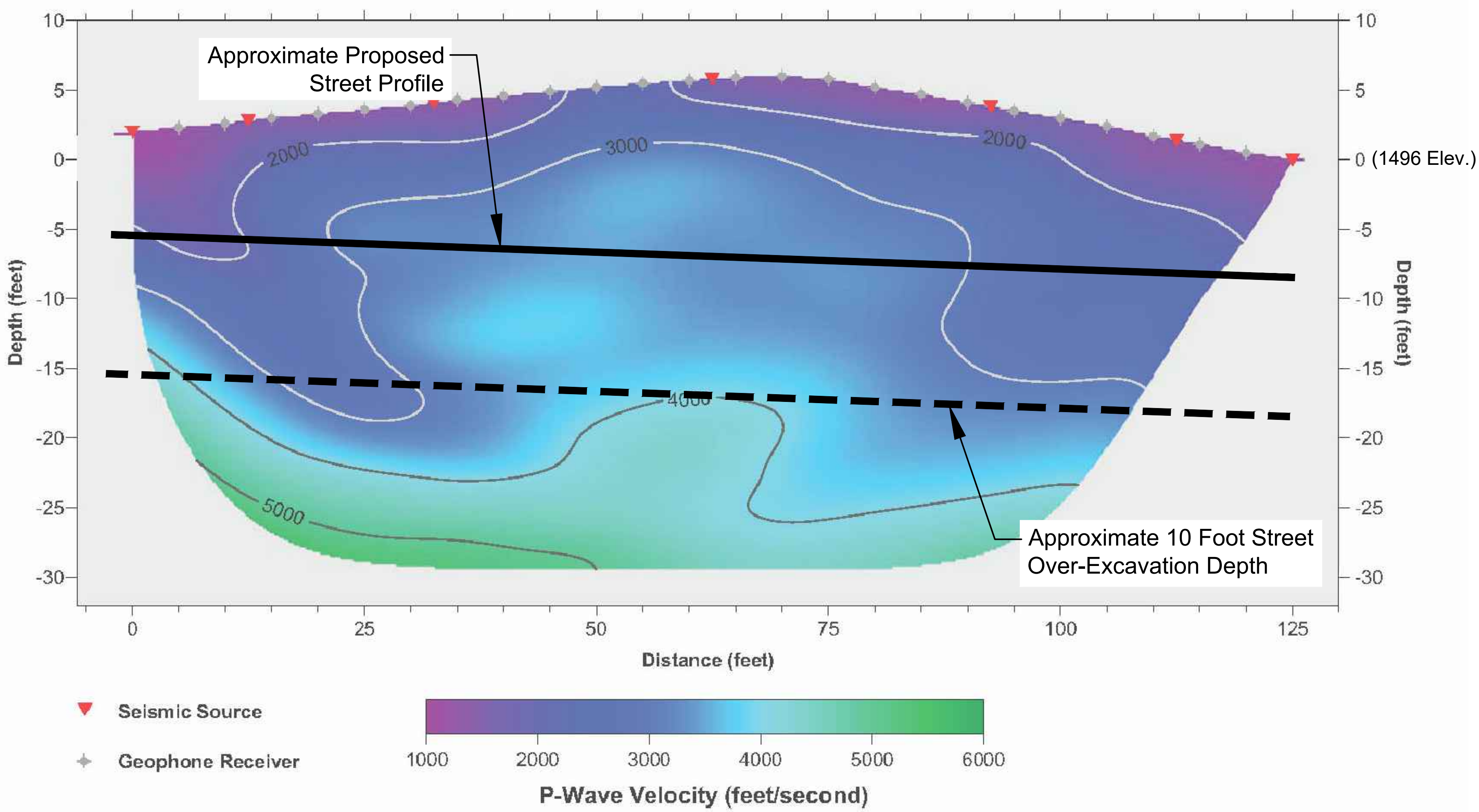
SEISMIC LINE S-1

< West - East >

Approximate Depths From Existing Ground Surface to Non-Rippable Bedrock

>30-35 Feet

REFRACTION TOMOGRAPHIC MODEL



LGC Geotechnical, Inc.

Seismic Line S-1 Tomographic Model

PROJECT NAME	KNE - Murrieta
PROJECT NO.	20254-01
ENG. / GEOL.	DJB / KAD
SCALE	Not to Scale
DATE	January 2021

SEISMIC LINE S-2

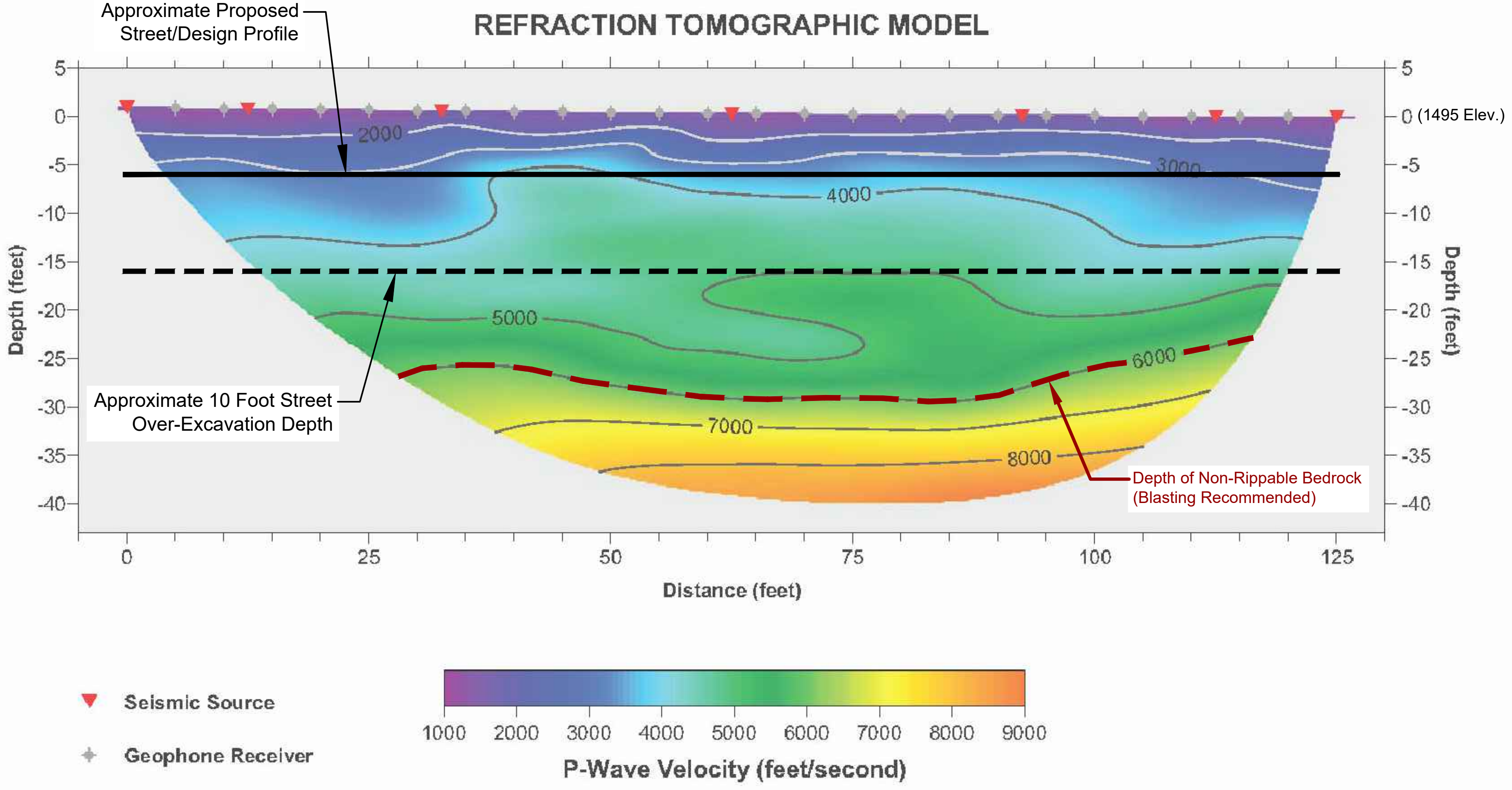
< South - North >

Approximate Depths From Existing Ground Surface to Non-Rippable Bedrock

Minimum Depth = 22'

Maximum Depth = 30'

Average Depth = 27'



LGC Geotechnical, Inc.

Seismic Line S-2 Tomographic Model

PROJECT NAME	KNE - Murrieta
PROJECT NO.	20254-01
ENG. / GEOL.	DJB / KAD
SCALE	Not to Scale
DATE	January 2021

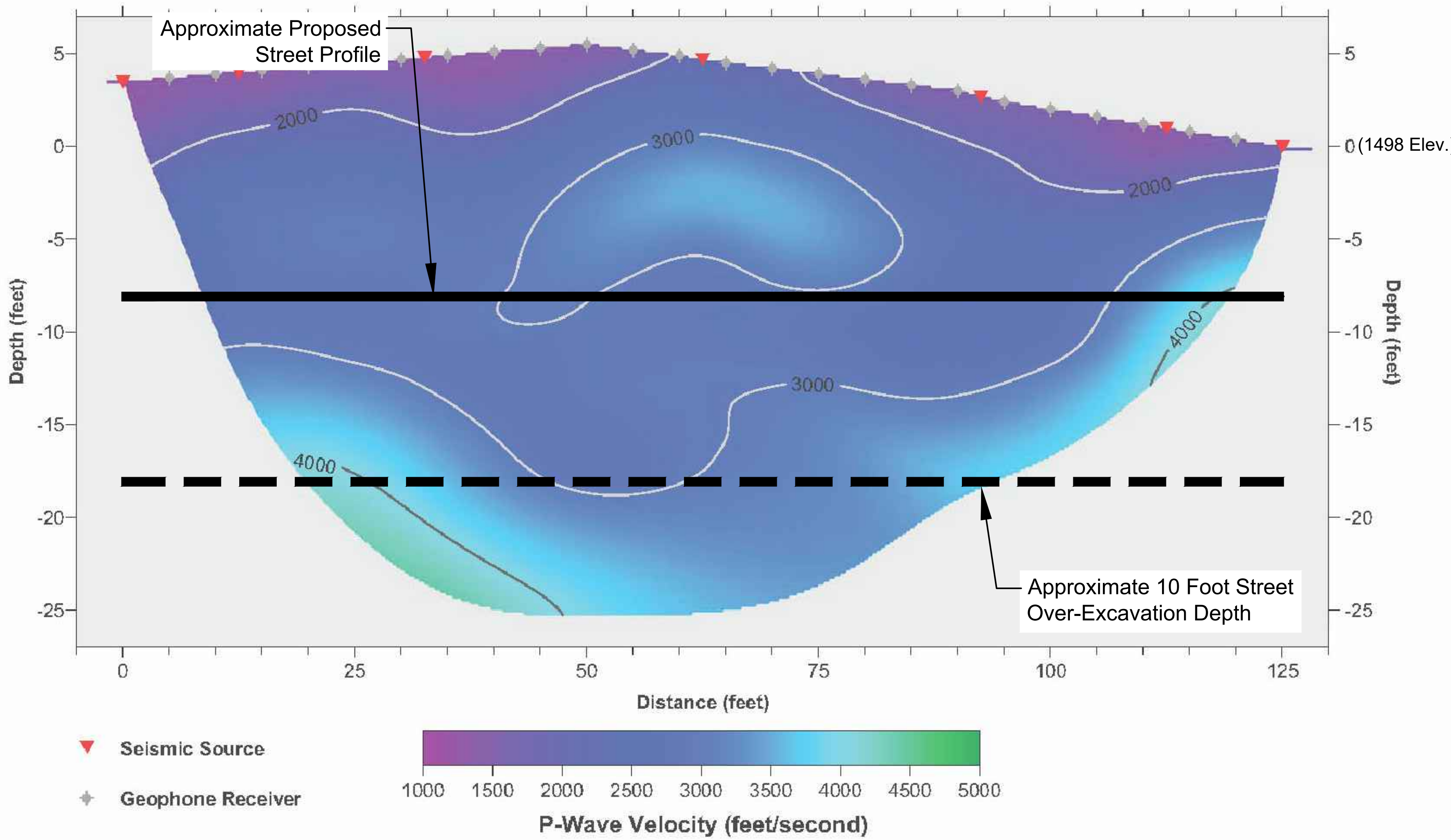
SEISMIC LINE S-3

< West - East >

Approximate Depths From Existing Ground Surface to Non-Rippable Bedrock

>25-30 Feet

REFRACTION TOMOGRAPHIC MODEL



LGC Geotechnical, Inc.

