POHAKULOA TRAINING AREA (PTA) QUARRY INVESTIGATION 2007

MATERIAL SOURCE REPORT

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POHAKULOA TRAINING AREA (PTA) SECOND QUARRY INVESTIGATION

SADDLE ROAD (SR 200), HAWAII

Executive Summary

An on-site material source would greatly benefit the Saddle Road project by eliminating long, costly hauls from coastal pits, preventing haul-related damage to the existing Saddle Road, minimizing traffic congestion and related safety issues and preventing the importing of noxious seeds and organisms. The PTA quarry located near MP 38 was investigated as a material source that can be used during Saddle Road construction.

This report presents the findings of a recent investigation of the suitability of PTA quarry materials for use as subbase, base, and hot asphalt concrete pavement (HACP) aggregates. The investigation covered approximately 25 acres of planned expansion of the existing quarry, and included core drilling and geophysical surveys to characterize subsurface units within the quarried lava flow.

In general, three basalt rock types were encountered during drilling within the PTA quarry: scoriaceous basalt, vesicular basalt, and hard "blue rock" basalt. The depth to the harder "blue rock" basalt unit varied significantly across the study area, ranging from 3.5 ft from the pioneered surface of the drill road to depths approaching 24.5 ft. Drill road elevations also varied significantly across the investigation area, generally following the compacted topography of the lava flow. The physical nature of the harder basalt units varied with depth, often being more vesicular closer to the interface with the overlying a'a portion of the flow. Scoria zones were prevalent across the quarry, ranging in thickness from 0-15 ft. Scoria elevation varies throughout the investigated area.

Although no materials were tested in the laboratory during this investigation, laboratory test results on previously obtained materials from similar units within the PTA quarry indicated that the materials in the subsurface are of a good quality for aggregates to be used as subbase and HACP. Other Saddle Road construction phases have used the PTA as a material source.

In general, the quality of material in the provided sources is acceptable, but may contain layers or pockets of unacceptable scoria. Variations and unusable overburden may be expected due to the nature of the lava flow. The contractor shall be responsible to determine the quantity and type of equipment and work necessary to select, combine and develop the source to produce acceptable material meeting the requirements of the contract, including waste materials that may not meet the requirements of the contract.

Due to the nature of the materials encountered in the subsurface and the limitations of the method, the compression (P)-wave velocity measured by the seismic refraction method may not be relied on to determine rippability. The shear (S)-wave velocities measured by the geophysical method (ReMi) are more indicative of the velocities in basalts.

1.0 Introduction

The Federal Highway Administration (FHWA), Central Federal Lands Highway Division (CFLHD), in cooperation with the Hawaii Department of Transportation (HDOT) and the Department of the Army (DOA) Military Surface Deployment and Distribution Command (SDDC), is developing the Saddle Road improvement project, State Route 200, in the County of Hawaii. The project extends from milepost MP 6, near Hilo, HI, westward to the Mamalahoa Highway, State Route 190.

Saddle Road Phase 1 construction began in early 2004, and includes a new 6-mile-long realignment segment passing through the Pohakuloa Training Area (PTA). Construction of Phases 2 and 3 started in early 2006. Phase 2 will consist of 7 miles of new alignment west of the PTA, and Phase 3 will include construction of aggregate subbase/base courses and paving of Phases 1 and 2. Other construction phases that have used the PTA as a source are also underway.

The PTA quarry is located approximately 1.5 miles south of Saddle Road, near MP 38, and (see map and photographs in Figures A-1 through A-4 Appendix A), and is readily accessible via improved gravel/dirt roads, off Saddle Road, within the PTA.

An on-site material source would greatly benefit the Saddle Road project in many ways, including:

- Eliminating costly, long, and uphill material hauls from remote coastal aggregate sources;
- Preventing inevitable haul truck damage to the existing Saddle Roads and bridges – largely eliminating additional roadway repair expenditures and extensive on-going maintenance operations;
- Minimizing construction-related traffic congestion along Saddle Road;
- Preventing traffic safety issues associated with slow-moving haul trucks on a narrow, winding highway (including roadway hazards associated with haul truck damage to the already deteriorating paved surfaces); and
- Eliminating the need to sterilize aggregate materials from remote sources to prevent the unwanted spread of alien plant and invertebrate species, in accordance with the Biological Opinion, issued by Fish and Wildlife, and the Record of Decision (ROD).

In support of the current and planned Saddle Road projects, this report presents the findings of a recent investigation of the suitability of PTA quarry materials for use as subbase, base, and hot asphalt concrete paving aggregates. The investigation covered the 25 acres planned expansion of the existing quarry, and included core drilling and geophysical surveys to characterize subsurface units within the quarried lava flow. More specifically, the investigation focused on **1)** locating and delineating suitable hard, durable, and dense rock units within the planned quarry expansion, and **2)** characterizing accessibility and approximate quantity and quality.

2.0 Regional and Local Geology

General Site Conditions

Saddle Road runs approximately 45 miles west from Hilo, HI, to its terminus with SR 190, approximately 8-miles south of Waimea (Figure A-1). The roadway is appropriately named as it passes through the various lava flows within the Humuula Saddle plateau region between the massive Mauna Kea and Mauna Loa volcanoes, rising impressively north and south of the roadway, respectively. In the vicinity of the PTA quarry (elevation 5,680 ft), the topography is generally comprised of sparsely vegetated, rugged a'a and pahoehoe lava fields (jagged, broken lava blocks versus smooth, rope-like lava flows) gently sloping west-northwest at an average grade of less than 3%. This plateau region is further characterized by frequent "Pu'u" cinder cone features, typically rising 100-400 ft above the plateau, interspersed amongst numerous geologically-recent lava flows (primarily originating from Mauna Loa; Figure A-2).

Geographically, the PTA quarry region may be described as a dry tropical upland, unique to the Hawaiian Islands. Temperatures are mild year round, with an annual mean temperature of approximately 60°F. The area is subject to occasional fog and frost, with frequent light rains in the winter months. Average annual rainfall is 15 inches – though precipitation is highly variable across the plateau region. Located within a trade wind inversion zone (elevation 5,000 to 7,000 ft), even a several hundred-foot change in elevation or location can make a noticeable difference in atmospheric conditions. Local climate is further complicated by ever changing wind patterns through the Humuula Saddle. Prevailing winds over the island are generally from the northeast; however, southerly and westerly winds are not uncommon. Localized patterns are quite variable, as influenced by Mauna Kea's mass and numerous prominent terrain features. Annual wind speeds average just over 10 mph; becoming gustier in the winter months (U.S. Army, 2003).

Regional Geology

Mauna Loa and Mauna Kea Volcanoes are the dominant geological features immediate to the PTA quarry site. Mauna Kea has not erupted in historic times or for centuries before the beginning of Hawaiian history; and is considered a dormant volcano that last erupted approximately 4,500 years ago. Originally erupting on the seafloor about 800,000 years ago, Mauna Kea is a "shield volcano", primarily comprised of basaltic lavas. Post-shield volcanism, beginning approximately 300,000 years ago, produced cinder cones and lava flows that cover most of the present day surface of the volcano. Mauna Kea has evolved beyond the shield-building stage, as indicated by **1)** the very low eruption rates (as compared to Mauna Loa and Kilauea), **2)** the absence of a summit caldera and elongated fissure vents that radiate from the summit, **3)** the steeper and more irregular topography (the upper flanks of the volcano are nearly twice as steep as those of Mauna Loa), and **4)** the different chemical compositions of the lava. Although presently dormant and characterized by long periods of quiescence, seismic activity in the region suggests that it will erupt again.

Rising gradually to nearly 14,000 ft above sea level, Mauna Loa covers approximately half of the Island of Hawaii. Mauna Loa is among the Earth's most active volcanoes, having erupted 33 times since its first documented eruption in 1843. Its most recent eruption was in 1984, and it is certain to erupt again. Located south of Mauna Kea (and the PTA quarry), the volcano has grown rapidly during its relatively short history (600,000 to 1,000,000 years) to become the largest volcano on earth. Although its rate of growth appears to have slowed in the past 100,000 years, geologic research has revealed that approximately 98% of the volcano's surface is covered by lava flows less than 10,000 years old. With the most recent period of summit overflows beginning about 2,000 years ago, Mauna Loa may be on the verge of shifting to a period of long-lived lava lake activity, shield building, increased summit overflows, and diminished rift zone eruptions. The caldera is as full as possible at this time, with lava flows now spilling out to the southwest. Recent measurements indicate the southern flank of the volcano is expanding; suggesting renewed volcanism may be imminent.

In Hawaii, lava flows are known to reach distances of 30 miles or more. Geologic mapping of Mauna Loa surface flows has identified more than 500 flows originating from the summit caldera area, rift zones, and radial vents. Many of the flows from Mauna Loa have originated along two major rift zones extending from the central caldera: the Southwest Rift Zone (SWRZ), producing lava flows covering the lower quarter of the island, and the Northeast Rift Zone (NERZ), producing flows covering the interior third of the island (Figure A-3). A less well-developed "rift zone" comprised of a chain of Pu'u cinder cones and substantial lava flows, also extends northwestward from the northern flank of Mauna Loa towards the Kona coast.

Surface flows into the Humuula Saddle plateau region from Mauna Loa date from the late 1900's to nearly 10,000 years B.P. (before present). In the area surrounding the PTA quarry, surface and near surface deposits consist of various a'a and pahoehoe lava flows, generally emanating from Mauna Loa within the last 3,000 years, atop late-Holocene and Pleistocene lavas, scoria (from cinder cones), tephra (ejected ash-to-boulder size material), and glaciated till from Mauna Kea. Because of the nonuniform nature of volcanism in the area, producing and distributing a wide array of volcanic rock types over the region, near-surface stratigraphy is highly variable, unpredictable, and laterally discontinuous, commonly consisting of interbedded a'a and pahoehoe lava units, which are often separated by scoria, ash, lipilli, and larger tephra materials.

PTA Quarry Geology

The PTA quarry, located approximately one and a half miles south of Saddle Road at MP 39 (Figure A-4), currently mines aggregate and riprap materials from the edge of an a'a lava flow originating along the NERZ of Mauna Loa. This particular lava flow is estimated to have occurred between 200 and 750 years B.P., and traveled nearly 30 miles from the NERZ; first down the north side of Mauna Loa, and then northwesterly toward the Kona coast along the southwest base of Mauna Kea. Figure A-5 shows a portion of the geologic map of surface flows in the area of the PTA quarry.

The "Kau Basalt" rock types emanating from Mauna Loa, and designated on the geology map in Figure A-5 as lava flow units "k-*", are generally described by Wolfe and Morris (1996) as tholeiitic basalts containing variable amounts of phenocrysts of olivine, plagioclase, and pyroxene. Most of the flows began as vesicular pahoehoe lava from vents along the overlying rifts, changing downslope, once to the flatter plateau region, to broken a'a that commonly formed long, narrow flows. These a'a flows, as the one at the PTA quarry site, typically consist of a highly broken and rubbly clinker surface consisting of loosely indurated basalt rock fragments full of gas bubbles (Geolabs, 2002). The rubble zone generally resides within the upper 3-15 ft of the flow, typically overlying a very dense and often massive basalt flow core material referred to as "blue rock." This core unit of hard basalt may range to several tens of feet thick – as is seen at the PTA quarry – and may vary in composition from a highly vesicular to dense rock mass, depending on the gas content at the time of deposition (Hazlett and Hyndman, 1996).

Core drilling across the pit expansion area revealed several key characteristics of the a'a flow being mined:

- The surface of the flow is comprised of a'a lava, ranging in thickness from 3.5-24.5 ft (estimated original a'a section thickness prior to drill road construction across the planned quarry expansion area).
- The depth to the harder "blue rock" basalt unit varied significantly across the study area, as might be expected within the dynamics of a lava flow – ranging from at the surface of the drill road to depths approaching 24 ft (as described in Section V – Subsurface Conditions).
- The physical nature of the harder basalt core rock commonly varied with depth, often being more vesicular closer to the interface with overlying a'a portion of the flow.
- Scoria zones were prevalent across the quarry, ranging in thickness from 0-15 ft.
- No significant void features or lava tubes were encountered during core drilling.

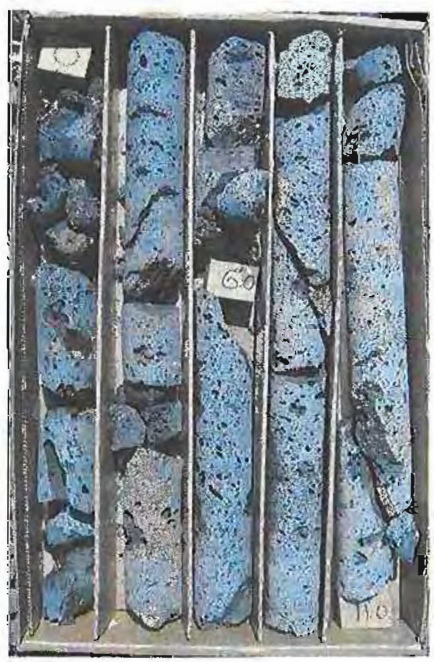
The existing PTA quarry will be expanded towards the north-northwest, encompassing a total of approximately 50 acres. This investigation in the PTA quarry included about 25-acres of the expansion area, as illustrated in Figure A-6. Figure A-7 illustrates the plan locations of subsurface investigations within the 25 acre planned quarry expansion: showing coreholes 101 through 131 and seismic refraction lines L1 through L12.

Figure 1 illustrates the range of materials most commonly encountered during core and probehole drilling across the initial study area.

A'a lava transition to "blue rock".

Dense, indurated "blue rock".

Scoria-cinder layer in "blue rock".



Vesicular, low density basalt.

Figure 1. Core from the PTA quarry site representing the variability of available basalt rock materials.

3.0 Field Investigation

The PTA quarry was selected for investigation as a material source because of its accessibility and close proximity to the Saddle Road project. The quarry has been utilized for several years by the Department of the Army as a source of hard, durable basalt, commonly referred to in Hawaii as "blue rock" and by previous Saddle Road Projects. Although the total available area at the quarry is approximately 50 acres, the geotechnical investigation described in this report was limited to the 25-acre planned expansion area adjoining the current quarry (Figure A-6). The investigation employed both conventional and geophysical methods to estimate the lateral and vertical extent of the preferred "blue rock" basalt. The following summarizes the investigative tasks performed within the initial quarry expansion area between July 16th and July 27th, 2007:

Geotechnical Exploration

Twenty five core holes (designated as 101 through 121 and 123,125,127,129) were drilled within the proposed quarry expansion area by Geolabs, Inc. Honolulu, Hawaii. The core holes were advanced with a Mobile B-53 truck-mounted drill rig, using an HX wireline core system, to depths ranging from 30 to 41.5 ft below the elevation of the pioneered roadways. Boring locations and depths determined by the on site CFLHD geotechnical engineer were generally distributed evenly within the area of exploration to characterize the subsurface conditions in the quarry. Borehole locations and elevations were surveyed and recorded for each exploratory boring. **It should be noted that all elevations were measured from the surface of the pioneered roads and not from the highly irregular original ground surface.**_A plan sheet with the surveyed locations of each boring is provided in Figure A-7 in Appendix A.

Core samples were obtained for each boring in general accordance with ASTM D2113. The recovery length of each run of core was measured and recorded as a percentage of the total length of the run. The Rock Quality Designation (RQD) – a quantitative rock mass quality index based on a core recovery criterion - was also calculated for each run. Both percent recovery and RQD are generally used to interpret the relative rock mass quality and rippability of the rock mass. The RQD however should not be used to determine material quality for base and HACP materials. Due to the rubblized, yet often welded nature of the interbedded scoria units, the RDQ may not be a true indicator of rock quality. The following table is generally used to describe the relative quality of the rock mass encountered in the subsurface:

Table 1. Description of relative rock mass quality.

ROCK QUALITY	RQD
Very Poor	0-25
Poor	25-50
Fair	50-75
Good	75-90
Excellent	90-100

All cores were logged, photographed, and preserved in appropriately labeled core boxes and are currently stored at the FHWA office in Hilo, Hawaii.

Upon completion of each boring, the test hole was backfilled with cuttings and on site material. Detailed logs for each boring were prepared using the gINT computer program, and are provided in Appendix B, Figures B-1 through B-24. Photographs of all recovered core samples (Figures C-1 through C-85) and coring sites (Figures C-86 through C-110) are provided in Appendix C.

Geophysical Exploration

Two techniques of non-invasive geophysical surveys, seismic refraction (SR) and the refraction microtremor (ReMi), were also used to estimate the depth of the basalt "blue rock" unit(s), and to determine the shear (S) and compression (P) wave velocities of the subsurface materials. The intension of the geophysical surveys was (1) to supplement the boring data, providing additional subsurface information between borings and (2) to characterize rippability potential. The refraction method specifically provides information on the depth to the hard basalt layer, and the P-wave velocities for subsurface units that may be utilized to assessing rippability. The ReMi technique provides a simplified characterization of relatively large volumes of the subsurface in a one-dimensional vertical depth profile of S-waves at the mid-point of the survey line.

Standard seismic refraction equipment was used for field data collection for both investigative methods. Twelve seismic lines (L1 through L12) were surveyed coincident with boring locations using both the two-dimensional SR and the one-dimensional ReMi techniques. Each line (with the exception of Line s 3 and 4) was laid out such that a boring was located at the middle of the line. The survey line layouts with respect to boring locations are depicted in Figure A-7.

The receivers used in all the geophysical surveys consisted of twenty-four low frequency (4.5 Hz) vertical geophones placed at 5 ft intervals. Due to the rubblized nature of the overlying a'a lava, the seismic survey locations were all conducted on pioneered roads within the investigation area.

- **Seismic Refraction (SR):** This method is generally used to determine the seismic P-wave velocity structure of subsurface units, and is highly dependent on the physical material properties, density, hardness, and indurations. However other factors such as bedding, fracturing, and saturation also affect the seismic velocity. Typically, low velocities are indicative of loose material, semi-consolidated sediments, and deeply weathered rock. Conversely, high velocities are indicative of intact rock, or dense or highly compacted sediments. The highest relative P-wave velocities are measured in rock that is competent and exhibit minor fracturing or weathering. A more thorough description of the seismic refraction method, equipment used, and its limitations are provided as an attachment in Appendix D.

For each seismic refraction line, a minimum of nine shot points (using a 20 lb sledgehammer) were used, located at 5, 15, and 40 ft away from each end of the geophone line, at the mid-point, and quarter points of the line. Twenty-four geophones were used in each spread and a Geometrics StrataView seismograph was used to record the data. The geophone spacing and shot locations were specifically designed to determine the depth to the harder basalt formation, rather than characterizing the immediate overburden material. Schematics of the seismic refraction arrays, relative to boring locations, are provided in Figures D-1 through Figure D-64, Appendix D. In addition, photos of the survey setup along each seismic line are provided in Figures D-7 through Figure D-18.

- **Refraction Microtremor (ReMi):** This method uses the standard seismic refraction equipment to measure background noise, or "microtremors". Ten, unfiltered, 30-second-long records of passive ambient background noise were recorded along each seismic refraction line for shear-wave velocity evaluation using the ReMi technique. Both ReMi and seismic refraction data were collected using the same geophone array spacing and setup as shown in Figures D-1 through Figure D-6, Appendix D. The noise records were processed using the ReMi software to develop one-dimensional shear-wave profiles to depths of up to 100 ft below the surface.

4.0 Laboratory Testing

Materials obtained from each of the aforementioned basalt types that were previously obtained from the quarry were visually evaluated and selected for testing. **No additional tests were conducted on samples obtained from this investigation.** Testing method selection was based on specifications in Section 703 of the FHWA "Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects" (FP-96). During the testing, that was done under previous investigations, all the materials obtained from that boring, irrespective of their type or strength, were combined to determine suitability for use as road base, and HACP aggregates. The materials were tested for hardness (LA Abrasion per AASHTO T96), weather resistance (Sodium Sulfate Soundness per AASHTO T104), and specific gravity and water absorption (per AASHTO T85). Sample obtained from a previously crushed aggregate stockpile at the PTA quarry was also tested for aggregate quality, superpave mix design parameters, and moisture susceptibility to determine material quality and suitability for Superpave System HACP. No HACP mix design information was developed using material from field core samples.

5.0 Subsurface Conditions

Geotechnical Data Analysis

Three general basalt rock types were commonly encountered during drilling at the PTA quarry:

- ***Scoriaceous Basalt*:** Defined as a highly vesicular, cindery crust material, this distinctive red-brown unit largely defines the surficial boundaries of a given flow, existing at the exposed a'a surface of the flow and as "markers" within the flow, indicating past flow boundaries.
- ***Vesicular Basalt*:** This gray-colored basalt unit is commonly seen along the margins of the lava flow's inner core, where gases are being liberated to the surrounding a'a cinder, creating a "bubbly" appearance within an otherwise dense and very hard rock mass.
- ***"Blue Rock" Basalt*:** This distinctive blue-gray unit forms the core of the lava flow, and is characterized as a very hard, durable, and dense rock type exhibiting small vesicules.

In general, the materials encountered at each boring appeared to become harder and more competent with depth. Core recovery was typically high (>80%), with the exception of the uppermost 5 ft (a'a section), and RQD's varied from "fair" within the scoriaceous and highly vesicular units to "excellent" within the "blue rock" units.

All borings generally encountered overburden materials consisting of medium dense basaltic boulders, cobbles, and gravel extending to depths of about 3.5 ft (boring 109) to 24.5 ft (boring 121) below the pioneered road elevation, which was compacted approximately 5-ft below the undulating a'a ground elevation. The depth to the hard/very hard un-weathered basalt units varied between 3.5 and 24.5 ft, with an average depth of about 10 ft. Core recovery in the gray vesicular basalt and "blue rock" units averaged over 90%, including occasional lenses of rubblized red-brown to gray scoria. Table 2 summarizes the approximate depths and thicknesses of the "blue rock" and vesicular basalt units for each of the coreholes at the PTA quarry.

Table 2. Summary of depths and thicknesses of the competent basalt units encountered during core drilling at the PTA quarry.

Boring Number	Approx. Depth from Pioneered Road Elevation, ft	Approx. Basalt Unit Thickness, ft	Total Boring Depth, ft	Scoria, ft
101	7.0	34	41.0	None: Excellent core recovery and RQD in basalt unit
102	6.5	32	41.5	38.5 to41.5
103	8.5	30.0	41.5	38.5-41.5.
104	8.5	30.5	41.5	38.5-41.5.

105	8.5	30.5	41.5	38.5-41.5
106	15.0	10.5	36.0	28.5 to 36.0
107	8.5	20	36.0	28.5 to 36
108	9	30	41.5	39.0 to 41.5
109	3.5	36.5	40.0	None: Excellent core recovery and RQD in basalt unit
110	15.5	24.5	41.5	40.0-41.5
111	16.5	15.0	37.0	31.5 to 37.0
112	4.0	32	36.0	None: Excellent core recovery and RQD in basalt unit.
113	14.5	17.5	32.0	None: Excellent core recovery and RQD in basalt unit
114	16.5	19	35.5	None: Excellent core recovery and RQD in basalt unit
115	11	21	32.0	None: Excellent core recovery and RQD in basalt unit
116	21.5	14	35.5	None: Excellent core recovery and RQD in basalt unit
117	5.5	9.0 upper and 9.0 lower	35.0	14.5 to 24.0
118	5	35.0	40.0	None: Excellent core recovery and RQD in basalt unit
119	8	26	30	None: Excellent core recovery and RQD in basalt unit
120	11	23	30.0	None: Excellent core recovery and RQD in basalt unit
121	24.5	6.5	31.0	None: Excellent core recovery and RQD in basalt unit
123	11	28.5	41.5	39.5 to 41.5
125	18	18	36.0	None: Excellent core recovery and RQD in basalt unit
127	7	29	36.0	None: Excellent core recovery and RQD in basalt unit
129	4	7.5 upper and 11.5 lower	39.5	11.5 to 28.0

Individual boring logs, including core recovery, quality, and run-time measurements, are included in Figures B-2 through B-26 in Appendix B. A plan view of the quarry 25.0-acre expansion area indicating boring locations is shown in Figure A-7.

Geophysical Data

Seismic Refraction (SR): The final survey results from each seismic refraction line (Lines 1 through 12) are shown in Figures D-19 through D-30, Appendix D, as combined profiles; with the travel-time data in the upper window, the depth section in the middle window, and the velocity profile in the lower window. Elevations were interpolated from the adjacent borehole surveys, and the results for all lines were plotted from North-West to South-East and from South-East to North-West (see figure A-7 in Appendix A for details).

Seismic refraction data analysis was conducted by Zonge Geosciences Inc. Seismic refraction processing involved picking the time of the signal arrival (first breaks) of the P-wave energy at each geophone using FIRSTPIX a commercially available refraction first-arrival picking program produced by Interpix Limitted. Generally, due to the nature of the materials tested at the site and the windy conditions during data collection, the SR records indicated low signal-to-noise ratio. Occasionally the ambient noise was of the same frequency as the first-arrival. This overlap prevents filtering any ambient noise that masks the first arrivals. Thus, no filtering was utilized and any record traces without a clear first arrival were left unpicked. This reduces the number of data points used during the modeling process, increasing the uncertainty in the resulting model.

The first breaks for the seismic traces on a given spread were subsequently processed using the GREMIX™ refraction-processing program to resolve subsurface profiles into distinct layers with average velocities. The Generalized Reciprocal Method (GRM) was used for delineating the bedrock/overburden interface. This technique was chosen because of its ability to delineate undulating refractors and directly calculate refractor depths, provided the dip angles of the lithologic interfaces are less than about 20°from the horizontal. If interface dip angles exceed 20°, the assumptions used in the GRM calculations become less accurate and modeling errors increase. However, if the bedrock has substantial relief and short period undulations, as expected at the PTA quarry site, GRM is the best refraction method for mapping these subsurface features. The arrival time for each channel and for each shot in a spread is plotted as a function of distance from the shot location. The time-distance plots for this survey are shown in the upper window of each seismic refraction line provided in Figures D-19 through D-30. Each arrival time is then assigned to a refracting layer, and the velocities are analyzed for each layer. After a velocity field has been established for the spread, the reciprocal times are adjusted to correct for offset, and a new velocity field is generated. These steps are iterated until the optimum reciprocal times are obtained. Once the optimum reciprocal times are calculated, the values are converted to a profile section that shows depths to each refractor (layer interface) and the lateral velocity variation for each interval (velocity field). This profile is used to construct the cross-section for each refraction line. This cross-section is shown as the middle window on each figure (Figure D-19 through D-30).

Typically, seismic velocities provide an indication of the properties of the material through which the seismic waves are traveling. In this case, highly vesicular basalt is a poor medium for seismic methods due to extensive fracturing and considerable void space within the rockmass, causing significant signal scattering and attenuation. The SR data indicated an overburden P-wave velocity between 700 ft/s and 1,300 ft/s and a refractor velocity between 1,500 ft/s and 3,200 ft/s which is relatively low (the refractor velocity is assigned to the highly vesicular gray basalt unit). Because of layering within the lava flows, and existence of interbedded scoria layers within the harder basalt units, the SR results may be biased, and lower than expected P-wave velocities may be indicated. It is, therefore, important to note that the actual in situ P-wave velocities could be much higher, as shown in the tomography results. Since the percent lateral variation in overburden velocity was somewhat large, this could also lead to greater depth estimate errors. Interbedded lava flows generally do not increase in layer velocity with depth, which is a fundamental analysis assumption of the refraction method. This can also lead to false anomalous velocities and depth estimates. It is, therefore, not recommended that P-wave velocity values obtained with this method be used solely for estimating material rippability. The hard basalt layers in the quarry are generally known to be non-rippable based on recent experience with developing the quarry.

Refraction Microtremor (ReMi): The noise records collected were processed using the SeisOpt® ReMi™ software. The ReMi technique is based on two fundamental ideas: first, that common seismic-refraction recording equipment, set out in a way almost identical to shallow P-wave refraction surveys, can effectively record surface waves at frequencies as low as 2 Hz and, second, that a simple, two-dimensional slowness-frequency (p-f) transform of a microtremor record can separate Rayleigh waves from other seismic arrivals, allowing recognition of true-phase velocity against apparent velocities. The method is inherently capable of detecting low velocity layers at depth, as appear to be present at the PTA quarry – a capability not available with standard seismic refraction surveys.

The calculated one-dimensional shear wave velocity profiles to a depth of 100 ft below the surface are presented in Figures D-38 through D-48 in Appendix D. The data are derived by averaging the ambient noise across the 115-ft array, and represent the bulk properties of the subsurface materials encountered. Although the data is presented to a depth of 100 ft, the values below 50 ft are considered "far-field", and should be valued as marginal. Supportive data are presented for each survey on Figures D-32, D-34, D-36; D-38, and D-40. These figures show the frequency dispersion plots (p-f curves) and the modeling curves used to generate the shear-wave velocities and layer thicknesses beneath each ReMi array. The S-wave velocities results from ReMi surveys have been shown to be within 10-15% of S-wave velocities obtained via crosshole or downhole testing, and can typically determine the depth to competent layers or bedrock also to within 10 to15%. However, poor data quality may increase this uncertainty. ReMi lines 1, 8, 9, 10, and 12 have the best quality data and are the only ones presented. Data from all other lines were considered poor quality and were not included in this report. The one-dimensional shear-wave profiles represent a "vertical sounding" centered at the middle of each ReMi array. The profiles from the ReMi lines are good representations of the shear wave velocities of the materials in the subsurface. In general, the data was within 10% of the actual measurements indicated on the boring logs. For comparison, P-wave velocities are generally 2 to 3 times the S-wave velocities.

The ReMi findings compare very well with the boring results, indicating about 10 ft of low velocity (<1,000 ft/s) overburden materials overlying higher (>1,000 ft/s) velocity hard basalt layers. In some cases, as was shown in the drilling logs, lower velocity layers are shown in the ReMi results beneath or within the high velocity layers.

As previously noted, seismic refraction (SR) and refraction microtremor (ReMi) results as provided in Appendix D should be interpreted by persons with expertise in the geophysical data interpertaion only. The shear-wave velocities measured by the geophysical method (ReMi) are more indicative of the velocities in basalts. Due to the nature of the materials encountered in the subsurface, the P-wave velocity measured by the seismic refraction method may not be relied on to determine rippability. The drilling information is more reliable and should be considered as the primary subsurface information for decision making.

6.0 Laboratory Test Results:

The laboratory test results obtained for materials acquired during the initial quarry investigation and from the previously available stockpile sample are summarized in Appendix E. The results indicated that the six core samples tested were comparable to one another, and were also similar to the results obtained from the existing stockpile samples. No significant variability in the data was identified between boreholes, regardless of the materials obtained. The LA abrasion tests results varied between 24 and 28% loss with an average of 26% loss, as compared to 27% loss for the stockpile sample. Sodium sulfate results for all samples tested indicated no measurable loss occurred. The percent water absorption varied from 1.5 to 2.4%, with an average of 1.9%. Since this is an expansion area near the previously investigated area, and the materials encountered are from the same flows, then this information can be relied upon to represent the new investigation area of the quarry.

Table 3.- Laboratory test results for the core and bulk samples obtained for the quarry.

Boring No.	B-2	B-5	B-7	B-10	B-12	B-13	Existing Department of the Army Stockpile
LA Abrasion % loss	24	27	28	27	26	26	27
Absorption %	2.0	2.4	1.9	2.3	1.5	1.6	2.7

The preliminary superpave asphalt concrete mix design laboratory results (Appendix E) indicated that the materials would meet all parameters for a Superpave System design HACP. . However, the preliminary test results indicate that the aggregate is moisture sensitive, and may require an additive to minimize asphalt stripping.

The approved mix design for previous projects nearby that utilized the materials from this source (Saddle Road Projects 6(3) and 200(1)) for HATB and superpave are also included in Appendix E

7.0 Summary and Conclusions

Thicknesses of the various rock types encountered at the PTA quarry, including the upper rubblized a'a lava, hard gray and "blue rock" basalts, and intervening scoria layers, were primarily quantified through a comprehensive drilling program. Hard, gray vesicular basalt and very hard, "blue rock" basalt units were encountered in at various depths all borings. Generally, basalt quality (hardness, durability, and density) improved with depth. It should be anticipated that the depths and qualities of the harder basalt units may vary across the planned quarry expansion area, and that variable overburden depths and lenses of scoria and cinder may also be encountered. Due to undulation of the a'a flow in the overburden, it is difficult to estimate the exact thickness of the materials that would require stripping and removal to produce materials meeting contract requirements. Previous crushing and blending of materials at this source has produced material meeting acceptable quality requirements. As mentioned previously in this report "the quality of material in the provided sources is acceptable in general, but may contain layers or pockets of unacceptable material. Variations and unusable overburden may be expected due to the nature of the lava flow. The contractor shall be responsible to determine the quantity and type of equipment and work necessary to select, blend and produce acceptable material meeting the requirements of the contract, including having to waste materials that may not meet the requirements of the contract. Blending of materials, i.e. blue rock, scoriaceous basalt and vesicular basalt would be acceptable provided the combined materials meet all the contract requirements.

In most borings, drilling was terminated while still in the harder basalt unit (generally between depths of 30 to 41.5 ft). Because the drilling investigation was limited to depths above 40 ft, there is not sufficient information on the extent of the basalt units below this depth. In a few borings, red brown scoria was encountered within the hard basalt unit. The overburden thickness within the surveyed area varied between 3.5 ft (corehole 123) and 24.5 ft (corehole 129), with an average thickness of 8 ft from the elevation of the pioneered roads. The actual ground surface (top of the a'a flow elevation) varies significantly due to the chaotic nature of the flow, and could be up to 5 ft above the pioneered road elevations. The hard vesicular basalt and the "blue rock" basalt (best quality for aggregate use) also varied in thickness from one boring to another. The thickness and depths of the scoria encountered within the hard basalt units were highly variable.

Since the coring data is the most reliable information available, it was processed in three-dimensions to develop color coded interpolations between the borings to estimate the overall volume and thickness of the overburden, basalt, and scoria across the planned PTA expansion area. The approximate overall thickness contours of each subsurface material are presented in Figures 2 through 4. It is important to point out that the data between the boring locations is interpolated and not actual. For this reason, the data in these figures should be used for estimation purposes only. It is therefore the contractor's responsibility to obtain additional data if deemed necessary.

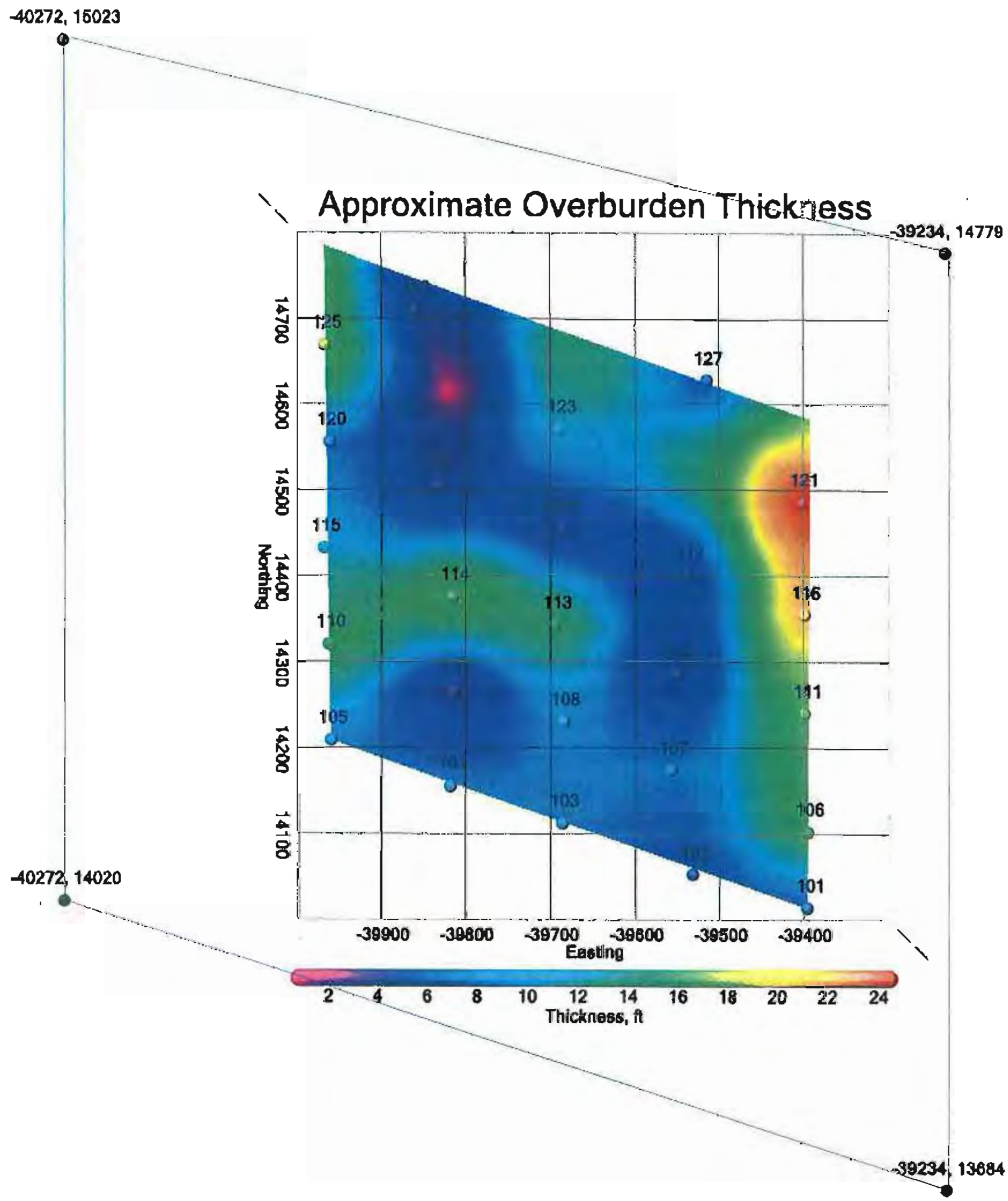


Figure 2.-Contours of approximate overburden thickness

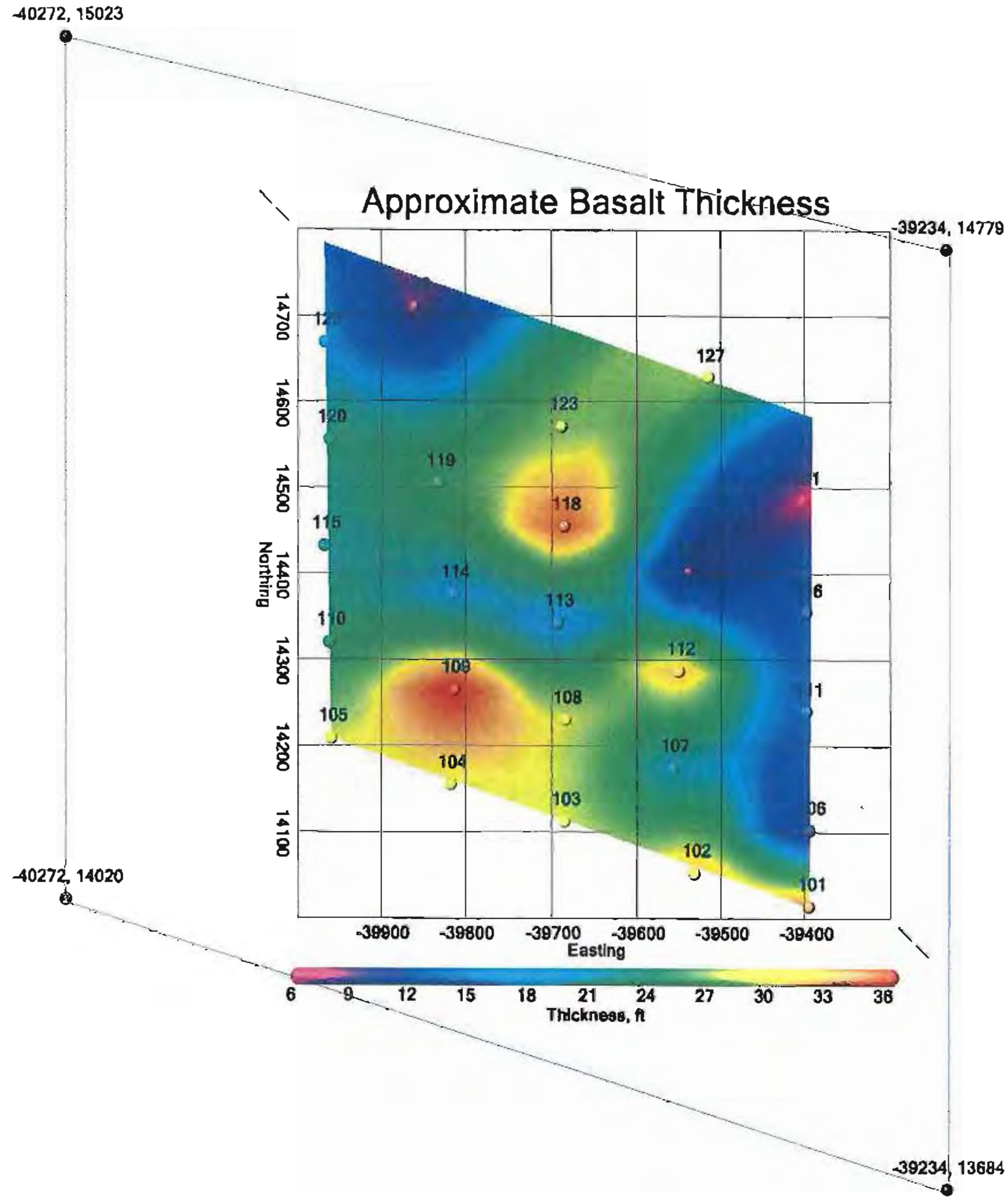


Figure 3.-Contours of approximate Basalt thickness

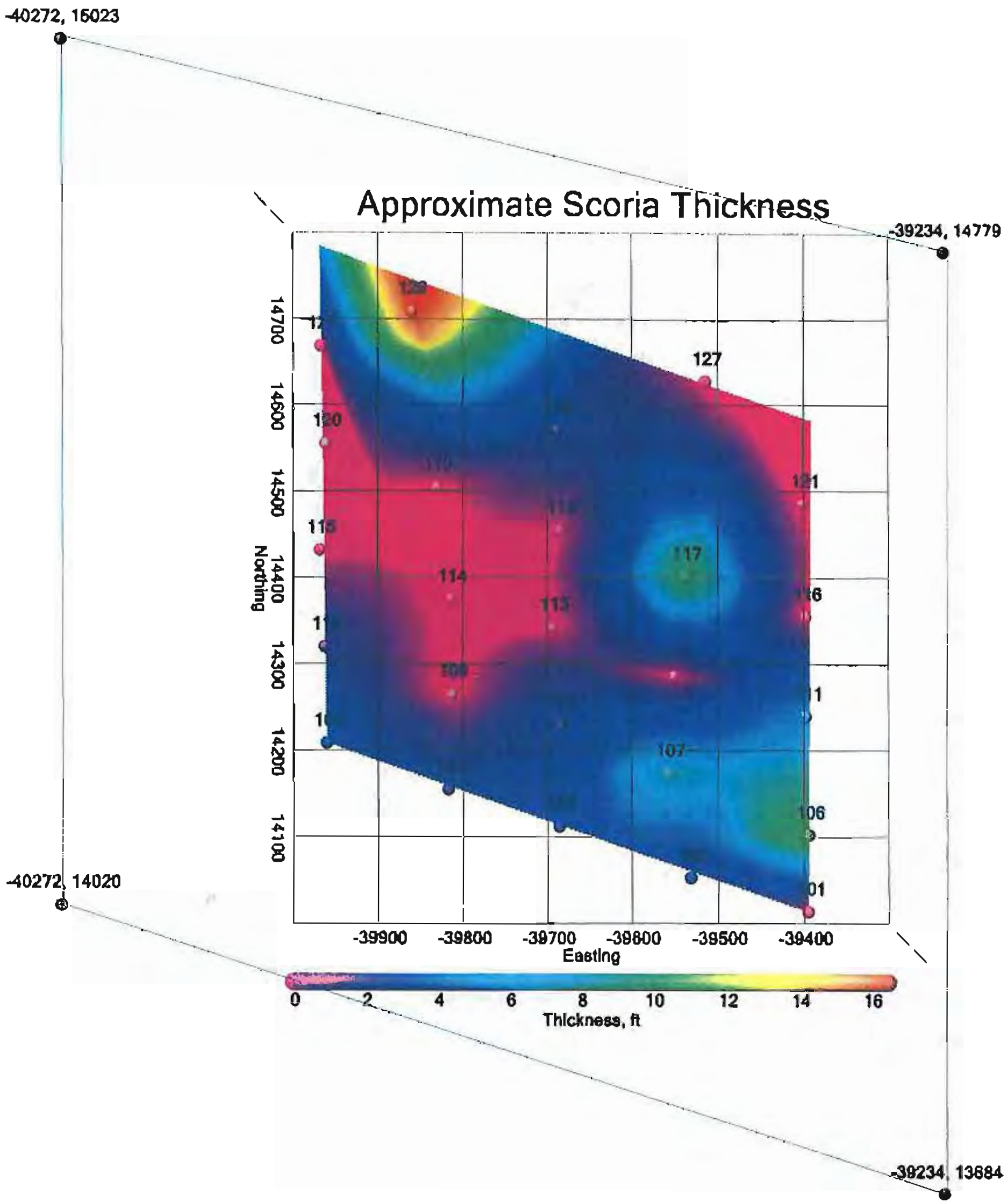


Figure 4.-Contours of approximate Scoria thickness.

