ALAN KROPP & ASSOCIATES, INC.

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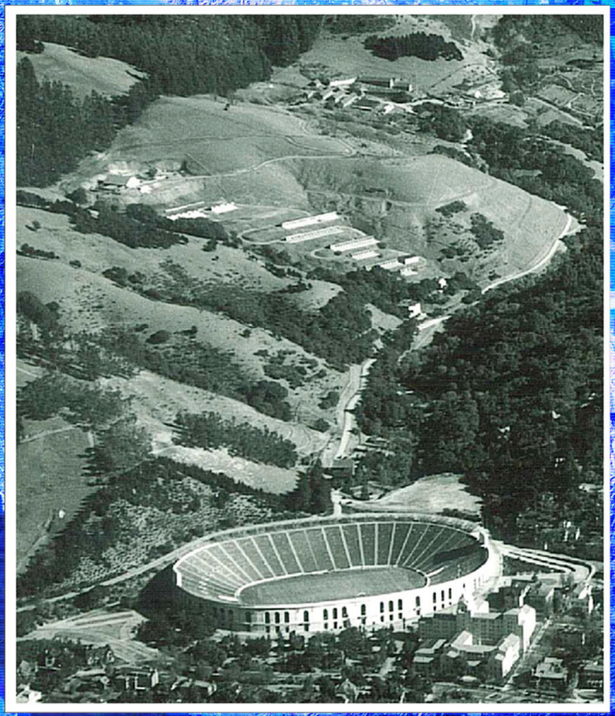
WLA

Geologic and Geotechnical Investigation Report

Helios Energy Research Facility

University of California, Berkeley
Berkeley, California



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January 30, 2009

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RE: Geologic and Geotechnical Investigation Report
Helios Energy Research Facility
University of California
Berkeley, California
(UCB Project 12313A)

Dear Ms. Swanson:

The attached report presents the results of our geologic and geotechnical investigation for the proposed Helios Energy Research Facility adjacent to the Material Science Research Cluster at the Lawrence Berkeley National Laboratory. The accompanying report presents information and data regarding geologic and geotechnical conditions at the site and presents our conclusions and recommendations pertaining to the design of the project. The interpretations, conclusions and recommendations presented in this report were developed in accordance with generally-accepted professional principles and practices at the time that the report was prepared.

Should you have questions or comments concerning our findings, the geotechnical design concepts discussed, or our recommendations, please do not hesitate to call.

Very truly yours,

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letter of transmittal - Jan09

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1.00 INTRODUCTION

This report presents the results of our geotechnical investigation for the University of California, Berkeley's (UCB's) proposed Helios Energy Research Facility, which will be located adjacent to the Material Science Research Cluster at the Lawrence Berkeley National Laboratory (LBNL). The project site is located between Lawrence Road and Centennial Drive in the Chicken Creek Canyon area of the LBNL facility. The approximate site location is shown on the Vicinity Map, Figure 1.

We obtained information regarding the proposed project primarily from the following design team members: Ms. Suzanne Napier of Smith Group, the project architects; Mr. David Bleiman of Rutherford & Chekene (R&C), the project structural engineers; and Mr. Trevor Greco of Creegan + D'Angelo (C+D), the project civil engineers. The locations of the proposed buildings, roads, and other improvements shown on the figures presented in this report are from schematic drawings dated October 31, 2008.

1.01 Project Description

The Helios Energy Research Facility (Helios) project will be constructed within Chicken Creek Canyon, an area of generally sloping hillside terrain. The proposed Helios project includes a research building, an access road from Centennial Drive, parking areas, retaining walls, cooling towers, and various other improvements. The various components of the project are shown on the Site Plan (Figure 2), and are described below.

1.01.1 Helios Building

The Helios building will be located along the eastern flank of Chicken Creek Canyon, downslope of LBNL Buildings 62, 66 and 67. The Helios building depicted on the schematic drawings is about 65 feet wide and 700 feet long and is curved to follow the existing surface topography. The structure will be aligned with its long axis paralleling the hillside and will be benched into the slope. Structural design will be per the 2007 California Building Code (CBC).

As currently envisioned, the Helios building will be a three-story steel structure supported on a conventional shallow foundation system comprised of (spread footings). Although it is a single building, structural separations (seismic gaps) are planned in two locations that will effectively divide the building into three separate structures. We understand that the building's structural system is likely to consist of moment frames in the long direction (parallel to the slope) and braced frames in the short direction (perpendicular to the slope). Structural loads on the new foundation system should be moderate and fairly typical for three-story steel-frame construction. Uplift resistance at the ends of the braced frames, if required, would be provided by either conventional drilled pier foundations or drilled and grouted ground anchors (tiedowns).

1.01.2 Building Pad

A retaining wall will be constructed directly upslope of the building along its entire length in order to construct the building pad, which will be near elevation +695 feet (project datum). Depending upon the final design, walls may also be needed to retain cut slopes at the ends of the building. Based on a +695-foot pad elevation, we estimate that the retaining wall behind the building would be about 20 feet high at its southern/eastern end and 55 feet high at its northern end. As currently envisioned, the permanent retaining walls would also serve as shoring and would be built using top-down construction methods using tiebacks. The building pad retaining walls will be stand-alone elements entirely separate from the Helios building.

The proposed excavation to +695 feet should expose bedrock over a significant portion of the building pad, however, the bedrock surface is estimated to be below elevation +695 feet in certain areas of the pad. In these areas, the materials that overlie bedrock will be excavated and replaced with engineered materials as part of the project.

1.01.3 Access Road

An access road will be constructed leading up from Centennial Drive (near elevation +630 feet) to the Helios building entrance (near elevation +695 feet). A turn-around loop will be provided at the northern end of the road and parking spaces are planned along the inboard edge of the road adjacent to the Helios building.

The access road crosses steeply-sloping terrain and retaining walls are planned at various locations along both the upslope and downslope sides of the road. As currently planned, the upslope retaining walls will be restrained by tiebacks and the downslope retaining walls will be of mechanically-stabilized earth (MSE) construction. MSE involves the placement of tensile georeinforcing elements (commonly referred to as Geogrids) between layers of engineered fill. Alternate systems comprised of metal straps or welded steel bars can also be used.

Centennial Drive and the access road entrance are located within Strawberry Canyon, which generally trends east-west. From there, the access road alignment initially trends west before turning north into Chicken Creek Canyon, which generally trends north-south. Within Strawberry Canyon, the access road centerline is near the elevation of the existing grade and the road is notched into steep south- and southwest-facing slopes. Within Chicken Creek Canyon, the access road alignment is higher than the elevation of the existing grade and the entire road is supported on a fill embankment. Towards its northern end, the face of the embankment will be inclined at approximately 2:1 (horizontal to vertical). As currently envisioned, this inclination will gradually steepen towards the south to allow the fill slope and MSE retaining wall to merge. Portions of the fill slope that are inclined steeper than 2:1 will also be of MSE construction.

1.01.4 Cooling Towers and Utilities

The project will include cooling tower units that are external to the Helios building. As currently envisioned the cooling towers would be situated on a reinforced concrete pad at one of two locations: (1) along the outboard edge of the parking lot directly southeast of Building 62 (near elevation +763 feet); or (2) directly east of the southern/eastern end of the Helios building. In the first option, the cooling towers would be located on a fill pad surrounded by downslope retaining walls. In the second option, the cooling towers would be located in cut and may be surrounded by cut slopes and/or upslope retaining walls.

We understand that most utilities (e.g. gas, electric and communications) will be brought to the Helios building site from the upslope side. Subsurface utility lines will also be installed between the Helios building and the external cooling tower units. The Helios building site crosses a buried electrical service line that extends from the area of LBNL Building 62 downslope (southwest) to the UCB corporation yard. We anticipate that this utility line will be relocated as part of the project. The retaining wall at the rear of the Helios building site also passes close to an existing access road that leads south and east from LBNL Buildings 62, 66 and 67 (towards LBNL Building 73); this road is underlain by a sanitary sewer and other utilities that may also need to be relocated as part of the project.

1.01.5 Wastewater and Stormwater Facilities

The project will include new wastewater and stormwater facilities. We understand that wastewater will flow by gravity south to an existing sanitary sewer along Centennial Drive. As currently envisioned, stormwater will be collected and pumped upslope to an underground hydromodification pond to be situated northwest of the Helios building. The hydromodification pond will consist of plastic units that are installed below-grade and covered with a surface parking lot. A short road will also be constructed leading down to the parking lot. We understand that the bottom of the hydromodification pond will be fully-lined to reduce the potential for groundwater infiltration.

1.01.6 Other Site Improvements and Modifications

A variety of other site improvements and modifications are likely to be considered as the project plans are developed and finalized. Based on our current project understanding, we anticipate that these may include:

- Various site retaining walls and surface grade modifications;
- Wetlands and/or habitat restoration; and
- Placement of fill in areas other than those shown (to achieve cut/fill balance).

It was our intent that this geotechnical and geologic investigation report address the various project components to the degree appropriate, given the information available to us at the time of report preparation.

1.02 Special Project Consideration – Engineering Geology Evaluations

The proposed Helios site is in an area of complex geology that includes both landslides and faults and it is an objective of this study to thoroughly characterize the geologic conditions in and surrounding the site. William Lettis & Associates, Inc. (WLA), our engineering geology subconsultant, characterized the geologic conditions at the site and assisted in the preparation of this report.

The site is located within an official State of California Earthquake-Induced Landslide Hazard Zone, as mapped by the California Geological Survey (CGS). This mapping, conducted under the Seismic Hazard Mapping Act of 1991, is intended to provide guidance to cities, counties and other lead agencies in their efforts to protect public health and safety, and is directed at structures intended for human occupancy. CGS Special Publication 117 (SP117) presents guidelines for evaluating and mitigating seismically-induced landslide hazards (as well as liquefaction hazards) in California. This publication is widely used by cities, counties and peer reviewers throughout California to determine the adequacy of geotechnical investigations conducted within the mapped seismic hazard zones. It was our objective that the evaluations and recommendations presented in this report pertaining to landslide hazards be developed in general conformance with the applicable SP117 guidelines.

The faults that exist in the direct vicinity of the site are not considered by the CGS to be active and the site is not within a previous or current State of California Earthquake Fault Zone, as delineated under the Alquist-Priolo Earthquake Fault Zoning Act. CGS Notes 42 and 49 provide guidelines for evaluating and mitigating fault rupture hazards within designated Earthquake Fault Zones. Although our overall geologic characterization of the site includes information on various faults in the project vicinity, it was not our objective to investigate or document these features in accordance with the rigorous CGS Note 42 and 49 guidelines as the faults in the direct vicinity of the site are not zoned as active.

1.03 Purpose and Scope of Services

The primary purpose of our investigation was to evaluate geologic and geotechnical conditions in the areas where new improvements are planned and to provide geotechnical engineering recommendations for the design and construction of the project. The scope of our services included:

- Compiling and reviewing existing data;
- Performing geologic field mapping;
- Drilling test borings;
- Conducting downhole geophysical measurements (including shear and pressure wave velocities);
- Performing geophysical surveys (seismic refraction, and multi-channel analysis of surface waves);
- Conducting geotechnical laboratory tests;
- Characterizing geologic and subsurface conditions;
- Evaluating potential geologic hazards;
- Conducting engineering analyses;
- Developing geotechnical conclusions and recommendations for project design; and
- Preparing this geotechnical investigation report.

This scope of work was accomplished over a period of time during which several possible building locations and configurations were being considered. Consequently, we developed new subsurface data for areas that may appear to be outside the current area of primary interest. These data, however, contributed substantially to our overall understanding of site geotechnical and geologic issues and are therefore included in this report (as are selected data from nearby projects by others).

1.04 Report Organization

The remainder of this report is organized into the following sections:

- Section 2 describes our methods of investigation;
- Section 3 describes the geologic setting and the results of our review of published information;
- Section 4 describes the local geology and our review of previous unpublished consulting reports;
- Section 5 describes site conditions and the results of our onsite investigations;
- Section 6 presents our engineering geology evaluations and conclusions;
- Section 7 presents our geotechnical engineering evaluations and conclusions;
- Section 8 presents our geotechnical recommendations for the project;
- Section 9 summarizes the limitations of our study; and
- Section 10 presents a list of selected references.

At the end of this report are figures that illustrate key points made in the text and a series of appendices:

- Appendix A presents logs of the borings drilled during this investigation;
- Appendix B includes logs of previous borings by others that were used in our evaluations;
- Appendix C includes the results of our downhole geophysical logging;
- Appendix D includes the results of our surface geophysical surveys;
- Appendix E includes the results of our geotechnical laboratory tests; and
- Appendix F includes the results of our slope stability analyses.

2.00 METHODS OF INVESTIGATION

2.01 Compilation and Review of Existing Data

2.01.1 Published Information

We reviewed published geologic maps and literature pertaining to geologic and seismic conditions in the site region and area. These references were used primarily to assess regional and local geologic conditions, tectonic framework, site-to-source distances to principal active faults, and to identify previously mapped landslides in the site region and area. A list of selected published references consulted during the investigation is presented in Section 10.01.

2.01.2 Review of Historic Aerial Photography

We obtained information about historic conditions at the site by reviewing oblique and vertical aerial photographs from the 1930s. The following photos are the oldest in our files of this particular area:

- One long-distance oblique aerial photograph taken of the UCB campus in 1935 (PAS-USNPS-5-I). This photograph looks east towards the Berkeley Hills and provides a clear vantage of the Helios site from that perspective.

- One set of sequential (paired) vertical photographs of the project study area that were taken in 1939 (BUT-BUU-289-67 and 68).

A portion of the oblique historic photograph is reproduced on Figure 3, 1935 Photograph. Identifying information for photos we reviewed is also included in the References section of this report (Section 10.03).

2.01.3 Unpublished Consulting Reports

We compiled an extensive collection of unpublished geotechnical, geologic and environmental reports relating to previous investigations conducted in the general project vicinity. These previous reports were initially screened to check for relevant subsurface data (e.g., boring logs, trench logs, groundwater depth measurements) and observations (e.g., geologic mapping) that would be useful in our overall characterization of the local geology. Data and observations obtained from the previous reports used in our geologic evaluations were further screened for relevance and consistency, particularly those data pertaining to the immediate Helios building area. The geotechnical and geologic materials that we compiled and screened during our study included geotechnical and geologic reports pertaining to:

- Centennial Drive;
- UCB Environmental Health and Safety Building (not built);
- LBNL Building 62 (MS, CH Lab);
- LBNL Building 66 (Center for SSC);
- LBNL Building 67 (Molecular Foundry);
- LBNL Building 72, A-C (National Center for Electron Microscopy);
- LBNL Building 77 (Radiation Laboratory); and
- LBNL Chicken Creek parking lot (not built).

Included in the documents that we screened were the following environmental reports, which pertain to geologic and hydrogeologic conditions in the Chicken Creek area.

- "Approval of the Geologic Controls of Groundwater Occurrence"; and
- "Hydrogeology and tritium transport in Chicken Creek Canyon".

Relevant data obtained from our review of previous unpublished consulting reports was entered into a Geographic Information System (GIS) database. Within the database, borings, test pits and trenches documented by others are identified by GIS identification numbers assigned during this investigation. The locations of individual data points are identified on the Site Plan and Data Compilation Map (Figure 4). A list of selected unpublished references consulted during our investigation is presented in Section 10.02.

2.01.4 Personal Communications

We conducted phone conversations, office meetings and field meetings with individuals having previous direct knowledge of geologic and historic conditions in the Chicken Creek Canyon area of the LBNL facility:

- Preston Jordan, a California-registered Professional Geologist and Hydrogeologist working for LBNL's Environmental Health & Services Department, was consulted to obtain additional local information on the geologic and engineering geologic conditions of the Chicken Creek area. Mr. Jordan is intimately familiar with the various geological investigations previously conducted in the Chicken Creek area having compiled geologic maps and cross sections for the RCRA Facilities Investigation (Parsons Engineering Science [Parsons], 2000), as well as performing detailed environmental studies (Jordan and Javendal, 2007) in Chicken Creek Canyon. WLA met with Mr. Jordan in the field on September 14, 2007. On October 5, WLA met again with Mr. Jordan at the location where the soil and rock samples obtained from our test borings were stored. WLA also met with Mr. Jordan in the Chicken Creek Canyon drainage to review local geologic conditions on April 23, 2008.

- Steven Korbay, previously of Harding Lawson Associates (HLA) and Kleinfelder, was contacted to discuss the work he completed concerning fault and landslide mapping for the construction of Building 67 and other similar works in the Chicken Creek area (Korbay, 2008). Mr. Korbay, a California-registered Certified Engineering Geologist, has directly observed a number of features of interest to this investigation, including excavations east of the site (near Buildings 66 and 67) and within the site (for the fill slope directly below Building 67). The WLA/AKA team also had an office meeting on January 7, 2008, with Mr. Korbay to discuss interpretations of faulting across the site area.

- Steve Blair, a California-registered Civil Engineer working for LBNL's Facilities Division, was consulted to obtain information on previous investigations and engineering work performed in the Chicken Creek Canyon area. Mr. Blair has directly observed various aspects of construction in and around the Helios site, including keying and benching, drainage installation, fill placement, and foundation construction. Mr. Blair together with Tim Kemper (also of LBNL's Facilities Division) assisted us in obtaining the necessary clearances and authorizations needed to conduct our field investigations.

Other individuals with direct onsite experience from whom we obtained information included Joe Harkins (LBNL Project Manager for Building 67), Dave Bleiman of R&C (Structural Engineer for Building 67), and Fred Angliss (LBNL's Lead Structural Engineer).

2.02 Field Investigation

2.02.1 Geologic Field Mapping

Detailed mapping of the site area was performed on a 1:600-scale topographic base map with 10-foot contour intervals (2007 digital base map provided by Mr. Blair of LBNL). Mapping focused on identifying bedrock units, surficial deposits and artificial fill, and evaluating fault and landslide contacts depicted by previous investigators (e.g., HLA, 1975 and 1979; Lennert & Associates, 1979; Parsons, 2000; Jordan and Javandel, 2007), and our interpretation of historical aerial photography.

A primary motivation for evaluating the bedrock geology was to: (1) determine whether bedrock faults and folds were preferentially oriented so as to form local zones of instability for structurally-controlled bedrock landsliding; (2) identify geomorphic features suggestive of landsliding; and (3) develop an understanding of the cultural modifications to the site. Efforts to delineate landslide margins within Chicken Creek Canyon based on surface morphology were severely limited in the region of the proposed Helios site area because of past extensive grading and fill placement.

2.02.2 Borings

Between September 2007 and November 2008, we drilled borings at forty-five locations. The locations of the borings (AKA-1 through AKA-44, AKA-29A and AKA-32A) are indicated on both the Site Plan presented on Figure 2 and on the Site Plan and Data Compilation Map presented on Figure 4 (borings AKA-29 and AKA-29A are at the same location). Borings drilled prior to October 2008 (including AKA-1 through AKA-28) have been assigned GIS identification numbers, which are used in Figures 4 through 12 (see table below).

AKA-1 through AKA-28 GIS Identification numbers (for Figures 4 through 12)

GIS Identification Number	AKA Boring Number
199	AKA-1
196	AKA-2
197	AKA-3
198	AKA-4
210	AKA-5
209	AKA-6
208	AKA-7
206	AKA-8
207	AKA-9
205	AKA-10
204	AKA-11
203	AKA-12
202	AKA-13
201	AKA-14

GIS Identification Number	AKA Boring Number
200	AKA-15
211	AKA-16
213	AKA-17
212	AKA-18
186	AKA-19
187	AKA-20
188	AKA-21
189	AKA-22
190	AKA-23
191	AKA-24
192	AKA-25
193	AKA-26
194	AKA-27
195	AKA-28

The borings were drilled using specialized drilling equipment that was selected based primarily on: (1) sampling and rock coring capabilities; and (2) site access capabilities (i.e., truck-mounted, track-mounted or portable). Three different contractors drilled the borings:

- Pitcher Drilling Company of East Palo Alto, California, drilled twenty-seven borings (AKA-1 through AKA-18, AKA-25 through AKA-28, AKA-31, AKA-32, AKA-32A, AKA-34 and AKA-35) using truck- and track-mounted rotary wash drilling equipment.

- Gregg Drilling Company of Martinez, California drilled three borings (AKA-29A, AKA-30, and AKA-33) using truck- and track-mounted auger and rotary wash drilling equipment.

- Access Drilling Company of San Francisco, California drilled sixteen borings (AKA-19 through AKA-24, AKA-29, AKA 36 through AKA-44) using portable auger drilling equipment.

A table (Drilled Boring Table) summarizing the drill rig and drilling method used on each boring is included at the front of Appendix A.

WLA geologists and AKA engineers supervised the drilling operations and prepared detailed field logs of the materials encountered. Logs of borings AKA-1 through AKA-44, AKA-29A, and AKA- 32A are presented in Appendix A. In addition to AKA-1 through AKA-44, boring logs from previous investigations were also used to generate the geologic cross sections and are presented in Appendix B. Each boring log in Appendix B was assigned a GIS identification number by which the borings are identified on Figures 4 through 12.

It was an objective of our investigation to evaluate the possible depth and lateral extent of landsliding in certain areas within and surrounding the Helios project site. Selected borings were continuously-sampled over their entire depth or over specific targeted depth intervals for this specific purpose. Borings or portions of borings that were not continuously-sampled were typically sampled at about 5-foot depth intervals.

Samples of soil and highly weathered bedrock were obtained using Standard Penetration Test (SPT) sampling methods, a 2½-in. I.D. modified California (Mod CAL) split barrel drive sampler equipped with brass liners, or a "Pitcher barrel" sampler equipped with 3-in. diameter steel Pitcher tubes. Hard bedrock was cored using rock coring equipment and was sampled using a core barrel. Core samples were carefully removed from the inside liner, washed and transferred to core boxes. Pitcher samples for borings AKA-1 through AKA-18 were extruded onsite and transferred to core boxes. SPT samples were stored in plastic sample bags. Samples not in brass liners were covered with plastic wrap to retain moisture and preserve the core.

Soils were classified in general accordance with ASTM D2488, which is based on the Unified Soil Classification System (USCS). A Key to Symbols and Descriptions for Soil Logs is included at the front of Appendix A followed by a Key to Symbols and Descriptions for Rock Logs, which describes the criteria we used to characterize rock materials. We note that the attached logs and related information depict subsurface conditions only at the approximate locations shown on the Site Plan on the particular date designated on the logs. The attached logs represent our current interpretation of the subsurface materials at the boring locations and the passage of time may result in changes in the subsurface conditions. In general, the locations and elevations of the AKA borings shown on the attached materials are based on survey data provided to us by LBNL.

2.02.3 Downhole Geophysics

Norcal Geophysical Consultants, Inc. (Norcal) of Petaluma, California, performed downhole geophysical logging within borings AKA-2 and AKA-35 on September 14, 2007 and November 6, 2008, respectively. A variety of downhole geophysical logging methods were employed, including:

Optical/Acoustic Televiewers and Gamma Logging - The optical televiewer (OTV) is a downhole probe containing an analog-to-digital video camera. The OTV operates in either dry or water-filled portions of the boring provided the water-filled portion is optically clear. The acoustic televiewer (ATV) is an ultrasonic device that can image the boring sidewall by measuring variations in travel time and amplitude of a reflected signal generated by a rotating ultrasonic transducer (center frequency of 1.0 MHz). The ATV operation requires the boring to be fluid-filled with a medium such as water or thinned slurry. The OTV/ATV instruments (console, computer, and downhole tools) consisted of a digital Robertson Geologging, Ltd. Model Videologger 2000 System. The OTV/ATV images are referenced to magnetic north as measured by onboard magnetometer sensors. The interpreted OTV/ATV plot developed using the Robertson software shows an unwrapped, false color 2-D image of the boring wall. OTV/ATV tool strings can also accommodate devices for borehole diameter, conductivity, and natural gamma measurements.

P- and S-Wave Suspension Logging - Downhole suspension logging is performed using a long probe containing a source and two receivers. The source generates a pressure wave, which is converted to seismic pressure and shear waves (P- and S-waves) at the borehole wall. The elapsed time between the arrivals of the waves at the receivers is used to evaluate average P- and S-wave velocities in the column of soil/rock that surrounds the borehole.

A full suite of geophysical logs (OTV/ATV image plot, together with P- and S-wave velocity, natural gamma and conductivity measurements) was developed for Boring AKA-2. In Boring AKA-35, only P- and S-Wave Suspension Logging was performed. The downhole geophysical data is presented in Appendix C.

2.03 Surface Geophysics

On September 25 and 26, 2007, Norcal performed a series of surface geophysical surveys in the vicinity of the proposed Helios building site. The surface geophysical surveys were performed using the following methods:

Seismic Refraction - The seismic refraction (SR) survey method involves measuring the travel time of seismic energy from a seismic surface to a string of receivers (geophones) placed on the ground surface. The time it takes for pressure waves to arrive at the receivers is used to evaluate average P-wave velocities within the subsurface materials through which the waves travel.

Multi-Channel Analysis of Surface Waves - Multi-Channel Analysis of Surface Waves (MASW) is a surface geophysical method used to evaluate shear wave (S-wave) velocities within near-surface materials. In the MASW method, surface waves are recorded similarly to an SR survey and the dispersion of surface waves are analyzed to evaluate near-surface shear wave velocities.

Norcal's report presenting the surface geophysical survey results is presented in Appendix D.

2.04 Laboratory Testing

Soil and rock samples were examined in our laboratory for more detailed examination and to select specimens for laboratory analyses. The following geotechnical laboratory tests were performed to provide general data on the physical properties of the subsurface materials.

- Water content per ASTM Test Designation D-2216;
- Dry density per ASTM Test Designation D-2937;
- Atterberg Limits per ASTM Test Designation D-4318; and
- Drained Residual Torsional Ring Shear Test per ASTM Test Designation D-6467.

The above tests were conducted in general accordance with the current edition of the referenced ASTM standards at the time the tests were performed. The results of the tests are presented on the boring logs presented in Appendix A at the appropriate sample depths. Laboratory data sheets are included in Appendix E, where applicable.

The drained residual torsional ring shear tests were performed on samples of interpreted landslide slip surface materials. The test is performed by deforming a pre-sheared, remolded specimen at a controlled displacement rate until the constant minimum drained shear resistance is obtained on a single shear plane determined by the configuration of the apparatus. An unlimited amount of continuous shear displacement can be achieved to obtain a residual strength condition. Three normal stresses were applied to determine the drained residual friction angle of the test specimen. Atterberg Limits determinations (ASTM D-4318) were performed on the same samples to evaluate their Plastic and Liquid Limits.

We also conducted corrosivity tests (Caltrans suite) on three samples. These tests included resistivity, chloride content, sulfate content, pH, redox potential, and sulfate. The corrosivity test results are attached at the end of Appendix E.

3.00 REGIONAL GEOLOGIC AND SEISMIC SETTING

In the following sections, we discuss general (i.e., non site-specific) information obtained from our review of published and unpublished geologic information. More detailed discussions of local geologic conditions are presented in Section 4.00, "Local Geology."

3.01 Berkeley Hills Geology

The proposed Helios building site is situated on the west side of the northwest-trending Berkeley Hills, which is generally characterized by gentle to steep topography. Bedrock geology in the Berkeley Hills is complex and includes a variety of moderately to highly deformed (faulted and folded) sedimentary, volcanic and metamorphic rock units. These rock units range in age from Late Jurassic to Cretaceous (135 to 150 million years ago) to Tertiary (66.5 to 1.6 million years ago).

The Simplified Regional Geology Map presented on Figure 5 is based on a published geologic map of this area from the United States Geological Survey (Graymer, et al., 1996). Bedrock units mapped in the site area include the Cretaceous Great Valley Group (Ku), Miocene Orinda Formation (Tor), and Miocene Moraga Volcanics (Tmb). The Hayward fault (considered a major active fault) trends northwest and runs along the western side of the Berkeley Hills near its base. It is located approximately 2,500 feet southwest of the planned site (Figure 5).

3.02 Bay Area Active Faults

The San Francisco Bay Area is within a broad region of deformation at the boundary between the North American and Pacific tectonic plates. This seismic regime includes a series of major active northwest-trending faults, which include the San Andreas, Hayward, Rodgers Creek, Calaveras, San Gregorio, Concord-Green Valley, West Napa, and Greenville faults. These major faults are near-vertical and generally exhibit right-lateral strike-slip movement (which means that the movement is predominantly horizontal and when viewed from one side of the fault, the opposite side of the fault is observed as being displaced to the right). Faults that are defined as active exhibit one or more of the following: (1) evidence of Holocene-age (within about the past 11,000 years) displacement, (2) measurable seismic fault creep, (3) close proximity to linear concentrations or trends of earthquake epicenters, and/or (4) tectonic-related geomorphology. Potentially active faults are defined as those that have evidence of Quaternary-age displacement (within about the past 2 million years), but have not been definitively shown to lack Holocene movement.

Various researchers and government agencies have mapped the locations of active and potentially active faults in California. The closest known active fault to the project site is the Hayward fault, which has been mapped by Lienkaemper (1992), Geomatrix (2006) and WLA (2007) approximately 2,500 feet southwest of the site on the UCB Campus (Figure 5). The State of California has designated official Special Studies Zones (later renamed Earthquake Fault Zones) around known active faults. These official State zones were initially delineated by the State Geologist in conjunction with the California Division of Mines and Geology (CDMG, now the CGS) as part of the Alquist-Priolo Fault Evaluation Program and are commonly referred to as A-P Zones. The CGS continues to revise and update the A-P Zone maps. The proposed Helios site is not within a State-recognized Earthquake Fault Zone.

The CGS has also developed Active Fault Near-Source Zone maps to be used in conjunction with previous (pre-2008) versions of the California Building Code (CBC). The Active Fault Near-Source Zone Maps are used with the CBC to characterize earthquake groundshaking for code-based structural design. The following table shows approximate distances and directions from the site to major Bay Area active faults, based on the CGS/CBC mapping:

Principal Bay Area Active Faults, Site to Seismic Source Distances

Seismic Source	Approximate Distance from Site	Approximate Direction from Site
San Andreas	30 km	Southwest
San Gregorio	31 km	Southwest
Hayward/Rodgers Creek	0.75 km	Southwest
Northern Calaveras	19 km	East
Concord-Green Valley	22 km	Northeast
West Napa	33 km	North

3.03 Bay Area Seismicity

The greater San Francisco Bay Area region is characterized by a high level of seismic activity. Historically, this region has experienced strong ground shaking from large earthquakes, and will continue to do so in the future. Since 1800, five earthquakes of M6.5 or greater have occurred in the Bay Area (Bakun, 1999). These include the: 1836 M6.5 event east of Monterey Bay; 1838 M6.8 event on the Peninsula section of the San Andreas fault; 1868 M6.8-7.0 Hayward event on the Southern Hayward fault; 1906 M7.9 San Francisco earthquake on the San Andreas fault; and 1989 M6.9 Loma Prieta event in the Santa Cruz Mountains.

In 2003, The Working Group on California Earthquake Probabilities (WGCEP, 2003), in conjunction with the United States Geological Survey (USGS), published an updated report evaluating the probabilities of significant earthquakes occurring in the Bay Area over the next three decades, (2002-2031), which has since been updated on a state wide scale in 2008 for the time span of 2007-2036. The WGCEP (2008) report indicates that there is a 0.63 (63 percent) probability that at least one magnitude 6.7 or greater earthquake will occur in the San Francisco Bay region before 2037. This probability is an aggregate value that considers seven principal Bay Area fault systems and unknown faults (background values-WGCEP, 2003). The findings of the WGCEP (2008) report are summarized below:

WGCEP (2008) Probabilities

Fault System	Probability of At Least One Magnitude 6.7 or Larger Earthquake in 2007-2036
Hayward/Rodgers Creek	0.31
San Andreas	0.21
Calaveras	0.07
San Gregorio	0.07
Concord-Green Valley	0.03
Greenville	0.03
Mount Diablo Thrust	0.01
Background *(2002-2031)	0.14*

The published background values are not explicitly stated in the WGCEP (2008) and thus the WGCEP (2003) values were used. The background values indicate that between 2002 and 2031 there is a 14 percent chance that an earthquake with a magnitude of greater than 6.7 may occur in the Bay Area on a fault system not characterized in the study. It should be noted differences between the 2008 and 2003 WGCEP generally fall within the magnitude of error, and major differences in background values are not expected.

4.00 LOCAL GEOLOGY

In the following sections, we discuss the results of our geologic reconnaissance together with information obtained from our review of published and unpublished sources, including geologic, geotechnical and environmental consulting reports. The introductory discussions presented in this section refer extensively to the Site Geologic Map presented on Figure 6.

4.01 Topographic Evolution

The topography of Chicken Creek Canyon has been significantly altered from its original natural condition. Early maps of the site area depict pre-development morphology of the Chicken Creek Canyon as a fan-shaped valley containing a series of radial drainages that flowed south towards Strawberry Creek (Lawson, 1900; UCB, 1923; Lennert and Associates, 1979). In the region of Buildings 72 and 77, multiple (as many as three to four) unnamed ephemeral drainages flowed southwest to Chicken Creek. The smaller creeks originated at the head of the canyon and formed steep, northeast-trending ravines along the east side of Chicken Creek Canyon (Lennert and Associates, 1979). The canyon's western wall previously had a slope of about 2:1 (horizontal to vertical), its central axis had a slope of 3:1, and its eastern wall had a slope of about 1½:1 (Lennert and Associates, 1979).

Early 1900 (Lawson) topography shows an elongate topographic bulge trending in a northeast-southwest direction that projects into an unnamed tributary running parallel to and east of Chicken Creek. This elongate feature, located northwest of the proposed Helios building site, exhibits surface morphology that is generally suggestive of landsliding. In or around the 1920s, development within the Chicken Creek Canyon area was initiated by UCB with the construction of a poultry research station. Topographic maps of this area from the 1920s forward show a series of switchbacks and benches within the central portion of the canyon and buildings at various locations (UCB, 1923). The early development of the canyon floor therefore removed any surficial evidence of the elongate feature observed on the earlier Lawson (1900) map.

The photograph presented on Figure 3 is the earliest aerial photograph that we were able to locate showing the surface topography of Chicken Creek Canyon. This photograph, which was taken in1935, clearly shows the switchbacks, benches and buildings comprising the UCB poultry research station as well as the existing access road that now leads from the area of LBNL Buildings 62, 66 and 67 south and east towards Building 73 (crossing the upper portion of the proposed Helios building site). This photo is significant in that it depicts the surface geomorphology of the proposed Helios building site prior to grading for: (1) Buildings 62, 66, and 67; and (2) the various landslide repairs that have previously been constructed in this general vicinity. Essentially similar surface topography is shown on the earliest stereo-paired aerial photographs of the area, which were taken in 1939.

Since 1939, extensive alterations of the canyon topography have occurred to the north of the planned Helios building site, in the areas of Buildings 31, 77 and 67. In general, these modifications included cutting and filling to create level areas for the buildings, as well as to construct various other smaller buildings, equipment pads and roads, and to repair unstable slopes. From a project perspective, these extensive topographic modifications are mostly significant in that they completely mask the natural up-canyon topography, which was typified by a series of radial ephemeral drainages within a large bowl-shaped feature. Other more minor topographic modifications of the natural canyon morphology have been made to construct various roads, slope repairs and buildings, including (most recently) fairly extensive grading downslope of the Molecular Foundry (Building 67).

The current morphology of the Chicken Creek Canyon is one of a broad rounded and arcuate valley that is bounded by southwest-trending ridges. The canyon is defined by a prominent north/south-trending drainage (Chicken Creek), with several smaller tributary drainages that enter from the northwest. There are no remnants of the historical northeast drainages, which have been buried or otherwise removed during previous episodes of site grading and filling. An unnamed drainage (sometimes referred to as "No Name Creek") exists along the lower eastern canyon margin and is separated from Chicken Creek by a southwest-trending ridge. Chicken Creek and No Name Creek both flow into Strawberry Creek beyond the south end of Chicken Creek Canyon (as shown on the Site Geologic Map, Figure 6).

4.02 Bedrock Units

Bedrock within the project area consists of predominantly northeast-dipping Cretaceous Great Valley Group and Tertiary Orinda Formation. Jordan and Javandel (2007) define the boundary between the Great Valley Group and Orinda Formation at the site as a fault contact. Near Building 31 the contact is defined, in part, by folded Orinda Formation along a southeast-trending anticline (Figure 6). The southwestern limb is cut by an unnamed fault (named herein as the 'Chicken Creek fault') that juxtaposes Orinda Formation on the northeast against Great Valley Group on the southwest (Jordan and Javandel, 2007).

4.02.1 Cretaceous Great Valley Group

The Cretaceous sedimentary deposits are defined as part of Mesozoic rock complex that includes the Coast Range ophiolite and the Great Valley Group. Although the Great Valley Group is usually separated from the ophiolite, it is known from regional mapping that the Great Valley Group sedimentary rocks were originally deposited on the ophiolitic rocks (Graymer, 2000). This complex represents the accreted and deformed remnants of arc-related Jurassic oceanic crust covered by a thick sequence of turbidites (Graymer, 2000). The sedimentary rocks of this sequence are the oldest strata that crop out in the direct vicinity of the site and consist of sandstone and shale of the Great Valley Group. Based on borehole information acquired and interpreted as part of this study, the middle and lower portions of Chicken Creek Canyon consist of shale, claystone, and siltstone (in the southwest project region) and sandstone (in the northeast and southeastern project region) (Figure 6).

Locally, the Great Valley Group is intensely to moderately fractured into blocky pieces with distinctive clay lining and a heavy weathering patina present in the first 20 to 40 feet of rock encountered at depth. In addition, the shale and claystone are intensely weathered and in places very weak. In particular, the claystone often is encountered as thin (less than several feet thick) interbeds within the shale and tends to be plastic and soft having undergone a significant amount of ancient tectonic deformation and weathering.

Within Chicken Creek Canyon the Great Valley Group strikes northwest and dips 25° to 45° northeast on the east side of the canyon, and increases in inclination to 60° near Centennial Drive and Strawberry Creek (Figure 6). At the site, the Great Valley Group material has been identified as in fault contact with the overlying Miocene Orinda Formation (Figure 6). Great Valley rocks near the fault zone are described as a dark gray to black, fine-grained shale and siltstone, that is sheared and brecciated within the shear zone (Jordan & Javandel, 2007; Kleinfelder, 2004).

4.02.2 Tertiary Orinda Formation

The Miocene Orinda Formation is a non-marine, well- to poorly-bedded siltstone, claystone, fine lithic sandstone, and pebble conglomerate. The conglomerate contains a high percentage of detritus derived from the Franciscan Assemblage (Graymer, et al., 1996). The coarse-grained conglomerate was deposited under alluvial fan conditions, while the sandstone, mudstone and finer-grained conglomerate were deposited as flood plain and channel material (Jones and Curtis, 1992).

The Miocene Orinda Formation underlies the upper portion of Chicken Creek Canyon and portions of the campus northeast of Building 62 and is exposed in parts of upper Chicken Creek (Figure 6). Locally, it consists of well-bedded to massive siltstone and claystone and occasional lenses of coarse-grained sandstone. The top of bedrock consists of fluid-stained, yellowish/reddish brown weathered silty sandstone to siltstone. With increasing depth, the Orinda Formation gradually becomes less weathered and maintains coloration more indicative of the deposit, such as, greenish-gray, gray, olive gray, and grayish-blue colors with discontinuous lenses of sand stringers and high concentrations of calcite carbonate.

The coarse-grained assemblage underlies the western and southeastern portions of upper Chicken Creek Canyon and consists predominantly of fine- and medium-grained sandstone (Jordan and Javandel, 2007). The sandstone exposed along Cyclotron/Lawrence Road strikes northwest and dips approximately 30° northeast (Figure 6). Exposures in Chicken Creek, at or near the contact with the Great Valley Group, show the inclination within the Orinda Formation to be ~30° south to southwest. The southwest inclination is interpreted as the southwestern limb of a northwest-trending anticline confined to the region of Chicken Creek fault (Parsons, 2000).

The Orinda Formation is in fault contact with the Great Valley Group. The fault contact is interpreted as a northwest-striking low to steep east-dipping discontinuity, and is expressed as a brecciated, slickensided sheared zone (Dames and Moore, 1962; Parsons, 2000; Kleinfelder, 2004; Jordan and Javandel, 2007). To the north of the site, the Orinda Formation is in a depositional contact with the overlying Moraga Formation (Figure 6). Based on the geologic and geotechnical data compilation, the anticipated fault contact between the Orinda Formation and Great Valley Group is located near the northeast corner of the planned Helios building (Figure 6). Most of the Helios project site is therefore underlain by Cretaceous Great Valley Group and not Miocene Orinda Formation (Figure 6).

4.02.3 Tertiary Moraga Formation

The Miocene Moraga Formation is exposed in cut slopes along Centennial Drive to the north of the site. In the site area it consists of andesitic and basaltic flows, rhyolitic tuff, and volcaniclastics (locally described as agglomerate or volcanic breccia). Potassium-argon ages of the volcanic flows vary from 10.2 million years (Ma) to 8.5 Ma (Curtis, 1989). The source vent for the local basalts is believed to be the Round Top volcanic complex located several miles southeast of the site. Locally, the Moraga Formation depositionally overlies the Orinda Formation or is present as intact translated slide bodies (Parsons, 2000). The Moraga Formation typically consists of highly fractured and weathered, subangular to subrounded cobble to large, boulder-size conglomerate with a predominantly silty to fine gravelly matrix with minor weathered and altered ash. The Moraga Formation was not directly encountered during the subsurface exploration of the proposed Helios project. Only Moraga Formation-derived clasts were encountered within the Quaternary alluvium and colluvium exposed in cores.

4.03 Secondary Bedrock Faults

The proposed Helios building site is located about 2,500 feet east-northeast of the active Hayward fault. Several smaller secondary bedrock faults are mapped in the site area (Figures 5 and 6), none of which are zoned by the State of California as active. The Wildcat fault and the locally named East Canyon feature of Borg (1991) are mapped northeast of the project site along the margins of LBNL's East Canyon, and do not intersect the project site (WLA, 2008a and 2008b). The Strawberry Canyon fault lies south of the site in Strawberry Canyon and does not intersect the site.

At the planned site, the unnamed northwest-trending fault that delineates the boundary between the Cretaceous Great Valley Group on the southwest and the Tertiary Orinda Formation on the northeast is herein described for discussion purposes only as the Chicken Creek fault. The Chicken Creek fault is mapped within about 20 feet of the northeast corner of the proposed building footprint and, roughly 400 feet northwest of the proposed access road (Figure 6). The fault is not exposed at the ground surface within the project area. The Wildcat and Chicken Creek faults, as well as the East Canyon feature of Borg (1991), are briefly discussed in the sections that follow.

4.03.1 East Canyon Feature (Borg, 1991)

The East Canyon feature was first postulated to be a fault by Borg (1991) based on an alignment of historical springs depicted in a historical 1875 (Soulé, 1875) map, subtle morphology, and apparent right-lateral displacement of Tertiary bedrock units in upper East Canyon. The alignment of the apparent fault-related features was interpreted to represent a near-vertical, right-lateral strike-slip fault oriented north-south to N10°E along the west side of East Canyon (Figure 5). The East Canyon feature is mapped about 800 feet northeast of the proposed Helios building footprint (Figure 6).

Based on the recent findings of a surface-fault rupture investigation of the East Canyon feature near Building 85, the hypothesized fault has been demonstrated to not exist as mapped, and thus has been reclassified as a feature rather than a tectonic fault (WLA, 2008a). Multiple trenches that intersect the mapped location, as well as reasonable orientations for the feature, provide direct evidence on the absence of a laterally continuous bedrock fault along the western margin of the East Canyon as mapped previously by others (Borg, 1991; Collins, 1993; Graymer, et al., 2000; Parsons, 2000; and Collins, 2007).

4.03.2 Wildcat Fault

The approximately 20-to 25-km-long Wildcat fault is located within the Berkeley Hills and extends northwest-southeast from Richmond to Oakland, subparallel to the Hayward fault (Figure 5; Graymer, 1996). The Wildcat fault was first identified by Lawson and Palache (1900), and was later named by Untermann (1935) who identified the fault in the Claremont and San Pablo water tunnels. In the tunnel exposures, the fault offsets the Monterey Formation (Claremont tunnel), and both the Orinda Formation (west) and Monterey Formation (east) (San Pablo tunnel). Untermann (1935) interpreted the fault as accommodating both strike-slip and vertical components of displacement. More recent studies by Curtis (1989) characterize the Wildcat fault as a right-lateral strike-slip fault that dips near vertical to steeply southwest. The fault is interpreted to have accommodated as much as 7 km of horizontal displacement over the last 9.6 million years (Ma) (Curtis, 1989). Jones and Curtis (1992) later characterize the fault, in the region of the LBNL, as a laterally continuous thrust fault between Berkeley and Oakland.

In the region of the LBNL, the Wildcat fault locally separates Tertiary Claremont Chert on the east against Tertiary San Pablo Group on the west, and is mapped about 1,500 feet east-northeast of the proposed Helios building footprint (WLA, 2008b). Early studies along the fault linked observations suggestive of active deformation (e.g., aseismic creep) at the northern terminus of the Wildcat fault where it lies within close proximity to the Hayward fault (Bishop, et al., 1973). These early interpretations of activity resulted in the northern most Wildcat fault being zoned as potentially active by the State and associated with a special studies zone on the initial A-P Zone map of the Richmond and Mare Island quadrangles (CDMG, 1974). Later, after closer examination by Smith (1980), the features suggestive of active faulting were reinterpreted as due to other processes and were not considered strong evidence for supporting the Wildcat fault as Holocene active. The re-analysis resulted in the California Division of Mines and Geology reclassifying the Wildcat fault as inactive (CDMG, 1982; Smith, 1980). As mapped within the LBNL and UCB campus, the Wildcat fault has never been included as part of an Earthquake Fault Zone. In addition, recent subsurface exploration of the fault for a proposed building in the East Canyon also interpreted the absence of Holocene activity (WLA, 2008b).

4.03.3 Strawberry Canyon Fault

The Strawberry Canyon fault is mapped as an east/west-striking, near-vertical fault located 700 feet south of the proposed Helios building footprint (Figure 5; Graymer, et al., 1996; Converse Consultants, 1984). The fault is mapped within the active drainage of Strawberry Creek (Figure 5). According to Graymer, et al. (1996) the Hayward fault truncates the west end and the Wildcat fault truncates the east end of the fault. The State does not recognize the Strawberry Canyon fault as active, and recent studies for LBNL (Parsons, 2000), do not recognize this fault as present.

4.03.4 Chicken Creek Fault

Numerous investigators have interpreted both northwest-striking and north-striking (Section 4.03.5, below) bedrock faults across the project site (Dames and Moore, 1962; Lennert and Associates, 1978 and 1979; HLA, 1979; Graymer, et al., 1996; Jordan and Javandal, 2007) that juxtapose Tertiary and Cretaceous rocks. The herein-named Chicken Creek fault is an approximately 5-mile-long fault that strikes between N65°W to N80°W, and dips northeast between 16° and 70° (Jordan and Javandel, 2007; HLA, 1975). The location of the fault near the site is based on rock outcrops, interpretation of borehole data, and direct evidence from trench exposures. Multiple fault locations have been depicted in the site vicinity (HLA, 1975 and 1979; Converse Consultants, 1984; Graymer, et al., 1996; Kleinfelder, 2002 and 2003; Jordan and Javandel, 2007).

The data compilation and synthesis performed for this project represents a revised interpretation of the fault location. For instance, proximal to the northeast corner of the proposed Helios footprint, the fault is interpreted as a low-angle, east-dipping shear zone that locally separates Orinda Formation on the northeast from the Great Valley Group on the southwest (Jordan and Javandel, 2007). About 2000 feet northwest of the planned Helios site, recent grading excavations for a proposed LBNL Guest House showed the fault zone consisting of highly sheared and brecciated Tertiary Orinda Formation on the east against the Cretaceous Great Valley Group on the west. Faulting is expressed as a broad zone of shearing within the Orinda Formation and consists of abundant calcium carbonate lined shear planes and highly pulverized and brecciated bedrock. The orientations of shear planes within the Orinda Formation are widely variable ranging from northeast to northwest, however, the overall orientation of the fault zone is generally north to northwest and dips northeast.

East of the proposed Helios footprint and near Building 67, the fault is expressed as a broad (approximately 50 feet wide) zone of steep east-dipping shears, with slickensides trending N40°W and dipping northeast (trench logs in Appendix B). A trench excavated across the fault exposed a thin (greater than 3 feet thick) veneer of

colluvium unfaulted across a distinct zone of clay shears (HLA, 1975). HLA (1975) concluded that the fault was "ancient" and that it represented no threat to the proposed construction of Building 66. Converse Consultants (1984) reviewed the work of HLA (1975) and performed field reconnaissance, and similarly concluded that the fault was not active. The Chicken Creek fault has been inferred by previous investigations to be inactive (that is, not active within the past 11,000 years). More recently, Korbay (2008) commented on the low likelihood of activity on the Chicken Creek fault in a meeting with members of the Helios project team. Mr. Korbay's assessment of fault activity was based, in part, on his previous field studies at LBNL, which include numerous site-specific studies within the Chicken Creek Canyon area, as well as direct observations of the feature in subsurface excavations. Although there is a possibility of minor sympathetic displacement of the fault contact during a major earthquake on the nearby Hayward fault, Mr. Korbay considers the likelihood of such an occurrence to be remote.