Seismic Line S-3
Tomographic Model

PROJECT NAME	*KNE - Murrieta*
PROJECT NO.	*20254-01*
ENG. / GEOL.	*DJB / KAD*
SCALE	*Not to Scale*
DATE	*January 2021*

SEISMIC LINE S-4

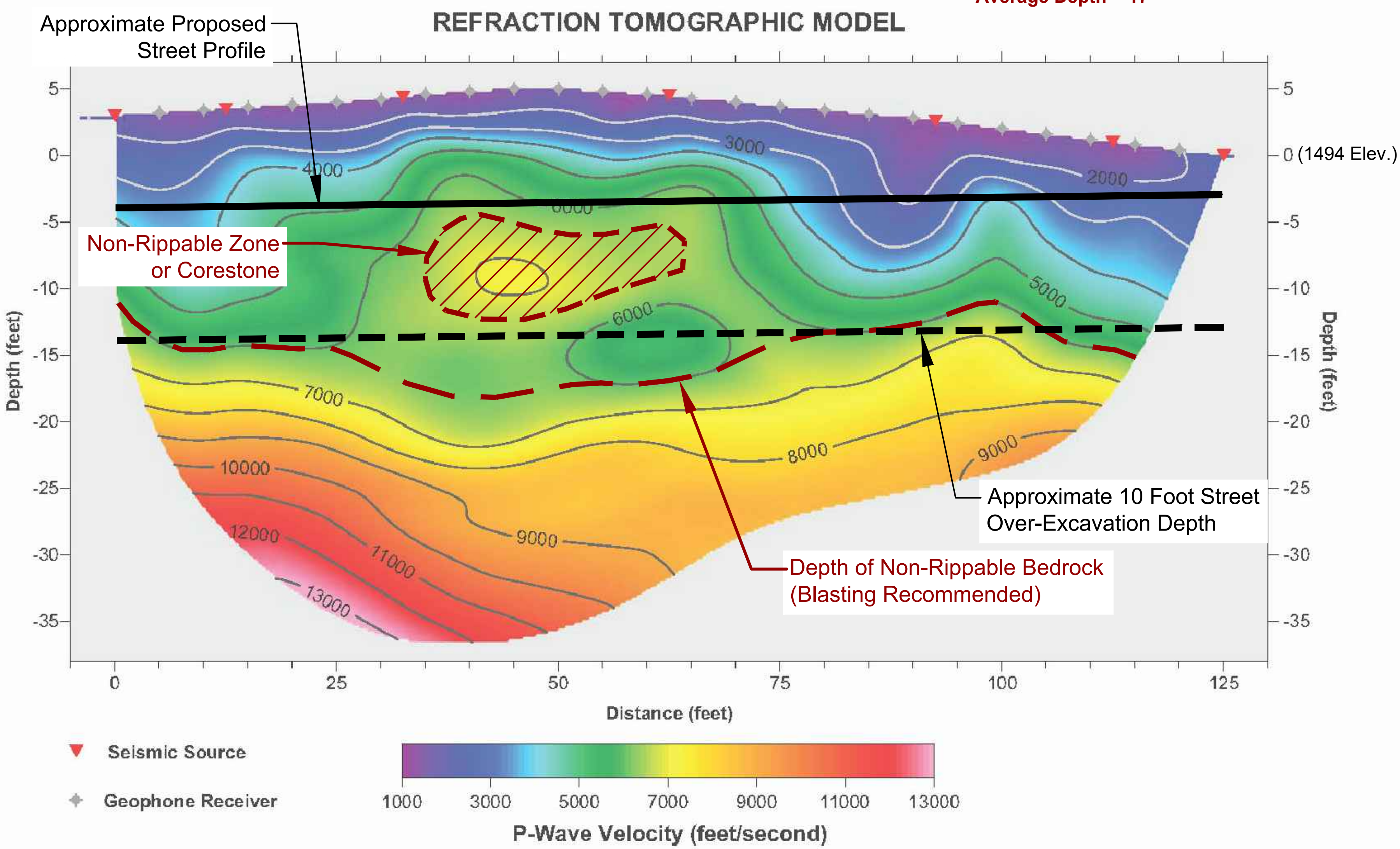
< West - East >

Approximate Depths From Existing Ground Surface to Non-Rippable Bedrock

Minimum Depth = 13'

Maximum Depth = 23'

Average Depth = 17'



LGC Geotechnical, Inc.

Seismic Line S-4 Tomographic Model

PROJECT NAME	*KNE - Murrieta*
PROJECT NO.	*20254-01*
ENG. / GEOL.	*DJB / KAD*
SCALE	*Not to Scale*
DATE	*January 2021*

Appendix C
Seismic Refraction Report by Terra Geosciences for LGC Geotechnical

TERRA GEOSCIENCES

SEISMIC REFRACTION SURVEY

KNE – MURRIETA PROJECT

SOUTHEAST OF WHITEWOOD ROAD AND LEE LANE

CITY OF MURRIETA, CALIFORNIA

Project No. 213566-1

January 12, 2021

Prepared for:

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January 12, 2021
Project No. 213566-1

Attention: Mr. Kevin Dyekman, Project Geologist

Regarding: Seismic Refraction Survey
KNE – Murrieta Project
Southeast of Whitewood Road and Lee Lane
City of Murrieta, California
LGC Project No. 20254-01

EXECUTIVE SUMMARY

As requested, this firm has performed a geophysical survey using the seismic refraction method for the above-referenced site. The purpose of this investigation was to assess the general seismic velocity characteristics of the underlying earth materials and to evaluate whether high velocity bedrock materials (non-rippable) may be present. Additionally, the structure and seismic velocity distribution of the subsurface earth materials was also assessed. This report will describe in further detail the procedures used and the results of our findings, along with presentation of representative seismic models for the survey traverse.

For this study, four survey traverses were performed across the subject property, as selected by your office. The traverses were located in the field by use of Google™ Earth imagery (2020) and GPS coordinates. The approximate locations of these traverses are shown on the Seismic Line Location Map, Plate 1, of which the base map is a captured Google™ Earth image (2020).

This opportunity to be of service is sincerely appreciated. If you should have questions regarding this report or do not understand the limitations of this study or the data and results that are presented, please do not hesitate to contact our office.

Respectfully submitted,
TERRA GEOSCIENCES

Donn C. Schwartzkopf
Principal Geophysicist
PGP 1002

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INTRODUCTION

The subject project is located at the southeast corner of Whitewood Road and Lee Lane, in the City of Murrieta, California. Geomorphically, the site is located within the southwestern portion of the Perris Block, which is an eroded mass of Cretaceous and older crystalline rock forming generally flat-lying erosion surfaces now present at various elevations. These rocks formed during the emplacement of the Cretaceous Age Peninsular Ranges Batholith and are associated with the Paloma Valley pluton, which is composed mainly of gabbro, granodiorite, and monzonite, with lesser tonalite and other associated granitoid rocks (Morton and Miller, *ed.*, 2014). The main structural fabric is generally dominant along a northeast-southwest orientation, conforming to the ring emplacement structure that parallels the geometry of the ring dike.

Locally, as shown on Figure 1 below, mapping by Kennedy and Morton (2003) indicates the subject property to be underlain by Cretaceous age granitic rock, comprised of mainly hornblende gabbro (map symbol Kgb). These rocks are generally described as being brown-weathering, medium- to very coarse-grained, with the gabbro being pegmatitic very locally. The rocks are noted as being quite heterogeneous in composition and texture and includes noritic and dioritic composition rocks, with abundant stoped blocks of gabbro.

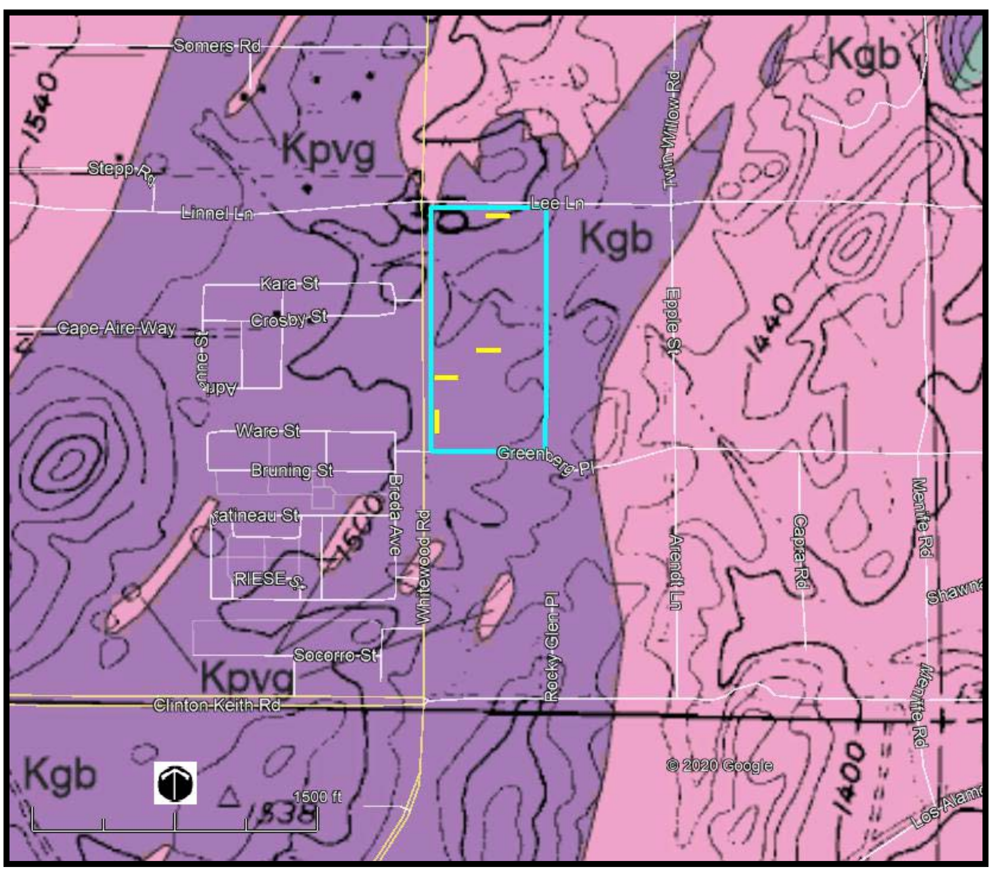


FIGURE 1- Geologic Map (Kennedy and Morton, 2003); seismic traverses shown as yellow lines.

SEISMIC REFRACTION SURVEY

Methodology

The seismic refraction method consists of measuring (at known points along the surface of the ground) the travel times of compressional waves generated by an impulsive energy source and can be used to estimate the layering, structure, and seismic acoustic velocities of subsurface horizons. Seismic waves travel down and through the soils and rocks, and when the wave encounters a contact between two earth materials having different velocities, some of the wave's energy travels along the contact at the velocity of the lower layer. The fundamental assumption is that each successively deeper layer has a velocity greater than the layer immediately above it. As the wave travels along the contact, some of the wave's energy is refracted toward the surface where it is detected by a series of motion-sensitive transducers (geophones). The arrival time of the seismic wave at the geophone locations can be related to the relative seismic velocities of the subsurface layers in feet per second (fps), which can then be used to aid in interpreting both the depth and type of materials encountered.

Field Procedures

Four seismic refraction survey lines (Seismic Lines S-1 through S-4) have been performed along representative areas across the subject study area as selected by you. The traverses were located in the field by use of Google™ Earth imagery (2020) and GPS coordinates and have been delineated on the Seismic Line Location Map, as presented on Plate 1. The survey traverses were each 125 feet in length, which consisted of a total of twenty-four 14-Hertz geophones, spaced at regular five-foot intervals, in order to detect both the direct and refracted waves. A 16-pound sledge-hammer was used as the energy source to produce the seismic waves. Multiple hammer impacts were utilized at each shot point in order to increase the signal to noise ratio, which enhanced the primary seismic "P"-waves.