Figures 2 through 4 illustrate the thickness of the overburden, hard vesicular basalt and the "blue rock" basalt, considered as one unit, and the scoria layers to depths of 40 ft from the elevation of the top of borings. The results also indicate that the basalt layer increases in depth towards the eastern boundary of the investigated quarry. No significant void features or lava tubes were encountered during core drilling.

Generally, individual basalt blocks are very hard and dense, possessing high P-wave velocities; however, basalt flows tend to be vesicular and fractured, especially near the surface of the flow (where the refracted wave travels). Therefore, the refractor surface contains significant air-filled fracture space between the basalt cobbles. This leads to a calculated P-wave velocity that is significantly slower than expected. Additionally, frequency and wavelength of the refracted energy has an effect on the acoustic wave's sensitivity to void space and cobble size. Basically, with basalts there are several factors that need to be noted in terms of seismic results. Interbedded lava flows generally do not increase in layer velocity with depth, which is a fundamental analysis assumption of the refraction method. This can lead to false anomalous velocities and depth estimates.

In conclusion, with certain material types that include basalt, low P-wave velocity does not necessarily translate directly into rippability. The shear-wave velocities measured by the ReMi method are more indicative of the velocities of basalts.

8.0 References

Wolfe, E.W. and J. Morris, 1996, Geologic Map of the Island of Hawaii, Geological Investigation Series Map I-2524-A, U.S. Dept. of Interior, U.S. Geological Survey (3 map set and unit descriptions).

Geolabs, Inc., 2002, "Geotechnical Engineering Exploration, Consolidated Command and Range Control Facility, Pohakuloa Training Area, Island of Hawaii," W.O. 4691-00(B), February 22, 2002, Geolabs Engineering and Drilling Services, 2006 Kalihi St., Honolulu, HI 96819.

U.S. Geological Survey, 2005, "Lava Flow Hazard Zone Maps: Mauna Loa," http://pubs.usgs.gov/gip/hazards/mauna-loa.html.

U.S. Army, 2003, "Integrated Wildland Fire Management Plan, Oahu and Pohakuloa Training Areas," 25th Infantry Division (Light) and U.S. Army Hawaii, October 2003, Chapter 7, pp. 7-44/45.

URS Group Inc., 2004, "Geophysical Survey for Detection of Lava Tubes, State Route 200, Saddle Road, Milepost 19 to Milepost 28, Hilo, Hawaii County, Hawaii," URS Group Inc., 615 Piikoi St., Honolulu, HI, 96814.

Appendix A

Location and Geology Maps/Photos

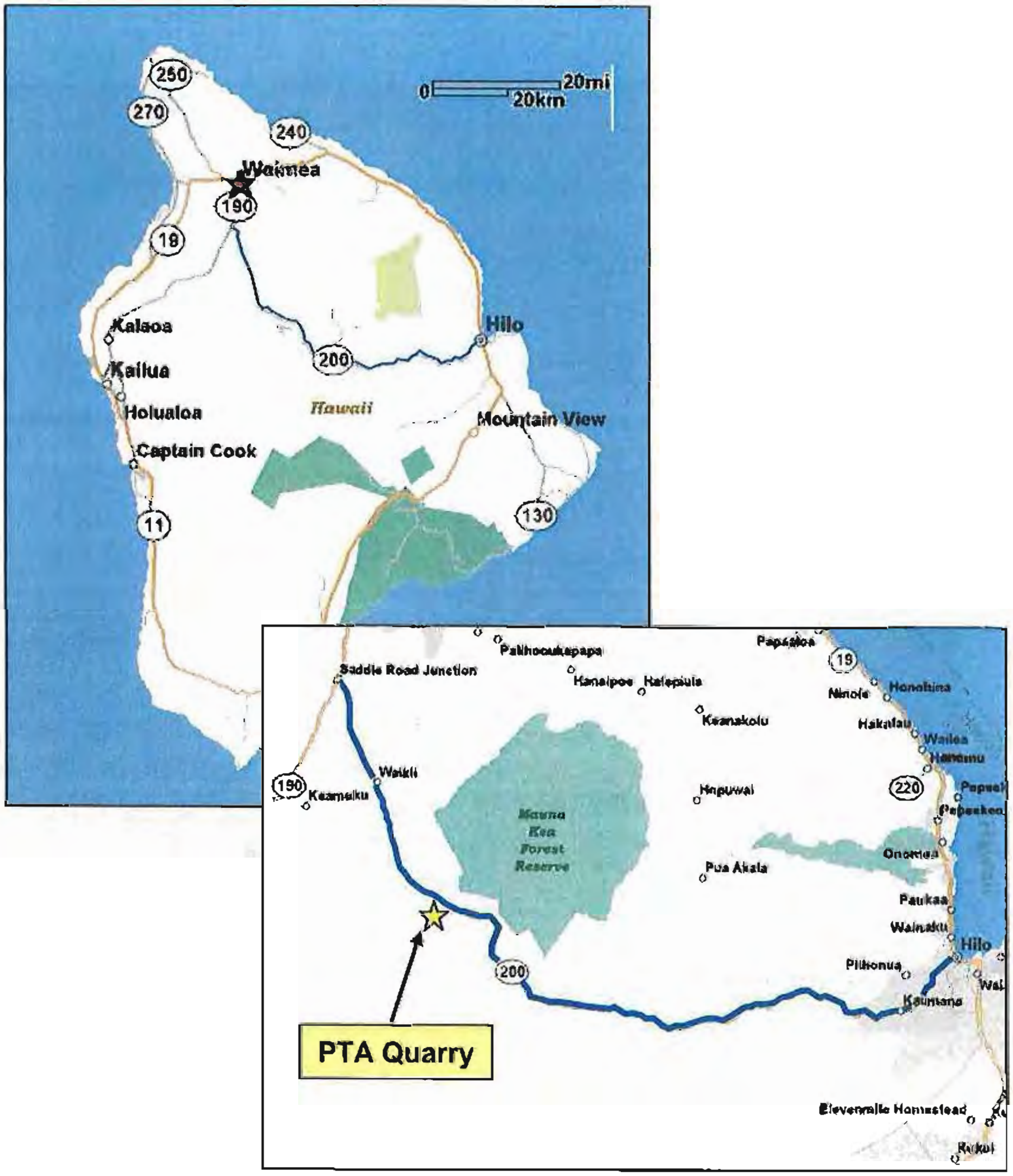


Figure A-1. Map showing Saddle Road (in blue) extending westward from Hilo to the intersection with SR 190. The PTA Quarry is shown to the southwest of Mauna Kea at approximate MP 38. (MapQuest, 2005)

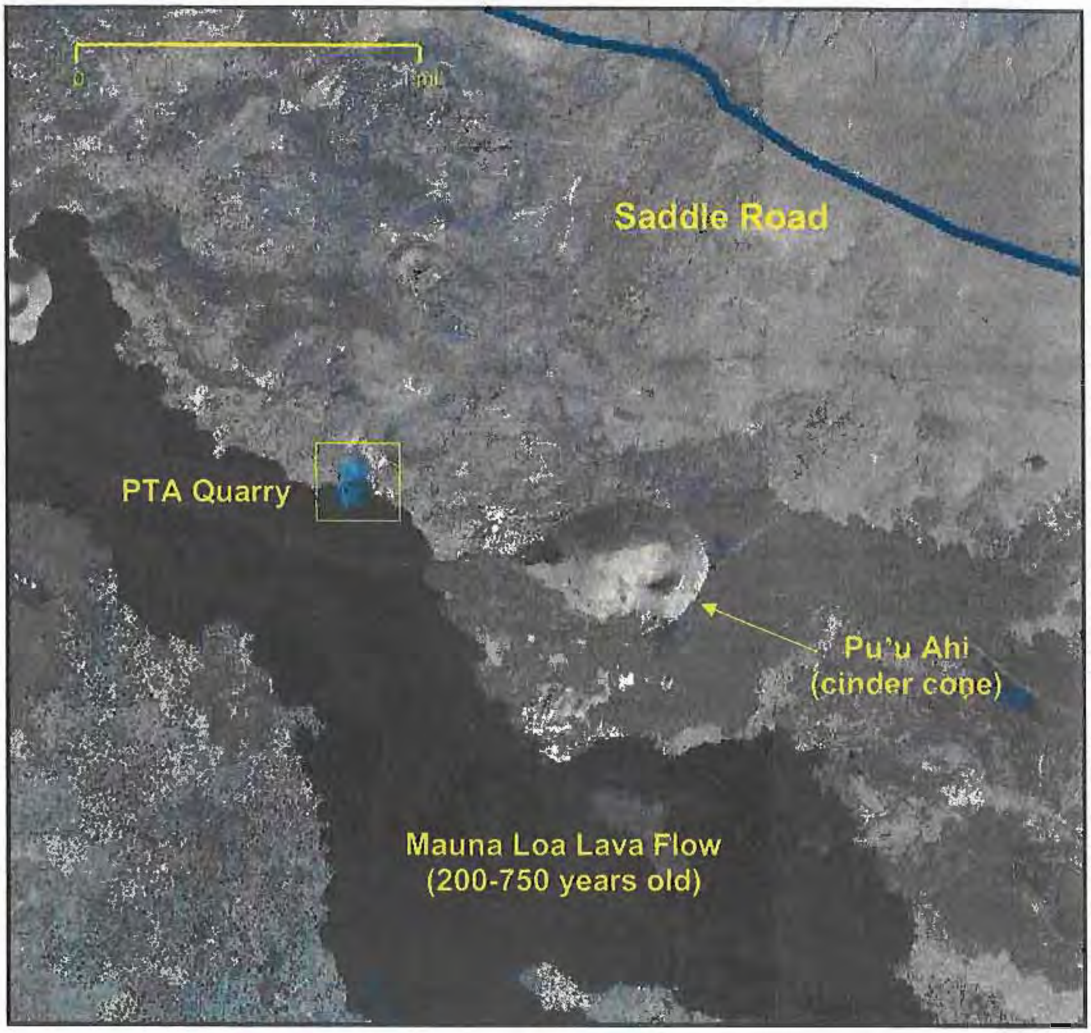


Figure A-2. Aerial photo showing typical lava flow and cinder cone topography in the vicinity of the PTA Quarry.

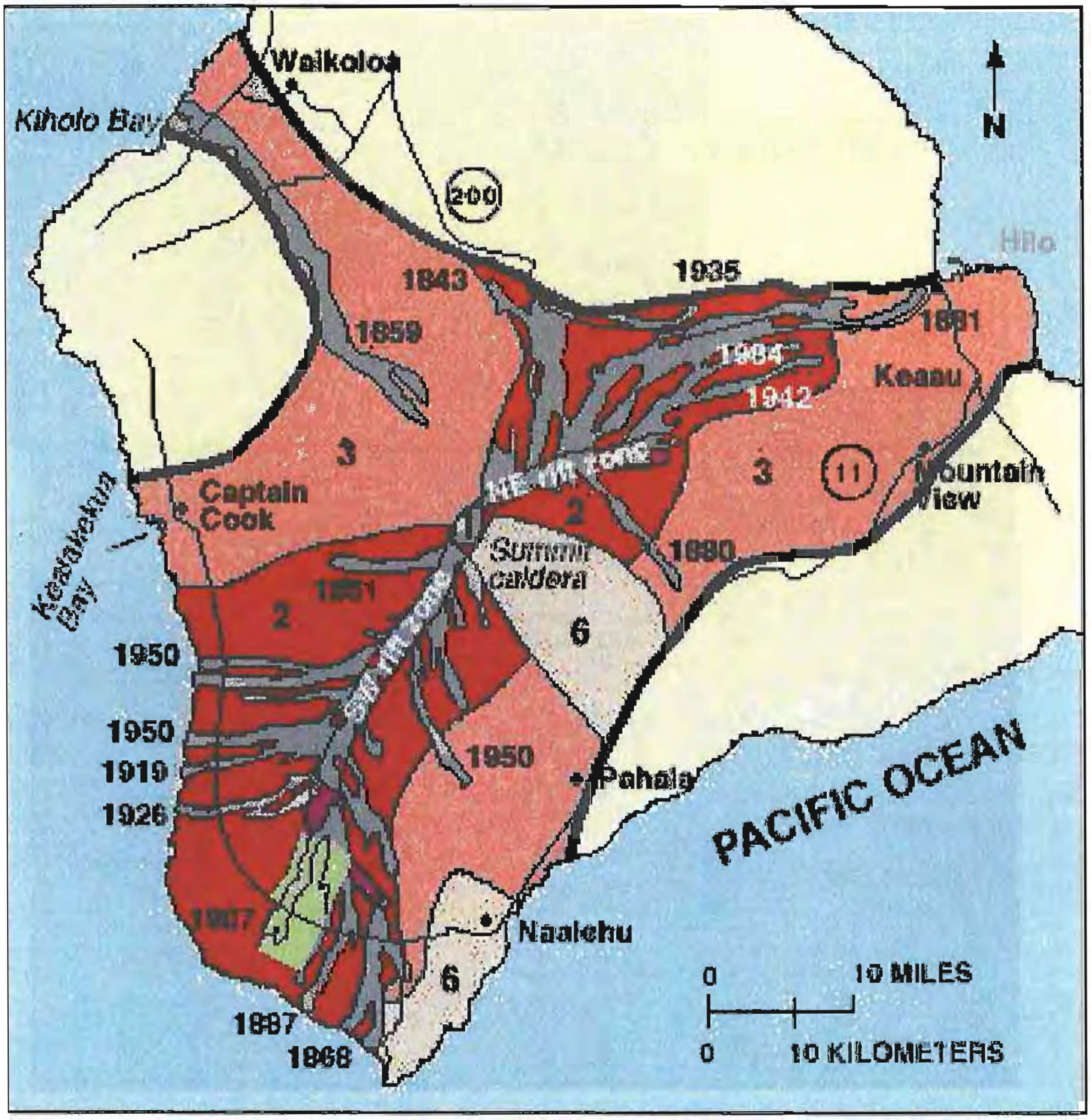


Figure A-3. Generalized map of Mauna Loa Volcano lava flows. Lava flows within the last 150 years are shown in gray and dated. Relative modern day hazard zones are indicated by colored and numbered zones. (USGS, 2005)

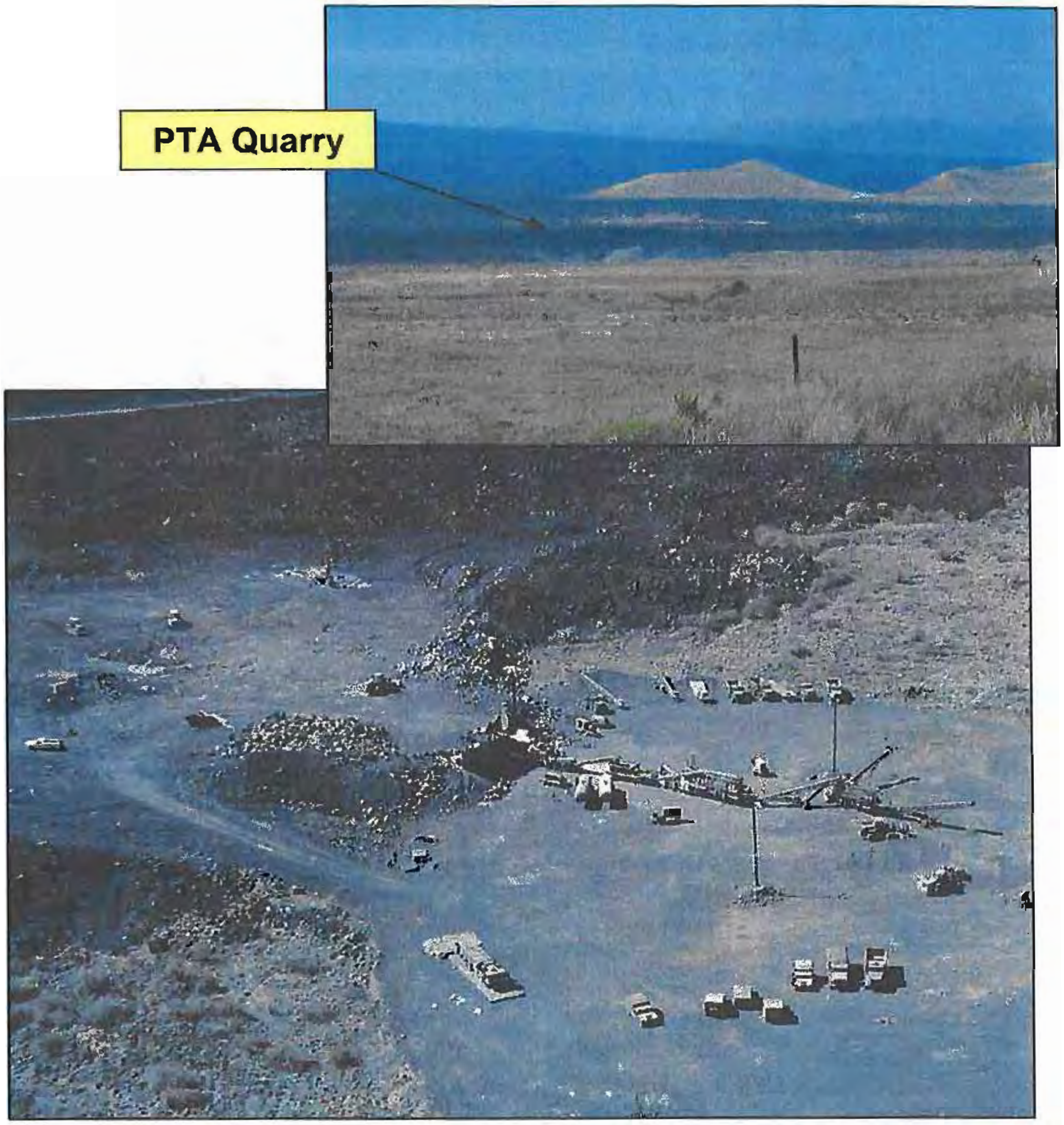


Figure A-4. Upper photos are looking south across the Humuula Saddle plateau region. The PTA quarry currently produces aggregate from the edge of an extensive a'a lava flow originating from Mauna Loa from 1,500 to 3,000 years ago.

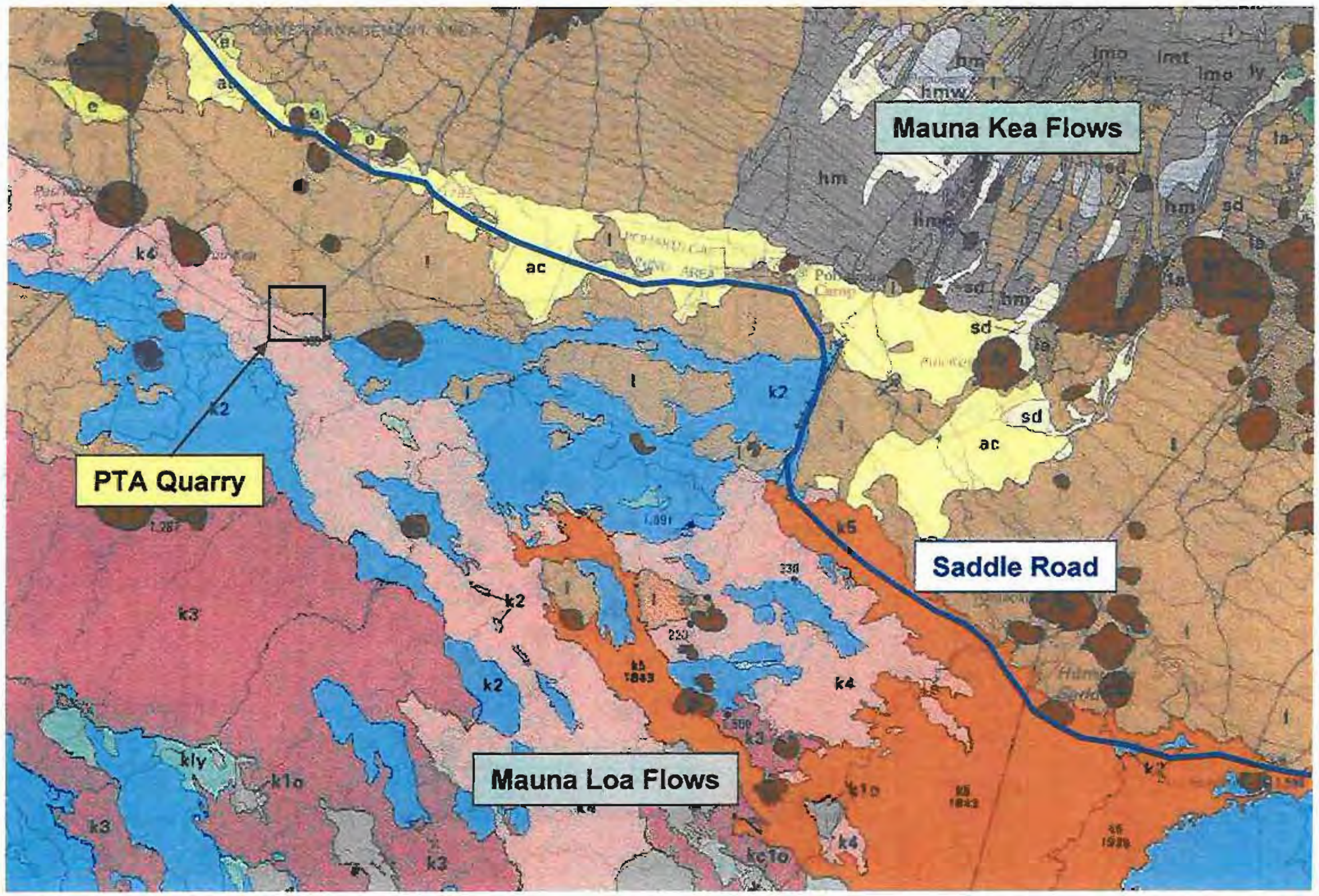
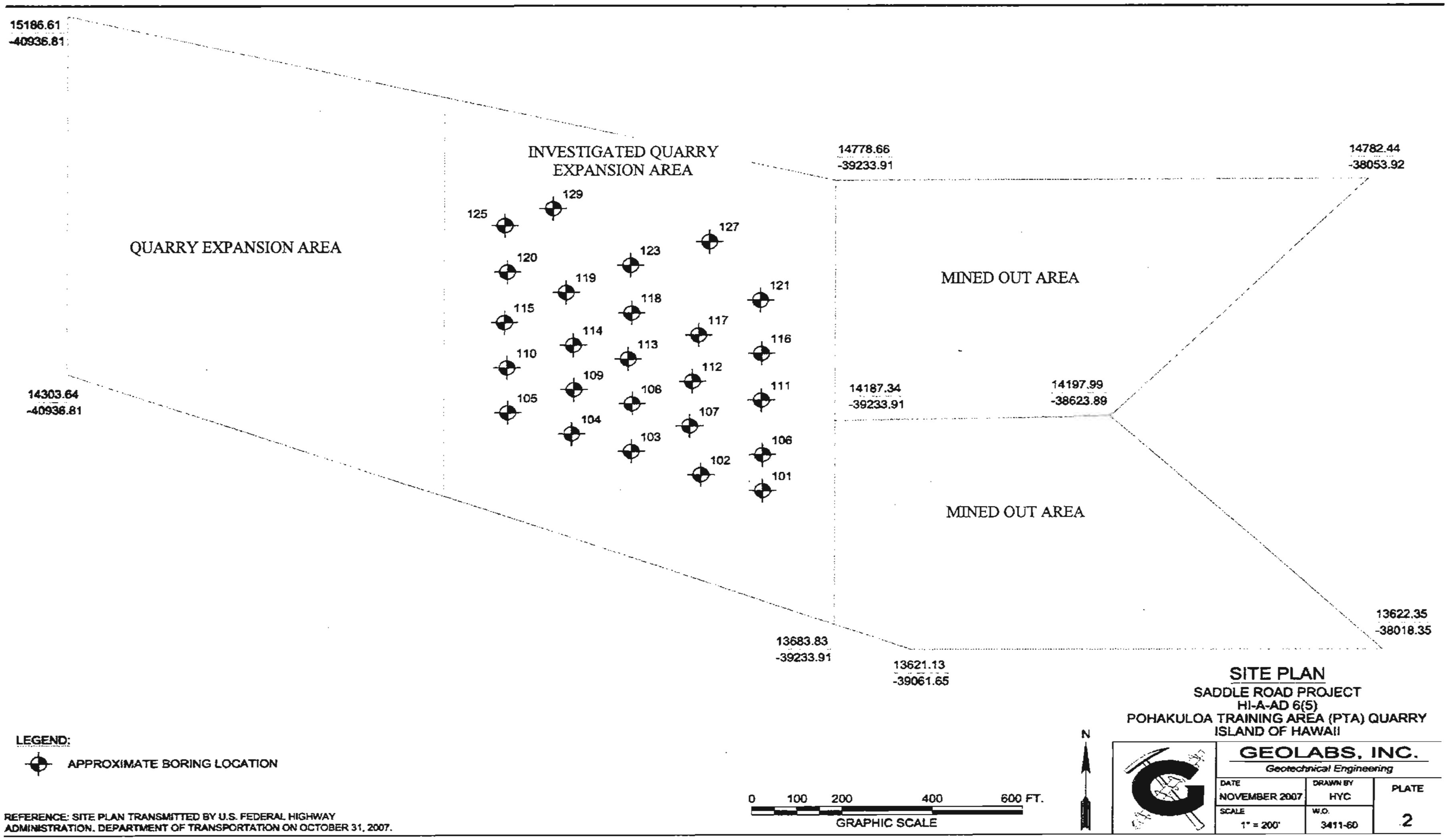
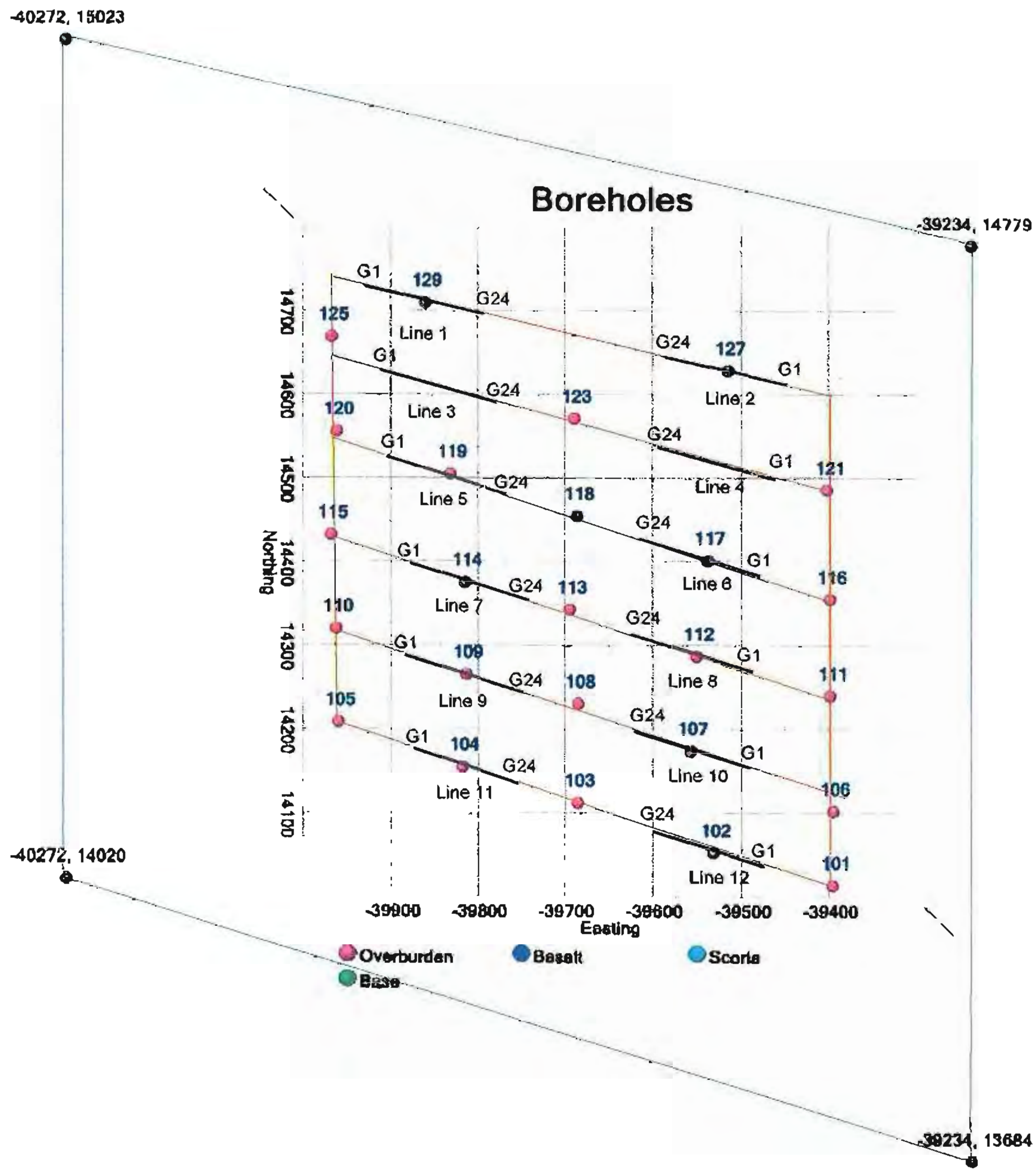


Figure A-5. Geologic map indicating general lava flow trends in the vicinity of the Humuula Saddle plateau and PTA quarry.



A-6. Plan map showing initial quarry areas, and possible subsequent expansion areas with approximate boring locations within one of the expansion areas.



A-7 Plan map showing the investigated quarry area, with approximate boring locations and seismic line locations relative to area boundaries.

Appendix B

Corehole Field Logs

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 101

Laboratory			Field								Approximate Ground Surface Elevation (feet MSL): 5700 *
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
											Gray **GRAVEL AND COBBLES (BASALTIC)** with traces of boulders, medium dense, dry (clinker)
			17	0							
							5				
			80	50							
											Gray vesicular to vugular **BASALT**, moderately fractured, unweathered, hard (a'a basalt)
							10				
			55	25							Gray **GRAVEL (BASALTIC)**, medium dense (clinker)
											Gray vesicular to vugular **BASALT**, closely fractured, unweathered, hard (a'a basalt)
							15				
			100	93							grades to dense
											Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
							20				
			100	88							
							25				
			97	92							
							30				
			100	100							grades to massive
							35				

Date Started:	July 17, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 17, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	41 feet	Drilling Method:	HQ Coring	A - 1.1
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

Figure B-1. Boring log for corehole 101.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 101

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	(Continued from previous plate) Description
			57	35							Reddish gray scoriaceous **BASALT**, severely fractured, unweathered, medium hard
							40				Reddish gray vugular **BASALT**, moderately fractured, unweathered, hard (a'a basalt)
											Boring terminated at 41 feet
											* Elevations of borings based on Surveys by FHWA-CFLHD.
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 17, 2007	Water Level: ∑	Not Encountered	Plate
Date Completed:	July 17, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	41 feet	Drilling Method:	HQ Coring	A - 1.2
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 101.

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring
102

Approximate Ground Surface Elevation (feet MSL): 5397 *

Other Tests (Laboratory)	Moisture Content (%) (Laboratory)	Dry Density (pcf) (Laboratory)	Core Recovery (%) (Field)	RQD (%) (Field)	Penetration Resistance (blows/foot) (Field)	Pocket Pen. (tsf) (Field)	Depth (feet)	Sample	Graphic	USCS	Description
			62	12			0				Gray vugular **BASALT**, moderately fractured, unweathered, hard (a'a basalt)
											Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, dry to damp (clinker)
							5				
			100	73							Reddish gray vugular **BASALT** with welded clinker, moderately fractured, unweathered, hard
							10				Gray vugular **BASALT**, slightly fractured, unweathered, hard (a'a basalt)
			100	92							grades with scoria
											grades to very hard
							15				Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			100	85							
							20				
			100	47							
							25				grades to moderately fractured
			100	87							
							30				
			100	80							
							35				

Date Started:	July 17, 2007	Water Level: ⊻	Not Encountered	Plate
Date Completed:	July 17, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	41.5 feet	Drilling Method:	HQ Coring	A - 2.1
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-2. Boring log for corehole 102.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 102

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	(Continued from previous plate) Description
			60	37							
							40				Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, damp (clinker)
											Boring terminated at 41.5 feet
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 17, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 17, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 2.2
Total Depth:	41.5 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS8_30.GDT 11/13/07

Continue boring log for corehole 102.

	GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring **103**

Approximate Ground Surface Elevation (feet MSL): 5695 *

Laboratory: Other Tests	Laboratory: Moisture Content (%)	Laboratory: Dry Density (pcf)	Field: Core Recovery (%)	Field: RQD (%)	Field: Penetration Resistance (blows/foot)	Field: Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			58	15							Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, dry (clinker)
							5				
			70	40							
											Reddish gray **BASALT** with welded clinker, moderately fractured, unweathered, hard
							10				
			98	83							Gray dense **BASALT**, massive, unweathered, very hard
							15				
			100	85							
											grades to slightly fractured
							20				
			100	82							
							25				
			100	75							
							30				
			100	63							
							35				

Date Started:	July 17, 2007	Water Level: ▽	Not Encountered	Plate
Date Completed:	July 18, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 3.1
Total Depth:	41.5 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS8_30.GDT 11/13/07

Figure B-3. Boring log for corehole 103.

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **103**

Other Tests (Laboratory)	Moisture Content (%) (Laboratory)	Dry Density (pcf) (Laboratory)	Core Recovery (%) (Field)	RQD (%) (Field)	Penetration Resistance (blows/foot) (Field)	Pocket Pen. (tsf) (Field)	Depth (feet)	Sample	Graphic	USCS	Description (Continued from previous plate)
			63	42							
							40				Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, damp (clinker)
											Boring terminated at 41.5 feet
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 17, 2007	Water Level: ⊻	Not Encountered
Date Completed:	July 18, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	41.5 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate A - 3.2

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 103.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 104

Approximate Ground Surface Elevation (feet MSL): 5695 *

Other Tests (Laboratory)	Moisture Content (%) (Laboratory)	Dry Density (pcf) (Laboratory)	Core Recovery (%) (Field)	RQD (%) (Field)	Penetration Resistance (blows/foot) (Field)	Pocket Pen. (tsf) (Field)	Depth (feet)	Sample	Graphic	USCS	Description
			40	0			0–1.5				Gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, dry (clinker)
			80	50			5				grades to welded clinker
			100	55			10				Gray dense **BASALT**, moderately fractured, unweathered, very hard (a'a basalt)
			100	93			15				grades to massive
			100	100			20				
			100	92			25				
			100	92			30				
							35				

Date Started:	July 18, 2007	Water Level: ∇	Not Encountered
Date Completed:	July 18, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	41 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate A - 4.1

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-4. Boring log for corehole 104.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 104

Laboratory: Other Tests	Laboratory: Moisture Content (%)	Laboratory: Dry Density (pcf)	Field: Core Recovery (%)	Field: RQD (%)	Field: Penetration Resistance (blows/foot)	Field: Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description (Continued from previous plate)
			85	50							
							40				Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, damp (clinker)
											Boring terminated at 41 feet
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 18, 2007	Water Level: ⊻	Not Encountered	Plate
Date Completed:	July 18, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 4.2
Total Depth:	41 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 104.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 105

Laboratory: Other Tests	Laboratory: Moisture Content (%)	Laboratory: Dry Density (pcf)	Field: Core Recovery (%)	Field: RQD (%)	Field: Penetration Resistance (blows/foot)	Field: Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description (Approximate Ground Surface Elevation (feet MSL): 5692 *)
							0				Gray **COBBLES AND GRAVEL (BASALTIC)**, medium dense, dry (clinker)
			52	15							
							5				
			95	35							
											Gray vugular **BASALT**, moderately fractured, unweathered, hard to very hard (a'a basalt)
							10				
			60	37							
											VOID
							15				
			100	30							grades to closely vertically fractured
							20				
			100	75							Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
							25				
			100	100							
							30				
			100	80							
							35				

Date Started:	July 19, 2007	Water Level: ▽	Not Encountered	Plate
Date Completed:	July 19, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 5.1
Total Depth:	41.5 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-5. Boring log for corehole 105.

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **105**

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	(Continued from previous plate) Description
			60	20							
							40				Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, damp (clinker)
											Boring terminated at 41.5 feet
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 19, 2007	Water Level: ∇	Not Encountered
Date Completed:	July 19, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	41.5 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate **A - 5.2**

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 105.

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **106**

Approximate Ground Surface Elevation (feet MSL): 5699 *

Other Tests (Laboratory)	Moisture Content (%) (Laboratory)	Dry Density (pcf) (Laboratory)	Core Recovery (%) (Field)	RQD (%) (Field)	Penetration Resistance (blows/foot) (Field)	Pocket Pen. (tsf) (Field)	Depth (feet)	Sample	Graphic	USCS	Description
			37	10			0–5				Gray **GRAVEL, COBBLES, AND BOULDERS (BASALTIC)**, medium dense, dry (clinker)
			70	20			5				Gray dense **BASALT**, closely fractured, unweathered, very hard (a'a basalt)
			45	20			10				Gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, dry (clinker)
			100	92			15				Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			90	42			20				grades to vugular, moderately fractured
			40	0			25				Reddish gray **GRAVEL (BASALTIC)** with some cobbles, medium dense, damp (clinker)
			53	0			30–35				

Date Started:	July 16, 2007	Water Level: ⊻	Not Encountered
Date Completed:	July 16, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	36 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate **A - 6.1**

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-6. Boring log for corehole 106.

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **106**

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	(Continued from previous plate) Description
											Boring terminated at 36 feet
							40				
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 16, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 16, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	36 feet	Drilling Method:	HQ Coring	A - 6.2
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 106.

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **107**

Approximate Ground Surface Elevation (feet MSL): 5696 *

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	USCS	Description
			73	17			0		Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, dry (clinker)
									Gray vugular **BASALT**, closely fractured, unweathered, hard
			67	47			5		Reddish gray **GRAVEL (BASALTIC)**, medium dense, dry to damp (clinker)
									Gray dense vugular **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			100	83			10		
			100	93			15		
			100	73			20		
			62	35			25		
									Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, damp (clinker)
			58	18			30		
							35		

Date Started:	July 20, 2007	Water Level: ⊽	Not Encountered
Date Completed:	July 21, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	36 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate **A - 7.1**

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-6. Boring log for corehole 107

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **107**

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
											(Continued from previous plate)
											Reddish gray vugular **BASALT**, closely fractured, unweathered, hard (a'a basalt)
											Boring terminated at 36 feet
							40				
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 20, 2007	Water Level: ▽	Not Encountered	Plate
Date Completed:	July 21, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	36 feet	Drilling Method:	HQ Coring	A - 7.2
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 107.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 108

Approximate Ground Surface Elevation (feet MSL): 5696 *

Other Tests (Laboratory)	Moisture Content (%) (Laboratory)	Dry Density (pcf) (Laboratory)	Core Recovery (%) (Field)	RQD (%) (Field)	Penetration Resistance (blows/foot) (Field)	Pocket Pen. (tsf) (Field)	Depth (feet)	USCS	Description
							0		Gray **GRAVEL AND COBBLES (BASALTIC)**, loose to medium dense, dry (clinker)
			32	0					
							5		
			75	50					
							10		Gray dense **BASALT**, moderately fractured, unweathered, hard to very hard (a'a basalt)
			88	58					
							15		
			73	23					Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, damp (clinker)
									Gray vugular **BASALT**, severely fractured, unweathered, hard to very hard (a'a basalt)
							20		
			80	8					
							25		
			100	80					grades to slightly fractured
							30		
			100	80					grades to closely fractured
							35		

Date Started:	July 20, 2007	Water Level: ∇	Not Encountered	Plate A - 8.1
Date Completed:	July 20, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	41.5 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-7. Boring log for corehole 108

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **108**

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
											(Continued from previous plate)
			72	37							
							40				Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, damp (clinker)
											Boring terminated at 41.5 feet
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 20, 2007	Water Level: ⊻	Not Encountered
Date Completed:	July 20, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	41.5 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate **A - 8.2**

BORING_LOG 3411-60.GPJ GEOLABS8_30.GDT 11/13/07

Continue boring log for corehole 108.

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **109**

Approximate Ground Surface Elevation (feet MSL): 5695 *

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			48	10			0–3.5				Gray **COBBLES AND GRAVEL (BASALTIC)**, medium dense, dry (clinker)
							3.5				Gray vugular **BASALT**, moderately fractured, unweathered, hard (a'a basalt)
			95	30			5				
			100	72			10				grades to very hard
			100	80			15				Gray dense vugular **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			100	100			20				grades to massive
			100	100			25				
			100	100			30				grades to slightly fractured
							35				

Date Started:	July 19, 2007	Water Level: ⊻	Not Encountered
Date Completed:	July 20, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	40 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate **A - 9.1**

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-8. Boring log for corehole 109

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **109**

Laboratory: Other Tests	Laboratory: Moisture Content (%)	Laboratory: Dry Density (pcf)	Field: Core Recovery (%)	Field: RQD (%)	Field: Penetration Resistance (blows/foot)	Field: Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description (Continued from previous plate)
			100	100							
							40				Boring terminated at 40 feet
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 19, 2007	Water Level: ⊻	Not Encountered
Date Completed:	July 20, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	40 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate **A - 9.2**

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 109.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 110

Approximate Ground Surface Elevation (feet MSL): 5691 *

Other Tests (Laboratory)	Moisture Content (%) (Laboratory)	Dry Density (pcf) (Laboratory)	Core Recovery (%) (Field)	RQD (%) (Field)	Penetration Resistance (blows/foot) (Field)	Pocket Pen. (tsf) (Field)	Depth (feet)	Sample	Graphic	USCS	Description
											Reddish gray **COBBLES AND GRAVEL (BASALTIC)**, medium dense, dry (clinker)
			38	0							
							5				
			35	0							
							10				
			40	8							
							15				
											Reddish gray scoriaceous **BASALT** with welded clinker, closely to moderately fractured, unweathered, medium hard to hard
			70	37							
							20				
											Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			100	83							
							25				
			100	95							
											grades to massive
							30				
			100	92							grades to slightly fractured
							35				

Date Started:	July 19, 2007	Water Level: ⊻	Not Encountered	Plate
Date Completed:	July 19, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	41.5 feet	Drilling Method:	HQ Coring	A - 10.1
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-9 Boring log for corehole 110

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **110**

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	(Continued from previous plate) Description
			77	70							
							40				Reddish gray **GRAVEL (BASALTIC)**, medium dense, damp (clinker)
											Boring terminated at 41.5 feet
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 19, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 19, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	41.5 feet	Drilling Method:	HQ Coring	A - 10.2
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 110.