4.03.5 Unnamed North-Striking Faults

Multiple, discontinuous and short north-striking faults have been mapped in the Chicken Creek Canyon area (Figures 5 and 6). HLA (1979; 1982) originally mapped three north-striking faults in the northern part of Chicken Creek Canyon based on bedrock relations exposed in road cuts and interpretation of previous excavations in the site vicinity (Dames and Moore, 1962). Two of the faults were interpreted from observed bedrock offsets during the construction of Building 77 and adjacent roads (Dames and Moore, 1962) as seen in the northern limit of the Site Geologic Map (Figure 6). A southerly projection of the faults beyond Building 77 and toward the proposed Helios site was first suggested by HLA (1964 and 1979) and is depicted as inferred fault projections (Figure 6). Dames and Moore (1962) did not consider these faults as active. Dames and Moore (1962) stated that without detailed trenching, the origin, activity and extent of the faulting could not be determined, including any direct relation with the pervasive landsliding at the site.

The north-striking faults shown in red at the top of Figure 6 are defined based on road cut, trench, and borehole data. On the basis of the synthesis of regional and local geologic and geotechnical data, the locations of the north-striking faults have been revised in extent and appear to be limited to the area north of the Chicken Creek fault (Figure 6; HLA, 1982). On the basis of the limited mapped extent of these faults (<2,000 ft) and their apparent truncation by laterally more continuous northwest and west-striking faults to the north and south of the site, these faults pose at best a very remote surface-fault rupture hazard to the site.

Lastly, Graymer, et al. (1996) map a block of Orinda Formation bound on the west and east by two north-striking faults in the Chicken Creek area. These faults project north where they are truncated by the northwest-trending Chicken Creek fault (Figure 5). The easternmost fault of Graymer, et al. (1996) intersects the present-day footprint of the Helios building. As discussed above, similarly located and orientated faults have been inferred by Dames and Moore (1962), Harza Kaldveer, (1993), HLA (1975), and Kleinfelder (2003) near Buildings 69 and 77 north and northeast of the Helios footprint, as well as two faults traversing the southeastern and northwestern margins of Chicken Creek Canyon. No direct evidence is available for these faults and thus the traces are not presented in the geologic model (Figure 6). None of the north-striking faults are recognized by the State as Holocene active.

4.04 Landslides

Compilation of existing geologic and geotechnical data, coupled with geologic mapping, indicates landslide deposits within the Chicken Creek Canyon are extensive, and are derived from reworked Quaternary deposits, Orinda and Moraga Formations, and the Great Valley Group. Nilsen (1975) maps nearly the entire Chicken Creek Canyon as underlain by potential landslide deposits. The landslides mapped in Figure 6 depict earthflows, rotational slumps and translational slides. These features are introduced in the sections that follow.

4.04.1 Large Landslides

Two large landslides are mapped within the study area (Figure 6). One large landslide occupies much of the basin of East Canyon and is shown on the eastern edge of the Site Geologic Map. This slide is mapped directly east of the access road entrance off of Centennial Drive, and does not intersect the project site and thus, is not discussed further. The second large landslide is inferred from previous mapping in the site area. On the basis of geomorphic expression and logging of multiple hydraugers, Lennert and Associates (1979) interpret the entire drainage basin of Chicken Creek as a poorly constrained, large Plio-Pleistocene landslide complex. The eastern margin of this hypothesized landslide intersects the northern portion of the proposed Helios footprint and is depicted on Figure 6 as a thick gray dashed line (note that only the eastern boundary of the inferred slide lies within the figure area). Nilsen (1975) and Parsons (2000) also map several large landslides in this region of the LBNL. The headwall of the hypothesized large landslide of Lennert and Associates (1979) is mapped north of Building 77 within both Moraga and Orinda Formations, and includes an arcuate headscarp encompassing Building 69. The upper part of this slide has had several medium-sized slope repairs, including the installation of numerous hydraugers for dewatering purposes. The lateral margins of the landslide generally coincide with the ridges bounding Chicken Creek Canyon and the former drainage. The large inferred landslide spans most of the canyon floor between Building 69 and the UCB corporation yard and thus is comprised of Tertiary Orinda and Moraga Formations and Great Valley Group rocks (Lennert and Associates, 1979). Lennert and Associates (1979) indicate part of the large landslide may be active based on an apparently displaced hydrauger, as well as a large bedrock void present along the western margin of the slide that was encountered during the drilling of a hydrauger. It is unclear if the displaced hydraugers are attributed to the large inferred slide or numerous smaller nested slides that are mapped extensively within the inferred slide body.

Subsequent geologic and geotechnical reports have portrayed the mapped landslide boundaries of Lennert and Associates (1979), but few have addressed the presence or absence of the landslide. Multiple small and medium-scale slides have been mapped and encountered within this interpreted large slide mass providing evidence for localized slope instabilities. The mapped location of the landslide headwall is consistent with the presence of weak and highly fractured Tertiary Moraga and Orinda Formation slide blocks that were encountered during excavations for Building 77, as well as the arcuate shape of the upper canyon. Geologic cross sections presented by Parsons (2000) and Holland and Wollenberg (1992) show the upper portion of the large inferred slide consists of a thin mantle (i.e., less than about 15 feet) of colluvium overlying Orinda Formation. The cross sections depict the slide mass as transitioning to the southwest into a paleovalley (the Northern Intermediate Landslide of the following section) obscured by a thick volume of Quaternary colluvium. Geotechnical evaluation by Harza Kaldveer (1993) characterizes the Quaternary colluvium as exhibiting high unit weights and shear strength "indicating that it has likely been in-place for a significant period of time."

Geologic mapping and previous slope repairs in the canyon support the presence of multiple smaller landslides rather than a single large landslide as interpreted by Lennert and Associates (1979). The mapping of a single large landslide within Chicken Creek Canyon appears to us to be speculative, and the existence of such a feature could not be confirmed or refuted by this investigation. To our knowledge, there is no evidence of coherent movement of a landslide of this scale at the site during historic time. Consequently, the feature hypothesized and delineated by Lennert and Associates (1979) is not considered "potentially active" or of "potential impact to the project."

4.04.2 Intermediate Landslides

At least three landslides classified as "intermediate scale" are mapped within the study area (Figure 6). These landslides occur in a variety of rock types, range from 350 to 850 feet long and 100 to 300 feet wide, and have an estimated maximum thickness of about 70 to 80 feet. On the basis of this study, these intermediate landslides directly intersect the proposed Helios development. The three intermediate landslides proximal to the proposed footprint are referred to herein as the Northern, Central and Southern Intermediate Landslides (the other intermediate landslides that do not intersect the project area are not discussed). The Northern, Central and Southern Intermediate Landslides are delineated on Figure 6 by name.

The margins of the landslides depicted on the Site Geologic Map (Figure 6) are based on field observations, interpretation of aerial photography and historical topographic maps, and/or available subsurface information, and should be considered approximate. The Top of Bedrock Contour Map presented on Figure 7 is an interpretation of approximate surface elevation contours for "in-place" bedrock (i.e., below the depth of significant landsliding). The bedrock contours shown on Figure 7 have been interpreted based on the available subsurface data, geologic/historic information and assumptions regarding possible geomorphologic development and should be considered approximate.

Northern Intermediate Landslide - The Northern Intermediate Landslide lies within a prominent buried paleovalley that extends from near Building 31 southwest to Chicken Creek (Figure 7). The landslide lies north and west of the planned Helios building and access road, with the minor exception that the eastern margin of the landslide may intersect the proposed access road turn-around west of the building footprint (Figure 6). The buried paleovalley depicted in Figure 7 trends northeast-southwest and generally aligns with the former location of Chicken Creek (e.g., topography from 1900 and 1922-23). Minor undulations and swales border the larger paleovalley and may suggest that the landslide is composed of multiple smaller landslide complexes occupying narrow swales similar to the present-day geomorphic setting (e.g., Central Intermediate Landslide; see discussion below). Based on the dimensions of the paleovalley, the Northern Intermediate Landslide may be as much as 550 feet long (up to a maximum of 850 feet) with an estimated width of 250 to 275 feet. The slide body consists of unconsolidated Quaternary alluvium and colluvium, and highly weathered and fractured Orinda Formation and Great Valley Group rock. The lateral extent of sliding is poorly constrained (noted by dotted lines on the Site Geologic Map, Figure 6). The Northern Intermediate Landslide margins shown on Figure 6 are estimated based on interpretation of compiled geologic and geotechnical data, borehole data collected during this study, and our interpretive mapping of the bedrock surface defined by the buried paleovalley (Figure 7). To our knowledge, there is no evidence of coherent movement of the Northern Intermediate Landslide during historic time.

Central Intermediate Landslide - The Central Intermediate Landslide is located on the eastern side of Chicken Creek Canyon and intersects the central part of the proposed Helios building footprint and access road alignment (Figure 6). This intermediate-scale landslide is characterized as trending northeast-southwest (similar to the Northern Intermediate Landslide) and extends from the eastern end of Building 67 southwest across the proposed Helios development. Using historical aerial photography (Figure 3) and topographic maps, coupled with review of existing geotechnical information and new borehole data, we interpret the Central Intermediate Landslide as a landslide complex rather than a single coherent slide mass. It consists of multiple shallow to moderately deep landslide blocks comprised of Quaternary colluvial material deposited along a narrow former northeast-trending paleo-swale, as well as translated weathered Orinda Formation and Great Valley Group materials. The landslide complex is about 675 feet long and 200 feet wide and has previously been identified by

LBNL as a region of known slope instability. Portions of the Central Intermediate Landslide have experienced movement during historic time and portions of this landslide have been previously repaired (most recently during the construction of the Molecular Foundry, Building 67; Kleinfelder, 2004). The actual lateral extent and depth of the previously-constructed landslide repairs are uncertain. Figure 6 depicts an approximation of the repaired extent based on review of pre- and post-repair topography, as well as geotechnical maps that outline a proposed region of repair.

Southern Intermediate Landslide - The Southern Intermediate Landslide is located east of Chicken Creek Canyon on a south-facing slope above Centennial Drive and Strawberry Creek (Figure 6). The Southern Intermediate Landslide is also interpreted as a landslide complex consisting of multiple nested, shallow earthflow and translational debris slides that extend across the existing LBNL access road (from Building 73) and downhill toward Centennial Drive. Slide material includes fine-to coarse-grained colluvial debris and highly weathered Great Valley Group rock that makes up multiple short and recently-active failures. On the basis of reconnaissance mapping and interpretation of aerial photography and borehole data the Southern Intermediate Landslide is about 350 feet long and 125 feet wide.

The locations of the interpretive geologic cross sections intersecting the North, Central and Southern Intermediate landslides are shown on the Site Geologic Map (Figure 6). The cross sections (attached as Figures 8 through 12 are discussed further in Section 6.01, "Landsliding."

4.04.3 Medium Landslides

Numerous medium-scale landslides (200 to 350 feet long and 100 to 200 feet wide) are mapped within Chicken Creek Canyon and along south-facing slopes within Strawberry Canyon (Figure 6). Many of the medium-scale landslides delineated on the Site Geologic Map are considered "active." These slides occur in both the Orinda Formation and Great Valley Group. The depth of slide material for the medium-sized slides is estimated to be between 20 and 50 feet. None of the mapped medium-scale landslides intersect the proposed Helios project.

4.04.4 Small Landslides

Numerous small-scale earthflow and slump-type landslides are present on hillsides and graded slopes in the site vicinity. Theses slides are typically about 100 to 300 feet long and less than about 100 feet wide and are interpreted to be about 15 to 25 feet deep. The smaller slides commonly represent reactivation of localized portions of larger slides and slumps within colluvial hollows (e.g., linear topographic swales). Several small-scale landslides intersect the proposed access road for the Helios project (i.e., slides intersected by AKA borings 39, 40, and 43). The dimensions of the landslides are based on field mapping, review and interpretation of historical aerial photography and topographic maps, and borehole data. Many of these slides extend into thick forested canopy and shrubbery making the dimensions of the slides uncertain.

4.04.5 Previous Landslide Repairs

Within the project vicinity, at least eight previous slope failures have been identified and repaired during recent LBNL grading operations and/or building excavations (seven of those LBNL repaired slopes are shown as pink stippled areas on Figure 6). Construction-related slope repairs exist in areas proximal to Buildings 31, 66, 67, 69, 72, 77, and the present-day switchback access road between Building 31 and the UCB corporation yard (HLA, 1989; Kleinfelder, 2002). The slope repairs typically included the removal of landslide material followed by the placement of subsurface drains and fill.

Repaired slopes directly downslope of the Molecular Foundry (Building 67) intersect the proposed footprint of the main Helios building (Kleinfelder, 2002; Kleinfelder 2004). Based on a review of these documents it appears that the grading for the Molecular Foundry included excavating previously unstable materials, installing subdrains, and placing buttress fills. The exact dimensions and depth of the slope repair is unknown and is broadly estimated on Figure 6 and the subsequent geologic cross sections. The areas shown in pink on Figure 6 typically are derived from planning documents that outline the proposed slope repairs. Portions of the map depicted by the fill symbol also may represent undocumented repairs as noted by distinct topographic changes in the present-day slope geometry (e.g., areas between the pink zones near Building 67 and 66).

4.05 Quaternary Surficial Deposits

The landscape of Chicken Creek Canyon has been culturally modified by grading and placement of artificial fill. The landscape modifications place limits on the detailed mapping of unconsolidated Quaternary deposits at the site. Quaternary surficial deposits include alluvial, colluvial and fluvial materials as well as artificial fill.

4.05.1 Colluvium

Quaternary colluvial material is widespread throughout the study area (map symbol Qu) and includes: (1) mudflow and debris-flow materials deposited on canyon floors; (2) colluvium-filled hollows located on steep slopes; and (3) thinner surficial deposits (<10 ft) of colluvium that are generally not mapped (shown as bedrock in Figure 6). These areas are described below:

Canyon Floor Colluvium - The most prevalent surficial deposit in the direct vicinity of the proposed Helios building site is undifferentiated Quaternary colluvium consisting of a thick sequence of poorly-bedded fine-grained clay and silt with minor amounts of gravel. The colluvium that currently comprises the floor of Chicken Creek Canyon ranges in thickness from 2 to 3 feet north of Building 31 to greater than 80 feet within the buried paleovalley that exists northwest of the planned Helios building site. The eastern edge of Chicken Creek Canyon is defined by the No Name Creek paleovalley now filled with roughly 25 to 40 feet of colluvial deposits. We interpret the colluvium within the buried paleovalleys as being remobilized (e.g., translated) following deposition by the Northern and Central (Intermediate) Landslides. The colluvium is remobilized as debris flow and landslide material within the paleovalleys and is mapped as slide debris (Qls).

Colluvial Hollows - Multiple north/south-trending colluvium-filled hollows, some with active landsliding, are mapped on the steep south-facing slope above Centennial Drive and intersect the Helios footprint and access road. The colluvial hollows are on the order of 200 to 250 feet long by 50 to 100 feet wide and consist of fine-grained colluvium with highly weathered and loose bedrock.

Hillslope Colluvium - Variable amounts of colluvium mantle the shallow bedrock slopes and consists of clay, silt and weathered bedrock clasts.

4.05.2 Alluvial/Fluvial Deposits

Localized deposits of silty and clayey gravel alluvium have been encountered in boreholes (map symbol Qu). In general, these buried deposits are thought to be associated with various former tributary creeks that once existed within Chicken Creek and Strawberry Canyon during prehistoric and (perhaps) historic time. Significant thicknesses of alluvial/fluvial materials are generally absent over most of the ground surface and alluvial/fluvial deposits are not differentiated on the Site Geologic Map (Figure 6).

4.05.3 Artificial Fill

Review of aerial photography, historical topographic maps, and geotechnical reports, indicates that fill exists in many areas of Chicken Creek Canyon. Fill has been placed for roadway embankments, building pads and slope repairs. Artificial fill also exists within the former stream channels west and northeast of the project site, as well as within the former No Name Creek drainage basin.

Attempts to estimate the amount of artificial fill and grading at the site included reconstructing the former topography based on older topographic maps (Lawson, 1900; UCB, 1923); however, these maps were not of sufficient resolution to interpolate the limits of removal and filling of the canyon. (Where the older topographic maps appear to exhibit some semblance of topographic consistency, the former 1922-23 ground surface has been shown on some geologic cross sections for interpretative purposes only). Note that the dotted shading depicted on the Site Geologic Map (Figure 6) provides an approximation of the location of fill placed at the site after about 1940. Earlier fills placed during the construction of the terraces and switchbacks within the lower floor of Chicken Creek Canyon are not shown.

5.00 SITE CONDITIONS

This section presents general descriptions of conditions in the areas where new improvements are planned. The locations of planned improvements and the AKA borings drilled for this study are shown on the Site Plan (Figure 2). The locations of all of the borings and other data subsets contained in the project GIS database are shown on the maps presented on Figures 4 and 6.

5.01 Surface Conditions

5.01.1 Helios Building Site

Chicken Creek Canyon is topographically complex and includes both extensive cultural modifications and remnants of pre-existing natural topography. The long axis of the proposed Helios building generally parallels the topography and can be divided into three physiographic regimes:

> ***Northern Site:*** Much of the northern portion of the Helios building site (northern site) is within the engineered fill slope located directly downslope of Building 67. The fill slope is inclined at approximately 2:1 (horizontal to vertical) and includes two gently-sloping drainage benches oriented roughly parallel to the long axis of the Helios building. The fill slope and drainage benches are generally covered in grassy vegetation; narrow concrete v-ditches are present along the upslope (eastern) side of the drainage benches. The fill slope transitions to natural ground at the far north end of the northern site, where bedrock can be observed in portions of the slope.
>
> ***Central Site:*** The central portion of the Helios building site (central site) crosses a topographic swale related to the Central Intermediate Landslide complex. The swale has previously been graded and contoured to approximately a 2:1 inclination and is covered with grassy vegetation; a shallow concrete gutter exists within the central portion of the swale that trends roughly upslope-downslope.
>
> ***Southern Site:*** The southern portion of the Helios building site (southern site) is curved to cross the topographic ridge that exists at the juncture of Chicken Creek and Strawberry Canyons. The southern site is within mostly natural terrain comprised of west- and south-facing hillslopes. An asphalt-paved LBNL access road passes through the upslope margin of the southern site. Upslope and downslope of the access road the terrain is inclined at about 2:1; however portions of the slope are locally steeper. The upper portion of the southern site is generally covered in grassy vegetation with some trees present. The lower portion of the southern site is more densely vegetated with brush and trees.

5.01.2 Access Road Alignment

The Helios access road alignment leads from Centennial Drive north and west to the proposed Helios building; within this alignment, the topography can be divided into two physiographic regimes:

> ***Southern Alignment:*** From Centennial Drive to about the southern-central site transition, the access road traverses vegetated soil and rock slopes containing various pre-existing landslides and colluvium-filled hollows. In general, average slope inclinations in this area are about 2:1; however, locally steeper areas exist particularly within areas mapped as landslides or colluvial hollows. Vegetation along the access road alignment varies from grassland to dense brush and trees.
>
> ***Western Alignment:*** Southwest of the Helios building, the access road transitions into the more gently-sloping area of the Chicken Creek Canyon floor, which includes the area of the UCB

corporation yard. The Chicken Creek Canyon floor is generally comprised of 1920s-era switchbacks and benches. Surface grades in this area vary from nearly-level to as steep as about 2:1 (between benches and east of the canyon floor). Lower benches within the UCB corporation yard are occupied by a variety of lightweight metal and frame buildings. The uppermost bench within the UCB corporation yard and all of the benches on LBNL property are generally covered in gravel and are occasionally used for various storage purposes. The switchback road is unpaved or marginally paved with asphalt concrete.

5.01.3 Features of Environmental Significance

Discrete areas of the Chicken Creek Canyon floor are considered environmentally significant, as discussed below:

Wetland Areas: As previously discussed, the Chicken Creek Canyon floor has been extensively modified by grading, much of which occurred during the 1920s. Subsequently, subsurface drainage improvements were installed in various portions of the canyon to increase upslope stability. Two horizontal drains installed for this purpose outlet within the project site (Figure 4). Over time, water exiting from these drains has produced conditions favorable to plant growth. We understand that this area is now designated as wetlands and will require mitigation.

Riparian Areas: A narrow stand of trees exists on the slope between two benches within the UCB corporation yard. This row (or "finger") of trees extends east from the riparian corridor surrounding Chicken Creek and is considered to be of environmental significance. We anticipate that mitigation would be required for any individual trees that are disturbed within either the Chicken Creek riparian corridor or within the riparian "finger" located within the UCB corporation yard.

5.01.4 Hydromodification Pond and Mitigation Areas

As currently envisioned, the project will include a hydromodification pond and wetlands mitigation areas located within the western portion of the Chicken Creek Canyon floor (Figure 2). Outside of the Chicken Creek riparian corridor, the topography of this area consists of relatively level benches with intervening graded slopes inclined at about 2:1. In general, the benches are mostly bare soil or gravel, and the slopes are sparsely-vegetated with grasses.

5.02 Subsurface Conditions

5.02.1 General

As shown on the Site Geologic Map (Figure 6), the Helios project covers an area that is both geographically broad and geologically complex. Our focus has therefore been to:

- Establish a coherent geologic context for the conditions that currently exist (Section 4.00);
- Provide reference datasets of location-specific subsurface information (Appendices A through E); and
- Present our interpretations of subsurface conditions based on the available data (Figures 7 through 12).

Figure 7 presents an interpretive contour map showing the surface of in-place bedrock and Figures 8 through 12 present interpretive cross sections depicting subsurface conditions. These figures were developed using the

following datasets: (1) topographic data files provided to us by LBNL and C+D; (2) borehole data from this investigation and previous investigations by others; (3) direct onsite observations of physiographic features; (4) observation of physiographic features on historic photography and old topographic maps; (5) assumptions regarding likely geomorphologic development; and (6) geometric constraints provided by bedrock interpreted to be in-place.

5.02.2 Fill, Colluvium and Landslide Deposits

The cross sections on Figures 8 through 12 present our interpretation of subsurface conditions in selected areas of the Helios project site. The locations of the cross sections (shown on Figures 4, 6, and 7) are discussed briefly, below:

- Cross Section A-A' is approximately aligned along the interpreted central axis of the buried paleovalley containing the Northern Intermediate Landslide. This section was developed to analyze the stability of this feature, which (as currently envisioned) will not be mitigated as part of the proposed Helios project.

- Cross Sections B-B' and C-C' are aligned within the central portion of the Helios building site generally perpendicular to the slope and intersect deposits related to the Central Intermediate Landslide. These sections were developed to evaluate likely depths of in-place bedrock mostly for the purposes of evaluating upslope retainage and required depths of overexcavation beneath the Helios building and access road.

- Cross Section D-D' is aligned generally perpendicular to the slope within the Southern Intermediate Landslide and was developed to evaluate likely depths of in-place bedrock mostly for the purposes of evaluating upslope retainage and required depths of overexcavation beneath the Helios access road.

- Cross Section E-E' is aligned generally parallel to the slope along the curving back (upslope) wall of the Helios building, as depicted on the October 31, 2008 schematic plans. This section was developed mostly for the purpose of evaluating upslope retainage requirements.

These five cross section alignments were selected to evaluate areas of particular geologic and/or geotechnical interest (often involving deep soil and/or landsliding) and should not be considered representative of subsurface conditions elsewhere at the site. As discussed in Section 4.00, hillside areas not subject to previous landsliding are typically underlain by relatively shallow in-place bedrock, whereas in-place bedrock is generally deeper within mapped landslide areas and below the Chicken Creek Canyon floor.

5.02.3 "In-Place" Bedrock

A critical first step in our interpretation of "in-place" bedrock involved the drilling of multiple borings within regions of inferred slope instability to evaluate the presence or absence of suspected landslide deposits. The locations and sampling intervals of these borings were selected to investigate the working hypotheses that the former paleovalleys of Chicken Creek Canyon were rimmed by intermediate-sized landslides and that an elongate bulge seen in the pre-development topography (Lawson, 1900; UCB, 1923) and the deep soil deposits found in previous borings (Harza Kaldveer, 1993) were landslide-related. Collectively the investigations performed for the planned Helios project identified multiple features in the field and cores that can be

attributed to landslide-related processes. Detailed descriptions of the materials encountered in the borings are provided on the boring logs (Appendix A). More information on the various landslides that intersect the project is presented in Section 6.01, "Landsliding".

Deliberate care was taken by the engineering geologists involved in this study in making "calls" as to whether rock materials observed in core samples were from bedrock that was in-place or from rock that had been part of a deep, perhaps ancient, bedrock landslide. These interpretations were made more difficult by the fact that bedrock within the study area has generally been folded and sheared by tectonic processes. In addition, where boreholes extended a less-than-significant distance into rock (less than about 5 feet), we have generally less confidence in "calls" as to whether the rock materials encountered were in-place. Due to these uncertainties, the top of in-place bedrock surface depicted on Figures 7 through 12 must be considered approximate.

In some areas, it was necessary to re-interpret "calls" of bedrock made by previous investigators (non-AKA related studies) based on: (1) new borehole evidence (i.e., of nearby rock interpreted to be translated), and/or (2) qualitative judgments involving plausible slide plane geometries. This is particularly the case in areas where cross sections developed for this study intersected previous borings by others. However, we did not (nor would we be able to) re-interpret top of bedrock "calls" by other investigators in areas where new borehole data is absent. Although we found it useful to extend our top of bedrock contouring into nearby areas not explored by recent borings, it is possible that the actual surface of in-place bedrock within these areas may differ significantly from what is shown on Figure 7.

5.03 Groundwater Conditions

Groundwater elevation data for the site is derived from multiple datasets that span several decades of subsurface investigation. The most current groundwater conditions likely to be representative of the project site area come from groundwater wells located southwest of Building 31. These groundwater monitoring wells provide water-level data spanning a nine-year period (from July 1995 through July 2004). The data indicate relatively shallow groundwater located about 12 to 17 feet below the ground surface in the northwestern region of the proposed Helios building footprint. Subsurface studies conducted by Geomatrix Consultants (1994) for a proposed UCB Environmental Health and Safety building (not built) south of the proposed Helios footprint near the base of Chicken Creek Canyon encountered groundwater between 32 and 45 feet in depth. North of the proposed UCB Environmental Health and Safety building site, Borehole 4A (GIS-39) near the inferred toe of the Northern Intermediate Landslide encountered water at about a depth of 25 feet (Geomatrix, 1994).

Hydraugers installed as part of a dewatering program to stabilize small- and large-scale landslides (e.g., the Plio-Pleistocene landslide) in the Chicken Creek and East Canyon area (e.g., Centennial Drive overpass landslide) of LBNL by Lennert and Associates (1978 and 1979) indicate a significant amount of groundwater is present in the upper reaches of the hills. Two hydraugers installed by Lennert and Associates (1979) intersect or underlie the proposed Helios building footprint (HA-22 and HA-23, Figure 4). The hydraugers were drilled northward from Chicken Creek Canyon to intersect the base of the Moraga Formation with lengths of approximately 2,100 (HA-22) and 910 (HA-23) feet. The drains daylight southwest of the Helios footprint, where water was observed draining from pipes during drilling operations in September and October 2007. These hydraugers apparently intersected the east margin of the Plio-Pleistocene slide margin about 130 feet northeast of Building 31 (Lennert and Associates, 1979). Over a five-year period between 1979 and 1984, these two hydraugers produced an average flow rate of 3 to 12 gallons per minute (gpm; Converse Consultants, 1984). These flow rates are apparently too low to provide much influence on groundwater levels in this part of the LBNL campus (Converse Consultants, 1984).

Test borings AKA-1 through AKA-18 (GIS-186 to 213) were drilled using rotary wash drilling methods, which generally obscure the depth at which groundwater is encountered. There was one exception in Borehole AKA-1 (GIS-199) where groundwater was noted because of an anomalous rate of seepage at or below 77 feet in depth. The borehole was bailed twice for downhole geophysical profiling and was found to have filled at a rate of approximately ½ gallon to 1 gallon per 10 minutes. Groundwater levels at the site may vary substantially depending on variations in rainfall, surface runoff and other factors. In addition, locally perched groundwater and seepage conditions likely exist, particularly during and following periods of rainfall.

6.00 ENGINEERING GEOLOGY EVALUATIONS

The discussions in this section refer extensively to the Site Geologic Map presented on Figure 6 and the five interpretive cross sections (A-A' to E-E') presented on Figures 8 through 12. The cross section locations are shown on the Site Plan and Data Compilation Map (Figure 4), the Site Geologic Map (Figure 6), and the Top of Bedrock Contour Map (Figure 7).

6.01 Landsliding

6.01.1 Northern Intermediate Landslide

Borehole data provide evidence for the interpretation of translated Quaternary colluvium and bedrock within the margins of the Northern Intermediate Landslide. These data include highly fractured Orinda Formation and Great Valley Group rock, which are overlain by colluvium and massive landslide deposits. The basal contact is delineated by heavily disturbed and mixed colluvium and bedrock that contains clay seams, fractures and brecciated rock. In the Orinda Formation, deformation includes fat clay-lined fractures (AKA-1 and AKA-4/GIS Nos. 199 and 198) present at roughly 70 to 75 feet below ground surface. Landslide deformation features also were noted at the top of Great Valley Group rock as evidenced by the presence of weak and fractured shale and/or sandstone with clay seams, disturbed colluvium in the overlying 5 to 10 feet, and similar fractures within 5 feet of the basal contact.

Cross section A-A' is located along the central axis of the Northern Intermediate Landslide (Figure 8). As shown on the Site Geologic Map (Figure 6), Section A-A' trends northeast-southwest and is closely aligned with a tributary to Chicken Creek (based on 1922-23 topographic map). The Northern Intermediate Landslide occupies a buried paleovalley of Chicken Creek that is filled with as much as 80 feet of colluvial and landslide debris overlying highly weathered and fractured bedrock. The margins of the landslide are broadly inferred to represent the northwestern and southeastern boundaries of the paleovalley. It is unclear if the Northern Intermediate Landslide is a continuous landslide block as simply inferred in Figures 6 and 8, or alternatively, if it is composed of multiple smaller nested landslides rimming the steep sides of paleo-Chicken Creek. The interpretative Top of Bedrock map (Figure 7) indicates considerable complexity to the geometry of the paleovalley floor, including buried bedrock ridges that protrude southwest across the Northern Intermediate Landslide. The buried paleovalley morphology suggests that the current geometry of the Northern Intermediate Landslide (shown on Figure 8) may be over-simplified, and that the adjacent Central Intermediate Landslide with its numerous smaller active landslides is a better analog.

As depicted on the Site Geologic Map (Figure 6), the Northern Intermediate Landslide is a minimum of about 550 feet long and ranges in width from 200 feet near the inferred head wall to about 275 feet wide near the inferred toe. The lateral extent and depth of sliding is estimated based on analysis of the buried morphology of the paleovalley, exploratory borehole data, seismic refraction profiles, and historical topographic maps. The slide is composed primarily of a thick sequence of poorly bedded colluvium and alluvium, and weathered Orinda Formation and Great Valley Group rocks. Present-day morphology of the landslide has been significantly altered by the placement of artificial fill along the switchbacks and terraces between the UCB corporation yard and Building 31, as well as by grading and removal of material near the assumed head of the landslide. Furthermore, the historical topographic maps suggest that the previous locations of Chicken and No Name Creeks have been modified, and originally may have defined the margins of the Northern and Central Intermediate Landslides.

As depicted on Section A-A' (Figure 8), compilation of the subsurface exploration data indicates that the buried paleovalley is filled with colluvium that is up to about 80 feet thick. A large landslide mass (symbol

Qls) is depicted on Section A-A' that extends from near Building 31 down to the central part of Chicken Creek Canyon that includes both colluvium and translated bedrock. The colluvium consists of poorly bedded packages of fining upward sequences that are bound by dark brown paleosols (top) and occasional clay deposits containing coarse-grained material (base). The upper portion of the landslide has been partly removed by previous grading in the vicinity of Building 31. North of Building 31 a small localized slope repair exists, which is depicted on both Section A-A' (Figure 8) and the Site Geologic Map (Figure 6).

The primary evidence for deep-seated landsliding comes from core samples collected near the basal contact between colluvium and bedrock. Interpreted features strongly suggestive of landsliding include wet and soft, thinly laminated clay seams, subhorizontal clay-filled fractures at or near brecciated zones of bedrock, shears in colluvium and bedrock, and abrupt geologic contacts defined by one or more of the above deformation features. Additional evidence comes from a reduction in measured pressure and shear wave velocities (Vp and Vs), near the interpreted basal contact. The upper and central portions of the landslide are moderately well constrained based on abundant borehole information, the shallow nature of the colluvium and the previous mapped toes of landslides near Building 77.

The lower portion of the landslide is poorly defined and is based on limited subsurface data (Figure 6). Exploratory borehole AKA-31 encountered clay-rich seams in Quaternary colluvium, and a 5-to 8-ft-wide disturbed zone near the top of bedrock. The lowermost colluvial deposits contained variegated gray and reddish brown clay with Orinda Formation clasts overlying intensely fractured and mixed Great Valley Group. Between 72 and 73 feet in depth, a soft, clay-rich seam is present between two shale units. The shale is highly weathered and brecciated to about 76 feet in depth. Southeast of borehole AKA-31 evidence of landsliding is less robust due to sparse geotechnical data; however, subtle landslide features and variable lithologic conditions interpreted in boreholes 211 and GMX-4A *(*GIS-39*)* suggest the slide may continue farther downslope (Figure 6). Geomatrix Consultants (1994) drilled 10 boreholes and excavated 21 test pits as part of a geological and geotechnical investigation for a proposed UCB Environmental Health and Safety building. No evidence of deep-seated landslide slip surfaces were noted in the boreholes or excavations (Geomatrix, 1994). The majority of the exploration studies were performed in the vicinity of the proposed UCB Environmental Health and Safety building; therefore, the absence of landslide-related deformation features in the lower portions of Chicken Creek Canyon provide limited constraint on the southwesterly extent of the inferred toe of the Northern Intermediate Landslide. Note that there is considerable uncertainty on the location of the landslide toe, thus Section A-A' provides maximum and minimum boundaries interpolated from existing geologic and geomorphic data (shown as dotted landslide boundary in Figure 6). On the basis of these constraints the landslide may be up to 850 feet long and as much as 80 feet thick.

The lateral margins of the landslide are defined by buried bedrock geomorphology, geophysical profiles and borehole data. Near the head of the landslide, the western margin is limited to several boreholes that document shearing in bedrock or at the bedrock-colluvial contact. In addition, structural contours of the bedrock surface define and constrain the northwestern margin of the paleovalley (Figure 7). Interpretation of geophysical profiles in this region suggests there is weak and fractured landslide material near Building 31 (see GIS data points 32-34). The eastern landslide margin is defined by the presence or absence of sheared colluvium or bedrock material, coupled with the morphology of the buried eastern margin of the paleovalley. From Building 31, the western margin projects beneath present-day Chicken Creek suggesting some antiquity to the slide mass. Limits of uncertainty are placed on the lateral margins (dashed vs. dotted) using the structural contour map and the presence or absence of sheared bedrock or colluvium; these interpretations should be considered approximate.

6.01.2 Central Intermediate Landslide

Exploratory boreholes AKA-29, AKA-30, AKA-34, and AKA-36 through AKA-38 lie within the mapped boundary of the Central Intermediate Landslide. Exploratory boreholes AKA-5, AKA-7, AKA-9, and AKA-15 (GIS Nos. 210, 208, 207, and 200) lie on the mapped perimeter of the Central Intermediate Landslide and in regions where landslide slope repairs have occurred (Figure 6). Collectively, these boreholes provide constraints on the lateral and vertical extent of landsliding within the paleo-drainage of No Name Creek. The borehole data suggest landslide debris may still underlie the previously-repaired portions of the slope and outside of the previous slope repair boundaries shown on Figure 6. Mixed landslide debris is noted in the borings within Quaternary colluvium, as well as inferred in the Great Valley Group as noted by extremely weak and fractured and brecciated shale, sandstone, and claystone interbeds at or near the top of bedrock. It is therefore our interpretation that the previous slope "repairs" cannot be assumed to be stable; this report includes recommendations to remove or retain these materials where they are of potential impact to the Helios project.

The Central Intermediate Landslide is intersected by cross sections B-B', C-C' and E-E' (see Figures 9, 10 and 12). The Central Intermediate Landslide is interpreted as a group of coalescing small-scale earth flows and translational slides located in the upper drainage basin of No Name Creek between Buildings 62, 66 and 67. This landslide intersects the north-central portion of the proposed Helios building footprint and crosses the proposed road alignment (Figure 6). Some of the slides can be observed in Figure 3.

The group of coalescing landslides trends northeast-southwest parallel to the former location of No Name Creek and consists of material derived from Orinda Formation and Great Valley Group rocks. The Central Intermediate Landslide contains as much as 30 to 40 feet of fill, colluvium, and alluvium near the axis of the drainage. The slide mass is approximately 675 feet long and 200 feet wide, and occupies primarily the eastern slope of No Name Creek. As mapped, the landslide headwall terminates west of Building 62, downslope of the LBNL access road leading to Building 73. The northeastern extent of landsliding is based on compilation of previous geotechnical studies and slope repairs for buildings 62, 66 and 67 and interpretation of historical photography. (Some of the slope repairs in the site area were performed recently due to destabilization concerns during the construction of Building 67 [Kleinfelder, 2002; Kleinfelder 2004]).

The southwestern extent of landsliding is delineated by an active, relatively shallow earthflow-translational slide evaluated by boreholes AKA-34, 37 and 38. The extent of landsliding shown on Figure 6 is delineated, in part, from (1) 1935 oblique aerial photography that shows extensive slope failures along the west-facing slope of No Name Creek, (2) compilation of previous landslide mapping (Kleinfelder, 2003) and, (3) recent borehole data. Review of former recommended grading plans and personal communications with LBNL engineers, coupled with an analysis of pre- and post-Building 67 topography indicates that portions of the Central Intermediate Landslide have been mitigated through extensive grading and placement of buttress fills. The approximate limits of the repairs as depicted in proposed repair schemes are shown as the pink dotted area near Building 67. It is probable that some of the areas shown as fill and unrepaired in the direct vicinity of Building 67 actually were repaired to some degree based on present-day topography and foundation grading for Building 67; however, the extent (vertical and lateral dimensions) of the repair is unknown.

The Central Intermediate Landslide is composed of as many as four smaller nested landslides with slump-related morphology and has an overall dimension of about 675 feet in length and 200 feet in width. The landslides with present-day geomorphology tend to fail in a west to southwest direction toward No Name Creek. The interpretative Top of Bedrock map defines a relatively broad paleodrainage upslope at Building 67 that narrows and constricts downslope (Figure 7). Geologic sections prepared approximately parallel (Figures 9

and 10) and normal (Figure 12) to the direction of inferred movement characterize the landslide mass as mixed colluvial and alluvial material and bedrock. The deepest part of the slide body coincides with the former location of No Name Creek and consists of as much as about 30 to 35 feet of colluvium and translated bedrock. The extent of landslide repair is unknown and thus, the thickness of landslide debris in this part of the site may be less than estimated, and portions of slide material may still remain beneath the fill. The landslide toe is inferred to extend to at least the former (1922-23) base of No Name Creek, and possibly further west based on the dimensions of the paleovalley defined by the top-of-rock map and exploratory boreholes AKA-29 and 34.

6.01.3 Southern Intermediate Landslide

Exploratory borehole AKA-41 is located along the eastern margin of the Southern Intermediate Landslide. Based on a previous borehole located near the headwall, coupled with geologic mapping, the Southern Intermediate Landslide is inferred as extending about 10 feet into rock, or roughly 15 to 30 feet below ground surface.

Sections D-D' and E-E' intersect the Southern Intermediate Landslide and provide some constraint on the dimensions of landslide material near the southeastern end of the planed Helios footprint and access road. Section D-D' trends roughly through the principal axis of the landslide, whereas section E-E' obliquely intersects the upper portion of the landslide (Figure 6). The Southern Intermediate Landslide is comprised of a series of coalescing earthflows and translational landslides consisting of unconsolidated colluvium and weathered Great Valley Group blocks. Geologic mapping indicates that the slide initiates south of the parking lot for Building 62 and continues downslope to Centennial Drive (Figure 6).

The Southern Intermediate Landslide is up to approximately 350 feet in length and between 100 to 130 feet in width (Figure 6). The landslide is characterized by multiple 1- to 3-foot-high headscarps and slump-related morphology within a northeast-southwest trending topographic hollow. On the basis of morphology, slope inclination, and borehole data, the slide varies in depth from about 15 to 30 feet. Exploratory borehole AKA-12 (GIS-203) (located in the upper portion of the slide mass) encountered multiple clay shears and bedrock fractures between 23 and 27 feet in depth suggesting the slide mass may be as deep as 25 to 30 feet and comprised primarily of weak and fractured Great Valley Group shale and claystone.

6.01.4 Small Landslides

Multiple small landslides are mapped adjacent to the Southern Intermediate Landslide (two to the east and west, respectively). These small landslides range from about 100 to 300 feet in length to about 80 to100 feet in width. The eastern slides are interpreted on the basis of historical aerial photography, existing slope repairs, and active deformation of the existing LBNL access road leading to Building 73A (Figure 6). Exploratory boreholes AKA-43 and GIS-202 encountered weak and fractured siltstone and sandstone. Possible landslide related material consists of shallow colluvium and weak bedrock extending as much as 25 feet in depth. Recent exploratory boreholes AKA-42 and 44, located downslope of the eastern small landslides indicate that the bedrock in this area is highly fractured and weak, and where over-steepened may undergo translation. The eastern small landslide intersected by AKA-43 impacts the proposed road.

The western slides are interpreted based on historical aerial photography, existing slope conditions, and borings AKA-35, 39, and 40 and intersect the proposed Helios building and road. Possible landslide related material consists of weak and intensely weathered siltstones and claystones extending to as much as 25 feet in depth. AKA-35 encountered deformation features at a depth of 25 feet that were interpreted as evidence for a basal slide plane.

6.02 Faulting

6.02.1 Chicken Creek Fault

The northwest-striking fault, herein referred to as the Chicken Creek fault, extends from Strawberry Creek in the southwest to the northwest through the Berkeley Hills, where Graymer, et al. (1996) show it bifurcating into at least two fault traces (Figure 5). The Chicken Creek fault strikes northwest across the proposed site as a moderate to steeply east-dipping fault. The fault juxtaposes Orinda Formation on the northeast against Great Valley Group on the southwest, and in the region of the proposed Helios building is believed to be associated with a tight northwest-trending antiform (Jordan and Javandel, 2007). The mapped location of the fault is located near the northeast corner of the proposed Helios building footprint (Figure 6). The Chicken Creek fault is not within a previous or current State of California Earthquake Fault Zone, as delineated under the Alquist-Priolo Earthquake Fault Zoning Act (A-P Act; 1972, California Public Resources Code, Chapter 7.5, Division 2), and is not considered Holocene active.

The inclination (dip) of the fault ranges from 65° to 70° northeast near Building 66 and shallows to about 16° near Building 31 suggesting some structural complexity along the length of the fault (Jordan & Javandel, 2007). Multiple fault locations have been suggested (HLA, 1975 and 1979; Converse Consultants, 1984; Kleinfelder, 2002; Kleinfelder 2004; Jordan & Javandel, 2007); however, based on the data compilation for this study and re-interpretation of borehole and trench data, the location of the fault across the site has been revised. Jordan & Javandel's (2007) fault trace was used for delineating the northwest section of the fault between Chicken Creek and Building 67. Southeast of Building 67 (Figure 6) the location of the fault is based on borehole and trench data (HLA, 1975; Kleinfelder, 2002; Kleinfelder 2004; personal communications with S. Korbay, 2007 and 2008). Trench exposures define the Chicken Creek fault as a sub-horizontal fault with slickensides trending N40°W and dipping northeast. Trench excavations across the fault did not identify bedrock shearing extending upsection across a colluvial-bedrock contact suggesting some antiquity to the fault. No estimates on the age of the overlying unfaulted deposits were provided (HLA, 1975), however, Korbay (personal communication) interprets the fault as inactive. The fault also is not designated as active by the State of California. Lastly, multiple geologic maps show the unnamed north-striking faults (next section) of HLA (1979) and Graymer, et al. (1996) either terminating on the north or south side of the Chicken Creek fault.

6.02.2 North-Striking Faults

A review of existing published and unpublished geologic maps for this portion of Strawberry Canyon indicates several previously mapped north-striking faults. Graymer, et al. (1996) and Graymer (2000) map two north-striking faults that roughly bound the western and eastern margins of Chicken Creek Canyon (Figure 5). These relations generally are consistent with past geologic maps prepared for the LBNL (Kleinfelder, 2002; Lennert and Associates, 1979) that depict a narrow block of Tertiary Orinda Formation within Chicken Creek Canyon that is juxtaposed against Cretaceous Great Valley Group rocks on the east and west. The north-striking faults generally align with the paleovalleys of Chicken Creek and No Name Creek. Recent compilation and re-interpretation of borehole data (Jordan and Javandel, 2007), coupled with the findings of this study, provide evidence for the absence of Tertiary Orinda Formation in the central axis of Chicken Creek Canyon. For instance, recent boreholes drilled in the cental part of the canyon encountered sandstone and shale from the Great Valley Group rock, thus indicating a block of Orinda Formation does not exist as previously mapped (Figure 5). Furthermore, a detailed analysis of existing borehole and trench information, as well as site-specific maps (Dames and Moore, 1962; Subsurface Consultants, 1987; HLA, 1975; and Jordan and Javandel, 2007) did not yield convincing evidence for a through-going north-striking fault along the east side of the Canyon near Buildings 66 and 67.

The Chicken Creek fault was previously described by Kleinfelder (2002) as offset by a secondary fault striking north between Buildings 66 and 67. However, review of this information for the Helios project shows the boring logs (Harza Kaldveer, 1993) that form the basis of this apparent offset, misidentified Great Valley Group as Orinda Formation. This apparent misidentification eliminates the need for a north-striking fault along the east side of Chicken Creek Canyon. Alternatively, where the fault is mapped near Buildings 66 and 67, this region also is underlain by landslide material associated with the Central Intermediate Landslide. The presence of slide debris consisting of Orinda Formation and Great Valley Group rocks likely complicates the interpretation of tectonic faulting along slide margins that trend parallel to the hypothetical north-striking faults.

Similar north-striking faults are mapped north of the Chicken Creek fault (Dames and Moore, 1962; HLA, 1975; HLA, 1979; Subsurface Consultants, 1987; and Kleinfelder, 2002). Graymer, et al. (1996) do not depict these faults (Figure 5). Direct evidence for north-striking faults includes bedrock relations exposed in road cuts in the LBNL campus and previous building excavations north of the proposed Helios footprint. North-striking faults were observed as bedrock offsets during the construction of Building 77 and the adjacent access roads (Dames and Moore, 1962). Note that one of these interpreted north-striking faults intersects landslide debris and slopes that have been previously repaired. If the faults do exist they are discontinuous and short. Dames and Moore (1962) do not consider these faults to be active. This interpretation would be consistent with their apparent more northerly orientation with respect to the major northwest-striking active faults in the San Francisco Bay area and their discontinuous short fault lengths. Finally, the site does not lie within a previous or current State of California Earthquake Fault Zone, as delineated under the Alquist-Priolo Earthquake Fault Zoning Act (A-P Act; 1972, California Public Resources Code, Chapter 7.5, Division 2).

6.02.3 Surface Fault Rupture Hazard Potential

Historically, coseismic earthquake fault rupture most often occurs along pre-existing, previously active faults. The site is not within an Alquist-Priolo Earthquake Fault Zone, and there are no known active faults on or near the site. The references that we reviewed indicate the closest mapped active fault is the Hayward fault, which is approximately 2,500 feet to the west-southwest. Other faults that have been mapped in the direct vicinity of the site are not considered active. Based on the available data, we judge the overall risk of coseismic surface faulting at the site to be generally low. This evaluation includes the very low likelihood of sympathetic displacement of the Chicken Creek fault as the result of a large earthquake on the Hayward fault.

7.00 GEOTECHNICAL ENGINEERING EVALUATIONS

We conclude that the proposed development is feasible from a geotechnical standpoint, provided that the conclusions and recommendations presented in this report are appropriately incorporated into the project plans and specifications. The primary geotechnical considerations for the project are discussed in the following sections.

7.01 Ground Shaking

7.01.1 Seismicity

The entire San Francisco Bay Area is subject to periodic earthquake ground shaking. As previously reported, The Working Group on California Earthquake Probabilities (WGCEP, 2008) has estimated that there is a combined risk of 31 percent that a large earthquake (magnitude approximately 6.7 or greater) will occur on the Hayward and Rodgers Creek faults between the years 2007 and 2036. The San Francisco segment of the San Andreas fault is estimated to have a risk of 21 percent of a similar large earthquake during the same period. Overall, the USGS estimates a 63 percent probability of one or more large earthquakes occurring within the San Francisco Bay Region between the years 2007 and 2036. Based on the above information, we conclude that strong ground shaking is likely to occur within the life of the project as a result of future earthquakes. For this reason, structures at the site should be designed to resist strong ground shaking in accordance with the requirements of the California Building Code (CBC) and local design practice.