The seismic wave arrivals were digitally recorded in SEG-2 format on a Geometrics StrataVisor™ NZXP model signal enhancement refraction seismograph. Seven shot points were utilized along each spread using forward, reverse, and several intermediate locations in order to obtain high resolution survey data for velocity analysis and depth modeling purposes. The data was acquired using a sampling rate of 0.0625 milliseconds having a record length of 0.07 seconds. No acquisition filters were used during data collection.

During acquisition, the seismograph displays the seismic wave arrivals on the computer screen which were used to analyze the arrival time of the primary seismic "P"-waves at each geophone station, in the form of a wiggle trace for quality control purposes in the field. If spurious "noise" was observed, the shot location was resampled during relatively quieter periods. Each geophone and seismic shot location were surveyed using a hand level and ruler for topographic correction, with "0" being the lowest point along each survey line.

Data Processing

The recorded seismic data was subsequently transferred to our office computer for processing and analyzing purposes, using the computer programs **SIPwin** (**S**eismic Refraction **I**nterpretation **P**rogram for **Win**dows) developed by Rimrock Geophysics, Inc. (2004); **Refractor** (Geogiga, 2001-2020); and **Rayfract™** (Intelligent Resources, Inc., 1996-2020). All of the computer programs perform their individual analyses using exactly the same input data, which includes the first-arrival times of the "P"-waves and the survey line geometry.

- **SIPwin** is a ray-trace modeling program that evaluates the subsurface using layer assignments based on time-distance curves and is better suited for layered media, using the "Seismic Refraction Modeling by Computer" method (Scott, 1973). The first step in the modeling procedure is to compute layer velocities by least-squares techniques. Then the program uses the delay-time method to estimate depths to the top of layer-2. A forward modeling routine traces rays from the shot points to each geophone that received a first-arrival ray refracted along the top of layer-2. The travel time of each such ray is compared with the travel time recorded in the field by the seismic system. The program then adjusts the layer-2 depths so as to minimize discrepancies between the computed ray-trace travel times and the first arrival times picked from the seismic waveform record.

  The process of ray tracing and model adjustment is repeated a total of six times to improve the accuracy of depths to the top of layer-2. This first-arrival picks were then used to generate the Layer Velocity Models using the **SIPwin** computer program, which presents the subsurface velocities as individual layers and are presented within Appendix A for reference. In addition, the associated Time-Distance Plot for each survey line, which shows the individual data picks of the first "P-wave" arrival times, also appears in Appendix A.

- **Refractor** is seismic refraction software that also evaluates the subsurface using layer assignments utilizing interactive and interchangeable analytical methods that include the Delay-Time method, the ABC method, and the Generalized Reciprocal Method (GRM). These methods are used for defining irregular non-planar refractors and are briefly described below.

  - The Delay-Time method will measure the delay time depth to a refractor beneath each geophone rather than at shot points. Delay-time is the time spent by a wave to travel up or down through the layer (slant path) compared to the time the wave would spend if traveling along the projection of the slant path on the refractor.

  - The ABC (intercept time) method makes use of critically refracted rays converging on a common surface position. This method involves using three surface to surface travel times between three geophones and the velocity of the first layer in an equation to calculate depth under the central geophone and is applied to all other geophones on the survey line.

- The GRM method is a technique for delineating undulating refractors at any depth from in-line seismic refraction data consisting of forward and reverse travel-times and is capable of resolving dips of up to 20% and does not over-smooth or average the subsurface refracting layers. In addition, the technique provides an approach for recognizing and compensating for hidden layer conditions.

Rayfract™ is seismic refraction tomography software that models subsurface refraction, transmission, and diffraction of acoustic waves which generally indicates the relative structure and velocity distribution of the subsurface using first break energy propagation modeling. An initial 1D gradient model is created using the DeltatV method (Gebrande and Miller, 1985) which gives a good initial fit between modeled and picked first breaks. The DeltatV method is a turning-ray inversion method which delivers continuous depth vs. velocity profiles for all profile stations. These profiles consist of horizontal inline offset, depth, and velocity triples. The method handles real-life geological conditions such as velocity gradients, linear increasing of velocity with depth, velocity inversions, pinched-out layers and outcrops, and faults and local velocity anomalies. This initial model is then refined automatically with a true 2D WET (Wavepath Eikonal Traveltime) tomographic inversion (Schuster and Quintus-Bosz, 1993).

WET tomography models multiple signal propagation wave-paths contributing to one first break, whereas conventional ray tracing tomography is limited to the modeling of just one ray per first break. This computer program performs the analysis by using the same first-arrival P-wave times and survey line geometry that were generated during the layer velocity model analyses. The associated Refraction Tomographic Models, which display the subsurface earth material velocity structure, is represented by the velocity contours (isolines displayed in feet/second), supplemented with the color-coded velocity shading for visual reference, and are presented within Appendix B.

The combined use of these computer programs provided a more thorough and comprehensive analysis of the subsurface structure and velocity characteristics. Each computer program has a specific purpose based on the objective of the analysis being performed. **SIPwin** and **Refractor** were primarily used for detecting generalized subsurface velocity layers providing "weighted average velocities." The processed seismic data of these two programs were compared and averaged to provide a final composite layer velocity model which provided a more thorough representation of the subsurface. **Rayfract™** provided tomographic velocity and structural imaging that is very conducive to detecting strong lateral velocity characteristics such as imaging corestones, dikes, and other subsurface structural characteristics.

SUMMARY OF GEOPHYSICAL INTERPRETATION

To begin our discussion, it is important to consider that the seismic velocities obtained within bedrock materials are influenced by the nature and character of the localized major structural discontinuities (foliation, fracturing, relic bedding, etc.), creating anisotropic conditions. Anisotropy (direction-dependent properties of materials) can be caused by “micro-cracks,” jointing, foliation, layered or inter-bedded rocks with unequal layer stiffness, small-scale lithologic changes, etc. (Barton, 2007). Velocity anisotropy complicates interpretation and it should be noted that the seismic velocities obtained during this survey may have been influenced by the nature and character of any localized structural discontinuities within the bedrock underlying the subject site.

Generally, it is expected that higher (truer) velocities will be obtained when the seismic waves propagate along direction (strike) of the dominant structure, with a damping effect when the seismic waves travel in a perpendicular direction. Such variable directions can result in velocity differentials of between 2% to 40% depending upon the degree of the structural fabric (i.e., weakly-moderately-strongly foliated, respectively). Therefore, the seismic velocities obtained during our field study and as discussed below, should be considered minimum velocities at this time.

The first computer method described below used for data analysis is the traditional layer method (**SIPwin** and **Refractor**). Using this method, it should be understood that the data obtained represents an average of seismic velocities within any given layer. For example, high seismic velocity boulders, dikes, or other local lithologic inconsistencies, may be isolated within a low velocity matrix, thus yielding an average medium velocity for that layer. Therefore, in any given layer, a range of velocities could be anticipated, which can also result in a wide range of excavation characteristics.

In general, the site where locally surveyed, was noted to be characterized by three major subsurface layers (Layers V1 through V3) with respect to seismic velocities. The following velocity layer summaries have been prepared using the **SIPwin** and **Refractor** analysis, with the representative Layer Velocity Models presented within Appendix A along with their respective Time-Distance Plots.

- ***Velocity Layer V1***: This uppermost velocity layer (V1) is most likely comprised of colluvium, topsoil, and/or completely-weathered and fractured bedrock materials. This layer has an average weighted velocity of 1,244 to 1,459 fps, which is typical for these types of unconsolidated surficial earth materials.

- ***Velocity Layer V2***: The second layer (V2) yielded a seismic velocity range of 3,016 to 4,261 fps, which is generally typical for highly-weathered granitic bedrock materials. This velocity range may indicate the presence of homogeneous weathered bedrock with a relatively wide spaced joint/fracture system and/or the possibility of buried relatively-fresher boulders within a very highly-weathered bedrock matrix.

- **Velocity Layer V3**: The third layer (V3) indicates the presence of moderately-weathered bedrock, having a seismic velocity range of 6,360 to 7,425 fps. These higher velocities signify the decreasing effect of weathering as a function of depth and could indicate a moderately-weathered bedrock matrix that has a wide-spaced fracture system, or possibly the presence of abundant widely-scattered buried fresh large crystalline boulders in a moderately-weathered matrix.

The following table summarizes the results of the survey lines with respect to the "weighted average" seismic velocities for each layer, as indicated on the Layer Velocity Models, presented within Appendix A.

TABLE 1- VELOCITY SUMMARY OF SEISMIC SURVEY LINES

Seismic Line	V1 Layer (fps)	V2 Layer (fps)	V3 Layer (fps)
S-1	**1,244**	**3,160**	**------**
S-2	**1,387**	**3,856**	**6,360**
S-3	**1,391**	**3,392**	**------**
S-4	**1,459**	**4,261**	**7,425**

Using **Rayfract™**, tomographic models were also prepared for comparative purposes to better illustrate the general structure and velocity distribution of the subsurface, using velocity contour isolines, as presented within Appendix B. Although no discrete velocity layers or boundaries are created, these models generally resemble the corresponding overall average layer velocities as presented within Appendix A. In general, the seismic velocity of the bedrock gradually increases with depth, with occasional lateral velocity differentials suggesting the local presence of buried corestones, lithologic variabilities, and/or dike structures. The colors representing the velocity gradients have been standardized on all of the models for comparative purposes.

GENERALIZED RIPPABILITY CHARACTERISTICS OF BEDROCK

A summary of the generalized rippability characteristics of bedrock based on a compilation of rippability performance charts prepared by Caterpillar, Inc. (2019; see Figure 2, Page 8), Caltrans (Stephens, 1978), and Santi (2006), has been provided to aid in evaluating potential excavation difficulties with respect to the seismic velocities obtained along the local areas surveyed. These seismic velocity ranges and rippability potentials have been tabulated below for reference.

TABLE 2- CATERPILLAR RIPPABILITY CHART (D9 Ripper)

Granitic Rock Velocity	Rippability
< 7,200	Rippable
7,200 – 9,000	Moderately Rippable
> 9,000	Non-Rippable

Additionally, we have provided the Caltrans Rippability Chart as presented below within Table 2 for comparison. These values are from published Caltrans studies (Stephens, 1978) that are based on their experience and which appear to be more conservative than Caterpillar's rippability chart. It should be noted that the type of bedrock was not indicated.

TABLE 3- STANDARD CALTRANS RIPPABILITY CHART

Velocity (feet/sec ±)	Rippability
< 3,500	Easily Ripped
3,500 – 5,000	Moderately Difficult
5,000 – 6,600	Difficult Ripping / Light Blasting
> 6,600	Blasting Required

Table 3 is partially modified from the "Engineering Behavior from Weathering Grade" as presented by Santi (2006), which also provides velocity ranges with respect to rippability potentials, along with other rock engineering properties that may be pertinent.

TABLE 4- SUMMARY OF ROCK ENGINEERING PROPERTIES

ENGINEERING PROPERTY:	Slightly Weathered	Moderately Weathered	Highly Weathered	Completely Weathered
Excavatability	Blasting necessary	Blasting to rippable	Generally rippable	Rippable
Slope Stability	½ :1 to 1:1 (H:V)	1:1 (H:V)	1:1 to 1.5:1 (H:V)	1.5:1 to 2:1 (H:V)
Schmidt Hammer Value	51 – 56	37 – 48	12 – 21	5 – 20
Seismic Velocity (fps)	8,200 – 13,125	5,000 – 10,000	3,300 – 6,600	1,650 – 3,300

The Caterpillar D9R Ripper Performance Chart (Caterpillar, 2019) has been provided on Figure 2 below for reference.