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **111**

Approximate Ground Surface Elevation (feet MSL): 5704 *

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			100	50			0–3				Reddish gray **COBBLES AND GRAVEL (BASALTIC)**, medium dense, dry (clinker); grades to welded clinker
							3–5				Gray vugular **BASALT**, moderately fractured, unweathered, hard
			70	63			5–10				Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			10	0			10–16.5				Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, loose to medium dense, damp (clinker)
			100	78			16.5–26				Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			100	90							grades with welded clinker
			100	80			26–31.5				Reddish gray scoriaceous **BASALT** with welded clinker, closely to moderately fractured, unweathered, hard
			17	0			31.5–35				Reddish gray **GRAVEL (BASALTIC)**, loose to medium dense, damp (clinker)

Date Started:	July 21, 2007	Water Level: ⊻	Not Encountered
Date Completed:	July 21, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	36.5 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate A - 11.1

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-10. Boring log for corehole 111

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 111

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	(Continued from previous plate) Description
											Boring terminated at 36.5 feet
							40				
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 21, 2007	Water Level: ⊻	Not Encountered	Plate
Date Completed:	July 21, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 11.2
Total Depth:	36.5 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 111.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 112

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Approximate Ground Surface Elevation (feet MSL): 5696 * Description
			58	7							Reddish gray **COBBLES AND GRAVEL (BASALTIC)**, medium dense, dry (clinker)
							5				Gray vugular **BASALT**, severely fractured, unweathered, hard (a'a basalt)
			65	0							
							10				
			100	90							grades to moderately fractured, very hard
											Gray dense vugular **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
							15				
			100	100							
							20				
			95	72							
							25				
			100	62							grades to closely to moderately fractured
											grades to massive
							30				
			92	92							
							35				

Date Started:	July 21, 2007	Water Level: ⊻	Not Encountered	Plate
Date Completed:	July 21, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 12.1
Total Depth:	36 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-11. Boring log for corehole 112

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **112**

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description (Continued from previous plate)
											Boring terminated at 36 feet
							40				
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 21, 2007	Water Level: ∇	Not Encountered
Date Completed:	July 21, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	36 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate **A - 12.2**

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 112.

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **113**

Approximate Ground Surface Elevation (feet MSL): 5696 *

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	USCS	Description
							0		Reddish gray **GRAVEL (BASALTIC)**, loose to medium dense, dry (clinker)
			55	0					
			13	0					
			78	40					
							14.5		Gray dense **BASALT**, moderately fractured, unweathered, very hard (a'a basalt)
			100	63					
							19.5		Reddish gray scoriaceous **BASALT** with welded clinker, moderately fractured, unweathered, hard
			100	95			22		Gray dense **BASALT**, slightly fractured to massive, unweathered, very hard (a'a basalt)
			100	87					
							32		Boring terminated at 32 feet

Date Started:	July 23, 2007	Water Level: ▽	Not Encountered
Date Completed:	July 23, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	32 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate A - 13

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-12. Boring log for corehole 113

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 114

Laboratory			Field									
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Approximate Ground Surface Elevation (feet MSL): 5697 *	Description
												Gray **COBBLES AND GRAVEL (BASALTIC)**, medium dense, dry (clinker)
			83	50								
												Gray vugular **BASALT**, moderately fractured, unweathered, hard
							5					
												Reddish gray **GRAVEL (BASALTIC)**, medium dense, damp (clinker)
			17	0								
							10					
			37	8								
							15					
			97	70								Gray vugular **BASALT**, moderately fractured, unweathered, hard to very hard (a'a basalt)
							20					
			100	75								Reddish gray **BASALT** with welded clinker, moderately fractured, unweathered, medium hard
							25					
			100	92								grades to hard
							30					Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			100	75								
							35					

Date Started:	July 23, 2007	Water Level: ⊻	Not Encountered	Plate
Date Completed:	July 23, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	35.5 feet	Drilling Method:	HQ Coring	A - 14.1
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-13. Boring log for corehole 114

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **114**

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	(Continued from previous plate) Description
											Boring terminated at 35.5 feet
							40				
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 23, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 23, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 14.2
Total Depth:	35.5 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS8_30.GDT 11/13/07

Continue boring log for corehole 114.

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **115**

Approximate Ground Surface Elevation (feet MSL): 5692 *

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Description
			25	0			0–11	Gray **COBBLES AND GRAVEL (BASALTIC)**, medium dense, dry (clinker)
			47	7				
			98	35			11–15	Reddish gray vugular **BASALT** with some welded clinker, moderately fractured, unweathered, hard
			100	80			15–21	Gray dense **BASALT**, slightly fractured, unweathered, very hard
			97	60			21–22.5	Reddish gray **BASALT** with welded clinker, severely fractured, unweathered, medium hard
							22.5–32	Gray dense **BASALT**, slightly fractured to massive, unweathered, very hard (a'a basalt)
			97	75				
			100	100				
							32	Boring terminated at 32 feet

Date Started:	July 24, 2007	Water Level: ⊻	Not Encountered	Plate
Date Completed:	July 24, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	32 feet	Drilling Method:	HQ Coring	A - 15
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-14. Boring log for corehole 115

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 116

Approximate Ground Surface Elevation (feet MSL): 5697 *

Laboratory: Other Tests	Laboratory: Moisture Content (%)	Laboratory: Dry Density (pcf)	Field: Core Recovery (%)	Field: RQD (%)	Field: Penetration Resistance (blows/foot)	Field: Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			50	12			0				Reddish gray **COBBLES AND GRAVEL (BASALTIC)** with traces of boulders, medium dense, dry (clinker)
			47	0			5				
			43	17			10				
			30	0			15				
			100	73			20				grades to welded clinkers
											Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			95	95			25				
			100	40			30				
							35				

Date Started:	July 25, 2007	Water Level: ▽	Not Encountered
Date Completed:	July 26, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	35.5 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate A - 16.1

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-15. Boring log for corehole 116

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 116

Other Tests (Laboratory)	Moisture Content (%) (Laboratory)	Dry Density (pcf) (Laboratory)	Core Recovery (%) (Field)	RQD (%) (Field)	Penetration Resistance (blows/foot) (Field)	Pocket Pen. (tsf) (Field)	Depth (feet)	Sample	Graphic	USCS	Description (Continued from previous plate)
											Reddish gray vugular **BASALT** with some clinker, moderately fractured, slightly weathered, hard (a'a basalt)
											Boring terminated at 35.5 feet
							40				
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 25, 2007	Water Level: ▽	Not Encountered	Plate
Date Completed:	July 26, 2007			A - 16.2
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	35.5 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 116.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 117

Approximate Ground Surface Elevation (feet MSL): 5697 *

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			17	0			0				Reddish gray **GRAVEL (BASALTIC)**, loose to medium dense, dry (clinker)
			90	35			5				Gray vugular **BASALT**, moderately fractured, unweathered, hard (a'a basalt)
											grades to massive
			93	72			10				
			38	0			15				Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, damp (clinker)
			60	12			20				
			100	75			25				Gray dense **BASALT**, slightly to moderately fractured, unweathered, very hard (a'a basalt)
			100	67			30				
							35				Boring terminated at 35 feet

Date Started:	July 25, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 25, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 17
Total Depth:	35 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-16. Boring log for corehole 117

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 118

Approximate Ground Surface Elevation (feet MSL): 5694 *

Other Tests (Laboratory)	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%) (Field)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			60	8							Gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, dry (clinker)
			83	47			5				Gray vugular **BASALT**, moderately fractured, unweathered, hard (a'a basalt)
							10				grades to very hard
			100	83							grades to slightly fractured
			100	88			15				
											grades to dense
			100	73			20				Gray dense vugular **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			100	48			25				grades to moderately fractured
			100	75			30				
							35				

Date Started:	July 25, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 25, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 18.1
Total Depth:	40 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-17. Boring log for corehole 118

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **118**

Other Tests (Laboratory)	Moisture Content (%) (Laboratory)	Dry Density (pcf) (Laboratory)	Core Recovery (%) (Field)	RQD (%) (Field)	Penetration Resistance (blows/foot) (Field)	Pocket Pen. (tsf) (Field)	Depth (feet)	Sample	Graphic	USCS	Description (Continued from previous plate)
			100	63							
							40				Boring terminated at 40 feet
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 25, 2007
Date Completed:	July 25, 2007
Logged By:	S. Latronic
Total Depth:	40 feet
Work Order:	3411-60
Water Level: ⊻	Not Encountered
Drill Rig:	MOBILE B-53
Drilling Method:	HQ Coring
Driving Energy:	140 lb. wt., 30 in. drop

Plate A - 18.2

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 118.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 119

Approximate Ground Surface Elevation (feet MSL): 5692 *

Laboratory: Other Tests	Laboratory: Moisture Content (%)	Laboratory: Dry Density (pcf)	Field: Core Recovery (%)	Field: RQD (%)	Field: Penetration Resistance (blows/foot)	Field: Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			47	12			0				Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, dry (clinker)
							4				Gray vugular **BASALT**, moderately fractured, unweathered, hard (a'a basalt)
			100	30			5				
			88	72			10				grades with traces of clinker from 10.5 to 11 feet
							15				grades to very hard
			100	100			16				Gray dense **BASALT**, massive, unweathered, very hard (a'a basalt)
			100	100			20				
			100	58			25				grades to moderately fractured
							30				Boring terminated at 30 feet
							35				

Date Started:	July 24, 2007	Water Level: ⊽	Not Encountered	Plate
Date Completed:	July 24, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 19
Total Depth:	30 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS8_30.GDT 11/13/07

Figure B-18. Boring log for corehole 119

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **120**

Approximate Ground Surface Elevation (feet MSL): 5692 *

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Description
							0	Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, dry (clinker)
			43	0				
			70	43			5	
								Gray dense vugular **BASALT**, moderately fractured, unweathered, hard (a'a basalt)
							10	
			95	80				grades with traces of clinker from 10.8 to 11.2 feet
							15	
			100	97				grades to massive
							20	
			100	100				grades to slightly fractured
							25	
			100	63				
							30	
								Boring terminated at 31 feet
							35	

Date Started:	July 24, 2007	Water Level: ⊻	Not Encountered
Date Completed:	July 24, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	31 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate **A - 20**

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-19. Boring log for corehole 120

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 121

Approximate Ground Surface Elevation (feet MSL): 5698 *

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			70	15			0				Reddish gray **COBBLES, GRAVEL, AND BOULDERS (BASALTIC)**, medium dense, dry (clinker)
			45	8			5				
			53	10			10				
			23	0			15				
			65	28			20				
			100	90			25				Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
							30				Boring terminated at 31 feet
							35				

Date Started:	July 26, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 26, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 21
Total Depth:	31 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS8_30.GDT 11/13/07

Figure B-20. Boring log for corehole121

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **123**

Approximate Ground Surface Elevation (feet MSL): 5695 *

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Description
							0	Gray **GRAVEL AND COBBLES (BASALTIC)**, loose to medium dense, dry (clinker)
			23	0				
							5	
			38	12				
							10	
			100	85				Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
							15	
			100	100				
							20	
			100	82				
							25	
			100	98				
							30	
			100	100				
							35	

Date Started:	July 27, 2007	Water Level: ⊻	Not Encountered
Date Completed:	July 28, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	41.5 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate **A - 22.1**

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-21. Boring log for corehole 123

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **123**

Other Tests (Laboratory)	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%) (Field)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
											(Continued from previous plate)
			62	37							Reddish gray scoriaceous **BASALT** with welded clinker, moderately fractured, unweathered, medium hard
							40				Reddish gray **GRAVEL (BASALTIC)**, medium dense, damp (clinker)
											Boring terminated at 41.5 feet
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 27, 2007	Water Level: ⊻	Not Encountered
Date Completed:	July 28, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	41.5 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate A - 22.2

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 123.

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **125**

Approximate Ground Surface Elevation (feet MSL): 5696 *

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
							0				Reddish gray **COBBLES, GRAVEL, AND BOULDERS (BASALTIC)**, medium dense, dry (clinker)
			60	28							
							5				
			65	33							
							10				
			58	15							
							15				
			87	60							Gray dense **BASALT**, moderately fractured, unweathered, very hard (a'a basalt)
							20				
			100	100							
							25				grades to massive locally
			97	58							
							30				
			100	87							
							35				

Date Started:	July 27, 2007	Water Level: ⊻	Not Encountered
Date Completed:	July 27, 2007		
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53
Total Depth:	36 feet	Drilling Method:	HQ Coring
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop

Plate **A - 23.1**

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-22. Boring log for corehole 125

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **125**

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	(Continued from previous plate) Description
											Boring terminated at 36 feet
							40				
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 27, 2007	Water Level: ∇	Not Encountered	Plate A - 23.2
Date Completed:	July 27, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	36 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 125.

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **127**

Approximate Ground Surface Elevation (feet MSL): 5695 *

Laboratory: Other Tests	Laboratory: Moisture Content (%)	Laboratory: Dry Density (pcf)	Field: Core Recovery (%)	Field: RQD (%)	Field: Penetration Resistance (blows/foot)	Field: Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			63	30			0–5				Reddish gray **GRAVEL, COBBLES, AND BOULDERS (BASALTIC)**, medium dense, dry (clinker)
			95	43			5				grades to welded clinker
											Reddish gray **BASALT** with welded clinker, moderately fractured, unweathered, medium hard
			78	47			10				
											Gray dense **BASALT**, slightly fractured, unweathered, very hard (a'a basalt)
			100	87			15				
			100	100			20				grades with vugs
			100	70			25				
			100	71			30				grades with some welded clinker
							35				Boring terminated at 35 feet

Date Started:	July 26, 2007	Water Level: ⊻	Not Encountered	Plate
Date Completed:	July 26, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	35 feet	Drilling Method:	HQ Coring	A - 24.1
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-23. Boring log for corehole 127

GEOLABS, INC.

Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring **127**

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	(Continued from previous plate) Description
							40				
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 26, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 26, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	35 feet	Drilling Method:	HQ Coring	A - 24.2
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 127.

GEOLABS, INC. Geotechnical Engineering	SADDLE ROAD PROJECT HI-A-AD 6(5) POHAKULOA TRAINING AREA (PTA) QUARRY ISLAND OF HAWAII	Log of Boring 129

Approximate Ground Surface Elevation (feet MSL): 5699 *

Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	Description
			65	27			0				Reddish gray **GRAVEL AND COBBLES (BASALTIC)**, medium dense, dry (clinker)
			100	68			5				Gray dense **BASALT**, moderately fractured, unweathered, very hard (a'a basalt)
			57	22			10				Reddish gray **COBBLES AND GRAVEL (BASALTIC)**, medium dense, damp (clinker)
			52	0			15				
			70	25			20				
			70	20			25				Reddish gray **BASALT** with welded clinker, moderately fractured, unweathered, medium hard to hard
			100	33			30				Gray dense **BASALT**, moderately fractured, unweathered, very hard (a'a basalt)
							35				

Date Started:	July 27, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 27, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	A - 25.1
Total Depth:	39.5 feet	Drilling Method:	HQ Coring	
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Figure B-24. Boring log for corehole 129

GEOLABS, INC.
Geotechnical Engineering

SADDLE ROAD PROJECT
HI-A-AD 6(5)
POHAKULOA TRAINING AREA (PTA) QUARRY
ISLAND OF HAWAII

Log of Boring
129

Laboratory			Field								
Other Tests	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	RQD (%)	Penetration Resistance (blows/foot)	Pocket Pen. (tsf)	Depth (feet)	Sample	Graphic	USCS	(Continued from previous plate) Description
			98	25							
							40				Boring terminated at 39.5 feet
							45				
							50				
							55				
							60				
							65				
							70				

Date Started:	July 27, 2007	Water Level: ∇	Not Encountered	Plate
Date Completed:	July 27, 2007			
Logged By:	S. Latronic	Drill Rig:	MOBILE B-53	
Total Depth:	39.5 feet	Drilling Method:	HQ Coring	A - 25.2
Work Order:	3411-60	Driving Energy:	140 lb. wt., 30 in. drop	

BORING_LOG 3411-60.GPJ GEOLABS 8_30.GDT 11/13/07

Continue boring log for corehole 129.