7.01.2 CBC Site Class

The California Building Code (CBC) outlines standard procedures for seismic design intended to account for the effects of earthquake shaking. In recent versions of the CBC, the effect of soil conditions on surface ground motions is accounted for through the use of site classifications. In the 2007 CBC, sites are classified as A through F based on average properties for the upper 100 feet of underlying material (soil or rock). The material properties used in site classification are average shear wave velocity (for soil and rock), sampler blow counts (for cohesionless soil, and undrained shear strength for cohesive soils). Recommended geotechnical parameters for CBC-based design are presented in Section 8.02, "Building Code Seismic Design Parameters."

7.01.3 Campus Ground Motions

The seismic design provisions of the 2007 CBC also allow the use of earthquake ground motions developed through a site-specific probabilistic seismic hazard assessment (PSHA). Recent UCB projects have utilized PSHA-derived UCB campus design ground motions (response spectra and time histories) developed by URS Corporation (URS). The latest ground motions developed by URS take advantage of "next generation" attenuation models (NGA models), which generally predict lower levels of groundshaking for the UCB campus than previous models. The most recent URS report (2008) has been expanded to include ground motions applicable to the LBNL campus. We used the LBNL campus ground motions developed by URS for our geotechnical evaluations and anticipate that they may also be appropriate for structural design of the Helios building, if such a structural design approach is to be taken.

7.02 Soil Liquefaction

Liquefaction is a phenomenon under which groundshaking can cause soils under groundwater to lose strength and gain mobility (i.e., liquefy) under certain conditions. The soils generally considered most susceptible to liquefaction are clean sands, silts and gravels having little or no cohesion. However, recent research has

demonstrated that cohesive silts and clays of low plasticity can exhibit generally similar types of seismic behavior. The range of conditions over which this behavior occurs is the subject of continuing research.

In general, most of the soil materials encountered in the borings are of sufficient plasticity to preclude liquefaction. In some borings, isolated zones of sandy or gravelly alluvium were encountered; however, these materials appear to be neither continuous across the site nor of sufficient thickness to be a significant concern. Therefore, based on the available data, we judge the overall risk of significant liquefaction occurring at the site that would affect the project is low.

7.03 Stability of Northern Intermediate Landslide

7.03.1 Analysis Objectives

The Helios building was intentionally sited entirely outside of the Northern Intermediate Landslide. This particular landslide is largest of the many landslides located within the Chicken Creek Canyon area, both in depth and lateral extent. However, some of the lesser and potentially more resilient improvements (e.g., the hydromodification pond, non-critical driveways and parking, and wetlands mitigation areas) are situated within the area mapped as the Northern Intermediate Landslide. As part of our study, we analyzed the stability of the Northern Intermediate Landslide under both static (i.e., non-earthquake) and seismic conditions. The primary objectives of our analyses were to evaluate:

- The effects of fill placement on static slope stability;
- Whether the landslide is stable under design-level earthquake groundshaking; and
- If unstable, how much movement might occur in a design-level earthquake event.

In our analyses, we used generally-accepted "simplified" methods to evaluate seismic slope stability and deformations of the Northern Intermediate Landslide. All of the other landslides that underlie or exist upslope of planned Helios improvements will be removed or retained as part of the project.

7.03.2 Analysis Methods

Our evaluations of slope stability and deformations were performed in general accordance with the guidelines presented in:

> Blake, T.F., et al. (2002), *"Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Analyzing and Mitigating Landslide Hazards in California,"* Southern California Earthquake Center, Blake, T.F., Hollingsworth, R.A., and Stewart, J.P., editors; and
>
> California Geological Survey (2008), *"Special Publication 117, Guidelines for Mitigating Seismic Hazards in California, 2008,"* (SP 117).

For our seismic screening and deformation analyses, we used the Uniform Hazard Spectra (UHS) for the LBNL Rock Site presented on Figure 24 in the following report:

> URS Corporation (2008), "*Updated Probabilistic Seismic Hazard Evaluation and Development of Seismic Design Ground Motions for the University of California, Berkeley and Lawrence Berkeley National Laboratory,*" report dated September 9, 2008.

This UHS is for a 10 percent probability of exceedence in 50 years level-of-hazard (475-year return period). Our evaluations of deformations were performed in general accordance with the procedures outlined in:

> Bray, Jonathan D., and Travasarou, Thaleia, (2007), "*Simplified Procedure for Estimating Earthquake-Induced Deviatoric Slope Displacements*," Journal of Geotechnical and Geoenvironmental Engineering, April 2007, pp. 381-392.

We used the computer program SLIDE, version 5.037 (October, 2008) and Spencer and Bishop Simplified Methods for our static and seismic slope stability analyses. SLIDE is a commercially available geotechnical software package that uses conventional two-dimensional limit-equilibrium analysis methods to evaluate slope stability.

7.03.3 Material Properties and Groundwater

We interpret that the slip surface for the Northern Intermediate Landslide is located within the disturbed zone above the bedrock contact. This zone varies in thickness between about 4 and 8 feet. Direct observation of materials obtained from the borings indicates that this zone is comprised of deeply weathered/translated bedrock with clay seams and clay-lined fractures. Torsional ring shear tests were performed on four samples of slide plane material from within this zone. The tests resulted in residual friction angles between 13° and 27°. The results are summarized in the following table and the laboratory data sheets are included in Appendix E.

Results of Torsional Ring Shear Tests

Boring	Depth (ft)	Residual Friction Angle (°)
AKA-2	64	27
AKA-25	69.5	19
AKA-27	74.5	19
AKA-31	73	13

We modeled the slope as a one-layer system with the landslide slip surface explicitly specified. For material properties, we used an average residual friction angle of 20° (with no cohesion) and a unit weight of 120 pcf. A groundwater level of approximately 15 to 20 feet below the existing ground surface was used in our analyses.

7.03.4 Static Slope Stability and Seismic Screening Analyses

We initially checked slope stability under static (i.e., non-earthquake) conditions. A factor of safety (FS) of 1.2 was calculated. The computer output plot from the static slope stability analysis is attached in Appendix F.

We then conducted a screening-level investigation in general accordance with the Blake, et al. (2002) guidelines to determine that a further quantitative evaluation of seismically-induced landsliding was appropriate. The screening-level investigation was based on a pseudo-static representation of seismic loading in a conventional limit-equilibrium slope stability analysis. The screening analysis consisted of the following steps:

1. Calculating the yield acceleration, k_y, which is equal to the horizontal seismic coefficient at which the potential sliding surface develops a factor of safety (FS) equal to one.

2. Evaluating the site seismic coefficient, k_{eq}, which represents the fraction of the weight of the sliding mass that is applied as an equivalent horizontal force acting through the centroid of the sliding mass.

3. Comparing k_{eq} to k_y. If the site seismic coefficient, k_{eq}, is greater than the yield acceleration, k_y, then it can be assumed that the FS against sliding is less than one and further quantitative evaluation is required.

Step 1 essentially estimates the *capacity* of the site to resist seismic slope deformations. In Step 1, we calculated the yield acceleration, k_y, by varying the horizontal seismic coefficient until the FS equaled 1.0 for the specified failure surface. We calculated a k_y of 0.035. The computer output plot is attached in Appendix F.

Step 2 essentially estimates the seismic *demand* that will occur at the site as a result of an earthquake. The site seismic coefficient, k_{eq}, is defined in Blake, et al. (2002) as:

$$k_{eq} = f_{eq} \times (MHA_r / g)$$

Where: MHA_r = maximum horizontal acceleration of rock; and
f_{eq} = a factor relating to the seismicity of the site.

The procedure used to estimate f_{eq} presented in Section 11.2.2 of Blake, et al. (2002) considers the MHA_r, earthquake magnitude (M), and distance to the causative fault (r). Threshold displacements of 5cm and 15cm were both considered in the calculations. We used the following values to evaluate 5cm and 15cm threshold displacements: $MHA_r = 0.85$ g (i.e., PGA from UHS); M = 7.1 and r < 10 km. The results are summarized in the table below.

Calculated Site Seismic Coefficient, k_{eq}

Threshold Displacement	Seismicity Factor, f_{eq}	Seismic Coefficient, k_{eq} ($f_{eq} \times 0.85$)
5 cm (~ 2 inches)	0.50	0.43
15 cm (~ 6 inches)	0.39	0.33

Step 3 essentially compares the site's available seismic *capacity* (yield acceleration) to seismic *demand* caused by the earthquake (seismic coefficient).

Results of Screening Analysis

Threshold Displacement	Yield Coefficient, k_y	Seismic Coefficient, k_{eq}
5 cm (~ 2 inches)	0.035	0.34
15 cm (~ 6 inches)	0.035	0.27

For both cases, the calculated site seismic coefficient, k_{eq}, is greater than the yield acceleration, k_y; therefore, it can be assumed that the factor of safety against sliding is less than one and further quantitative evaluation is required.

7.03.5 Slope Deformation Analyses

Bray and Travasarou (2007) utilizes a Newmark-type model for evaluating seismic performance of slopes and was developed based on the results of nonlinear, fully coupled sliding block analyses using a comprehensive database of horizontal components of recorded ground motions from 41 earthquakes. The Bray and Travasarou (2007) procedure uses an Excel spreadsheet published by the authors to calculate displacements. The input parameters for the spreadsheet include yield acceleration (k_y), initial fundamental period (T_s), moment magnitude (M_w), spectral acceleration (Sa) at a degraded period of 1.5 times the T_s, and displacement threshold. These parameters are discussed below.

The yield acceleration, k_y, was calculated during the screening-level investigation, the results of which are discussed and presented in the previous section of this report ($k_y = 0.035$). The fundamental period, T_s, was calculated using the following relationship:

$$T_s = 4H/V_s$$

A weighted average shear wave velocity for the sliding mass, V_s, of 1,200 feet/second was used to calculate T_s. This corresponds to a very stiff soil. The maximum thickness of the slide mass, H, was estimated to be 74 feet. The average mean magnitude of 7.1 was obtained from published data on the Hayward fault and was used for the moment magnitude, M_w, in the analysis. The spectral acceleration at 1.5 times the T_s was taken from the URS spectrum (Figure 24; URS, 2008). A displacement threshold of 15cm was used for the analyses. The input parameters are summarized in the following table.

Input Parameters for Deformation Analyses

Parameter	Value
k_y	0.035
T_s	0.25 seconds
Sa @ 1.5 T_s	1.74g
M_w	7.1
Threshold Displacement	15cm

The program output and results are presented in Appendix F and are summarized below.

Seismic Deformation Analysis Results
(Bray and Travasarou, 2007)

Yield Acceleration	Deformations (feet)		
	16th Percentile	50th Percentile	84th Percentile
0.035g	17	9	5

Where: 16th Percentile = 16% chance of exceeding the calculated deformation,
50th Percentile = 50% chance of exceeding the calculated deformation, and
84th Percentile = 84% chance of exceeding the calculated deformation.

7.03.6 Slope Stability and Deformation Analysis Discussion

We calculated a factor of safety of 1.2 for the Northern Intermediate Landslide under static, non-earthquake conditions. We view this calculated value as generally reasonable and consistent with the observation that the Northern Intermediate Landslide is not known to have experienced significant movement in historic time (i.e., since the Chicken Creek area was developed). This static factor of safety was calculated using a groundwater surface intended to be representative of "high" wet-weather groundwater conditions.

We calculated a median (50th percentile) displacement value of 9 feet for the Northern Intermediate Landslide for a 10 percent probability of exceedance earthquake event (M7.1). Our calculated deformation values were obtained using simplified methods developed by Bray and Travasarou (2007), which are intended to provide an index of likely seismic slope performance. The calculated seismic deformation values were also obtained using a groundwater surface intended to be representative of "high" wet-weather groundwater conditions.

We anticipate that slope-related deformations within the Northern Intermediate Landslide during an actual seismic event will likely be complex and may include: (1) coherent down-canyon movement of the type modeled in the deformation analysis; (2) incoherent movement of discrete portions of the landslide in an oblique direction towards Chicken Creek; and (3) localized shallower failures occurring within the banks of Chicken Creek. It should therefore be anticipated that the seismic performance of new improvements constructed on the Northern Intermediate Landslide is likely to be poor. However, poor seismic performance may still be considered acceptable, provided that no occupied structures are sited in the area. As previously discussed, all existing landslides located beneath or upslope of occupiable Helios structures will be removed or retained as part of the project.

Due to the relatively low calculated static factor of safety (~1.2) and the possibility of alternative failure modes that were not analyzed, we believe that the placement of potentially de-stabilizing fill should be generally avoided within the area of the Northern Intermediate Landslide. Alternatively, additional investigation and analyses could be performed to evaluate the static slope stability of specific fill placement and remedial grading alternatives.

7.04 Expansive Soils

7.04.1 Soil Plasticity and Expansion Potential

We conducted Atterberg Limits determinations on thirty-one samples of onsite materials obtained from the borings to evaluate their plasticity characteristics and expansion potential. A tabular summary of the Atterberg Limits results is included in Appendix E.

The Plasticity Index (PI) results ranged from about 12 to 51, with twenty of the samples (65 percent) having a PI of 20 or greater. The Liquid Limit (LL) results ranged from about 31 to 76, with fifteen of the samples (48 percent) having a LL of 40 or greater. These test results suggest that most of the onsite soil and rock materials can be considered moderately to highly expansive. For comparison purposes, onsite non-expansive fill material is commonly required to have a PI of 15 or less and a LL of 40 or less; only four samples (13 percent) would meet these criteria.

7.04.2 Expansive Soil Considerations

For this project, the primary considerations associated with the onsite expansive soil and rock materials include:

Foundation, Pavement and Slab-on-Grade Performance: Expansive materials shrink and swell in response to changes in moisture content and, unless mitigated, can directly cause damage to structures and other types of improvements. These concerns are mostly related to seasonal changes in moisture content (wetting and drying) occurring within shallow near-surface expansive materials.

Mechanically-Stabilized Earth (MSE) Performance: Plastic soils that exhibit expansive behavior can also be susceptible to creep under sustained loading. MSE construction involves the placement of tensile elements between layers of compacted fill and the potential for long-term creep behavior within this composite system is not well understood. For this reason, expansive soils are typically not used in MSE construction.

A variety of mitigation approaches exist to address concerns associated with onsite expansive soils. Considerations associated with the selection of preferred approaches include: (1) acceptability/reliability of long-term performance; (2) relative cost(s); (3) soil import/offhaul requirements; (4) material handling and processing requirements; and (5) other environmental aspects associated with mitigation.

7.04.3 Mitigation Approaches for Structures

Expansive soils are common throughout the Bay Area and various methods are used to reduce the potential for damage to structures from shrink/swell behavior. In general, there are three basic approaches:

Deepened Foundations: In this approach, structures are supported entirely on deepened foundations that extend below the depth of significant seasonal moisture changes. Foundations used for this purpose can either be deepened spread footings or true "deep foundations" such as drilled piers or driven piles. If near-surface expansive soils are to remain in place, other elements of the structure (e.g., grade beams and ground floor concrete slabs) are typically: (1) designed to resist uplift pressures caused by expansive soils, or (2) designed to span over and not come in contact with the expansive soils.

Non-Expansive Fill Layer: In this approach, structures are supported on a layer of material having a low expansion potential. In local practice, the "non-expansive" fill layer is commonly comprised of either: (1) onsite soils having a naturally low expansion potential; (2) quarried import materials such as drainrock or aggregate base; or (3) onsite expansive soils that are processed (e.g., by mixing with an additive) to reduce their expansion potential.

Combination Approach: In this approach, the building's structural frame is supported on deepened foundations that extend below the depth of significant seasonal moisture changes whereas interior ground floor slabs are cast on-grade and underlain by a layer of non-expansive material. This approach is commonly used for structures constructed on level ground due to: (1) the difficulty of placing and removing formwork from beneath structurally-supported slabs, and (2) general unfamiliarity with the various degradable cardboard form systems intended for this purpose.

As currently envisioned, the Helios building will be supported on a conventional foundation system comprised of either (1) spread footings; or (2) drilled piers and grade beams. We anticipate that the ground floor slab will be cast on-grade without an underlying void and will therefore be directly underlain by a layer of non-expansive material (import granular fill and/or processed onsite soil).

7.04.4 Mitigation Approaches for Pavements and MSE

In most cases, pavements are constructed on-grade and not structurally-supported. For this reason, placing a non-expansive fill layer beneath and surrounding the pavement section is the only realistic approach to reduce the adverse effects of expansive soils. This approach is described in the previous Section (Section 7.04.3).

Most guidelines for MSE construction specify that granular non-expansive materials be used as fill. However, it is currently considered a project objective to reduce truck trips to and from the site. This objective, together with various associated cost-related considerations, has led the project team to consider the use of treated onsite materials for the MSE fill. As part of this process, the project Civil Engineer (C+D) has engaged the technical resources of a prominent geogrid manufacturer (Tensar) to assist in developing specifications and guidelines for the use of lime-treated onsite soils as MSE fill.

7.04.5 Lime Treatment

Lime treatment is commonly used to mitigate expansive soil effects and to enhance the workability of over-wet clayey soils. When mixed with plastic clay soil, lime (quicklime) is known to chemically react and, when compacted, form a strong, low-compressibility soil mixture. Lime treatment is also used to reduce the expansion potential of clayey soils. Lime treatment involves the following general steps:

1. Adding lime to the soil at a predetermined rate. Typical lime contents are in the range of 3% to 5% of the soil, on a dry weight basis.
2. Mixing the lime with the soil using a specialized rotating pulverizer.
3. Allowing the lime/soil mixture to react or cure for at least 24 hours (so-called mellow period).
4. Remixing the lime-treated soil a second time and compacting the mixture to a specified density.

The Standard Specifications published by the State of California Department of Transportation (Caltrans) include specifications for lime treatment (Section 24), which are commonly used in local grading practice.

7.05 <u>Foundation Support</u>

7.05.1 Foundation Conditions

As introduced in Section 5.01.1, the long axis of the proposed Helios building can be divided into three physiographic regimes, which we refer to as the Northern Site, Central Site and Southern Site. This nomenclature is also useful for discussions pertaining to foundation conditions. In general, bedrock is shallower at the Northern and Southern Sites and deeper at the Central Site, which is located within a topographic swale. The Top of Bedrock Contour Map presented on Figure 7 is an interpretation of approximate bedrock surface elevation contours within the project area. The bedrock contours shown on Figure 7 have been interpreted based on the available subsurface data, geologic/historic information and assumptions regarding possible geomorphologic development, and are necessarily approximate.

The soil and rock materials that overlie in-place bedrock at the site include colluvium, fill, and landslide debris. The natural colluvium and landslide materials have moved downslope solely by gravity and are therefore

considered inherently heterogeneous. The fill materials encountered, although less heterogeneous, locally overlie colluvium and landslide materials. In general, all of the natural materials at the site (colluvium, landslide debris and bedrock) are considered potentially expansive.

7.05.2 Non-Expansive Layer

In this report, we recommend that the Helios building be directly underlain by a layer of non-expansive material comprised of a drainage layer (comprised of import crushed rock) overlying a layer of non-expansive fill (comprised of non-expansive import or lime-treated onsite soils). The non-expansive layer may serve several purposes, including: (1) isolating the bottom of slabs, footings and/or grade beams from underlying expansive soil materials; (2) draining subsurface water that might otherwise rise to the level of the bottom of the ground floor slab-on-grade; and (3) providing a uniform compacted surface on which to support the ground floor slab-on-grade.

Building pad excavation will need to extend at least as deep as the bottom of the non-expansive fill layer. The required thickness of the non-expansive layer (and therefore the elevation of the building pad) is a design issue that will depend upon: (1) the planned elevation of footings and/or grade beams; and (2) and the methods used to mitigate potential expansive soil effects (as discussed further in Section 7.05.4, Foundation Design").

7.05.3 Building Pad Preparation

The area over which bedrock will be exposed for a given pad elevation can be estimated using the interpretive Top of Bedrock Contour Map presented on Figure 7. Following excavation, variable soil and rock materials will underlie areas of the building pad that do not expose bedrock. We judge these materials to be generally unsuitable in their current state, due to their: (1) variable strengths and compressibilities; and (2) unpredictable seismic stability and dynamic response characteristics. Preparation for the building pad will therefore require that these existing soil and rock materials be removed and replaced with appropriately-engineered fill. Because post-construction settlement and soil dynamic properties are viewed as significant considerations fill placement beneath building areas will need to be tightly controlled, as discussed below:

> ***Settlement Considerations:*** Engineered fill can be expected to settle over time, although the magnitude of settlement can be difficult to predict. The basic reason for this is that long-term settlement of a drained (and therefore unsaturated) engineered fill occurs mostly through particle rearrangement rather than conventional consolidation processes under which water is slowly expelled from between clay particles. In the absence of a simple conceptual framework by which to calculate long-term fill settlement (such as that which exists for consolidation), experience, judgment and "rules of thumb" are often used to evaluate foundation types and estimate fill settlement in engineering practice.
>
> ***Dynamic Response Considerations:*** Another consideration in the structural design is the issue of site dynamic response. In our judgment, use of a "C" (stiff soil and soft rock) site class can be justified given the CBC requirement that the average undrained shear strength of cohesive fill materials would need to exceed 2,000 pounds per square foot (psf). Similarly, a well-compacted lime-treated fill would also warrant a "C" site classification while producing a fill that would be more similar in nature to the soft bedrock that directly underlies other parts of the Helios building site.

Recommendations for the placement of engineered fill beneath the building pad (including keying, benching and subdrainage requirements) are presented in Section 8.07. Additional considerations pertaining to fill settlement as it relates to foundation selection and design are presented in the following section (Section 7.05.4).

7.05.4 Foundation Selection and Design

It is currently envisioned that the Helios building will be supported on a conventional foundation system comprised of: (1) spread footings; and/or (2) drilled piers and grade beams. Both systems are considered acceptable, from a geotechnical standpoint, provided that the building pad is suitably prepared, as discussed in the previous section (Section 7.05.3). A combination foundation system with footings on bedrock and drilled piers in engineered fill areas is also considered acceptable. Recommendations for the design of drilled pier and spread footing foundation systems are presented in Sections 8.03 and 8.04, respectively. Considerations associated with each of the proposed foundation systems are discussed below.

> ***Drilled Piers and Grade Beams:*** Drilled pier foundations can be designed to gain support from skin friction in the soil and rock materials that underlie the site. In this report, we recommend that any contribution to axial capacity from end bearing be ignored, due to difficulties associated with obtaining and confirming adequate clean out of the pier bottoms. Drilled piers can be designed to resist both compressive and tensile axial loads.
>
> ***Spread Footings:*** New spread footing foundations can be designed to: (1) bear directly on underlying expansive soil and rock materials and resist expansive uplift pressures; (2) extend a sufficient depth into underlying expansive materials to be below the depth of significant shrink/swell behavior; or (3) bear directly on non-expansive fill material of sufficient thickness to mitigate the potential for significant uplift pressures. In this report, we recommend that footings underlain by a significant thickness of engineered fill be interconnected. This recommendation is intended to provide a more robust foundation system capable of tolerating differential settlement. If uplift resistance is required, it can be provided by either: (1) drilled and grouted tiedown anchors; or (2) conventional drilled pier foundations.

We anticipate that settlement-related concerns are likely to be a key consideration in the selection of a preferred foundation type. Spread footings that are supported on or underlain at shallow depth by in-place bedrock can be expected to settle very little, probably on the order of ½ inch or less. However, spread footings supported on engineered fill will experience greater settlements due to: (1) the greater compressibility of compacted fill relative to in-place bedrock; (2) the tendency of the fill materials to compress and settle over time. As previously indicated, it is not unusual to assume that a compacted fill may, over time, settle up to 1 percent of its total thickness. Because the fill thickness will vary, a Helios building supported on spread footings can be expected to settle differentially. From a structural perspective, an angular rotation value is often used to quantify allowable differential settlements and a maximum angular rotation value of 1/360 (1 inch in 30 feet) is commonly considered "acceptable." If calculated settlements exceed this threshold or are not considered acceptable based on project-specific considerations: (1) portions or all of the Helios building can be supported on drilled piers (which should experience negligible settlement); or (2) lime treatment might be used to reduce the compressibility of the engineered fill materials.

7.05.5 Lime Treatment to Reduce Settlement

Lime treatment is not commonly used for the purpose of reducing fill settlement. However, it is expected that the long-term compressibility of a lime-treated fill will be less than that of a similar fill comprised of natural untreated clayey soil. In the event that the design team wishes to consider lime treatment as a means of reducing fill settlement, we would recommend that additional laboratory testing be performed on samples of lime-treated fill materials. Variables that can be adjusted in the lime treatment process include: (1) lime content; (2) moisture content; and (3) compaction levels. The effects of these three variables on compressibility and settlement can be evaluated in the laboratory by performing tests on prepared lime-treated samples of the onsite soils. An objective of such tests would be to develop optimal lime treatment procedures (from cost and constructability perspectives) that will also result in acceptable long-term settlements (from a structural perspective). Geotechnical recommendations that pertain to this issue are presented in Section 8.07.6, "Special Benching and Fill Placement Requirements."

7.06 Upslope Retaining Walls

7.06.1 Retaining Wall Type

As currently envisioned, an upslope retaining wall will be constructed across the entire width of the Helios building pad that will be structurally separate from the Helios building. Upslope retaining walls are also planned along the Helios access road and along the north side of Centennial Drive directly east of the access road intersection. Tieback retaining walls are currently envisioned for this purpose. We anticipate that tieback retaining walls for the project will consist of: (1) soldier piles with wood or concrete lagging; (2) soldier piles with reinforced shotcrete lagging; or (3) reinforced shotcrete bearing on-grade. The tiebacks themselves will consist of permanent drilled and grouted soil/rock anchors that are equipped with double corrosion protection and pre-tensioned at the wall face.

Tieback retaining walls are typically installed using top-down construction methods whereby tiebacks are installed and the wall is constructed incrementally as the adjacent soil/rock is excavated. This approach is viewed as advantageous as the wall installation methods will minimally disturb the adjacent natural upslope terrain and the permanent wall can also serve as shoring during building pad and access road excavation. Tieback retaining walls can either be designed by a member of the design team (typically the Project Structural or Civil Engineer), or they can be designed by the contractor under a design-build project approach. The tiebacks themselves are commonly designed by a specialty drilling contractor based on: (1) lateral loads and "no-load" zone restrictions provided by the project Geotechnical Engineer; and (2) tieback performance requirements (load-deflection characteristics and corrosion protection) provided by the project Civil or Structural Engineer. The load-deformation behavior and capacity of installed tiebacks needs to be confirmed by load testing.

7.06.2 Static Earth Lateral Pressures

We used conventional geotechnical analysis methods to develop our estimates of static (i.e., non-earthquake) lateral earth pressures acting on tied-back upslope retaining walls. We assumed that upslope retaining walls would generally be restrained by multiple tieback rows and that a trapezoidal "apparent" earth pressure distribution would be appropriate for the static short- and long-term load cases. We utilized active earth pressure theory to estimate lateral earth pressures over the full wall height; the triangular earth pressure distribution obtained was then converted to an equivalent trapezoidal distribution. For the temporary load case, the height of the wall is assumed to extend down to the bottom of the deepest adjacent excavation. For the permanent load case, the height of the wall can be assumed to extend down to the final finished grade.

Recommended lateral pressure distributions for the static design of tieback retaining walls are presented in Section 8.08.1. The static lateral earth pressures presented in this report are based on calculated (i.e., unfactored) values; normal factors of safety and load factors for long-term sustained loading are appropriate when utilizing these load distributions for wall design.

7.06.3 Seismic Lateral Pressures

Earthquake shaking has the potential to increase lateral loads on retaining walls. To evaluate these effects, we considered three separate cases based on characteristics of the retained materials:

Retained Colluvium and Fill: We evaluated seismic lateral pressure increases in colluvium and fill using simplified geotechnical analyses based generally on the Mononobe-Okabe (M-O) method. For colluvium and fill overlying bedrock, we used a pseudostatic horizontal acceleration value of approximately one-third to one-half of the PGA to evaluate the seismic lateral thrust. This force was converted to a uniform (rectangular) lateral pressure distribution for the colluvium/fill case.

Retained Landslide Deposits: We evaluated the total seismic lateral thrust for the retained portions of the Central Intermediate Landslide using: (1) modified M-O inertial methods; and (2) deviatoric displacement methods based on Bray and Travasarou (2007). For our modified M-O analyses, we considered pseudostatic horizontal acceleration values of approximately one-third to one-half of the PGA. For our displacement-based analyses we used the spectral acceleration for the degraded period obtained from the UHS (URS, 2008) and a maximum seismic displacement threshold of 6 inches.

Retained Bedrock: In general, the geologic characterization did not identify bedding or other bedrock discontinuities that were in an adverse orientation (i.e., dipping out of slope). In our geotechnical analyses, we therefore assumed that an M-O-type failure wedge would not occur within in-place bedrock and that (consequently) any seismic lateral pressure increase in bedrock could be neglected.

Recommended lateral pressure distributions for the seismic design of tieback retaining walls are presented in Sections 8.08.2 and 8.08.3. The seismic lateral earth pressures presented in this report are based on calculated (i.e., unfactored) values. Normal factors of safety and load factors for short-term earthquake loading are appropriate when utilizing these load distributions for wall design.

7.07 Access Road Embankment and MSE Walls

Over much of its alignment, the access road will be supported on an engineered fill embankment that is more or less contiguous with the Helios building pad. Two slope conditions exist along the outboard (downslope) side of the access road that can be described generally as follows:

- West of the Helios building, the embankment face will consist mostly of an engineered fill slope; as currently planned, the inclination of the embankment face will vary from about 2:1 (north end) to about 1:1 (south end).

- South of the Helios building, the embankment face will consist of an MSE wall. We anticipate that the inclinations of the MSE wall face will generally be ½:1, or steeper, except at its northern end where the wall will transition to meet the 1:1 embankment slope.

In this report, we recommend that the embankment supporting the access road be constructed entirely upon in-place bedrock. This will require that the downslope edge of the embankment be solidly keyed into bedrock over its entire length (i.e., beneath the toe of the embankment slope and at the base of MSE wall units). Recommendations for the placement of engineered fill beneath the access road (including keying, benching and subdrainage) are presented in Section 8.07, "Embankment Construction."

The approximate depth/elevation of keyways at the downslope edge of the fill embankment can be evaluated using the data from borings drilled along the approximate embankment alignment (AKA-32 through AKA-34 and AKA-39 through AKA-41). Interpretive information can also be obtained from geologic cross sections B-B' through D-D' (Figures 9 through 11) and the Top of Bedrock Contour Map (Figure 7). In areas where the bedrock surface slopes steeply down and away from the embankment toe (cross sections B-B' and D-D', Figures 9 and 11, respectively) special design measures may be warranted to limit the depth of keyway excavations that would otherwise be required. We anticipate that such measures might include reconfiguring (e.g., by steepening the embankment face) and/or internally strengthening the embankment to allow the keyway to be placed where bedrock is shallower.

MSE retaining walls involve the use of proprietary materials and are often designed with the assistance of an MSE wall system manufacturer. Such an approach typically involves the use of proprietary engineering software, which is used to evaluate internal stability (i.e., within the MSE mass) and external stability (i.e., global stability outside of the MSE mass). Similar analyses are employed in the design of MSE soil slopes, which also use manufacturer-supplied georeinforcing elements.

Geotechnical program input may vary, but typically includes standard geotechnical slope stability parameters such as unit weight and soil strengths. These input parameters can be evaluated by the MSE wall system manufacturer using: (1) the geotechnical data presented in this report; and/or (2) supplemental investigations and laboratory testing performed specifically for this purpose. Alternatively, various programs are available commercially or through the public sector that can be used by the project Civil Engineer to design the MSE walls and slopes. If this approach is to be taken, we should be consulted during the selection of geotechnical parameters and during the analysis and development of MSE systems.

7.08 Construction Considerations

7.08.1 General Excavation

We anticipate soil and bedrock at the site can be excavated with conventional heavy earth-moving equipment. The existing fill materials at the site are variable and may include subsurface obstructions. Removal of buried obstructions may require equipment capable of breaking concrete. In addition, it is possible that locally harder bedrock could be encountered that would require jack-hammering or hoe-ramming to excavate, particularly in confined areas such as trenches or keyway excavations. Note that seismic refraction profiles are presented in Appendix D that can be used to evaluate the ripability of shallow bedrock in some areas of the site.

7.08.2 Temporary Shoring

Temporary shoring will need to be installed at the upslope perimeter of the Helios building area in order to: (1) excavate to planned building basement foundation levels; and (2) further excavate to remove all landslide and colluvial materials from beneath the planned Helios building. The interpretive Top of Bedrock Contour Map presented on Figure 7 is provided for general informational purposes and for the preliminary evaluation of shoring requirements. However, variations in the bedrock surface should be anticipated and the actual depths to competent in-place bedrock will not be known until construction. The stability of site shoring and all temporary

construction slopes and the protection of nearby site improvements during construction are responsibilities of the contractor.

In addition, all excavations deeper than 4 feet that will be entered by workers should be shored or sloped for safety in accordance with the California Occupational Safety and Health Administration (Cal-OSHA) standards. We suggest that the contractor thoroughly document the condition of nearby buildings, pavements and storm drains by video or other means prior to excavation. The contractor should also perform regular surveys during excavation to monitor for deflection of nearby site improvements.

7.08.3 Drilling for Foundation Piers and Soldier Piles

We judge that bedrock materials that underlie the site are likely able to be penetrated with conventional heavy drilling equipment; however, zones of relatively hard rock could be encountered. The contractor should be prepared to utilize suitable hard rock drilling techniques, if necessary. Special drilling procedures and/or equipment may also be required to maintain vibrations from drilling to within acceptable limits (see Section 7.08.6, "Monitoring").

If water accumulates in the holes, it should be removed by pumping or bailing prior to concrete placement unless tremie methods are used. Also, drilling for piers may encounter soils and/or fractured bedrock material that may cave. The drilled pier contractor should anticipate having to drill with slurry and/or case pier holes, as appropriate.

7.08.4 Temporary Dewatering

The deeper portions of site excavations will likely extend below groundwater. Although low-permeability clayey soils exist over much of the site, higher-permeability zones may exist that would produce higher groundwater flows. The types of higher-permeability materials that are anticipated include sandy/gravelly alluvial soils within former drainages and fractured bedrock comprising the excavation bottom. However, other seepage zones or locally perched groundwater conditions could also be encountered.

The control of groundwater during construction is the responsibility of the contractor. The contractor should anticipate that multiple groundwater control methods may be needed to effectively dewater site excavations. Possible groundwater control methods include the installation of low-permeability shoring or cut-off walls at the excavation perimeter, pumping from sumps at low points within excavations, and dewatering wells. The design, permitting, installation, monitoring, and abandonment of site dewatering and discharge systems are the contractor's responsibility. These responsibilities also include any special regulatory or health and safety requirements that may be associated with environmentally-impacted soil or groundwater (e.g., tritium).

7.08.5 Soil Moisture

We conducted moisture/density tests on 32 samples of onsite materials obtained from the borings. All of the samples were from depths shallower than 35 feet. The moisture content results ranged from 9.2 percent to 34.5 percent. Fourteen tests had moisture contents of 20 percent or greater. Only two tests had moisture contents less than 10 percent, and both of these samples were from depths of 5 feet or shallower. A tabular summary of the moisture/density results is included in Appendix E.

In general, the onsite soils include soil and rock materials that are wetter than optimum, from a construction standpoint. Deeper excavations at the site will extend below the groundwater table and encounter soils that are

in a saturated condition. The contractor should anticipate that soils obtained from site excavations will include clayey soil and clayey rock materials that will need to be processed (i.e., by air drying or lime treatment) prior to being placed as engineered fill.

7.08.6 Monitoring

We understand that certain scientific equipment within the adjacent buildings and certain existing subsurface utilities may be particularly intolerant of construction vibration, settlement and lateral movement. In our opinion, the contractor's responsibilities should include: (1) documenting the condition of the adjacent improvements prior to the commencement of drilling and excavation activities; (2) designing a drilling and excavation program that will keep surface settlements and vibrations within acceptable limits; and (3) coordinating with University of California personnel and providing settlement and vibration monitoring, as needed, to assure that adjacent facilities are not adversely affected during the geotechnical aspects of construction. In addition, the University of California will likely want to specify additional installation and/or monitoring requirements to protect existing or new improvements in the general area of the work. AKA and the University of California should review (favorably) the contractor's proposed excavation, drilling and monitoring plans prior to the commencement of the work.

7.08.7 Wet Weather Construction

Although it is possible for construction to proceed during or immediately following the wet winter months, a number of geotechnical problems may occur which may increase costs and cause project delays. The water content of onsite soils may increase during the winter and rise significantly above optimum moisture content for compaction of subgrade or backfill materials. If this occurs, the contractor may be unable to achieve the specified levels of compaction. Dewatering requirements will potentially increase due to rainfall, surface runoff, seepage and rises in groundwater level. The stability of temporary slopes will decrease, potentially increasing the lateral extent of excavation required. If utility or footing trenches are open during winter rains, caving of the trench walls may occur. Subgrade preparation beneath mat foundations and pavement sections may prove difficult or infeasible. In general, we note that it has also been our experience that increased clean-up costs may be incurred, and greater safety hazards may exist, if the work proceeds during the wet winter months.

8.00 RECOMMENDATIONS

8.01 General

The following sections present our geotechnical recommendations for the design and construction of the project. If the project design differs significantly from that discussed previously in this report, we should be consulted regarding the applicability of the conclusions and recommendations presented herein, and be provided the opportunity to provide supplemental recommendations, where appropriate. Contractors responsible for the geotechnical aspects of the project (e.g., general, shoring, grading, foundation) should become familiar with the contents of this report and acknowledge:

- The site conditions, as described in this report and the attached Appendices;
- The construction considerations discussed in Section 7.08 of this report; and
- University of California requirements for excavations, safety and vibration monitoring.

We recommend that these and all other contractor responsibilities be clearly defined in the project plans and specifications.

The sections that follow are organized such that structural engineering design considerations related to the Helios building (Sections 8.02 through 8.05) are addressed first, followed by recommendations pertaining to sitework (Sections 8.06 through 8.10). However, all of the recommendations presented should be considered together in developing a rational, integrated geotechnical approach.

8.02 Building Code Seismic Design Parameters

Structures at the site should be designed to resist strong groundshaking in accordance with the applicable building codes and local design practice. This section provides seismic design parameters for use with the 2007 California Building Code (CBC, 2007).

Site Class Definition
C = Very Dense Soil and Soft Rock Profile

Latitude and Longitude
Latitude: 37.87507°
Longitude: -122.24323°

Mapped Acceleration Parameters
S_S = 1.995g (mapped spectral acceleration at short periods)
S_1 = 0.777g (mapped spectral acceleration at 1-second period)

Site Coefficient Values (for Site Class C)
F_a = 1.00 (site coefficient for short periods)
F_V = 1.30 (site coefficient for 1-second period)

MCE Spectral Response Accelerations
(Mapped Acceleration × Site Coefficient)
SM_S = 1.995g (MCE spectral acceleration at short periods)
SM_1 = 1.010g (MCE spectral acceleration at 1-second period)

Design Spectral Response Acceleration
(MCE Spectral Acceleration × 2/3)
SD_S = 1.330g (design spectral acceleration at short periods)
SD_1 = 0.777g (design spectral acceleration at 1-second period)

The Type C Site Class is judged as appropriate for the bedrock and engineered fill materials that will directly underlie the Helios building pad. The site's latitude and longitude were approximately determined using website-based mapping tools (Google Earth). The mapped acceleration values and corresponding spectral accelerations were obtained from the site latitude and longitude using tools made available by the United States Geological Survey (USGS, 2007).

8.03 Drilled Piers and Soldier Piles

8.03.1 Axial Pier/Pile Design

Drilled piers and soldier piles can be designed to resist axial loads through skin friction in soil and bedrock. Foundation piers should be spaced no closer than three pier diameters, center-to-center. Piers at closer spacings may have a reduced compressive capacity due to group effects and would need to be evaluated on an individual basis. Drilled pier groups should be structurally tied together at their tops by grade beams or a thickened structural concrete slab. The axial capacity of drilled piers can be evaluated using the allowable skin friction values presented in the following table:

Pier/Pile Allowable (DL+LL) Skin Friction Values

Supporting Material	Allowable Skin Friction (psf)
Natural Soil	500
Engineered Fill	750
In-Place Bedrock	1500

These skin friction values can be increased by one-third for total compressive loads (including wind and seismic), but should not be increased for uplift loads. For design purposes, the elevation of bedrock can be estimated using the Top of Bedrock Contour Map presented on Figure 7. We recommend that design assumptions regarding bedrock support be re-evaluated by our firms (AKA and WLA): (1) once excavation is complete and the top of bedrock is exposed within building pad areas (for building piers); and (2) during pier drilling based on the subsurface conditions encountered (for building piers and soldier piles).

We recommend that any contribution to axial capacity from end bearing in bedrock be ignored due to difficulties associated with obtaining and confirming adequate cleanout at the bottom of pier holes. Skin friction can be considered over the full pile/pier diameter for the embedded portion of the soldier piles and over one-half of the pier diameter for the upper portion of soldier piles that are retained by tiebacks. We recommend that skin friction above the uppermost row of tiebacks be ignored.

8.03.2 Pier/Pile Lateral Resistance

Lateral load resistance may be developed by the passive resistance of soil/rock acting on: (1) the vertical cross-sectional area of the piers/piles; and (2) the vertical faces of pier/pile caps and grade beams. Lateral resistance can also be provided through the bending resistance of the piers/piles themselves. Any effects of base friction acting on the bottom of elements that are pier/pile-supported (e.g., pier/pile caps, grade beams, structurally-supported slabs) should be neglected in evaluations of lateral resistance.

Passive resistance provided by firm soil (including compacted fill) can be evaluated using a triangular distribution with a uniform increase of 300 psf per foot of depth. For footings that are poured neat into excavations within in-place bedrock, a minimum passive resistance value of 1,200 pounds per square foot (psf) can be used starting at the bedrock surface which can then be increased at a rate of 450 psf per foot of depth. Passive resistance can be applied over two (horizontal) pier diameters. The above passive resistance can be considered "allowable" values under long-term loading conditions and include factors of safety of at least 2.0.

The lateral resistance of individual piers/piles and pier/pile groups can also be evaluated using engineering software such as L-Pile or Group, which consider pier bending and soil/structure interaction effects. Such analyses require structural information that has not yet been developed for the Helios project. We recommend that AKA be consulted in the event that the project team determines that such analyses will be needed during the development of preliminary foundation designs.

8.03.3 Pier/Pile Installation

Holes for drilled piers and soldier piles should be drilled straight and plumb (within 1 percent of vertical) and should be cleaned of loose soil and rock fragments. We judge that the holes can likely be drilled using heavy auger drilling equipment; however, zones of relatively hard rock could be encountered. The contractor should be prepared to utilize suitable hard rock drilling techniques, if necessary. The contractor should also anticipate that drilling for piers could encounter subsurface materials that may cave or squeeze (e.g., granular drainage materials, fractured bedrock and/or soft clays) and should be prepared to case pier holes or drill using slurry, as appropriate.

Concrete placement should start as soon as possible after the drilling and cleanout is complete. In all cases, holes for piers and soldier piles should be concreted on the day they are drilled. Following placement of the reinforcing steel, H-section or welded channel sections, holes should be concreted from the bottom up in a single operation. If water or slurry is present in the hole, tremie methods should be used; the tremie pipe should be constantly maintained at least 5 feet below the surface of the concrete during casting of the pier. As the concrete is placed, any casing used to stabilize the hole should be withdrawn. The bottom of the casing should be maintained not more than 5 feet or less than 1 foot below the surface of the concrete. The tops of the pier holes should be vibrated as concrete placement is completed.

Drilled piers and soldier piles should be installed by a qualified drilling contractor. We recommend that AKA observe drilled pier and soldier pile installation to confirm that subsurface conditions are as anticipated and that the piers/piles are constructed in accordance with the recommendations presented in this report.

8.03.4 Grade Beams, Pier Caps and Structural Slabs

This section provides recommendations that pertain to onsite expansive soils and bedrock. It should be assumed that all of the materials exposed at the level of the building pad (i.e., below the non-expansive layer) may be potentially expansive. The recommendations presented in this section are provided for the purposes of mitigating potential expansive soil effects.

We recommend that grade beams and pier caps either: (1) be directly underlain by at least 18 inches of non-expansive material; or (2) extend through the non-expansive layer and be bottomed at least 12 inches below it. Under these conditions, uplift pressures acting on the bottom of pier caps and grade beams need not be considered.

Where the building pad is underlain by a significant thickness of engineered fill, it should be expected that the pad surface will settle differentially with respect to building elements supported on drilled piers. We therefore recommend that, for a pier-supported building, the ground floor slabs be structurally-supported within engineered fill areas. Ground floor slabs should be underlain by at least 18 inches of non-expansive material unless a minimum 6-inch-high vertical gap (void) is provided between the bottom of the slab and the potentially expansive subgrade.

8.03.5 Optional Pier Load Tests

The objective of the optional pier load test program would be to determine ultimate pier/rock adhesion values for the in-place bedrock materials at the site. Favorable results (i.e., high skin friction values) may allow for subsequent production piers to be shortened relative to the lengths calculated using the skin friction values calculated in Section 8.03.1. This section presents preliminary recommendations for an optional pier test program involving tension tests; these tests can be performed more economically than compressive tests, which would require the installation of reaction piers/piles. Additional geotechnical recommendations should be provided by AKA if it is determined that pier load testing is warranted and should therefore proceed.

We recommend that a minimum of four test piers be installed within the footprint of the planned Helios building. The test piers would be drilled, cast-in-place reinforced concrete piers, although they may differ in diameter from planned building piers. We recommend that the test piers be designed and detailed by the project Structural Engineer. The bottom 10 feet of each pier would comprise the test section; this portion of the pier is referred to as the "test pier section". The pier above this level is to be isolated from the surrounding ground with casing so that the entire test load is transmitted to the test pier section.

The pier load test set-up should conform to the general requirements of ASTM D 3689-90 (Standard Test Method for Individual Piles Under Static Axial Tensile Load); the "cribbing" method of reaction is acceptable. We recommend that a load cell be used to determine the actual test load on the pier. Safety should be of primary importance in the set-up and performance of the load test; we recommend that electronic displacement gauges (and not mechanical "dial gauges") be used to measure pier head movement. Two tell-tales should be installed in each test pier. One tell-tale should be positioned near the bottom of the test pier segment and the second should be near the top of the segment. Movement of the tell-tales should be monitored with a laser level. The Contractor should also provide a cost for installing strain gauges in the test pier section; gauges would be located at three levels.

The Contractor should retain an independent Foundation Engineering Testing Specialist (Testing Specialist) to oversee the pier construction, load test set-up, provide instruments for electronically measuring test loads and pier movement, acquire and reduce data, provide a final test load report, and provide general quality control of the testing. The Testing Specialist shall have at least 5 years of experience in pile/pier load testing and electronic data acquisition. The University of California will retain the Project Geotechnical Engineer (AKA) to review Contractor submittals, observe during test pier installation and performance of the pier load test, and review/interpret the Contractor's load test results. The Project Geotechnical Engineer (AKA) should be notified at least 48 hours prior to the start of pier construction.

Pier loading should follow the Standard Loading Procedures outlined in ASTM D 3689-90. After the test load reaches two times the "design load", the test will continue until pier failure occurs or the maximum adhesion of 5 kips per square foot (ksf) is achieved. For test piers, the "design load" should be calculated as the capacity of the pier test section based on an adhesion of 1.5 ksf. The Project Geotechnical Engineer should be notified at least 48 hours prior to the start of pier load tests.

The Testing Specialist should be required to submit a report to the Project Geotechnical Engineer (AKA) describing the pier construction and test set-up and presenting the load test results. The report should include information regarding the load cell (recent calibration data), pier head movement data, strain gauge readings, tell-tale movement data, and plots of movement vs. load for pier head and tell-tales. Interpretation of the strain gauge measurements should also be presented. The report shall include a summary of concrete volume vs. depth and descriptions of any unusual construction and/or conditions that could affect the pier test.

8.04 Shallow Foundations

8.04.1 Spread Footing Design

Spread footings supported on at least 18 inches of non-expansive material should extend at least 18 inches below lowest adjacent grade. Spread footings that extend through the non-expansive layer and are supported directly on potentially expansive materials (soil or bedrock) should extend at least 24 inches below lowest adjacent grade or at least 12 inches below the non expansive layer (whichever is greater). Spread footings for the Helios building should be at least 18 inches wide. We recommend that exterior wall footings be continuous and fully enclose the perimeter of the building. Interior footings can consist of continuous or isolated footings; however, in engineered fill areas, all footings should be structurally interconnected. Footings located adjacent to other footings or utility trenches should have their bearing surfaces situated below an imaginary 1.5 horizontal to 1 vertical plane projected upward from the bottom of the adjacent footing or utility trench.

Deepened footings supported directly on in-place bedrock can be designed using the maximum allowable bearing values presented below:

Foundation Bearing Pressures for Footings on In-Place Bedrock

Load Case	Bearing Pressure (psf)	Factor of Safety
DL	4000	3.0
DL+LL	6000	2.0
Total	8000	1.5
Ultimate	12000	1.0

Footings supported on fill placed and compacted in accordance with the recommendations presented in this report can be designed using the maximum allowable bearing values presented in the following table:

Foundation Bearing Pressures for Footings on Engineered Fill

Load Case	Bearing Pressure (psf)	Factor of Safety
DL	3000	3.0
DL+LL	4500	2.0
Total	6000	1.5
Ultimate	9000	1.0

The above engineered fill bearing pressures can be used for shallow footings supported on non-expansive fill material or deepened footings bearing on general fill materials.