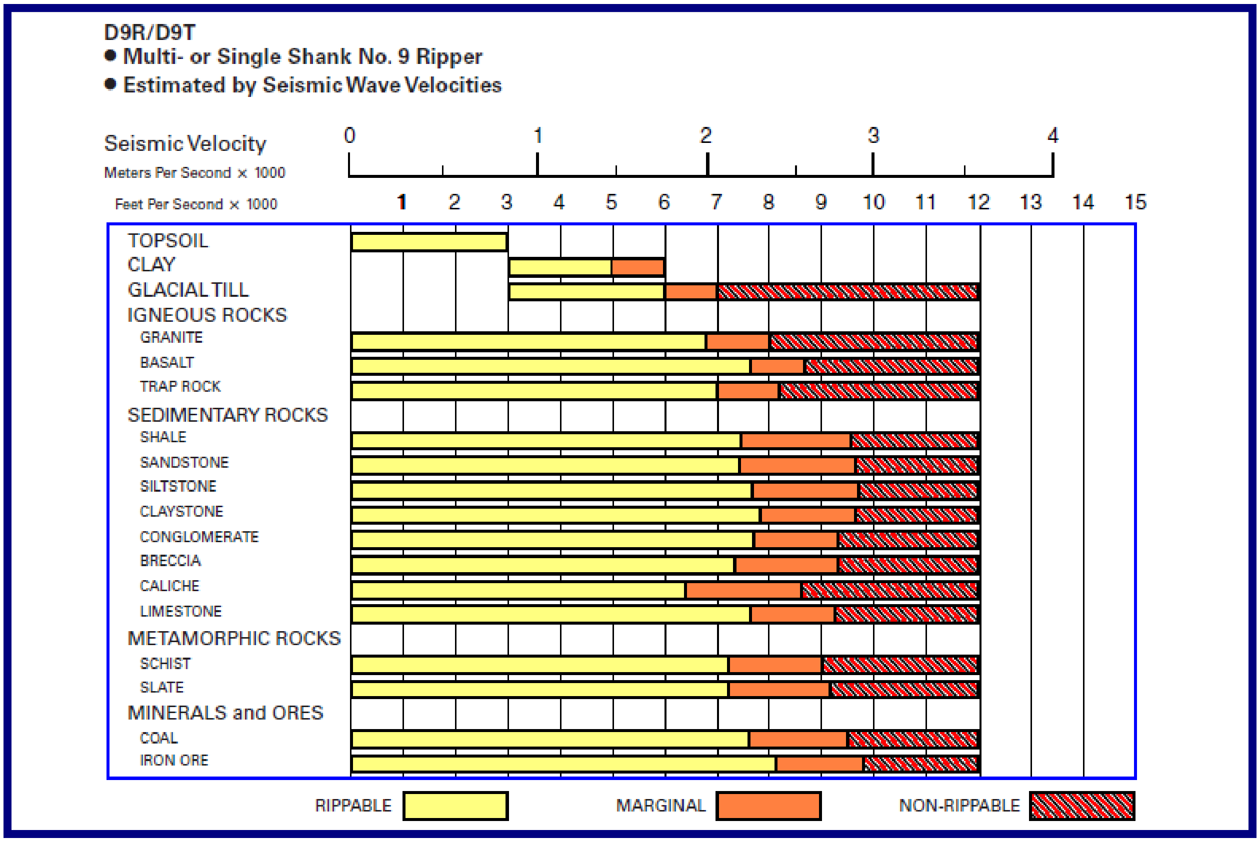


FIGURE 2- Caterpillar D9R Ripper Performance Chart (2019).

For purposes of the discussion in this report with respect to the expected bedrock rippability characteristics, we are assuming that a D9R/D9T dozer will be used as a minimum, such as discussed further below and as shown in Figure 2 above. Smaller excavating equipment will most likely result in slower production rates and possible refusal within relatively lower velocity bedrock materials. It should be noted that the decision for blasting of bedrock materials for facilitating the excavation process is sometimes made based upon economic production reasons and not solely on the rippability (velocity/hardness) characteristics of the bedrock.

A summary of the generalized rippability characteristics of bedrock has been provided below to aid in evaluating potential excavation difficulties with respect to the seismic velocities obtained along the local areas that were surveyed. The velocity ranges described below are general averages of Tables 2 and 3 presented in this report (see Page 7) and assume typical, good-working, heavy excavation equipment, such as D9R dozer using a single shank, as described by Caterpillar, Inc. (2000 and 2019).

However, different excavating equipment (i.e., trenching equipment) may not correlate well with these velocity ranges as the rippability performance charts are tailored for conventional bulldozer equipment and cannot be directly correlated. Trenching operations which utilize large excavator-type equipment within granitic bedrock materials, typically encounter very difficult to non-productable conditions where seismic velocities are generally greater than 4,000± fps, and less for smaller backhoe-type equipment.

These average seismic velocity ranges are summarized below:

- **Rippable Condition (0 - 4,000 ft/sec)**:

  This velocity range indicates rippable materials which may consist of alluvial-type deposits and decomposed granitic bedrock, with random hardrock floaters. These materials typically break down into silty sands (depending on parent lithologic materials), whereas floaters will require special disposal. Some areas containing numerous hardrock floaters may present utility trench problems. Large floaters exposed at or near finished grade may present problems for footing or infrastructure trenching.

  Marginally Rippable Condition (4,000 - 7,000 ft/sec):

  This range of seismic velocities indicates materials which may consist of moderately weathered bedrock and/or large areas of fresh bedrock materials separated by weathered fractured zones. These bedrock materials are generally rippable with difficulty by a Caterpillar D9R or equivalent. Excavations may produce material that will partially break down into a coarse silty to clean sand, with a high percentage of very coarse sand to pebble-sized material depending on the parent bedrock lithology. Less fractured or weathered materials will probably require blasting to facilitate removal.

- **Non-Rippable Condition (7,000 ft/sec or greater)**:

  This velocity range includes non-rippable material consisting primarily of moderately fractured bedrock at lower velocities and only slightly fractured or unfractured rock at higher velocities. Materials in this velocity range may be marginally rippable, depending upon the degree of fracturing and the skill and experience of the operator. Tooth penetration is often the key to ripping success, regardless of seismic velocity. If the fractures and joints do not allow tooth penetration, the material may not be ripped effectively; however, pre-blasting or "popping" may induce sufficient fracturing to permit tooth entry. In their natural state, materials with these velocities are generally not desirable for building pad grade, due to difficulty in footing and utility trench excavation. Blasting will most likely produce oversized material, requiring special disposal.

GEOLOGIC & EARTHWORK CONSIDERATIONS

To evaluate whether a particular bedrock material can be ripped or excavated, this geophysical survey should be used in conjunction with the geologic and/or geotechnical report and/or information gathered for the subject project which may describe the physical properties of the bedrock. The physical characteristics of bedrock materials that favor ripping generally include the presence of fractures, faults, and other structural discontinuities, weathering effects, brittleness or crystalline structure, stratification or lamination, large grain size, moisture permeated clay, and low compressive strength. If the bedrock is foliated and/or fractured at depth, this structure could aid in excavation production.

Unfavorable bedrock conditions can include such characteristics as massive and homogeneous formations, non-crystalline structure, absence of planes of weakness, fine-grained materials, and formations of clay origin where moisture makes the material plastic. Use of these physical bedrock conditions along with the subsurface velocity characteristics as presented within this report should aid in properly evaluating the type of equipment that will be necessary and the production levels that can be anticipated for this project.

A summary of excavation considerations is included within Appendix C in order to provide you and your grading contractor with a better understanding of the complexities of excavation in bedrock materials, so that proper planning and excavation techniques can be employed.

SUMMARY OF FINDINGS AND CONCLUSIONS

The raw field data was considered to be of good quality with moderate amounts of ambient "noise" that was introduced during our survey, originating from vehicular traffic along the nearby roadways. Analysis of the data and picking of the primary "P"-wave arrivals was therefore performed with some difficulty, with interpolation of some data points being necessary. Based on the results of our comparative seismic analyses of the computer programs **SIPwin**, **Refractor**, and **Rayfract™**, the seismic refraction survey line models appear to generally coincide with one another, with some minor variances due to the methods that these programs process, integrate, and display the input data. The anticipated excavation potentials of the velocity layers encountered locally during our survey are as follows:

- **Velocity Layer V1**:

  No excavating difficulties are expected to be encountered within the uppermost, low-velocity V1 layer (average weighted velocity of 1,244 to 1,459 fps) and should excavate with conventional ripping. This surficial velocity layer is expected to be comprised of topsoil, colluvium, and/or completely-weathered and fractured bedrock materials.

- **<u>Velocity Layer V2</u>**:

  The second V2 layer (average weighted velocity of 3,016 to 4,261 fps) is believed to consist of highly-weathered granitic bedrock. Using the rock classifications as presented within Tables 2 through 4 and Figure 2, seismic wave velocities of less than 6,600 to 7,200± fps are generally noted to be within the threshold for conventional ripping. Isolated floaters (i.e., boulders, corestones, etc.) may be locally present within this layer, and could produce somewhat difficult conditions locally. Trenching and/or placement of infrastructure within this velocity layer using excavator equipment may require some breaking and/or light blasting to obtain desired grade.

- **<u>Velocity Layer V3</u>**:

  The third V3 layer is believed to consist of moderately-weathered bedrock. Hard excavation difficulties within this velocity layer (average weighted velocity range of 6,360 to 7,425 fps) should be anticipated if encountered during grading. This layer may consist of relatively homogeneous bedrock with wide-spaced fracturing, or may contain higher velocity scattered corestones, dikes, and other lithologic variables, within a relatively lower velocity bedrock matrix. Although not highly anticipated, blasting may be necessary along local areas within this layer to achieve desired grade, including any infrastructure. Caterpillar (2019; see Figure 2) indicates this velocity range to be “rippable” to “moderately-rippable” using a D9R dozer or equivalent. Larger equipment may facilitate excavation potentials within this higher velocity layer.

The ray sampling coverage of the subsurface seismic waves that were acquired during the processing of the refraction tomographic models using **Rayfract™**, appeared to be of good quality, which was verified by having a Root Mean Square Error (RMS) of 2.6 to 4.6 percent (see lower right-hand corner of the models). The RMS error (misfit between picked and modeled first break times) is automatically calculated during the processing routine, with a value of less than 5.0% being preferred, which was obtained on all of the seismic models.

Based on the tomographic modeling and typical excavation characteristics observed within granitic bedrock materials of the southern California region, anticipation of gradual increasing hardness with depth should be anticipated during grading. Some lateral velocity variations should be expected to be encountered across the subject property generally due to the presence of buried corestones, dikes, and/or lithologic variabilities.