Appendix C

Rock Core and Drilling Photos

Figure C-1. Corehole 101: Box 1—1.0 - 18.0 ft

Figure C-2. Corehole 101: Box 2 —18.0 - 26.0 ft

Figure C-3. Corehole 101: Box 3 —26.0 - 35.0 ft

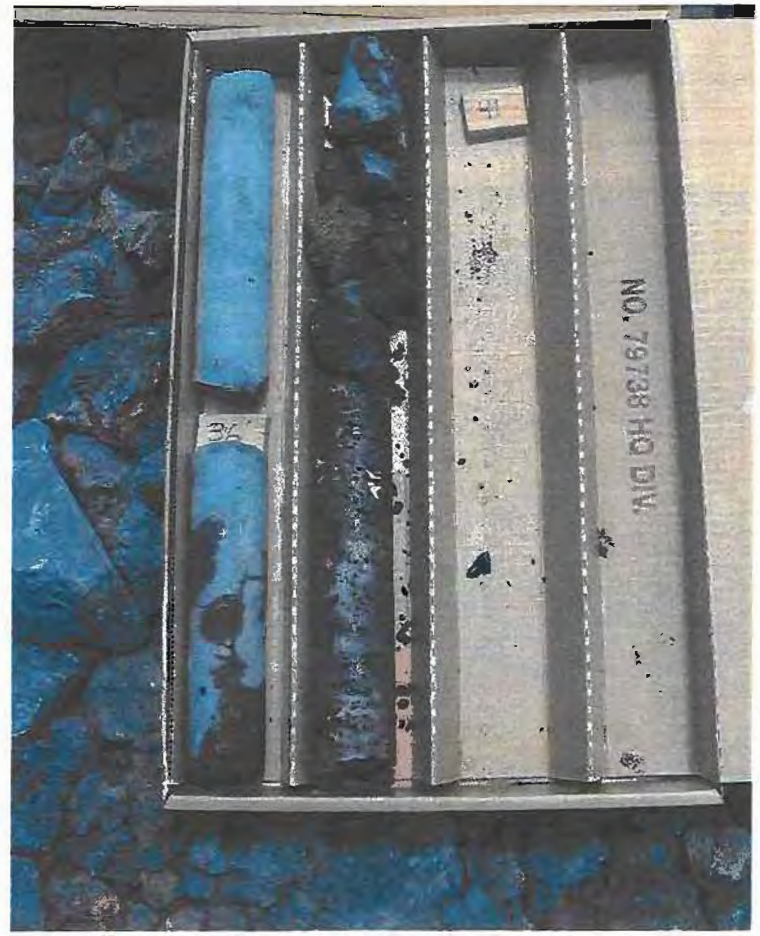


Figure C-4. Corehole 101: Box 4 —35.0 - 41.0 ft

Figure C-5. Corehole 102: Box 1 —1.0 - 11.5 ft

Figure C-6. Corehole 102: Box 2 —11.5 - 21.0 ft

Figure C-7. Corehole 102: Box 3 —21.0 - 30.0 ft

Figure C-8. Corehole 102: Box 4 —30.0 - 41.5 ft

Figure C-9. Corehole 103: Box 1 —1.5 - 14.5 ft

Figure C-10. Corehole 103: Box 2 —14.5 – 23.5 ft

Figure C-11. Corehole 103: Box 3 —23.5 - 33.0 ft

Figure C-12. Corehole 103: Box 4 —33.0 – 41.5 ft

Figure C-13. Corehole 104: Box 1 —1.0 - 14.0 ft

Figure C-14. Corehole 104: Box 2 —14.0 – 23.0 ft

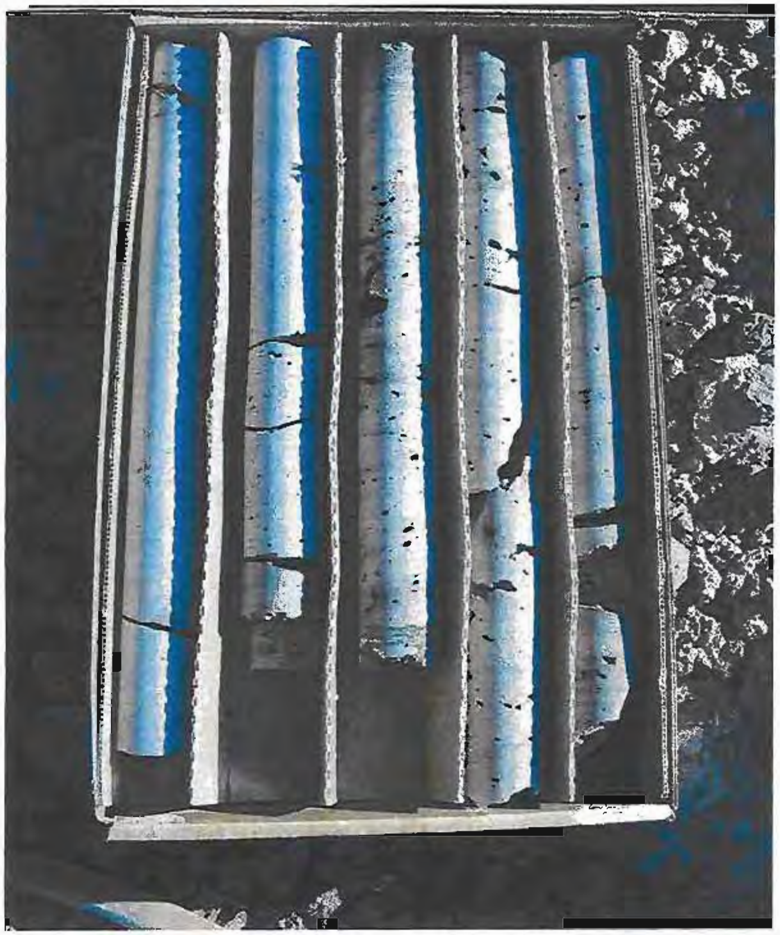


Figure C-15. Corehole 104: Box 3 —23.0 - 31.5 ft

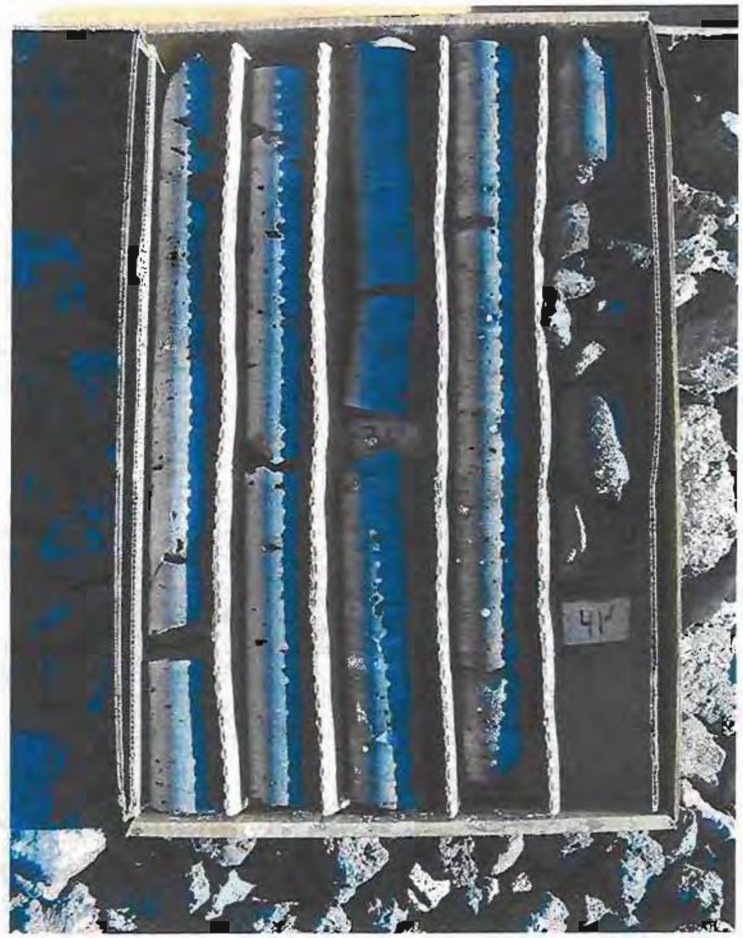


Figure C-16. Corehole 104: Box 4 —31.5 – 41.0 ft

Figure C-17. Corehole 105: Box 1 —1.5 - 15.5 ft

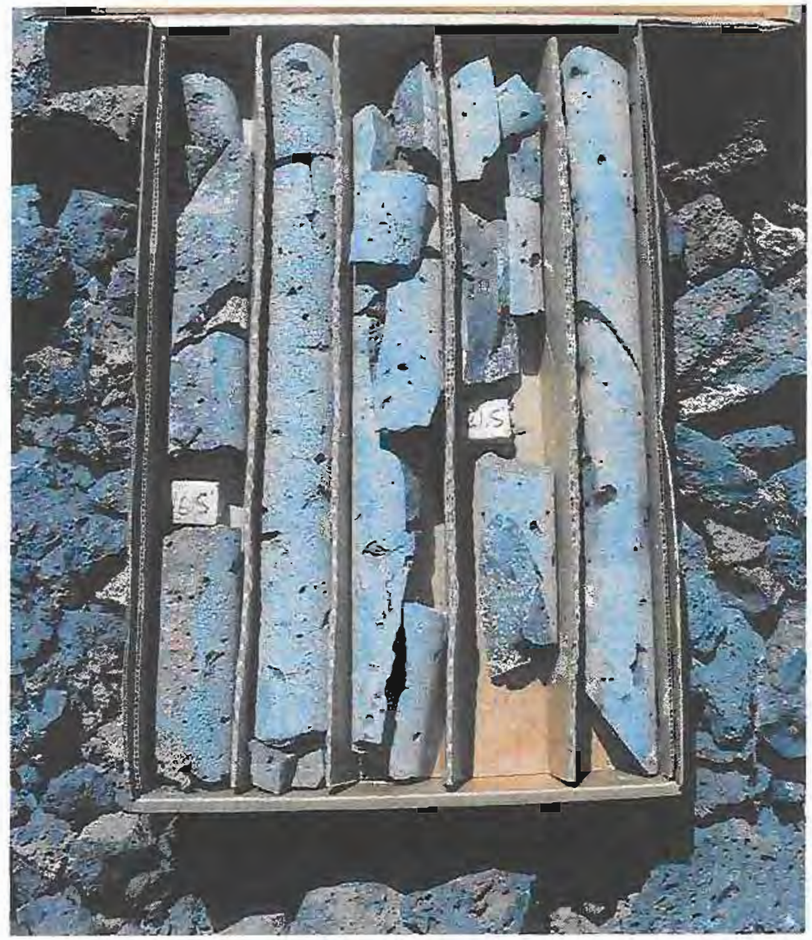


Figure C-18. Corehole 105: Box 2 —15.5 – 24.0 ft

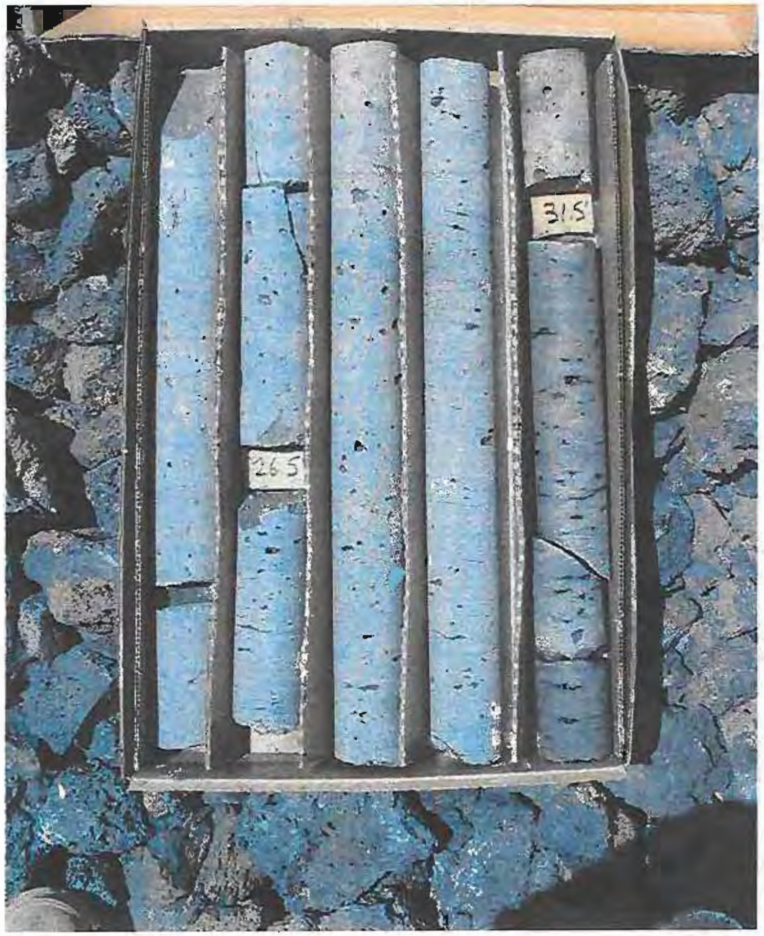


Figure C-19. Corehole 105: Box 3 —24.0 – 33.0 ft

Figure C-20. Corehole 105: Box 4 —33.0 – 41.5 ft

Figure C-21. Corehole 106: Box 1 —1.0 – 17.0 ft

Figure C-22. Corehole 106: Box 2 —17.0 – 26.5 ft

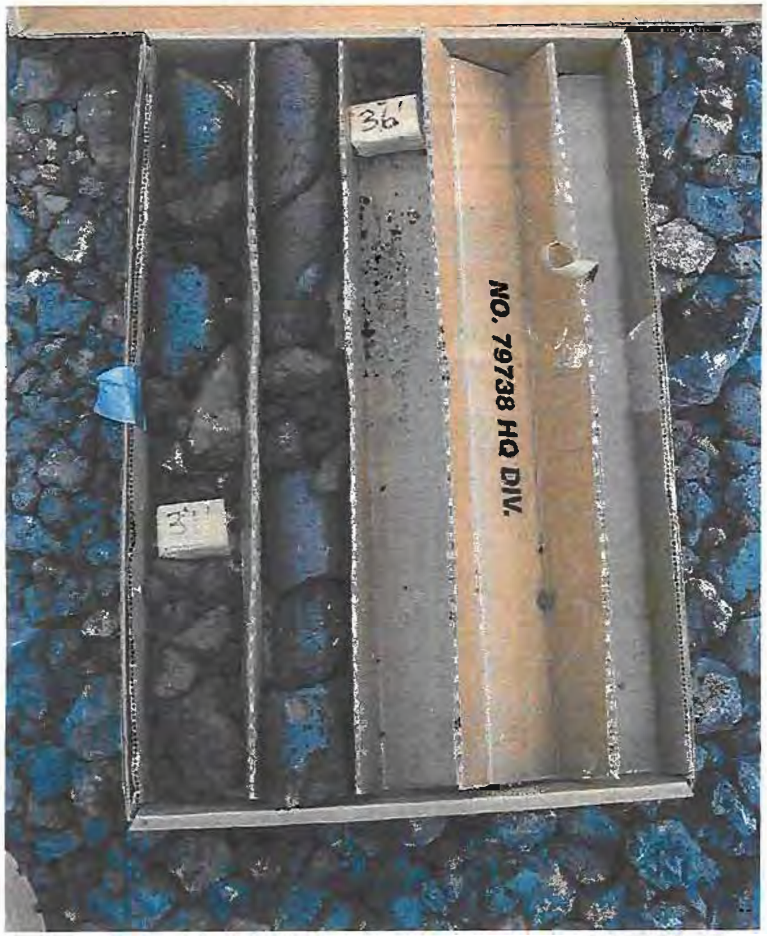


Figure C-23. Corehole 106: Box 3 —26.5 – 36.0 ft

Figure C-24. Corehole 107: Box 1 —1.0 – 13.5 ft

Figure C-25. Corehole 107: Box 2 —13.5 – 22.0 ft

Figure C-26. Corehole 107: Box 3 —22.0 – 36.0 ft

Figure C-27. Corehole 108: Box 1 —1.5 - 15.5 ft

Figure C-28. Corehole 108: Box 2 —15.5 – 27.5 ft

Figure C-29. Corehole 108: Box 3 —27.5 – 36.5 ft

Figure C-30. Corehole 108: Box 4 —36.5 – 41.5 ft

Figure C-31. Corehole 109: Box 1 —1.0 - 13.5 ft

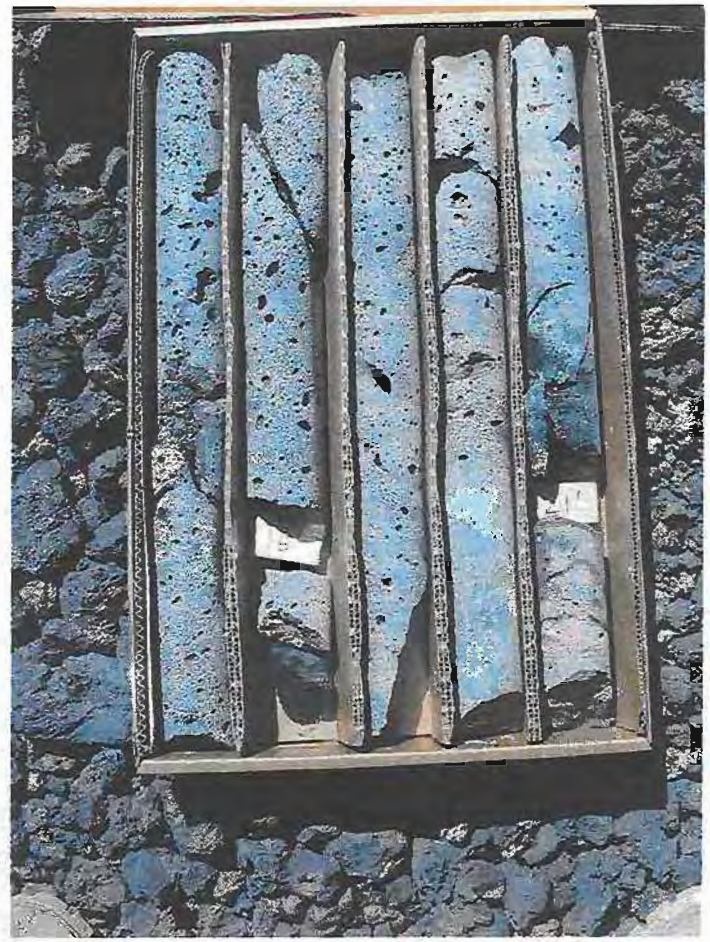


Figure C-32. Corehole 109: Box 2 —13.0 – 21.5 ft

Figure C-33. Corehole 109: Box 3 —21.5 - 31.0 ft

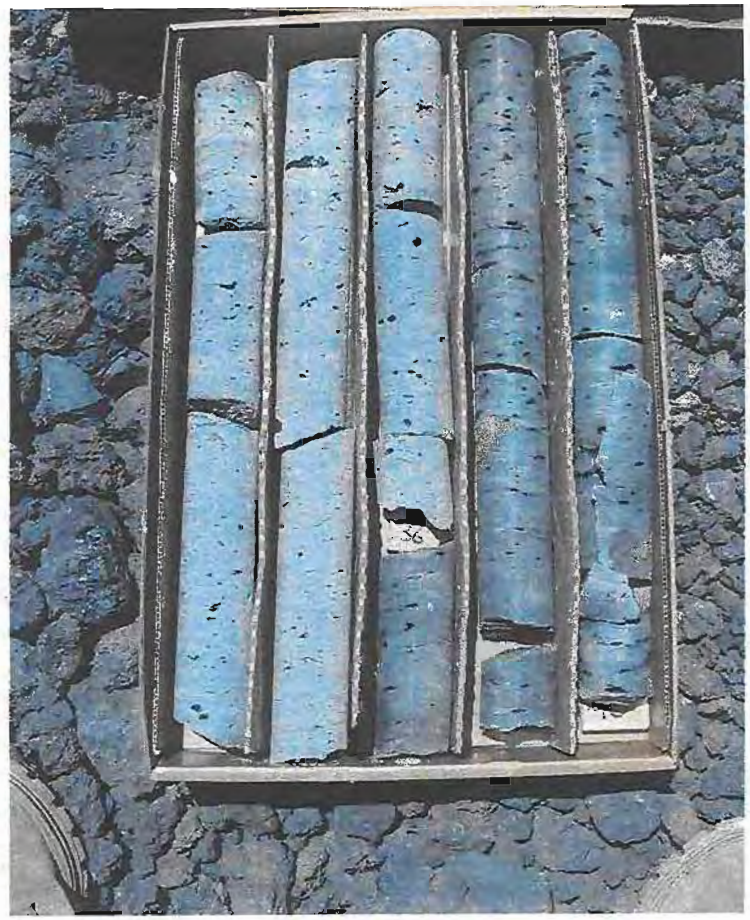


Figure C-34. Corehole 109: Box 4 —31.0 – 40.0 ft

Figure C-35. Corehole 110: Box 1 —1.5 - 21.5 ft

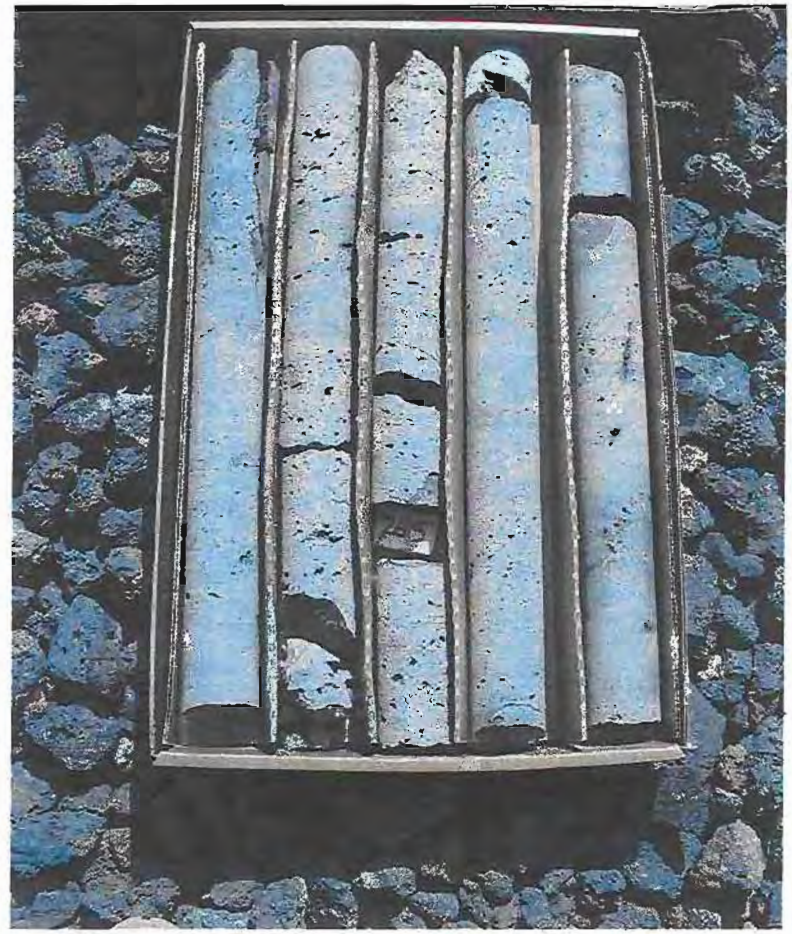


Figure C-36. Corehole 110: Box 2 —21.5 – 31.0 ft

Figure C-37. Corehole 110: Box 3 —31.0 - 41.5 ft

Figure C-38. Corehole 111: Box 1 —1.5 – 11.5 ft

Figure C-39. Corehole 111: Box 2 —11.5 - 25.5 ft

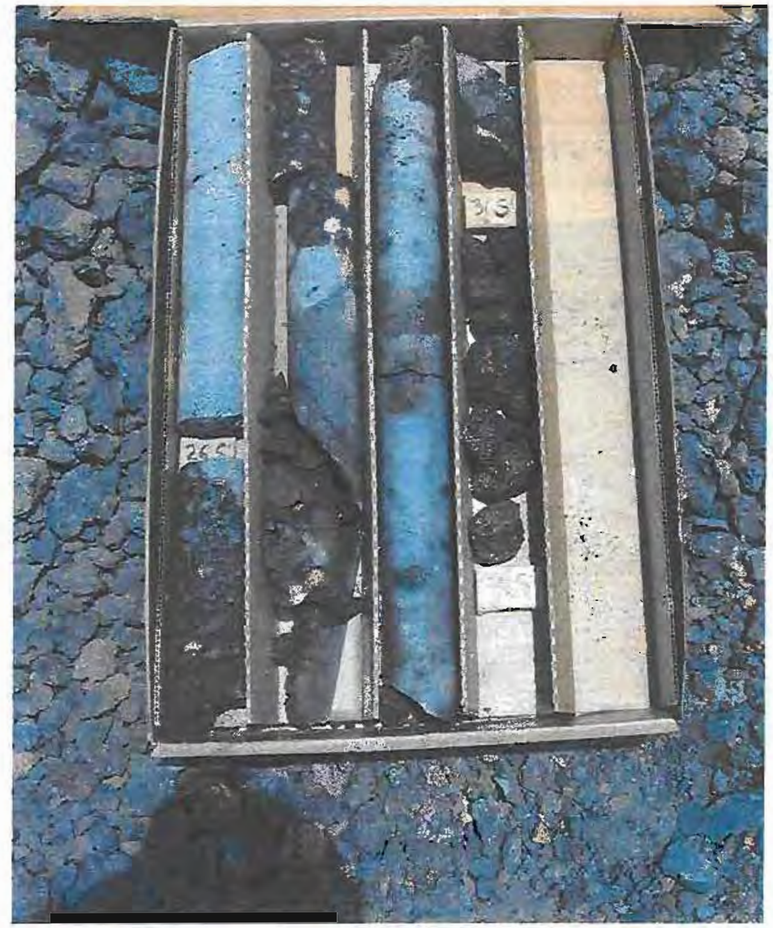


Figure C-40. Corehole 111: Box 3 —25.5 – 36.5 ft

Figure C-41. Corehole 112: Box 1 —1.0 - 14.0 ft

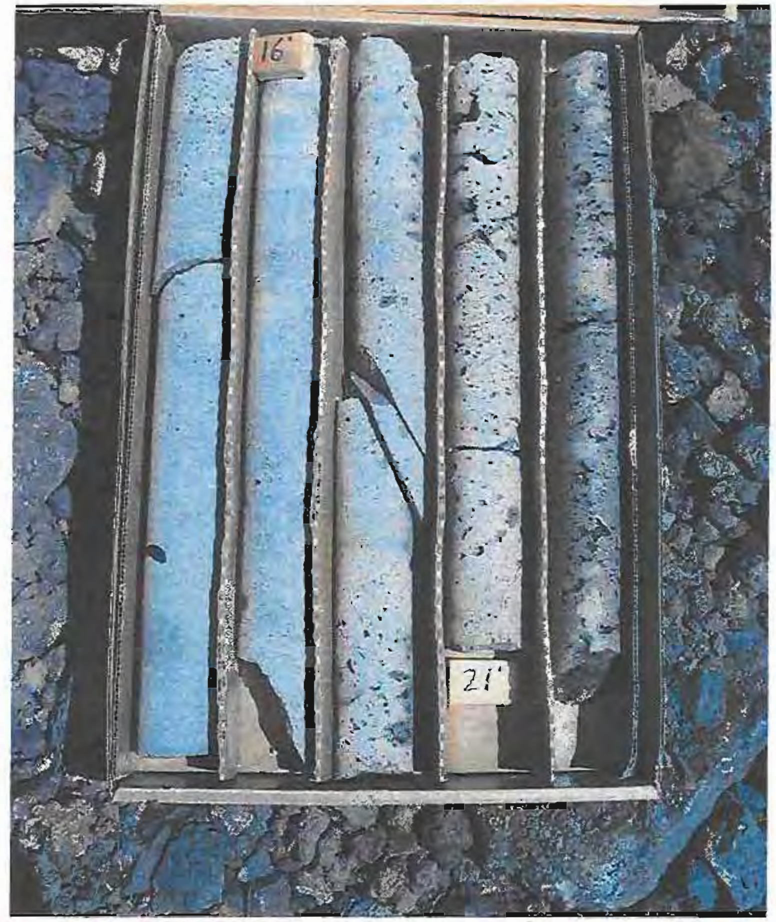


Figure C-42. Corehole 112: Box 2 —14.0 – 23.0 ft

Figure C-43. Corehole 112: Box 3 —23.0 – 31.0 ft

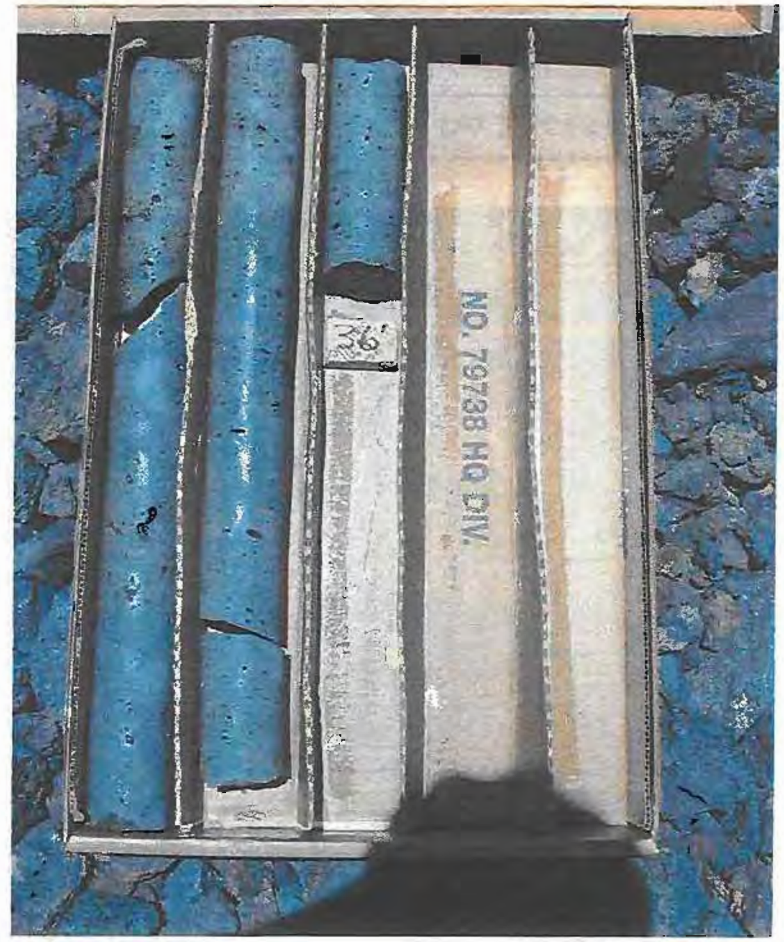


Figure C-44. Corehole 112: Box 4 —31.0 – 36.0 ft

Figure C-45. Corehole 113: Box 1 —2.0 - 19.0 ft

Figure C-46. Corehole 113: Box 2 —19.0 – 27.5 ft

Figure C-47. Corehole 113: Box 3 —27.5 – 32.0 ft

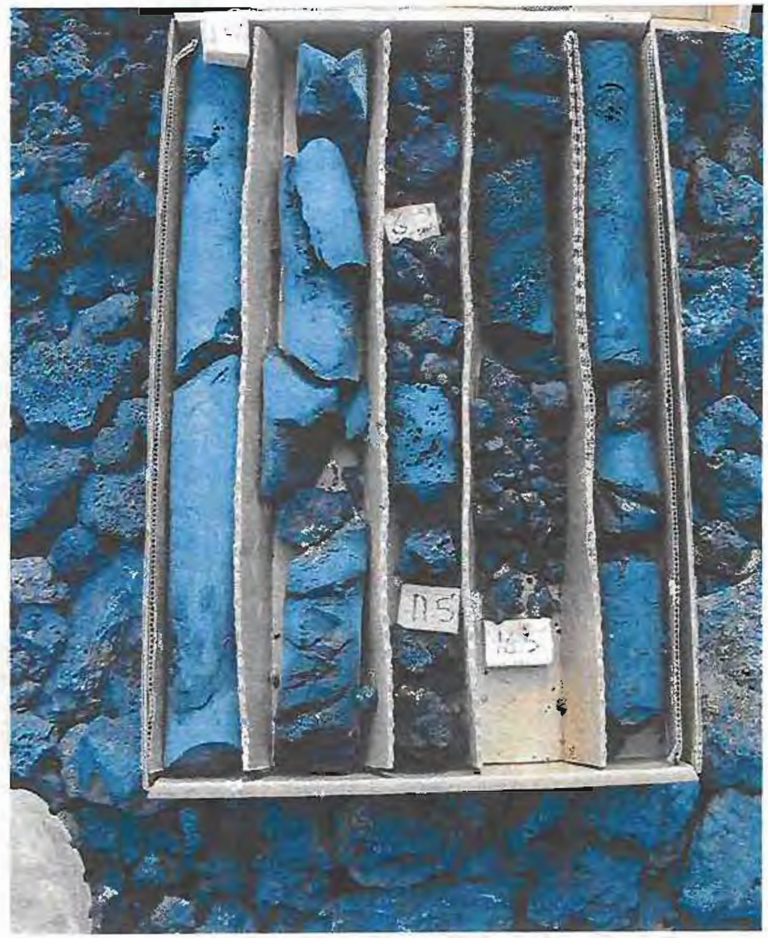


Figure C-48. Corehole 114: Box 1 —1.5 – 18.5 ft

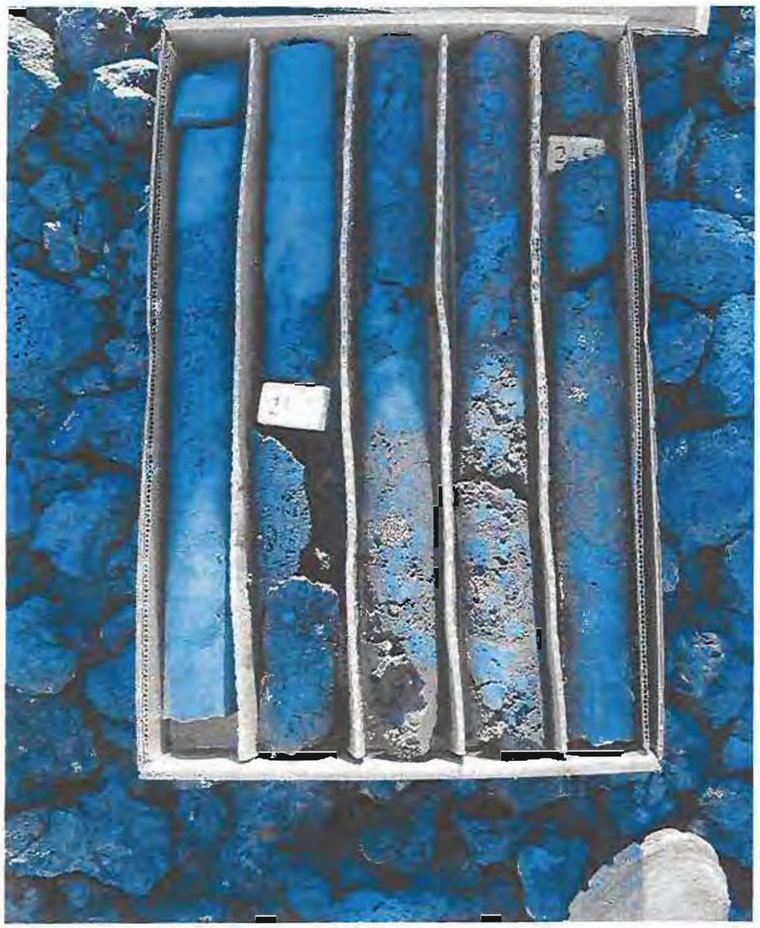


Figure C-49. Corehole 114: Box 2 —18.5 – 28.0 ft

Figure C-50. Corehole 114: Box 3 —28.0 – 35.5 ft

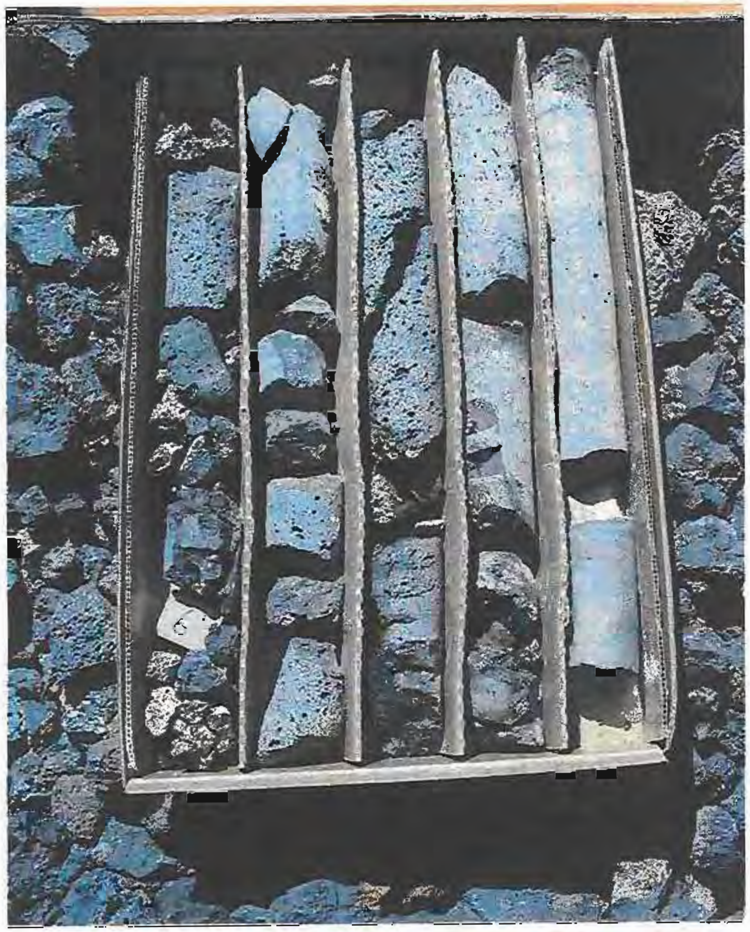


Figure C-51. Corehole 115: Box 1 —1.0 - 16.5 ft

Figure C-52. Corehole 115: Box 2 —16.5 – 26.0 ft

Figure C-53. Corehole 115: Box 3 —26.0 – 32.0 ft

Figure C-54. Corehole 116: Box 2 —0.5 – 20.5 ft

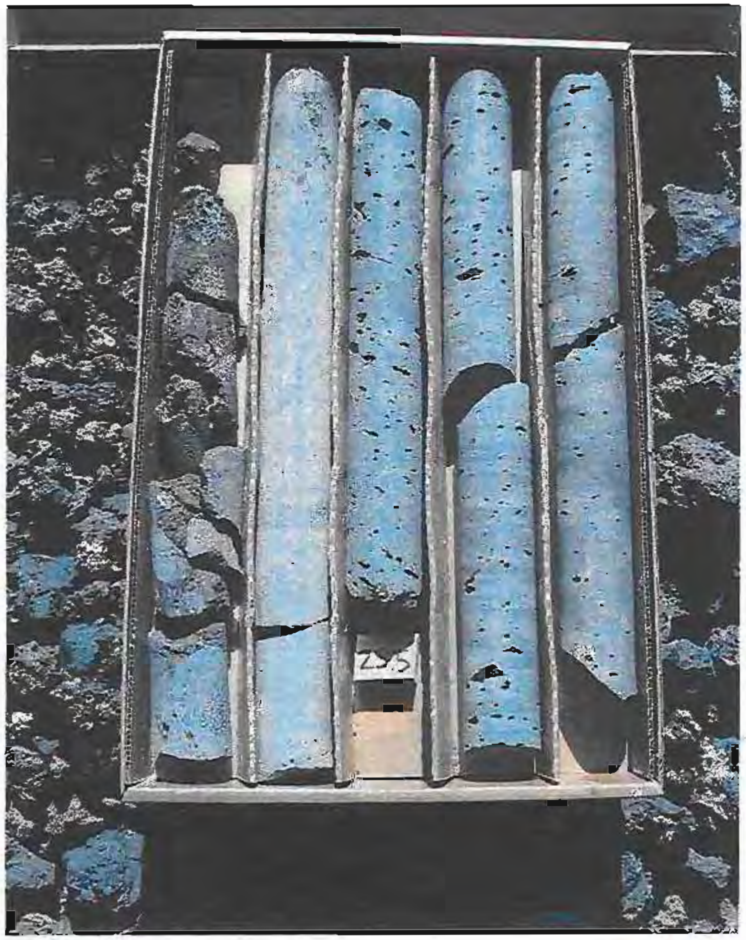


Figure C-55. Corehole 116: Box 2 —20.5 - 29.5 ft

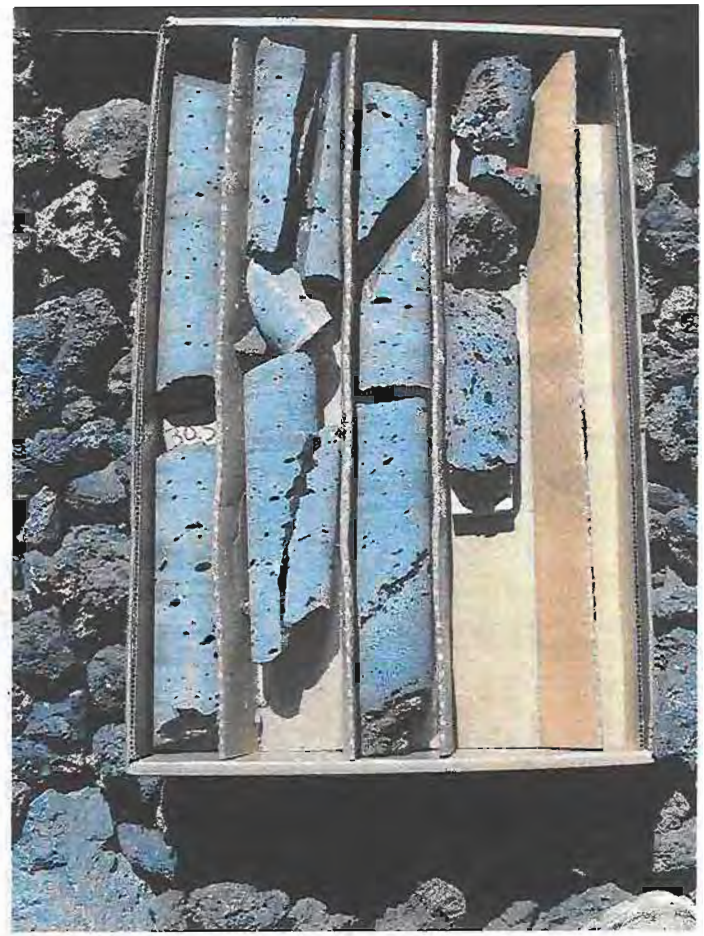


Figure C-56. Corehole 116: Box 3 —29.5 – 35.5 ft

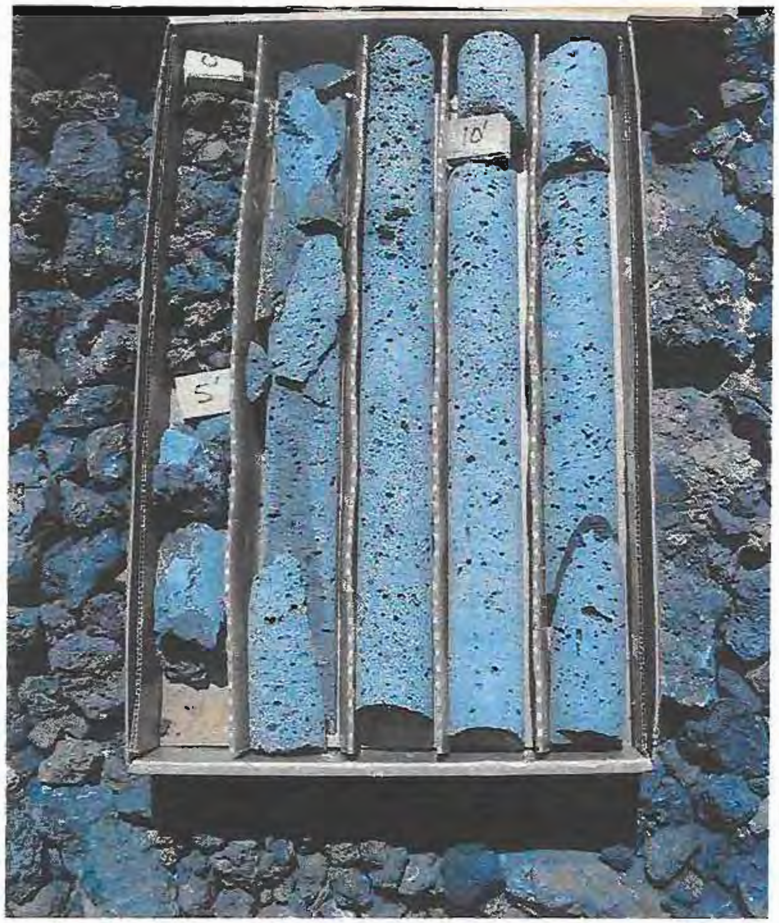


Figure C-57. Corehole 117: Box 1 —0.0 – 14.0 ft

Figure C-58. Corehole 117: Box 2 —14.0.- 28.0 ft

Figure C-59. Corehole 117: Box 3 —28.5 – 33.0 ft

Figure C-60. Corehole 118: Box 1 —1.0 – 13.0 ft

Figure C-61. Corehole 118: Box 2 —13.0 – 22.0 ft

Figure C-62. Corehole 118: Box 3 —22.0 – 30.5 ft

Figure C-63. Corehole 118: Box 4 —30.5 – 40.0 ft

Figure C-64. Corehole 119: Box 1 —0.5 – 12.5 ft

Figure C-65. Corehole 119: Box 2 —12.5 – 22.0 ft

Figure C-66. Corehole 119: Box 3 —22.0 – 30.0 ft

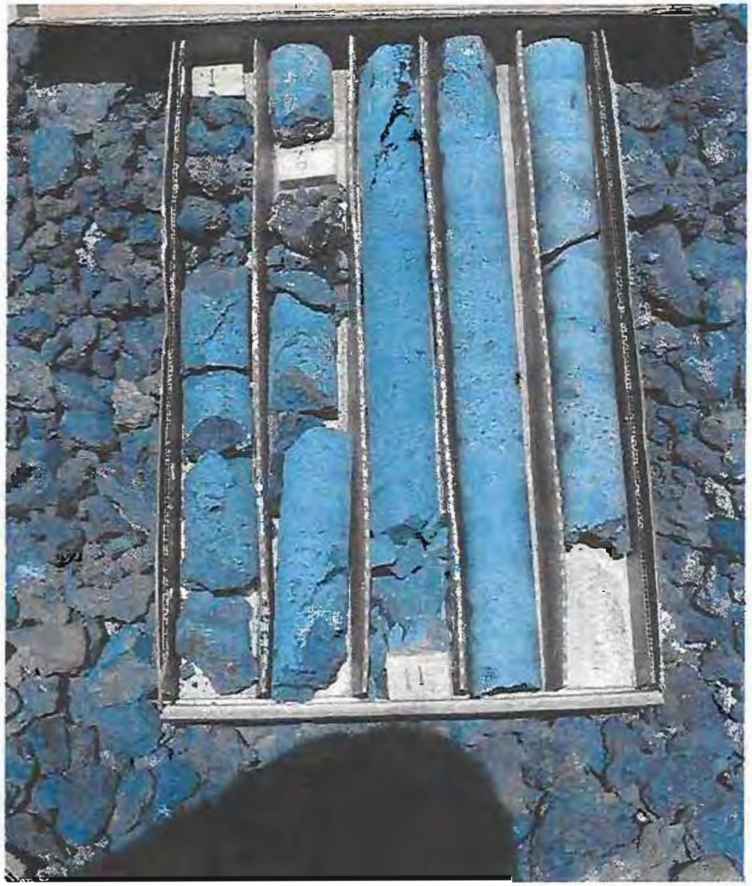


Figure C-67. Corehole 120: Box 1 –1.0 – 15.0 ft

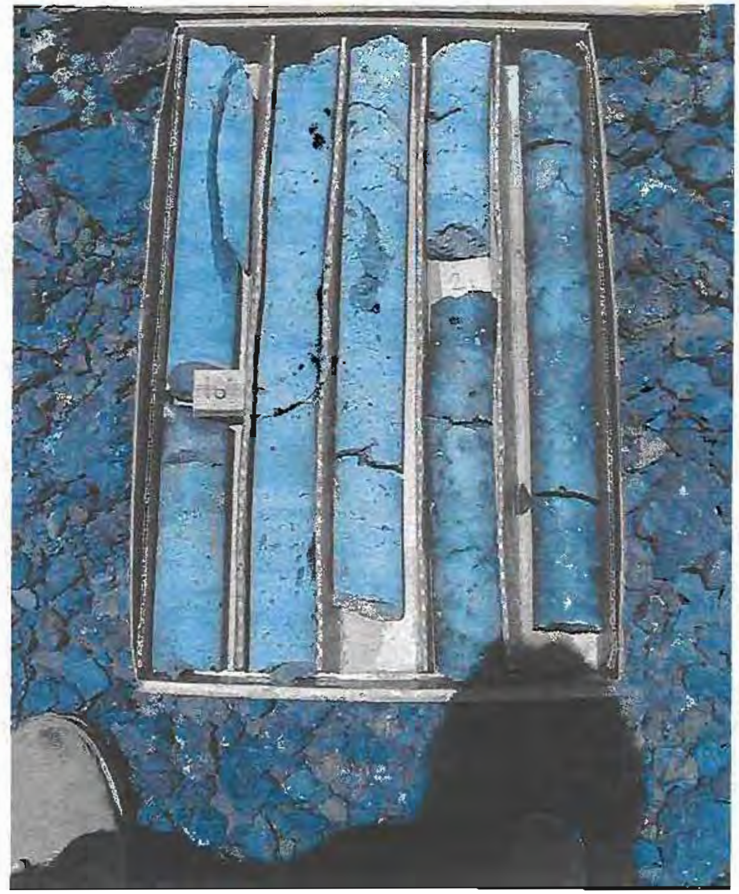


Figure C-68. Corehole 120: Box 2 —15.0 – 24.0 ft

Figure C-69. Corehole 120: Box 3 —24.0 – 31.0 ft

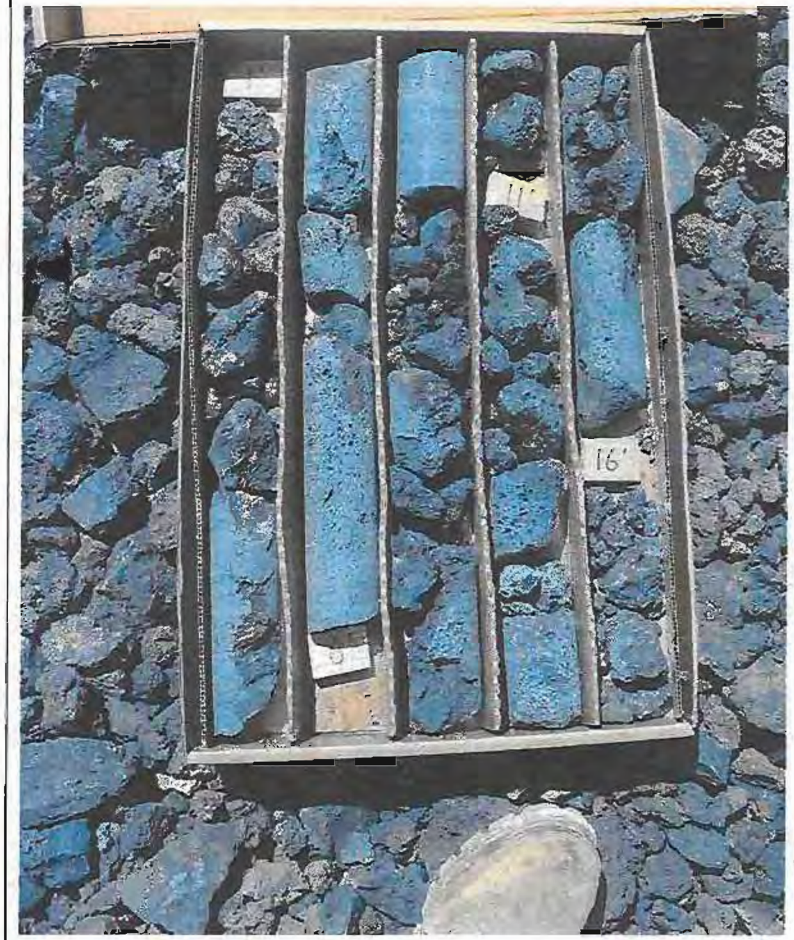


Figure C-70. Corehole 121: Box 1 —1.0 – 16.5 ft

Figure C-71. Corehole 121: Box 2 —16.5 – 31.0 ft

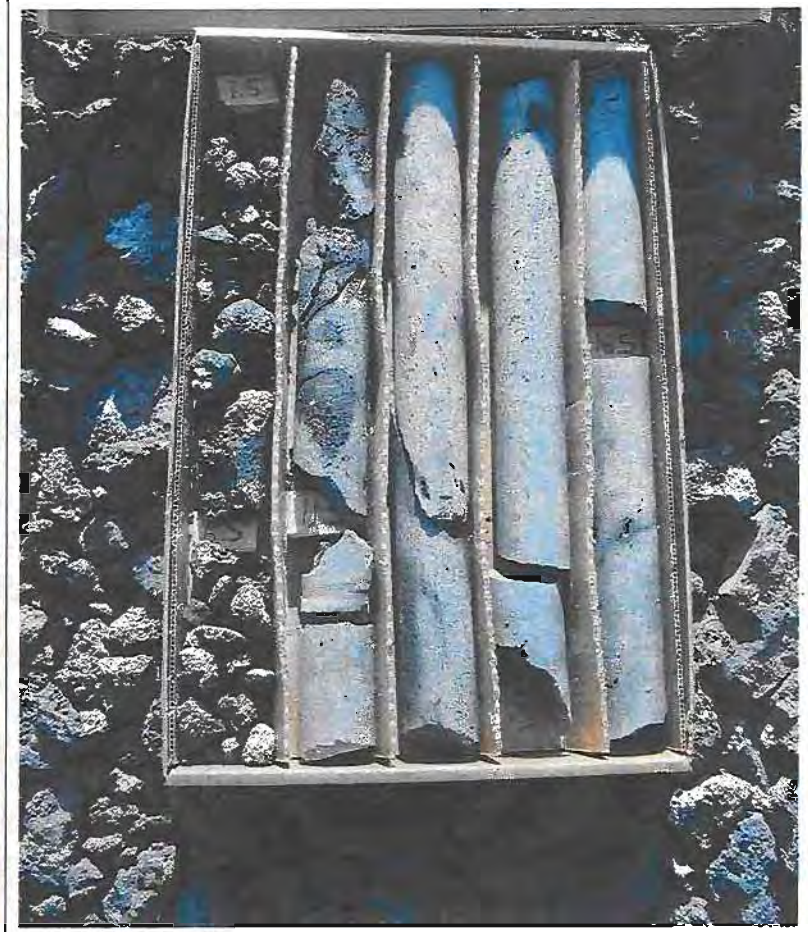


Figure C-72. Corehole 123: Box 1 —1.5 – 17.5 ft

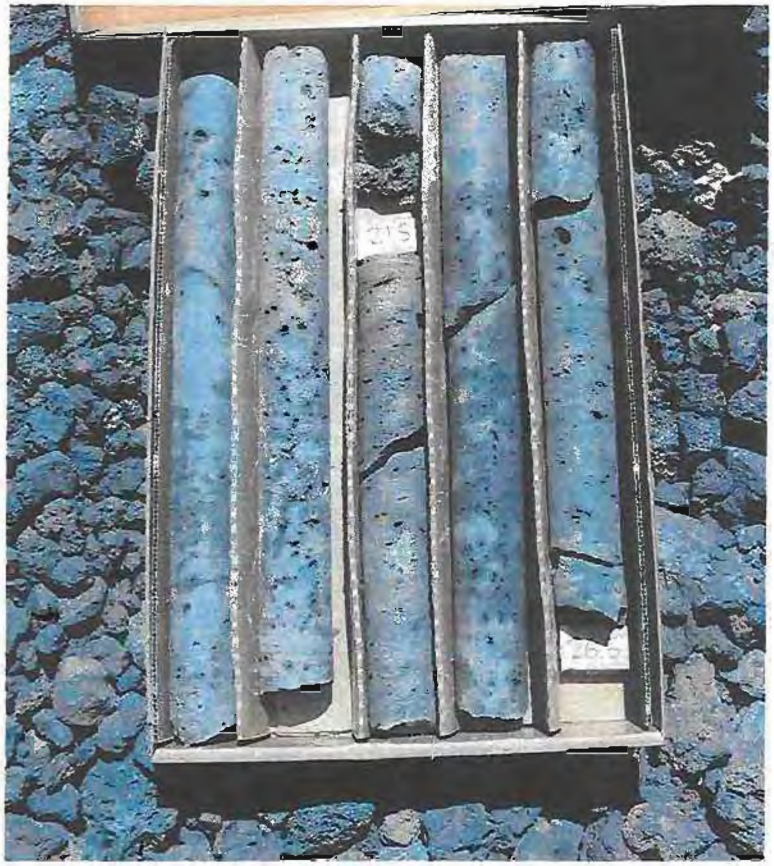


Figure C-73. Corehole 123: Box 2 —17.5 - 26.5 ft

Figure C-74. Corehole 123: Box 3 —26.5 – 35.5 ft

Figure C-75. Corehole 123: Box 4 —35.5 - 41.5 ft

Figure C-76. Corehole 125: Box 1 —1.5 – 16.5 ft

Figure C-77. Corehole 125: Box 2 —16.5 - 26.5 ft

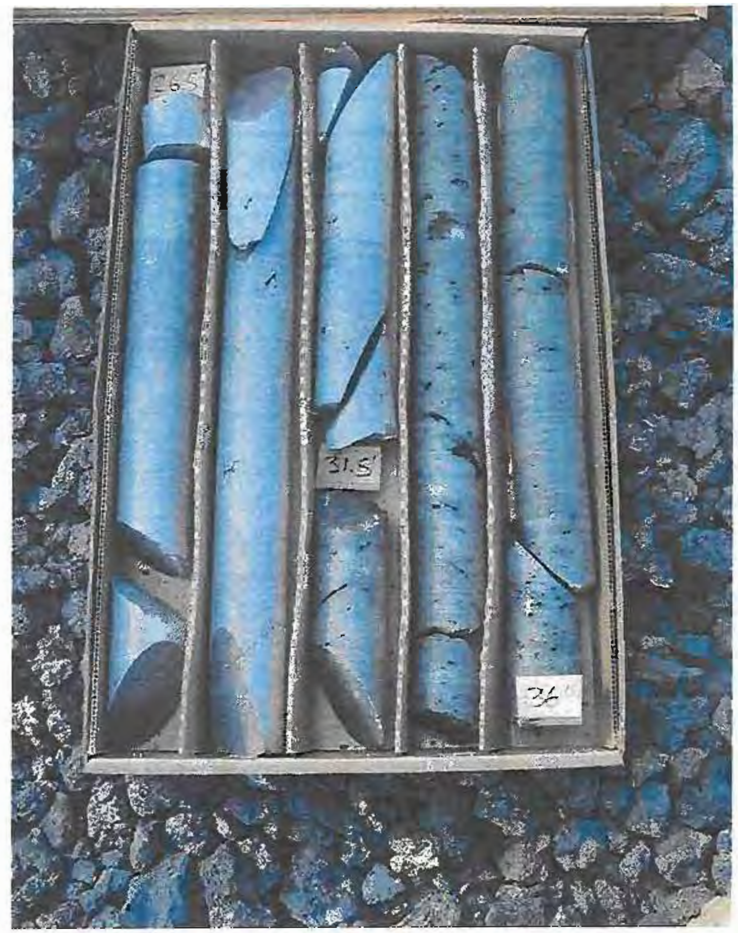


Figure C-78. Corehole 125: Box 3 —26.5 – 36.0 ft

	
Figure C-79. Corehole 127: Box 1 —1.5 – 12.0 ft	**Figure C-80. Corehole 127: Box 2 —12.0 – 22.5 ft**

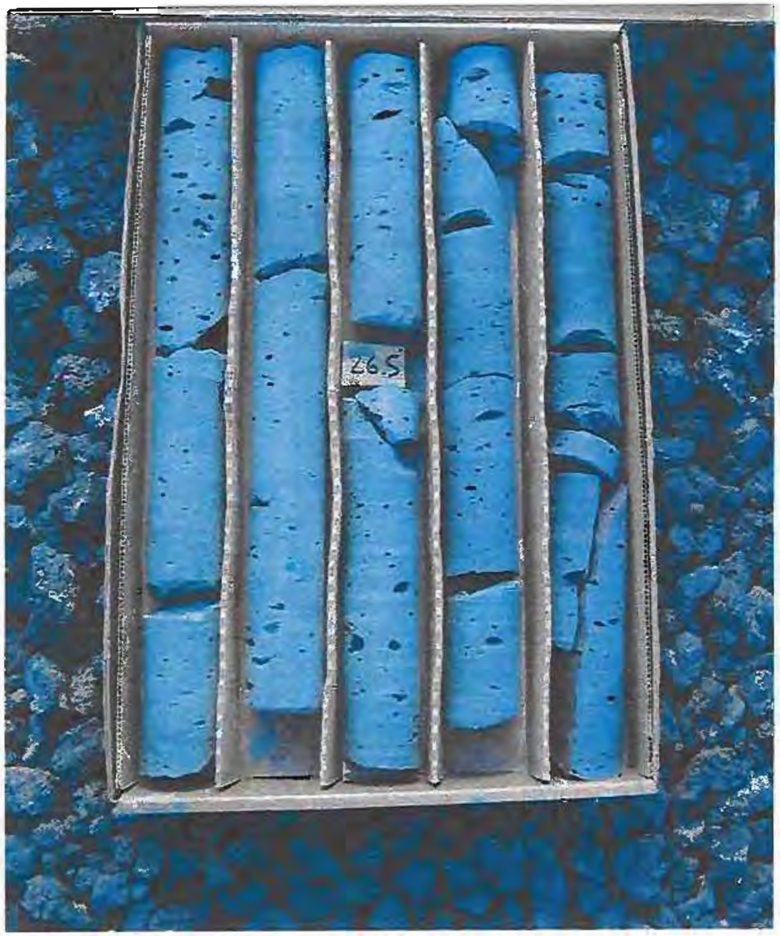


Figure C-81. Corehole 127: Box 3 —22.5 - 30.5 ft

Figure C-82. Corehole 127: Box 4 —30.5 – 35.0 ft

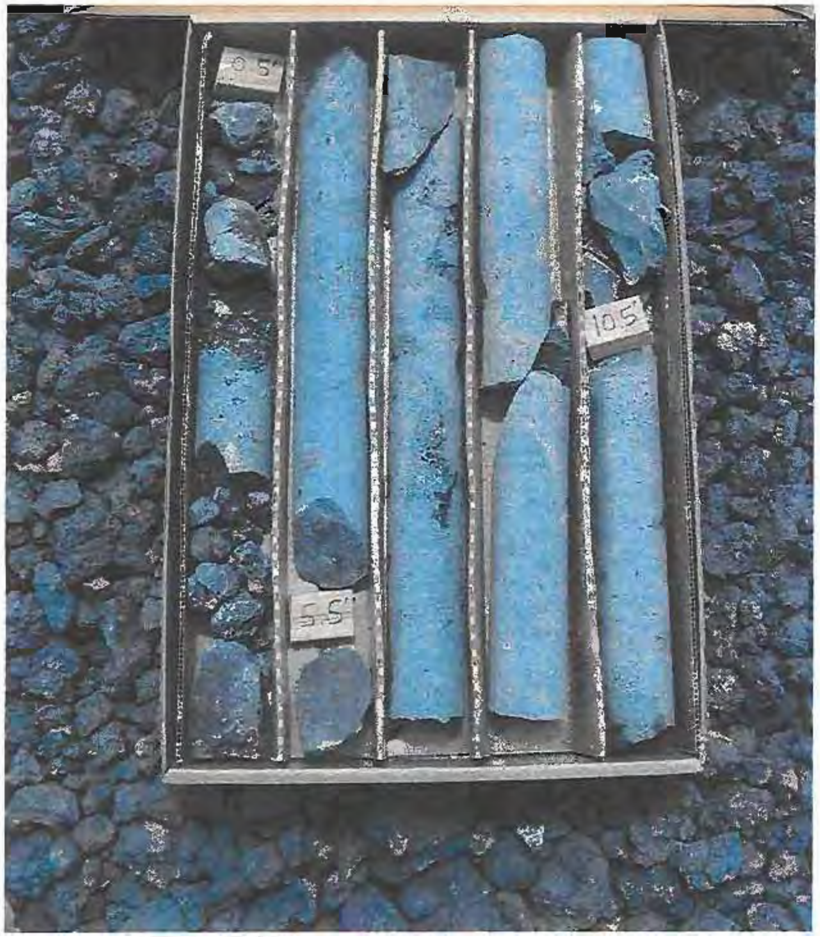


Figure C-83. Corehole 129: Box 1 —0.5 - 11.5 ft

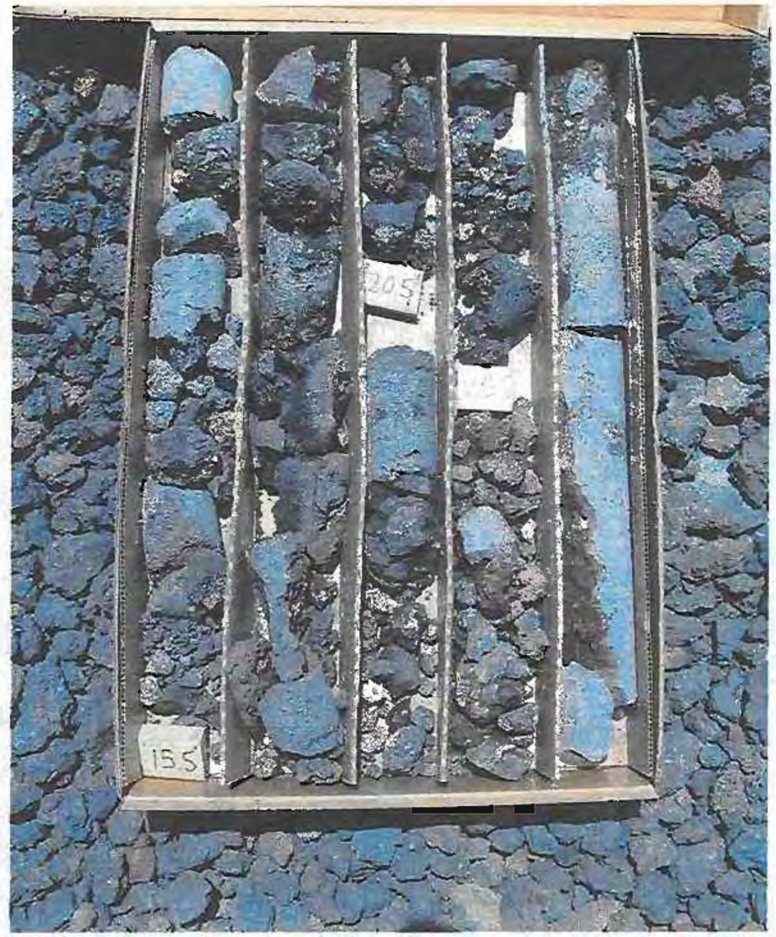


Figure C-84. Corehole 129: Box 2 —11.5 – 30.0 ft

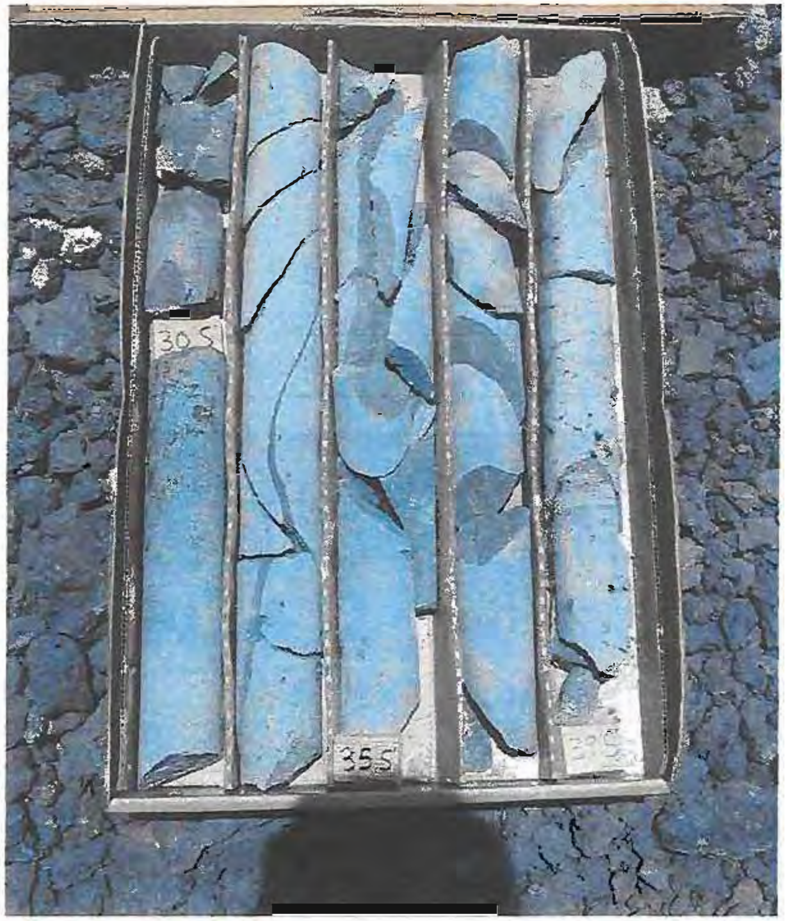


Figure C-85. Corehole 129: Box 3 —30.0 – 39.5 ft

Figure C-86 Drill rig set up for corehole 101 (Blurred)