8.04.2 Lateral Resistance for Footings

Lateral load resistance may be developed in friction between the footing bottoms and the supporting subsurface materials and by the passive resistance of soil/rock acting on the vertical faces of below-grade structural elements. Friction coefficients of 0.30 and 0.40 can be used for footings bottomed on soil (including non-expansive fill) and in-place bedrock, respectively. If the foundations are poured neat against the soil/rock, friction and passive resistance may be used in combination. Passive resistance provided by firm soil (including compacted fill) can be evaluated using a triangular distribution with a uniform increase of 300 psf per foot of depth. For footings that are poured neat into excavations within in-place bedrock, a minimum passive resistance value of 1,200 pounds per square foot (psf) can be used starting at the bedrock surface which can then be increased at a rate of 450 psf per foot of depth. The above frictional coefficients and passive resistance values can be considered "allowable" values under long-term loading conditions and include factors of safety of at least 1.5 and 2.0, respectively.

8.04.3 Construction Procedures

Completed footing excavations should be maintained in a moist condition and should be free of standing water and loose material at the time the footings are cast. We recommend that the footing excavations be monitored by a representative of our firm to confirm the adequacy of the bearing materials, verify compliance with appropriate moisture control, and check for adequate cleanout prior to concrete placement.

8.04.4 Tiedowns

Drilled and grouted tiedown anchors (tiedowns) can be used in lieu of or to supplement the uplift resistance provided by drilled piers. Tiedowns (if used) should be anchored in bedrock. All tiedowns that are designed to be post-tensioned should have an unbonded length of at least 15 feet. For estimating the lengths of tiedowns grouted or post-grouted under pressure, we recommend using a skin friction value of 2,400 pounds per square foot (psf) in bedrock. A lesser skin friction value of 1,500 psf should be used where pressure grouting or post-grouting is not performed. These values are considered appropriate for short-term seismic loading and include a factor of safety of at least 1.5.

All tiedowns should be tested to at least 1.25 times the design load and should be sized such that the magnitude of the test load does not exceed 80 percent of the guaranteed ultimate strength of the tendons or bars. Permanent tiedowns should be equipped with double corrosion protection. Appropriate corrosion protection should also be provided at the anchorage connection. If tiedowns are to be used, we recommend that AKA be consulted as preliminary anchorage designs are being developed so that we can provide supplemental design-specific recommendations, as appropriate. AKA and the project Structural Engineer should also review and approve all submittals from the contractor pertaining to the design, installation and testing of tiedowns.

8.05 <u>Ground Floor Concrete Slabs</u>

8.05.1 Slab Underdrainage

A continuous underdrainage layer should be installed below ground floor concrete slabs to intercept and drain away seepage that could otherwise become trapped beneath the building. We recommend that the underdrainage layer consist of at least 8 inches of ¾-inch clean, open-graded, compacted drainrock. A series of shallow trenches with perforated collector pipes should be placed at the base of the drainrock layer. Minimum 4-inch-diameter SDR 35 or Schedule 40 PVC pipes should be used that are placed no more than 20 feet apart. The drainrock should be compacted by mechanical means, with care taken not to damage the collector pipes during the compaction efforts. The collector pipes should drain, by gravity, to an appropriate discharge.

8.05.2 Moisture Retarder

A moisture retarder should be installed above the slab underdrainage layer beneath concrete slabs that are cast on-grade; if a waterproof barrier is desired, we recommend that a waterproofing consultant be retained to provide appropriate recommendations. Either of the following moisture retarders are considered generally acceptable, from a geotechnical standpoint:

- A vapor retardant membrane (Class A Vapor Retarder [ASTM E1745, latest revision] or better), covered with 2 inches of sand, or

- A heavy-duty impermeable membrane (Stego® wrap 15-mil or an approved equivalent) installed and taped in accordance with the manufacturer's recommendations.

8.05.3 Non-expansive Fill Layer

All ground floor slabs should be underlain by at least 18 inches of non-expansive fill unless they are structurally-supported with a (minimum) 6-inch gap between the bottom of the slab and the subgrade. The granular materials that comprise the slab underdrainage layer and moisture retarder are considered non-expansive and can be included in the non-expansive fill layer. The remainder of the required 18-inch thickness can consist of compacted: (1) import granular fill; and/or (2) lime-treated onsite soil.

Prior to the placement of the non-expansive fill layer, the underlying building pad surface should be proof-rolled under our observation and confirmed to be uniform and non-yielding. Similar proof-rolling should be performed at the top of the non-expansive fill layer before the vapor retardant membrane is placed.

8.05.4 Slab-on-Grade Design

Slab reinforcing should be provided in accordance with the anticipated use and loading of the slab. We recommend that interior slabs-on-grade be at least 5 inches thick and be reinforced with steel bar reinforcement. We also recommend that the specifications for slab-on-grade floors require that moisture emission tests be performed on the slab prior to the installation of flooring. No flooring should be installed until safe moisture emission levels are recorded for the type of flooring to be used.

8.06 <u>Site Preparation</u>

8.06.1 Clearing and Grubbing

Prior to clearing, all active subsurface utilities in and immediately surrounding areas to be graded should be located, marked and protected or relocated. Any trees within the limits of grading should be cleared and tree stumps and rootballs should be grubbed to the extent sufficient to remove organic-laden materials. The site should be cleared of pavements, aggregate base, slabs-on-grade, fences, and other near-surface improvements. Soils containing vegetation and organic matter should be stripped. Stripped and grubbed materials are not suitable for re-use as engineered fill and should be removed from the site or stockpiled for later use as landscape material. Pavements, aggregate base, broken concrete, and other cleared improvements should be removed from the site or stockpiled for later use, subject to the approval of our firm and the University of California.

8.06.2 Shoring

Excavation cuts will need to be laid back or shored in accordance with Cal-OSHA requirements. Temporary shoring will be required where safe cutback slopes are not possible, or where the protection of adjacent utilities, structures or other improvements is necessary. The design, installation and maintenance of all shoring and excavation slopes and the protection of workers, utilities and adjacent improvements during construction are responsibilities of the contractor. We recommend that the contractor document the location and condition of nearby buildings, pavements, walls, vaults, and utilities in as thorough a manner as is practical prior to the commencement of site excavation. The contractor should also perform regular and frequent surveys during excavation and construction to monitor and document any observed settlement or deflection of nearby utilities, structures or other site improvements. We recommend that AKA and the University of California review (favorably) the contractor's proposed shoring and monitoring plans prior to the commencement of shoring and site excavation activities.

The project design includes permanent walls that will serve as shoring in the following locations: (1) at the upslope perimeter of the proposed Helios building; (2) along portions of the Helios access road; and (3) along Centennial Drive directly east of the access road entrance. Recommendations for the design of permanent retaining walls are presented in Sections 7.09 through 7.11 of this report.

8.07 <u>Embankment Construction</u>

8.07.1 Keyway Excavation

A keyway should be excavated into in-place bedrock at the toe of the fill embankment that will support the Helios building and access road. The keyway should be at least 12 feet wide and should extend at least 3 feet into in-place bedrock at its downslope edge. Keyways in MSE areas should be wide enough to accommodate the length of any required georeinforcing elements, plus at least 5 feet to allow for the installation of subdrainage at the excavation back cut. We recommend that each of the co-authors of this report or their designated representative(s) observe the keyway excavation to check that in-place bedrock is exposed.

Based on the available data, we judge that excavation can likely be accomplished using conventional heavy earthmoving equipment. However, zones of relatively hard rock could be encountered. The contractor should be prepared to utilize suitable hard rock excavation techniques such as jackhammering or hoe-ramming, if necessary. Excavated soil and rock that do not meet the requirements for fill materials should be processed to conform to project specifications or removed from the site.

8.07.2 Subdrainage

Subdrainage should be installed along the back cut of the keyway and up the back cut of the excavation. Subdrainage should consist of 6-inch, rigid, perforated pipes, surrounded by ¾-inch, open-graded drainrock encapsulated in non-woven polyester geotextile filter fabric such as Mirafi 140N or 140NL, or a 4-ounce equivalent. Caltrans Class 2 Permeable Material can be used in lieu of drainrock, in which case the filter fabric can be omitted. Subdrain pipes should be installed along the back cut of the new fill at no greater than 10-foot vertical intervals as filling proceeds. Additional subdrain pipes should be added to intercept water from springs or seepage zones, if encountered. The perforated drainpipe should be sloped to drain with a minimum positive gradient of 2 percent. We recommend the use of SDR 35 or Schedule 40 PVC for the upper portions of the drain system; stronger pipe (SDR 23.5 or an approved equivalent) should be used for portions of the drain system that are deeper than about 40 feet.

The subdrain pipe at each level should be connected to a closed pipe (non-perforated) that drains, by gravity, to a suitable discharge facility. Since the keyway will be well below the elevation of the final ground surface in the general area of the UCB corporation yard, the gravity discharge will be located well downslope and may need to be located offsite.

Subdrains on different levels should not be interconnected. At the location where the perforated subdrain pipe connects with the solid discharge drainpipe, the drainrock or Class 2 Permeable Material should be discontinued. A "clay plug" should be constructed out of relatively impervious soils to direct collected water into the perforated pipe and minimize the potential for water collecting around the solid drainpipe and saturating the adjacent soils. In addition to the drainage details noted above, the "high" end and all 90-degree bends of the subdrain pipe should be connected to a riser that extends to the surface and acts as a cleanout.

8.07.3 Fill Materials

General fill can be used as engineered fill, except where non-expansive fill is specifically required. General fill material should have an organic content of less than 3 percent by volume and should not contain rocks or lumps larger than 6 inches in greatest dimension. The soil and rock obtained from site excavations are generally suitable for re-use as fill provided that they meet, or can be processed (i.e., by crushing and/or blending) to meet the requirements for general fill.

Non-expansive fill material should conform to the following requirements:

- Have an organic content of less than 3 percent, by volume;
- Be generally free of rocks or lumps larger than 6 inches in greatest dimension;
- Have a Plasticity Index of 12 or less; and
- Have a Liquid Limit of 40 or less.

Non-expansive fill can be comprised of: (1) onsite materials that meet or can be processed (e.g., by crushing and/or lime treatment) to meet the above requirements; or (2) import materials that meet the above requirements and are free of environmental contaminants. All proposed fill materials should be approved by AKA prior to their use; import material should be evaluated by our firm prior to its importation to the site.

Although some of the onsite materials may meet the requirements for non-expansive fill, the contractor should anticipate that most of the soil and rock materials generated by site excavations will not meet the specified PI/LL thresholds to be considered non-expansive. Processing of these materials for re-use will likely involve the mixing of proposed fill soils with lime prior to placement. Soils and rock materials that do meet the specified PI/LL thresholds may exist in certain areas of the site; if and where this is the case, these naturally non-expansive materials may be selectively segregated and stockpiled for use as non-expansive fill. Materials previously used for construction (aggregate base, crushed concrete or crushed asphalt) may also be suitable for re-use as fill from a geotechnical standpoint; however, the use of such materials as fill would need to be approved by the University of California.

8.07.4 Fill Placement and Benching

Fill materials should be placed in a manner that minimizes lenses, pockets and/or layers of materials differing substantially in texture or gradation from the surrounding fill materials. Fill that has not been lime-treated should be spread in uniform layers not exceeding 8 inches in loose thickness and compacted using mechanical

means in a uniform and systematic manner based on the following requirements (per ASTM D-1557 Test Methods):

- General fill should be moisture conditioned, as necessary, to between 3 and 5 percent over optimum moisture content and compacted to between 90 and 95 percent relative compaction.

- Non-expansive fill should be moisture conditioned, as necessary, to near optimum moisture content and compacted to at least 90 percent relative compaction.

Fill should be placed in layers such that the surface of each layer is nearly level and the fill should be benched into bedrock as filling proceeds. In general, we recommend that the vertical interval between bedrock benches be approximately 5 feet. Compaction at the faces of slopes should be obtained by "overbuilding" followed by trimming the completed slope back to design grades.

8.07.5 Lime Treatment

We recommend lime treatment by a qualified specialty contractor with demonstrated experience in the use of lime-treated soils to construct embankment fills. The lime treatment work should be performed in general accordance with Caltrans Standard Specification, Section 24. The amount of lime to be added to the soil should be sufficient to provide a laboratory 7-day unconfined compressive strength of 300 to 400 psi on compacted samples based on Caltrans Test Method 373. These tests should be performed on samples prepared in the laboratory.

Additional constraints may be placed on the lime treatment mix design in the event that lime treatment is to be used to mitigate settlement beneath the future Helios building. Additional tests may also be recommended pertaining to the long-term pullout resistance of geo-reinforcement (geogrids) embedded in lime-treated soils. The need for additional tests should be evaluated by AKA in consultation with the design team after preliminary foundation and wall designs have been developed.

For testing during construction, the lime would be mixed with the actual soil materials to be used as lime-treated fill. The specified lime content will be based on laboratory test results; however, for planning purposes we anticipate that the required amount of lime will range from 3% to 5% by dry weight. Considering the large volume of earth fill and the variation between the different onsite materials, there could be sufficient differences in the natural soil to warrant revisions to the amount of lime as the work is progressing. Therefore, periodic laboratory testing should also be performed during construction.

Lime/soil mixing should be performed in two steps using a rotary pulverizer that is specially designed for soil mixing. The depth of mixing depends on the pulverizing equipment, but typically mixing depths of 12 to 15 inches can be obtained. The initial mix is performed immediately after lime is spread onto the soil. After the initial mix, the soil should be lightly rolled and allowed to cure for at least 24 hours. During the curing period, the lime reacts with the soil to break down the clay. Moisture conditioning should be performed as needed. The mixing can be performed either in-place (where the embankment fill will be compacted) or at a nearby site where the material can be mixed but hauled to the final embankment fill location. The location for the initial mix should be selected by the contractor to accommodate the filling operation.

After the minimum 24-hour cure, the treated soil should be mixed a second time, placed and spread in a thin layer (maximum of 12 inches in loose thickness) and then compacted to at least 95% relative compaction

(ASTM D-1557 Test Method). Once compacted, the next layer of soil or soil/lime mix can be placed and the procedure should be repeated. The fill should be benched into bedrock in accordance with the recommendations of Section 8.07.4.

8.07.6 Special Benching and Fill Placement Requirements

The recommendations presented in this section apply only in the event that the Helios building is to be supported on spread footing foundations underlain by a significant thickness of embankment fill. In that event, special considerations related to fill settlement would apply.

Non-Lime-Treated Embankment Materials: In the event that the Helios Building is to be supported on non-lime-treated fill embankment materials, a maximum average gradient should be specified for the benching to limit long-term differential settlement. For an allowable angular distortion value due to long-term settlement of 1/360, the bedrock surface beneath the planned buildings should be benched such that the average fill thickness varies by no more than 8 feet over a horizontal distance of 30 feet (an average gradient of about 26 percent). If allowable angular distortions due to long-term settlement are different than the 1/360 value assumed, the recommended average fill thickness gradient presented above can be scaled proportionally. For example: for an allowable angular distortion value due to long-term settlement of 1/720 (1/2 inch over 30 feet) the average fill thickness should vary by no more than 4 feet over a horizontal distance of 30 feet (an average gradient of about 13 percent). The maximum allowable angular distortion due to long-term settlement for a footing-supported building would need to be evaluated by the project structural engineer.

Lime-Treated Embankment Materials: In the event that the Helios Building is to be supported on lime-treated fill embankment materials, the settlement characteristics of the lime-treated fill should be pre-evaluated by laboratory tests that are performed prior to start of construction. Compaction curves (per ASTM D-1557) should be performed on one sample of untreated soil, and a suite of soils treated to the target lime contents (preliminarily estimated to be in the range of 3, 5 and 7 percent). The compaction curve results should be used to identify the maximum dry density and the optimum moisture contents of the untreated and treated soils. New samples should then be created by compacting the untreated and treated soils to 95 percent of the ASTM D-1557 maximum dry density under wet-of-optimum conditions. The compacted samples of the treated soils should then be allowed to cure under controlled conditions, after which they should be tested to evaluate their strength and compressibility characteristics. At this time, we anticipate that tests would be performed to evaluate both the unconfined strength and the consolidation properties of the untreated and treated materials and that the results of the laboratory tests would be used to determine appropriate fill placement and benching requirements.

8.07.7 Slope Trimming

Upon completion of fill slope construction, the outboard face of the fill should be cut back to provide a firm, uniform slope. The completed slope and adjacent sloping areas disturbed by construction activities should be planted or hydroseeded to resist erosion. We recommend all new cut or fill slopes at the site have a maximum inclination of 2:1. At this inclination, soil slopes may still be subject to some minor erosion and/or sloughing, thus requiring periodic maintenance of the slopes. We recommend any new cut or fill slopes be planted with erosion-resistant vegetation and that an erosion control netting system be installed. A landscape architect experienced in erosion control planting should be consulted prior to selection of vegetation.

8.08 Retaining Wall Lateral Pressures and Backdrainage

8.08.1 Static Lateral Pressures for Tieback Walls

Our recommended lateral pressure distribution diagram for static lateral earth pressures on tieback walls is presented on Figure 13. The recommended static lateral pressure distribution is based on active earth pressures redistributed into a trapezoidal "apparent" earth pressure diagram. The maximum (uniform) lateral pressures shown on Figure 13 are also presented below; the column titled "Increase over Level Backslope" is being provided for comparison purposes.

Static Lateral Pressures for Tieback Walls

Slope Behind Wall	Uniform Horizontal Lateral Pressure (psf for wall height in feet)	Increase over Level Backslope
Level	25H	1.00
3:1	28H	1.12
2:1	33H	1.32

For the temporary (i.e., during construction) load case, H should be taken as the vertical distance from the bottom of the adjacent excavation to the top of the retaining wall. For the long-term (i.e., after construction) load case, H can be taken as the vertical distance from the adjacent finished grade to the top of the retaining wall. The static lateral earth pressures in this section are unfactored; normal factors of safety for long-term sustained loading should be used when utilizing these load distributions for wall design.

8.08.2 Static Lateral Pressures on Walls Considered Free-to-Rotate

We anticipate that there may be locations where site retaining walls are not retained by tiebacks and are therefore considered "free to rotate". The recommended lateral pressure distribution for this case is based on active soil pressures and increases uniformly with depth (triangular distribution). Increases in lateral pressure per foot of depth (also commonly referred to as equivalent fluid weights) for this case are presented in the table below; the column titled "Increase over Level Backslope" being provided for comparison purposes.

Static Lateral Pressures for Free-to-Rotate Site Retaining Walls

	SOIL		ROCK	
Slope Behind Wall	Horizontal Lateral Pressure (psf per foot of depth)	Increase over Level Backslope	Horizontal Lateral Pressure (psf per foot of depth)	Increase over Level Backslope
Level	45	1.00	30	1.00
3:1	50	1.11	33	1.10
2:1	60	1.33	40	1.33

This load case would apply to any site retaining walls that are truly free-to-rotate and therefore unrestrained by tiebacks, other structural elements or wall geometry. The static lateral earth pressures in this section are unfactored; normal factors of safety for long-term sustained loading should be used when utilizing these load distributions for wall design.

8.08.3 Seismic Lateral Pressure from Upslope Landslide Deposits

This section provides recommendations for the seismic design of walls retaining upslope landslide deposits. Where upslope landslide deposits are not present, the recommendations presented in the following section (Section 8.08.4) can be used.

The retaining wall along the back side of the Helios building will retain upslope portions of the Central Intermediate Landslide. The extent of landslide deposits are shown on the Geologic Map (Figure 6) and on Cross Section E-E' (Figure 12). The landslide deposits shown on Figure 12 include: (1) Quaternary Colluvium and Quaternary Landslide Deposits (symbol (Qu/Qls – grayish-orange shade); (2) Fill and Quaternary Landslide Deposits (Fill/Qls – purplish shade); and (3) "Repaired slope/fill" (purplish shade).

The magnitude of seismic lateral pressure increase caused by earthquake shaking depends upon the upslope lateral extent of landsliding (Figure 6). In general, the northern lobes of the Central Intermediate Landslide (Cross Section B-B', Figure 9) extend farther upslope than the southern lobes (Cross Section C-C', Figure 10) and thereby have the potential to exert a greater seismic lateral pressure. The following seismic surcharge values can be used to evaluate increases in lateral wall pressures exerted by the retained portions of the Central Intermediate Landslide:

Seismic Lateral Pressures from Central Intermediate Landslide

Lobe Location and Representative Cross Section	Lobe Location Relative to Horizontal Distance Scale Shown on Cross Section E-E' (Figure 12)	Seismic Horizontal Lateral Pressure Increase
northern lobe (Cross Section B-B')	between 200 feet and 385 feet	3,000 psf
southern lobe (Cross Section C-C')	between 385 feet and 500 feet	800 psf

The seismic lateral pressures calculated are intended for the evaluation of possible increases in wall pressure during the period of earthquake shaking. The seismic lateral earth pressures in this section are unfactored; normal factors of safety and load factors for short-term dynamic loading should be used when utilizing these seismic lateral pressure increases for wall design. Where seismic lateral pressures are to be considered, they should be added to the earth pressure distribution used for static conditions (per Section 8.08.1).

In the case of the Southern Intermediate Landslide, the permanent upslope retaining wall (i.e. that portion of the retaining wall that is above the level of the finished access road) is relatively low and there is no landslide slip surface present at that elevation. Seismic lateral pressures on the permanent exposed portion of the wall can be evaluated using seismic lateral pressures presented in the following section (Section 8.08.4). However; the upslope portion of the Southern Intermediate Landslide can still be expected to exert seismic lateral pressures on the retaining wall/engineered fill/MSE wall system at this location. This stability condition should be checked by AKA at a later stage in the design process as future grading plans and MSE wall designs are being developed.

8.08.4 Seismic Lateral Pressures Exclusive of Landslide Deposits

We recommend that seismic lateral pressures only be applied over the portions of the retaining walls that overlie in-place bedrock. This section provides recommended lateral pressure distributions to evaluate seismic pressure increases for soils not underlain by an existing landslide slip surface. Seismic lateral pressure increases within landslide areas should be evaluated using the seismic lateral pressure distributions presented in the following section (Section 8.08.5)

For the retaining wall along the upslope side of the Helios building and access road, the geologic cross section presented on Figure 12 (Section E-E') can be used to evaluate the approximate thicknesses and elevations of the retained materials. The following seismic surcharge values can be used to evaluate increases in lateral wall pressures caused by earthquake shaking within soil materials outside of landslide areas. These areas are identified on Figure 12 as: (1) Quaternary colluvium (symbol Qu – light orange shade); and (2) Fill (grayish-blue shade).

Seismic Lateral Pressures Exclusive of Landslide Deposits

Slope Behind Wall	Uniform Horizontal Lateral Pressure Increase (psf for wall height in feet)	Increase over Level Backslope
Level	18H	1.00
3:1	20H	1.11
2:1	24H	1.33

For the seismic load case, H can be taken as the vertical height (thickness) of the retained soil.

The seismic lateral pressures calculated are intended for the evaluation of possible increases in wall pressure during the period of earthquake shaking. The seismic lateral earth pressures in this section are unfactored; normal factors of safety for short-term dynamic loading should be used when utilizing these load distributions for wall design. Where seismic lateral pressures are to be considered, they should be added to the earth pressure distribution used for static conditions (per Section 8.08.1), but factored appropriately for the load condition.

8.08.5 Surcharge Loads

The increases in lateral wall pressures caused by vehicles operating behind the top of the wall can be evaluated by adding an additional uniform 100 psf horizontal pressure over the upper 10 feet of the wall height. Temporary surcharge loads near the top of the wall can be evaluated using a uniform lateral pressure equal to one-half of the vertical surcharge load, applied over the upper 10 feet of the wall. If unusually heavy and/or long-term surcharge loads are anticipated, we should be consulted to provide supplemental recommendations, as appropriate.

Protection of retaining walls throughout the construction phase is the responsibility of the contractor. We recommend that particular care be exercised directly upslope of retaining walls with respect to: (1) construction vehicles (including cranes); (2) material stockpiles; and (3) any necessary soil compaction operations. Protective measures should be considered especially important in areas upslope of the Helios building once it has been constructed as access to the wall face will be severely restricted.

8.08.6 Retaining Wall Backdrainage and Waterproofing

The lateral forces and pressures presented in this report are based on the assumption that all retaining walls will be fully drained to prevent the buildup of hydrostatic pressure. We therefore recommend that the retaining wall backdrainage system be robust, redundant, maintainable, and capable of functioning reliably over the life of the project. Backdrainage should be provided to within approximately two feet of the top of the retained soil/rock using one or more of the following approaches:

- Prefabricated drainage material or drainage mat (Miradrain or an approved alternative);
- A drainrock layer at least 12 inches in horizontal thickness; and/or
- Weepholes, gaps or slots that allow water to freely drain through the wall face.

The upper 2 feet of retained soil behind the wall should be backfilled with low permeability soil to limit surface water infiltration into the wall backdrainage system. A lined V-ditch or gutter should be installed behind the wall above the low-permeability soil that directs water away from the back of the wall and toward a suitable gravity discharge.

Once the Helios building is constructed, there will be physical limitations associated with future access to the face of the retaining wall located directly upslope. Future access limitations should be taken into account by the designer of the upslope retaining wall when designing the retaining wall backdrainage system, particularly with respect to: (1) maintenance access to service cleanouts, weepholes or other components of the wall backdrainage system; (2) moisture and humidity concerns (including mold growth) within the space behind the Helios building; and (3) difficulties that would be associated with any necessary wall repairs, should the backdrainage system cease to function properly. An appropriate moisture barrier or waterproofing system should be specified in all areas where seepage or moisture transmission through the walls would be considered objectionable. The design team should be responsible for specifying, designing and detailing the type of moisture barrier or waterproofing system to be used and should observe that it is appropriately installed.

Prefabricated drainage material should be in direct contact with the retained soil/rock materials behind the wall and should be designed to drain into a perforated plastic pipe or other approved prefabricated drainage conduit. If prefabricated drainage material is used, the elements comprising the wall backdrainage system should be specified and detailed in accordance with the manufacturer's recommendations. Drainage material should have sufficient crushing strength to support the expected lateral earth pressures.

Drainrock should conform to Caltrans specifications for Class 2 Permeable Material. Alternatively, locally available, clean, ½- to ¾-inch maximum size open-graded rock could be used, provided it is encapsulated in a non-woven geotextile filter fabric (such as Mirafi 140N or an approved alternative). The Caltrans Class 2 Permeable Material or geotextile-encapsulated open-graded rock should be in direct contact with the retained soil/rock materials behind the wall. Drainrock should drain into a perforated plastic pipe installed (with perforations down) on a 2-inch-thick bed of drainrock. The upslope end of the perforated drain pipe should be extended to near the ground surface with a non-perforated pipe that serves as a cleanout. The pipe/cleanout should be in an accessible location, capped and fitted with an enclosure (Christy box or similar), where appropriate. Water from the backdrainage system should be conveyed in non-perforated collector pipes by gravity to a suitable discharge facility. Perforated and non-perforated plastic pipe used in the drainage system should consist of 4-inch diameter or larger SDR 35 or Schedule 40 PVC.

8.09 Retaining Wall Foundations and Tiebacks

8.09.1 Soldier Pile Axial Capacity

The axial capacity of soldier piles can be evaluated using the recommendations previously presented in Section 8.03.1, "Axial Pier/Pile Design." These recommendations include the use of an allowable skin friction value of 500 psf in natural soil, 750 psf in engineered fill, and 1500 psf in bedrock, which can be increased one-third for total compressive loads (including seismic). The recommended allowable skin friction values can be considered over the full pile/pier diameter for the embedded portion of the soldier piles and over one-half of the pier diameter for the upper portion of soldier piles that are retained by tiebacks, ignoring any skin friction from above the uppermost tieback row.

8.09.2 Allowable Bearing Pressures for Retaining Wall Footings

In general, spread footings for retaining walls can be designed using the recommendations previously presented in Section 8.04.1, "Spread Footing Design." Footings may only be used where the toe of the footing is located a minimum distance of 5 feet from the edge of a firm, natural or engineered slope (neglecting landslide debris or colluvium on slopes steeper than 4:1). All footings should extend at least 18 inches below the lowest adjacent finished grade and be at least 18 inches wide.

8.09.3 Pier/Pile and Footing Lateral Resistance

In general, the lateral resistance of piers/piles and footings can be evaluated using the recommendations previously presented in Sections 8.03.2 and 8.04.2, respectively. Where there is a non-level ground surface on the downslope side of the retaining wall, lateral resistance may be less. The lateral resistance values presented in Sections 8.03.2 and 8.04.2 are considered appropriate for firm in-place soil and rock defined as "natural in-place soil/rock or engineered fill extending at least 5 feet horizontally beyond below-grade structural elements in the direction of loading." Firm in-place soil and rock *does not include* landslide debris or colluvium on slopes steeper than 4:1 (horizontal to vertical). These relationships are depicted schematically on Figure 14.

8.09.4 Tieback Design

Tieback holes should be inclined downward at an angle of at least 10 degrees below the horizontal. Tiebacks not retaining landslide debris should be anchored in an anchorage zone located behind an imaginary plane inclined 60 degrees from the horizontal passing through a line 5 feet behind the base of the excavation (Figure 13). For the special cases where tiebacks will retain landslide debris, tiebacks should be anchored in bedrock below the depth of landsliding. Portions of the tieback that are not within the anchorage zone should be designed to be unbonded. A minimum unbonded length of 15 feet should be provided.

The allowable capacities of tiebacks will depend upon a variety of factors including the installation method, hole diameter, grout pressure, and workmanship. Consequently, we recommend that the contractor be responsible for providing tiebacks of the required design capacity that meet specified deflection limits. The axial capacity of tiebacks grouted under gravity flow alone (i.e., not post-grouted or grouted under pressure) can be evaluated using the allowable skin friction values previously presented for drilled piers (Section 8.03.1). The following allowable skin friction values can be used to preliminarily estimate the lengths of tiebacks post-grouted under pressure:

Estimated Skin Friction Values for Post-Grouted Tiebacks

Anchorage Material	Allowable Skin Friction with Post-Grouting (psf)	
	Long-Term DL+LL	Total Loads
Soil	900	1200
Rock	2400	3200

The allowable skin friction values for static earth loads and total loads presented above include safety factors of approximately 2.0 and 1.5, respectively. The Top of Bedrock Contour Map presented on Figure 7 can be used for preliminary design purposes when evaluating tieback length and capacities. Tiebacks that are designed to restrain upslope landslides should be anchored entirely in bedrock. This special requirement applies specifically to walls that will retain the upslope portions of the landslides depicted on Figure 6. All permanent tiebacks should be equipped with double corrosion protection. Appropriate corrosion protection should also be provided surrounding the tieback/wall anchorage connection.

8.09.5 Tieback Testing

The required anchor bond length or each tieback should be confirmed by a load test program conducted under the observation of the Geotechnical Engineer. All tiebacks should be proof-tested to at least 1.25 times the design load. In addition, performance tests should be performed on the following tiebacks to 1.5 times the design load:

- The first two production tiebacks;
- 2 percent of the tiebacks located in areas without upslope landslides; and
- 10 percent of the tiebacks located in areas with upslope landslides.

Tiebacks should be sized such that the magnitude of the load test does not exceed 80 percent of the guaranteed ultimate strength of the tendons or bars. Replacement tiebacks should be provided for tiebacks that fail the load test.

The load at which tiebacks should be permanently locked off should be determined by the project Structural Engineer. Approximately 10 percent of the tiebacks should be checked 24 hours after the initial lock-off to check that stress relaxation has not occurred. We recommend that AKA be consulted once it has been determined whether the tieback retaining walls will be designed by the design team or under a design-build approach so that we can provide supplemental geotechnical recommendations, as appropriate.

8.10 Subsurface Utilities, Exterior Flatwork and Pavements

8.10.1 Utility Trenches

Utility trenches should be backfilled with fill placed in lifts not exceeding 8 inches in uncompacted thickness. Trenches should be filled by placing a granular shading layer beneath and around the pipe, and then 6 to 12 inches of shading should be carefully placed and tamped above the pipe. The remaining portion of the trench should be backfilled with onsite or import soil. The backfill (above shading layers) should be placed and compacted to a minimum relative degree of compaction of 90 percent based on ASTM D-1557. The compaction requirements given above should be considered minimum recommended requirements. If UCB and/or utility company specifications require more stringent backfill requirements, those specifications should be followed.

If imported granular soil is used, sufficient water should be added during the trench backfilling operations to prevent the soil from "bulking" during compaction. All compaction operations should be performed by mechanical means only. We recommend against jetting.

Where granular backfill is used in utility trenches, we recommend an impermeable plug or mastic sealant be used where utilities enter the building to minimize the potential for free water or moisture to enter below the building. Finally, because of the potential for collapse of trench walls, we recommend the contractor carefully evaluate the stability of all trenches and use temporary shoring, where appropriate. The design and installation of the temporary shoring should be wholly the responsibility of the contractor. In addition, all state and local regulations governing safety around such excavations should be carefully followed.

8.10.2 Exterior Slabs-on-Grade

We recommend exterior slabs-on-grade be supported on a minimum of 12 inches of lime-treated soil or non-expansive fill. Subgrades beneath future slabs-on-grade should be proof-rolled under our observation and confirmed to be uniform and non-yielding prior to the placement of the slab reinforcement. Concrete slabs that may be subject to vehicle loadings should be designed in accordance with Section 8.10.4, "Rigid Pavements." Slab reinforcing should be provided in accordance with the anticipated use and loading of the slab. We recommend that exterior slabs-on-grade be at least 4 inches thick and be reinforced with steel bar reinforcement. Exterior slabs should be structurally independent from buildings and be free floating. Score cuts or construction joints should be provided and minor movement and cracking of the slab should be expected. Steps to the building from exterior slab areas should include a gap between the steps and the building foundations. The recommendations presented above, if properly implemented, should help reduce the frequency and magnitude of exterior slab cracking.

8.10.3 Flexible Pavements

Flexible asphalt concrete (AC) pavements may be used for parking areas and driveways. We developed the following recommended pavement sections for various traffic indices using the Caltrans R-value design method for flexible pavements. The sections below are based on an assumed subgrade R-value of 30 for non-expansive fill and lime-treated soil. The R-value of the non-expansive fill or lime-treated soil beneath the aggregate base should be confirmed during construction (R-values significantly higher than 30 could be used to substantiate a revised thinner and potentially more economical flexible pavement section design).

Flexible Pavement Thickness Design for Subgrade R-Value = 30

Traffic Index	Asphalt Concrete (inches)	Caltrans Class 2 Aggregate Base (inches)	Total Thickness (inches)
4	2	6	8
5	3	6	9
6	3	9	12
7	3	12	15

We recommend the aggregate base be underlain by at least 18 inches of lime-treated soil or non-expansive fill to reduce adverse expansive soil effects and that this layer extend at least 3 feet beyond the outside pavement edge unless a deepened curb or other moisture cutoff (at least 24 inches deep) is provided.

The assumed traffic indices of 4.0 and 5.0 are commonly used for automobile and light truck parking areas and access driveways, respectively. Traffic indices of 6.0 and 7.0 are commonly used for moderate truck access and parking areas. A traffic study has not been conducted by our firm for this project and our opinion regarding the applicability of the assumed traffic indices is experience-based and judgmental. The project civil engineer should choose the appropriate traffic indices for the pavement areas of the site and then use the given section for that traffic index.

The upper 6 inches of subgrade beneath planned pavements should be compacted to at least 95 percent relative compaction per ASTM D-1557. Pavement subgrades should be proofrolled and confirmed to be uniformly firm and non-yielding prior to the placement of aggregate base. Aggregate base for use in pavements should conform to Caltrans Standard Specifications for Class 2 Aggregate Base. The aggregate base used in pavement sections should be compacted to at least 95 percent relative compaction as determined by ASTM D-1557.

8.10.4 Rigid Pavements

Rigid Portland cement concrete (PCC) pavements may also be used in driveway/loading areas. This section provides recommendations for Caltrans jointed plain concrete pavement (JPCP), which is engineered with longitudinal and transverse joints to control where cracking occurs. JPCPs do not contain steel reinforcement, other than tie bars and dowel bars. The project civil engineer should design and detail the JPCP pavement per Caltrans specifications.

We developed the following pavement thickness design using the Caltrans R-value design method for rigid pavements and an assumed traffic index. The section below is for subgrade soils with an R-value between 10 and 40. The R-value of the non-expansive fill or lime-treated soil beneath the aggregate base should be confirmed during construction (R-values significantly higher than 40 could be used to substantiate a revised thinner and potentially more economical rigid pavement section design).

Portland Cement Concrete Pavement Thickness Design

Traffic Index	Portland Cement Concrete (inches)	Caltrans Class 2 Aggregate Base (inches)	Total Thickness (inches)
< 9	9	12	21

In addition, we recommend the aggregate base be underlain by at least 12 inches of lime-treated soil or non-expansive fill to reduce adverse expansive soil effects. In parking areas and driveways, the non-expansive layer should extend at least 3 feet beyond the outside pavement edge unless a deepened curb or other moisture cutoff (at least 24 inches deep) is provided.

The upper 6 inches of subgrade beneath planned pavements should be compacted to at least 95 percent relative compaction per ASTM D-1557. Pavement subgrades should be proofrolled and confirmed to be uniformly firm and non-yielding prior to the placement of aggregate base. Aggregate base for use in pavements should conform to Caltrans Standard Specifications for Class 2 Aggregate Base. The aggregate base used in pavement sections should be compacted to at least 95 percent relative compaction as determined by ASTM D-1557.

8.11 Future Geotechnical Services

8.11.1 Design Consultation and Plan Reviews

We recommend that we continue to provide geotechnical consultation to the University of California and the project team during the design phase in order to: (1) check that the design recommendations presented in this report are appropriately incorporated into the project plans and specifications; and (2) provide supplemental geotechnical recommendations, as needed. We recommend that we review the project plans and specifications as they are being developed so that we may provide timely input. We should also perform a general review of the geotechnical aspects of the final plans and specifications, the results of which we should document in a formal plan review letter.

8.11.2 Review of Contractor Requests and Submittals

During the bidding and construction phases, we should review all Requests for Clarification (RFCs) and Requests for Information (RFIs) that are geotechnical in nature. We recommend that we also review all geotechnical submittals from the contractor, including (but not necessarily limited to) those pertaining to shoring, dewatering, tiebacks, excavation/grading, lime treatment, and geotechnical materials.

8.11.3 Construction Observation and Testing

The analyses and recommendations submitted in this report are based in part upon the data obtained from our geologic mapping, test borings and data review. These analyses rely upon direct observations of surface conditions and discrete data points; the nature and extent of subsurface variations may therefore not become evident until construction. If variations then become apparent, it will be necessary to re-examine the recommendations of this report.

It is critical that we be retained to provide geotechnical engineering services during the construction phases of the work in order to observe compliance with the design concepts, specifications, and recommendations and to allow design changes in the event that subsurface conditions differ from those anticipated prior to the start of construction. The scope of our construction-phase observation and testing services should include (but not necessarily be limited to) site preparation, shoring installation, excavation, subsurface drainage installation, lime treatment, fill placement and compaction, pile/pier installation, footing excavations, retaining wall construction, tieback installation and testing, pavement and slab-on-grade subgrade preparation, aggregate base, slope trimming, and utility installation.

9.00 LIMITATIONS

This report has been prepared for the exclusive use of the University of California and their consultants for specific application to the proposed Helios Energy Research Facility project in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made. Note that the findings presented in this report are based, in part, upon data collected by previous investigators. We cannot accept responsibility for the accuracy of the data obtained from others or (consequently) for interpretations that we have made based on existing available data. In the event that any changes in the nature or design of the building are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed and the conclusions of this report are modified or verified in writing.

The findings of this report are valid as of the present date. However, the passing of time will likely change the conditions of the existing property due to natural processes or the works of man. In addition, due to legislation or the broadening of knowledge, changes in applicable or appropriate standards may occur. Accordingly, the findings of this report may be invalidated, wholly or partly, by changes beyond our control. Therefore, this report should not be relied upon after a period of three years without being reviewed by this office.

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Lennert & Associates, 1979, "Geologic Consultation, Hillside Access Road, Lawrence Berkeley Laboratory, Berkeley, California," December 1978 (LBNL revceieved1979), Job No. 789.

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Soulé, F., Jr., 1875, Map of Strawberry Valley and Vicinity Showing the Natural Sources of the Water Supply of The University of California.

Subsurface Consultants, 1987, Consultation Building 62 Addition, Lawrence Berkeley Laboratory, Berkeley, California," November 1987, Project No. 364.002.

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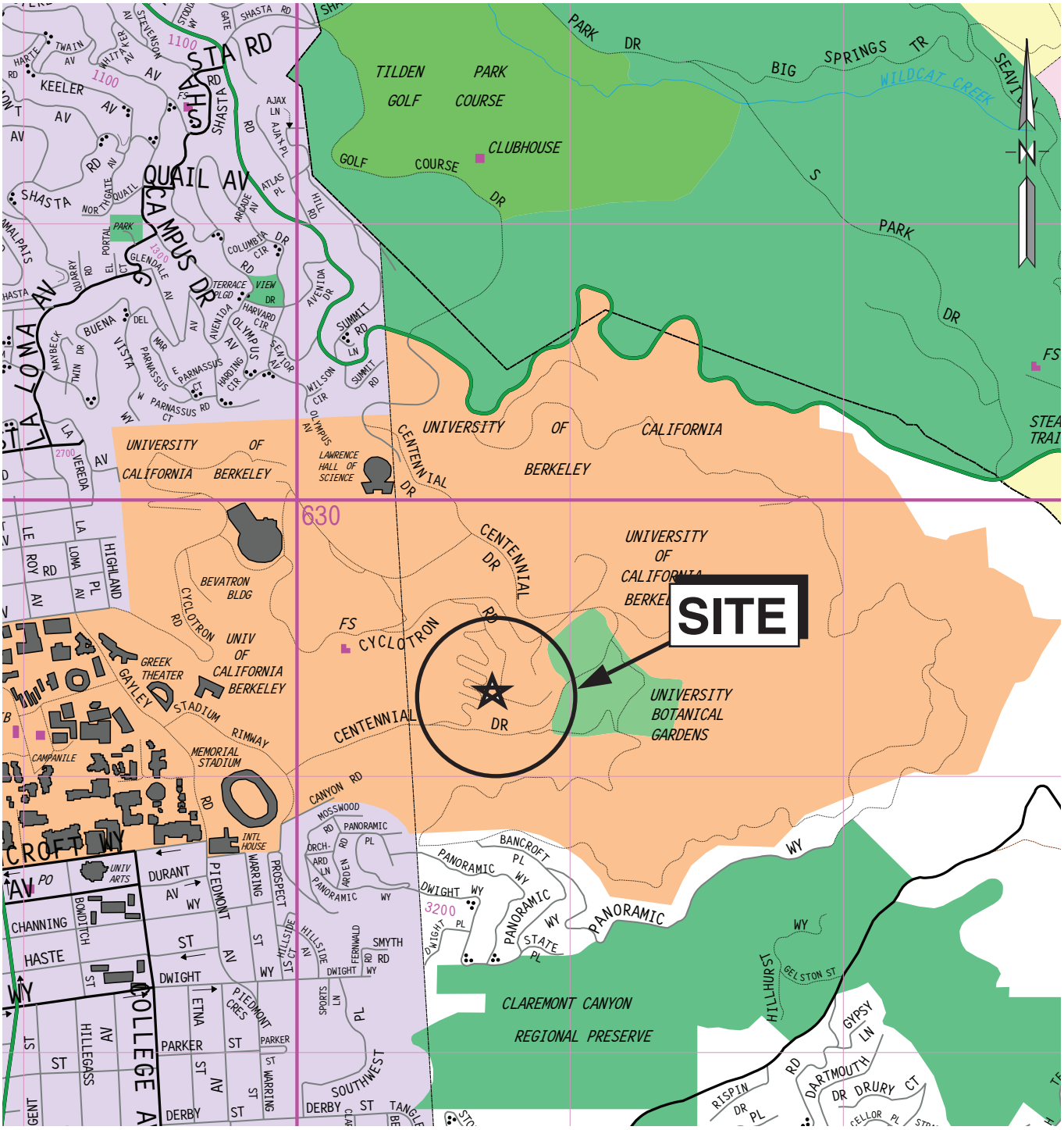
WLA 2008a, Surface-fault Rupture Hazard Investigation of the Wildcat Fault - East Canyon Fault, Proposed Helios Research Facility, Lawrence Berkeley Laboratory, Berkeley, California," WLA Project No. 2026.

WLA, 2008b, Surface-fault Rupture Hazard Investigation of the Wildcat Fault - Proposed General Purpose Lab, Lawrence Berkeley Laboratory, Berkeley, California," WLA Project No. 2023.001.