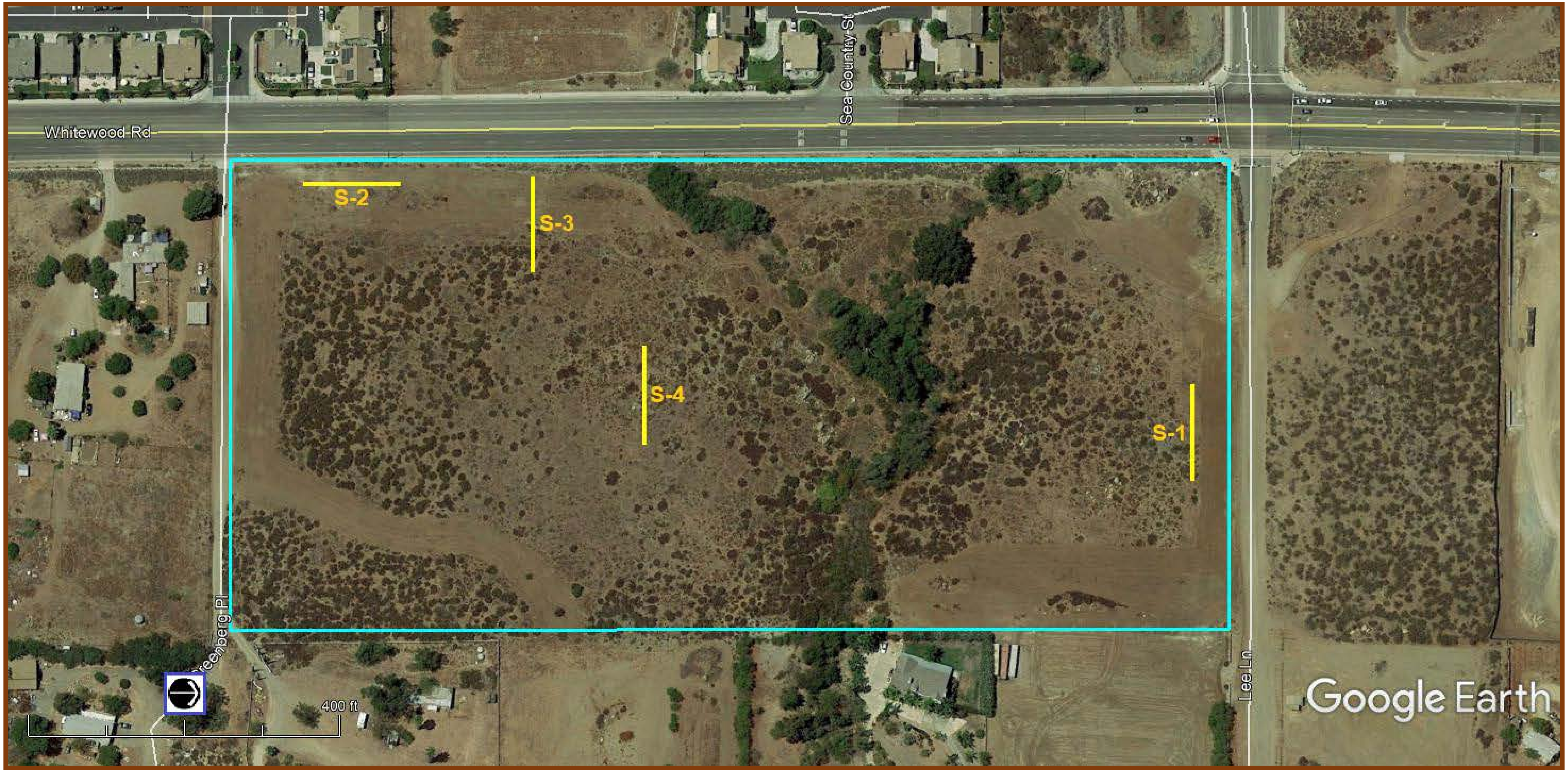
CLOSURE

The field geophysical survey was performed on January 9, 2021 by the undersigned using "state of the art" geophysical equipment and techniques along the selected seismic traverse locations. The seismic data was further evaluated using recently developed computerized tomographic inversion techniques to provide a more thorough analysis and understanding of the subsurface velocity and structural conditions. It should be noted that our data presented within this report was obtained along four specific locations therefore other areas in the local may contain different velocity layers and depths not encountered during our field survey. Additional survey traverses may be necessary to further evaluate the excavation characteristics across other portions of the site where cut grading will be proposed, if warranted. Estimates of layer velocity boundaries as presented in this report are generally considered to be within 10± percent of the total depth of the contact.

It is important to understand that the fundamental limitation for seismic refraction surveys is known as nonuniqueness, wherein a specific seismic refraction data set does not provide sufficient information to determine a single “true” earth model. Therefore, the interpretation of any seismic data set uses “best-fit” approximations along with the geologic models that appear to be most reasonable for the local area being surveyed. Client should also understand that when using the theoretical geophysical principles and techniques discussed in this report, sources of error are possible in both the data obtained, and in the interpretation, and that the results of this survey may not represent actual subsurface conditions. These are all factors beyond **Terra Geosciences** control and no guarantees as to the results of this survey can be made. We make no warranty, either expressed or implied.

In summary, the results of this seismic refraction survey are to be considered as an aid to assessing the rippability and excavation potentials of the bedrock locally. This information should be carefully reviewed by the grading contractor and representative “test” excavations with the proposed type of excavation equipment for the proposed construction should be considered, so that they may be correlated with the data presented within this report.

SEISMIC LINE LOCATION MAP



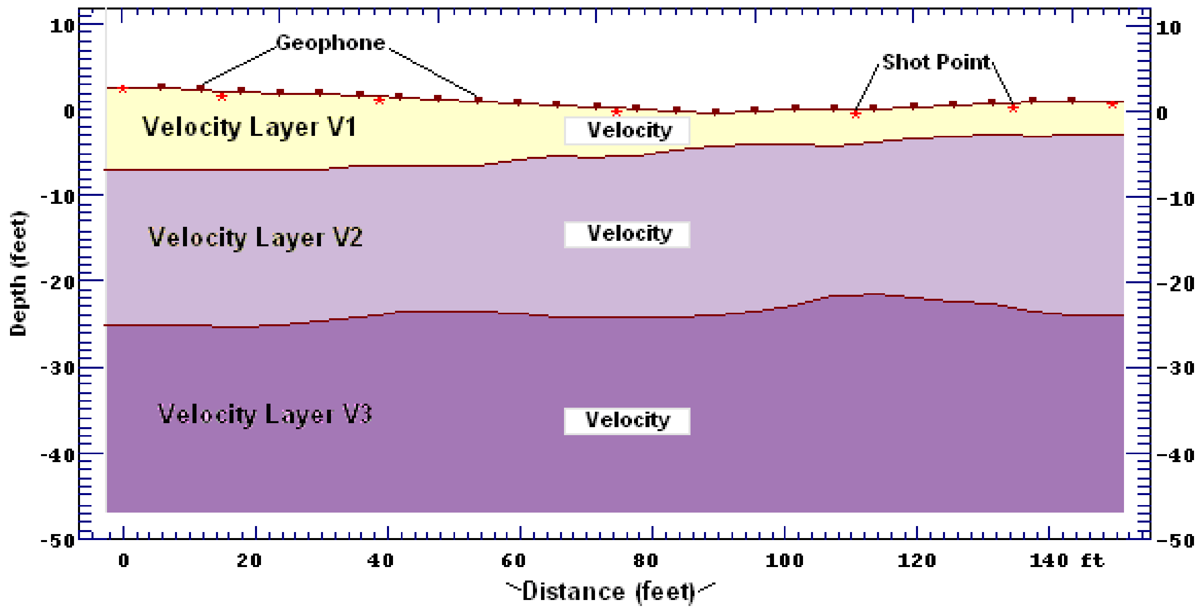
Base Map: Google™ Earth imagery (2020); Seismic traverses S-1 through S-4 shown as yellow lines, site outlined in blue.