Figure C-87 Drill rig set up for corehole 102

Figure C-88 Drill rig set up for corehole 103

Figure C-89 Drill rig set up for corehole 104

Figure C-90 Drill rig set up for corehole 105

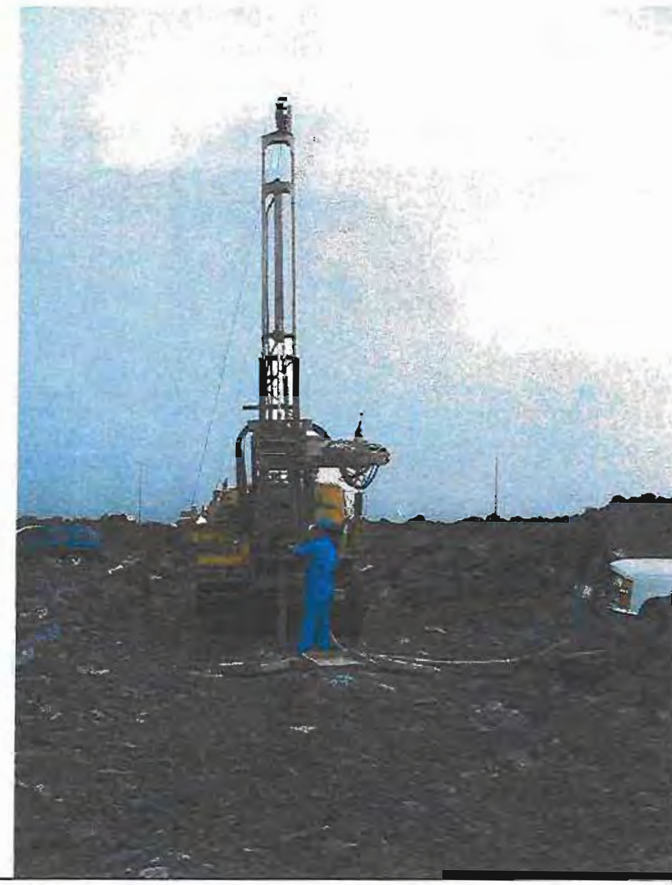


Figure C-91 Drill rig set up for corehole 106

Figure C-92 Drill rig set up for corehole 107

Figure C-93 Drill rig set up for corehole 108

Figure C-94 Drill rig set up for corehole 109

Figure C-95 Drill rig set up for corehole 110

Figure C-96 Drill rig set up for corehole 111

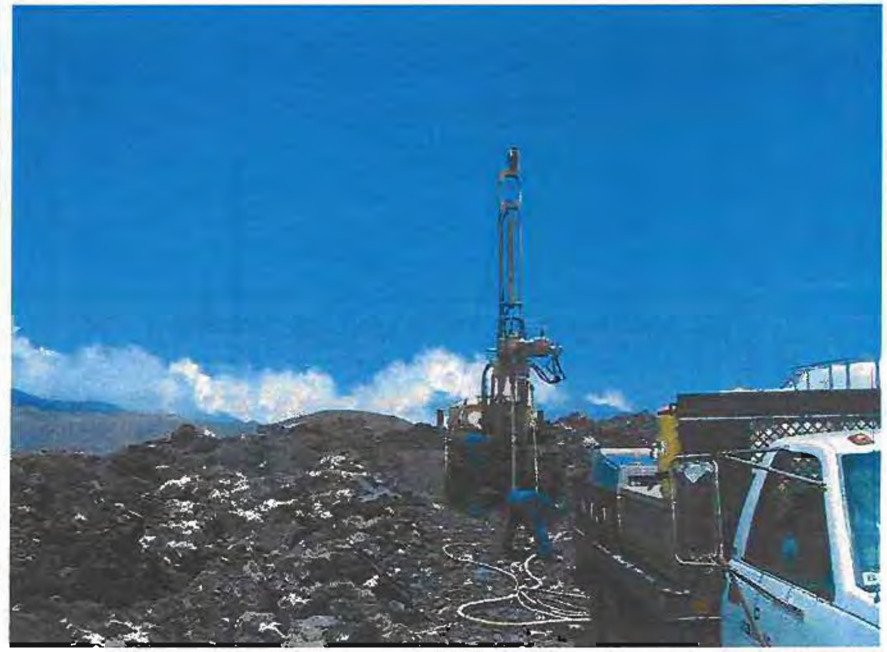


Figure C-97 Drill rig set up for corehole 112

Figure C-98 Drill rig set up for corehole 113

Figure C-99 Drill rig set up for corehole 114

Figure C-100 Drill rig set up for corehole 115

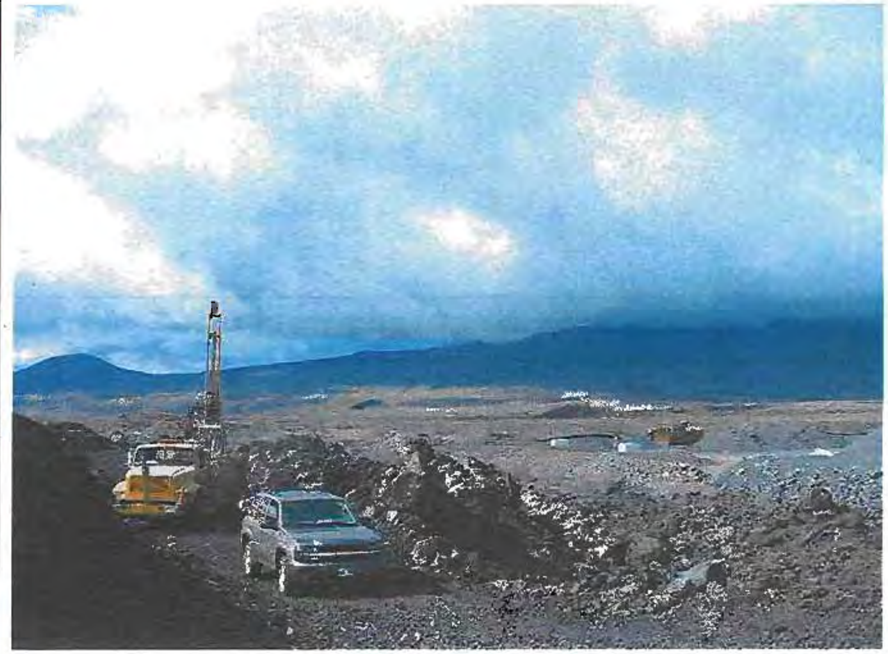
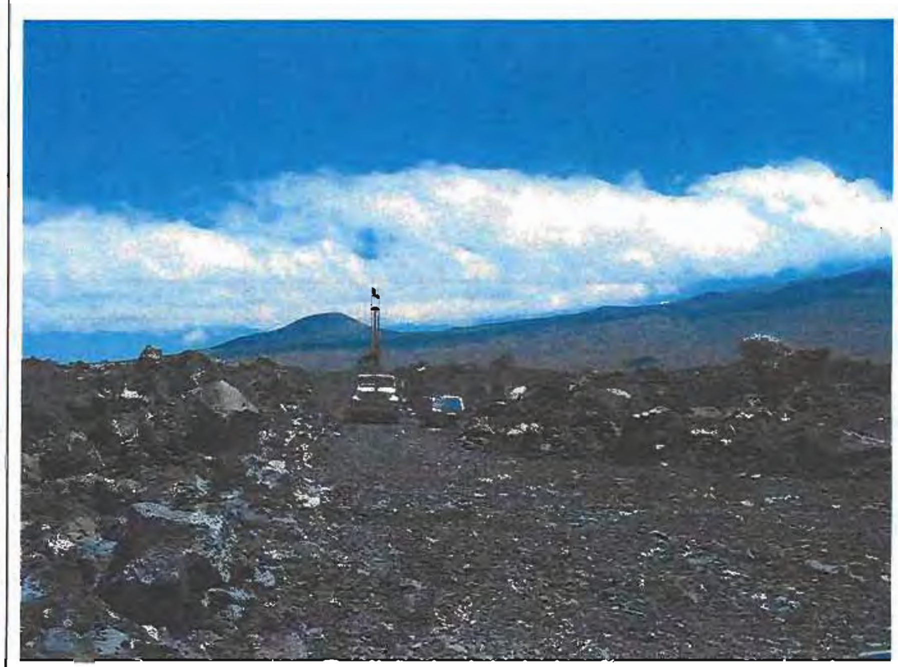


Figure C-101 Drill rig set up for corehole 116


Figure C-102 Drill rig set up for corehole 117


Figure C-103 Drill rig set up for corehole 118

	
Figure C-104 Drill rig set up for corehole 119	Figure C-105 Drill rig set up for corehole 120

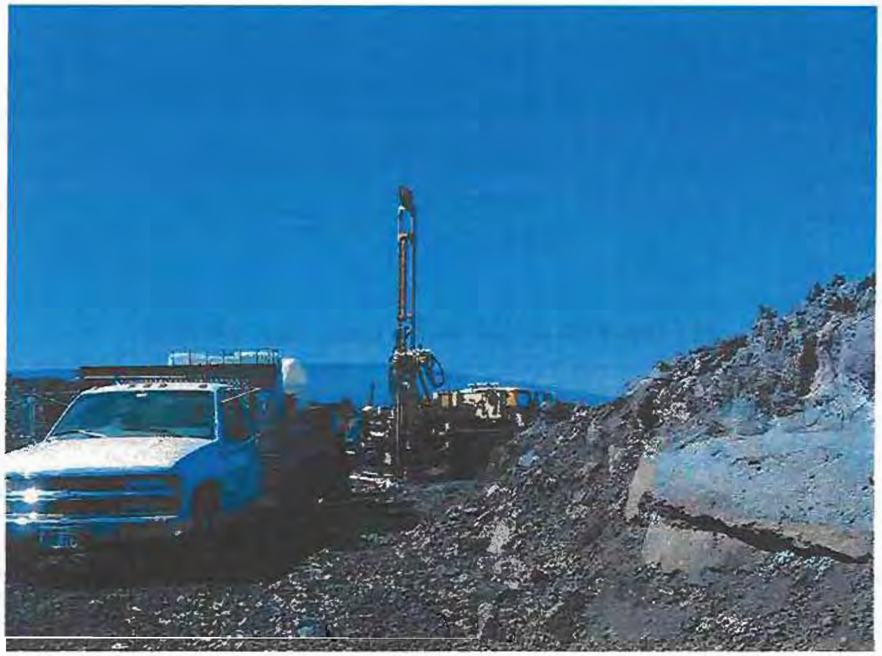


Figure C-106 Drill rig set up for corehole 121

Figure C107- Drill rig set up for corehole 123

Figure C-108 Drill rig set up for corehole 125

Figure C-109 Drill rig set up for corehole 127

Figure C-110 Drill rig set up for corehole 129

Appendix D

Geophysics Investigation Results

Seismic Refraction and ReMi Surveys

Seismic Refraction Surveys

INTRODUCTION

Seismic refraction surveys are often used to enhance subsurface geotechnical investigations where laterally discontinuous soil and rock units are anticipated and/or drilling access may be physically or economically limited. Refraction surveys can provide quick and affordable subsurface characterization over large areas, providing both strata characterization and rock mass physical parameters useful in developing construction alternatives. However, the method does rely on several simplifying assumptions the user should be aware of, limiting its application in some settings.

CONDUCTING THE SURVEY

Seismic refraction involves placing a line of regularly spaced sensors (geophones) on the surface and measuring the relative arrival time of seismic energy transmitted from a specified source location. Refraction data are recorded in the field using a portable seismograph, multiple geophones (generally 12 per line), a repeatable seismic source, and a power source. For example, a 24-channel Geometrics SmartSeis seismograph is used for data collection and display by CFLHD. Geophones, generally <15Hz, are vertically implanted in the ground at a predetermined spacing (5-6 m) to record travel times and amplitude of the seismic energy traveling through the earth. Typical seismic sources include such things as a sledgehammer striking a metal plate, shotgun source (e.g., Seisgun), or possibly light explosive charges. Sledgehammer sources are generally used for depths less than 10-15 m; whereas explosives may be required in soft ground conditions for depths up to 30 m. Seismic sources generate both compression (P) and shear (S) waves and, although either may be used for subsurface imaging, P waves are preferred since they are not absorbed by saturated soil units (shear waves cannot transmit through water). Seismic energy travels with a compression velocity that is characteristic of the density, porosity, structure, and water content of each geologic layer.

The design of a seismic refraction survey reflects the anticipated soil/rock velocities to be encountered, overburden depths to be interrogated, and the end-use of the data (e.g., subgrade evaluation or deep foundation design). With this knowledge a plan is developed which defines the data collection parameters best suited for a successful survey. These parameters include the length of the geophone spread, spacing between the geophones, expected "first-break" arrival times at each of the geophones, and the best locations for off-end shots. Normally, five seismic source locations are selected for each seismic spread; one at each end of the spread (forward and reverse shots), one at a predetermined distance from each end of the spread (off-end shots), and one between the two centermost geophones within the spread (center shot). Multiple shot points permit improved delineation of soil/rock interfaces throughout the depths covered by the survey.

Data processing and interpretation at CFLHD is conducted using the SeisImager interactive refraction interpretation code. Using this software, seismic refraction data is refined, analyzed, and interpreted using either the *intercept-time term* inversion method or the *tomographic* inversion method. If the time inversion method is used, the subsurface profile is resolved into distinct layers with average velocities. The tomographic inversion method conducts a similar analysis as that of the time inversion method, but portrays the subsurface velocity profile as color-coded gradient plot. Both methods are equally useful for identifying key subsurface units and their distribution along the survey.

Seismic refraction surveys are commonly used to characterize:

- Thickness and lateral continuity of specific soil/rock units;
- Depths to competent subsurface layers or the soil/rock interface; and
- Absolute soil/rock unit velocities for estimating material rippability.

The color-coded sectional plots (shown in this appendix) represent the subsurface velocity distribution – which *may or may not represent the distribution of material types*. Saturated soil zones, localized differences in soil density, and increased frequency of jointing within a given rock unit are all examples of structural features within a rock or soil type that may substantially alter the velocity at that location. A particular velocity can represent more than one rock or soil setting, largely influenced by the presence of structures. For example, a moderate to dense sandy soil may have a similar velocity to a highly jointed and weathered granite rock mass. Successful interpretation requires correlation to nearby borings or surface outcrop maps. Seismic surveys are not intended to supplant more traditional subsurface sampling investigations, but aid in quickly and economically extending subsurface characterization over larger areas – "filling-in" the gaps between discrete borings.

Limitations of the Method

A restrictive limitation of seismic refraction is that each of the successively deeper refractors (soil/rock layers) must have a higher velocity than the one above. This limitation is not generally restrictive when attempting to characterize bedrock depths (deeper rock units almost always have higher velocities); however, situations do arise where overlying soil or rock units have higher velocities than the lower units (e.g., saturated clays over loose sands, or volcanic extrusive over sedimentary rock). For this reason, seismic refraction surveys should always be correlated to subsurface borings to determine applicability of the results.

Another restriction involves imaging in saturated soils – seismic energy is transmitted through the saturated soil mass at the velocity of water (1,400-1,600 m/s), *not* the velocity of the unsaturated soil. If saturated soils overlie weak rock units, or strong units with frequent discontinuities (e.g., highly jointed granite), the boundary may become indistinguishable.

Background seismic noise, propagating through both the ground and air (e.g., commuter traffic, construction equipment, nearby blasting operations, moving water, wind, etc.), may interfere with data collection, obscuring refraction survey arrival times and making analysis and interpretation difficult to impossible. Oftentimes, this problem can be overcome by employing various filtering techniques, "stacking" the source signals, or by using larger impact sources. In general, "noisy" data leads to greater uncertainty in data refinement and interpretation.

Seismic refraction results are presented as representing subsurface conditions in a *vertical* plane directly beneath the survey line. While for most cases this may be true, source-to-receiver raypaths may actually be traveling out of this vertical plane, through nearby higher-velocity materials (e.g., in the case of steeply dipping strata). In discontinuous ground, or settings with highly variable deposition, seismic surveys could result in inaccurate subsurface profiles.

The data for each line is presented as follows:

1. A data sheet showing geophone and source location for each seismic spread.
2. A travel time versus distance plots for each seismic spread
3. A tomographic Image depicting various velocities in the subsurface along a given spread.
4. A figure with three average velocities in the subsurface.

Seismic Refraction Surveys

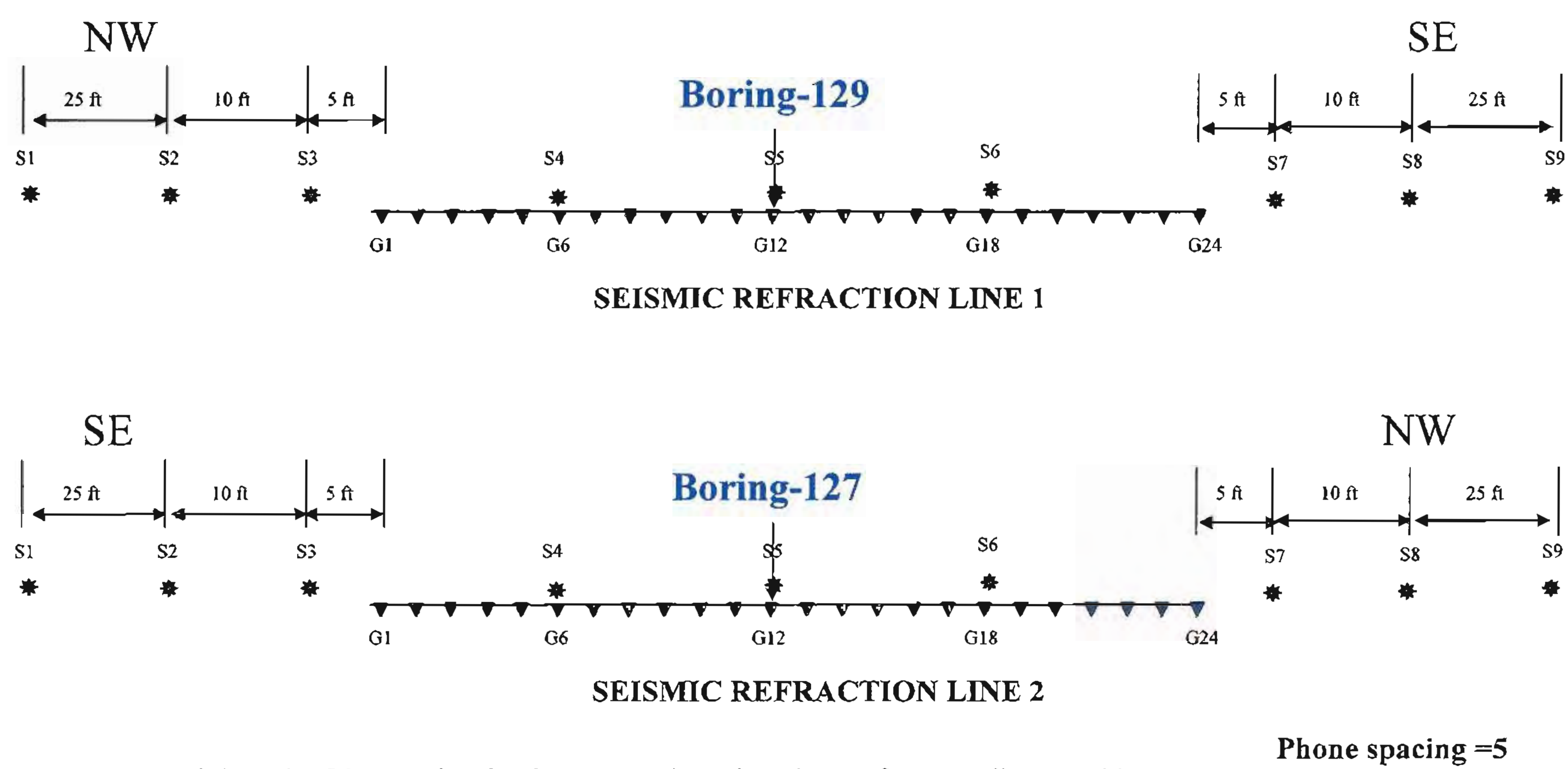


Figure D-1. Schematic of the seismic refraction and ReMi geophone layouts for survey lines 1 and 2.

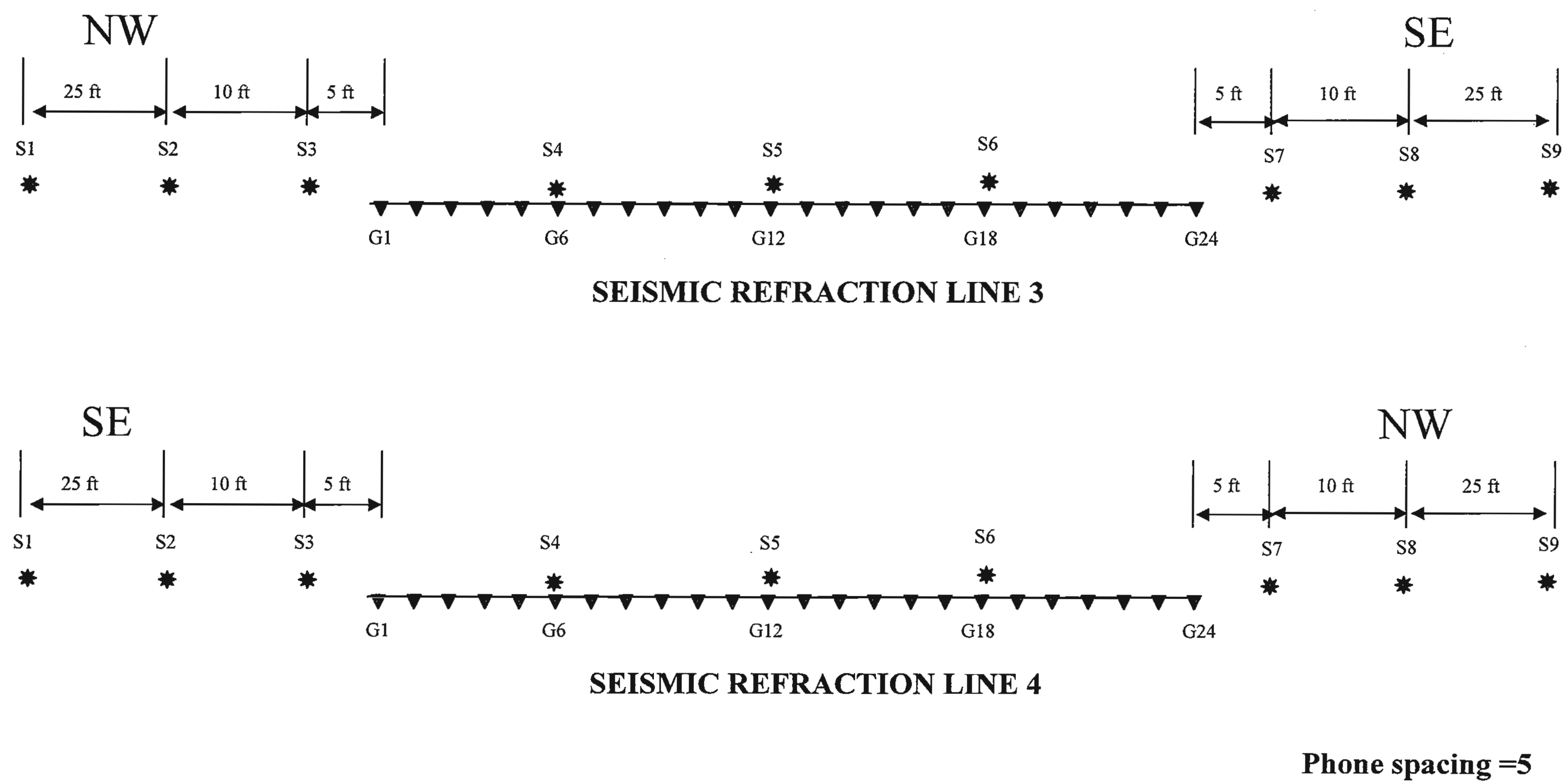


Figure D-2. Schematic of the seismic refraction and ReMi geophone layouts for survey lines 3 and 4

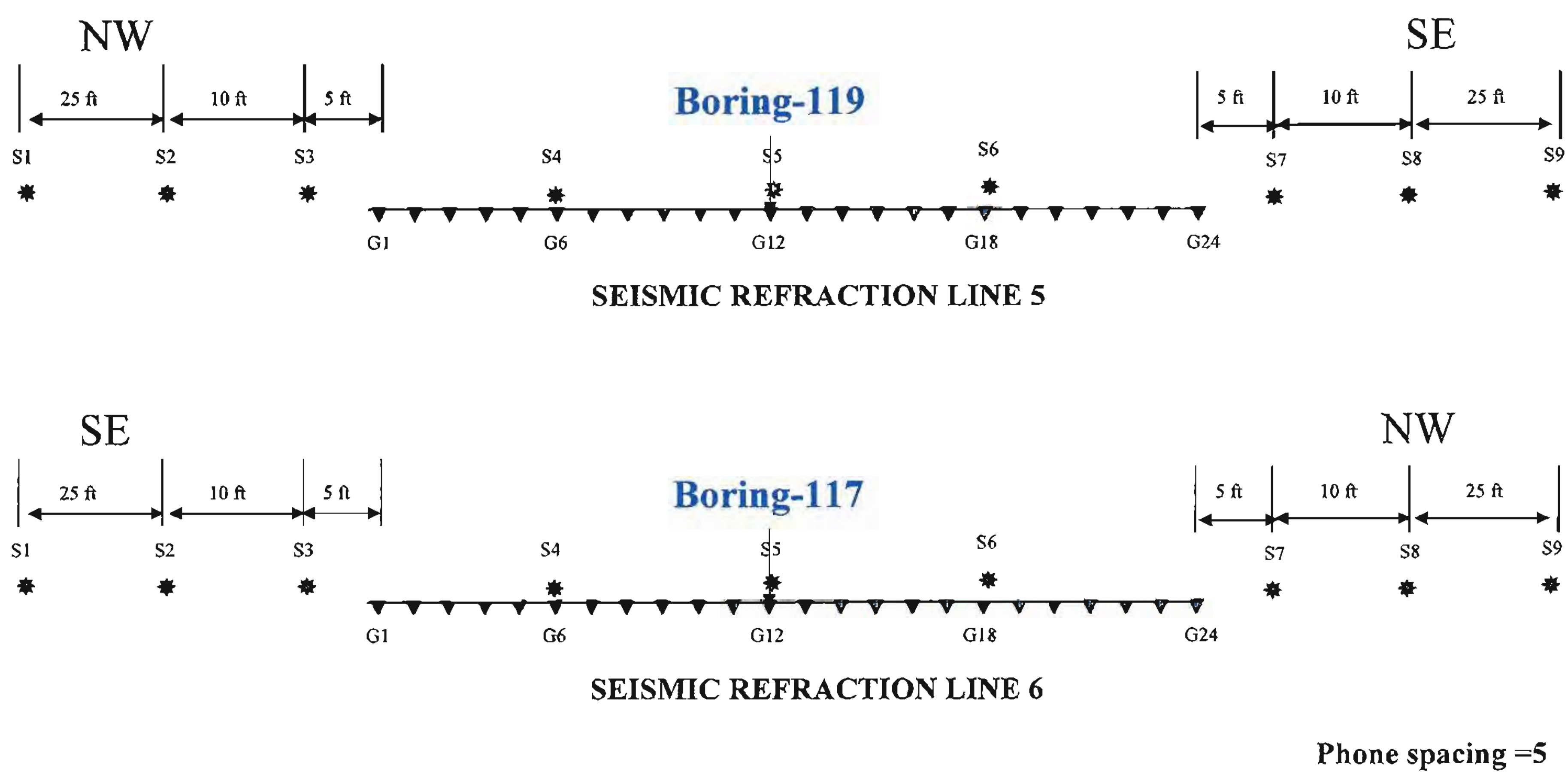


Figure D-3. Schematic of the seismic refraction and ReMi geophone layouts for survey lines 5 and 6

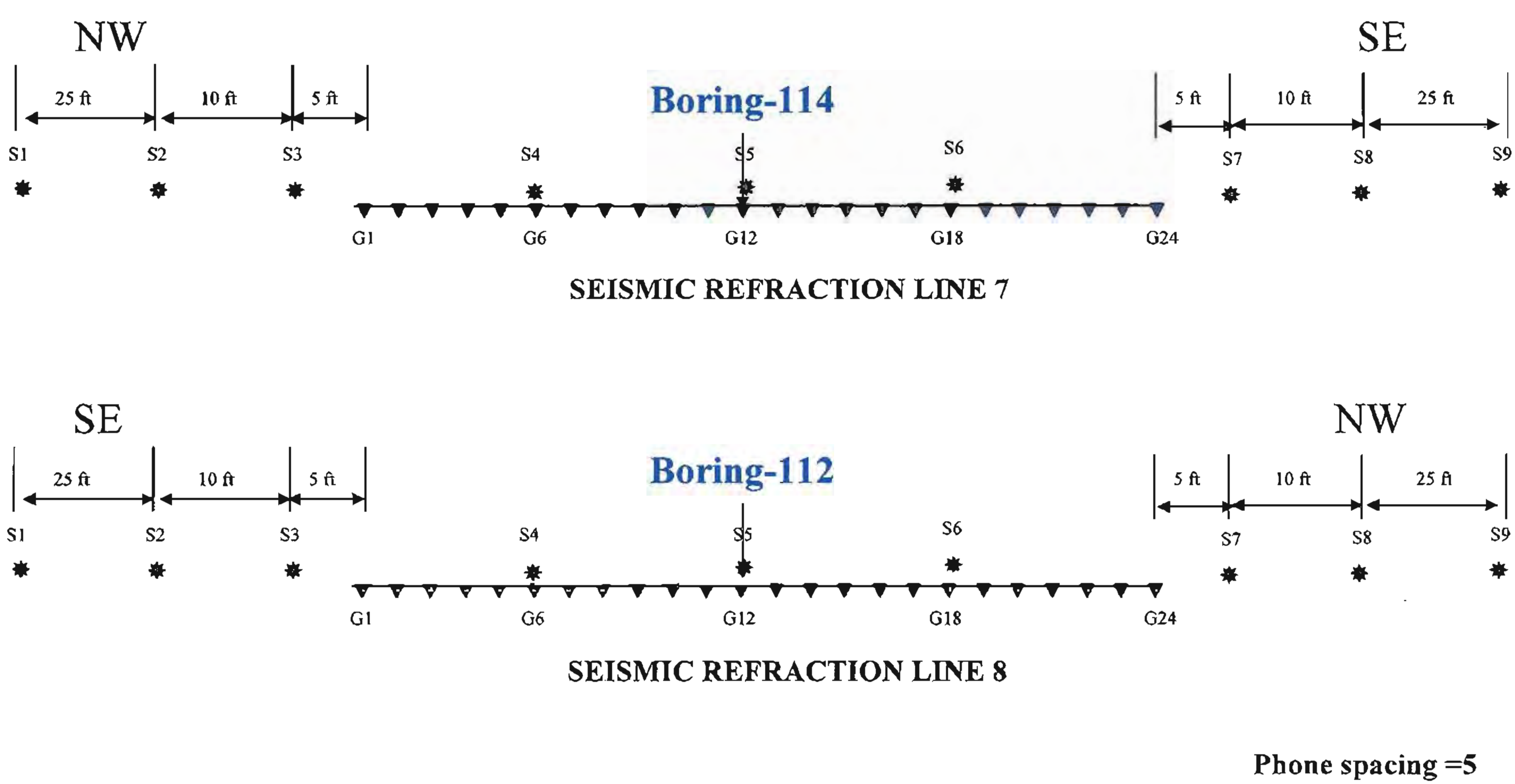


Figure D-4. Schematic of the seismic refraction and ReMi geophone layouts for survey lines 7 and 8

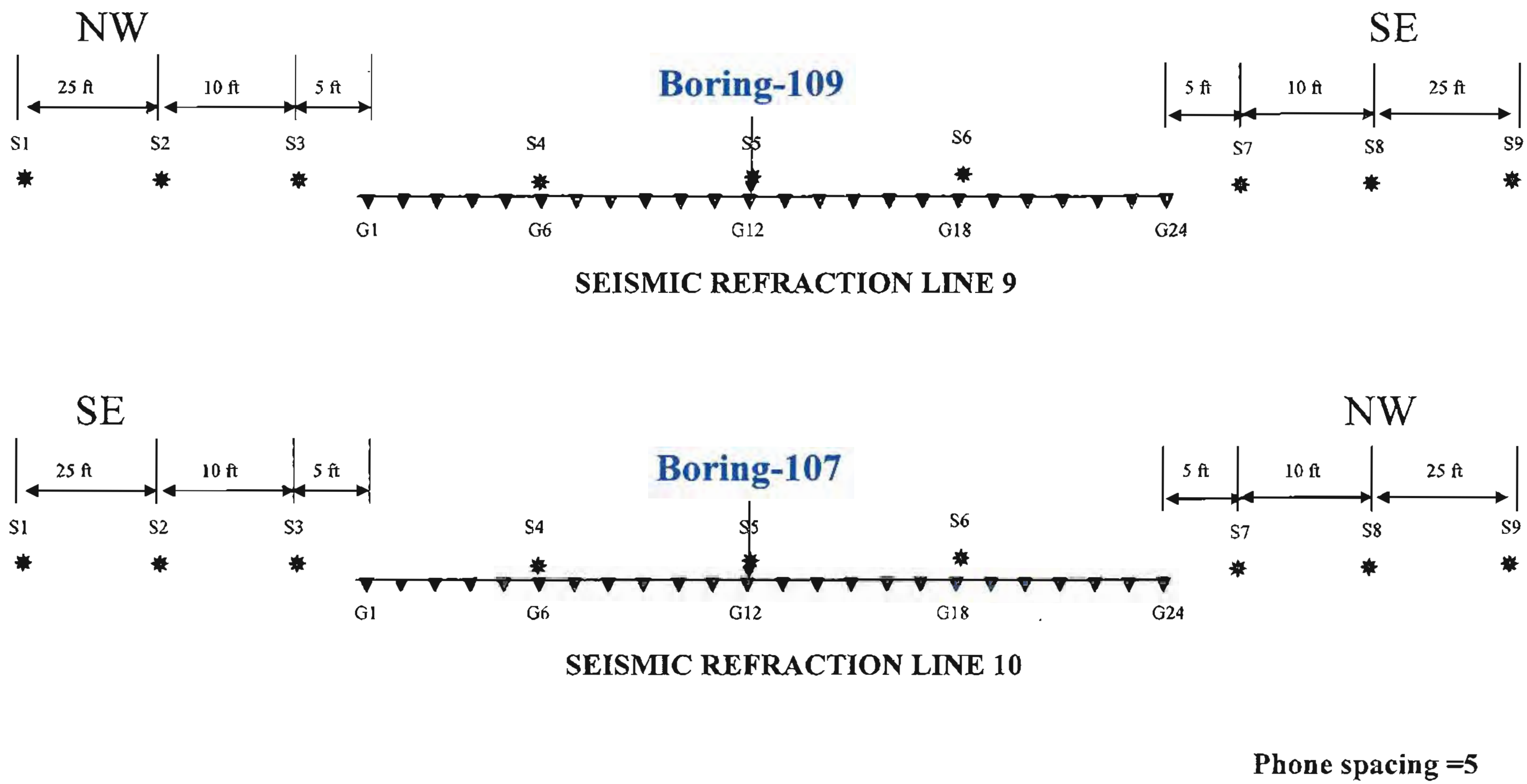


Figure D-5. Schematic of the seismic refraction and ReMi geophone layouts for survey lines 9and 10

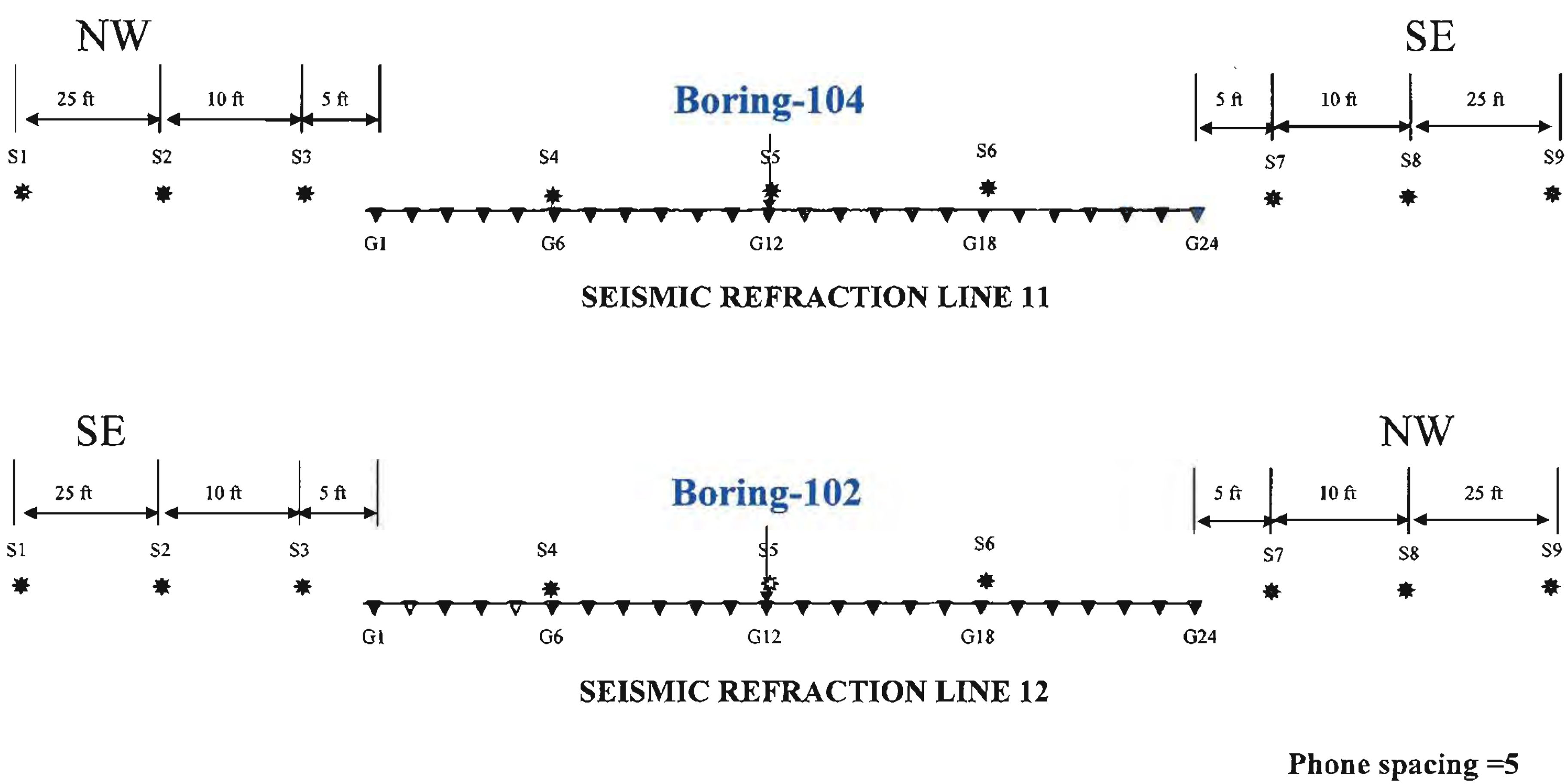


Figure D-6. Schematic of the seismic refraction and ReMi geophone layouts for survey lines 11 and 12

Figure D-7. General layout of seismic line 1.

Figure D-8. General layout of seismic line 2.

Figure D-9. General layout of seismic line 3.

Figure D-10. General layout of seismic line 4.

Figure D-11. General layout of seismic line 5.

Figure D-12. General layout of seismic line 6.

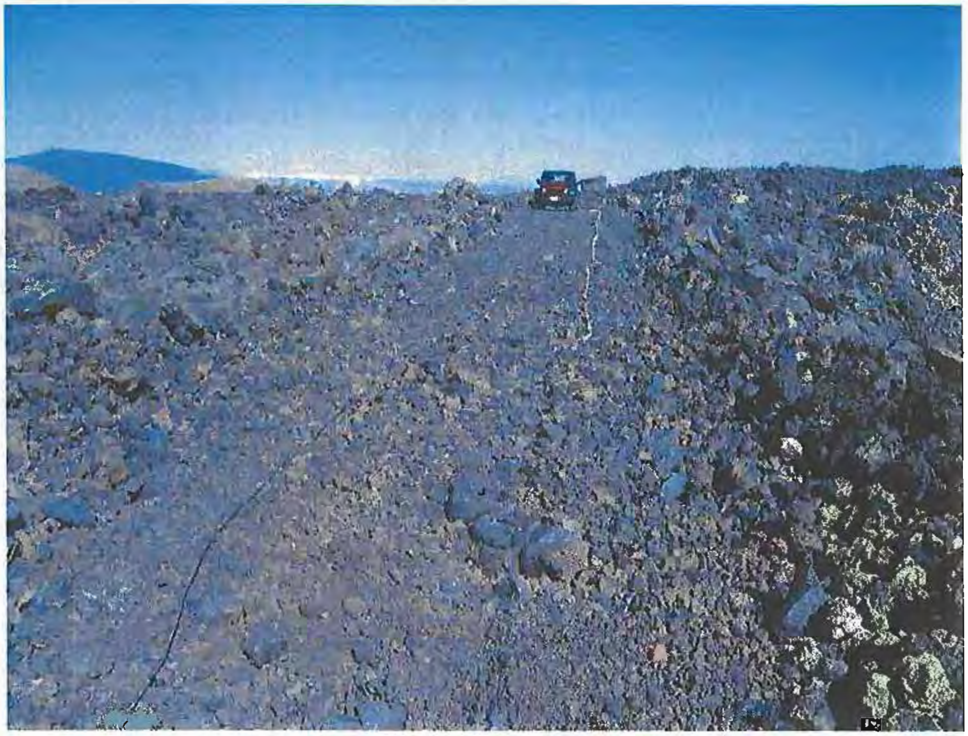


Figure D-13. General layout of seismic line 7.

Figure D-14. General layout of seismic line 8.

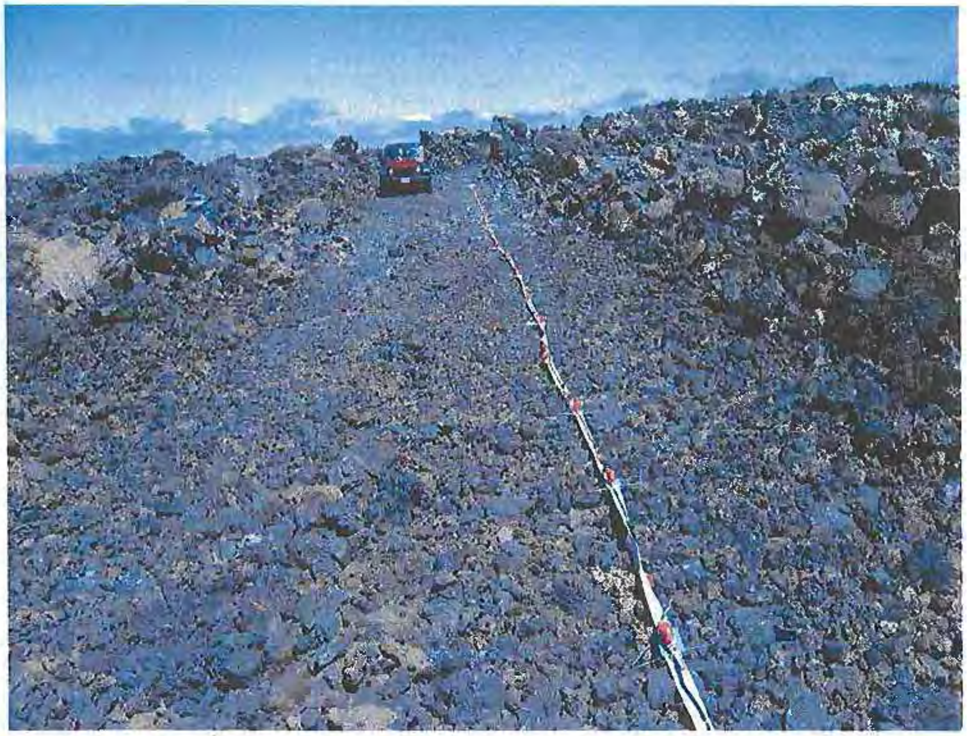


Figure D-15: General layout of seismic line 9.

Figure D-16. General layout of seismic line 10.

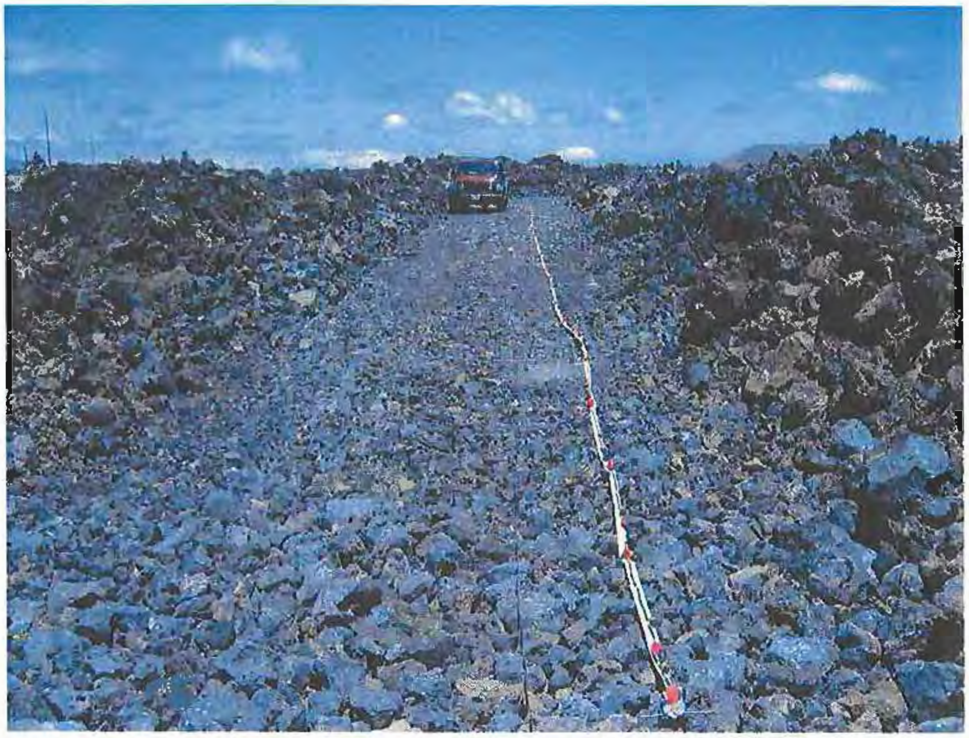


Figure D-17. General layout of seismic line 11.

Figure D-18. General layout of seismic line 12.