10.03 Historic Aerial Photographs

Type	Date	Scale	Photo No.	Source
Oblique	1935	N/A	PAS-USNPS-5-I	Pacific Aerial Surveys
Black and White, Stereo Pair	08/02/39	1:20,000	BUT-BUU-289-67, 68	United States Soil Conservation Service



Source: 2004 Thomas Brothers Maps

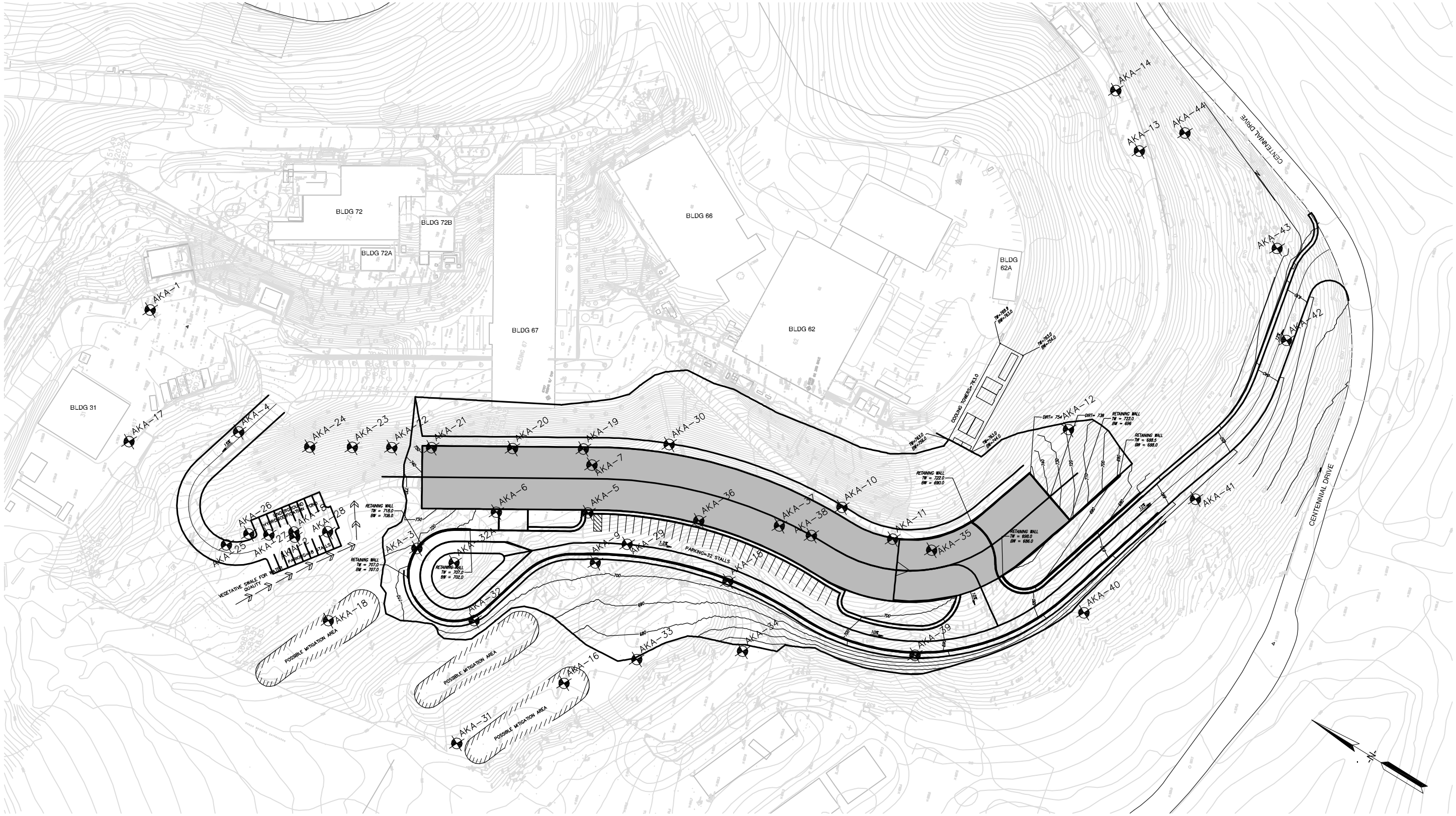
500 0 500 1000 2000
APPROX. SCALE FEET

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

VICINITY MAP

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	FIGURE 1
2500-4	**December 2008**	



LEGEND:

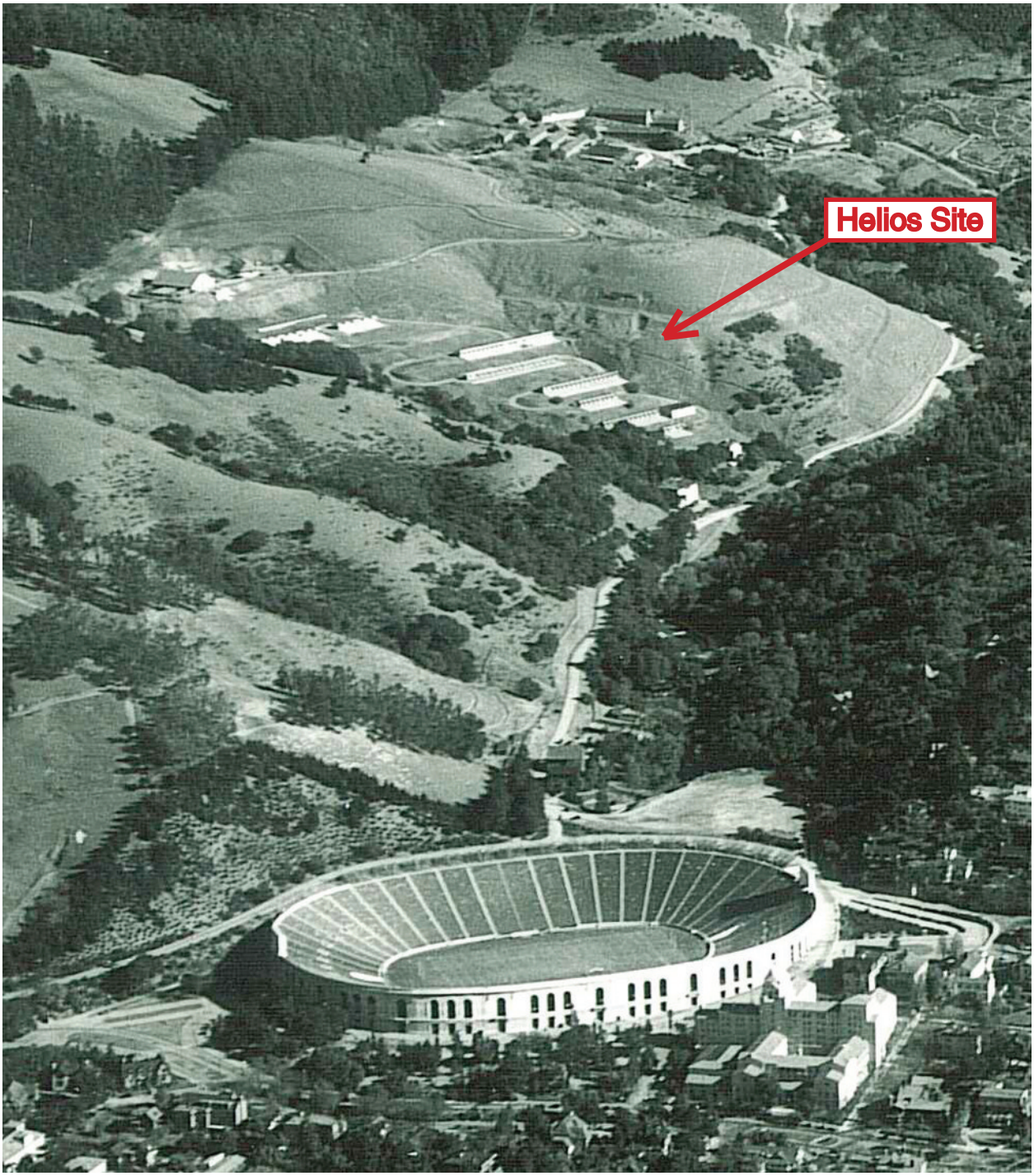
AKA-1 Approximate location of exploratory borings

50 0 100 200
APPROXIMATE SCALE FEET

Base: "Option 3-Alt Concept Grading Plan" by Creegan & D'Angelo Infrastructure Engineers, dated October 31, 2008.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

SITE PLAN		
HELIOS PROJECT University of California; Berkeley, California		
PROJECT NO.	DATE	FIGURE 2
2500-4	December 2008	



Source: Pacific Aerial Surveys

ALAN KROPP & ASSOCIATES
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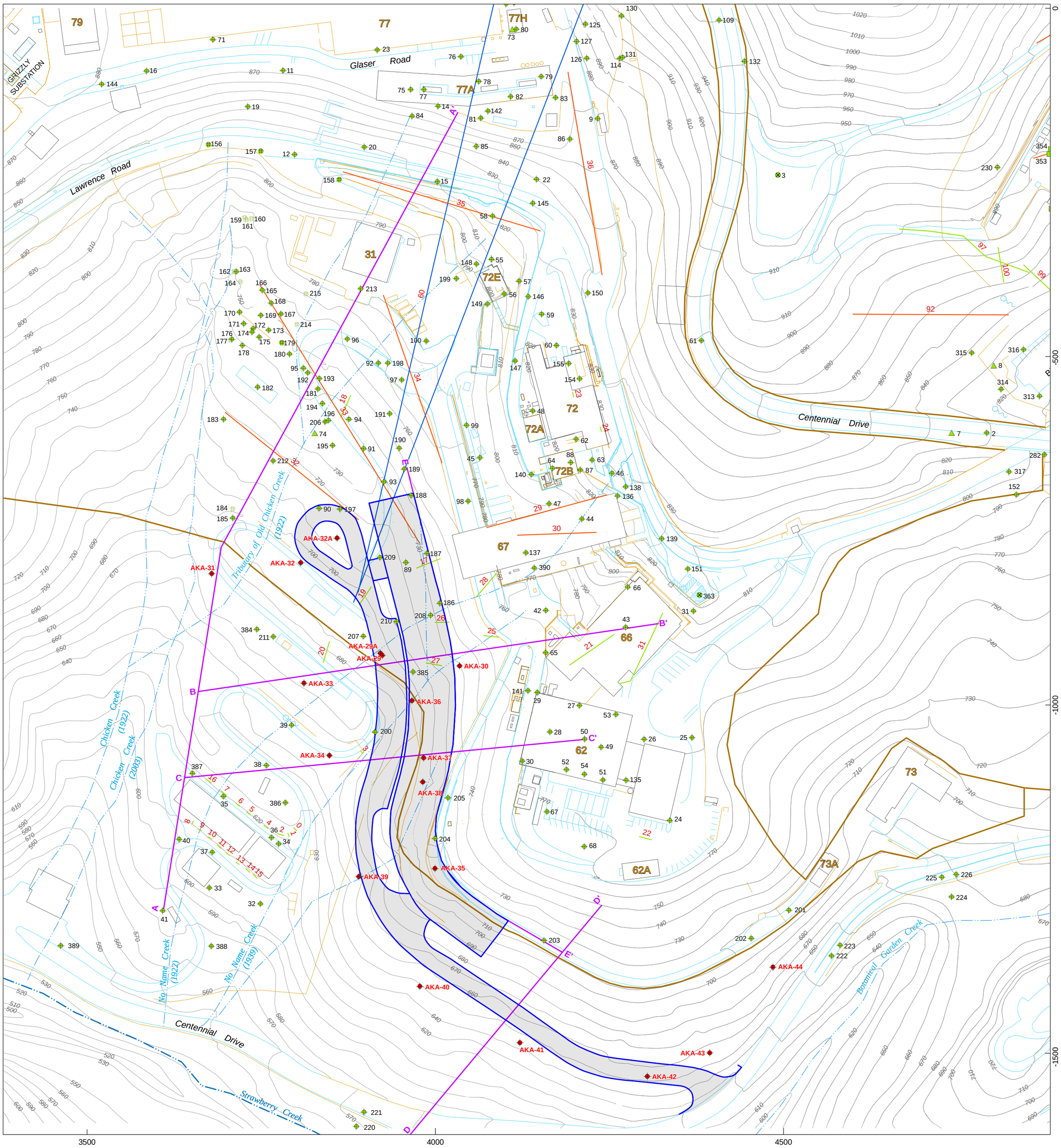
1935 PHOTOGRAPH

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	FIGURE
2500-4	**December 2008**	**3**



Explanation

- Contour, 10-foot interval (2007)
- Building, roads and structures (October, 2007)
- Spring (Parsons, 2000)
- Stream, dashed where uncertain (LBNL, 2003), unless otherwise noted)
- Strawberry Creek — Underground diversion pipe
- A — A' Cross section (this study)
- LBNL/UCB boundary
- Proposed building and road outline (November 10, 2008)

AKA-42	Boring (this study)
GIS Data Point Identification	
24	Boring
294	Pier hole
72	Slope indicator
4	Piezometer
283	Monitoring well
164	Well boring
352	Test pit
103	Borehole-hydrograph

GIS Data Line Identification	
60	Hydroauger
34	Seismic line
22	Trench or test pit
72	Cut wall

Grid north — True north

0 50 100 200 feet

Grid north is ~16° west of true north

Notes: 1. Coordinate system is the University of California, Berkeley grid system.
2. Data is from the compilation of previous studies.
3. The location accuracy of all data is only as good as the source location information. Georeferencing error can be as much as +/- 10 feet.

H E L I O S

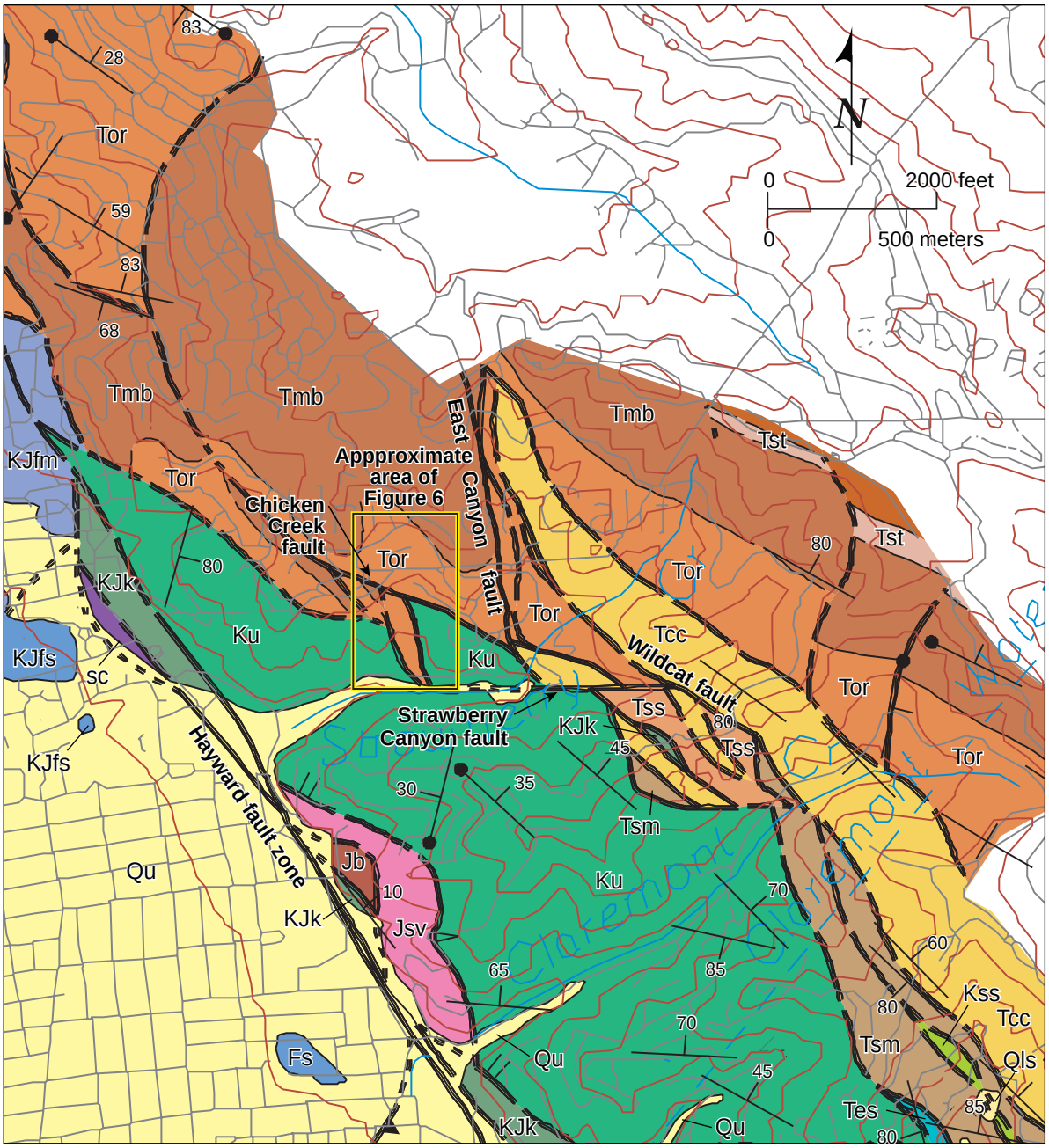
Site Plan and Data Compilation Map

WLA William Lettis & Associates, Inc.

Figure 4

Modified 12.08.08

1930.01 Alternate Helios Tower



Source: U.S.G.S. Department of the Interior by R.W. Graymer, D.L. Jones, and E.E. Brabb, 1996

Explanation

- Fault, dashed where uncertain, dotted where concealed, triangle indicates dip direction of inclined thrust fault
- 70 — Strike and dip of bedding
- Strike and dip of bedding, top direction known
- Strike of vertical bedding
- Hydrologic feature
- Road
- Elevation contour (10-meter interval)

Quaternary Units	*Tertiary Units*		*Cretaceous Units*	*Jurassic/ Cretaceous Units*	*Jurassic Units*
Qls	Tes	Tsm	Kss	KJfm	Jb
Qu	Tcc	Tss	Ku	KJfs	Jsv
	Tmb	Tst		KJk	
	Tor	fs			
		sc			

H E L I O S

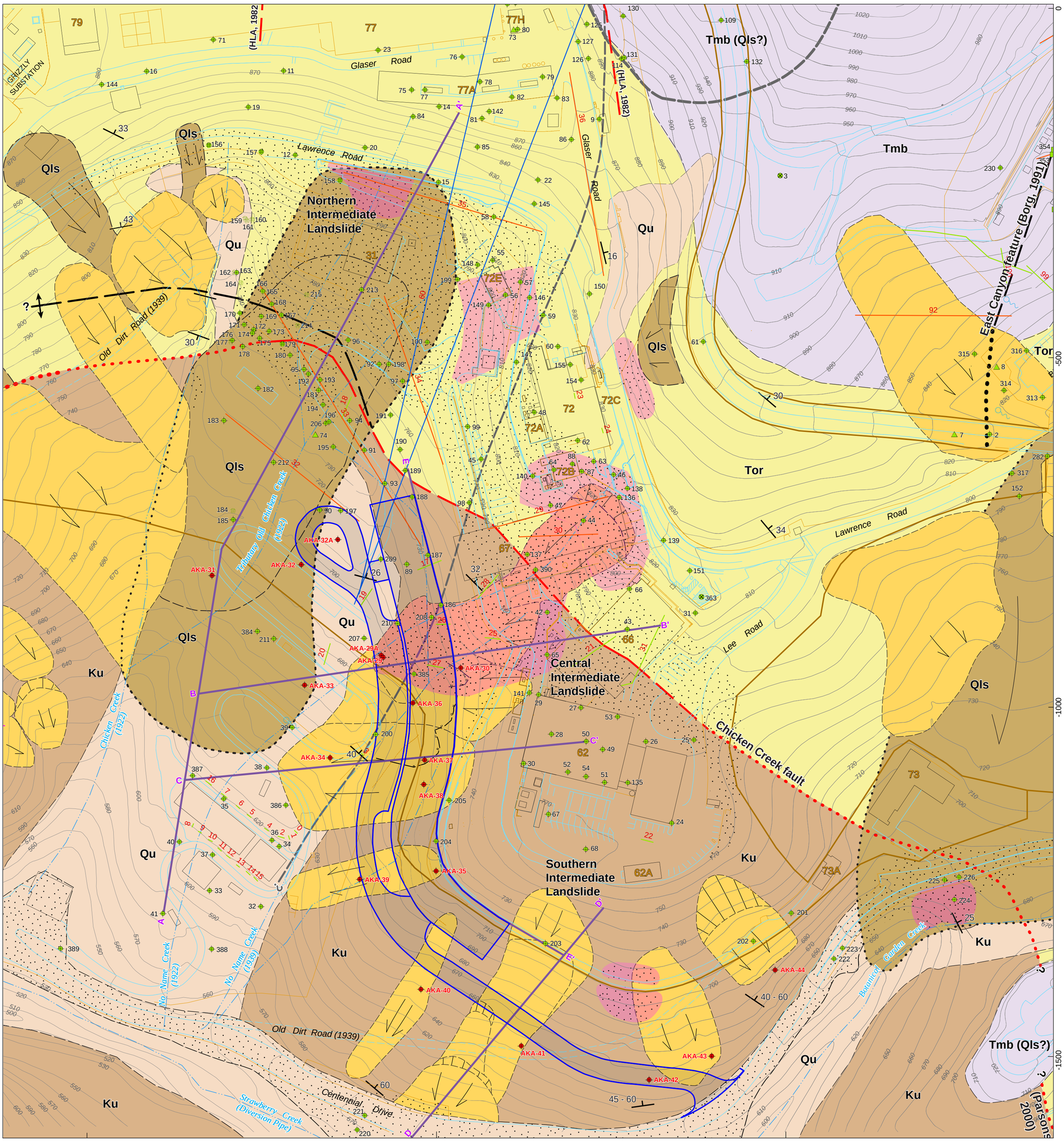
Simplified Regional Geology Map

WLA William Lettis & Associates, Inc.

Figure 5

Modified 12.08.08

1930.01 Alternate Helios Tower



Explanation

Unit Descriptions

- Fill - cover (10 feet or greater mapped by previous authors)
- Active or former location of slide, which has been removed or mitigated
- Recently active landslide
- Qls — Quaternary landslide with the inferred maximum (dotted) and minimum (dashed) landslide extent
- Previously inferred landslide (Plio-Pleistocene) (Lennert & Assoc., 1979)
- Qu — Quaternary colluvium/alluvium
- Tmb — Miocene Moraga Formation (volcanics)
- Tor — Miocene Orinda Formation (sandstone, siltstone, conglomerate)
- Tc — Miocene Claremont Formation (chert-shale)
- Ku — Cretaceous Great Valley Group (sandstone, shale)

Symbols

- Contour, 10-foot interval (2007)
- Contact; dashed where approximate
- ? Fault projected vertical from depth, dashed where approximate, dotted where concealed and uncertain
- 60 Strike and dip of bedding
- Anticline
- Building, roads and structures (October, 2007)
- Spring (Parsons, 2000)
- Stream, dashed where uncertain (LBNL, 2003)
- A — A' Cross section (this study)
- LBNL/UCB boundary
- Proposed building and road outline (November 10, 2008)

AKA-42 Boring (this study)

GIS Data Point Identification

- 24 Boring
- 294 Pier hole
- 72 Slope indicator
- 4 Piezometer
- 283 Monitoring well
- 164 Well boring
- 352 Test pit
- 103 Borehole-hydrograph

GIS Data Line Identification

- 60 Hydrauger
- 34 Seismic line
- 22 Trench or test pit
- 72 Cut wall

Notes: 1. Coordinate system is the University of California Grid system.
2. Mapping is based on field reconnaissance and compilation of previous studies.
3. The location accuracy of all data is only as good as the source location information. Georeferencing error can be as much as +/- 10 feet.

Grid north — True north

0 50 100 200 feet

Grid north is ~16° west of true north

H E L I O S

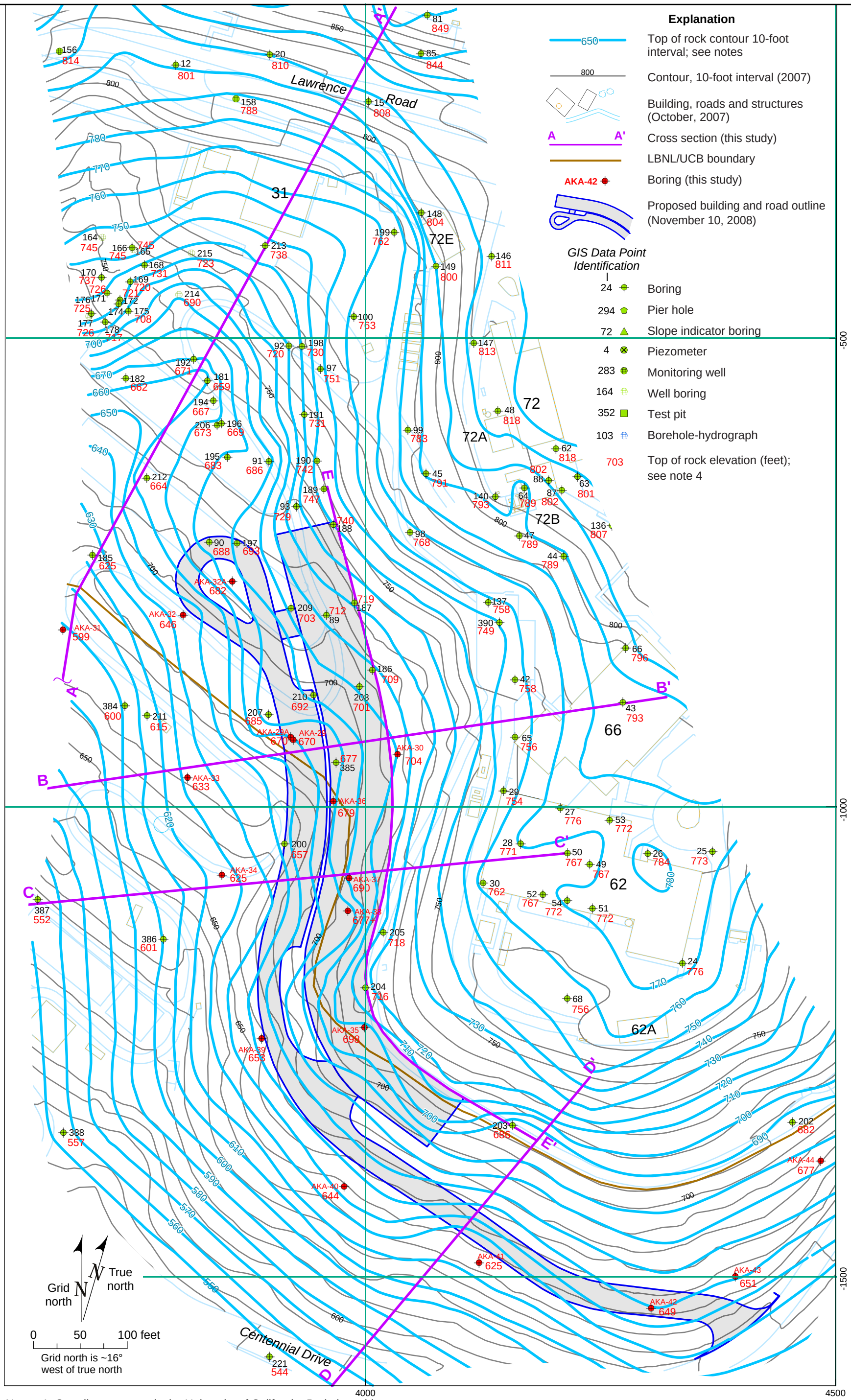
Site Geologic Map

WILLIAM LETTIS & ASSOCIATES, INC.

Figure 6

Modified 12.08.08

1930.01 Alternate Helios Tower



Notes: 1. Coordinate system is the University of California, Berkeley grid system.
2. Data is from the compilation of previous studies. Only data with elevation information was used.
3. The location accuracy of all data is only as good as the source location information. Georeferencing error can be as much as +/- 10 feet.
4. Previous data was disregarded in areas with updated information (only for contours intersecting cross sections).

H E L I O S

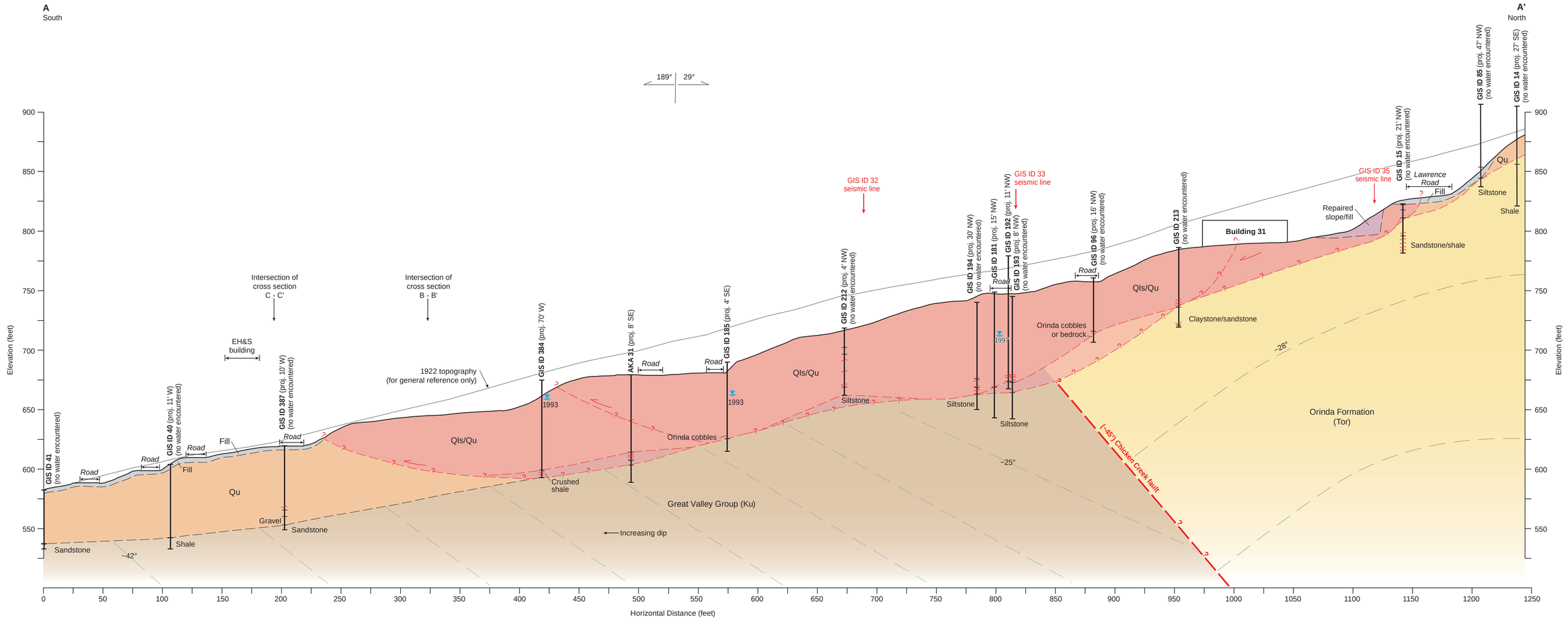
Top of Bedrock Contour Map

WLA William Lettis & Associates, Inc.

Figure 7

Modified 12.08.08

1930.01 Alternate Helios Tower



Explanation

- Artificial fill / with landslide overlay
- Qu — Quaternary colluvium / with landslide overlay
- Tor — Orinda Formation (Miocene) / with landslide overlay
- Ku — Great Valley Group (Cretaceous) / with landslide overlay
- Approximate location of fault
- Contact
- Potential landslide boundary
- Potential landslide direction
- Bedding dip, apparent
- 1993 — Depth to groundwater and year

Boring Details

- GIS ID 40 (proj. 11' W) — Projection direction and distance
- GIS ID 40 — GIS data identification (red indicates line data)
- Change in lithology or facies
- Potential offset/sheared feature observed

Notes: 1. Borings labeled by GIS ID (WLA project 2032).
2. Topography from October 2007 LBNL transmittal.
3. Coordinate system in University of California, Berkeley grid.

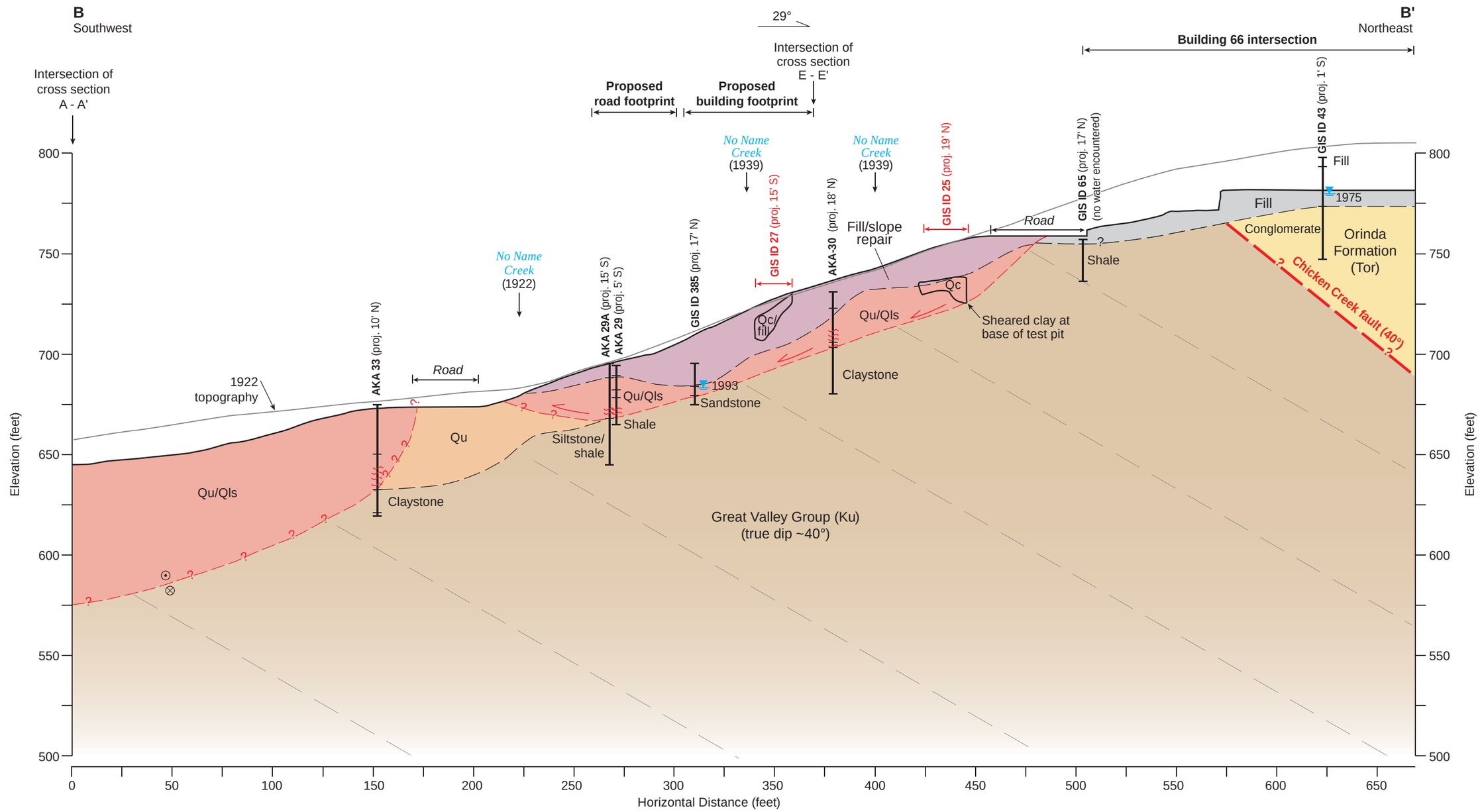
HELIOS

Section A - A'

WLA William Lettis & Associates, Inc. | Figure 8

Modified 12.08.08

1930.01 Alternate Helios Tower



Explanation

- Artificial fill / with landslide overlay
- Qu — Quaternary colluvium / with landslide overlay
- Tor — Orinda Formation (Miocene) / with landslide overlay
- Ku — Great Valley Group (Cretaceous) / with landslide overlay

- Approximate location of fault
- Contact
- Potential landslide boundary
- Potential landslide direction
- 1993 — Depth to groundwater and year
- Bedding dip, apparent
- ⊙ / ⊗ — Direction of movement: towards/away

Boring Details

GIS ID 43 (proj. 1' S)

- Projection direction and distance
- GIS data identification (red indicates line data)
- Change in lithology or facies
- Potential offset/sheared feature observed

Notes:
1. Borings labeled by GIS ID (WLA project 2032).
2. Topography from October 2007 LBNL transmittal.
3. Coordinate system in University of California, Berkeley grid.

H E L I O S

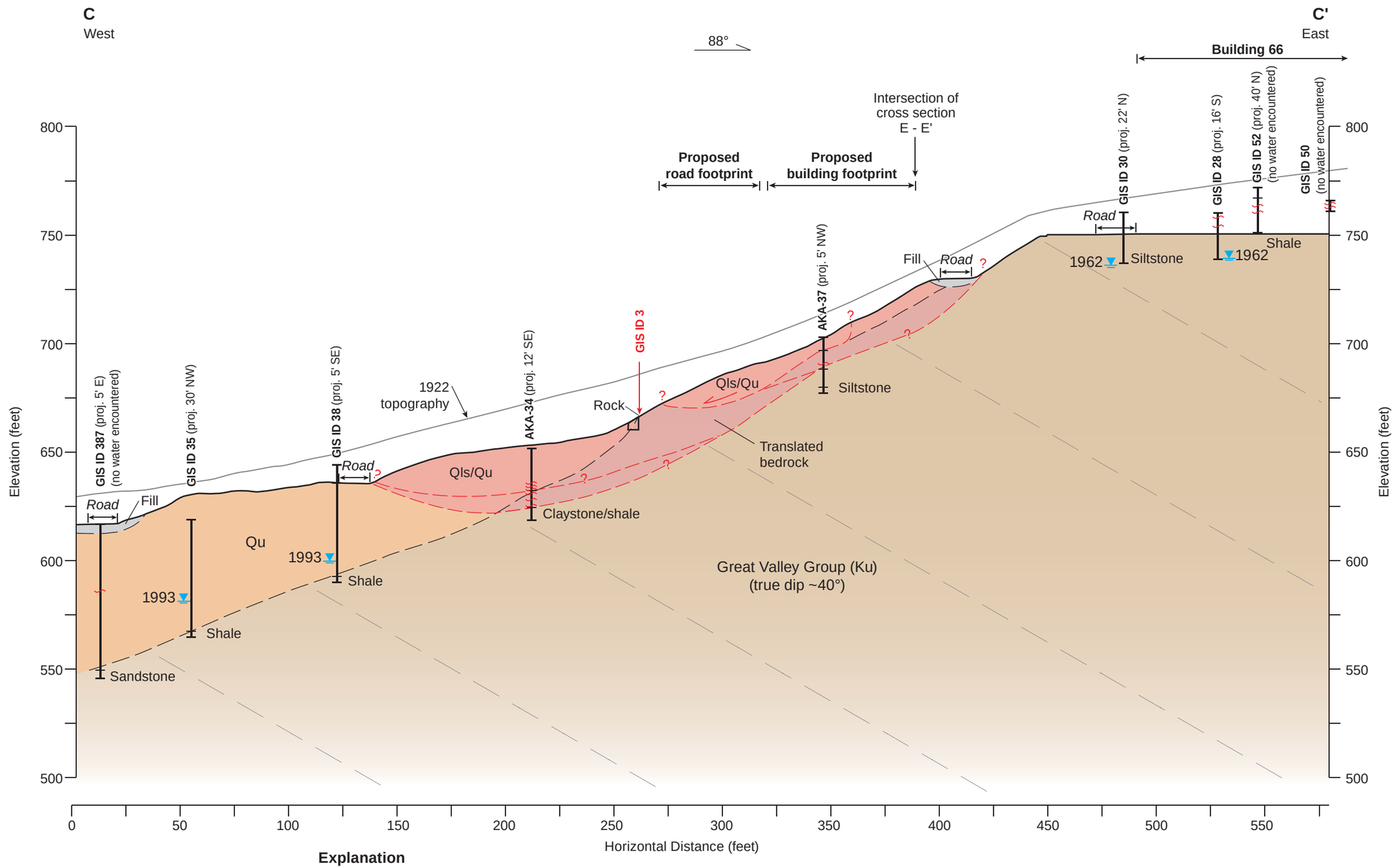
Section B - B'

WLA William Lettis & Associates, Inc.

Figure 9

Modified 12.08.08

1930.01 Alternate Helios Tower



Explanation

- Artificial fill / with landslide overlay
- Qu — Quaternary colluvium / with landslide overlay
- Ku — Great Valley Group (Cretaceous) / with landslide overlay
- Contact
- Potential landslide boundary
- Potential landslide direction
- 1993 — Depth to groundwater and year
- Bedding dip, apparent

Boring Details

- GIS ID 38 (proj. 5' SE) — Projection direction and distance
- GIS ID 38 — GIS data identification (red indicates line data)
- Change in lithology or facies
- Potential offset/sheared feature observed

Notes: 1. Borings labeled by GIS ID (WLA project 2032).
2. Topography from October 2007 LBNL transmittal.
3. Coordinate system in University of California, Berkeley grid.

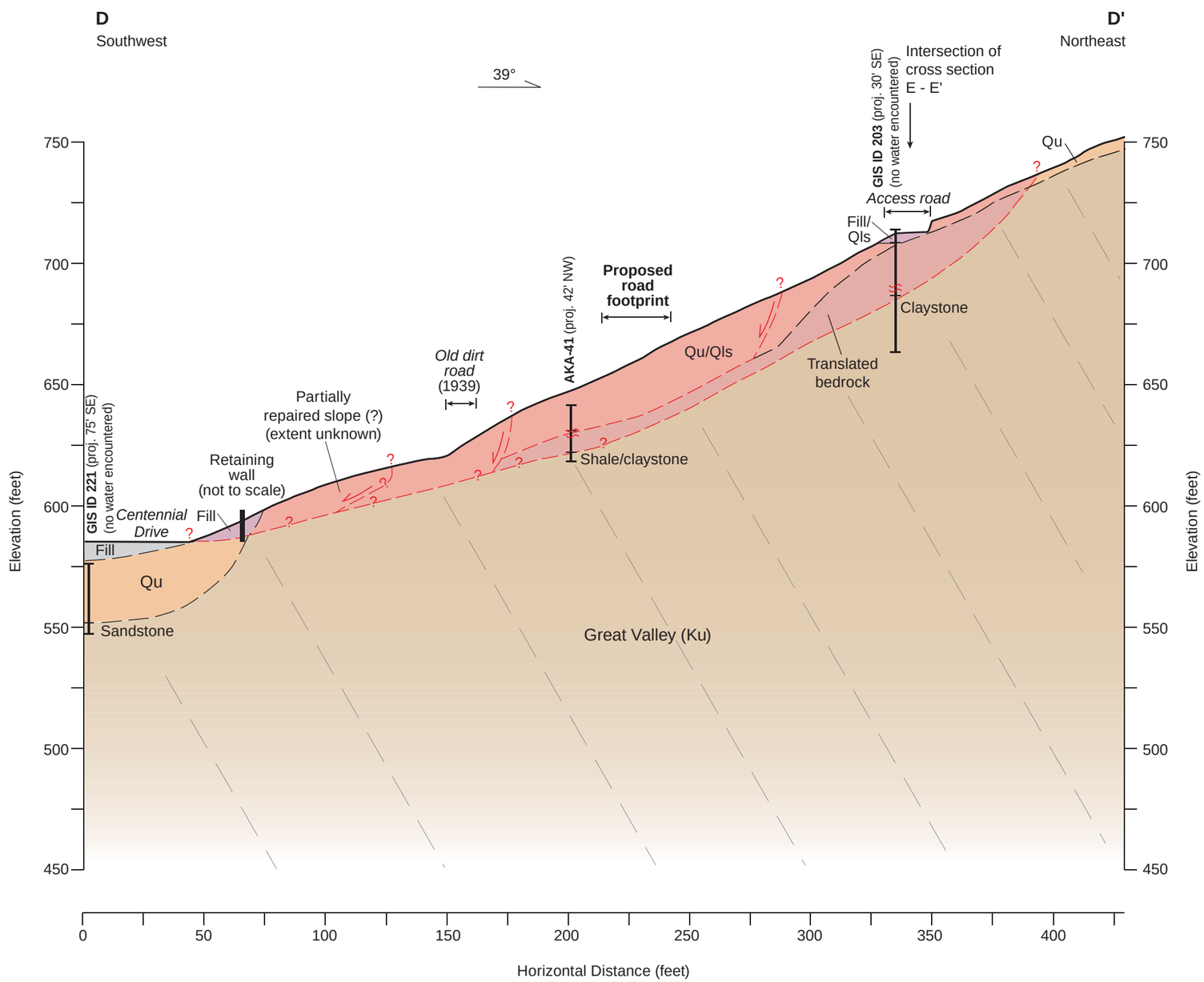
HELIOS

Section C - C'

WLA William Lettis & Associates, Inc. | Figure 10

Modified 12.08.08

1930.01 Alternate Helios Tower



Explanation

- Artificial fill / with landslide overlay
- Qu — Quaternary colluvium / with landslide overlay
- Ku — Great Valley Group (Cretaceous) / with landslide overlay
- Contact
- Potential landslide boundary
- Potential landslide direction
- Bedding dip, apparent

Boring Details

- GIS ID 203 (proj. 30' SE) — Projection direction and distance
- GIS ID 203 — GIS data identification
- Change in lithology or facies
- Potential offset/sheared feature observed

Notes:
1. Borings labeled by GIS ID (WLA project 2032).
2. Topography from October 2007 LBNL transmittal.
3. Coordinate system in University of California, Berkeley grid.
4. Groundwater depth not available from borehole data.

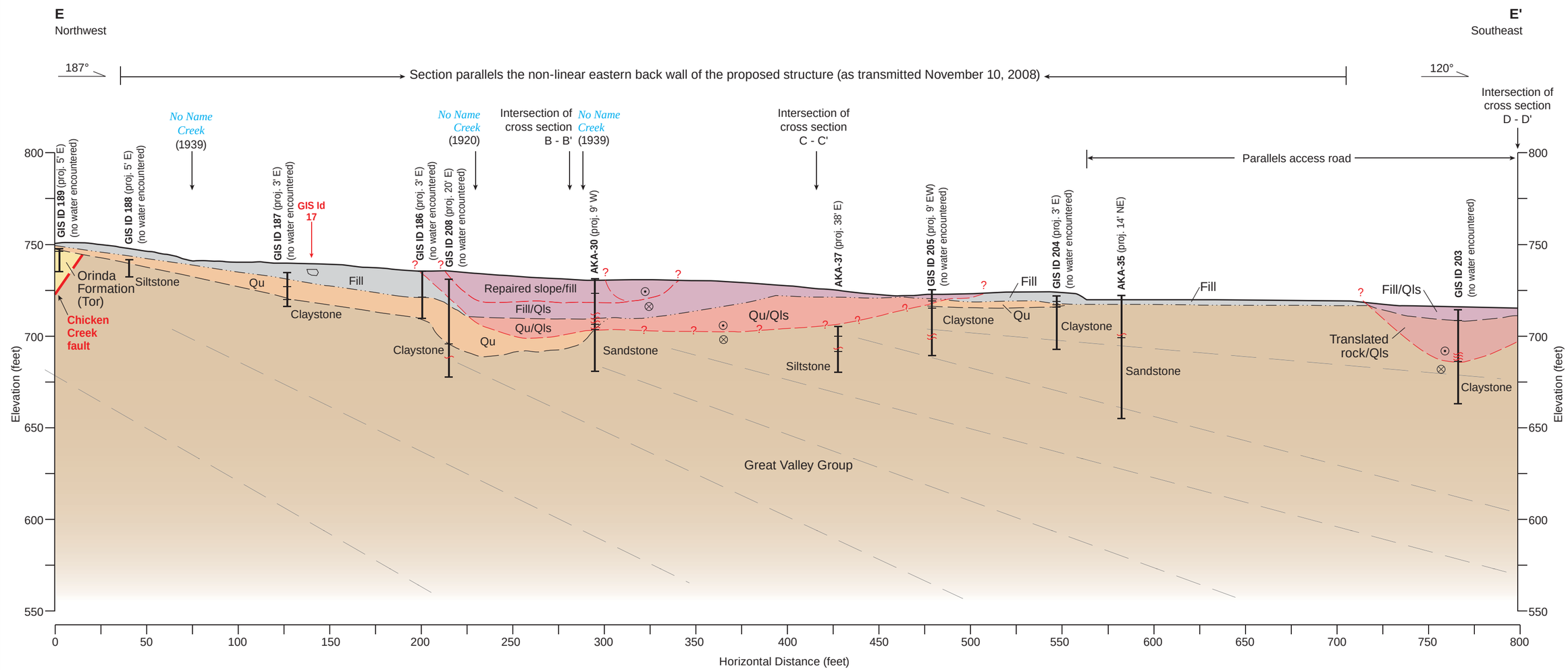
H E L I O S

Section D - D'

WLA William Lettis & Associates, Inc. | Figure 11

Modified 12.08.08

1930.01 Alternate Helios Tower



Explanation

- Artificial fill / with landslide overlay
- Qu — Quaternary colluvium / with landslide overlay
- Tor — Orinda Formation (Miocene) / with landslide overlay
- Ku — Great Valley Group (Cretaceous) / with landslide overlay

- Approximate location of fault
- Contact
- Fill contact (defined by pre Building 67 topography)
- Potential landslide boundary
- Potential landslide direction
- Bedding dip, apparent
- ⊙ / ⊗ Direction of movement: towards/away

Boring Details

GIS ID 204 (proj. 3' E)

- Projection direction and distance
- GIS data identification (red indicates line data)
- Change in lithology or facies
- Potential offset/sheared feature observed

Notes:
1. Borings labeled by GIS ID (WLA project 2032).
2. Topography from October 2007 LBNL transmittal.
3. Coordinate system in University of California, Berkeley grid.
4. Groundwater depth not available from borehole data.