APPENDIX A

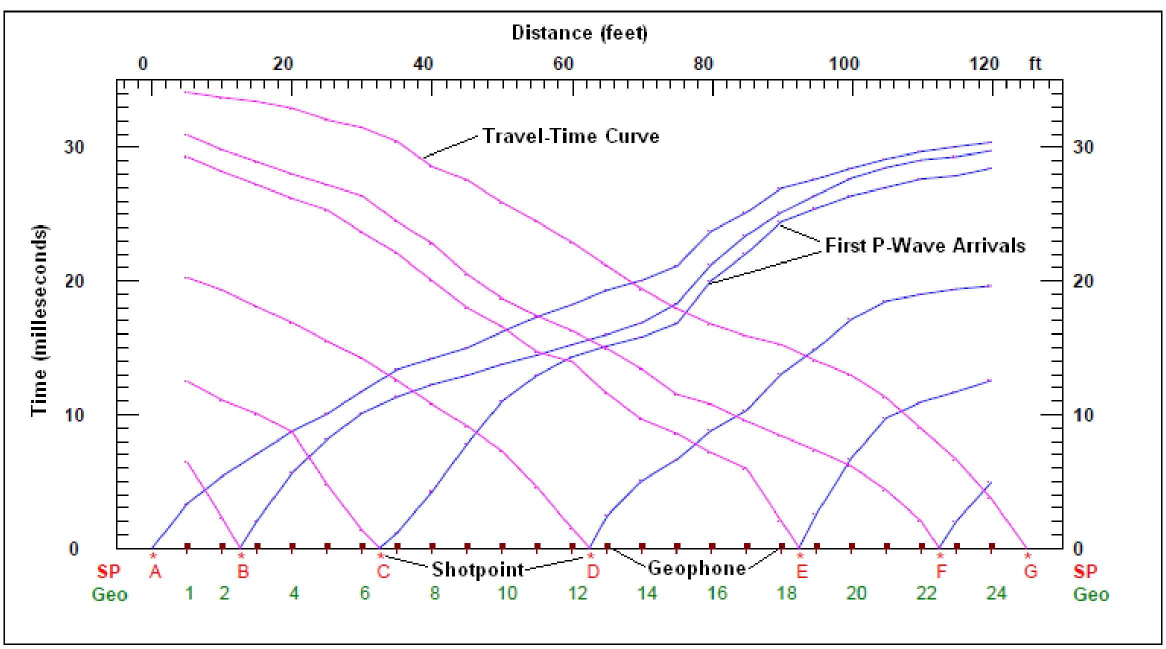
LAYER VELOCITY MODELS

LAYER VELOCITY MODEL LEGEND

LAYER VELOCITY MODEL



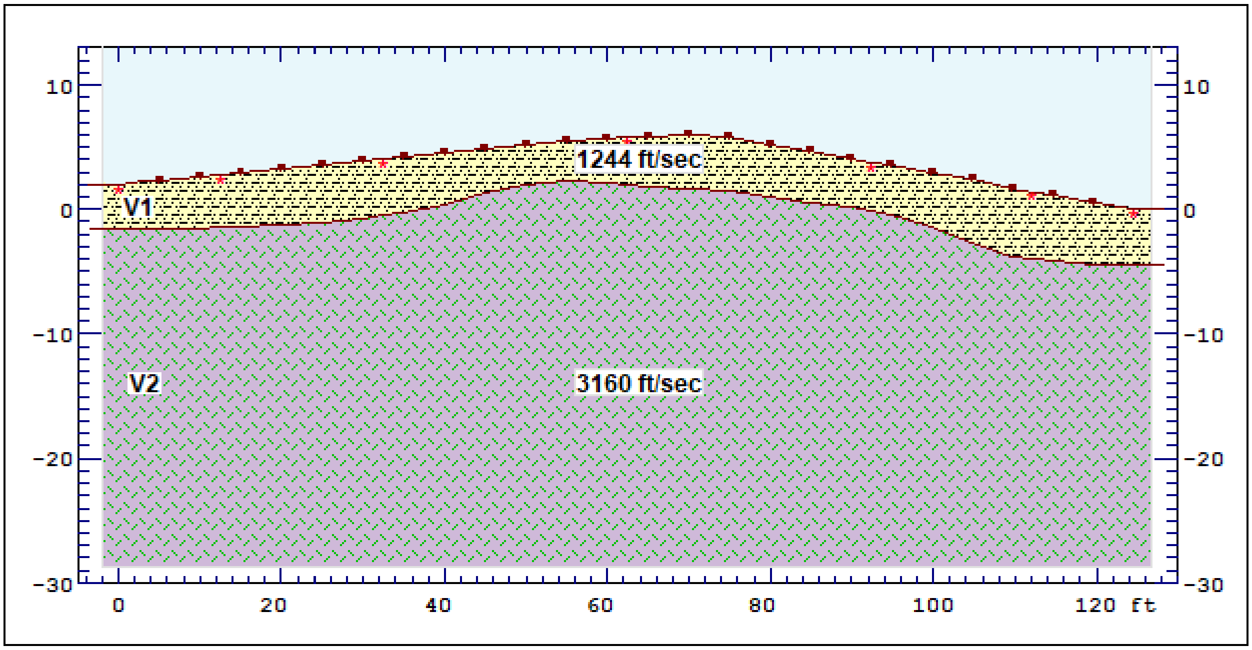
TIME-DISTANCE PLOT



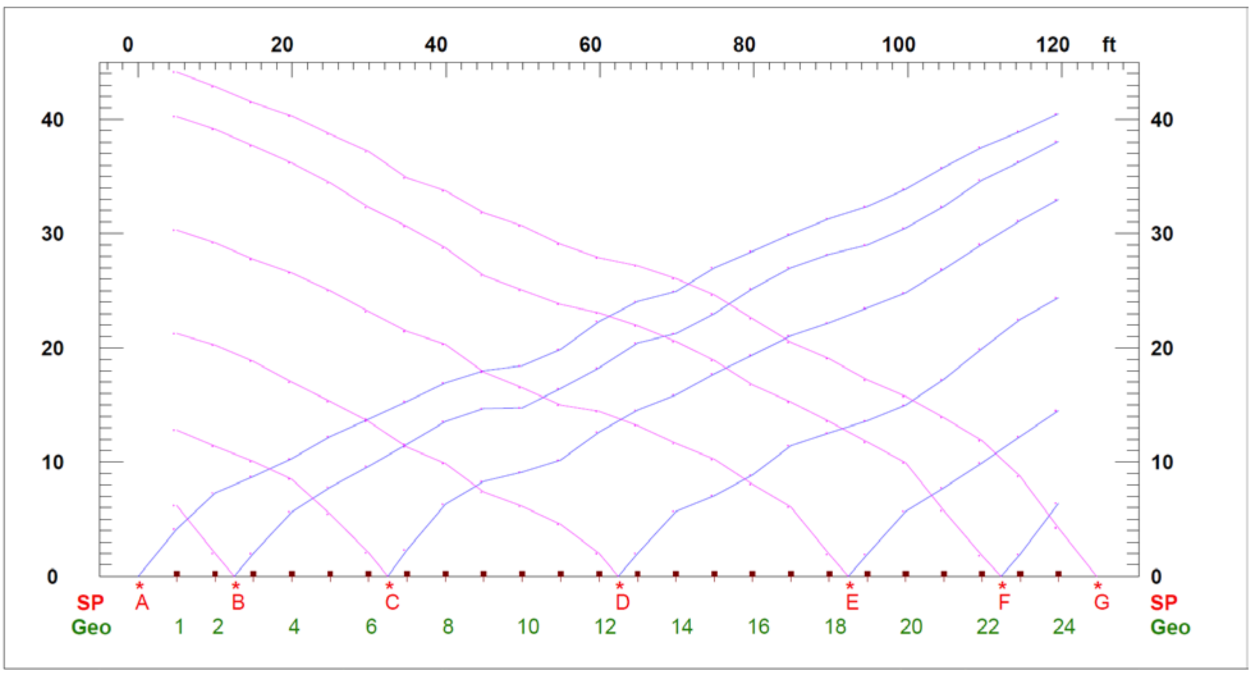
SEISMIC LINE S-1

< West - East >

LAYER VELOCITY MODEL



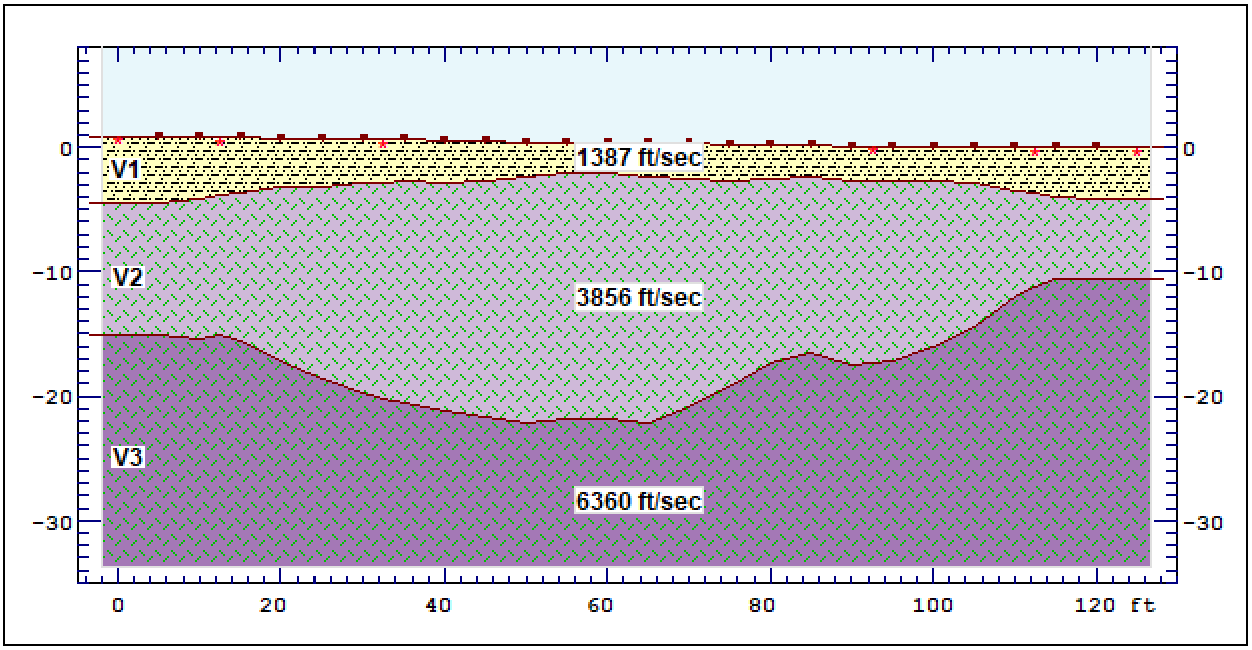
TIME-DISTANCE PLOT



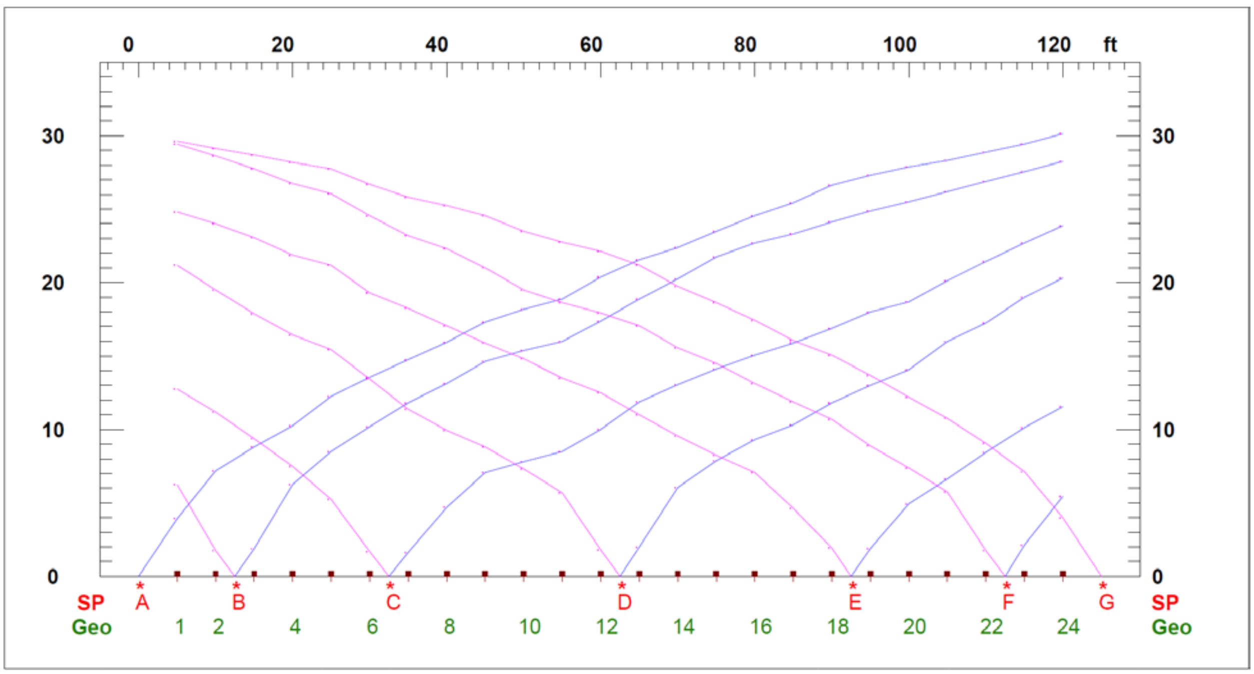
SEISMIC LINE S-2

< South - North >

LAYER VELOCITY MODEL



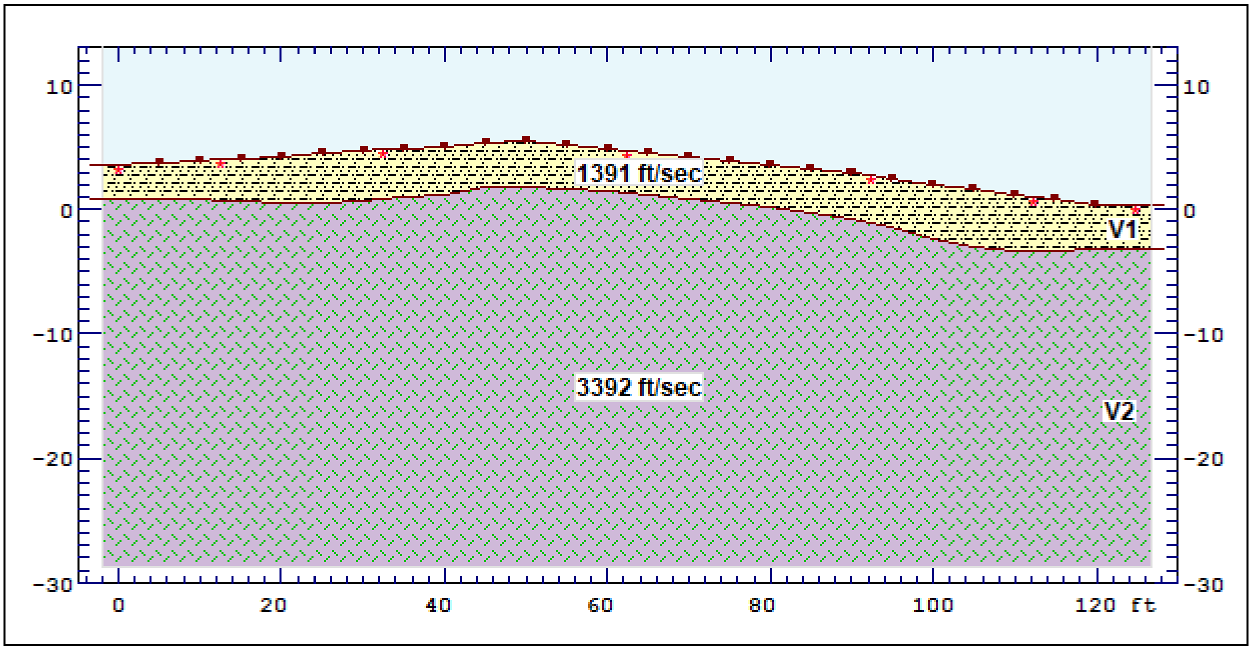
TIME-DISTANCE PLOT



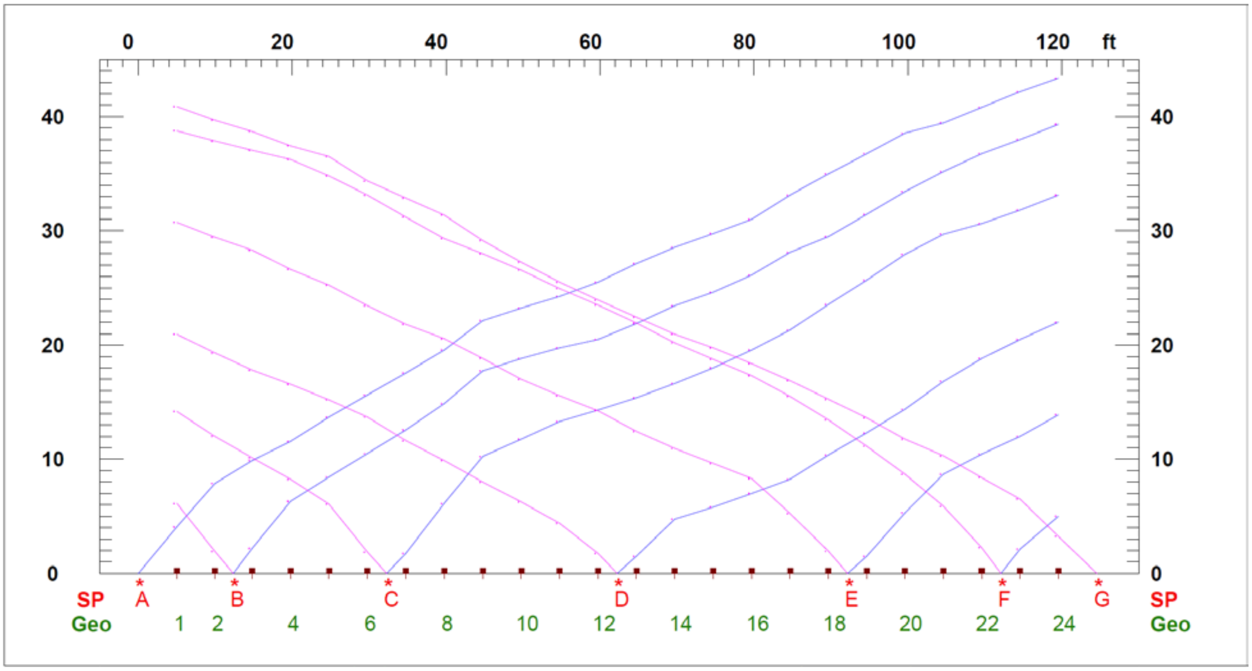
SEISMIC LINE S-3

< West - East >

LAYER VELOCITY MODEL



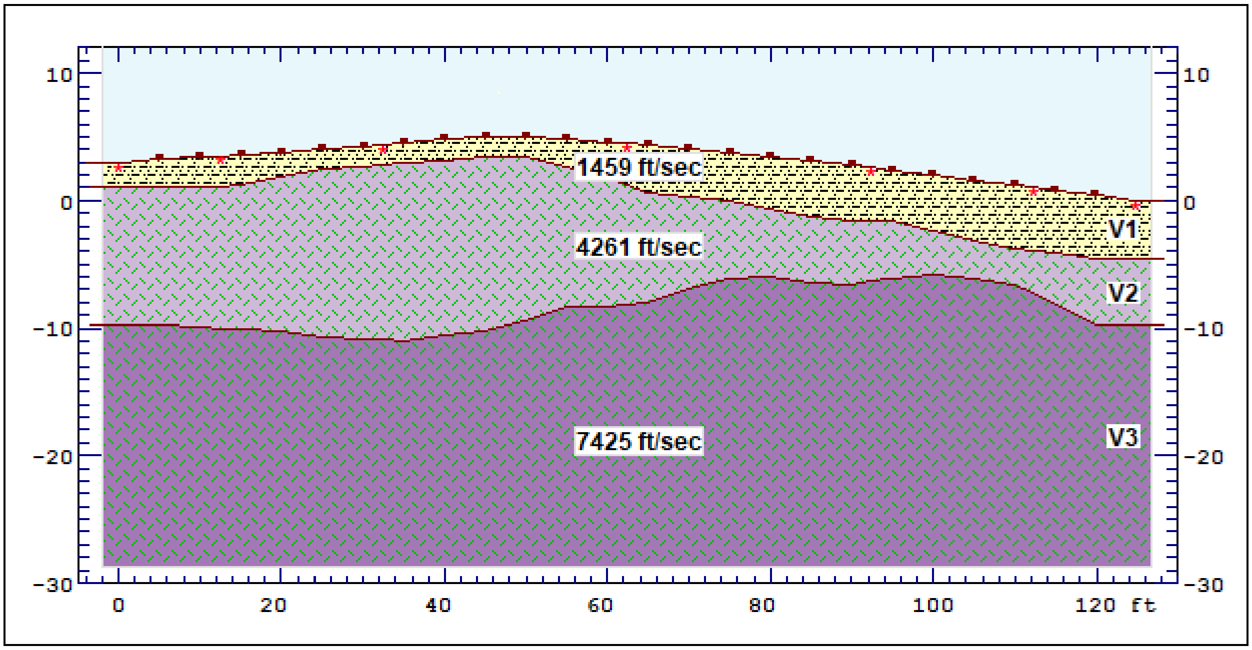
TIME-DISTANCE PLOT



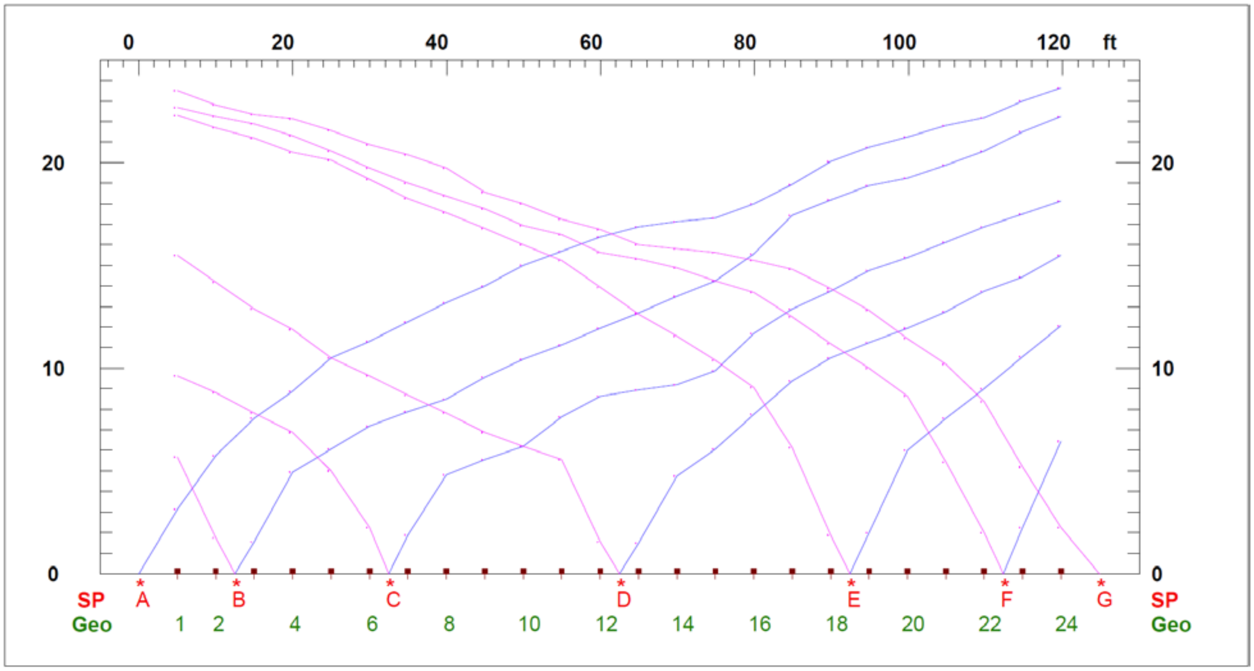
SEISMIC LINE S-4

< West - East >

LAYER VELOCITY MODEL



TIME-DISTANCE PLOT



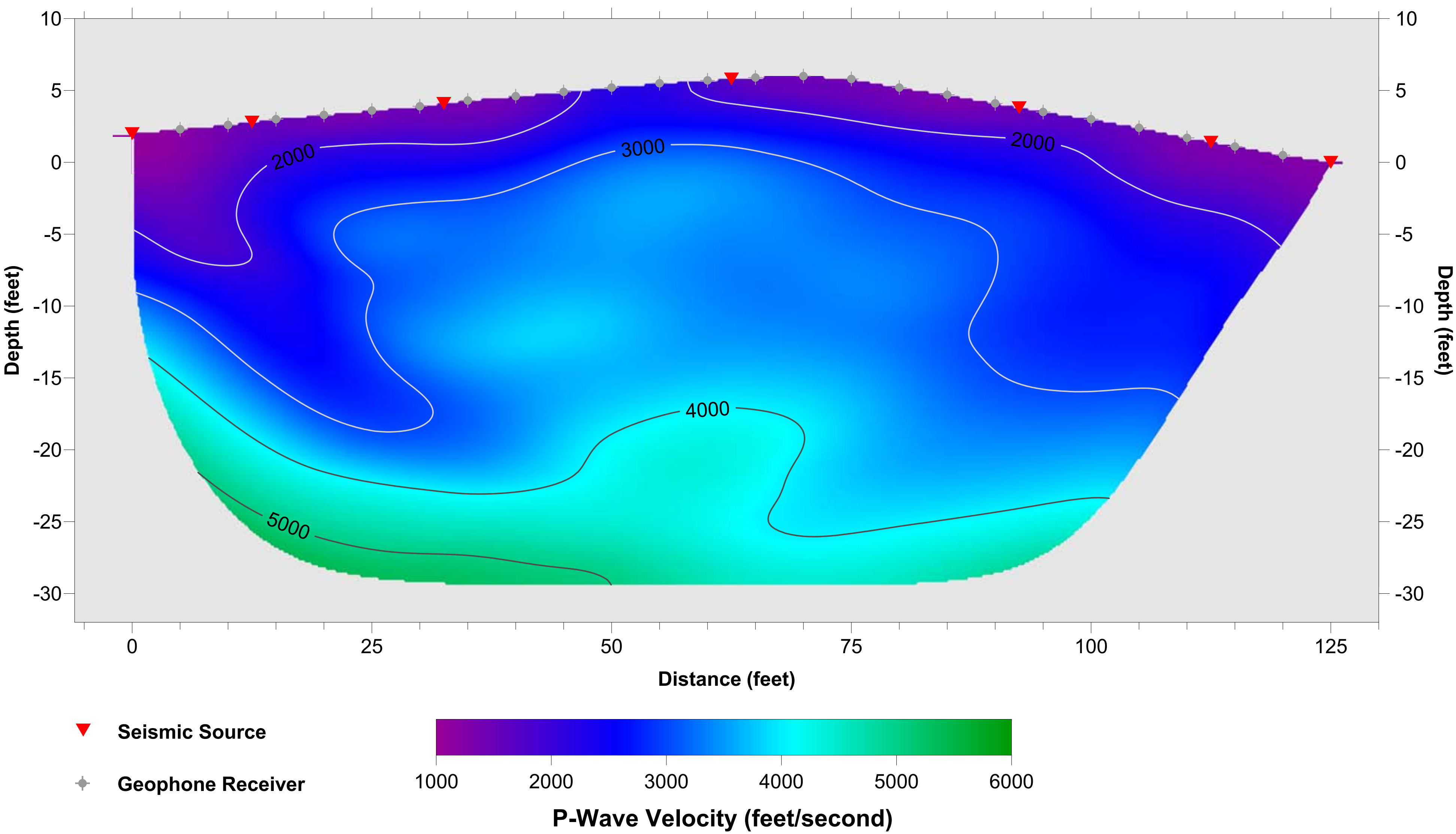
APPENDIX B

REFRACTION TOMOGRAPHIC MODELS

SEISMIC LINE S-1

< West - East >

REFRACTION TOMOGRAPHIC MODEL



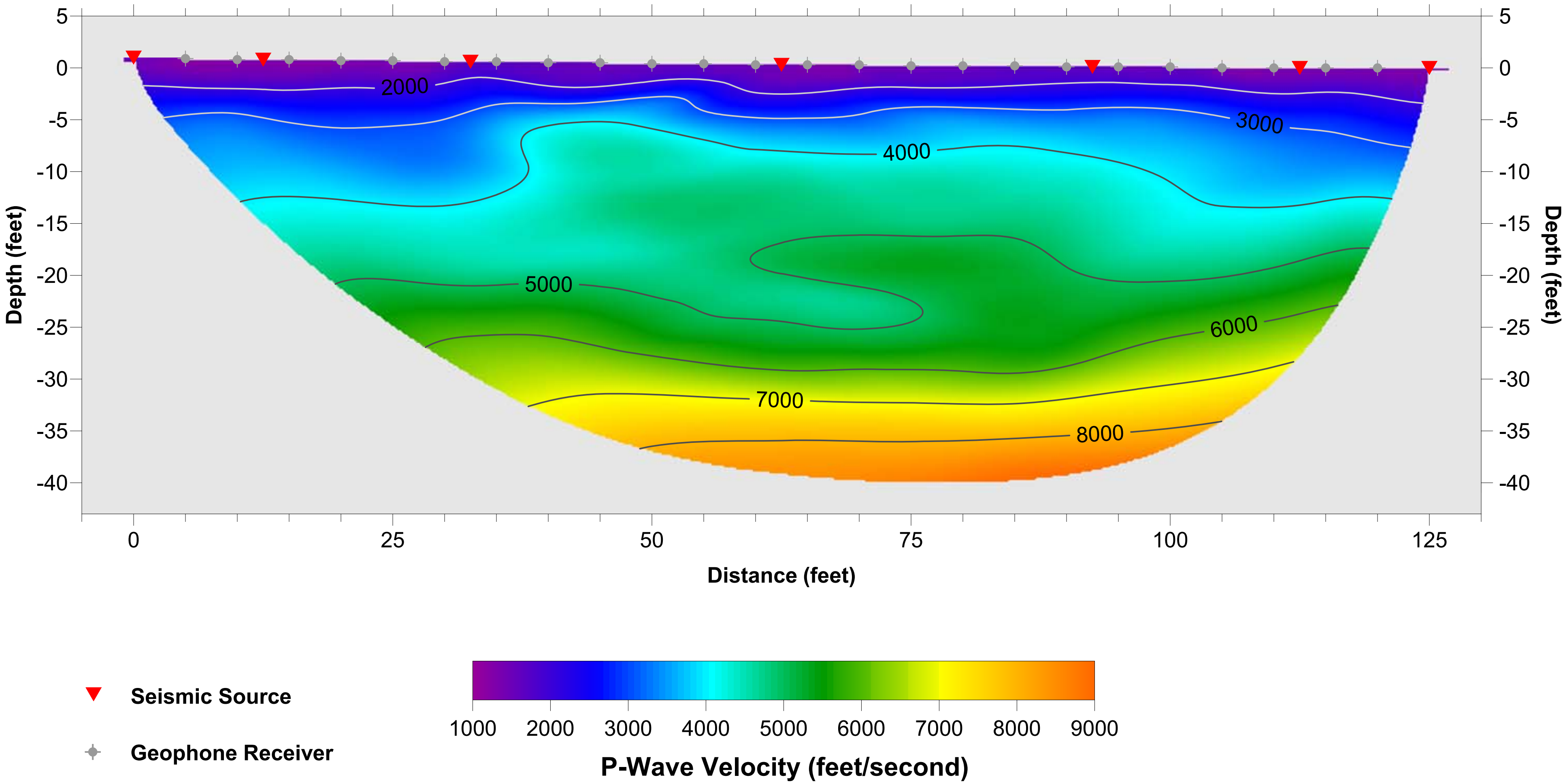
SCALE: Vertical Exaggeration 1.5X

RMS error 3.9%; Rayfract Version 4.01

SEISMIC LINE S-2

< South - North >

REFRACTION TOMOGRAPHIC MODEL



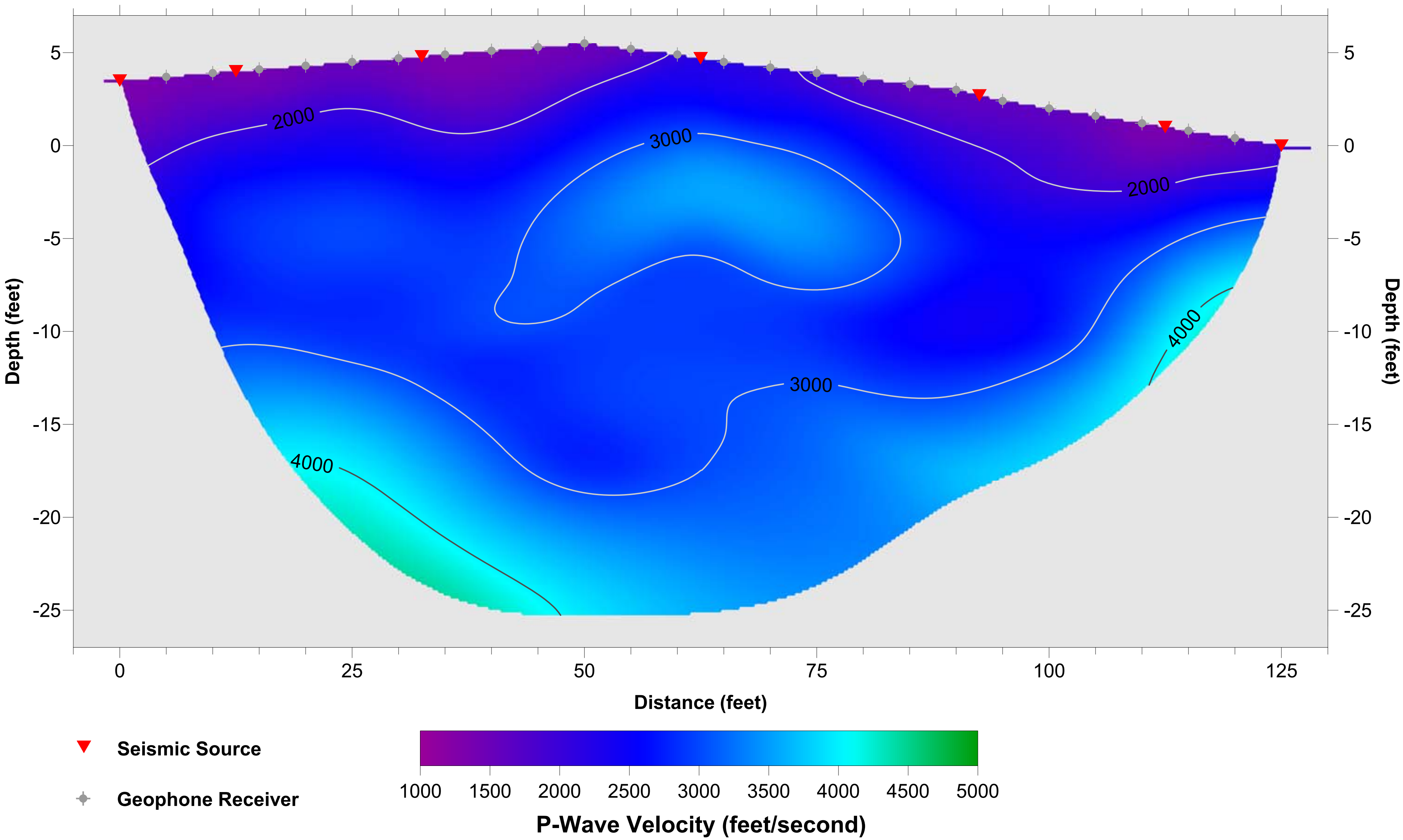
SCALE: 1:1 (Horizontal = Vertical)

RMS error 2.6%; Rayfract Version 4.01

SEISMIC LINE S-3

< West - East >

REFRACTION TOMOGRAPHIC MODEL



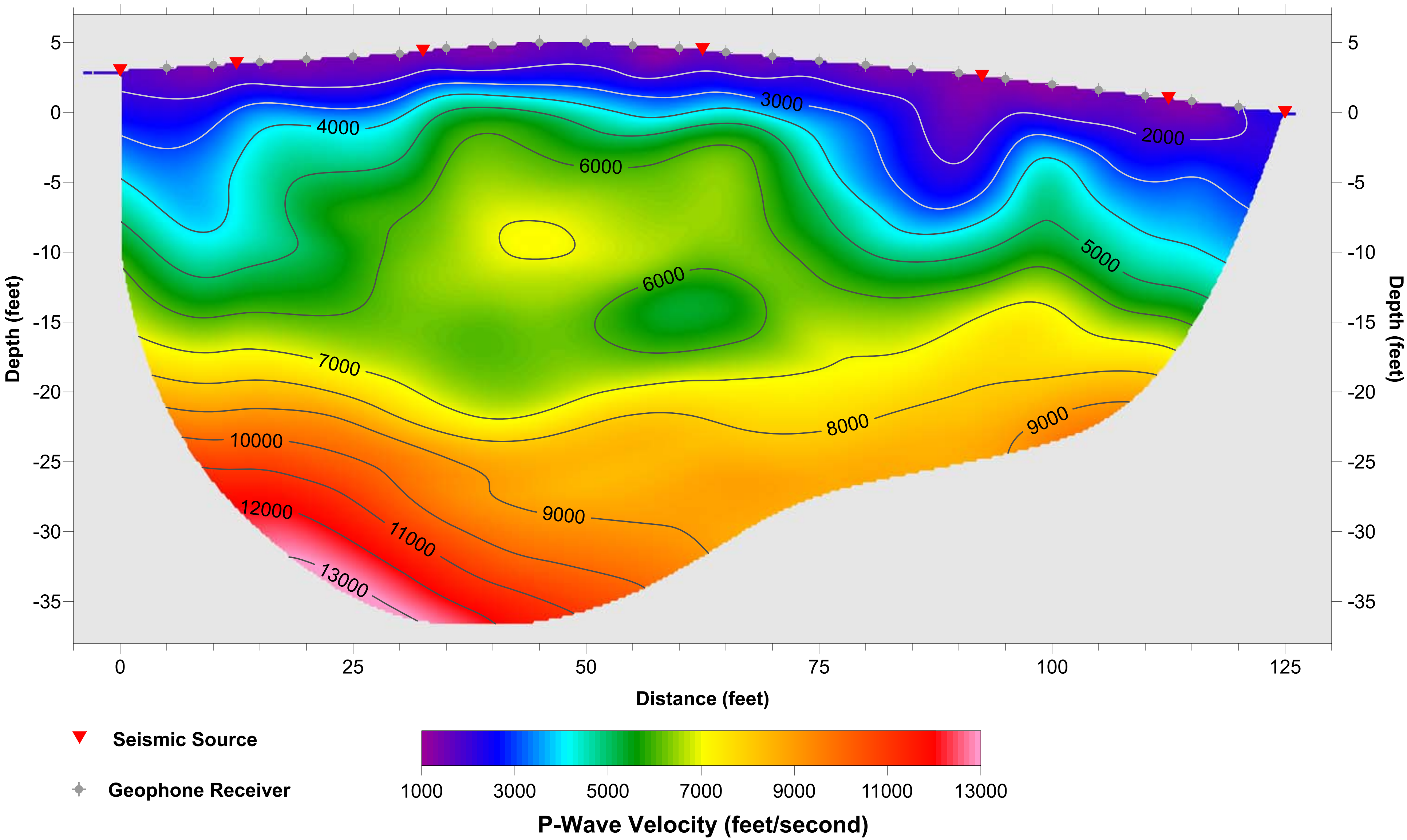
SCALE: Vertical Exaggeration 2X

RMS error 4.1%; Rayfract Version 4.01

SEISMIC LINE S-4

< West - East >

REFRACTION TOMOGRAPHIC MODEL



SCALE: Vertical Exaggeration 1.5X

RMS error 4.6%; Rayfract Version 4.01

APPENDIX C

EXCAVATION CONSIDERATIONS

EXCAVATION CONSIDERATIONS