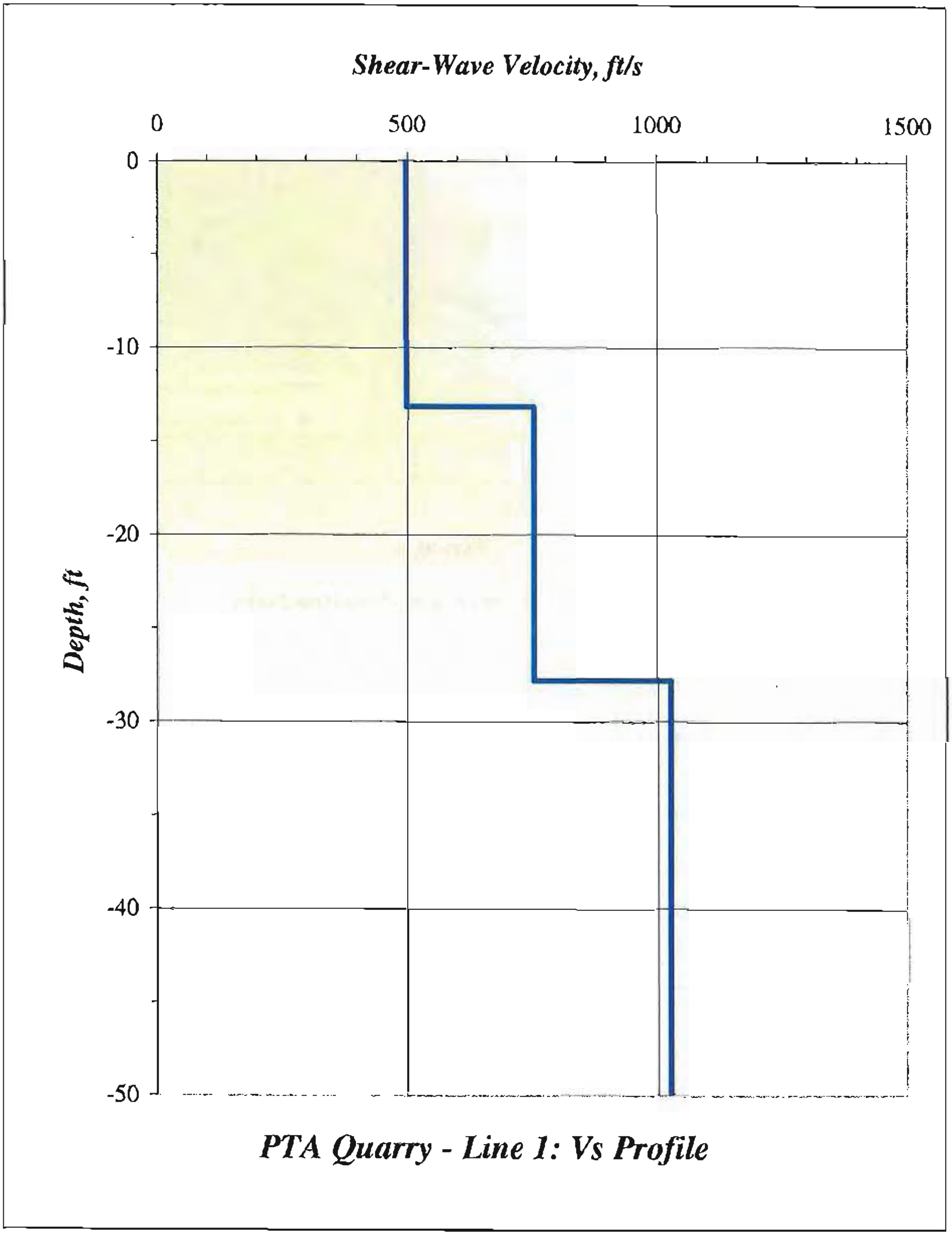
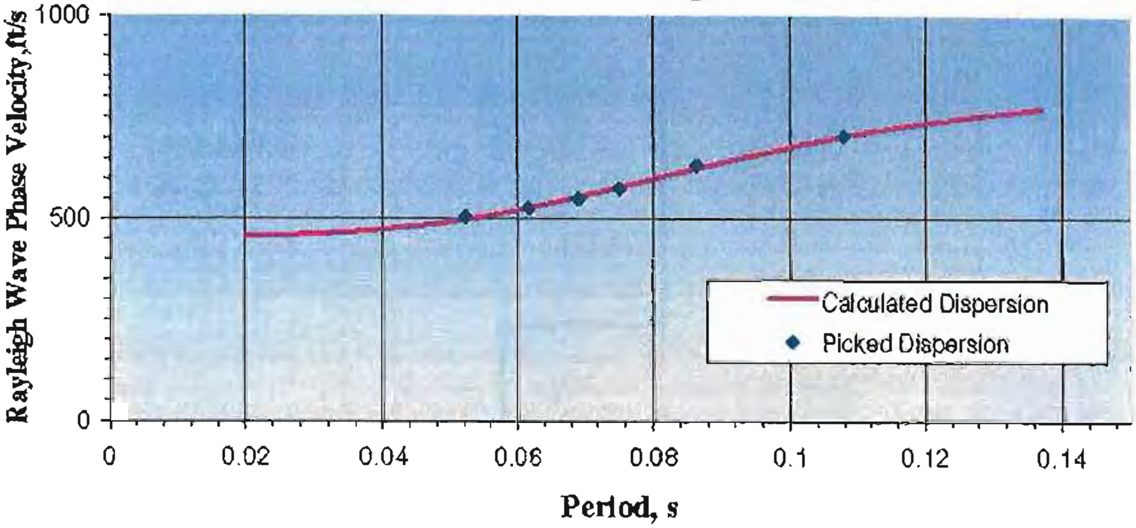


Figure D-31. ReMi data analysis line 1

PTA Quarry - Line 1: Supportive Illustration

Dispersion Curve Showing Picks and Fit



p-f Image with Dispersion Modeling Picks

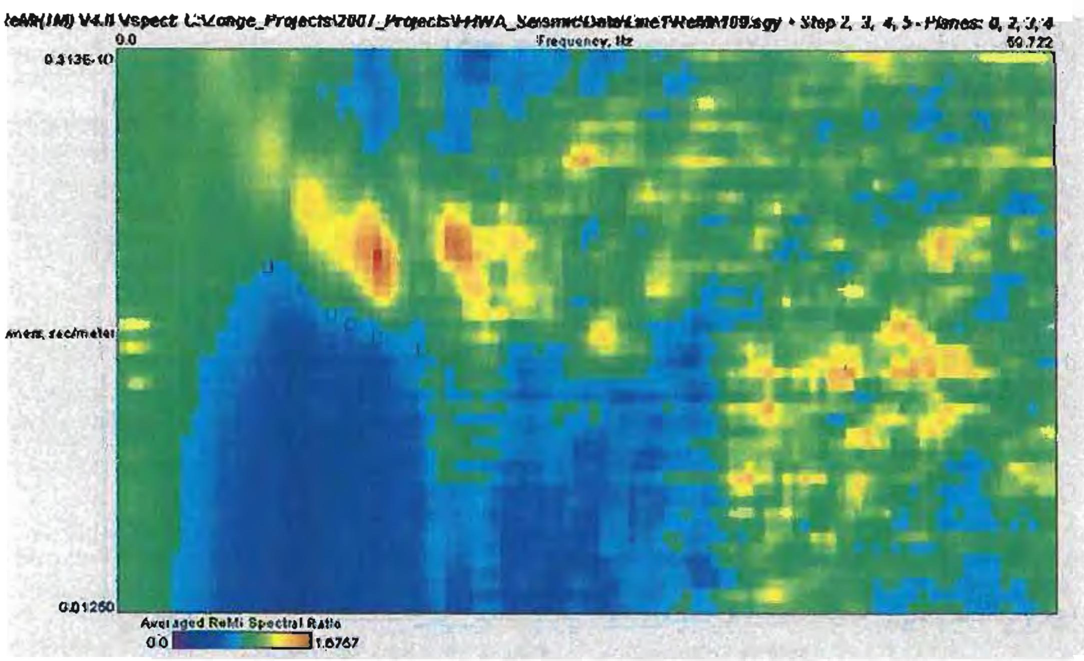


Figure D-32. ReMi data analysis line 1

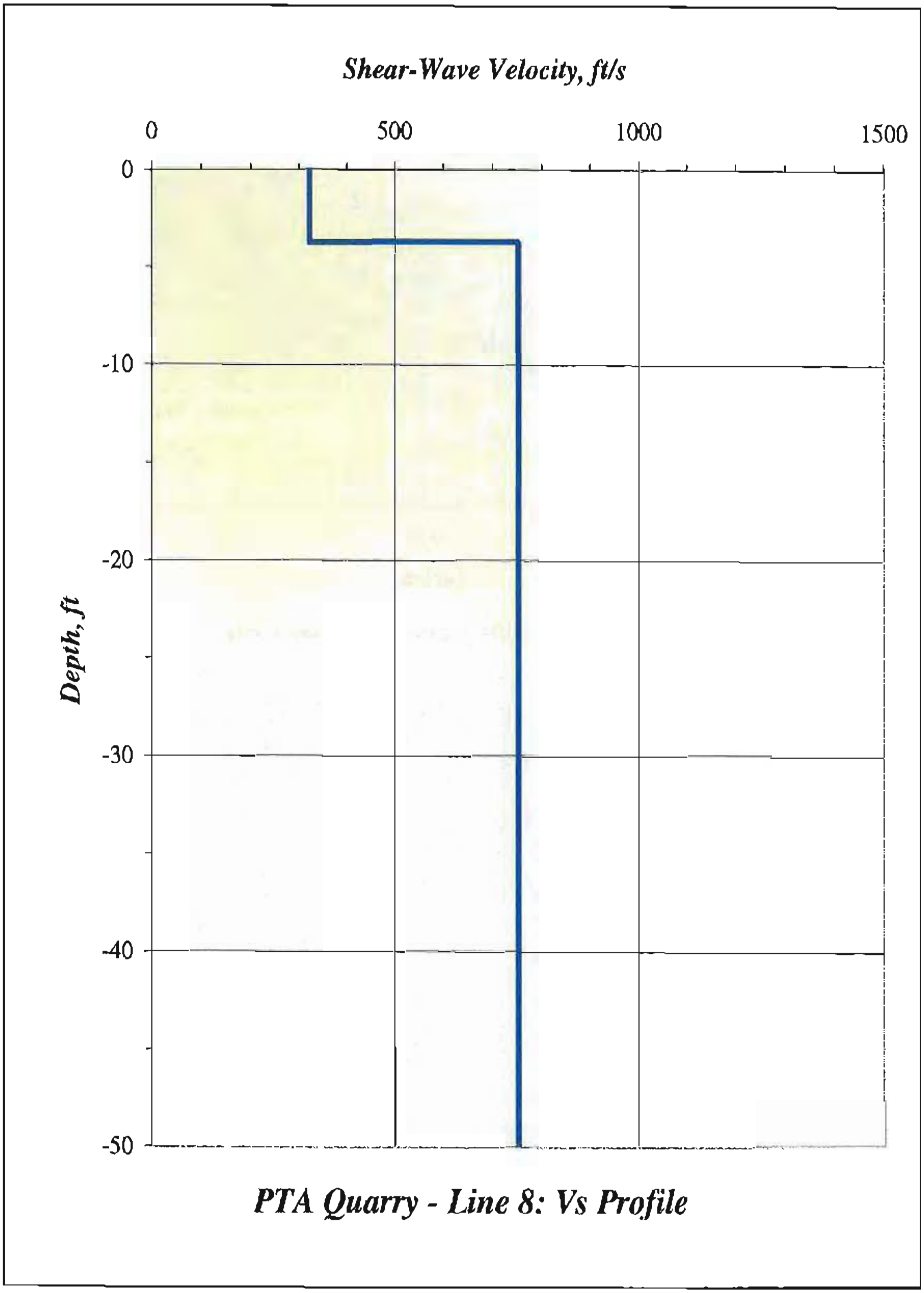
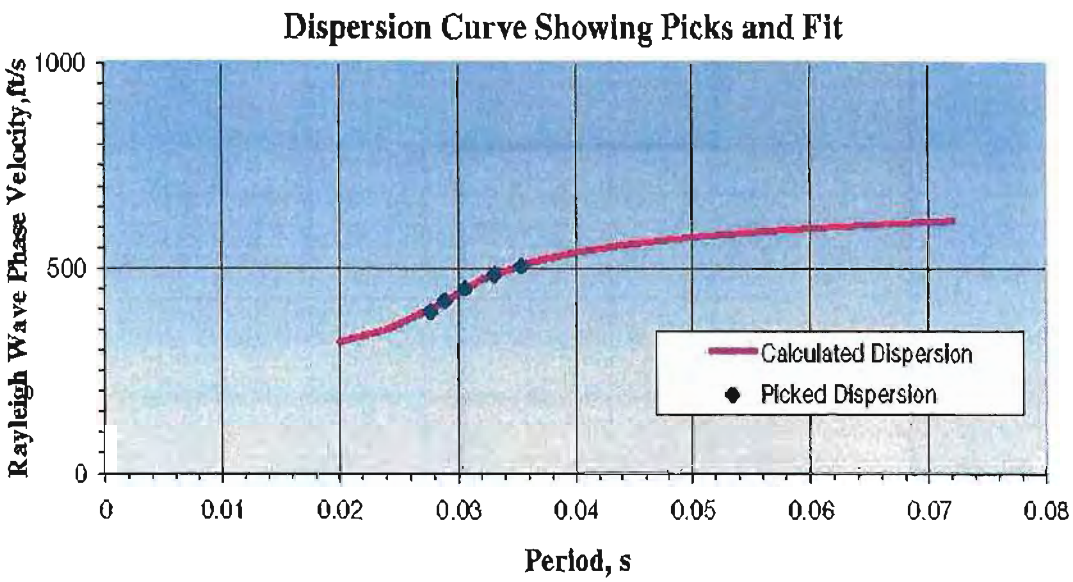


Figure D-33. ReMi data analysis line 8

PTA Quarry - Line 8: Supportive Illustration



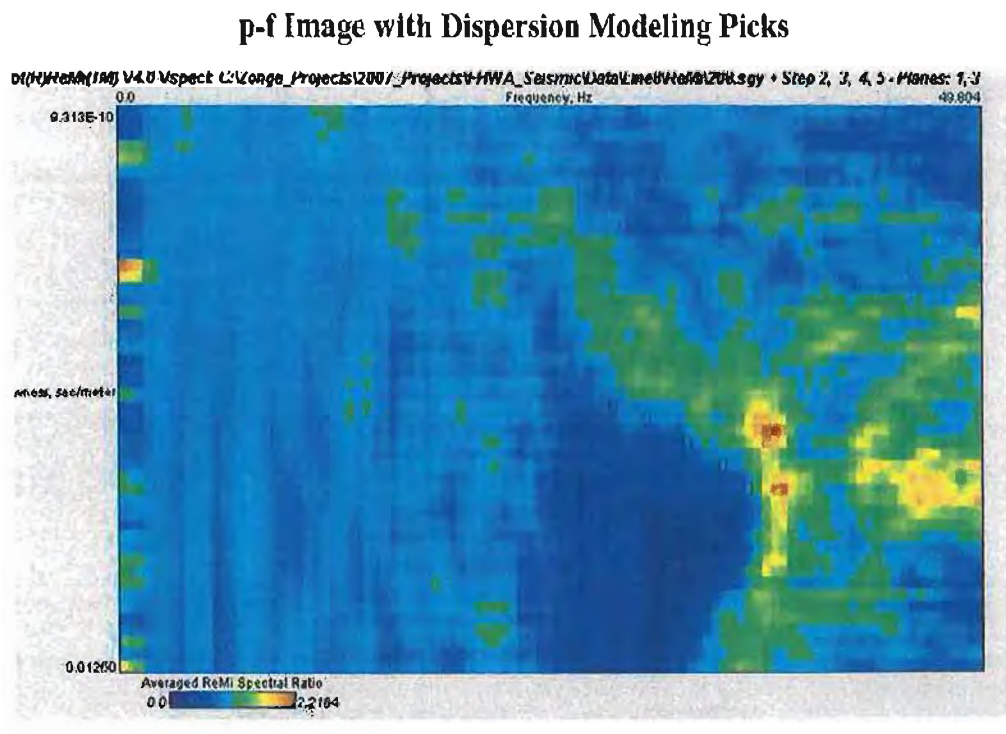


Figure D-34. ReMi data analysis line 8

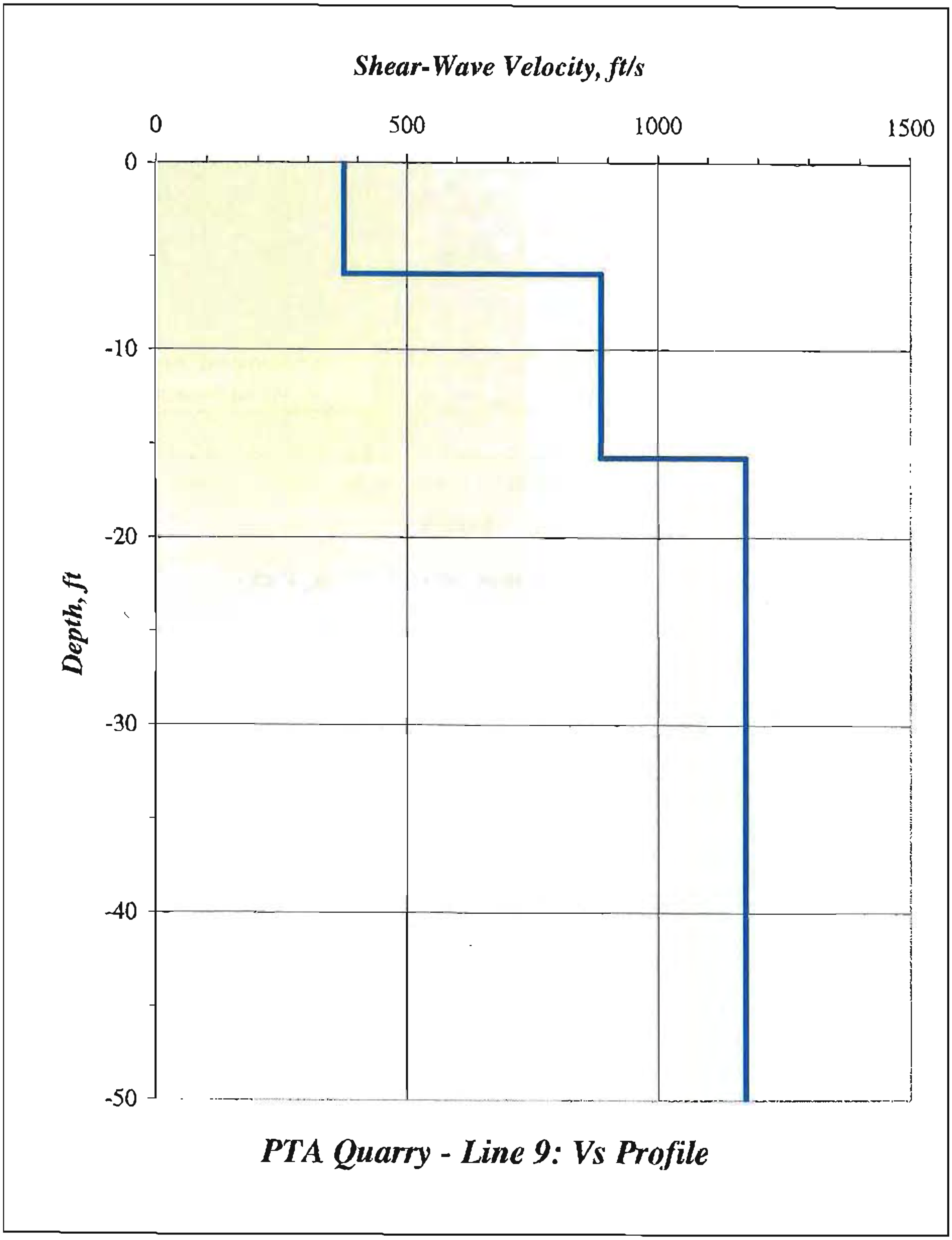


Figure D-35. ReMi data analysis line 9

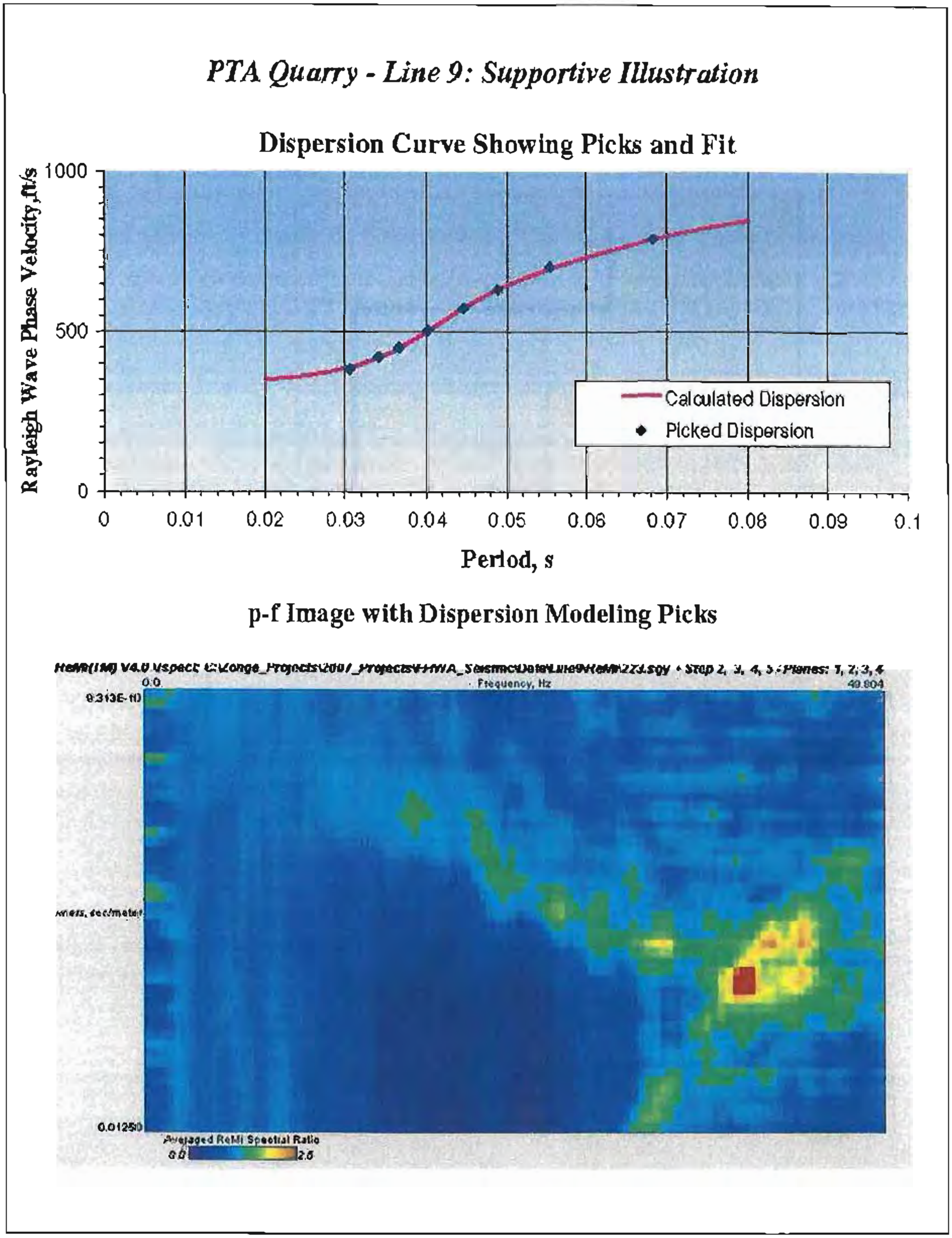


Figure D-36. ReMi data analysis line 9

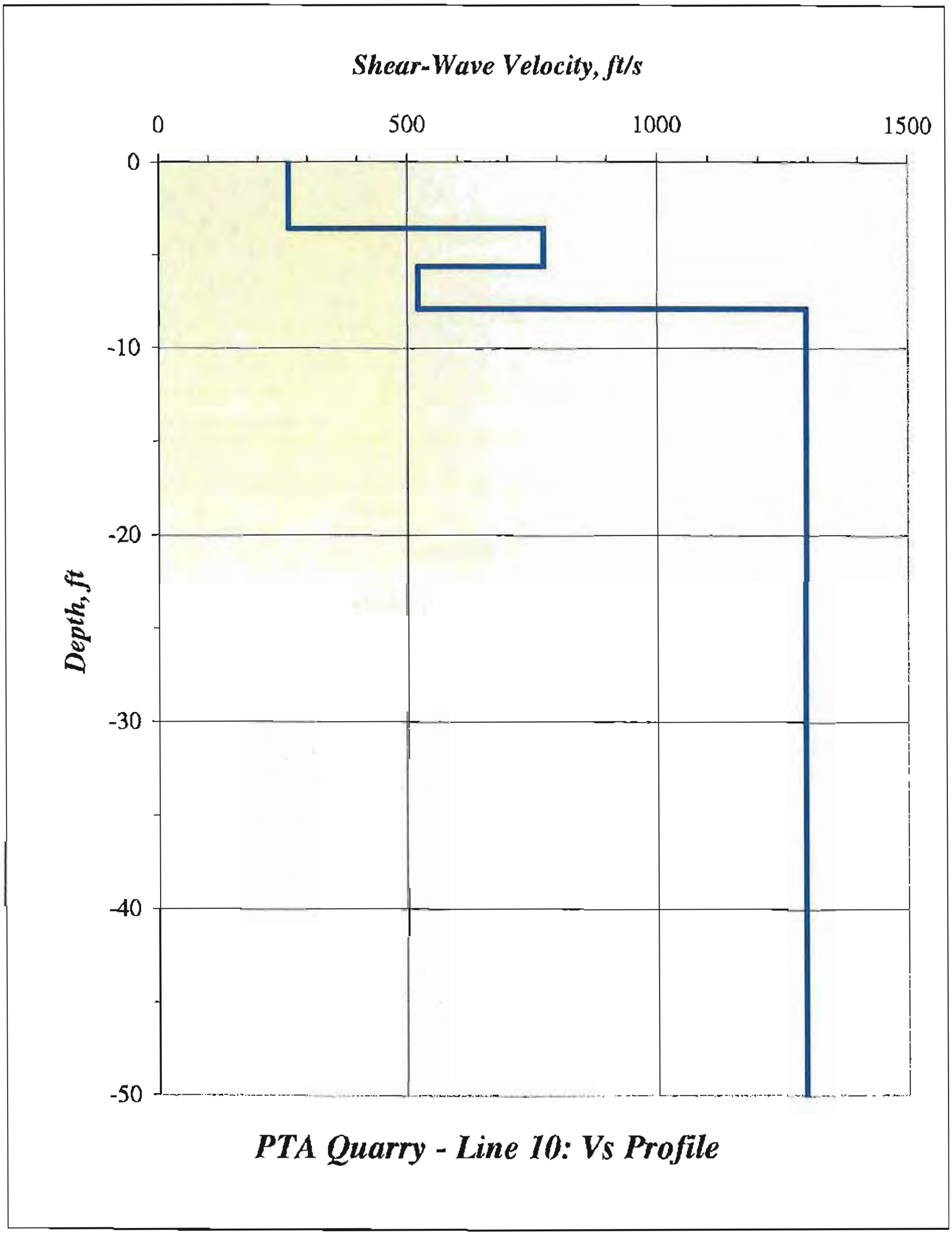
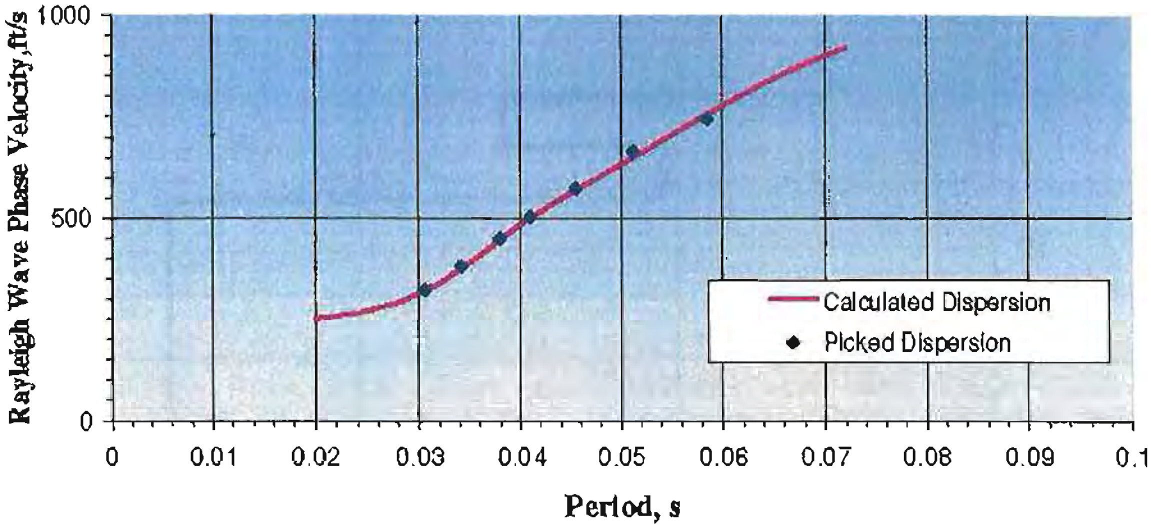


Figure D-37. ReMi data analysis line 10

PTA Quarry - Line 10: Supportive Illustration

Dispersion Curve Showing Picks and Fit



p-f Image with Dispersion Modeling Picks

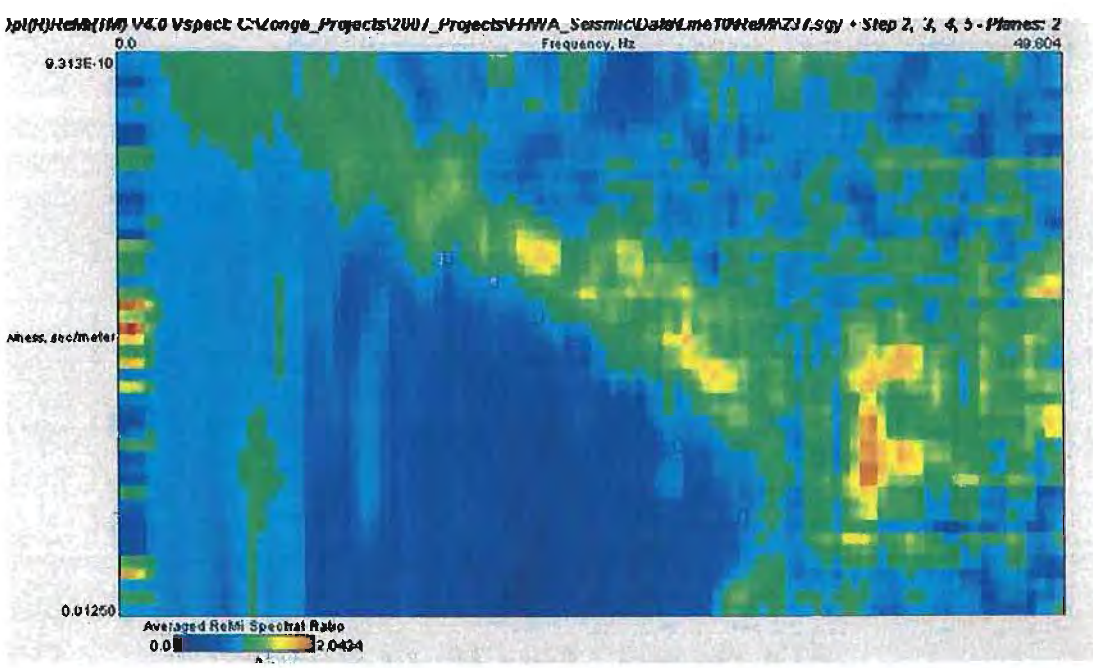


Figure D-38. ReMi data analysis line 10

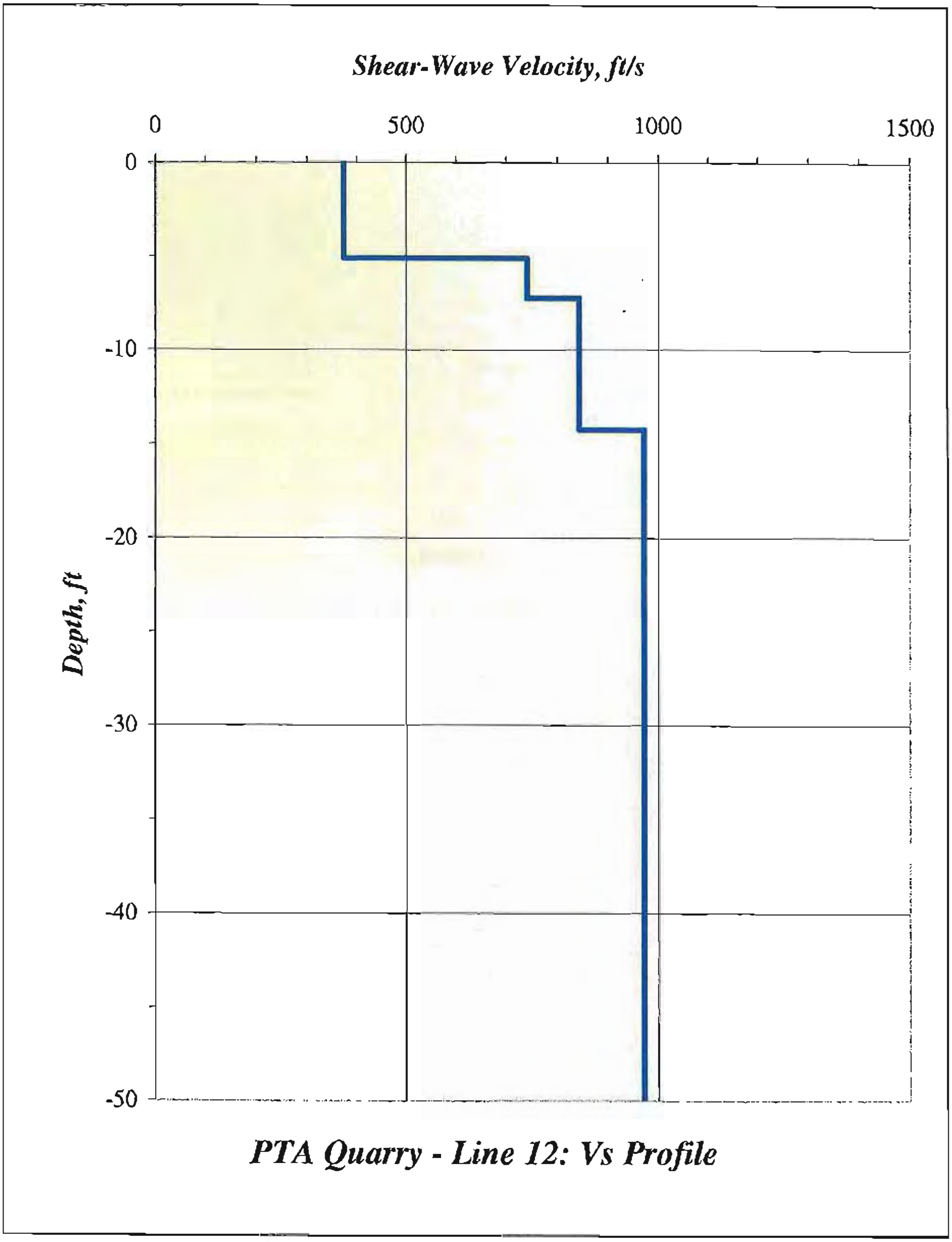
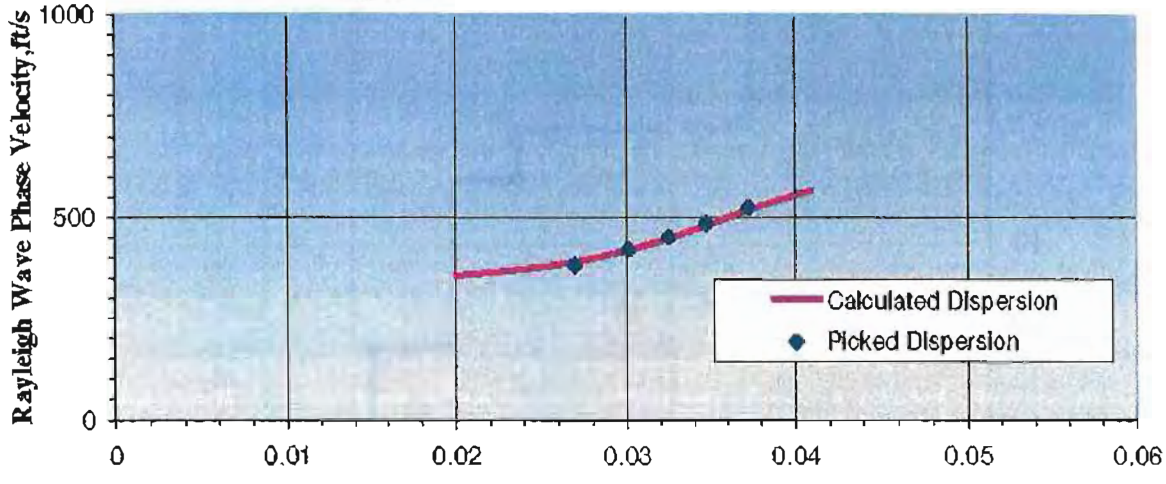


Figure D-39. ReMi data analysis line 12

PTA Quarry - Line 12: Supportive Illustration

Dispersion Curve Showing Picks and Fit



p-f Image with Dispersion Modeling Picks

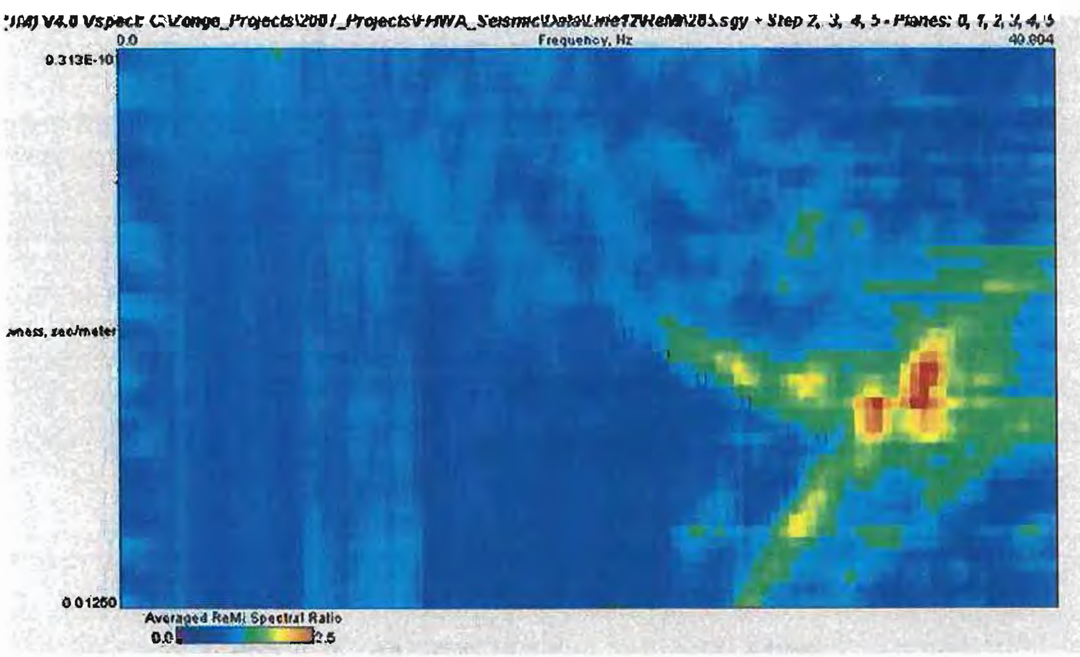
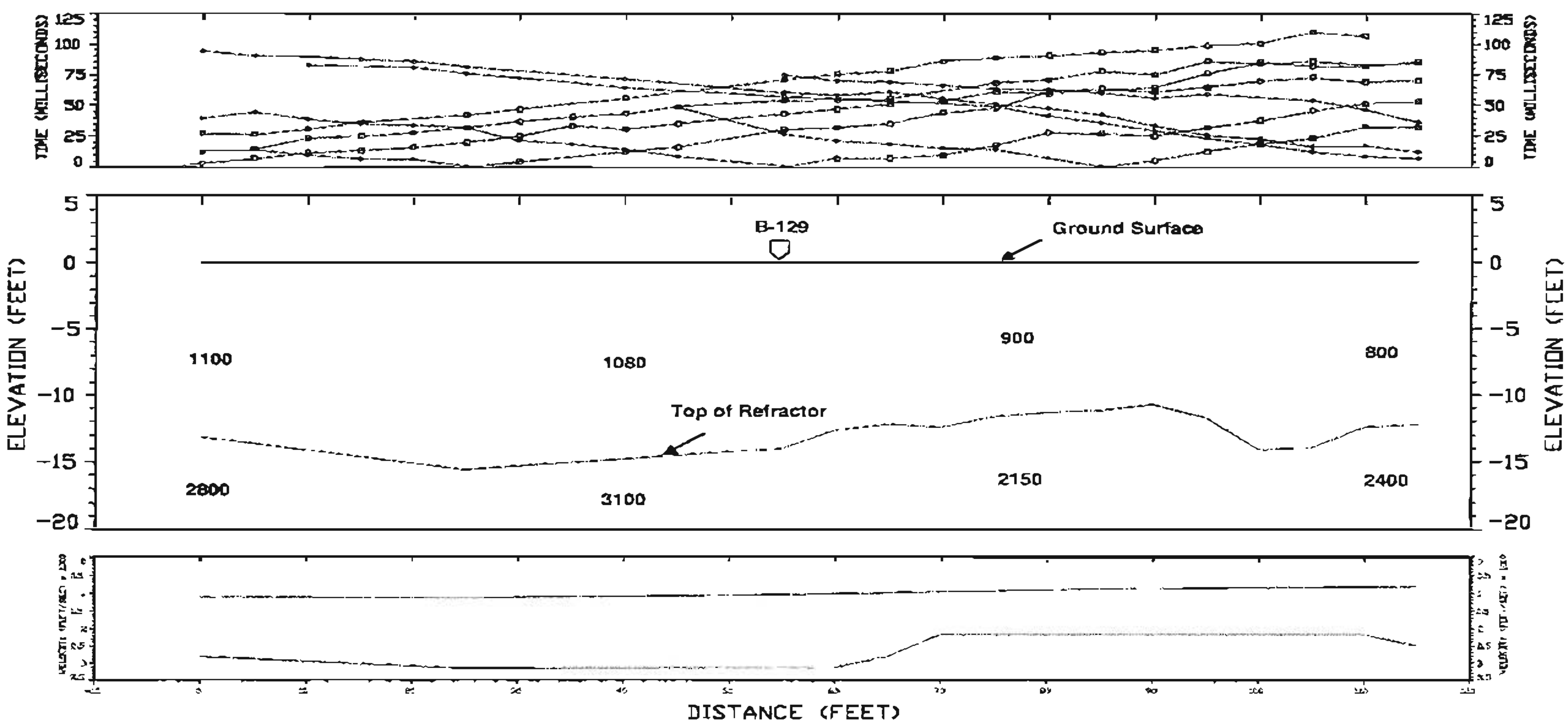


Figure D-40. ReMi data analysis line 12



ZONGE GEOSCIENCES, INC. Lakewood, Colorado	**Line 1** **PTA Quarry-Saddle Road Project**	**FHWA** **Refraction Data Analysis**
	September 2007	