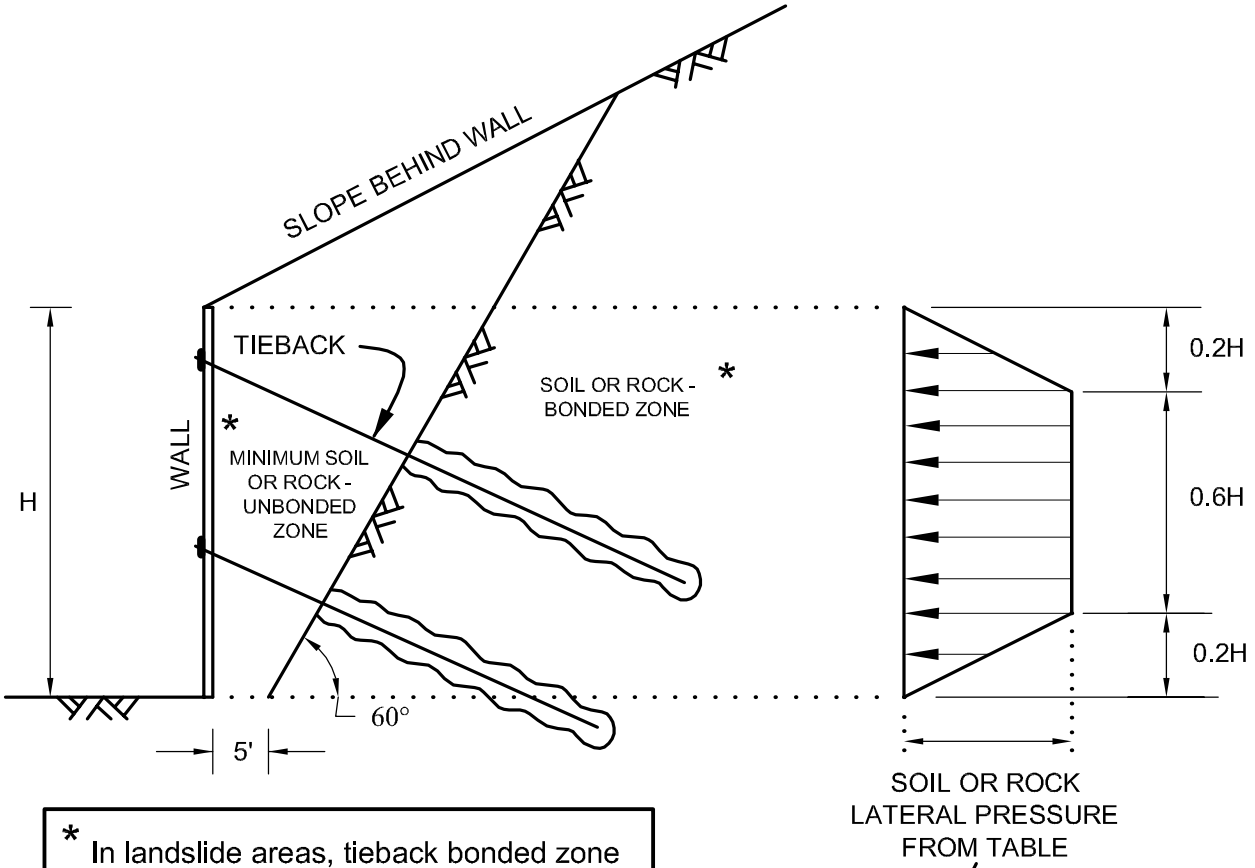
HELIOS

Section E - E'

WLA William Lettis & Associates, Inc. | Figure 12

Modified 12.08.08

1930.01 Alternate Helios Tower



* In landslide areas, tieback bonded zone should be entirely within in-place bedrock

SLOPE BEHIND WALL	LATERAL PRESSURE (psf for wall height in feet)
LEVEL	25H
3:1	28H
2:1	33H

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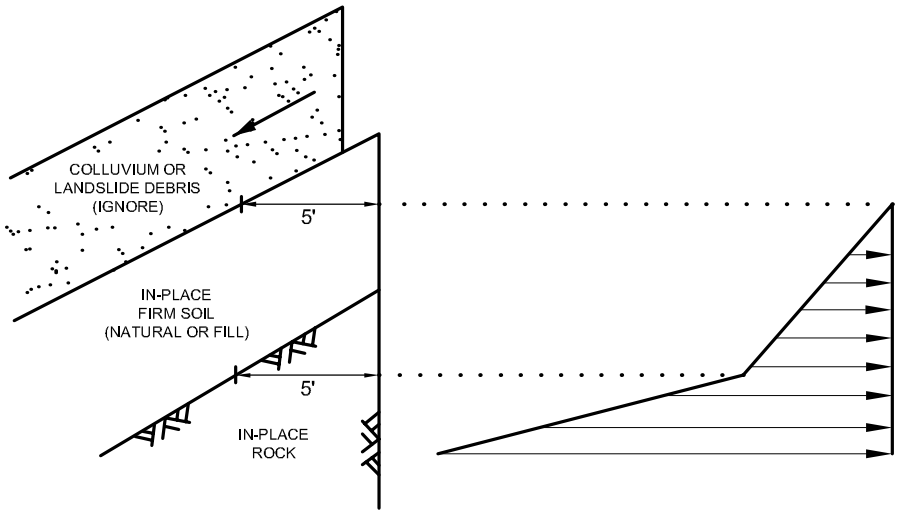
Geotechnical Consultants

STATIC LATERAL PRESSURES ON TIEBACK WALLS

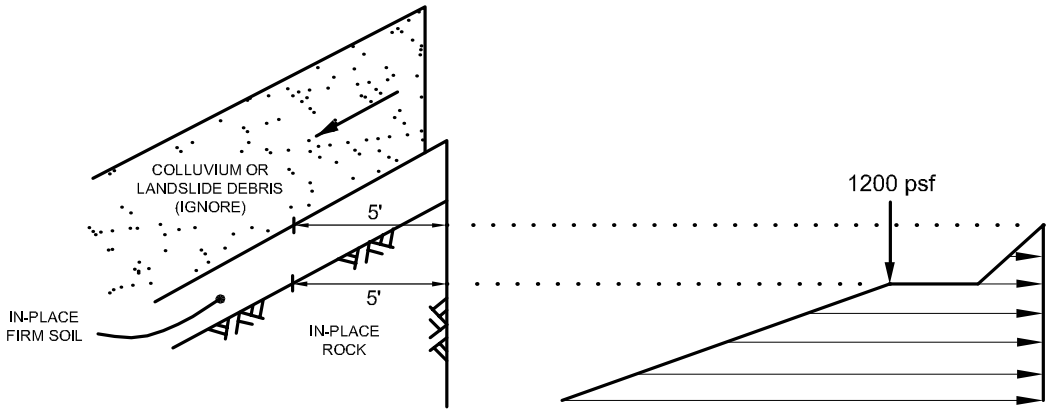
HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	FIGURE 13
2500-4	December 2008	

IN-PLACE FIRM SOIL (MORE THAN 4' THICK)



IN-PLACE FIRM SOIL (LESS THAN 4' THICK)



PASSIVE RESISTANCE VALUES FOR FIRM IN-PLACE SOIL AND ROCK:

SOIL: 300 psf per foot of depth

ROCK: 450 psf per foot of depth; 1,200 psf minimum at rock surface

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

RETAINING WALL
PASSIVE PRESSURE DIAGRAMS

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	FIGURE **14**
2500-4	**December 2008**	

APPENDIX A
BORING LOGS FROM THIS INVESTIGATION

Drilled Boring Table

Soil and Rock Classification Keys to Borings AKA-1 through AKA-18
AKA-1 through AKA-18 Exploratory Boring Logs

Soil and Rock Classification Keys to Borings AKA-19 through AKA-28
AKA-19 through AKA-28 Exploratory Boring Logs

Soil and Rock Classification Keys to Borings AKA 29, AKA 29A, AKA 30, AKA 31 and AKA 32A
AKA 29, AKA 29A, AKA 30, AKA 31 and AKA 32A Exploratory Boring Logs

Soil and Rock Classification Keys to Borings AKA 32 through AKA 44
AKA-32 through AKA-44 Exploratory Boring Logs

DRILLED BORING TABLE

Boring Number	Date	Drill Days	Ground Elevation (feet)	Datum	Depth	Ground water Depth (ft)	Drilling Company	Drilling Type	Sampling Types				
									SPT	Mod Cal	"Pitcher" Tube	Shelby Tube	Rock Core
AKA-1	9/18/2007	2	790	LBNL	77	-	Pitcher	RW		x	x		
AKA-2	9/12/2007	3	735	LBNL	105	19	Pitcher	RW		x	x	x	x
AKA-3	9/17/2007	1	720	LBNL	48	-	Pitcher	RW		x	x	x	
AKA-4	9/20/2007	1	777	LBNL	62	-	Pitcher	RW		x	x	x	
AKA-5	10/3/2007	1	710	LBNL	41.5	-	Pitcher	RW	x	x	x		
AKA-6	10/3/2007	1	714	LBNL	37	-	Pitcher	RW	x	x	x		
AKA-7	10/4/2007	1	730	LBNL	53.1	-	Pitcher	RW	x	x	x		
AKA-8	10/4/2007	2	737	LBNL	71.5	-	Pitcher	RW	x	x	x		x
AKA-9	10/4/2007	1	693	LBNL	32.5	-	Pitcher	RW	x	x	x		
AKA-10	10/8/2007	1	724	LBNL	35.5	-	Pitcher	RW	x	x			
AKA-11	10/8/2007	1	721	LBNL	29.3	-	Pitcher	RW	x	x	x		
AKA-12	10/9/2007	1	713	LBNL	50.5	-	Pitcher	RW	x	x	x		
AKA-13	10/9/2007	2	707	LBNL	50	-	Pitcher	RW	x	x	x		
AKA-14	10/10/2007	1	707	LBNL	45	-	Pitcher	RW	x	x	x		
AKA-15	10/15/2007	1	663	LBNL	13	-	Pitcher	RW	x				
AKA-16	10/12/2007	4	674	LBNL	74.4	-	Pitcher	RW	x	x			
AKA-17	10/10/2007	2	786	LBNL	65	-	Pitcher	RW	x	x	x	x	
AKA-18	10/11/2007	2	719	LBNL	55.5	-	Pitcher	RW	x				
AKA-19	5/5/2008	1	734	LBNL	27.5	None*	Access	SFA (MM)	x	x			
AKA-20	5/5/2008	1	733.5	LBNL	17.5	None*	Access	SFA (MM)	x				
AKA-21	5/6/2008	1	741.5	LBNL	9	None*	Access	SFA (MM)	x	x			
AKA-22	5/6/2008	1	748.5	LBNL	12	None*	Access	SFA (MM)	x				
AKA-23	5/7/2008	1	751	LBNL	15	None*	Access	SFA (MM)	x	x			
AKA-24	5/8/2008	1	755	LBNL	30	None	Access	SFA (MM)	x	x			
AKA-25	7/3/2008	1	743	LBNL	103.7	-	Pitcher	RW	x	x			x
AKA-26	6/30/2008	2	741	LBNL	100.3	-	Pitcher	RW	x	x			
AKA-27	7/1/2008	2	739	LBNL	105.2	-	Pitcher	RW	x	x			x
AKA-28	6/30/2008	1	734	LBNL	90.9	-	Pitcher	RW	x	x			
AKA-29	10/30/2008	1	694.1	LBNL	28.7	-	Access	SFA (MM)	x				
AKA-29A	11/10/2008	1	694.1	LBNL	50	-	Gregg	HSA		x			x
AKA-30	11/7/2008	1	729.7	LBNL	50	-	Gregg	HSA		x			x

DRILLED BORING TABLE

Boring Number	Date	Drill Days	Ground Elevation (feet)	Datum	Depth	Ground water Depth (ft)	Drilling Company	Drilling Type	Sampling Types				
									SPT	Mod Cal	"Pitcher" Tube	Shelby Tube	Rock Core
AKA-31	11/3/2008	2	675.8	LBNL	90	-	Pitcher	HSA					x
AKA-32	10/31/2008	1	694	LBNL	60.9	-	Pitcher	RW	x	x			
AKA-32A	11/4/2008	2	716.4	LBNL	50	-	Pitcher	HSA					x
AKA-33	11/15/2008	1	674	LBNL	55	-	Gregg	RW			x	x	x
AKA-34	11/5/2008	1	653	LBNL	32.3	-	Pitcher	RW	x		x	x	x
AKA-35	11/6/2008	1	719	LBNL	66.5	-	Pitcher	RW	x	x		x	
AKA-36	10/29/2008	1	693	LBNL	30	21	Access	SFA (MM)	x	x			
AKA-37	10/28/2008	1	703	LBNL	24.5	None	Access	SFA (MM)	x	x			
AKA-38	10/27/2008	1	704	LBNL	27.5	22	Access	SFA (MM)	x	x			
AKA-39	11/5/2008	1	657	LBNL	10.5	None	Access	SFA (MM)	x	x			
AKA-40	11/6/2008	1	648	LBNL	11	None	Access	SFA (MM)	x	x			
AKA-41	11/6/2008	1	644	LBNL	22.8	None	Access	SFA (MM)	x	x			
AKA-42	11/6/2008	1	652	LBNL	11.2	None	Access	SFA (MM)	x	x			
AKA-43	11/7/2008	1	653	LBNL	10.8	None	Access	SFA (MM)	x	x			
AKA-44	11/7/2008	1	679	LBNL	11.3	None	Access	SFA (MM)	x	x			

General Notes:

1) Drilling Types: RW=Rotary Wash, HSA=Hollow Stem Auger, SFA (MM)=Solid Flight Auger (Minuteman Rig)
2) Sample types: SPT=Standard Penetration Test sampler, Mod Cal=Modified California Sampler
3) LBNL datum denotes Lawrence Berkeley National Laboratory Datum

Groundwater Notes

1) Groundwater depths were measured during or immediately after drilling except where noted below
2) Where "*" is shown the borings were left open for 1 to 3 days before measurement
3) Where "none" is shown, no groundwater was noticed prior to grouting
4) Where "-" is shown, groundwater levels were not measured

SOIL AND ROCK CLASSIFICATION KEYS TO BORINGS AKA-1 THROUGH AKA-18

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS (More than 50% of material is LARGER than No. 200 sieve size)	GRAVELS (More than 50% of coarse fraction is LARGER than the No. 4 sieve size)	CLEAN GRAVELS (Little or no fines)	GW	Well graded gravels, gravel - sand mixtures, little or no fines.
			GP	Poorly graded gravels or grave - sand mixtures, little or no fines.
		GRAVELS WITH FINES (Appreciable amount of fines)	GM	Silty gravels, gravel - sand - silt mixtures.
			GC	Clayey gravels, gravel - sand - clay mixtures.
	SANDS (More than 50% of coarse fraction is SMALLER than the No. 4 Sieve Size)	CLEAN SANDS (Little or no fines)	SW	Well graded sands, gravelly sands, little or no fines.
			SP	Poorly graded sands or gravelly sands, little or no fines.
		SANDS WITH FINES (Appreciable amount of fines)	SM	Silty sands, sand - silt mixtures
			SC	Clayey sands, sand - clay mixtures.
FINE GRAINED SOILS (More than 50% of material is SMALLER than No. 200 sieve size)	SILTS AND CLAYS (Liquid limit LESS than 50)		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts and with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silty clays of low plasticity.
	SILTS AND CLAYS (Liquid limit GREATER than 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS			PT	Peat and other highly organic soils.

BOUNDARY CLASSIFICATIONS: Soils possessing characteristics of two groups are designated by combinations of group symbols.

SILT OR CLAY	SAND			GRAVEL		Cobbles	Boulders
	Fine	Medium	Coarse	Fine	Coarse		

No.200 No.40 No.10 No.4 3/4" 3" 12"

U.S. STANDARD SIEVE SIZE

References: ASTM D 2487-00, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Soil Classification System)
ASTM D 2488-00, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

Water Level Measured in Boring

	GROUP SYMBOLS	TYPICAL NAMES
SAMPLE TYPE	SPT	Split Spoon Sample
	MC	Modified California Sampler
	UD	Undisturbed Sample
	P	Pitcher Sample
	S	Shelby Tube

Inidcates Samples removed for lab tests

ABBREVIATIONS

NA - Not Applicable, LL - Liquid Limit, PI - Plasticity Index, T Shear - Drained Torsional Ring Shear Secant Phi value.

Correlation of Penetration Resistance with Relative Density and Consistency

SAND & GRAVEL		SILT & CLAY	
No. of Blows	Relative Density	No. of Blows	Consistency
< 4	Very Loose	< 2	Very Soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium Dense	4 - 8	Medium Stiff
30 - 50	Dense	8 - 15	Stiff
> 50	Very Dense	15 - 30	Very Stiff
		> 30	Hard

Datum Reference Information	Horizontal - State Plane NAD 83
	Elevation - LBNL Datum, CA Zone III

KEY TO SYMBOLS AND DESCRIPTIONS FOR SOIL LOGS

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1) Color descriptors in Lithology Section - Color code for soil and rock (e.g. 5YR 5/8) is based on Munsell Soil Color Chart (1994) designations

GENERAL NOTES FOR SOIL AND ROCK LOGS

References: Brown, E. T. (1981) Rock characterization testing and monitoring ISRM suggested methods
Hoek, E. and Brown, E. T. (1997) Practical estimates of rock mass strength
ASTM 6032-02, Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core

ROCK STRENGTH (abbreviation)

EXTREMELY WEAK (R0) - Can be indented with difficulty by thumbnail. May be friable or moldable with finger pressure.

VERY WEAK (R1) - Crumbles under firm blows with point of hammer. Can be pealed by a knife.

WEAK (R2) - Can be pealed or scraped by a knife with difficulty. Cannot be scratched by fingernail. Shallow indentation made by firm blow of hammer.

MEDIUM STRONG (R3) - Cannot be scraped or picked with a knife.

STRONG (R4) - More than one blow of geologic hammer required to fracture specimen.

VERY STRONG (R5) - Specimen requires many hard blows of hammer to fracture or chip.

Modified from Brown (1981), Hock (1997)

ROCK SYMBOLS AND NAMES

ROCK		SANDSTONE
		SILTSTONE
		SHALE

DEFINITIONS

RQD = The sum of the length of intact and sound rock pieces over 100 mm in length divided by the total length of the core run, multiplied by 100% (ASTM D 6032-02)

Datum Reference Information	Horizontal - State Plane NAD 83
	Elevation - LBNL Datum, CA Zone III

KEY TO SYMBOLS AND DESCRIPTIONS FOR ROCK LOGS

WLA William Lettis & Associates, Inc. / AKA

1930, Proposed Helios Alternative Fuels Research Facility

AKA-1 THROUGH AKA-18 EXPLORATORY BORING LOGS

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-01**	
Type and Diameter of Boring Auger / Mud Auger / 5"	Boring Location: CA State Plane (Zone III) N 6058599.432 E 2146053.783		Total Depth 77 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 790 LBNL (feet)	Ground Water Depth 77 feet	Depth to Bedrock 21'
Sampling Method MC & Pitcher	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 37	Date Started 9/18/07
	Borehole Inclination 90	Logged by K. Krug	Date Completed 9/19/07

Reviewed by / Date K. Krug/J. Baldwin 10/5/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0									FILL	ASPHALT and FILL: CLAY, Very dark grayish brown (10YR)		790
1		MC 1	4 8 12	18/18					CL	Gravelly CLAY with sand, (CL), mottled colors, very dark grayish brown (10YR 3/2) to yellowish brown (10YR 5/6), damp to dry, stiff, low plasticity, 10% angular gravels concentrated near top, 0.5" - 1.2" diameter, 5-10% sand. Contact indicated by mottled blues and tans at high angles.		789
2									CL	Two Base Colors: 1) greyish brown (10YR 5/2), 2) S.S. clasts lighten to yellow Color		788
3		MC 2	13 23 20	18/18					CL	CLAY with sandstone gravel, (CL), light olive brown (2.5 YR 5/4), dry, stiff, medium to fine grained and intermixed with 10-15 % clay, gravels are sub angular (non-local origin?) 10-30%, heavily weathered/oxidized. Chert nodules at 5.5', clay grades to dark red brown.		787
4		MC 3	15 21 17	18/18								786
5												785
6		MC 4	12 20 24	18/18							Box 1/Box 2	784
7		MC 5	10 13 10	18/18					SP	Grades into "pure Sand", (SP), pockets of clay at 8.4', olive yellow (2.5YR 4/6).		783
8											Damp- Potential Water table	782
9		MC 6	4 6 9	12/18					SP	SAND with Gravel and Clay, (SP), as above, 20-50% subrounded gravels, 0.5" - 1.2" diameter, clast lithologies include shale, chert, quartz, and rhyolite.	Swtiched to Mud Rot. Drilling	781
10		P 7	150 psi	21.6/30					SP	Same as above with increase in sand grain size medium to large, poor sorting. Organics present at 12'. Oxidized.	Box 2/Box 3	780
11												779
12												778
13		P 8	250 psi	21.6/30					CL	Sandy CLAY with Gravel, (CL), olive brown (2.5YR 4/3), wet to damp, 10 - 40% clay, poor to moderate sorting. Reduced.		777
14										Large 0.1' x 0.2' shale clasts - subrounded		776
15												775

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-01

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15												775
									CL	Little to no gravel, fining of gravels.		
16		P 9	400 psi	22.8/30					CL	CLAY with Sand and Gravel, dark greenish gray (GLEY 1 4/5G), damp to wet, moderate to well sorting, stiff to hard, low plasticity, 10-20% sand, 5-10% gravel, 0.1" to 0.5" diameter. (COLLUVIUM)		774
17										SILT/SANDSTONE (Orinda), Blue-Green, Dry, Hard, very fine grained, well sorted and rounded, massive. (TOP OF WEATHERED ROCK)	Box 3/Box 4	773
18		P 10	450 psi	15.6/24								772
19												771
20										Calcite crystals present (19.8'). Composition grading into pure Claystone.		770
21		P 11	450 psi	21.6/30						Bedding defined by coloration sub-horizontal to 40 deg. Red (2.5YR 5/6) and Olive brown (2.5YR 4/3). Becomes paler: light reddish grey (2.5YR 6/3)		769
22										Top of Competent Rock	Box 4/Box 5	768
23		P 12	250 psi	30/30						CLAYSTONE, mottled coloration dominantly greenish grey (Gley 1 4/5G), bands of olive brown (2.5YR 4/6) and red (2.5YR 5/6), damp to dry, low to medium plasticity, extremely weak (R0), massive, very tight. Soft zones with calcite present No Shear		767
24										Grades to Red		766
25										Zones of high angle coloration contacts. (between red and olive brown)		765
26		P 13	300 psi	24/30						25.9' Red over Blue		764
27										Red dominate coloration changes to blue. Pales with depth. Reduced	Box 5/Box 6	763
28		P 14	250 psi	30/30						CLAYSTONE, dark reddish brown (5YR 3/2, blue interlayering, calcite rich lenses follow colored planes at med-high angles. Oxidized. 27.2' Contact marked by 5 mm thick clay seam, 3 to 6" of crushed and fractured rock above and below contact. [possible Qls?]		762
29												761
30												760

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

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1930

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SOIL LOG - Boring No. AKA-01

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30		P 15	300 psi	25.2/30						CLAYSTONE, dark reddish brown (5YR 3/2), 0.1 - .01' thick layers of colors: olive brown (2.5YR 4/3), blebs of greenish grey (Gley 1 4/5), dry-damp, friable, low plasticity, extremely weak (R0), bedding defined by colors dipping 40 degrees, subangular contacts. Pales and hardens at end of sample. [Orinda] *(Continued from previous page)*		760
31												759
32		P 16	300 psi	24/24						Multiple colors appear as small pockets ~0.1' - .01' in diameter. Structure becomes Blocky-massive. Heavily fractured with non-contiguous randomly oriented polished fractured surfaces. Red colors brighten. Oxidized.	Box 6/Box 7	758
33												757
34		P 17	400 psi	18/30						70 degree sharp color & composition contact. CLAYSTONE w/ cobbles, greenish grey (Gley1 4/5), dry, extremely weak (R0), cobbles 5-20% shales-well rounded, 0.1'-.01' diameter, 5- 20% calcite clasts/crystals, mixed in with clay in .001-.1' pockets. Reduced [Orinda]		756
35												755
36		P 18	400 psi	18/30						no more cobbles	Box 7/Box 8	754
37												753
38												752
39		P 19	400 psi	24/24						39.5' - 41' Softening-Clay rich zone. Grey, no clear orientation of clay. [potential Qls?]	Run 19 warped pitcher barrel	751
40												750
41		P 20	250 psi	28.8/30						becomes grey CLAYSTONE, some fractures, hard, very competent, bedding massive. Reduced	Box 8/Box 9	749
42												748
43										43'- Joint, dips 65 degrees, smooth to polished continuous surface.		747
44		P 21	250 psi	30/30								746
45												745

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Standard Penetration Test (SPT) sampler

Project Name and Job Number
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1930

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SOIL LOG - Boring No. AKA-01

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45										Grades to CLAYSTONE, Dark reddish brown (5YR 3/2), Dry, Thin lamellae bedding defined by coloration, extremely weak (R0). Oxidized [Orinda]		745
46										Colors mixed as thin .01-.001' thick sub-horizontal layers, greenish grey (Gley1 4/5) intermixed.	Box 9/Box 10	744
47		P 22	250 psi	22.8/24						47' - 70 degree dipping weak zone		743
48										30-70 degree dipping color contacts. New color dominate: light brownish grey (10YR 6/2). Intermixed with dark reddish brown (5YR 3/2) and greenish Grey (Gley1 4/5)	Driller notes fluid loss	742
49		P 23	300 psi	21.6/18						49' - dark reddish grey clay seam, hard-stiff, dry-moist. [Potential old clay gouge zone?]	Box 10/Box 11	741
50												740
51		P 24	250 psi	21.6/30						Calcite rich high angle layers (Most common in green colored layers), 70 degree dipping coloration bands		739
52												738
53		P 25	250 psi	32.4/30								737
54										Green coloration dominant		736
55										Calcite stringers. Prominent calcite crystals along steep dipping to veridical fractures that separate claystone of green to brownish-but no clay seam. Fractures widely spaced; not bedding, based on similarity of material texture across fractures.	Box 11/Box 12	735
56		P 26	150 psi	20.4/30								734
57										Calcite becomes more prominent, increase in crystal size		733
58		P 27	.250 psi	13.2/24						70 degree dipping contact: color change to red		732
59										Green coloration only	Run 28 stuck in pitcher barrel	731
60												730

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SOIL LOG - Boring No. AKA-01

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
60		P 28	300 psi	7.2/30						Green coloration only *(Continued from previous page)*		730
61										CLAYSTONE, heavily weathered/broken up, two intermixed colors, dark reddish brown (5YR 3/2), greenish grey (Gley1 4/5G), bedding distorted, some reaction to HCl, high angle coloration contacts dip 40-60 degrees		729
62		P 29	150 psi	18/18								728
63		P 30	180 psi	14.4/18							Box 12/Box 13	727
64										Red becomes dominant color, patches of green present accompanied by calcite, marked by high angle contacts (80 degree dip)		726
65		P 31	200 psi	14.4/18						Addition of new color: greyish brown (10YR 5/2)		725
66										Green becomes dominant color, layering of colors .01-.001' thick sub-horizontal		724
67		P 32	180 psi	26.4/24						Heavily fractured CLAYSTONE, minor clay seams? Discontinuous. Single color CLAYSTONE, grey (Gley1 5/N), blocky and competent rock, clay rich.		723
68		P 33	400 psi	12/18						Back to previous, weak to medium strong (R2 to R3) shale-like rock	Box 13/Box 14	722
69										High angle contact: Bedding joint, smooth, tight, polished, dipping 70 degrees, grey color below.		721
70		P 34	150 psi	25.2/24						CLAYSTONE, Greyish Brown (10YR 5/2), very competent, Calcite stringers present.		720
71										CLAYSTONE, Mixed; Greenish Grey (Gley1 4/5G), dark reddish brown (5YR 3/2), bedding, dips 40 degrees, .001-.05' thick banding (Like runs 23-24). Contact is a linear 70 degree dipping feature lined with red clay.		719
72		P 35	150 psi	24/24						Linear high angle features with polished surfaces. Calcite dispersed throughout at .001-.005' diameter pockets.		718
73										Red "stain"		717
74		P 36	180 psi	19.2/18						CLAYSTONE, dark reddish brown, competent w/ laminations, Hard. 74.8' - Bedding joint, stepped, tight	Box 14/Box 15	716
75												715

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SOIL LOG - Boring No. AKA-01

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
75										CLAYSTONE, dark reddish brown, competent w/ laminations, Hard. *(Continued from previous page)* Bedding clearly defined		715
76		P 37	180 psi	18/24								714
77										Boring Terminated at 77 ft. Total Depth 77 ft. Groundwater encountered at 77 ft.	Fluid uplfow encountered during Downhole Geophysics	713
78												712
79												711
80												710
81												709
82												708
83												707
84												706
85												705
86												704
87												703
88												702
89												701
90												700

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Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-02**	
Type and Diameter of Boring Mud Auger / 5"	Boring Location: CA State Plane (Zone III) N 6058431.394 E 2145321.809		Total Depth 105 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 735 LBNL (feet)	Ground Water Depth 19 feet	Depth to Bedrock ~64-70.
Sampling Method MC/ Pitcher/ HQ core	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 29	Date Started 9/12/07
	Borehole Inclination 86	Logged by K. Krug	Date Completed 9/14/07

Reviewed by / Date K. Krug/J. Baldwin 10/5/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0												735
1		MC 1	14 8 6	18/18					FILL	CLAY with gravel, (CL), red, damp, soft, medium plasticity, Clasts.1-.05' ~20% local and non-local (Non-Orinda Clasts). [Fill]		734
2												733
3		MC 2	5 7 7	15.6/18					FILL	Color change: Green- more Orinda Fm. clasts, ~40%, angular, fresh. [FILL]		732
4		MC 3	7 5 6	18/18						Green brightens in color		731
5												730
6		MC 4	11 8 11	19.2/18						sandy CLAY with gravel, (CL), damp, soft, medium plasticity, sand is medium grained, well rounded and sorted, ~20%, clasts, ~5% 0.1"x 0.1" weathered sandstone. [Native Soil]	Box 1/ Box 2	729
										CLAY with gravel, brown, damp, soft, ~30% pea-size gravels		
7										CLAY with sand lenses, few clasts, brown-light brown, damp, medium plasticity, clay is blackish with lenses of yellowish, fine grained brown sand around weathered, subrounded clasts of fine grained sandstone, quartz-rich, 10% Sandstone mixed colors, greenish and light brown. [Native Soil]		728
8		P 5	? psi	7.2/30					No Sample			727
9												726
10		P 6	200 psi	30/30					CH	CLAY with gravel, (CH), very dark grey (10YR 3/1), damp, soft, medium to high plasticity, trace sand, ~5%, coarse, intermixed, 10% clasts, .01x.01' in size [COLLUVIUM]	Fining upwards sequence (from~18'-10.5')	725
11												724
12		P 7	170 psi	30/30						Gradational color change to very dark greyish brown (10YR 3/2) [Potential buried soil horizon A-B]	Box 2/ Box 3	723
13												722
14												721
15												

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SOIL LOG - Boring No. AKA-02

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15												720
16		P 8	300 psi	30/30					CL	CLAY with gravel and sand, (CL), brown (10YR 4/3), damp, soft, medium plasticity, ~10-15% gravels, .01x .01', multicolored, weathered, intermixed yellowish brown (10YR 5/4) sandstone clasts [Colluvium - Qc1]	Fining upwards sequence.	719
17												718
18											Box 3/ Box 4	717
19		P 9	260 psi	30/30					CL ▽	Color change to reddish/oxidized tone, gravels increase to 20% [Colluvium - Qc2]		716
20										20' - 20.5' - Faint soil horizon? [Colluvium - Qc2?]		715
21		P 10	400 psi	30/30								714
22												713
23										CLAYSTONE cobbles w/ sand, olive (5Y 5/3), defined non-linear, "wavy" bedding with interbedded brown clays. (Cobble sheared?)	Box 4/ Box 5	712
24		P 11	200 psi	22.8/30					CL	CLAY with gravel and sand, (CL), brown (10YR 4/3), damp, very soft, medium plasticity, ~30% gravels, like Run 8 [Colluvium Qc2] 24' - Fine charcoal/Organics present		711
25												710
26												709
27		P 12	200 psi	27.6/30					Cobbles	26.6' - Thin clay seam, reddish brown, hard to stiff, separates Light Yellow Qc from Dark Yellow Qc below. Highly weathered cobbles/clasts of sandstone to siltstone, yellowish brown (2.5YR 6/4) to light olive brown [possible soil horizon?]		708
28										CLAY with gravel and sand, (CL), brown (10YR 4/3), Disseminated Charcoals rare and fine, similar to Run 11 [Colluvium - Qc3]	Box 5/ Box 6	707
29		P 13	200 psi	27.6/30					CL			706
30												

Undisturbed sample
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
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1930

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SOIL LOG - Boring No. AKA-02

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30												705
31		P 14	150 psi	27.6/30					CL	CLAY with sand and gravel, (CL), dark brown (10YR 3/3), damp, stiff, medium plasticity, 0.01' x 0.01' gravels, sandstone clasts and large angular volcanics (Moraga Basalt) at 31.4' and 32.2' [Colluvium - Qc3]		704
32												703
33		P 15	150 psi	27.6/30					CL	CLAY with gravel and sand, (CL), very dark grey (Gley1 3/N), massive, with intermixed sand weathered from sandstone/siltstone clasts, greenish grey (Gley 1 4/5G), ~.001' x .01', evenly dispersed, 15-20% clasts. [Colluvium - Qc4]	Box 6/ Box 7	702
34											Fining upwards sequence.	701
35												700
36		P 16	250 psi	24/30						36'-36.2' - large Moraga volcanic clast		699
37												698
38		P 17	250 psi	27.6/30						Cobbles (Possible slough) quartz, sandstone, and basalt	Box 7/ Box 8	697
39												696
40												695
41		P 18	100 psi	27.6/30						SANDSTONE to SILTSTONE Cobbles, weathered, layered colors indicate bedding. [Colluvium - Qc5]		694
42									CL	CLAY with gravel and sand, grey As Previous		693
43		P 19	100 psi	27.6/30					CL	CLAY with sand and gravel, (CL), dark reddish brown (5YR 3/3) matrix, damp, medium plasticity, soft, sand clasts are greenish grey (Gley1 5/5G), 0.01' x 0.01', weathered to sand as small blebs/clasts, oxidized [Colluvium - Qc6]	Box 8/ Box 9	692
44												691
45												

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Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-02

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45												690
46		P 20	150 psi	24/30					CL	CLAY with sand, (CL), dark greenish grey (Gley 1 4/10GY), damp, soft, medium to low plasticity, massive, reduced, with sand from weathered sandstone [Colluvium - Qc6]		689
47										CLAYSTONE/Sandstone Cobble, brownish yellow (10YR 6/6), mixed - 50% sand, 10-30% rip ups or clasts.		688
48		P 21	200 psi	21.6/30					CL	CLAY with sand and gravel, (CL), greenish grey (Gley 1 5/5GY), mottled with dark reddish brown (5YR 3/3), damp, soft, medium to low plasticity, clasts of fine grained greyish green sandstone, heavily weathered, pockets of yellowish brown sands, layering of colors. [Colluvium - Qc7]	Box 9/ Box 10	687
49												686
50												685
51		P 22	150 psi	27.6/30					CL	Clasts change to basalt (Moraga), 0.1x 0.1' in size, angular and fresh	Full water recovery	684
52												683
53										Sandstone clasts	Box 10/ Box 11	682
54		P 23	150 psi	8.4/30						Change in Clay Matrix color: Olive Grey (5Y 4/2).		681
55										54' - 55.5' - NO SAMPLE - poor recovery		680
56		P 24	220 psi	24/30					CL	CLAY with gravel and sand, (CL), dark olive grey (5Y 3/2), damp, soft, med to low plasticity, sandstone clasts 0.01 x 0.01' in size, weathered to sand, greenish grey (Gley1 5/5G), disseminated though out (Same As Run 15-17 33-40.5' bgs)		679
57												678
58										58' - 58.4' - soft grey clay with little to no clasts, diffuse to gradational contact		677
59		P 25	270 psi	24/30								676
60												

Undisturbed sample
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Project Name and Job Number
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SOIL LOG - Boring No. AKA-02

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
60												675
61		P 26	300 psi	18/30					CL	CLAY with gravel and sand, (CL), dark greyish brown (10YR 4/2), stiff, mottled colors in layers, multicolored gravels, sand intermixed as rinds around sandstone clasts, thin discolored bands of "redder" clay. potential shear indicated by banding 61' - 62.8' - large sandstone clasts, olive (5Y 5/5), fine grained, well sorted.	Box 11/ Box 12	674
62												673
63		P 27	? psi	18/30	T Shear =27. LL=38. PI= 15.		●		CL	Very distinct laminated clay, wet, soft, with colluvium overlying. Abrupt contact [Qls Basal Plane]	63-67' Zone of crushed seam rich rock.	672
64										TOP OF WEATHERED ROCK: SILTSTONE to SANDSTONE, greenish grey (Gley1 5/5G), fine grained, well sorted, moderately weathered.	64-71' Weathered rock	671
65												670
66		P 28	200 psi	19.2/24						65.5' - 66' broken up sandstone SILTSTONE to SANDSTONE, greenish grey (Gley1 5/5G), damp, very weak, moderately weathered, no jointing or discernable bedding 67' - clay seam between brownish colluvium and weathered rock		669
67												668
68		P 29	175 psi	16.8/18						sandy SILTSTONE with clay and gravel, dark greyish brown (10YR 4/2), soft to stiff, clasts of sandstone .01'-0.1', weathered to sand, greenish grey (Gley1 5/5G), clay discontinuous.	Box 12/ Box 13	667
69		P 30	500 psi	22.8/24						69' -69.5' - Broken up Sandstone SAND/CLAYSTONE, Greenish Grey (Gley1 5/5G), Damp, loosely consolidated, weak-very weak, moder. Weathered, no jointing or discernable bedding. Reacts w/ HCl. Fine grained and well sorted. Thin Clay seam 0.5' thick, sub-hoiz. AT 70.5'		666
70												665
71		P 31	600 psi	18/18						TOP OF COMPETENT ROCK		664
72												663
73		P 32	200 psi	18/18						Fracture planes at 10 deg and grades into higher angle (40 deg) fracture planes. Bedding visible-subhorizontal	Box 13/ Box 14	662
74												661
75		P	300	24						Sandstone, stronger (R0-R1), heavily broken up, calcite coated. Sandstone slightly "dirty" greywacke?		

Undisturbed sample
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Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-02

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
75		33	psi	24						SANDSTONE, greywacke, greenish grey (Gley1 5/5G), fine grained, well sorted, extremely to very weak (R0-R1), no discernable bedding, fractures at high angles and coated with calcite. Broken into gravel pieces. 76' - Clay coating	Fluid Loss (75.5' bgs)	660
76											Box 14/ Box 15	659
77		P 34	200 psi	28.8/30						SANDSTONE, greenish grey (Gley1 5/5G), damp, very weathered, extremely weathered, loosely cemented, massive. Color-defined high angle bedding. Contains clay rich seams.	Collapse of Boring Hole (77' bgs)	658
78												657
79		P 35	300 psi	18/18						Returns to Greywacke- broken into gravels.		656
80										CLAYSTONE, very dark grey (Gley1 3/n), thin layered color changes, no reaction to HCl, stiff, dry, breaks along horizontal planes. 70.8'-80.2' possible clay/crushed zone		655
81		P 36	400 psi	2.4/24						SANDSTONE, greywacke, veined with calcite stringers		654
82										LOST TO DRILLING- NO SAMPLE	Box 15/ Box 16- Change to New Auger bit.	653
83										CLAYSTONE, layers of colors: reddish grey (5YR 5/2), pale yellow (5Y 8/3), greenish grey (Gley1 5/5G), very stiff, dry, extremely weak to very weak (R0-R1), no reaction to HCl, structural layers with different colors - 0.001'-0.1' thick, subhorizontal, some potential dewatering structures.		652
84		P 37	500 psi	22.8/24								651
85												650
86		P 38	400 psi	19.2/24						grey dominate color (Gley1 5/N), replaces greenish color in distinct bands, non-contiguous through core, very weak (R1). 86' - Red 86.5' - All colors mixed		649
87											Box 16/ Box 17	648
88		P 39	400 psi	24/24						Only Grey color remains, extremely weak (R0), Subhorizantal bedding visible Weak layer .1' thick at high angles		647
89										Returns to CLAYSTONE, w/ oxide patina on broken surfaces, rock breaks at stepped right angles, very weak (R1)		646
90		P 40	600 psi	24/15.6						extremely weak (R0)		

Undisturbed sample
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-02

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
90										very weak		645
		P 41	600 psi	14.4/14.4						SANDSTONE, greywacke, weak (R2), thin planar or bedding dips 45 degrees, broken up with calcite coating on fracture surfaces.	Box 17/ Box 18	
91												644
92		P 42	400 psi	24/24						CLAYSTONE, grey (Gley1 5/N), extremely weak (R0), dry, massive, fine layering of blebs and stringers.		643
93												642
94		P 43	400 psi	18/18						AT 94' BGS; Breaks along 45 deg angled (like runs 37-38 single color like 39)	Box 18/ Box 19	641
95										gradual change, rock becomes friable with laminations defined by blebs/rip up clast, subhorizantal, disturbed, very weak (R1)		640
96		P 44	500 psi	18/30						95.5' - bedding break, dips 5 degrees, stepped, tight to open 96.3' - bedding break, dips 10 degrees, steeped, rough		639
97												638
98		P 45	? psi	15.6/24						97.5' - 98' - heavily fractured zone, not displaced. extremely weak, broken along bedding, dips 70 degrees, planar, oxidized, healed very weak (R1), heavily crushed due to drilling	Box 19/ Box 20	637
99												636
100		P 46	600 psi	20.4/18								635
101										100.6' - Abrupt contact contact marked a bedding joint, dipping 45 degrees, smooth, tight, calcite coated SANDSTONE, greywacke? broken up, bluish grey (Gley2 5/5B), crystalline, calcareous - reacts to HCl, bedding defined and offset/healed, weak (R2), 70 degree dip on calcite healed fractures	Box 20/ Box 21-Swicthed to HQ	634
102												633
103												632
104												631
105												

Undisturbed sample
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Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**ROCK LOG - Boring No. AKA-02**	
Type and Diameter of Boring HQ	Boring Location: CA State Plane (Zone III) N 6058431.394 E 2145321.809		Total Depth 105 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 735 LBNL (feet)	Ground Water Depth 19 feet	Depth to Bedrock. ~64-70'.
Casing Size and Depth	Length of Core Barrel and Bit	No. of Core Boxes 21	Date Started 9/12/07
	Borehole Inclination 86	Logged by K. Krug	Date Completed 9/14/07

Reviewed by / Date K. Krug/J. Baldwin 10/5/07

Reviewed by / Date

Depth (feet)	Lithology	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Lithology	Remarks	Elevation (feet)
101									Box 20/ Box 21-Swicthed to HQ	634
102								GRAVEL with clay, wet, poorly sorted, composed of sub-angular clasts of shale and claystone, and sandstone (rock crumbled due to drilling pressure).		633
103		47	2.2/3.5	63				CLAYSTONE, grey (Gley1 5/N), dry, friable, extremely weak (R0), grades to very weak (R1) at bottom of sample, weathered, finely bedded-subhorizantal layers, fractures along 15 to 45 degree dipping stepped planes with polished non-contiguous surfaces w/ patina (Like run 39), sharp contact.		632
104										631
105								Boring Terminated at 105 ft. b.g.s. Total Depth 105 ft. Groundwater encountered at 19 ft.		630
106										629
107										628
108										627
109										626
110										625
111										624
112										623
113										622
114										621
115										620
116										

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-03**	
Type and Diameter of Boring Auger / 5"	Boring Location: CA State Plane (Zone III) N 6058485.622 E 2145692.265		Total Depth 48 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 720 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock .~28'
Sampling Method MC/ Shelby/ Pitcher	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 24	Date Started 9/17/07
	Borehole Inclination 90	Logged by K. Krug	Date Completed 9/17/07

Reviewed by / Date K. Krug/J. Baldwin 10/5/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0												720
1		MC 1	14A 16B 16C	18/18						CLAY w/ Sand and Gravel, (CL), Olive Brown (2.5Y 4/3), Dry, Very Stiff, Low Plasticity, Fine Grained sand mixed w/ Clay ~5-10%, Gravels- Angular-rounded pea gravel range 20-40% 0.1-0.01' diameter clasts volcanics? [FILL]		719
2												718
3		MC 2	6A 6B 7C	18/18					CH	CLAY w/ trace Gravel and Sand, (CH), Very Dark Greyish Brown (2.5YR 3/2), Damp, Stiff, Med-High plasticity, 5% sand & Gravel intermixed. Sub-horizontal bedding .01' Alt. brown and black colors. [SOIL HORIZON]		717
4												716
5		S 3	250 psi	21.6/30								715
6												714
7		S 4	300 psi	30/30					CH	CLAY w/ Sand and Gravel, (CH), Dark Reddish Grey (5YR 4/2), Damp, Stiff, Med.-High Plasticity, 10-15% Gravels .01-.01\5' diameter clasts Shale and Tan Sandstone, well sorted and equally distributed, rare fine organics/charcoal disseminated [Colluvium]	Box 1/ Box 2	713
8												712
9		S 5	400 psi	16.8/24						No more charcoal.		711
10												710
11		P 6	400 psi	31.2/30							Box 2/ Box 3	709
12												708
13									CH	Gradual Color and Composition change: Increase in Sand content 15-20% well mixed, color: Dark Greyish Brown (10YR 4/2). 13.5-14' oxidized Sandstone clasts		707
14		P 7	400 psi	24/24								706
15												705

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-03

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15											Good water return	705
										Almost pure sandstone.	Box 3/ Box 4	
16		P 8	450 psi	19.2/24								704
17									CH	Color change and increase in Gravel content: Brown (10YR 4/3), Gravels 25% clast size increases dominantly sandstone and some volcanics and Qtz. Clasts. [Colluvium]		703
18		P 9	400 psi	12/12								702
									CH	Sandstone and Chert Clasts, Olive (5Y 4/4), Damp	Box 4/ Box 5	
19		P 10	400 psi	30/30					CL	Back to Previous, Olive Brown (2.5YR 4/4), 15%-20% sand, clasts		701
20									CL	Abrupt Color Change: CLAY, with sand and Gravel, (CL), Olive Brown (2.5YR 4/3), Damp, Stiff, Low Plasticity, 30% Clasts, 0.1 to 0.1' maximum size, gravel composed of Qtz, chert, sandstone, shale, subangular to subrounded, slightly weathered, oxidized sandy pockets occur around sandstone clasts [Colluvium - Qc]		700
21		P 11	450 psi	22.8/24								699
22												698
23		P 12	400 psi	14.4/14.4							Box 5/ Box 6	697
									CL	Interlayered contact: Sandy CLAY w/ Gravels Brown (10YR 4/3), Light pink and green gravels [Colluvium - Qc]		696
24									CL	Volc. Clasts (Brown/Olive 30-40% clasts)		
25		P 13	150 psi	19.2/27.6					CL	sandy CLAY, (CL), layered colors ~.1' thick subhorizantal, Yellowish Brown (10YR 5/6), Pale Olive (5Y 6/3), Oxidized or dark red stains around clasts, white sand pockets disturb layers. [Colluvium - Qc]		695
26										Clay rich zone 27' BGS: BJ, 70deg., SM, Clay lined, Tl, Slicks.		694
27		P 14	325 psi	19.2/24						TOP OF WEATHERED ROCK: SANDSTONE in Clay Olive Brown (2.5YR 4/4), Broken up in angular clay coated clasts.		693
28										SANDSTONE, light yellowish brown (2.5YR 6/4), bedded, MnO staining		692
29		P 15	450 psi	18/18						CLAYSTONE, heavily weathered/oxidized. Fractured and broken up at right angles w/ smoothed patina on surfaces.	Box 6/ Box 7	691
										Unoxidized: Very Dark Grey (2.5YR 3/1) weathered rind Clay rich mix of brown and olive brown At 29.7' -		
30												690

Undisturbed sample
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-03

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30										Volcanic Clast (R3) crystalline rock/cobble (29.7-30' bgs).		690
31		P 16	300 psi	30/30						SILTSTONE Olive Grey (5Y 4/2), Weak-Friable, Massive-no distinct bedding. Smoothed vitreous surfaces non-contiguous. Presence of sand, rare. Calcite rich lenses present.		689
32										Chert clast at 32'		688
											Box 7/ Box 8	
33		P 17	300 psi	21.6/24							Drill notes shale oil in run 17.	687
34										Oxidized clay rich lenses (34-34.5' bgs)		686
35		P 18	300 psi	24/24						Same As run 16- Gravely in appearance due to broken up rock. Clay present, Dark Grey (5Y 4/1). Darkens and strengthens at transition below.		685
36										Competent lenses of CLAYSTONE, blocky pieces, Vitreous coating. Dark greenish Grey (Gley1 4/5GY), Massive		684
37		P 19	300 psi	30/30						CLAYSTONE/ Clay, Very Dark Greenish Grey (Gley1 3/10Y), Darker from above, Clay-rich and weak. Large Calcite nodule at 36.7' Soft zone at 37.5'		683
38										Heavily weathered to Clay, Colors mottled (Patina?)		682
39										Calcite present, Layering (Similar to Run 35 78' in AKA-02)	Box 8/ Box 9	681
40		P 20	300 psi	27.6/30						Blocky structure, coated in calcite. Coloration increases in variance, calcite on surfaces.		680
41										AT 41' BGS: HOLE COLLAPSES -RUN 21 FILLED WITH SLUFF.	Good water return until 41'-Driller notes fluid loss and collapse of Boring Hole.	679
42		P 21	325 psi	9.6/24						Rusty layer, returns to Clay/SILTSTONE, Dark Grey (Gley1 4/N)		678
43												677
44		P 22	300 psi	15.6/18								676
45												675

Undisturbed sample
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Driven (2.5 to 3.0 inch) with liners
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Project Name and Job Number
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SOIL LOG - Boring No. AKA-03

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45											Box 9/ Box 10	675
46		P 23	325 psi	19.2/24						SILTSTONE, Very Dark Grey (10YR 3/1), Damp, Clay/Rock, Friable/very weak, blocky-no bedding structure.	poor water return since 41'	674
47		P 24	400 psi	12/12						46.8' - Sharp 70 deg color contact: Lightens to dark Grey (Gley1 4/N), Large calcite nodules present (.1x .2')		673
48										Termination of Boring at 48 ft.		672
49										Total Depth 48 ft. Hole grouted upon completion		671
50												670
51												669
52												668
53												667
54												666
55												665
56												664
57												663
58												662
59												661
60												660

Undisturbed sample
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Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-04**	
Type and Diameter of Boring Auger / Mud Auger / 5"	Boring Location: CA State Plane (Zone III) N 6058530.812 E 2145855.674		Total Depth 62 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 770 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~39.5.
Sampling Method MC/SHELBY/ Pitcher	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 29	Date Started 9/20/07
	Borehole Inclination 90	Logged by K. Krug	Date Completed 9/20/07

Reviewed by / Date K. Krug/J. Baldwin 10/5/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0									GM	Gravel and Loose Soil, Very Dark Greyish Brown (2.5YR 3/2).		770
1												769
2		MC 1 a-c	n/a	18/18					CL	CLAY w/ Sand and Gravels, (CL), Very Dark Greyish Brown (2.5YR 3/2), Damp, low plasticity, stiff, charcoal present, poorly sorted, sandstone clasts very weathered 10-15%. [Fill]		768
3		MC 2a-c	n/a	18/18						2.9' - 3.1' - Pocket of lighter color: Dark Greyish Brown (10YR 4/2).		767
4									CL	CLAY, sandy with gravel, (CL), very Dark Grey (2.5YR 3/1), Dry, Loose. [Fill]		766
5		MC 3 a-c	n/a	14.4/18					CL	Returns to Previous [Fill]		765
6									CL	CLAY W/ Sand and Gravel, Brown (7.5YR 4/3),Clasts increase to 20-40%- Sand rich-sandier composition color variable, sandstone: Olive (5Y 5/4), Dry, Crumbles, Clay Matrix. [Fill?] Pocket/lenses of Pure Sandy Silt, Olive (5Y 5/3), .2' thick	Box 1/ Box 2	764
7		S 4	250 psi	10.8/30					CL	Color Change: CLAY, Black (5Y 2.5/1) (Buried Soil beneath Fill)		763
8									SW	SAND, (SW), Light Grey (5Y 7/2), Fine grained, well sorted and rounded, no cementation, dry, loose.	AT 8' bgs: switched to Mud Rotary.	762
9		S 5	325 psi	18/30					CL-CH	CLAY, (CL-CH), Black (5Y 2.5/5), Damp, Stiff, Med-High Plasticity. (Buried Soil #2)		761
10												760
11		S 6	200 psi	21.6/30					CL	Addition of Gravels (Volcanic Moraga clasts)		759
12									CL	CLAY with Gravel, (CH), Dark Greyish Brown (10Y 4/2), Damp, Stiff, Low- Med plasticity, Gravels 10%, well dispersed .001-.005' diameter basalt and Sandstone clasts. Dominate color returns to Black (5Y 2.5/2).		758
13											Box 2/ Box 3	757
14		S 7	300 psi	20.4/30						Large diameter Volcanic Clasts present 0.5" to 1" diameter.		756
15												755