These excavation considerations have been included to provide the client with a brief overall summary of the general complexity of hard bedrock excavation. It is considered the client's responsibility to ensure that the grading contractor they select is both properly licensed and qualified, with experience in hard-bedrock ripping processes. To evaluate whether a particular bedrock material can be ripped, this geophysical survey should be used in conjunction with the geologic or geotechnical report prepared for the project which describes the physical properties of the bedrock. The physical characteristics of bedrock materials that favor ripping generally include the presence of fractures, faults and other structural discontinuities, weathering effects, brittleness or crystalline structure, stratification of lamination, large grain size, moisture permeated clay, and low compressive strength. Unfavorable conditions can include such characteristics as massive and homogeneous formations, non-crystalline structure, absence of planes of weakness, fine-grained materials, and formations of clay origin where moisture makes the material plastic.

When assessing the potential rippability of the underlying bedrock of a given site, the above geologic characteristics along with the estimated seismic velocities can then be used to evaluate what type of equipment may be appropriate for the proposed grading. When selecting the proper ripping equipment there are three primary factors to consider, which are:

- ***Down Pressure available at the tip, which determines the ripper penetration that can be attained and maintained,***
- ***Tractor flywheel horsepower, which determines whether the tractor can advance the tip, and,***
- ***Tractor gross-weight, which determines whether the tractor will have sufficient traction to use the horsepower.***

In addition to selecting the appropriate tractor, selection of the proper ripper design is also important. There are basically three designs, being radial, parallelogram, and adjustable parallelogram, of which the contractor should be aware of when selecting the appropriate design to be used for the project. The penetration depth will depend upon the down-pressure and penetration angle, as well as the length of the shank tips (short, intermediate, and long).

Also, important in the excavation process is the ripping technique used as well as the skill of the individual tractor operator. These techniques include the use of one or more ripping teeth, up- and down-hill ripping, and the direction of ripping with respect to the geologic structure of the bedrock locally. The use of two tractors (one to push the first tractor-ripper) can extend the range of materials that can be ripped. The second tractor can also be used to supply additional down-pressure on the ripper. Consideration of light blasting can also facilitate the ripper penetration and reduce the cost of moving highly consolidated rock formations.

All of the combined factors above should be considered by both the client and the grading contractor, to ensure that the proper selection of equipment and ripping techniques are used for the proposed grading.

APPENDIX D

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REFERENCES

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