Figure D-19. Refraction data analysis line 1

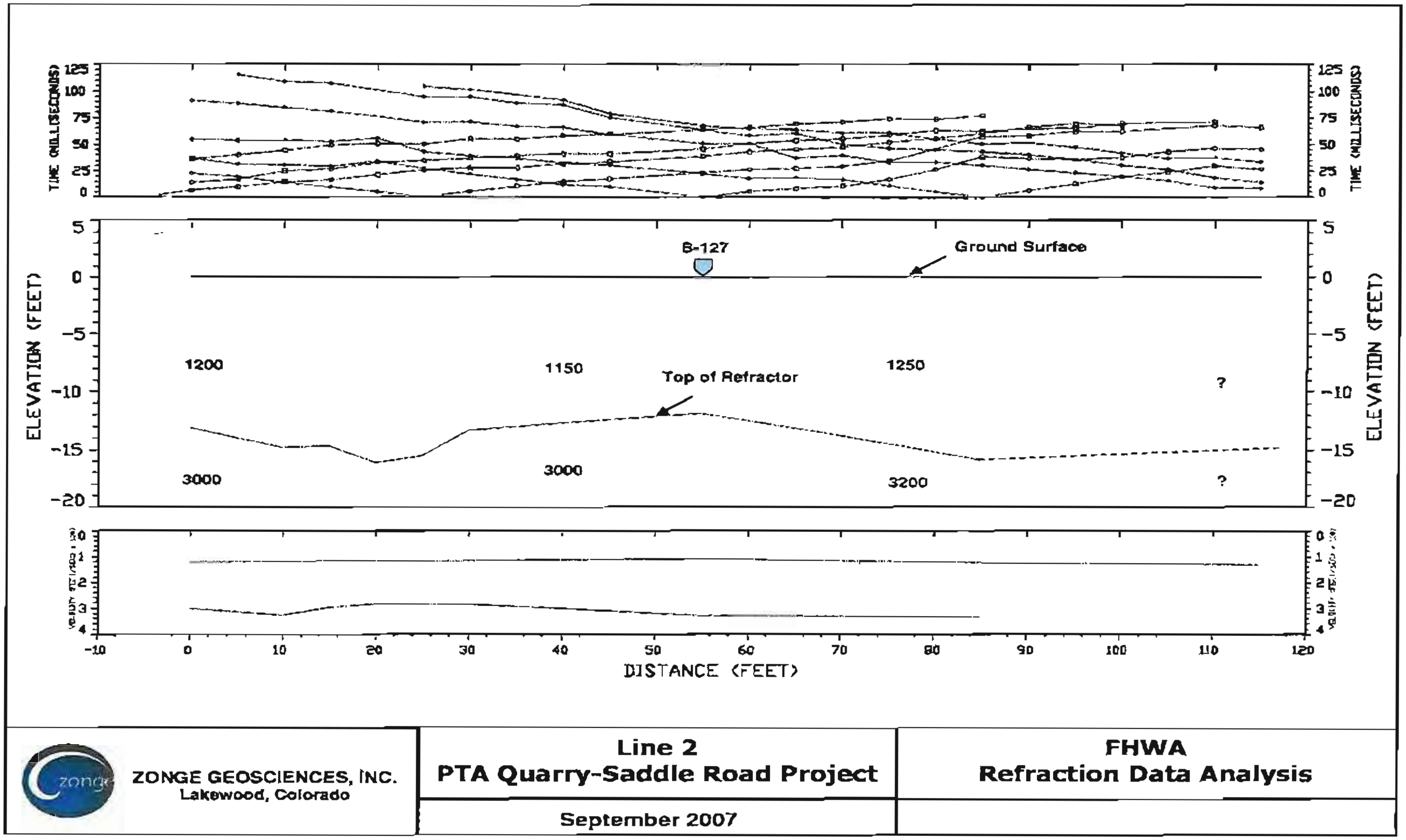
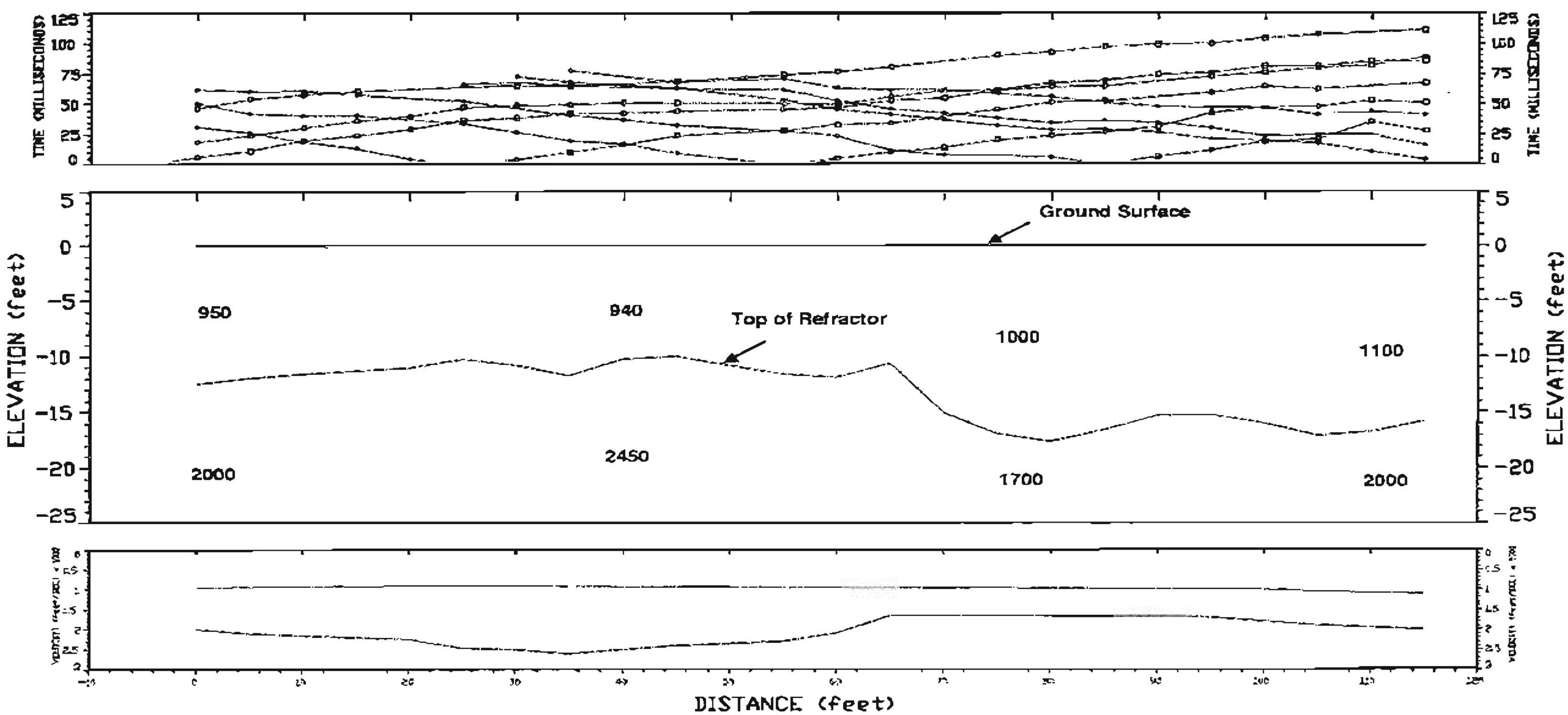


Figure D-20. Refraction data analysis line 2.



ZONGE GEOSCIENCES, INC. Lakewood, Colorado	Line 3 PTA Quarry-Saddle Road Project September 2007	FHWA Refraction Data Analysis

Figure D-21. Refraction data analysis line 3.

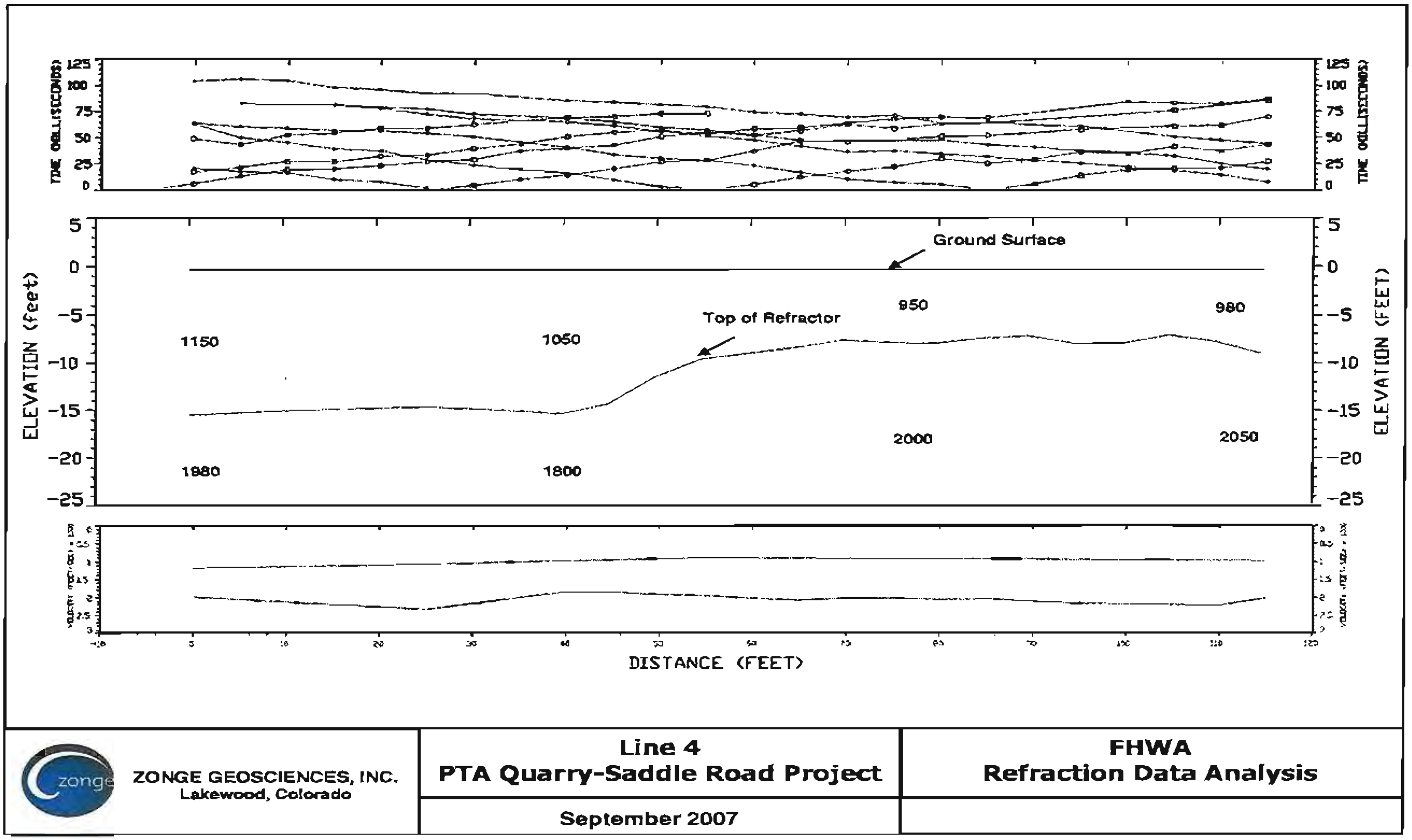


Figure D-22. Refraction data analysis line 4.

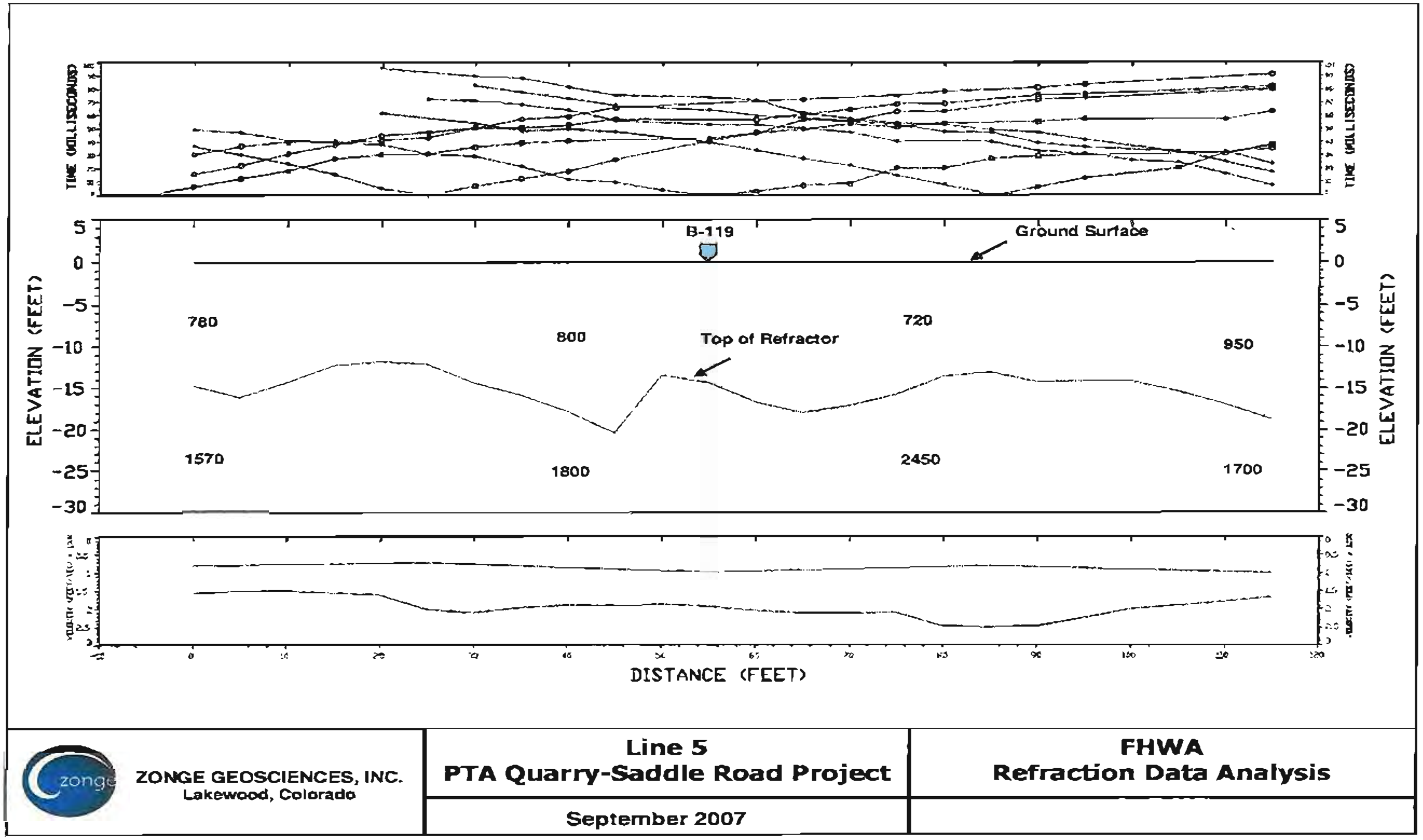


Figure D-23. Refraction data analysis line 5.

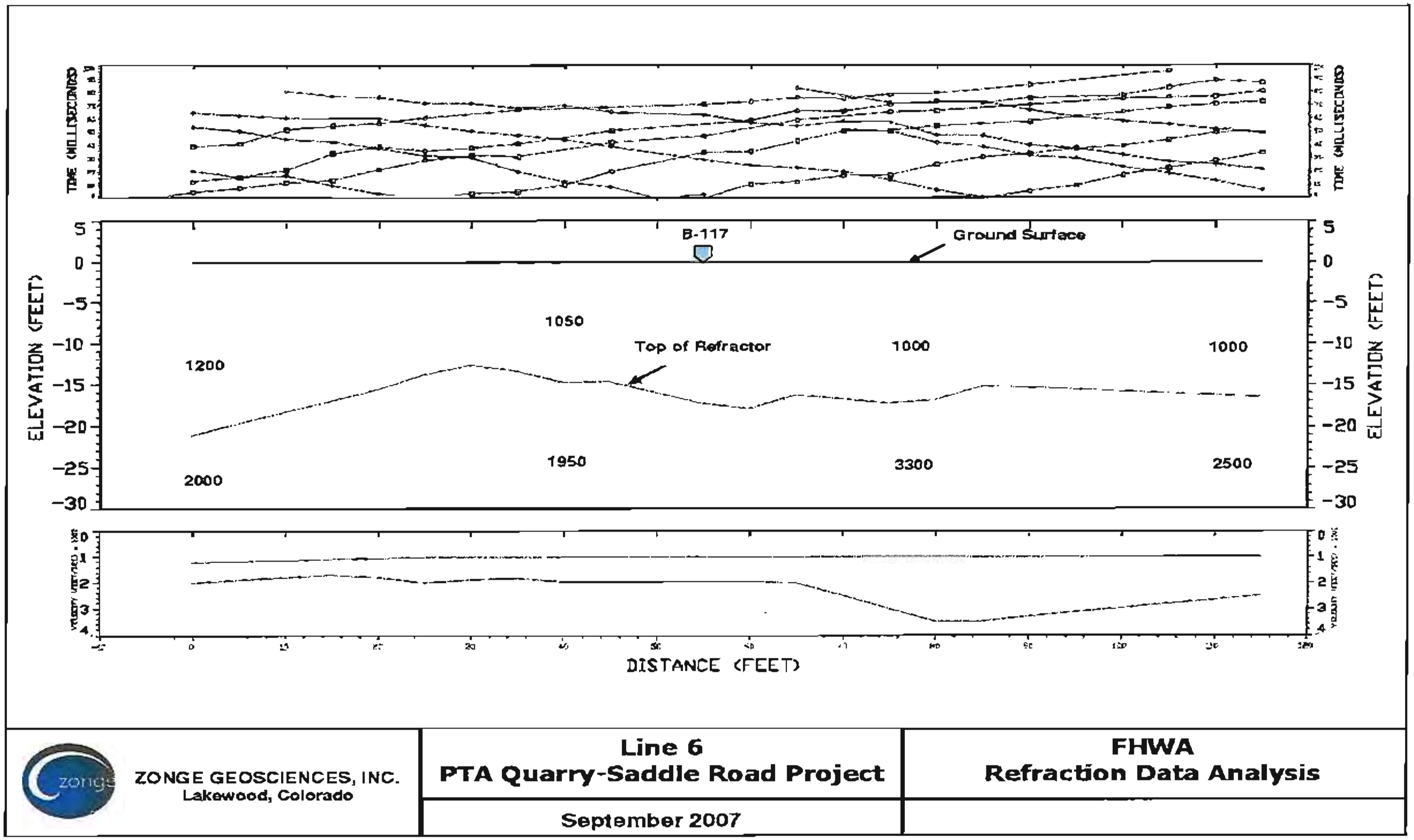
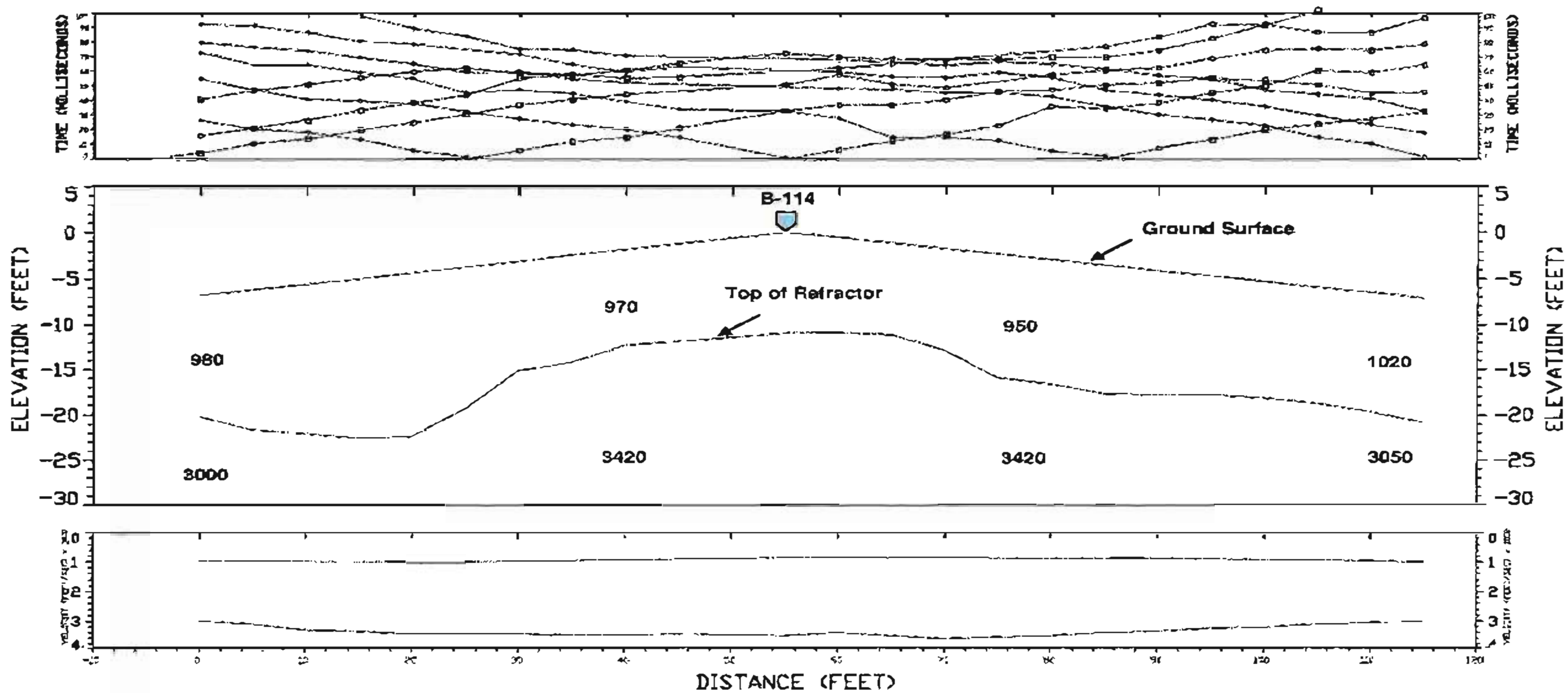


Figure D-24. Refraction data analysis line 6.



ZONGE GEOSCIENCES, INC. Lakewood, Colorado	Line 7 PTA Quarry-Saddle Road Project	FHWA Refraction Data Analysis
	September 2007	

Figure D-25. Refraction data analysis line 7.

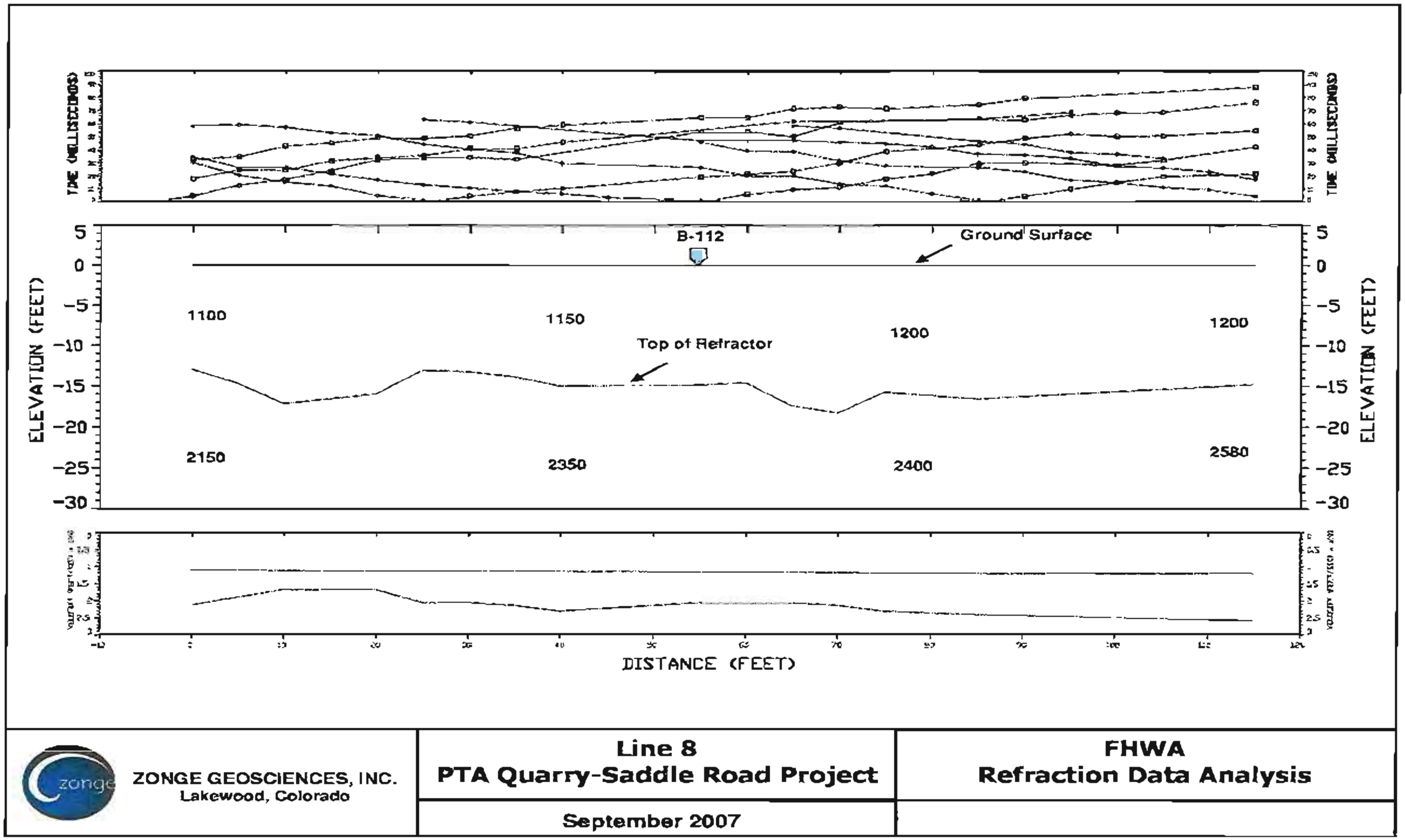


Figure D-26. Refraction data analysis line 8.

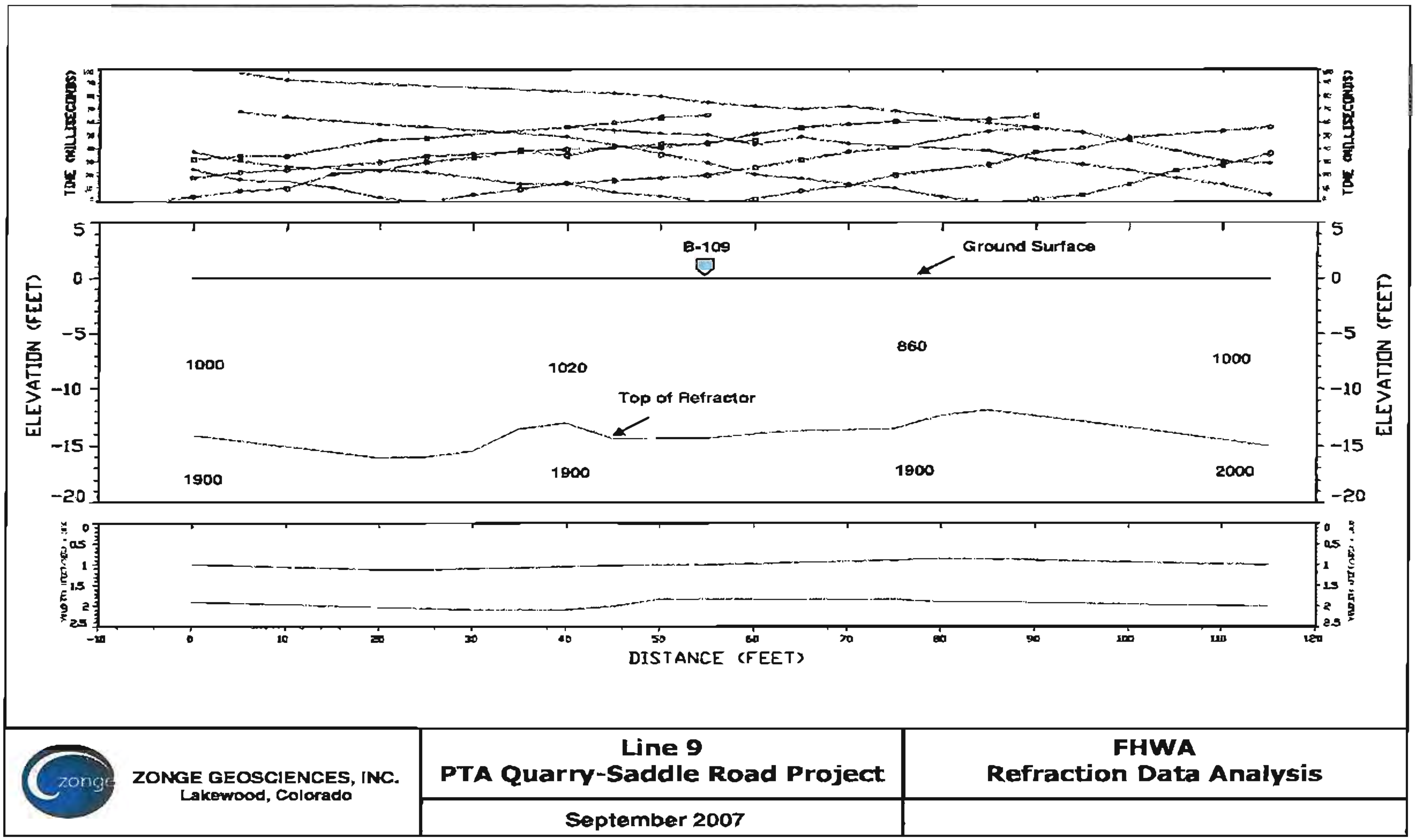


Figure D-27. Refraction data analysis line 9.

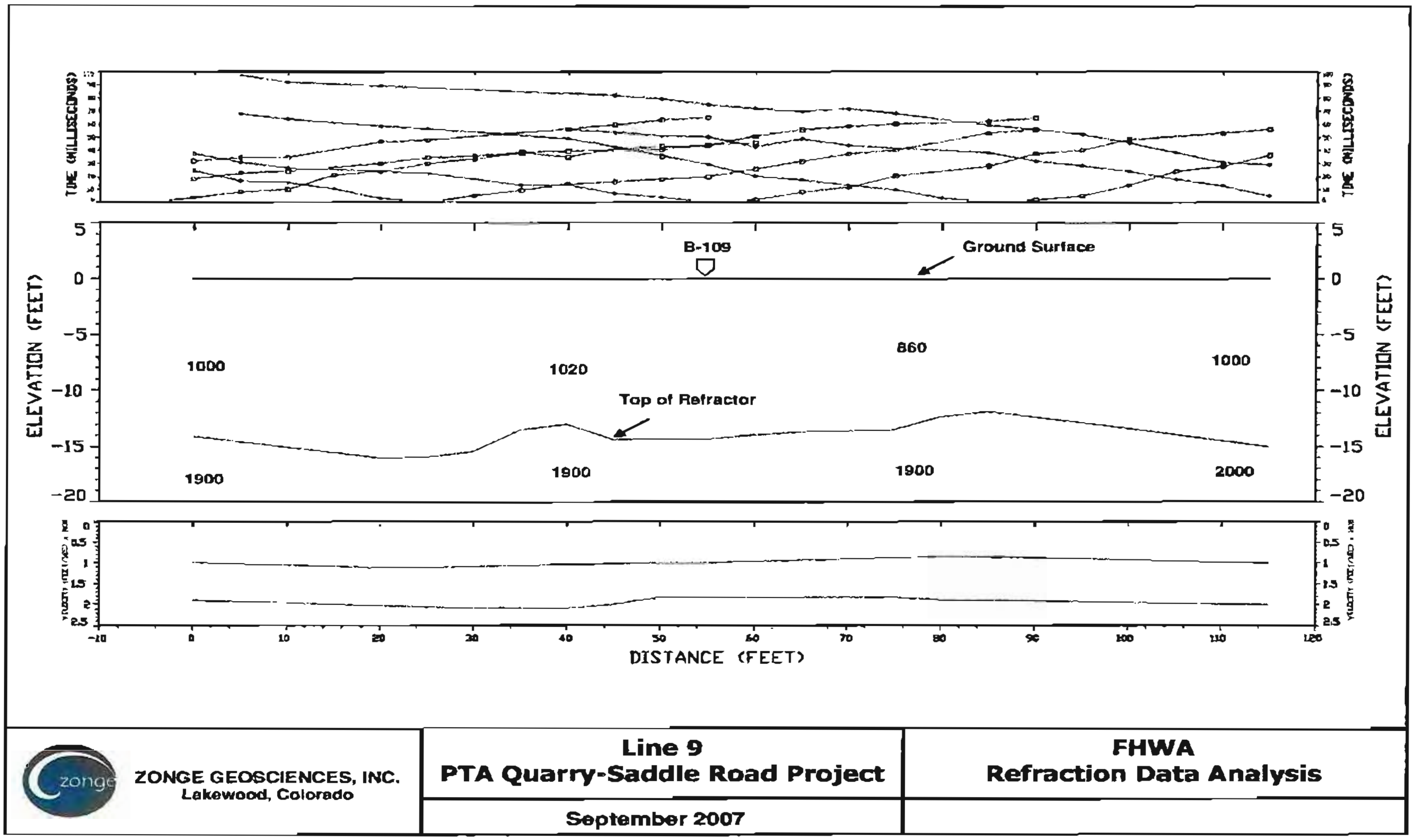
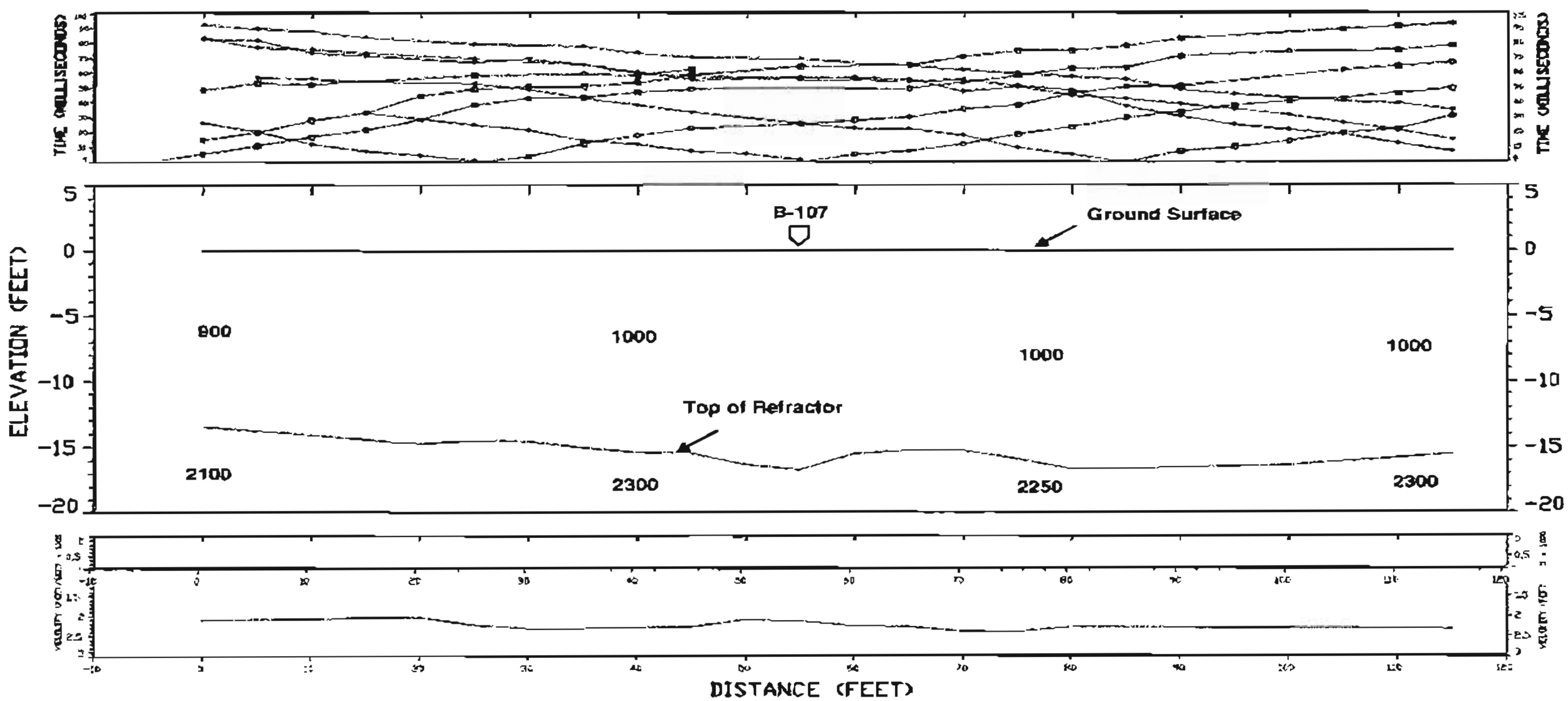


Figure D-27. Refraction data analysis line 9.



ZONGE GEOSCIENCES, INC.
Lakewood, Colorado

Line 10
PTA Quarry-Saddle Road Project

September 2007

FHWA
Refraction Data Analysis

Figure D-28. Refraction data analysis line 10.

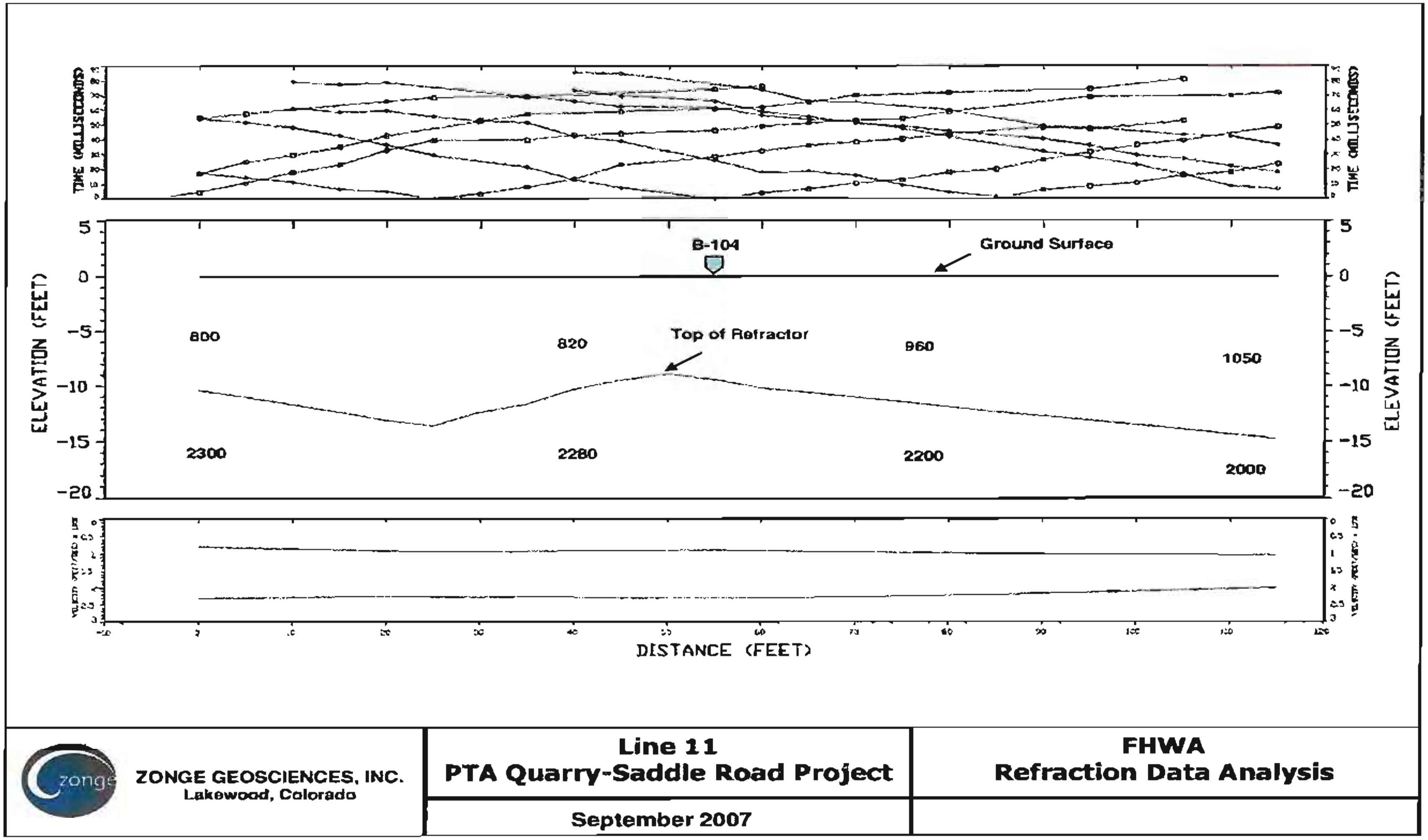
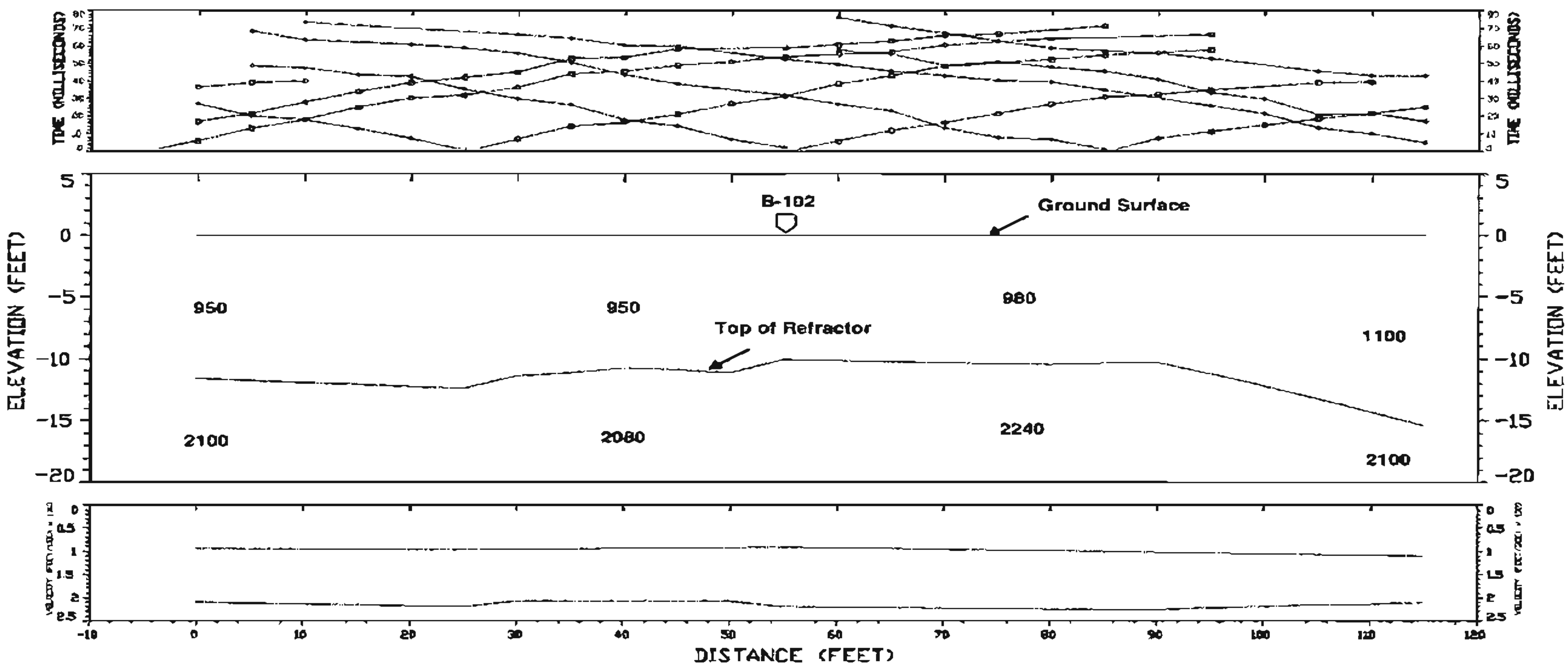


Figure D-29. Refraction data analysis line 11.



ZONGE GEOSCIENCES, INC.
Lakewood, Colorado

Line 12
PTA Quarry-Saddle Road Project

September 2007

FHWA
Refraction Data Analysis

Figure D-30. Refraction data analysis line 12.