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-04

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15									CH	CLAY with Gravel, (CH), Black (5Y 2/1), Damp, Stiff, Med-High Plasticity, gravels-Volcanics, angular 0.1-.05' in diameter, composed of sandstone and volcanic 15%.		755
16		S 8	300 psi	18/30					CL	Color Change: CLAY with gravel, (CH), Yellowish Brown (10YR 5/4), Damp-Wet, Stiff, Med-High Plasticity, gravels-Volcanics, angular 0.1-.05' in diameter.		754
17												753
18									CH			752
19		S 9	350 psi	16.8/30						Colors alternate: sandy CLAY with Gravel, (CL), Dark Greyish Brown (10YR 4/2), Damp, Low Plasticity, Stiff, 15-20% Gravels- weathered sandstone and volcanic clast 0.1-0.05' diameter, sands concentrated around clasts, sub angular. Slight bedding visible with color variants, subhorizantal.		751
20												750
21		P 10	300 psi	24/24					CL	Color Change & Increase in clasts: Brown (10YR 4/3), gravel composed of Qtz, Volc., and Sandstone subangluar-20-25%		749
22												748
23		P 11	320 psi	26.4/24					CL		Box 3/ Box 4	747
24												746
25		P 12	180 psi	24/24						26.2-26.5' Sandy/Silty layer of Yellowish Brown (10YR 5/4). AT 27- 27.9' BGS: Higher sand content		745
26									SP-SM		Box 4/ Box 5	744
27		P 13	180 psi	12/24								743
28										becomes sandier, increasing along with gravels (25-30%)	Sampel 13 bent pitcher barrell	742
29		P 14	200 psi	12/12								741
30		Undisturbed sample SH = Shelby; P = Pitcher; O = other										

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-04

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30		P 15	300 psi	18/18					CL	CLAY w/ Sand and Gravel, Yellowish Brown (10YR 5/4), Damp, Low Plasticity, 35-40% Gravels-weathered sandstone, volcanic and qtz sub angular clasts, .01-.001' diameter, in layers or "chunks", bedding defined by color. Sand ~10-20%.	Box 5/ Box 6	740
31		P 16	200 psi	15.6/24					CL	Color Change: CLAY w/ Sand and Gravel, Brown (10YR 4/3)		739
32									SP	32-32.4' Sandy/Silty pockets, Yellowish Brown (10YR 5/4).		738
33		P 17	200 psi	24/24						33-34' Softer-Damp and Moist.		737
34										34-35' More gravel rich		736
35		P 18	200 psi	24/24						Less Gravels Present (10-20%)	Box 6/ Box 7	735
36									CL	Sharp Contact at 36'-Very Thin Dark Red Brown, Clay seam at contact: Mixed in Qc below		734
37									CL	Qc mixed in with above, some fine Lammella Qc/Siltstone [COLLUVIUM - Qc].		733
38		P 19	150 psi	24/24						TOP OF ROCK: SAND/SILTSTONE, Pale Olive (5Y 6/4), Damp, Soft, Fine grained, well rounded, well sorted, charcoal present, no discernable gravels, no cementation, bedding-Massive? Iron stains present. (Orinda Fm)		732
39		P 20	200 psi	18/18							Box 7/ Box 8	731
40										Color Change (gradual Over .2'): SILTSTONE, Greenish Grey (Gley1 5/5BG), Damp, Soft, No Plasticity, Massive-no Bedding, 40 deg. Linear "hairline" structures present. Very Competent, few fractures, tight and annealed, Very clean undeformed Siltstone to Very Fine sand. [Orinda Fm]		730
41		P 21	200 psi	20.4/24								729
42												728
43		P 22	250 psi	20.4/24								727
44										Color Change (43.5-44.5'): No faulting or seams, Contact on sharp high angle contact- Yellowish Brown (10YR 5/4).		726
45											Box 8/ Box 9	725

Undisturbed sample
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Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-04

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45		P 23	200 psi	20.4/30						44.5' - 46' SILTSTONE, yellowish brown (10YR 5/4), dry to damp, massive		725
46										Gradational Color Change : Light Grey (5Y 7/2), marked by Horizontal .001' thick clay seam.		724
47		P 24	200 psi	28.8/30						oxidation along subverticle Fractures (competent rock)		723
48												722
49										Iron stain in "Bulls eye" pattern	Box 9/ Box 10	721
50		P 25	450 psi	28.8/30						Color Change: SILTSTONE, greenish Grey (Gley2 5/5BG), Dry-Damp, Weak, almost unconsolidated, no cementation, bedding not discernable/massive (Competent Rock)		720
51												719
52		P 26	300 psi	18/30								718
53										53.1'-53.5' - Clay Rich Band at 65 deg, "Soft"		717
54										54'-57.5' Matrix contains darker clay rich and calcite rich zones	Box 10/ Box 11	716
55		P 27	200 psi	21.6/30						55'-56' bgs: Calcite rich zone.		715
56												714
57		P 28	200 psi	24/30						57'-57.6' bgs: heavily fractuted zone.		713
58												712
59										59' - Calcite rich zone, dips 40 deg.		711
60										Calcite rich to end of boring	Box 11/ Box 12	710

Undisturbed sample
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Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-04

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
60		P 29	200 psi	26.4/30						SILTSTONE, greenish Grey (Gley2 5/5BG), Dry-Damp, Weak, almost unconsolidated, no cementation, bedding not discernable/massive 60-70 angled bedding? Coated with clay .001' thick Clay layers (no offset visible)		710
61												709
62										Boring terminated at 62 ft. Total Depth 62 ft. Hole grouted upon completion		708
63												707
64												706
65												705
66												704
67												703
68												702
69												701
70												700
71												699
72												698
73												697
74												696
75												695

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-05**	
Type and Diameter of Boring Bucket Auger / Mud Rotary / 6" to 4 7/8"	Boring Location: CA State Plane (Zone III) N 2145550.632 E 6058608.967		Total Depth 41.5 feet
Drilling Contractor and Rig Pitcher Drilling / Fraste Multidrill XL (Track)	Elevation and Datum 710 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~18.5'.
Sampling Method MC & SPT & PITCHER	Sample Driving Hammer/Drop 140 lb. Auto / 30 inches	No. of Samples 10	Date Started 10/3/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/3/07

Reviewed by / Date J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0											Start Augering to 1'	710
1		MC 1 a-c	14 15 17	16.5/18	9.2%	115.1			ML	SILT, with gravel, (ML), brown (10YR 4/3), very stiff, dry, with light greenish gray fine to medium gravels, occasionally yellowish brown, siltstone to fine sandstone [Colluvium]		709
2												708
3											mud tub set up after first Mod. Cal. sample	707
4												706
5											Drilling picked up between 5' and 5.5'	705
6		MC 2 a-c	9 13 18	12/18	17.3%	115.1			CL	CLAY, silty, with gravel, (CL), dark yellowish brown (10YR 3/4), moist, stiff, medium to high plasticity and toughness, greenish gray and yellowish brown gravels of siltstone up to 1" diameter [Colluvium]	Bottom liner empty	704
7											Good water circulation, 100% return	703
8												702
9											Easy drilling to 9 ft. slight chatter 10'-11'	701
10												700
11		MC 3 a-c	12 17 14	12/18					CL	Same as previous, clasts become smaller, 1/4" generally, sparse 1" clasts		699
12												698
13												697
14											Rig chatter at 15', 2" layer	696
15												695

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-05

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15										CLAY, silty, with gravel, (CL), dark yellowish brown (10YR 3/4), moist, stiff, medium to high plasticity and toughness, greenish gray and yellowish brown gravels of siltstone 1/4" generally, sparse 1" clasts		695
16		MC 4 a-c	9 15 16	12/18	16.8%	112.8	LL:36 PI: 18		CL	CLAY, gravelly, (CL), brown (10YR 4/3), moist, very stiff, abundant greenish gray and yellowish brown siltstone fine gravel, also dark greenish gray claystone clasts ~1/2" in size [Colluvium]		694
17												693
18												692
19		MC 5 a-c	12 25 43	15/18						TOP OF WEATHERED ROCK CLAYSTONE, dark yellowish brown (10YR 4/6) to dark gray (10YR 4/1), heavily weathered, extremely to very weak (R0-R1), no HCL reaction, occasional clayey lenses, predominantly heavily fractured to brecciated rock w/silty to clayey matrix, greenish gray clay planar partings 0.1" to 0.2" thick appear between 19.5' and 20'. [Great Valley Claystone]	Water loss at 18.5' From 18.5' to 19' really smooth drilling 18.5' = Top of Weathered Rock	691
20												690
21												689
22											Similiar drilling, hardend up at 23'	688
23												687
24		SPT 6	47 50/4"	7.5/10						CLAYSTONE, like above however more intact/competent with oxidized fractures, very weak (R1), friable, sparse matrix, massive rock	SPT at 24' to get back to 5 foot intervals	686
25												685
26												684
27												683
28												682
29			500 to 700							CLAYSTONE, like above, very dark gray (N3), heavily weathered to brown (7.5YR 5/4), contains vertical fracture/brecciated zone, oxidized and weathered 30' - 65 degree dipping 0.2" thick, heavily weathered and oxidized fracture zone		681
30												680

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-05

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30		P 7	psi 500	26.4/30						TOP OF WEATHERED ROCK *(Continued from previous page)* CLAYSTONE, very dark gray (N3), heavily weathered to brown (7.5YR 5/4), more competent rock, fracture defined, fractures are oxidized and weathered 30.7' - 31.5' rock returns to weakened/friable and heavily fractured to blocky with clay coatings Split spoon contains same material		680
31												679
32		SPT 8	700 psi 22 37 50/5.5"	12/17.5								678
33											steady drilling 100% water return	677
34												676
35												675
36										color change - approximate		674
37												673
38		P 9	500 to 700 psi	25.2/30						CLAYSTONE, very dark gray (N3) to black (N2.5), fresh to slightly weathered, very weak to weak (R1-R2), massive, conchoidal fractures with polished surfaces and slicks, black occasionally white. 38.6' - planar fracture along bedding, slightly rough to rough, with calcite coating, dipping 45 degrees 39.4' - wavy to stepped fracture, polished/slicks, smooth, dipping 60 degrees below 39.5' - competent rock, fewer fractures Split spoon at 40.5' contains same material		672
39												671
40												670
41		SPT 10	33 50/5.5"	6/11.5								669
42										Boring Terminated at 41.5' Hole grouted upon completion		668
43												667
44												666
45												665

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-06**	
Type and Diameter of Boring Bucket Auger / Mud Rotary / 6" to 4 7/8"	Boring Location: CA State Plane (Zone III) N 2145634.353 E 6058561.741		Total Depth 37 feet
Drilling Contractor and Rig Pitcher Drilling / Fraste Multidrill XL (Track)	Elevation and Datum 714 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~12'.
Sampling Method MC & SPT & PITCHER	Sample Driving Hammer/Drop 140 lb. Auto / 30 inches	No. of Samples 10	Date Started 10/3/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/3/07

Reviewed by / Date J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0									ML	SILT, with gravel, (ML), to GRAVEL, with silt, (GM); dark grayish brown (10YR 4/2), dry to damp, hard, gravel up to 1", low plasticity and toughness, high dilantency, pieces of glass, brick [FILL]	Auger to 1', gravelly, slight rig chatter	714
1		MC 1 a-c	27 23 9	18/18	14.5%	94.4						713
2												712
3									CH	CLAY, with trace gravel, (CH), yellowish brown (10YR 5/6), damp to moist, medium stiff, medium to high plasticity and toughness, no dilantancy, massive, sparse gravel ~5%, <1/4" in size, trace sand	Drillers set up mud tub after 1st Mod Cal sample	711
4											return water murky strong brown to dark gray 100% water return steady drilling	710
5												709
6		MC 2 a-c	7 10 13	12/18	23.9%	100.5			CH	CLAY, (CH), yellowish brown (10YR 5/6) to dark yellowish brown (10YR 3/6), moist, very stiff, trace fine sand, sparse coarse-grained sand At 7', appearance of fine gravel-sized, heavily weathered, very dark gray (N3) claystone clasts, ~5%		708
7												707
8												706
9												705
10												704
11		MC 3 a-c	5 7 14	11/18						CLAY, same as above, increase in amount of claystone clasts to ~10%, increase in size of clasts as well TOP OF WEATHERED ROCK CLAYSTONE, dark yellowish brown (10YR 3/6), heavily weathered, broken up, material similar to AKA-5, hard siltstone/claystone fragments at the tip of sampler at 12.5'		703
12												702
13												701
14											some drill chatter	700
15												699

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-06

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15										CLAYSTONE, dark yellowish brown (10YR 3/6), heavily weathered, broken up, material similar to AKA-5		699
16		SPT 4	7 14 23	14/18						SILTSTONE, very dark brown (7.5YR 3/2) to black (N2.5), heavily weathered, weak (R2), heavily fractured to brecciated, with clayey matrix 17' - gravelly silty clay, dark yellowish brown (10YR 4/8), low to medium toughness and plasticity, gravel is up to 1/2" composed of heavily weathered siltstone with a sandy texture	water level in hole dropped after SPT sampling	698
17												697
18												696
19											drill chatter in last 2.5' (18.5'-21')	695
20												694
21		P 5	1400 psi	18/24						SILTSTONE, like above but sandy, 10-16% coarse to medium sand, heavily weathered in a silty clay matrix, ~35-45% matrix, sub-horizontal Mn/Org. staining		693
22										CLAYSTONE, dark gray (10YR 4/1), moderately to heavily weathered, oxidized fractures and oxide staining on fracture planes, tight, healed fractures, mostly low angle to sub-horizontal, upper contact is erosional, sharp, dipping 15 degrees. 22.7' - fracture, stepped to planar, smooth, clay & MnO coated/healed, dipping at 45 degrees	Driller got only 2' down before tube got bent up	692
23		SPT 6	29 50/5"	7/11						Split spoon contains more massive to sparsely laminated claystone, with subvertical fractures		691
24												690
25												689
26										color change significantly less weathered rock	consistent drilling	688
27												687
28												686
29		P 7	700 1400 psi	14.4/18						CLAYSTONE, dark bluish gray (GLEY2 5/1), fresh to slightly weathered, extremely to very weak (R0-R1), massive to sparse subhorizontal bedding, moderately fractured, oxidized fracture planes.		685
30												684

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-06

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30										CLAYSTONE, dark bluish gray (GLEY2 5/1), fresh to slightly weathered, extremely to very weak (R0-R1), massive to sparse subhorizontal bedding, moderately fractured, oxidized fracture planes.		684
		SPT 8	50/5"	5/5						Split spoon contains same material		
31												683
32												682
33											Rig chatter at 33 ft.	681
34										very dark gray (N3) claystone/shale, with subhorizontal laminations		680
35		P 9	2000 psi	14.4/18						SILTSTONE, greenish gray (GLEY1 5/1), fresh to slightly weathered, very weak (R1), subhorizontal bedding, some laminations of claystone	Sample fractured upon handling	679
36		SPT 10	19 29 50/5"	11/17						34.4' - fracture, planar, smooth, tight bedding break dipping 30 degrees Split spoon contains same material		678
37										Boring terminated at 37 ft. Total Depth 37 ft. Grouted upon completion.		677
38												676
39												675
40												674
41												673
42												672
43												671
44												670
45												669

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-07**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA State Plane (Zone III) N 6058652.97581 E 2145574.02654		Total Depth 53.1 feet
Drilling Contractor and Rig Pitcher Drilling / Fraste Multidrill XL (track)	Elevation and Datum 730 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~29'.
Sampling Method MC & SPT & Pitcher	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 14	Date Started 10/4/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/4/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0												730
1		MC 1 a-c	10 13 16	15/18	11%	105.6			CH	CLAY, gravelly, (CH), dark grayish brown (10YR 4/2), dry, very stiff to hard, ~35% gravel, up to 1/2", trace silt, med to high toughness and plasticity [Fill]		729
2									CH	CLAY, gravelly, very dark grayish brown (10YR 3/2), damp, hard, with greenish gray and brownish yellow (GLEY1 5/1 and 10YR 6/8), siltstone-sandstone gravels up to 1/4" [Fill]		728
3												727
4												726
5											gray return water due to polymer	725
6		MC 2 a-c	8 10 16	12/18			LL: 31 PI: 14		CH	CLAY, sandy, with gravel, (CH), mottled, very dark grayish brown (10YR 3/2), greenish gray (GLEY1 6/1), brownish yellow (10YR 6/8), damp to moist, very stiff to hard, sand in poorly to moderately indurated lenses, lenses become larger with depth [Fill?]		724
7												723
8												722
9												721
10												720
11		MC 3 a-c	11 16 21	15/18	14.5%	116.6			CH	CLAY, sandy, with gravel, (CH), similar to previous sample, gravels are larger, rounded to subrouded, some oxidation in clay, generally sandier, large sand lens at 12' [Fill?]		719
12												718
13												717
14												716
15												715

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-07

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15										CLAY, sandy, with gravel, (CH), similar to previous sample, gravels are larger, rounded to subrouded, some oxidation in clay, generally sandier [Fill?]		715
16												714
	X	MC 4 a-c	10 15 22	17/18					SC	Becomes primarily sand, light yellowish brown (2.5Y 6/4), sparse grayish brown clay and greenish gray sand.		
17									CH	Returns to sandy clay with gravel, some woody debris, siltstone and claystone clasts [Colluvium/Fill?]		713
18											dark brown return water	712
19												711
20												710
21									CH	CLAY, gravelly, with sand, (CH), very dark grayish brown (10YR 3/2), moist, very stiff, ~35% siltstone and claystone fine gravels, pockets of fine sand [Colluvium/Fill?]		709
	X	MC 5 a-c	10 12 15	12/18	19.4%	106.6						
22												708
23												707
24												706
25												705
26									CH	CLAY, with gravel, trace sand, (CH), very dark grayish brown (10YR 3/2), moist, medium stiff to very stiff, sparse greenish gray siltstone clasts, some woody debris. [Colluvium - Qc?]		704
	X	MC 6 a-c	5 7 10	12/18			LL:53 PI: 37					
27									CH	CLAY, sandy, dark grayish brown (10YR 4/2), very stiff, ~30% brownish yellow to yellowish brown sand. [Colluvium - Qc]		703
28											water loss at around 28' to 29' after cleaning out sample interval, stiffer drilling below 29'	702
29										TOP OF ROCK- Heavily weathered bedrock - saprolite		701
30												700

Undisturbed sample
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Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-07

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30												700
31		SPT 7	13 22 25	11/18						CLAYSTONE, dark yellowish brown (10YR 4/6), heavily to completely weathered, extremely weak (R0), highly fractured rock, some sandy pockets, locally more competent rock ~1" thick lenses, rock fragments have oxide staining on faces, no dominant or pervasive clay seams or shears		699
32												698
33											Steady, stiff drilling	697
34												696
35												695
36		SPT 8	26 45 45	12/18						CLAYSTONE, similiar to previous, color change to black to dark brown, crushed and fractured, with subvertical seamy fractures, no gouge, stained dark yellowish brown to dark brown, root material at ~36.6',		694
37												693
38												692
39												691
40										CLAYSTONE, brown (10YR 5/3 to 4/3), moderately weathered, very weak (R1), faint subhorizontal bedding to massive, contains a series of relic/healed anastomosing fractures and crushed zones, occasional clay lined fractures, locally reduced	steady drilling, 100% water return	690
41		P 9	700 - 1400 psi	18/18						41.7' - fracture, planar to stepped, healed, tight with clay.		689
42										Below 42.2' - CLAYSTONE, dark greenish gray, fresh, containts relict/healed fractures with oxidized surfaces, contact is sharp, conformable, and dipping 40 degrees	Contact between "rusted" / oxidized rock and greenish gray "fresh" rock	688
43		SPT 10	47 50/4.5"	7/10.5								687
44												686
45												685

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-07

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45												685
46		P 11	700 - 2000 psi	13.2/13.2						CLAYSTONE, very dark gray (N3), fresh to slightly weathered, very weak (R1), massive to laminated, laminations are gently dipping, zone of slightly fractured material dipping 40 degrees in top 0.5', fractures are wavy to planar, smooth, and contain calcite/polished surfaces, locally carbonate crystals (1.4" in diameter) within claystone along bedding planes when broken open, some oxidation on fracture planes	Pitcher pushed only 1.1' before refusal	684
47												683
48		SPT 12	18 26 40	11/18								682
49											steady, consistent drilling, no water loss, dark gray return water	681
50												680
51		P 13	700 - 1500 psi	15.6/15.6						CLAYSTONE, like above, sparse bedding, sparse pebbly oxidized lenses of silty material, healed and tight fractures (70 degree dipping, 40 degree dipping) with oxidation on fracture planes, mechanical fracture at base of sample due to bent tube, overall tight coherent rock	pitcher refusal at 1.3'	679
52												678
53		SPT 14	41 50/4"	7/10								677
54										Boring terminated at 53.1 ft. Total Depth 53.1 ft. Hole grouted upon completion		676
55												7675
56												674
57												673
58												672
59												671
60												670

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-08**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA State Plane (Zone III) 5' from AKA-2 N 6058438.38634 E 2145806.29966		Total Depth 71.5 feet
Drilling Contractor and Rig Pitcher Drilling / Fraste Multidrill XL (track)	Elevation and Datum 737 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~64.3'.
Sampling Method MC / SPT / Shelby & Pitcher Tube	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 22	Date Started 10/4/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/5/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0												737
1		MC 1 a-c	5 7 7	14/18					GM	GRAVEL, silty, dark grayish brown (10YR 4/2), dry medium dense, up to 3/4", 25% silt [FILL]		736
2									CH	CLAY, gravelly, (CH), dark grayish brown (10YR 4/2), damp to moist, stiff, ~25% to 30%, gravel, up to 1/2" in size, greenish gray siltstone, very dark grayish brown claystone, angular gravels, medium toughness and plasticity, no to slow dilantency [FILL]	mud tub set up after first sample	735
3									SW-SC	SAND, with clay, (SW-SC), mottled, olive yellow (2.5Y 6/8), greenish gray (GLEY2 5/1), fine sand, clay like at 1.5' [FILL]		734
4											lots of rig chatter	733
5												732
6		MC 2 a-c	6 9 9	13/18	33.1%	89.7	LL:76 PI: 51		CH	CLAY, (CH), very dark gray to black (10YR 3/1 to 2/1), moist, stiff, massive, with occasional yellowish brown silty inclusions ~0.1" in diameter [COLLUVIUM]		731
7												730
8												729
9												728
10												727
11		MC 3 a-c	5 7 9	15/18	25.5%	101.5			CH	CLAY, (CH), very dark gray to black (10YR 3/1 to 2/1), moist, stiff, massive, sparse gravel, up to 1", generally 0.2", grades to very dark grayish brown (10YR 3/2) clay with trace gravel, roughly 5% medium gravels to coarse sand	hole isn't holding water, driller cases it	726
12												725
13												724
14												723
15												722

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-08

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15										CLAY, (CH), very dark grayish brown (10YR 3/2), moist, stiff, massive, trace gravel, roughly 5% medium gravels to coarse sand		722
16									CH	CLAY, with sand, (CH), brown to dark yellowish brown (10YR 4/3 to 4/4), moist, stiff to very stiff, high toughness and plasticity, fine to medium sand, ocassionally coarse, some organic material, claystone fragments		721
	X	MC 4 a-c	8 11 14	17/18	● 24.1%	101.7 ●						
17												720
18												719
19											drilling slowed at 20'	718
20												717
21									CH	CLAY, sandy, (CH), brown (10YR 4/3), with light greenish gray sand lenses, some yellowish brown, clay becomres strong brown at 21.5' with greenish gray silty partings, bottom of sample is sandy clay with gravel, light olive brown, angular claystone gravels up to 0.3"		716
	X	MC 5 a-c	12 23 39	12/18	● 19.7%	111.8 ●						
22												715
											slight water loss at 22.5'	
23												714
24											drilling stiffened up below 24'	713
25												712
26									CH	CLAY, sandy, (CH), brown (10YR 4/3), moist very stiff, lenses of fine sand, generally medium to coarse sand		711
	X	MC 6 a-c	11 18 23	14/18	● 17.4%	116. ●						
27									CH	CLAY, gravelly, (CH), mottled, yellowish brown and reddish brown, gravels are quartz, claystone, sparse siltstone, subrounded to angular gravels		710
28											rocky zone between 28' and 30'	709
29												708
30												707

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-08

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30									CH	CLAY, gravelly, (CH), mottled, yellowish brown and reddish brown, gravels are quartz, claystone, sparse siltstone, subrounded to angular gravels		707
31											rocky at 32'	706
32		P 7	500 psi	7/12					CH	CLAY, sandy, with gravel, (CH), dark gray to very dark gray (2.5Y 4/1 to 3/1), moist, stiff, greenish gray siltstone clasts ~0.3", fine sand, large cobbles at 32', very dark gray, subangular claystone, Moraga basalt in sluff at top of sample	pushed pitcher 32' to 33', stopped at a hard spot, could not get further	705
33											rig chatter at 33', 2" to 3" thick gravelly zone	704
34												703
35												702
36		SPT 8	11 15 16	17/18					CH	CLAY, gravelly, (CH), dark gray to very dark gray (2.5Y 4/1 to 3/1), moist, stiff, greenish gray siltstone clasts ~0.3", 37' - gravelly zone, 1" thick		701
37												700
38												699
39												698
40												697
41		SPT 9	17 18 12	13/18					CH	CLAY, same as above, gravelly zone between 41.5' and 41.8', pebbles and cobbles, some oxidation, trace sand, bottom of sample contains oxidized, gently dipping 0.3" thick zones of same material		696
42											Rig bouncing at 42.5', drilling through SPT sample zone	695
43												694
										New Colluviual Package		
44		P 10	450 psi	10/12					CH	CLAY, gravelly, (CH), moist, soft to medium stiff, large pebbles to cobbles, some siltstone, mottled greenish gray with occasional oxidation and pockets of yellowish brown clay, some basalt clasts, semi bedded, clay partings at high angles		693
45												692

Undisturbed sample
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-08

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45									CH	CLAY, sandy, with gravel, (CH), mottled, greenish gray to light olive brown (GLEY1 5/1 to 2.5Y 5/4), moist, medium stiff to stiff, thin to medium bedding, subhorizontal, gravels up to 1/4", siltstones and claystones.		692
46		P 11	400 psi	21.6/24						46' - light olive bedding 0.3' thick, dipping 37 degrees		691
47										Below 46.5' - finer gravel and greenish gray colored layers		690
48												689
49												688
50									CH	50' - 4" dark gray to dark olive gray (5Y 4/1 to 3/2) clay with red clay seams [buried AB horizon + weathered Qc] CLAY, sandy, with gravel, (CH), light olive brown like above, (2.5Y 5/2), contains larger gravels, apparent medium bedding.		687
51		SPT 12	12 15 18	18/18							some chatter through SPT zone	686
52												685
53											dark brown water return	684
54											cuttings are mostly dark gray claystone with some yellowish brown clay	683
55									GP	Aphanitic, black, basaltic boulder from 55' to 56', contains high angle incipient to healed fractures	lots of chatter around 55', rig jumping	682
56										Washed out, see remarks	Rig drilled only a few inches in 15+ minutes, basaltic angular cuttings with some black clay, switched to HQ to drill through boulder	681
57		HQ 13		8.4/36								680
58											Below boulder, gravelly dark greenish gray clay, based on drill cuttings	679
59		SPT 14	16 23 29	18/18					CH	CLAY, gravelly, (CH), dark gray (2.5Y 4/1), moist, very stiff to hard, massive, high toughness and plasticity, coarse sand to pebble sized clasts of greenish gray siltstone and very fine sandstone, occasionally brownish yellow, some small oxidized zones and clasts		678
60												677

Undisturbed sample
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-08

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
60		P 15	750 psi	12/12					CH	CLAY, gravelly (CH), mottled dark brown clay, similar to previous sample, some oxidation around basalt gravels, no clay seams or distinct shears. [Colluvium - Qc]	Sample appears to be gouged, went back down the hole with HQ rods to try and pick up rock, no good, 60' to 60.5' rig jumped, try pushing shelby 6" to pick up rock, no good, no recovery (61'-61.5'), take SPT-17 to attempt recovery, went back with drag bit to clean out hole	677
61		S 16		0/6						No sample retrieved		676
62		SPT 17	6 11 20	18/18					CH	CLAY, gravelly, (CH), mottled, very dark grayish brown (10YR 3/2) and greenish gray (GLEY1 5/1), moist, medium stiff, contains yellowish brown and greenish gray siltstone clasts, apparent bedding dips 40 degrees, very thin, faint clay seams through sample [possible Qls]		675
63									SW-SC	SAND, with clay, (SW-SC), light olive brown (2.5Y 5/4), some gravel, becomes clayier at base of sample, contact is sharp, wavy, dipping 20 degrees		674
64		SPT 18	10 13 16	18/18						TOP OF ROCK 63.5' CLAYSTONE, dark greenish gray (GLEY1 4/1), completely weathered grading to heavily weathered, crushed, with clay lined fractures, sample appears massive 64.3' - prominent fracture, dipping 31 degrees,		673
65		P 19	550 psi	12/12						65.0' - 66.0' - CLAYSTONE, greenish gray (GLEY1 5/1) with very dark gray interbeds, heavily weathered, very weak, mostly highly fractured and crushed, clay along reduced zones		672
66		P 20	1100 psi	24/24						65.6' - 0.1' thick zone of broken siltstone clasts 66.0' - 68.0' CLAYSTONE, as above, highly fractured/crushed, dipping 41 to 50 degrees, clay lining reduced zones of very dark gray material, oxidation near contact [Qls/Qc boundaries?]		671
67												670
68		P 21	700 psi	18/18						CLAYSTONE, dark gray (N4), heavily weathered, highly fractured to crushed, general attitude is subhorizontal to 40 degree dip, sample is heavily disturbed		669
69										69' - clay rich 0.5" to 0.6" thick clay gouge zone, very wet and sticky, grayish green in color, contains angular clasts of claystone		668
70		P 22	850 psi	24/24						Below 69.5' - Medium beds of heavily weathered to completely weathered rock, locally highly fractured areas of relatively fresh rock, clay rich, highly disturbed/brecciated, more so than same depth in adjacent boring.		667
71												666
72										Boring terminated at 71.5 ft. Total Depth 71.5' Hole grouted upon completion		665
73												664
74												663
75												662

Undisturbed sample
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Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-09**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA State Plane (Zone III) N 6058567.23127 E 2145519.90772		Total Depth 32.5 feet
Drilling Contractor and Rig Pitcher Drilling / Fraste Multidrill XL (track)	Elevation and Datum 693 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~8'.
Sampling Method MC & SPT & Pitcher Tube	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 11	Date Started 10/4/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/4/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0												693
1		MC 1 a-c	15 20 25	15/18					ML	SILT, gravelly, with trace sand, (ML), dark grayish brown (10YR 4/2), dry, hard, medium toughness and plasticity, ~25% 1/4" gravel, rarely up to 1"		692
2									ML	1.5' - becomes damp, more gravelly (30%), siltstone clasts appear, some claystone, rootlets, glass [Fill] At 2' completely weathered claystone, very dark gray (10YR 3/1), weathered to dark grayish brown (10YR 4/2) clay, dry to damp, oxidation on rock fragments	mud tub set up after 1st sample taken	691
3												690
4											Color change at 3.5' to a very dark grayish brown, cuttings are a stiff clay with silty lenses	689
5												688
6		MC 2 a-c	7 10 13	11/18	● 15.4%	115.7 ●			CH	CLAY, with sand (CH), very dark gray to very dark grayish brown (10YR 3/1 to 3/2), moist, very stiff, abundant coarse sand-sized pieces of yellowish brown siltstone to fine sandstone.	Driller says it feels stiff	687
7												686
8		SPT 3	4 7 15	11/18						TOP OF WEATHERED ROCK Gradational contact over 1" to heavily weathered claystone with yellowish brown colluvium.		685
9												684
10												683
11		MC 4	17 34 50/6"	13/18						CLAYSTONE, very dark gray (10YR 3/1), weathered to dark grayish brown (10YR 4/2), heavily weathered, very weak (R1), subhorizontal bedding, erratic and discontinuous, heavily factured and oxidized, fragments stained with iron oxide.	consistent drilling	682
12												681
13		SPT 5	19 25 50/5.5"	11/17.5						Split spoon contains same material		680
14												679
15												678

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-09

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15												678
16										CLAYSTONE, very dark grayish brown (10YR 3/2), heavily to completely weathered, extremely to very weak (R0-R1), faint bedding dipping 43 degrees, medium to thickly spaced, locally areas of fragmented rock, locally completely weathered, oxide staining on fracture surfaces, no distinct clay seams or shears		677
17		P 6	700 psi	30/30								676
18												675
19		SPT 7	17 15 25	8/18						Split spoon contains heavily weathered, fractured claystone	100% water return	674
20												673
21										CLAYSTONE, similar to above, clay rich, heavily to completely weathered, locally more competent and brecciated, dipping 41 degrees.		672
22		P 8	700 - 850 psi	27.6/30								671
23										23' - roughly 1" area of clay rich material, seperates crushed and fractured rock above from more competent rock below. [Possible Qls or tectonic?]		670
24		SPT 9	18 32 48	11/18						becomes moderately to completely weathered claystone with oxidized fractures		669
25											consistent drilling, occasional hard spots	668
26												667
27												666
28												665
29												664
30												663

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-09

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30		P 10	2000+ psi	12/12						CLAYSTONE, dark bluish gray (GLEY2 4/1), fresh to slightly weathered, very weak, massive to faintly laminated gently dipping, carbonate mineralization in bottom 0.2' of pitcher sample.	driller pushed to refusal - 1 foot only	663
31		SPT 11	24 24 42	1.5/18						Split spoon contains 1.5" of same material.		662
32												661
33										Boring terminated at 32.5 ft. Total Depth 32.5 ft. Hole grouted upon completion		660
34												659
35												658
36												657
37												656
38												655
39												654
40												653
41												652
42												651
43												650
44												649
45												648

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-10**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA State Plane (Zone III) N 6058745.08324 E 2145327.4793		Total Depth 35.5 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 724 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock0 ~10'.
Sampling Method MC & SPT & Pitcher Tube	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 8	Date Started 10/8/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/8/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0											Asphalt underlain by aggregate fill	724
1												723
2		MC 1 a-c	7 6 8	16/18					GP	GRAVEL, sandy, with trace silt, (GP), very dark gray (N3), wet (driller induced), dry otherwise, medium dense, 70% angular to subangular gravel, up to 1", 29% very fine to coarse sand, 1% silt, massive, poorly graded [AC Fill]		722
3												721
4									SP		Driller noted "sandier conditions, less gravel"	720
5		MC 2 a-c	9 12 20	18/18						SAND, with gravel, dark grayish brown (10YR 4/2), dry, medium dense to dense, ~25% subangular to subrounded gravel, up to 1/2" [FILL]		719
6										TOP OF WEATHERED ROCK CLAYSTONE, dark grayish brown, (10YR 4/2), top portion of sample much more weathered - clayey matrix supported. Bottom portion is clast supported, more competent, oxide staining on surfaces; heavily to completely weathered, very weak-weak (R0-R1),		718
7											7.5' of casing driven into the ground, mud tank set up	717
8												716
9		MC 3a	50/5"	5/5						CLAYSTONE, like above, heavily to completely weathered at top of sample, moderately weathered and more coherent at the base, fractured		715
10											Switch to SPT for next sample due to Mod. Cal. refusual	714
11												713
12												712
13												711
14		SPT 4	50/3"	3/3						CLAYSTONE, brown (10YR 4/3), moderately weathered, extremely weak (R0), faintly laminated, shoe contains gray siltstone pieces		710
15												709

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-10

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15										CLAYSTONE, brown (10YR 4/3), moderately weathered, extremely weak (R0), faintly laminated		709
16											drilling became softer at 16'	708
17												707
18												706
19		SPT 5	32 50/4.5"	9 / 10.5						SILTSTONE, very dark grayish brown (10YR 3/2), moderately weathered, extremely weak (R0), horizontal laminations.		705
20										19.4'- sharp contact with oxidation below 19.4' - heavily to completely weathered claystone, dark gray (10YR 4/1), with some subvertical, healed, oxidized fractures		704
21												703
22										decrease in weathering	dark gray clayey cuttings with fragments of claystone-siltstone	702
23												701
24		SPT 6	24 50/5.5"	7 / 11.5						CLAYSTONE, dark gray (N4), moderately to heavily weathered, extremely to very weak (R0-R1), planar horizontal bedding, locally clayey, seamy, with oxidation on fracture planes		700
25												699
26											intermittent hard and soft drilling	698
27												697
28										decrease in weathering		696
29		SPT 7	20 26	11 / 18						CLAYSTONE, dark gray (N4), slightly weathered, locally moderately weathered, extremely to very weak (R0-R1), horizontal to subhorizontal laminations, locally srong HCL rxn, locally silicic mineralization.		695
30												694

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-10

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30			40							CLAYSTONE, dark gray (N4), slightly weathered, locally moderately weathered, extremely to very weak (R0-R1), horizontal to subhorizontal laminations, locally srong HCL rxn, locally silicic mineralization.		694
31											Drilled itself down to 33'	693
32												692
33											Stiffened up at 33', pushing at 200 psi	691
34			17							CLAYSTONE, dark gray to very dark gray (N4 to N3), slightly weathered, horizontally laminated, soft clay rich claystone, 3" zone of clay or completely weathered claystone in sample		690
35		SPT 8	23 25	8 18							Shale oil in mud tub at end of drilling	689
36										Boring terminated at 35.5 ft. Total Depth 35.5 ft. Hole grouted upon completion		688
37												687
38												686
39												685
40												684
41												683
42												682
43												681
44												680
45												679

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-11**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA State Plane (Zone III) N 6058742.22758 E 2145265.96237		Total Depth 29.3 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 721 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~5.5'
Sampling Method MC & SPT & Pitcher Tube	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 8	Date Started 10/8/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/8/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0											1" of Asphalt underlain by AC base	721
1		MC 1 a-c	7 8 10	15/18					GW-GM	GRAVEL, with silt and sand, (GW-GM), olive brown (2.5Y 4/4), dry to damp, medium dense, sub-rounded to angular gravels, poorly graded, ~15% very fine sand to silt, grades to clay with gravel of the same color at 1.5'		720
2									GP	[Fill] 2' - heavily weathered siltstone fragments supported in a clay matrix [Fill]		719
3												718
4		MC 2 a-c	7 8 9	18/18					CH CH	CLAY, with gravel, (CH), olive brown (2.5Y 4/4), dry to damp, stiff to very stiff, poorly graded, angular to subangular volcanic gravels up to 1/2" 4.5' - mostly clay, 5% gravel <1/4", grades to completely weathered claystone with faint horizontal to subhorizontal bedding, mottled with gray (2.5Y 5/1), oxidation of relict fracture planes. At 5.5' weathered rock, locally competent blocks		717
5												716
6												715
7											Drove casing down to 7.5' and set up mud tub	714
8												713
9		MC 3a	38 50/3.5"	6.5/9.5	15.4%	115.7				CLAYSTONE, brown to yellowish brown (10YR 4/3 - 5/6), moderately weathered, extremely to very weak (R0-R1), contains 3 subvertical fractures, heavily oxidized, separate denser rock, continue through entire sample		712
10												711
11											cuttings are clayey with claystone pieces - yellowish brown	710
12												709
13												708
14										CLAYSTONE, yellowish brown (10YR 5/6), moderately weathered, very weak (R1), highly fractured, top 0.2' is a heavily fractured greenish tint clay		707
15												706

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-11

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15		P 4	400 psi	21.6/30						CLAYSTONE, yellowish brown (10YR 5/6), moderately weathered, very weak (R1), highly fractured, vertical healed fractures coated with MnO flowers truncating bedding, vertical fractures truncated against tight/healed subhorizontal fractures 15.5' - "soft zone"	attempted to capture contact with gray material, poor recovery	706
16												705
17		P 5	400 psi	18/24						16.5' - Top 0.4' of sample is a planar to subhorizontally bedded greenish gray claystone, heavily fractured to brecciated, with a 34 degree dipping 0.1" thick clay parting at its base. 16.8' - 17.4' - claystone with planar to convoluted bedding . 17.4' - massive claystone with multiple, laterally continuous, subvertical, healed fractures - 1" to 2" spacing		704
18												703
19		SPT 6	15 22 27	13/18						Split spoon contains material silmiar to top of sample 5, moderately to heavily weathered claystone, oxide stained fractures		702
20												701
21												700
22											change to gray clayey cuttings at 22 feet	699
23												698
24		SPT 7	50/2"	4/2						CLAYSTONE, dark gray (N4), slightly weathered, extremely weak (R0), planar, horizontal laminations, subvertical wedge of oxidized material with oxide stained boundaries		697
25												696
26											drilling softened up quite a bit at 26'	695
27											cuttings - gray claystone fragments with brown and gray clay	694
28		MC 8 a -c	23 25 50/3"	15/15			LL:39 ● PI:20			CLAYSTONE, dark gray (N4), slightly weathered, extremely weak to very weak (R0-R1), appears massive with subvertical fracture planes, heavily oxidized and very weak, spaced 1 to 2 inches apart	attempt Mod. Cal. due to softness and to capture a large sample	693
29												692
30										Boring terminated at 29.5 ft. Total Depth 29.5 ft. Hole grouted upon completion		691

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Leitis & Associates, Inc.	**SOIL LOG - Boring No. AKA-12**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA State Plane (Zone III) N 6058931.32827 E 2145165.19423		Total Depth 50.5 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 713 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~5.5'
Sampling Method MC & SPT & Pitcher Tube	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 13	Date Started 10/9/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/9/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0											Asphalt underlain by aggregate fill	713
1		MC 1 a-c	7 10 15	14/18	20.1%	104.6	LL:46 PI: 25		CH CH	CLAY, with gravel, (CH), dark grayish brown (10YR 3/2), dry to moist, very stiff to hard, ~20-25% subangular to angular gravels - siltstone and some volcanics, high toughness and plasticity. [Colluvium - Qc] At 2' mostly clay with small lenses (<0.3") of yellowish brown silt to sand, shoe contains cobbles of friable, subangular to angular sandstone in a clay matrix [Colluvium - Qc]		712
2												711
3												710
4		MC 2 a-c	11 21 31	18/18			LL:42 PI:21			CLAYSTONE, yellowish brown to dark grayish brown (10YR 5/4 to 10YR 4/2), completely weathered at 4', heavily weathered between 4.5' and 5'		709
5												708
6										TOP OF ROCK CLAYSTONE, yellowish brown to dark grayish brown (10YR 5/4 to 10YR 4/2), moderately weathered at 5.5', extremely weak to very weak (R0-R1), bottom of sample is dark gray (10YR 4/1) claystone in a clayey matrix	Switch to soil bit and set up mud tub with casing down to 7.5'	707
7											cuttings are clayey with flecks of gray claystone, return water is light brown	706
8												705
9		SPT 3	50/5"	5/5						CLAYSTONE, yellowish brown (10YR 5/6), moderately weathered, extremely to very weak (R0-R1), laminated, bottom portion of sample contains siltstone fragments, shoe contains clayey material		704
10												703
11												702
12											consistent drilling	701
13												700
14		SPT 4	50/4"	4/4						CLAYSTONE, dark greenish gray (GLEY2 4/1), weathered to yellowish brown, moderately weathered, extremely to very weak (R0-R1), laminated, subhorizontal to horizontal, 1/4" band of oxidized claystone dipping 28 degrees		699
15												698

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-12

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15										CLAYSTONE, dark greenish gray (GLEY2 4/1), weathered to yellowish brown, moderately weathered, extremely to very weak (R0-R1), laminated, subhorizontal to horizontal		698
16												697
17											clayey cuttings with flecks of claystone	696
18												695
19										CLAYSTONE, dark yellowish brown (10YR 4/4)		694
20		P 5	300 psi	21.6/24						CLAYSTONE, dark gray (10YR 4/1), slightly to moderately weathered, very weak (R1), horizontal to subhorizontal laminations, 2 major subvertical fractures, highly weathered and oxidized, bottom of sample is crushed/brecciated mechanically.	oxidized/reduced contact	693
21		SPT 6	50/4.5"	4.5/4.5						Split spoon contains same material		692
22												691
23										CLAYSTONE, dark gray (10YR 4/1), mottled with oxidation yellowish brown (10YR 5/6), heavily to completely weathered, extremely weak (R0), very oxidized - dark yellowish brown to dark reddish brown, contains several subvertical healed and oxidized fractures, somewhat sandier at clay parting.		690
24										[Potential Qls]	No significant drilling change from 22.5' to 24'	689
25		P 7	400 psi	24/24						24.4' - fat clay parting, very thin, dipping 30 degrees, appears to be a possible slide plane 24.5' - TOP OF COMPETENT ROCK CLAYSTONE, with discontinuous to planar bedding, moderately to highly weathered, very weak (R1), 0.2' zone of weaker claystone just below parting, bottom 0.4' of sample is more massive and fractured [appears to be old landslide deposits] 26' - convoluted bedding with gently dipping and vertical oxidized fractures. 26.6' to 27.1' - a series of 1" thick clayier zones dipping 15 degrees, no gouge - possible former failure planes or weak zones. Below 27.1' highly fractured to brecciated/crushed claystone interbedded with less fractured claystone, dark grayish brown, moderately to heavily weathered Split spoon contains gray claystone with sparse, gently dipping, oxidized bedding, moderately weathered	no issues with water circulation and 100% water return up to this point	688
26												687
27		P 8	400 psi	24/24								686
28		SPT 9	50/5"	5/5								685
29												684
30												683

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-12

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30												683
31											cuttings are abundantly gray consistent drilling 100% water return	682
32												681
33										CLAYSTONE to SHALE, dark gray (N4), moderately weathered, very weak (R1), horizontal laminations		680
34		P 10	650 psi	10.8/12						34' - 34.6' - prominent fracture, dips 60 to 45 degrees, planar, tight, slightly oxidized	lots of rig chatter and grinding while cutting pitcher	679
35										Below 34.6' - fine grained sandstone, very dark gray, weak to medium strong (R2 to R3), massive, strong to violent HCL reaction, heavily broken.		678
36										drilled through sandstone block, back into clayey material		677
37												676
38											clayey cuttings with flecks of claystone	675
39										CLAYSTONE to SHALE, dark gray to very dark gray (N4 to N3),slightly weathered, extremely to very weak (R0 to R1), very finely laminated, subhorizontal, locally oxidized with a prominent subvertical, oxidized fracture.		674
40		P 11	500 psi	24/24						39.5' to 40.2' - massive clay/weak zone, very soft, no clay gouge.		673
41		SPT 12	50/3.5"	3.5/3.5						Split spoon contains same material		672
42												671
43											consistent drilling no water loss return water is dark gray clayey cuttings	670
44												669
45												668

Undisturbed sample
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Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-12

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45										CLAYSTONE to SHALE, dark gray to very dark gray (N4 to N3),slightly weathered, extremely to very weak (R0 to R1), subhorizontal laminations		668
46											consistent drilling same material	667
47												666
48											at 48' drilling becomes harder - hit boulder or fractured rock?	665
49		SPT 13	23 32 34	10/18						CLAYSTONE, dark gray (N4), slightly weathered, extremely to very weak (R0 to R1), horizontal laminations, clayey zones with areas of slightly more competent rock		664
50											Finished at 12:00 pm, moved to AKA-13	663
51										Boring terminated at 50.5 ft. Total Depth 50.5 ft. Hole grouted upon completion		662
52												661
53												660
54												659
55												658
56												657
57												656
58												655
59												654
60												653

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-13**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA Sate Plane (Zone III) N 6059217.97458 E 2145245.65863		Total Depth 50 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 707 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~14.5'
Sampling Method MC & SPT & Pitcher Tube	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 16	Date Started 10/9/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/10/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0												707
1		MC 1 a-c	5 6 8	16/18	15.25	90.4			CH	CLAY, (CH), dark brown (10YR 3/3), dry in top 3", damp below, stiff, medium toughness and plasticity, 5% silt to fine sand <1/4" clasts, bottom 6" appear to have subvertical partings		706
2												705
3												704
4		MC 2 a-c	5 7 8	16/18	24.3%	90.4	LL:50 PI:36		CH	Same as above, damp to moist, no apparent vertical partings.		703
5									CH	CLAY, (CH), olive brown (2.5Y 4/3), moist, stiff, medium to high toughness and plasticity, <5% silty to fine sand lenses, Manganese nodules, softer brownish red clay [possible upper Qls plane at 5']		702
6												701
7												700
8												699
9		MC 3 a-c	3 5 7	12/18	24.2%	98.9	LL:55 PI:40		CH	color change back to dark brown (10YR 3/3), mottled with dark gray (10YR 4/1) silt, and yellowish brown very fine sand, very moist material, very soft, low to medium toughness [very soft/weak, Qls base]		698
10												697
11												696
12												695
13										CLAYSTONE, brownish yellow (10YR 6/8), completely weathered to residual soil (top 6"), very weak (R1), weathering decreases with depth to moderately weathered, laminated bedding, gently dipping, bottom of sample is a dark gray (N4), siltstone, moderately to heavily weathered, weak (R2).		694
14		MC 4	7A 14B	14/17							Driller stopped blowcounts because it stiffened up, worried about equipment	693
15												692

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-13

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15			39/4"C							CLAYSTONE, brownish yellow (10YR 6/8), moderately to heavily weathered, very weak (R1), laminated bedding, gently dipping		692
		SPT 5	50/4"	3/4								
16											major water loss at 15.5' to 16'	691
17											cuttings are flecks of gray siltstone to claystone	690
18												689
19		MC 6a	85/5"	3/5						CLAYSTONE, gray to dark gray (N5 to N4), moderately weathered, gently dipping laminations	Stiff material, possible rock?	688
20											driller added more EZ mud	687
21												686
22											Formation pulling water	685
23											clayey cuttings with flecks of claystone and Mn globs	684
24										CLAYSTONE, mottled, gray (N5) and dark gray (N4), heavily weathered, locally brecciated sections of competent rock with oxidized fracture planes. 24'-25' heavily weathered, brecciated.		683
25		P 7	500 psi	20.4/24						25'-25.5' very thinnly to thinnly bedded claystone, 1" thick dark gray medium stiff to stiff clay seams at 25'		682
26										26'-26.3' brecciated claystone, "soft"		681
27		P 8	500 psi	19.2/24						26.3'-27.2' massive to laminated clay to claystone, heavily weathered, locally oxidized, generally gently dipping. 27.2' heavily fractured, moderately weathered, gray (N5), claystone, fracture planes healed and oxidized.		680
28										28' - 29' moderately to heavily weathered claystone, "soft".		679
29		P 9	500 psi	18/24						29' - 30' more indurated claystone, massive.		678
30												677

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Leitis & Associates, Inc.