Appendix E

Laboratory Test Results

WesTest
845 Navajo Street • Denver, CO 80204
SPECIALISTS TO THE PAVING INDUSTRY
Phone: 303.975.9959 • Fax: 303.975.9969 • Email: office@westest.net

Federal Highway Administration
Central Federal Lands Division
Denver Federal Center
Building 52, PO Box 25246
Denver, CO 80225

November 1, 2006

Attention: Mr. Randall S. Caley

Subject: Hot Mix Asphalt Mix Design - Marshall Method – 75 Blows per Side
FHWA Grading E
Pohakuloa Training Area Quarry, Tesoro Refining PG 64-16 Binder
Saddle Road, FHWA Project No.: Hawaii – A-AD/STP 6(3) & 200(1)
WesTest Mix Design No. 166206

Gentlemen:

Enclosed are the results of a hot mix asphalt mix design done in general accordance with the Asphalt Institute's *Mix Design Methods for Asphalt Concrete* Marshall procedures, using 75 blows per side compactive effort. All tests have been conducted in general accordance with AASHTO procedures current at the time of design. The aggregate used in the mix design is from Pohakuloa Training Area Quarry. The asphalt cement used in the mix design consisted of a PG 64-16, with a specific gravity of 1.020, supplied by Tesoro Refining.

The aggregate gradations and blend percentages were provided, and are presented on Figure 1, along with a graphical presentation of the combined gradation plotted on a 0.45 Power Graph. The results of additional aggregate testing performed by WesTest or the FHWA are also included on Figure 1. Gradations of the aggregate as delivered are included on Table 2. The results of sodium sulfate soundness testing will be provided when complete.

The design was performed at asphalt cement contents of 5.0, 5.5, 6.0 and 6.5 percent. The results of the tests performed at each asphalt content are outlined on Table 1 and graphically presented on Figures 2 and 3. At a target asphalt cement content of 5.8% this mix indicates a theoretical maximum specific gravity of 2.605, bulk specific gravity of 2.474, unit weight of 154.0 pcf, 5.0% voids in total mix, 16.2% voids in mineral aggregate, 69.2% voids filled with asphalt, Marshall stability of 4600 lbs. and a flow of 0.13 inches. The effective specific gravity of the aggregate in the mix is 2.880.3

This hot mix asphalt mix design is based on specific materials and laboratory preparation of the test specimens. Variations between laboratories and variation between laboratory produced and field produced samples should be anticipated. It is recommended the mix design be field verified during initial production. Field verification often results in the optimum asphalt cement content being adjusted to meet design voids in total mix or voids in mineral aggregate criteria.

If you have any questions on the design presented, please contact us at your convenience.

Sincerely,
WesTest

Eric R. West, P.E.

COLORADO REGISTERED ERIC R. WEST 20475 11/1/06 PROFESSIONAL ENGINEER

WESTEST
SPECIALISTS TO THE PAVING INDUSTRY

Client:	Federal Highway Administration	November 1, 2006
Mix Design No.:	166206	
Mix Design Method:	Marshall, 75 Blows per Side	
Grading:	E	
Aggregate Source:	Pohakuloa Training Area Quarry	

AGGREGATE BLEND*

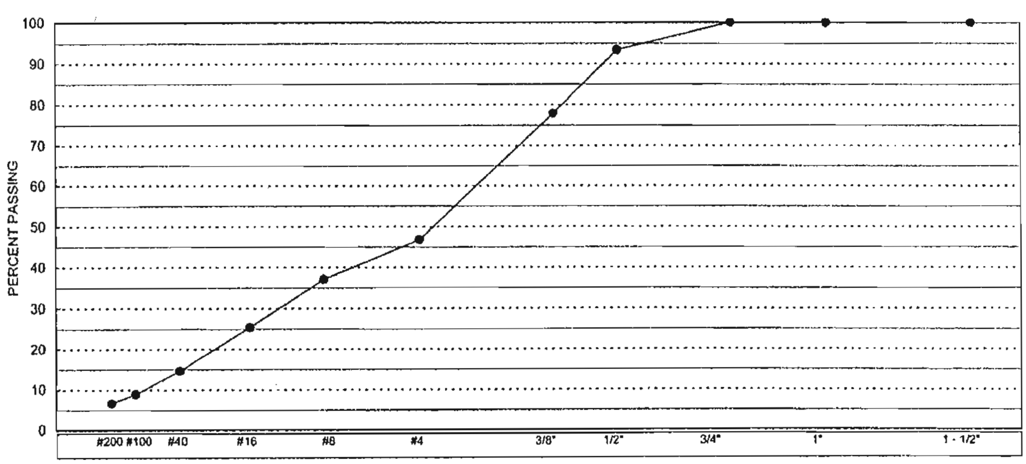
PERCENT OF BLEND	29%	27%	43%			1%	100%	Grading	PRODUCTION
DESCRIPTION	#67 Crushed Stone	#8 Crushed Stone	Manuf. Stone Sand			Lime	Combination	E	GRADATION
SOURCE	PTA Quarry	PTA Quarry	PTA Quarry			Hawaiian Cement	Job Mix	Spec.	TOLERANCE
1 1/2"	100	100	100			100	100		
1"	100	100	100			100	100		
3/4"	100	100	100			100	100	97 - 100	97 - 100
1/2"	77	100	100			100	93		86 - 100
3/8"	36	87	100			100	78		71 - 85
#4	5	7	99			100	47		41 - 53
#8	3	2	80			100	37		
#16	2	2	54			100	25		
#40	2	1	30			100	15		11 - 19
#100	1	1	17			100	9		
#200	1.1	0.7	11.7			97.0	6.5	4.0 - 8.0	3.5 - 9.5

AGGREGATE PHYSICAL PROPERTIES

BULK SPECIFIC GRAVITY						2.430	2.783		
APPARENT SPECIFIC GRAVITY						2.430	2.900		
WATER ABSORPTION (%)							1.5		
L.A. ABRASION (% LOSS)**							22	45 Max.	
FRACTURED FACES, 2+ (%)							100	80 Min.	
FLAT & ELONGATED 1:3 (%)							0	10 Max.	
AGGREGATE DURABILITY INDEX D_C**							96	35 Min.	Procedure A
AGGREGATE DURABILITY INDEX D_f**							90	35 Min.	Procedure B
FINE AGGREGATE ANGULARITY (%)							51.7	45.0 Min.	
LIQUID LIMIT (%)**							NV		
PLASTICITY INDEX**							NP	Non-Plastic	
SAND EQUIVALENT (%)							77	45 Min.	
SODIUM SULFATE SOUNDNESS, 5 CYCLES (% LOSS)								12 Max.	

*Aggregate gradations and blend percentages provided by client.
**Data provided by client.

0.45 POWER GRAPH



SIEVE SIZE RAISED TO THE 0.45 POWER

FIGURE 1

WESTEST
SPECIALISTS TO THE PAVING INDUSTRY

Client:	FHWA		November 1, 2006
Mix Design No.:	166206		
Mix Design Method:	Marshall, 75 Blows per Side		

Grading:	E	Mixing Temperature:	312 ± 5 °F
Aggregate Source:	Pohakuloa Training Area Quarry	Compaction Temperature:	292 ± 4 °F
A.C. Source & Grade:	Tesoro Refining		

ASPHALT CONTENT DETERMINATION

MIX PROPERTIES	LABORATORY TRIAL DATA				SPEC.	OPTIMUM
ASPHALT CEMENT CONTENT (% BY WEIGHT OF MIX)	5.0	5.5	6.0	6.5		5.8
THEORETICAL MAXIMUM SPECIFIC GRAVITY	2.640	2.618	2.596	2.575		2.605
THEORETICAL MAXIMUM DENSITY (PCF)	164.3	162.9	161.6	160.3		162.1
BULK SPECIFIC GRAVITY	2.445	2.460	2.486	2.510		2.474
DENSITY (PCF)	152.2	153.1	154.7	156.2		154.0
% VOIDS IN TOTAL MIX	7.4	6.0	4.3	2.5	3.0 - 6.0	5.0
% VOIDS IN MINERAL AGGREGATE	16.5	16.5	16.0	15.7	13.0 Min.	16.2
% VOIDS FILLED WITH ASPHALT	55.4	63.4	73.5	83.9		69.2
STABILITY (LBS.)	4685	5111	4277	3696	2000 Min.	4600
FLOW (0.01in.)	10	13	13	14	8 - 16	13

MOISTURE SENSITIVITY TEST

LOTTMAN MOISTURE SENSITIVITY TEST RESULTS (AASHTO T 283), FREEZE CYCLE INCLUDED, 6.0% BINDER			
DRY SUBSET	AVERAGE SPECIMEN VOIDS, 3 SPECIMENS (%)	6.5 - 7.5	7.0
	TENSILE STRENGTH, SPECIMEN A (PSI)		94
	TENSILE STRENGTH, SPECIMEN B (PSI)		104
	TENSILE STRENGTH, SPECIMEN C (PSI)		94
	AVERAGE TENSILE STRENGTH (PSI)		97
CONDITIONED SUBSET	AVERAGE SPECIMEN VOIDS, 3 SPECIMENS (%)	6.5 - 7.5	7.0
	TENSILE STRENGTH, SPECIMEN A (PSI)		84
	TENSILE STRENGTH, SPECIMEN B (PSI)		84
	TENSILE STRENGTH, SPECIMEN C (PSI)		87
	AVERAGE TENSILE STRENGTH (PSI)		85
TENSILE STRENGTH RATIO		70 Min.	88
Minor moisture damage noted in a few of the finer aggregate particles, Scale:1.			
Several broken aggregate particles in conditioned and dry specimens.			

TABLE 1

SPECIALISTS TO THE PAVING INDUSTRY

Client:	FHWA	November 1, 2006
Mix Design No.:	166206	
Grading:	E	
Mix Design Method:	Marshall, 75 Blows per Side	

VOLUMETRIC PROPERTIES

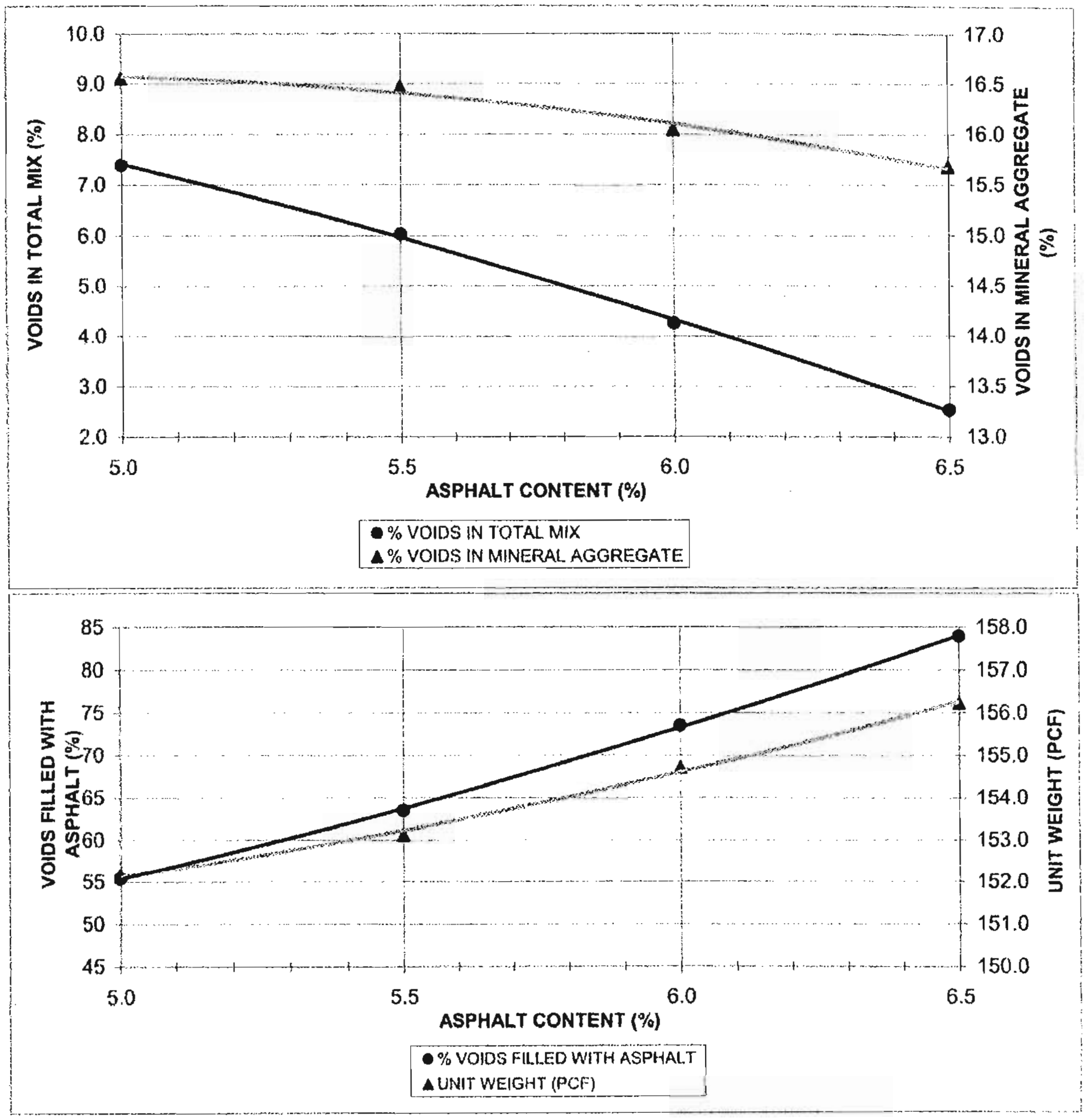


FIGURE 2

WESTEST
SPECIALISTS TO THE PAVING INDUSTRY

Client:	FHWA	November 1, 2006
Mix Design No.:	166206	
Grading:	E	
Mix Design Method:	75 Blows per Side	

MARSHALL PROPERTIES

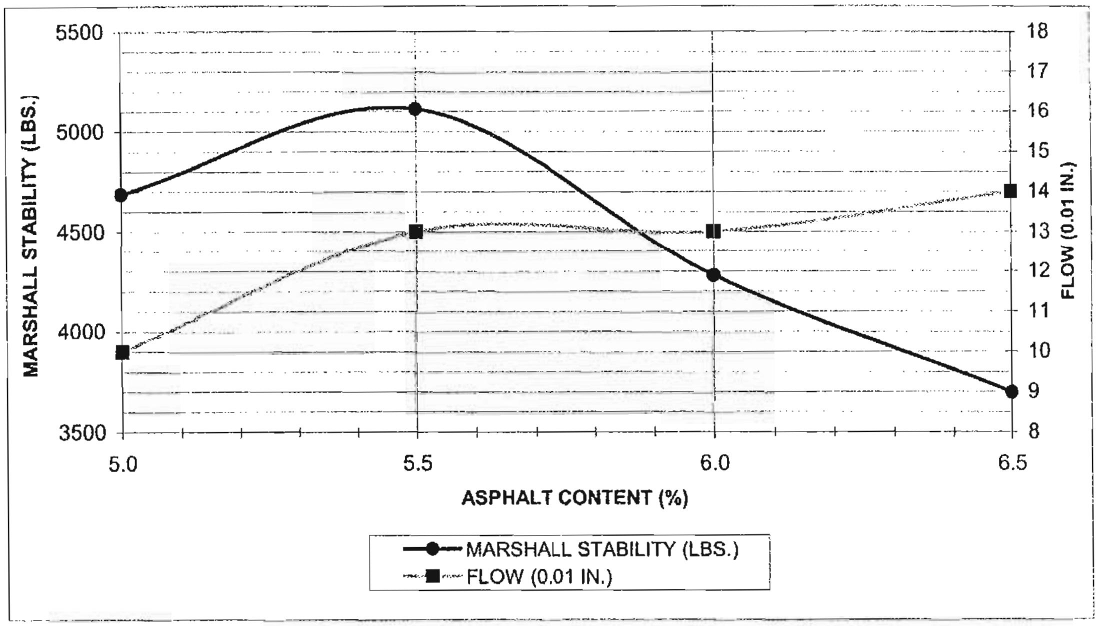


FIGURE 3

WesTest
Specialists to the Paving Industry
845 Navajo Street
Denver, CO 80204
303.975.9959, Fax: 303.975.9969

LABORATORY TEST REPORT

AS DELIVERED GRADATIONS

REPORT DATE: October 26, 2006
DATE SAMPLED: September 19, 2006
DATE RECEIVED: October 23, 2006
DATE TESTED: October 24, 2006
SAMPLED BY: Client
SOURCE: Pohakuloa Training Area Quarry

PROJECT: Saddle Road
FHWA PROJECT NO.: HI A-AD/STP 6(3) & 200(1)

WesTest PROJECT NO.: 166206
CLIENT: Federal Highway Administration
Denver Federal Center
Randall S. Caley
Building 2
Box 25246
Denver, CO 80225

GRADATION ANALYSIS - AASHTO T 11 & T 27

SIEVE SIZE	PERCENT PASSING					
SAMPLE DESCRIPTION	#67 CRUSHED STONE	TARGET	#8 CRUSHED STONE	TARGET	MANUF. STONE SAND	TARGET
2						
1 - 1/2"						
1"						
3/4"	100	100				
1/2"	72	77	100	100		
3/8"	27	36	92	87	100	100
#4	3	5	17	7	98	99
#8	2	3	3	2	73	80
#16	2	2	3	2	48	54
#40	2	2	2	1	26	30
#100	1	1	2	1	15	17
#200	1.2	1.1	1.9	0.7	11.4	11.7

TABLE 2

U.S. Department of Transportation
Federal Highway Administration

Central Federal Lands Highway Division Laboratory

An AASHTO and ISO Accredited Laboratory

AASHTO R18 ISO/IEC 17025

Report of Superpave Asphalt Concrete Mix Design

Gb=1.019

Project: Hawaii A-AD/STP 6(3) & 200 (1) Saddle Road

Submitted By: D.S. Scanlon

Date Reported:

Aggregate Source: Pohakuloa Training Area Quarry

Design Type: Hot Asphalt Concrete Pavement

Aggregate Nominal Maximum Size: 12.5 mm

Asphalt Cement Source and Grade: Tesoro Refining, Honolulu, Hawaii PG 64-16

Lab Number		06-1691-AGG	06-1692-AGG	06-1693-AGG			06-1977-AGG				
Field Number		ACC-5/8	ACC-3/8	ACC-#4 Sand			Combined				
Description		5/8" Aggregate (# 67 Stone*)	3/8" Aggregate (# 8 Stone*)	Sand (Manufactured Stone Sand*)	Lime		As Received	As Built	Specs	T.V.	(D)
Bin Combination%		29	27	43	1						
1"	25.0mm										
3/4"	19.0mm	100 (100)					100 (100)	100	100		
1/2"	12.5mm	74 (79)	100 (100)				92 (93.9)	94	90-100	94	
3/8"	9.5mm	34 (40)	93 (90)	(100)			79 (79.9)	80	90MAX		
#4	4.75mm	4 (14)	21 (21)	100 (97.6)			51 (52.7)	53		53	6
#8	2.36mm	2 (10)	5 (10)	72 (71.5)			34 (37.4)	37	28-58	37	6
#16	1.18mm										
#30	600µm	2 (3.4)	2 (4)	32 (33.3)			16 (17.4)	17		17	4
#40	425µm	2	2	26			13	14			
#50	300µm	1 (3.3)	2 (3.5)	21 (19.1)	(100)		11 (11.1)	12		11	3
#100	150µm										
#200	75µm	1.2 (1.5)	1.3 (2.6)	10.5 (11.2)	100 (95)		6.2 (6.9)	6.7	2-10	6.9	2
[illegible]imit				NV							
[illegible]ity Index				NP							

Design Parameters		Specs.	
Optimum AC by Total Mix Weight, %			6.8
Maximum Density, pcf	AASHTO T 209		158.6
Air Voids, %			4.0
VFA, %		65-78	77.0
VMA, %		14.0min	17.4
Lab Mixing Temperature, °C		—	160°
Dust-to-Binder Ratio		0.8-1.6	1.2
Antistrip, %, Type			

Moisture Induced Damage T 283	Specs.			
Asphalt Content, %				
Additive Type				
Additive, %				
Cond. Strength, psi				
Dry Strength, psi				
TSR, %				
Avg. Air Voids, %				
Saturation, %				
Crack/Broke Agg, %				

Aggregate Quality		Specs.	
L.A. Abrasion, Grading , %	AASHTO T 96	35MAX	
Micro-Deval Abrasion, % Loss	AASHTO T 327	— —	
$NaSO_4$ Soundness, % Loss	AASHTO T 104	12	
Fractured Faces, %	ASTM D 5821	90	100
Sand Equivalent, Ref. Alt. 2	AASHTO T 176	45	
Uncompacted FA Voids, A %	AASHTO T 304	40	
F & E Particles, 1:3 Ratio, %	ASTM D 4791	10	3.4

Design Gyratory Compactive Effort	ESAL's	Ninit	Ndesign	Nmax
Design High Air Temp, Centigrade				
Specification (% of Maximum Density)		< 90.5	96.0	< 98.0

Specific Gravity & Absorption T 84 & T 85 Reported values are one place more than AASHTO specifies	+#4	-#4	Combined
Apparent Specific Gravity			
Bulk Specific Gravity			
Absorption, %			
Effective Specific Gravity			

Distribution: Num. / Project File
[illegible] Darrell Harding
Project Engineer Eric Zeller
Construction Bill Hakala
Materials 4 Copies

Remarks: *As indicated in the mix design paperwork received 12/18/2006.
( ) indicates Jas. W. Glover's test results.

Reported By:

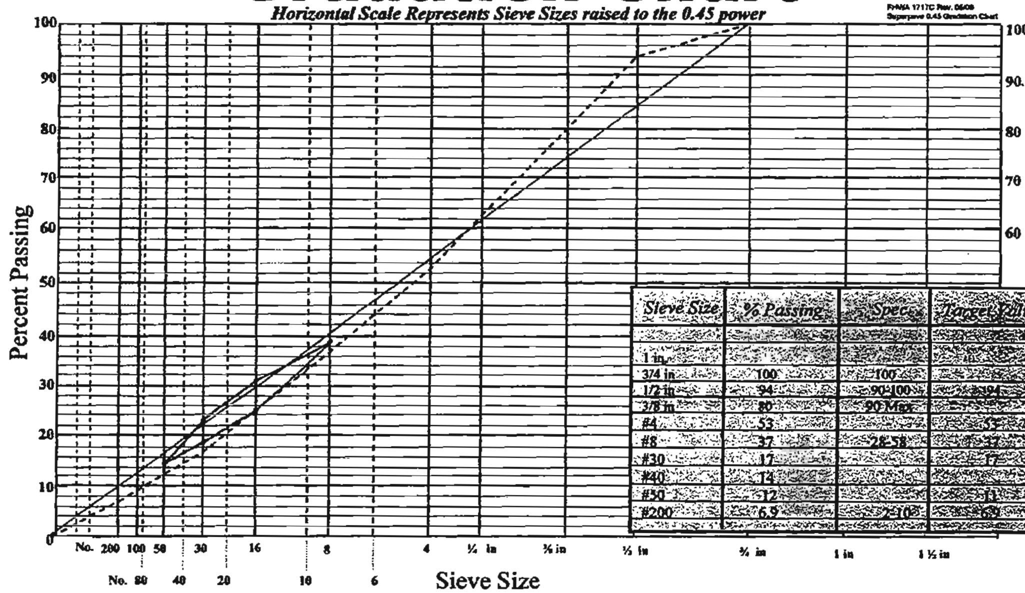
Form FHWA 1717A Rev. 05/06

Gradation Chart

Page of

FHWA 1717C Rev. 06/09
Superpave 0.45 Gradation Chart

Horizontal Scale Represents Sieve Sizes raised to the 0.45 power



Sieve Size	% Passing	Spec	Target Value
1 in			
3/4 in	100	100	
1/2 in	94	90-100	94
3/8 in	80	90 Max	
#4	53		53
#8	37	28-58	37
#30	17		17
#40	14		
#50	12		11
#200	6.9	2-10	6.9

State: Hawaii	Project: A-AD/STP 6(3) & 200(1) Saddle Road	Lab No. 06-1977-AGG	Date: 12/28/2006	Prepared By: PMK
Type, Source, Producer of Aggregate: PTA Quarry	Material Description: Superpave Hot Asphalt Concrete Pavement		Item: 401	Grading:
	Remarks:			

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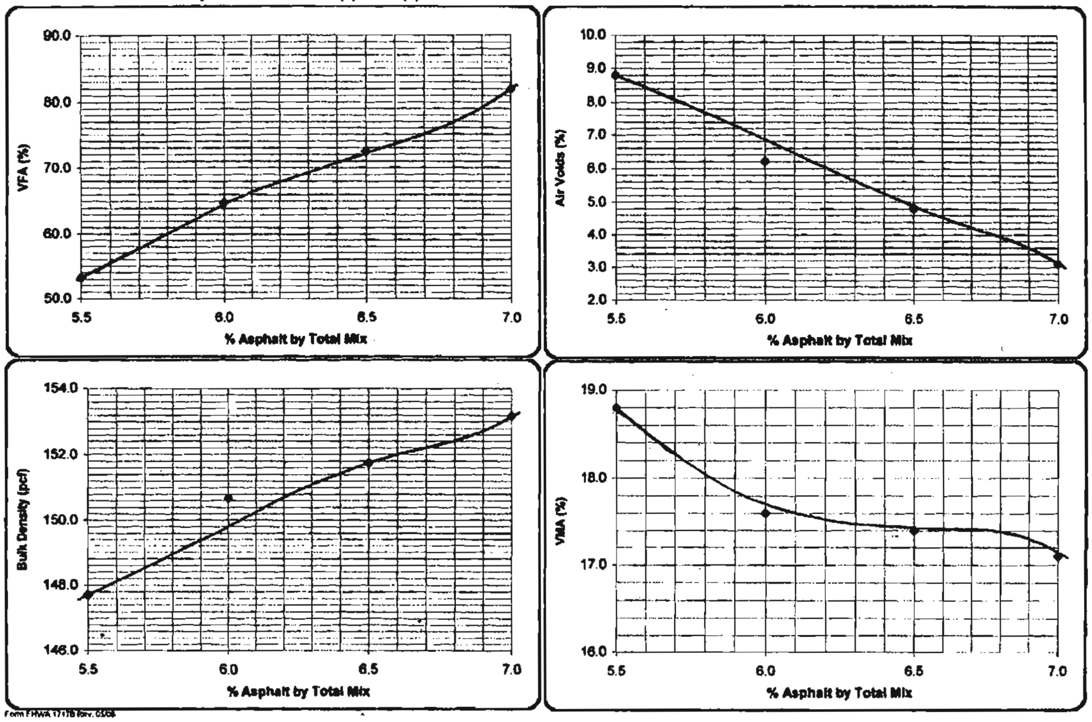
Superpave Mix Design

Page

Project: HI A-AD/STP 6(3) & 200(1) Saddle Road   Lab No: 06-1977-AGG   Date: 12/28/2006



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Report of Miscellaneous Tests

AASHTO R18 ISO/IEC 17025

Project: Hawaii SR 200 (2) Saddle Road East Side **Date Reported:** 6/15/2005

Laboratory Numbers: 05-(260, 263, 265, 268, 270 & 271)-C

Submitted By: Charlie Martinez **Material Type:** Mainly Basalt

Material Source: Bore Holes – PTA Quarry

Tested For: Aggregate Quality **Field Sample Numbers:** B-2, B-5 B-7, B-10, B-12 & B-13

Test Results

Laboratory Number	Boring Number	AASHTO T 96	AASHTO T 104	AASHTO T 85			
		Los Angeles Abrasion Grading A, % Loss	Sodium Sulfate Soundness, % Loss	Apparent Specific Gravity	Bulk Specific Gravity	Bulk SSD Specific Gravity	Absorption, %
05-260-C	B-2	24	0	2.84	2.70	2.74	2.0
05-263-C	B-5	27	0	2 82	2.65	2 71	2.4
05-265-C	B-7	28	0	2 87	2 72	2 78	1 9
05-268-C	B-10	27	0	2.85	2.68	2.74	2.3
05-270-C	B-12	26	0	2.93	2.80	2.85	1 5
05-271-C	B-13	26	0	2.92	2 79	2.84	1.6
05-207-AGG*	--	27	0	2.79	2.59	2.66	2.7

* This stockpiled material was previously reported on 5/19/2005.

Photos of all the submitted cores are attached.

The cores were laboratory crushed to –1½" before quality testing was initiated

Distribution:	Num. / Project File
Laboratory	Darrell Harding
Project Engineer	Eric Zeller
Construction	Bill Hakala
Project Management	Dave Gedeon
Geotechnical	[redacted]
Pavements	Mike Voth
Materials	4 Copies

Reported By.

Darrell Harding

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Figure E-1. Summary of material source testing on bulk samples from indicated coreholes.

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Federal Highway Administration

AASHTO R18 ISO/IEC 17025

Report of Superpave Asphalt Concrete Mix Design

Project: Hawaii SR 200(2) Saddle Road East Side — Page 1 of 4
Submitted By: Eric P. Zeller — **Date Reported:** 6/14/2005
Aggregate Source: PTA Quarry Stockpile; Pohakuloa Training Area — **Design Type:** Superpave Hot Asphalt Concrete Pavement
Aggregate Nominal Maximum Size: 12.5 mm — **Asphalt Cement Source and Grade:** Chevron, Kapolei, HI; PG 64-16

Lab Number								05-207-AGG				
Field Number								Combined				
Description								As Received	As Built	Specs	T.V.	(D)
Bin Combination%												
1"	25.0mm							After ½"				
3/4"	19.0mm							Scalp		100		
1/2"	12.5mm							100		90-100		
3/8"	9.5mm							87		90 Max.		
#4	4.75mm							64				6
#8	2.36mm							45		28-58		6
#16	1.18mm											
#30	600µm							22				4
#40	425µm							18				
#50	300µm							15				3
#100	150µm											
#200	75µm							7.1		2-10		2
Liquid Limit								NV				
Plasticity Index								NP				

Design Parameters		Specs.	
Optimum AC by Total Mix Weight, %			6.9
Maximum Density, pcf	AASHTO T 209		158.2
Air Voids, %		4.0	4.0
VFA, %		65-78	75.8
VMA, %		14.0 Min.	16.6
Lab Mixing Temperature, °C			158
Dust-to-Binder Ratio		0.8-1.6	1.3
Hveem, S-value		30 Min.	40
Antistrip, %, Type			

Moisture Induced Damage T 283	Specs.			
Asphalt Content, %		6.9	6.7	
Additive Type		None	Lime	
Additive, %		---	1.0	
Cond. Strength, psi		31.3	82.7	
Dry Strength, psi		88.3	91.8	
TSR, %	80 Min.	*35	90	
Avg. Air Voids, %	6-8	7.2	7.1	
Saturation, %	70-80	76.0	75.1	
Crack/Broke Agg, %				

Aggregate Quality		Specs.	
L.A. Abrasion, Grading A, %	AASHTO T 96	35 Max.	27
Micro-Deval Abrasion, % Loss	AASHTO TP 58		---
$NaSO_4$ Soundness, % Loss	AASHTO T 104	12 Max.	0
Fractured Faces,% 1 or more	ASTM D 5821	75 Min.	100
Sand Equivalent, Ref. Alt 2	AASHTO T 176	40 Min.	77
Uncompacted FA Voids, A %	AASHTO T 304	40 Min.	50.1
F & E Particles, 1:3 Ratio, %	ASTM D 4791	10 Max.	8

Design Gyratory Compactive Effort 7/75/115	ESAL's	Ninit	Ndesign	Nmax
Design High Air Temp, Centigrade				
	0.3-3	86.0	96.0	--
Specification (% of Maximum Density)		< 90.5	96.0	< 98.0

Specific Gravity & Absorption T 84 & T 85	+#4	-#4	Combined
Reported values are one place more than AASHTO specifies			
Apparent Specific Gravity	2.791	2.941	2.887
Bulk Specific Gravity	2.593	2.793	2.721
Absorption, %	2.74	1.80	2.14
Effective Specific Gravity			2.854

Distribution	
	Team / Project File
Laboratory	Daniel Harding
Project Engineer	Eric Zeller
Geotechnical	[redacted]
Construction	Bill Nekala
Pavements	Mike Voth
Project Management	Dave Gardner
Materials	A Cepilas

Remarks: The mix design was done without lime however T 283 results show that 1.0% lime is required.

The optimum asphalt content using 1.0% lime would be approximately 6.7%.

Reported By

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Figure E-2. Summary of Superpave asphalt concrete mix design.

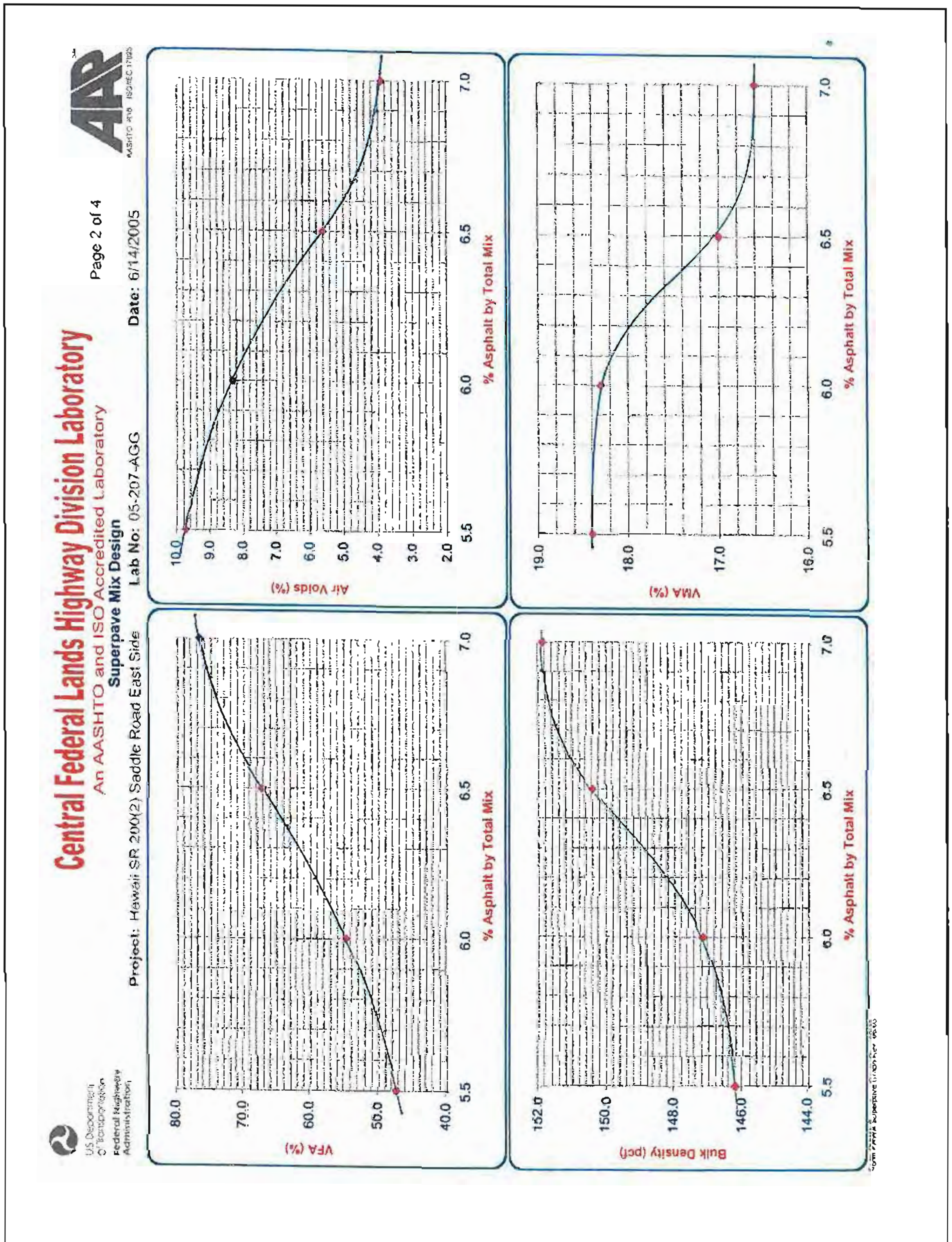
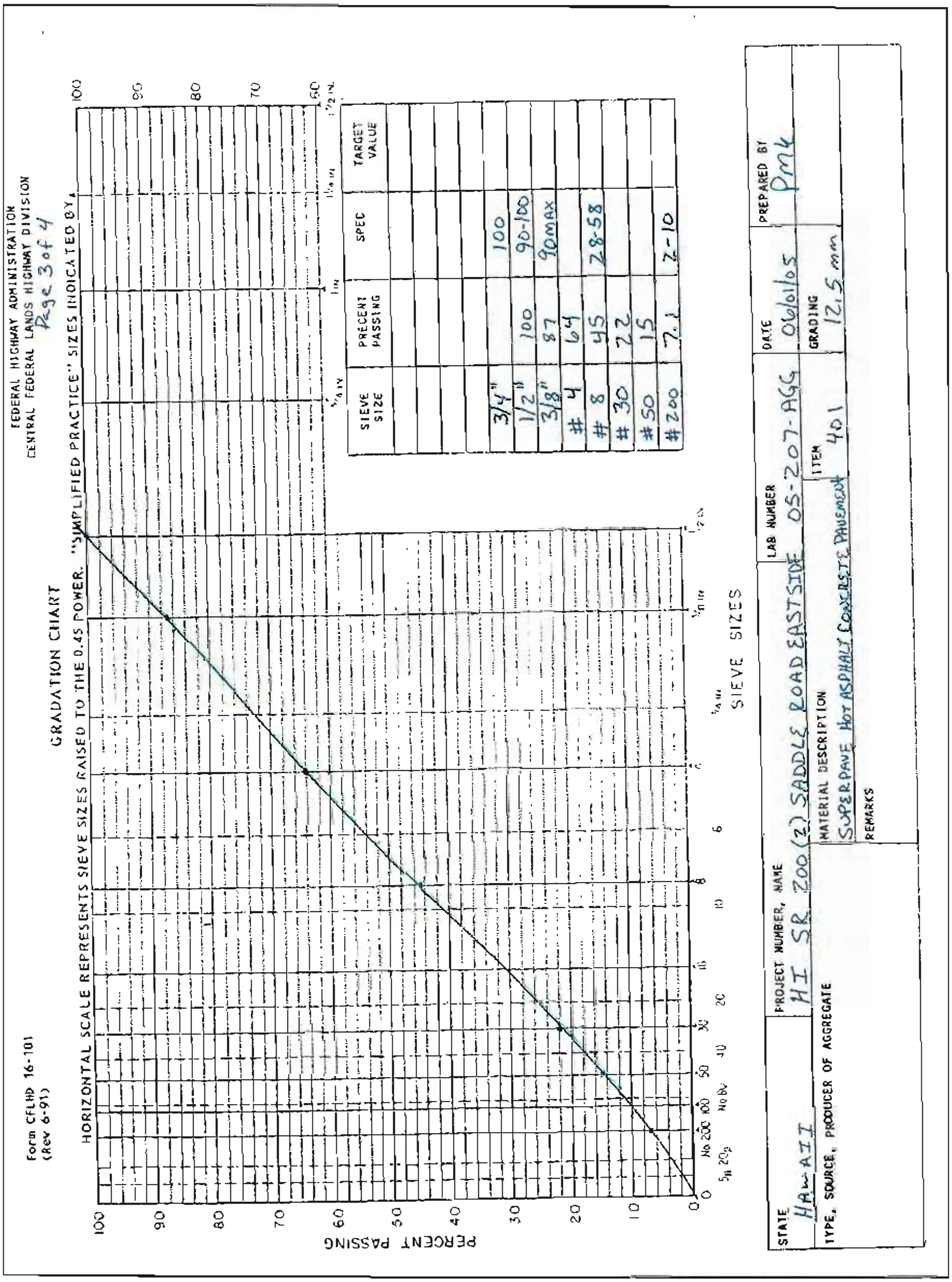


Figure E-3. Superpave mix design.



SIEVE SIZE	PRECENT PASSING	SPEC	TARGET VALUE
3/4"		100	
1/2"	100	90-100	
3/8"	87	90max	
# 4	64		
# 8	45	28-58	
# 30	22		
# 50	15		
# 200	7.1	2-10	

Figure E-4. Gradation tested for Superpave mix design.

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CHEVRONTEXACO, ASPHALT DIVISION, NORTHWEST REGION, PG TESTING LABORATORY, PORTLAND, OREGON *Page 4 of 4*

SuperPave PG 64-16 Binder Certification
ChevronTexaco Hawaii Refinery

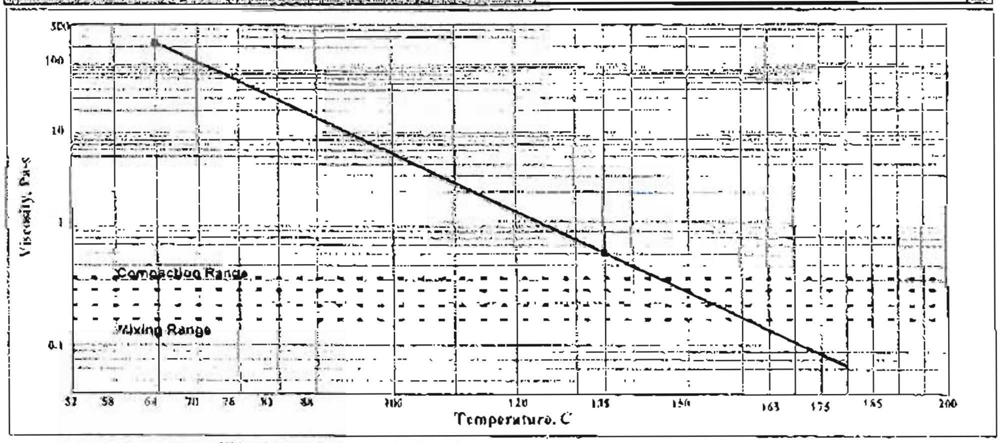
SAMPLE INFORMATION				SAMPLE I.D. #
BATCH NO.		TANK NO	102	LIMS # 25755
DATE SAMPLED	May 11, 2005	DATE TESTED	May 23, 2005	

ORIGINAL BINDER	Test Temperature	Test Result		AASHTO MP1 Specification	ChevronTexaco Target Specification
Flash Point, T48		288+	°C	Min. 230 °C	Min. 275 °C
Viscosity, ASTM D 2171	60 °C	3,980	P	None	3000-3200
Viscosity, ASTM D 4402	135 °C	0.512	Pa-S	Max. 3 Pa-s	Max. 1 Pa-s
	175 °C	0.137	Pa-S	None	Record
Dynamic Shear, TP5, G*/sin(delta)	64 °C	2.35	KPa	Min. 1.00 KPa	Min. 2.00 KPa
RTFO RESIDUE					
Mass Loss			wt %	Max 1.0 wt%	Max 0.5 wt%
Viscosity, ASTM D 2171	60 °C	7,342	P	None	8,000 - 11,000
Dynamic Shear, TP5, G*/sin(delta)	64 °C	3.87	KPa	Min. 2.20 KPa	Min. 4.0 KPa
PAV AGING					
PAV Aging Temperature	100 °C				
Dynamic Shear, TP5, G* sin(delta)	28 °C	2228	KPa	Max. 5000 KPa	Max. 4000 KPa
Creep Stiffness, TP1, S	-6 °C	93	MPa	Max. 300 MPa	Max. 250 MPa
m-value, TP1	-6 °C	0.387		Min. 0.300	Min. 0.32

TEMPERATURE-VISCOSITY CURVE (CALCULATED USING ASPHALT INSTITUTE PROGRAM)

Note: This data is for informational purposes. Actual mixing and compaction temperatures may require adjustments to meet field conditions. A compaction test strip is recommended.

CALCULATED CONSTRUCTION TEMPERATURES	
Mixing Temperature Range, °C	155°C - 161°C
Compaction Temperature Range, °C	145°C - 149°C
Mixing Temperature Range, °F	311°F - 321°F
Compaction Temperature Range, °F	292°F - 300°F



Mixing temperature range is where the binder viscosity is 0.17 +/- 0.02 Pa-s
Compaction temperature range is where the binder viscosity is 0.28 +/- 0.03 Pa-s

Lab Tester: RSRR OK to Ship: WTOL

ChevronTexaco PG Binder Laboratory, Chevron Asphalt Plant, El Paso, Texas.

Notes:

Hawaii Cert 23 may 05.XLS PRINTING DATE 5/23/2005

Figure E-5. Superpave binder certification.