SOIL LOG - Boring No. AKA-13

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30										CLAYSTONE, dark gray (N4), moderately to heavily weathered, massive, more indurated		677
31											Consistent drilling	676
32												675
33												674
34										CLAYSTONE, dark gray (N4), fresh to slightly weathered, extremely to very weak (R0 to R1), thin to medium bedding, interbedding of more and less competent rock, calcite crystals present on bedding joints, massive structure, rock fractures easily scraped.		673
35		P 10	300 psi	16.8/24								672
36			21									671
37		SPT 11	29 38	9/18						Split spoon contains similar material		670
38											dark gray return water	669
39										CLAYSTONE, like above, caliche zones at 39.5'-39.8' and 40.0' to 40.4', very fine sandstone cobbles in top 0.2', weak clay along vertical fractures, locally clay with cobbles.	clayey cuttings with flecks of claystone	668
40		P 12	600 psi	18/18								667
41		SPT 13	28 38 42	12/18						Rock strength back to "extremely weak" (R0) Split spoon contains claystone, more competent rock at bottom of sample		666
42												665
43												664
44										CLAYSTONE, dark gray (N4), slightly weathered, locally moderately weathered, massive	water dropped while collecting pitcher sample	663
45		P	300	14.4								662

Undisturbed sample
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Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-13

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45		14	psi	24								662
46		SPT 15	19 / 37 / 46	12/18						CLAYSTONE, dark gray (N4), slightly to moderately weathered, very weak (R0), same as previous		661
47												660
48												659
49		SPT 16	39 / 50/4.5"	7/10.5						CLAYSTONE, same as above		658
50										Boring terminated at 50 ft.		657
51										Total depth 50 ft. Hole grouted upon completion		656
52												655
53												654
54												653
55												652
56												651
57												650
58												649
59												648
60												647

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-14**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA State Plane (Zone III) N 6059259.83619 E 2145298.60555		Total Depth 45 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 707 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~8'
Sampling Method MC & SPT & Pitcher Tube	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 14	Date Started 10/10/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/10/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0												707
1		MC 1 a -c	9 12 14	14/18					CH	CLAY, gravelly, (CH), yellowish brown (10YR 5/6), dry, very stiff, contains roots, also contains pieces of veRy weak (R1) claystone, gray (10YR 5/1), moderately to heavily weathered [Soil]	Appears to be layers of soil and heavily weathered rock	706
2												705
3												704
4		MC 2 a - c	27 34 50/4"	18/18	9.8%	119.2	LL:35 PI:16		CH	CLAY, gravelly, (CH), yellowish brown (10YR 5/6), dry, hard, claystone gravels up to 1" in size, very stiff, below 5' heavily weathered siltstone, highly fractured, oxidized and stained fractures, bedding appears to be gently dipping, root at 5' [Colluvium - Qc]		703
5												702
6											Drive casing down to 7.5'	701
7												700
8										TOP OF WEATHERED ROCK	Siltstone pieces at 8' in cuttings, almost no clay	699
9		P 3	300 psi	24/24						SILTSTONE, dark gray (N4), heavily weathered to olive brown (2.5Y 4/3), extremely to very weak (R0 to R1), very thinnly to thinnly bedded, dipping 20 degrees, locally completely weathered, oxide staining, highly fractured to brecciated, between 10.2' and 10.4' hard zone, lower contact dipping 30 degrees.	Top of weathered/brecciated rock	698
10												697
11		SPT 4	21 42 37	9/18						Split spoon contains same material, less brecciated/fractured		696
12												695
13												694
14		P	350	24						SILTSTONE, like above, brecciated, heavily to completely weathered, gently dipping to subhorizontal		693
15												692

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-14

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15		5	psi	24						SILTSTONE, dark grey (N4), weathered to Olive Brown (2.5 Y 4/3), extremely to very weak (R0 to R1), heavily to completly weathered, very thin to thin bedding of oxidized zones, alternatin b/w brecciated and moderalty fractured, gently dipping to subhorizontal		692
16		SPT 6	10 14 22	8/18								691
17												690
18											steady drilling, good water return	689
19		P 7	400 psi	24/24						CLAYSTONE, gray (N5), heavily weathered, extremely weak to very weak (R0 to R1), locally very thin beds of organic rich material, dipping 15 degrees, generally massive, highly fractured to brecciated in top 0.7'		688
20												687
21		SPT 8	15 43 50/4"	11/16						SILTSTONE, sandy, light olive brown (2.5Y 5/6), moderately weathered, extremely to very weak (R0-R1), massive, moderately indurated, very fine sand, some subvertical, healed, oxidized fractures		686
22											Formation taking fluid at approximately 22'	685
23												684
24		P 9	250 psi	30/30						SILTSTONE, sandy, light olive brown (2.5Y 5/6), moderately weathered, massive, well indurated, numerous continuous subvertical, anastomosing fractures, fracture planes are oxide stained pervasive fractures dip 70 degrees, planar, slightly rough to smooth, tight, with manganese oxide coating		683
25												682
26												681
27		SPT 10	50/4"	4/4						Split spoon sample is an oxidized, gray, very fine sand		680
28												679
29		P	400	20.4						SILTSTONE, sandy, like above, top 0.7' oxidized, below 29.7' sample is reduced with oxidized zones around healed, tight, subvertical fractures, large cobble at 29.3'		678
30												677

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-14

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30		11	psi	20.4						SILTSTONE, sandy, gray (N5), very weak (R1), slightly weathered, massive, oxidized zones (olive brown in color 2.5Y 5/6) around healed, tight, subvertical fractures, well indurated		677
31												676
32												675
33												674
34		SPT 12	50/4"	3/4						SILTSTONE, same as above	Cuttings from 30.5' to 34' stay the same, gray silty to very fine sand	673
35												672
36												671
37												670
38											consistent drilling, 100% water return	669
39		SPT 13	21 33 25	9/18						SILTSTONE to CLAYSTONE, dark gray (N4), slightly weathered, slightly weathered, massive, locally more clayey, with very fine pyrite growth		668
40												667
41												666
42												665
43												664
44		SPT 14	45 50/3.5"	7/9.5						CLAYSTONE to SILTSTONE, same as above but clayier		663
45										Boring Terminated at 45 ft. Total depth of 45ft. Hole grouted upon completion.		662

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-15**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA State Plane (Zone III) N 6058619.22576 E 2145391.34949		Total Depth 13 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 663 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~6'
Sampling Method SPT	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 4	Date Started 10/15/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/15/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0									CH	CLAY, with gravel, (CH), claystone and sandstone gravel, yellowish brown and gray, subangular clasts up to 1/2"	actual boring is 2' to 3' downhill from marked location	663
1		SPT 1	5 13 14	15/18								662
2										1.7' - SANDSTONE, fine grained, yellowish brown, heavily weathered, very weak (R1), oxidation and staining, on fracture planes, massive to very thinnly bedded		661
3												660
4		SPT 2	5 9 13	16/18					CH	CLAY, sandy (to 4.7'), with sand and gravel (below 4.7), (CH), yellowish brown, damp to moist, stiff, massive, with trace sandstone gravels up to 1/4", up to 1/2" claystone clasts, gravels are heavily weathered below 4.7', some clasts have olive gray/brown fat clay line, Manganese clayey balls		659
5												658
6										TOP OF ROCK	At 6', harder, more competent claystone to siltstone	657
7												656
8											At 8' slightly more brecciated with some clayey matrix	655
9		SPT 3	50/6"	6/6						SILTSTONE, dark gray (10YR 4/1), moderately weathered, extremely to very weak (R0 to R1), massive, heavily fractured, healed and oxidized fracture planes		654
10												653
11											difficulty augering deeper, added some water	652
12		SPT 4	30 45/6"	10/12						SILTSTONE, like above, heavily fractured,weathered along fracture planes	Drove split spoon 1' only because of difficulty of pulling rods out once driven in	651
13										Boring terminated at 13 ft. Total Depth 13 ft. Material put Hole backfilled with cuttings and compacted with rig		650
14												649
15												647

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-16**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA Sate Plane (Zone III) N 6058442.78582 E 2145485.64773		Total Depth 74.4 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 674 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~59'
Sampling Method MC & SPT & Pitcher Tube	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 16	Date Started 10/12/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/15/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0												674
1		MC 1 a-c	5 7 6	16/18	16.9%	98.4			CH	CLAY, with trace sand, (CH), dark brown (10YR 3/3), moist, stiff, massive, ~5% very fine sand, medium to high toughness and plasticity [Fill]		673
2												672
3												671
4		MC 2 a-c	4 5 9	18/18	19.6%	103.1			CH	CLAY, with trace gravel, (CH), grades to dark yellowish brown (10YR 3/6), becomes slightly gravelly, claystone clasts, Mn nodules [Colluvium - Qc]		670
5												669
6												668
7												667
8												666
9		MC 3 a-c	12 13 19	15/18	17.1%	113.3	LL:52 PI:36		CH	CLAY, gravelly, (CH), dark yellowish brown (10YR 3/6), moist, stiff, massive, ~35% subrounded to subangular gravel, siltstone and basaltic gravels, up to 1/2", generally 1/4" [Colluvium - Qc]		665
10												664
11												663
12										Approximately 12' - basaltic flecks in cuttings with ~20% clay		662
13												661
14		MC 4	12A 13B	15/18	21.1%	108.3			CH	5% more sand, gravels become larger, generally 1/2", fewer small clasts, subrounded to subangular		660
15												659

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-16

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15			19C						CH	CLAY, gravelly, (CH), dark yellowish brown (10YR 3/6), moist, stiff, massive, ~35% subrounded to subangular gravel, siltstone and basaltic gravels, generally 1/2" [Colluvium - Qc]		659
16												658
17											clayey cuttings, less rock fragments	657
18												656
19			10			104.1			CH	CLAY, gravelly, (CH), dark yellowish brown (10YR 4/6), moist, very stiff, massive, gravel becomes finer, occasional 1/2" pieces, angular to subrounded, siltstone and basalt, with trace sand		655
20		MC 5 a-c	15 18	15/18	24.6%							654
21												653
22											good circulation	652
23												651
24			14			116.3			CH	CLAY, gravelly, with sand, (CH), dark yellowish brown (10YR 4/4), moist, hard, some claystone gravels, ~15% very fine to fine sand, gravel generally <1/4", some 1/2", mostly basalt		650
25		MC 6 a-c	25 34	17/18	18.4%							649
26												648
27										Color contact	more rock cuttings, less clay	647
28												646
29			9 A			108.6			CH	CLAY, gravelly, (CH), dark greenish gray (GLEY1 4/1), moist, very stiff, massive, 1/4" siltstone gravels, 1/2" to 1" basalt cobbles, subangular to angular, some dark brown mottling		645
30		MC 7	13 B	17/18	21.6%							644

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-16

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30	X		19C							CLAY, gravelly, (CH), dark greenish gray (GLEY1 4/1), moist, very stiff, massive, 1/4" siltstone gravels, 1/2" to 1" basalt cobbles, subangular to angular, some dark brown mottling [Colluvium - Qc]		644
31												643
32												642
33											32.5' color change to lighter greenish gray	641
34	X	MC 8 a-c	9 15 27	14/18	● 19.2%	● 113.5				CLAY, grayish green (GLEY1 4/2), slightly weathered, extremely to very weak (R0-R1), massive, oxidation zones at bottom of sample, some calcite lining [Colluvium - Qc]		640
35												639
36												638
37												637
38												636
39	X	MC 9 a-c	6 13 18	4/18					CH	CLAY, gravelly, (CH), mottled, greenish gray (GLEY1 5/1) and dark brown (10YR 3/3), moist, medium stiff, massive, fine gravel, siltstone, subrounded [Colluvium - Qc]		635
40												634
41												633
42												632
43											Attempted pitcher, no luck, rock slumped into hole and clogged pitcher bit	631
44												630
45												629

Undisturbed sample
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Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-16

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45–46.5	X	MC 10	22, 25, 27	0/18						No recovery except for piece of volcanic cobble that prevented pitcher sampling		629–628
47–48												627–626
49–50.5		SPT 11	8, 16, 18	15/18					CH	CLAY, gravelly, (CH), dark brown (10YR 3/3), moist, very stiff, with dark grayish green massive siltstone gravels, ~35%, some appear as lenses or 1" to 3" beds, possibly very large cobbles		625–624
51–53											cuttings are a brown clay and dark greenish gray siltstone flecks slight water loss	623–621
54–55.5		SPT 12	8, 9, 11	18/18					CH	CLAY, gravelly, (CH), similar to above, dark brown (10YR 3/3), interbedded with 1" thick beds of greenish gray clay, with 1/4" siltstone gravels, subrounded to subangular		620–619
56–58										55.5' to 59' - transition zone Qc/Qls/Weathered rock		618–616
59–60		SPT 13	7, 12	14/18					CH	TOP OF WEATHERED ROCK CLAY, gravelly, (CH), dark greenish gray (GLEY1 4/1), moist, stiff, massive, ~30-40% siltstone gravels, up to 1/2"		615–614

Undisturbed sample
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Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
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WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-16

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
60			17						CH	CLAY, gravelly, (CH), dark greenish gray (GLEY1 4/1), moist, stiff, massive, ~30-40% siltstone gravels, up to 1/2"		614
61												613
62												612
63											cuttings "rockier"	611
64		SPT 14	17 24 32	11/18					CH	CLAY, gravelly, (CH), dark greenish gray (GLEY1 4/1), moist, hard, massive to sparsely bedded, 40-45% siltstone gravels, up to 1/4", locally brecciated rock, highly weathered, seamy [Great Valley]		610
65												609
66											Rig chatter at 66.5'	608
67												607
										less weathered rock		
68											siltstone cuttings with clay	606
69		SPT 15	37 50/6"	9/12						CLAYSTONE, very dark greenish gray (GLEY 3/1), fresh to slightly weathered, extremely weak to very weak (R0-R1), massive, sparse calcite mineralization, top 3" of sample are clay like in sample 14	SPT refusal - bedrock?	605
70												604
71												603
72											consistent drilling, cuttings are claystone	602
73												601
74		SPT 16	50/4"	4/4						CLAYSTONE, like above		600
										Bottom of Hole at 74.4' Hole grouted upon completion		
75												599

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
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Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-17**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA Sate Plane (Zone III) N 6058434.22404 E 2146000.89584		Total Depth 65 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 786 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~48'
Sampling Method MC & SPT & Pitcher Tube	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 35	Date Started 10/10/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/11/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0										Asphalt underlain by AC Fill	Auger down to 1', still in coarse aggregate fill, auger to 2'	786
1												785
2		MC 1 a-c	6 5 7	18/18	19.7%	101			GC-GP	GRAVEL, with clay, (GP-GM to GC), very dark grayish brown (10YR 3/2), damp to moist, medium dense, subrounded angular siltstone (greenish gray) and sandstone (yellowish brown) gravels up to 1 inch, poorly sorted, moderately graded [FILL]		784
3												783
4		MC 2	3 A 3 B 3 C	12/18					CH	At 4' - CLAY, (CH), dark brown (5YR 3/3) and reddish brown (5YR 5/4), with lenses of sand and siltstone up to 1", siltstone is greenish gray, sand is poorly indurated, yellowish brown to brownish yellow [Colluvium - Qc]		782
5		MC 3	3 A 4 B 4 C	12/18					CH	At 5' - sand and siltstone lenses become very small, brown claystone clasts up to ~0.2" appear, predominantly clay from 5.5' to 6', very minor gravel component [Colluvium - Qc]		781
6												780
7		MC 4	3 A 4 B 5 C	15/18	21.3%	92.9			CH	At 6.5' - becomes considerably sandy with very large lenses of uncemented sand, siltstone, and claystone. [Colluvium - Qc]		779
8									CH	below 8' reddish clay dominant matrix and becoming sandier from 9' to 9.4' [Colluvium - Qc]		778
9		P 5	200 psi	22.8/30								777
10									ML	SILT, with sand, (ML), mottled, yellowish brown, grayish green, dark grayish brown, very fine sand, medium stiff to medium dense [Colluvium - Qc]		776
11		P 6	200 psi	4.8/30					ML	increase in clay content at 10.5'	Pitcher sample cut easily but when retreived, driller said it felt like it hadn't cut anything at all - low resistance, poor recovery - sand possibly?	775
12												774
13		MC 7 a-c	7 7 10	12/18	24.3%	97.2			SC	SAND, clayey, (SC), mottled, becomes sandier, with clay component rather than silt		773
14									CH	CLAY, with trace sand, (CH), black (10YR 2/1), moist, medium stiff, high toughness and plasticity, massive, less than 5% very fine sand [Qs1]		772
15												771

Project Name and Job Number
Helios Alternative Fuels Research Facility
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WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-17

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Dry Density (pcf)	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15												771
16		P 8	200 psi	10.8/30					CH	CLAY, with gravel and sand, (CH), mottled, black (10YR 2/1), red (2.5 YR 4/8), moist, medium stiff, ~20% subangular gravels up to 1/4", siltstone, sandstone, and claystone, lenses of very fine sand [Colluvium - Qc]		770
17		P 9	200 psi	15.6/18					CH	grades to 5- 10% gravels, <1/4", color becomes very dark grayish brown to black at 18'		769
18												768
19		P 10	150 psi	0/18							No recovery	767
20		P 11	200 psi	12/12					CH	CLAY, like previous, top of sample is highly disturbed, looks like previous clay sample	Drilling stiffened up at 20.5'	766
21		P 12	100 psi	14.4/18					SC	20.8' - hard layer 1/2" to 2/4" thick below 20.8' - SAND, clayey, (SC), light olive brown (2.5Y 5/6), mottled with strong brown (7.5YR 4/6), moist, medium dense to dense, subangular to angular gravels (Moraga), up to 2.5", generally 1/2"		765
22											rig chatter at 22.5'	764
23		P 13	125 psi	18/18					CH	22.8' - Oxidized layer of clay, acts as a contact - somewhat diffuse and wavy below 22.8' - CLAY, with sand and gravel, (CH), dark yellowish brown (10YR 3/6), moist, medium stiff, massive, with fine gravels, generally siltstone clasts, subrounded to subangular, with very fine sand, an instance of a rootlet [Colluvium - Qc]		763
24		P 14	300 psi	10.8/18							Major rig chatter and grinding at 24', 3" to 4" inches worth	762
25												761
26		P 15	300 psi	0/18						No recovery, sample chewed up by broken carbide of sampler	Metal against metal grinding - lost a carbide on pitcher bit	760
27												759
28		MC 16 a - c	5 5 5	18/18	28.1%	92.3			CH	color change CLAY, with sand and gravel, (CH), very dark grayish brown (10YR 3/2) to dark gray (10YR 4/1), moist, soft, massive, with siltstone and fine sandstone clasts, greenish gray and yellowish brown, clasts up to 0.4", some oxidized, sample becomes more gravelly towards bottom 29.5' to 30.5' - gravels increase in size and abundance	No sample at 27', cleaned out to 28' going with Mod. Cal. to try and pick up carbide	758
29												757
30												756

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
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WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-17

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30												756
31		S 17	160 psi	30/30					CH	30.5' - CLAY, with gravel, (CH), very dark grayish brown (10YR 3/2) to dark gray (10YR 4/1), moist, medium stiff, massive, coarse sand to fine gravel, mostly siltstone, some rootlets	material is soft - pushing shelby tubes	755
32									CH	32' - CLAY, with gravel, (CH), very dark grayish brown (10YR 3/2) to black (10YR 2/1), generally fine gravel, sparse coarse gravel, predominantly greenish gray siltstone, subrounded-angular, poorly to moderately indurated, some oxidation lenses		754
33		S 18	150 psi	24/30								753
34									CH	Almost 45% gravel at 34'		752
35									CH	35' - CLAY, with trace gravel, very dark gray to black (10YR 3/1 to 2/1), moist, medium stiff, massive, ~5-10% siltstone gravels, generally less than 0.1" in size, sparse oxidized clasts, medium to high toughness and plasticity		751
36		S 19	125 psi	24/30								750
37									CH	Same as above		749
38		S 20	190 psi	25.2/30								748
39									CH	39' - CLAY, with gravel, (CH), black (10YR 2/1), moist, medium stiff, massive, fine to medium gravel, mostly fine, greenish gray siltstone, some oxidized clasts, ~5% very fine sand, 15-20% gravel, sparse basalt clasts up to 1/2", subrounded		747
40												746
41		S 21	300 psi	28.8/30								745
42									CH	42' - 43.5' - increase in gravel to 25-30%, predominantly siltstone, gravels slightly larger than previous sample, more oxidation		744
43		P 22	150 psi	18/18							slight chatter at 43'	743
44		P 23	150 psi	19.2/24					CH	Same as above to 45.7'		742
45												741

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-17

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45									CH	45.7' - CLAY, with trace gravel, (CH), greenish gray to dark greenish gray (GLEY1 5/1 to 4/1), massive, stiffer than above, very thin clay gouge in top portion of sample caliche layer at 46.4', below caliche, oxidized greenish gray claystone, laminated, wavy to convoluted bedding, oxidation is predominant, continuing to 48.2', very thin clay gouge at Qc top and clay rich weathered rock below		741
46		P 24	300 psi	16.8/24								740
47												739
48		P 25	300 psi	12/18						TOP OF ROCK 48.2' - contact dips 45 to 60 degrees, stepped, sharp, reddish clay lines some fractures Below 48.2' - CLAYSTONE, greenish gray (GLEY2 6/1), mottled with olive yellow (5Y 6/6), slightly weathered, very weak, massive to faintly laminated, some subhorizontal to anastomosing oxidation planes, olive yellow appears in lenses up to 1/4", occasionally forms discontinuous, gently dipping bedding	Top of rock at 48.2'	738
49		P 26	300 psi	12/18								737
50												736
51		P 27	400 psi	12/18								735
52		P 28	250 psi	13.2/18						52.7' to 52.9' - large siltstone to fine sandstone calcified concretions		734
53										52.9' - SANDY SILTSTONE to SANDSTONE, same structure and characterisitic as above except rock is now a very fine grained sandstone to sandy siltstone, relict fractures, gently to steeply dipping		733
54		P 29	250 psi	9.6/18								732
55												731
56		P 30	400 psi	14.4/24						SANDSTONE, mottled, pale olive (5Y 6/3 to 6/4) and olive yellow (5Y 6/6), slightly to moderately weathered, very weak, massive, well indurated, very fine sand, oxidized, remenant greenish gray can still be seen, upper contact is diffuse over 2" and wavy		730
57		P 31	500 psi	7.2/18						Zone of reduced sand, with steeply dipping contact at 57.4' - color change to pale olive (5Y 6/4)	poor recovery, can only get 1' at a time	729
58												728
59		P 32	250 psi	14.4/18						59' - wavy, sharp contact, below contact color change to olive (5Y 5/4), thin to medium bedded sandstone		727
60												726

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-17

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
60												726
61		P 33	250 psi	12/18						SANDSTONE, olive (5Y 5/4), slightly weathered, very weak, moderately indurated, somewhat friable, oxidized to yellowish brown locally, some relict greenish gray coloring, appears massive, subhorizontal bedding below 61', very thinly bedded.	poor recovery, can only get 1' at a time	725
62		P 34	150 psi	10.8/18						oxidized and reduced beds alternating, occasional caliche to 63'		724
63		P 35	?	14.4/24						63' to 64' - bedding dipps 65 degrees with calcite crystals along banded contacts, below 64' bedding returns to subhorizontal banding		723
64												722
65										Boring terminated at 65 ft. Total Depth 65 ft. Hole grouted upon completion		721
66												720
67												719
68												718
69												717
70												716
71												715
72												714
73												713
74												712
75												711

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number Helios Alternative Fuels Research Facility 1930	WLA William Lettis & Associates, Inc.	**SOIL LOG - Boring No. AKA-18**	
Type and Diameter of Boring Mud Rotary / 4 7/8"	Boring Location: CA State Plane (Zone III) N 6058376.85299 E 2145729.4011		Total Depth 55.5 feet
Drilling Contractor and Rig Pitcher Drilling / Failing 1500	Elevation and Datum 719 LBNL (feet)	Ground Water Depth N/A	Depth to Bedrock ~ 55'
Sampling Method MC & SPT & Pitcher Tube	Sample Driving Hammer/Drop 140 lb. Auto / 30"	No. of Samples 10	Date Started 10/11/07
	Borehole Inclination 90	Logged by M. Buga	Date Completed 10/12/07

Reviewed by / Date K. Krug/J. Baldwin 10/15/07

Reviewed by / Date

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0												719
1										Augered down to 6' Switched to Mud-Rotary Drilled down to 19' without sampling as per direction Begin sampling at 19'		718
2												717
3												716
4												715
5												714
6												713
7												712
8												711
9												710
10												709
11												708
12												707
13												706
14											brown clay cuttings, some rock fragments	705
15												704

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-18

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15												704
16												703
17												702
18												701
19										Begin sampling at 19'		700
19–20		SPT 1	2 5 7	15/18					CH	CLAY, with trace gravel, (CH), black to very dark gray (N2.5 to N3), moist, medium stiff, massive, siltstone clasts, generally ~0.1" in size, up to 1/2" subrounded to subangular basaltic clasts, top 4" of sample contains heavily oxidized greenish gray clay with a sharp, steeply dipping, oxidized contact at 19.3' [Colluvium - Qc]	Drilling stiffened up at 19', took SPT - large cobble/boulder	
20												699
21												698
22												697
23											Clayey cuttings	696
24									CH	CLAY, like above with more gravel.		695
24–25		SPT 2	2 5 7	16/18						24.5' - changes to a heavily oxidized greenish gray, expansive clay with sparse caliche, contact is gently dipping, sharp, and oxidized [Colluvium - Qc]		
25												694
26												693
27												692
28											cuttings are greenish gray clay, some reddish brown	691
29									CH	At 29.5' - CLAY, (CH), very dark grayish brown clay (10YR 3/2), moist, very stiff, massive, with 10% fine siltstone gravels, some oxidized. 1.5" of oxidized gray clay like above, followed by 4.5" of volcanic cobbles.		690
29–30		SPT 3	10 10	13/18								
30												689

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-18

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30			8									689
31									GP-GC	volcanic cobbles and clay	greenish gray clayey cuttings, more gravel	688
32												687
33											At 32.5' drilling stiffened up, started pushing, prior to 32.5' drilling under its own weight	686
34		SPT 4	3 9 9	16/18					CH	CLAY, with gravel, (CH), very dark grayish brown (10YR 3/2), moist, medium stiff, massive, mostly fine siltstone gravels, some oxidized, large volcanic cobble at top of sample (sluff?), bottom of sample is more gravelly		685
35												684
36												683
37												682
38												681
39		SPT 5	6 8 9	18/18					CH	CLAY, with gravel (CH), like previous sample, with less gravel (15%), sparse to no caliche	Rig chatter at 39'	680
40												679
41												678
42											rockier cuttings	677
43											flecks of hard, dark gray to black sandstone	676
44		SPT 6	11 14	15/18					CH	CLAY, with gravel, (CH), greenish gray (GLEY1 5/1), moist, medium stiff, massive, moderately oxidized		675
45												674

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

Project Name and Job Number
Helios Alternative Fuels Research Facility
1930

WLA William Lettis & Associates, Inc.

SOIL LOG - Boring No. AKA-18

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
45			16						CH	45.5' to 45.8' - crushed siltstone below 45.8' is a dark brown clay with fine gravel, occasional cobbles		674
46												673
47												672
48											Lots of rig chatter 48' to 49'	671
49			27						CH	49' - angular basaltic cobbles		670
50		SPT 7	27 21	14/18					GC	Below 49.5', clayey gravel to gravelly clay, (GC), greenish gray (GLEY1 5/1), volcanic gravels, some oxidation	lots of grinding at 50'	669
51									GP-GC	GRAVEL, with clay, (GP-GC), clast supported, basaltic and siltstone cobbles, subangular to angular, clay is dark brown		668
52		SPT 8	27 30 46	12/18								667
53		SPT 9	16 25 27	5/18					CH	CLAY, gravelly, (CH), dark grayish brown (10YR 3/2), siltstone and basaltic angular to subangular gravels, volcanic gravels are up to 1/2" [~50' to 54' possible former paleochannel?/ Qc base rubble]	still raining	666
54		SPT 10	10 25 32	16/18					CH	CLAY, (CH), very soft to weak, very distinct reddish brown to strong brown clay, no volcanic material, no to few fine gravels, faint laminations near 55'		665
55										SILTSTONE to very fine SANDSTONE, greenish gray (GLEY1 5/1), massive		664
56										Boring terminated at 55.5 ft. Total Depth 55.5 ft. Hole grouted upon completion		663
57												662
58												661
59												660
60												659

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

SOIL AND ROCK CLASSIFICATION KEYS TO BORINGS
AKA-19 THROUGH AKA-28

SOIL CLASSIFICATION CHART

PRIMARY DIVISIONS			SECONDARY DIVISIONS		
			CRITERIA *	GROUP SYMBOL	GROUP NAME
COARSE-GRAINED SOILS MORE THAN 50% RETAINED ON NO.200 SIEVE	GRAVELS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO.4 SIEVE	CLEAN GRAVELS LESS THAN 5% FINES	$Cu \geq 4$ AND $1 \leq Cc \leq 3$ [A]	GW	Well-graded gravel
			$Cu < 4$ AND/OR $1 > Cc > 3$	GP	Poorly-graded gravel
		GRAVELS WITH FINES - MORE THAN 12% FINES	FINES CLASSIFY AS ML OR MH	GM	Silty gravel
			FINES CLASSIFY AS CL OR CH	GC	Clayey gravel
	SANDS 50% OR MORE OF COARSE FRACTION PASSES NO. 4 SIEVE	CLEAN SANDS LESS THAN 5% FINES	$Cu \geq 6$ AND $1 \leq Cc \leq 3$	SW	Well-graded sand
			$Cu < 6$ AND/OR $1 > Cc > 3$	SP	Poorly-graded sand
		SANDS WITH FINES - MORE THAN 12% FINES	FINES CLASSIFY AS ML OR MH	SM	Silty sand
			FINES CLASSIFY AS CL OR CH	SC	Clayey sand
FINE-GRAINED SOILS 50% OR MORE PASSES THE NO.200 SIEVE	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50%	INORGANIC	PI > 7 AND PLOTS ON OR ABOVE "A" LINE	CL	Lean clay
			PI < 4 OR PLOTS BELOW "A" LINE	ML	Silt
		ORGANIC	$\frac{\text{LIQUID LIMIT - OVEN DRIED}}{\text{LIQUID LIMIT - NOT DRIED}} < 0.75$	OL	Organic Clay & Organic Silt
	SILTS AND CLAYS LIQUID LIMIT 50% OR MORE	INORGANIC	PI PLOTS ON OR ABOVE "A" LINE	CH	Fat clay
			PI PLOTS BELOW "A" LINE	MH	Elastic silt
		ORGANIC	$\frac{\text{LIQUID LIMIT - OVEN DRIED}}{\text{LIQUID LIMIT - NOT DRIED}} < 0.75$	OH	Organic Clay & Organic Silt
	HIGHLY ORGANIC SOILS		PRIMARILY ORGANIC MATTER, DARK IN COLOR, AND ORGANIC ODOR	PT	Peat

REFERENCE: Unified Soil Classification System (ASTM D 2487-06)

* Criteria may be done on visual basis, not necessarily based on lab testing

A – $C_u = D_{60}/D_{100}$ & $C_c = (D_{30})^2 / (D_{10} \times D_{60})$

GRAIN SIZES

U. S. STANDARD SERIES SIEVE				CLEAR SQUARE SIEVE OPENINGS			
200	40	10	4	3/4"		3"	12"
SILTS AND CLAYS	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

ABBREVIATIONS

INDEX TESTS

LL - Liquid Limit (%) (ASTM D 4318-05)

PI - Plasticity Index (%) (ASTM D 4318-05)

-200 - Passing No. 200 Sieve (%) (ASTM D 1140-00)

STRENGTH TESTS

PP - Field Pocket Penetrometer test of unconfined compressive strength (tsf)

TV - Field Torvane test of shear strength (psf)

UC - Laboratory unconfined compressive strength (psf) (ASTM D 2166-06)

TXUU - Laboratory unconsolidated, undrained triaxial test of undrained shear strength (psf) (ASTM D 2850-03a)

MISCELLANEOUS

ATOD - At time of drilling

psf/tsf - pounds per square foot / tons per square foot

psi - pounds per square inch (indicates relative force required to advance Shelby tube sampler)

SYMBOLS

Standard Penetration Test Split Spoon (2-inch O.D.)

Modified California Sampler (3-inch O.D.)

Thin-walled Sampler Tube (either Pitcher or Shelby) (3-inch O.D.)

Rock Core

Bag Sample

Groundwater Level

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KEY TO EXPLORATORY BORING LOGS

HELIOS PROJECT

University of California; Berkeley, California

PROJECT NO.	DATE
2500-4	**December 2008**

CONSOLIDATION OF SEDIMENTARY ROCKS; usually determined from unweathered samples. Largely dependent on cementation.

U = unconsolidated
P = poorly consolidated
M = moderately consolidated
W = well consolidated

BEDDING OF SEDIMENTARY ROCK

Splitting Property	Thickness	Stratification
Massive	Greater than 4.0 feet	Very thick-bedded
Blocky	2.0 to 4.0 feet	Thick-bedded
Slabby	0.2 to 2.0 feet	Thin-bedded
Flaggy	0.05 to 0.2 feet	Very thin-bedded
Shaly or platy	0.01 to 0.05 feet	Laminated
Papery	Less than 0.01 feet	Thinly laminated

FRACTURING

Intensity	Size of Pieces in Feet
Very little fractured	Greater than 4.0 feet
Occasionally fractured	1.0 to 4.0 feet
Moderately fractured	0.5 to 1.0 feet
Closely fractured	0.1 to 0.5 feet
Intensely fractured	0.05 to 0.1 feet
Crushed	Less than 0.05 feet

HARDNESS

1. **Soft** - Reserved for plastic material alone.
2. **Low Hardness** - Can be gouged deeply or carved easily by a knife blade.
3. **Moderately Hard** - Can be readily scratched by a knife blade; scratch leaves a heavy trace of dust and is readily visible after the powder has been blown away.
4. **Hard** - Can be scratched by a knife blade with difficulty; scratch produces little powder and is often faintly visible.
5. **Very Hard** - Cannot be scratched by a knife blade; leaves a metallic streak

STRENGTH

1. **Plastic -** Very low strength.
2. **Friable** - Crumbles easily by rubbing with fingers.
3. **Weak** - An unfractured specimen of such material will crumble under light hammer blows.
4. **Moderately Strong** - Specimen will withstand a few heavy hammer blows before breaking.
5. **Strong** -Specimen will withstand a few heavy ringing hammer blows and will yield with difficulty only dust and small flying fragments.
6. **Very Strong** -Specimen will resist heavy ringing hammer blows and will yield with difficulty only dust and small flying fragments.

WEATHERING - the physical and chemical disintegration and decomposition of rocks and minerals by natural processes such as oxidation, reduction, hydration, solution, carbonation, and freezing and thawing.

D. **Deep** - Moderate to complete mineral decomposition; extensive disintegration; deep and thorough discoloration; many fractures, all extensively coated or filled with oxides, carbonates and/or clay or silt.
M. **Moderate** - Slight change or partial decomposition of minerals; little disintegration; cementation little to unaffected. Moderate to occasionally intense discoloration. Moderately coated fractures.
L. **Little** - No megascopic decomposition of minerals; little or no effect on normal cementation. Slight and intermittent, or localized discoloration. Few stains on fracture surfaces.
F. **Fresh** - Unaffected by weathering agents. No disintegration or discoloration. Fractures usually less numerous than joints.

AKA-19 THROUGH AKA-28 EXPLORATORY BORING LOGS

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 734 feet (see notes)	**LOGGED BY:** DI
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 5/5/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY - with silt, with sand, trace gravel, moist to dry (FILL)	Mottled Yellowish Brown to Dark Grayish Brown	Very Stiff	CL	1					
				2					
				3					
	Dark Brown to Grayish Brown			4					
				5					
-fewer gravels	Mottled Yellowish Brown to Dark Brown			6					
				7		24			
				8					
				9					
				10					
				11					
				12		17			
				13					
FILL				14					
CLAY - with silt, trace sand, moist	Dark Brown to Grayish Brown	Very Stiff	CL	15		19			
				16					
				17					
				18					
				19					
				20					
				21		26			
				22					
				23					
-slower drilling at 24'				24					

(Continued on Next Page)

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2500-4C	**May 2008**	**1 of 2**	**19**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAYSTONE - moderate to deep weathering (Great Valley Complex)	Olive Brown to Yellowish Brown	Soft to Low Hardness	BR	26 27		50/6" 85			

Bottom of boring at 27.5 feet.

NOTES:

1. No groundwater was encountered at the time of drilling. The boring was re-checked for groundwater on 5/8/08. No groundwater was encountered and the boring was backfilled following the second groundwater measurement.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were determined from survey stakes set by LBNL.

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 733.5 feet (see notes)	**LOGGED BY:** DI
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 5/5/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY - with silt, with sand, trace gravels, moist (FILL)	Brown to Grayish Brown	Stiff	CL	1, 2, 3, 4, 5, 6					
FILL				7					
CLAY - with silt, trace sand, moist	Yellowish Brown	Very Stiff to Hard	CL	8, 9		31			Sieve Analysis (See Appendix E)
		Very Stiff		10, 11, 12, 13		24			
CLAYSTONE - moderate to deep weathering (Great Valley Complex)	Grayish Brown	Soft to Low Hardness	BR	14, 15, 16		50/6"			
				17		51/3"			

Bottom of boring at 17.5 feet.

NOTES:

1. No groundwater was encountered at the time of drilling. The boring was re-checked for groundwater on 5/8/08. No groundwater was encountered and the boring was backfilled following the second groundwater measurement.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were determined from survey stakes set by LBNL.

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2500-4C	**May 2008**	**1 of 1**	**20**

AKA BORING LOG BORING LOGS.GPJ AKA_TEMPLATE.GDT 1/29/09

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 741.5 feet (see notes)	**LOGGED BY:** GH
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 5/6/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY - Silty, trace sand, dry	Dark Brown	Soft	CL						
SANDSTONE - friable, moderate to deep weathering (Great Valley Complex)	Yellowish Brown	Soft to Low Hardness	BR	1		[23]			
				2					
				3		19			
				4					
				5					
				6		20			
CLAYSTONE - moderate weathering (Great Valley Complex)	Reddish Brown	Low Hardness	BR	7					
	Grayish Brown			8					
				9		44			

Bottom of boring at 9.0 feet.

NOTES:

1. No groundwater was encountered at the time of drilling. The boring was re-checked for groundwater on 5/8/08. No groundwater was encountered and the boring was backfilled following the second groundwater measurement.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were determined from survey stakes set by LBNL.

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2500-4C	**May 2008**	**1 of 1**	**21**

AKA BORING LOG BORING LOGS.GPJ AKA_TEMPLATE.GDT 1/29/09

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 748.5 feet (see notes)	**LOGGED BY:** GH
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 5/6/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY - Silty, trace sand, dry	Dark Brown	Firm	CL	1					
SILTSTONE - friable, deep weathering, (Orinda Formation)	Light Yellowish Brown	Soft to Low Hardness	BR	2					
				3					
				4					
				5					
				6					
				7		42			
				8					Drilling refusal at 8.5'
				9					
				10		85			
				11		57			
				12		50/6"			

Bottom of boring at 12.0 feet.

NOTES:

1. No groundwater was encountered at the time of drilling. The boring was re-checked for groundwater on 5/8/08. No groundwater was encountered and the boring was backfilled following the second groundwater measurement.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were determined from survey stakes set by LBNL.

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2500-4C	**May 2008**	**1 of 1**	**22**

AKA BORING LOG BORING LOGS.GPJ AKA_TEMPLATE.GDT 1/29/09

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 751 feet (see notes)	**LOGGED BY:** GH
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 5/7/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY - trace fine to medium gravels, dry to moist	Dark Brown with Reddish Brown	Stiff	CH	1					
				2					
				3					
-increase in silt and sand content				4					
				5					
				6					
				7					
-increase in coarse sands	Yellowish Brown			8					
SILTSTONE - friable, moderate to deep weathering (Orinda Formation)	Light Gray	Soft	BR	9	☒	52/6"			
		Soft to Low Hardness		10		50/3"			
				11					
				12					
				13					
	Light Brown			14		50/2"			
				15					

Bottom of boring at 15.0 feet.

NOTES:

1. No groundwater was encountered at the time of drilling. The boring was re-checked for groundwater on 5/8/08. No groundwater was encountered and the boring was backfilled following the second groundwater measurement.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were determined from survey stakes set by LBNL.
5. Boring moved 2 feet south along line B to avoid subsurface utility.

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2500-4C	**May 2008**	**1 of 1**	**23**

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 755 feet (see notes)	**LOGGED BY:** AL/GH
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 5/8/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY - with silt, with coarse sand to coarse gravel, trace roots, moist	Dark Brown	Stiff	CL	1					
				2					
				3					
-decrease in coarse grain particle size				4					
				5					
				6					
				7					
				8					
CLAY - some silt, some medium grained sand, trace fine gravels, moist	Reddish Brown	Very Stiff	CL/CH	9		[39]			
				10					
				11					
				12					
				13					
				14					
				15		45			
				16					
				17					
				18					
				19					
CLAY - with fine grained sand and some coarse sand, moist	Olive Brown	Hard	CL	20					
				21		32			
				22					
				23					
SILTSTONE - low hardness, deeply to moderately weathered. (Orinda Formation)	Gray to Light Gray	Soft to Low Hardness	BR	24					

(Continued on Next Page)

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING NO.
2500-4C	**May 2008**	**1 of 2**	**24**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
SILTSTONE - low hardness, deeply to moderately weathered. (Orinda Formation)	Gray to Light Gray	Soft to Low Hardness	BR	26 27 28 29 30		50/4" 80			Drilling refusal @ 28.5'

Bottom of boring at 30.0 feet.

NOTES:

1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were determined from survey stakes set by LBNL.

DRILL RIG: D51, Rotary Wash	**SURFACE ELEVATION:** 743 feet (see notes)	**LOGGED BY:** AL
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 5" inches	**DATE DRILLED:** 7/3/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
-3" Asphalt Concrete **CLAY, Lean, Gravelly** - with sand	Dark Brown	Stiff	CL	1 2 3 4 5 6 7 8 9					
CLAY, Lean - with fine gravel, some sand lenses	Mottled Brown, Yellowish Brown, Olive Gray, Reddish Brown	Very Stiff	CL	10 11 12 13 14 15 16 17 18 19		[15] [36]			PP = 2.25 tsf
CLAY, Lean, Sandy - trace fine gravel, trace roots	Mottled Black and Bluish Gray	Stiff	CL	20 21 22 23 24 25 26 27 28 29		[14]			

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**1 of 4**	**AKA-25**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean, Sandy - trace fine gravel, trace roots	Mottled Black and Bluish Gray	Stiff	CL	31					
				32					
				33					
				34					
				35					
				36					
				37					
CLAY, Lean, Gravelly - with sand lenses, rock fragments, cemented areas	Mottled Olive Gray, Brown and Reddish Brown	Very Stiff	CL	38					
				39					
				40					
				41		[39]			
				42					
				43					
				44					
				45					
				46					
				47					
				48					
				49					
CLAY, Lean, Gravelly - some sand, pieces of basalt and trace quartz	Mottled Brown, Greenish Gray and White	Hard	CL	50					
				51		50/5"			
	Mottled Bluish Gray and Yellowish Brown			52					
				53					
				54					
				55					
CLAY, Lean, Gravelly - some sand	Grayish Blue	Hard	CL	56					
				57					
-some basalt fragments	Brown and Black			58					
				59					
	Brown and Dark Brown			60					
				61		50/2"			
CLAY, Lean, Gravelly - with sand and rock fragments	Bluish Gray and Reddish Brown	Soft	CL	62					
				63					
				64					

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**2 of 4**	**AKA-25**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean, Gravelly - with sand and rock fragments	Greenish Gray	Very Stiff	CL	65		37			
				66					
				67					
-with coarse gravel, sand, sandstone fragments, upper 6" conglomerate cemented and hard, basalt fragments up to 2"	Bluish Gray	Hard		68		[75]			
				69					LL = 38 PI = 18 -200 = 72.2 Sieve Analysis Torsional Ring Shear (See Appendix A)
-weak clay rich zone 69-69.5 feet		Soft		70					
				71					
				72					
-72-75 feet: zones of deeply weathered siltstone with gravel, zones of clay, abundant fractures	Dark Gray to Grayish Brown	Very Stiff		73					
				74					
				75					
		Hard		76					
				77					
				78					
SILTSTONE/SANDSTONE - competent bedrock below 78 feet, low hardness, friable to weak, moderately weathered	Gray to Bluish Gray		BR	79					
				80					
				81					
				82					
				83					
SILTSTONE - low hardness, friable, little weathered	Dark Gray to Black		BR	84					
				85		50/5.5"			
				86					
				87					
				88					
-moderately weathered				89					
				90		50/5.5"			
				91					
				92					
				93					
-weak, little weathered				94					
				95		50/4"			
				96					
				97					
				98					

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**3 of 4**	**AKA-25**

DESCRIPTION AND REMARKS *(Continued from Previous Page)*	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
SILTSTONE - low hardness, friable, little weathered	Dark Gray to Black		BR	99					
				100		50/6"			
				101					
				102					
				103		50/2"			

Bottom of boring at 103.7 feet.

NOTES:

1. Groundwater elevations obscured due to rotary wash drilling method.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Penetration resistance values shown have not been corrected for hammer energy.
5. Elevations were provided by LBNL.
6. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**4 of 4**	**AKA-25**

DRILL RIG: D51, Rotary Wash	**SURFACE ELEVATION:** 741 feet (see notes)	**LOGGED BY:** AL
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 5" inches	**DATE DRILLED:** 6/30/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
-3' Asphalt Concrete									
CLAY, Fat - with sand, some fine gravel, moist	Dark Brown to Black	Stiff	CH	1, 2, 3, 4, 5	X	[15]			
CLAY, Lean - with sand, some gravel	Mottled Brown and Light Brown	Stiff	CL	6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	X	[17]			
CLAY, Lean - some sand, trace fine gravel	Gray	Stiff	CL	22, 23, 24, 25, 26, 27, 28, 29					

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**1 of 4**	**AKA-26**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean - some sand, trace fine gravel -fine to coarse gravel, rock fragments	Gray Gray with Reddish Brown	Stiff	CL	31		[21]			PP = 3.0 tsf
				32					
				33					
				34					
				35					
				36					
				37					
				38					
				39					
				40					
				41					
				42					
				43					
CLAY, Lean - some sand, fine gravels	Mottled Reddish Brown and Bluish Gray	Very Stiff	CL	44					
				45		[39]			PP = 2.75 tsf
				46					
				47					
				48					
				49					
				50					
				51					
				52					
				53					
				54					
				55					
				56					
				57					
				58					
				59					
				60					PP = 2.25 tsf
CLAY, Lean - some sand, rock fragments	Mottled Gray, Bluish Gray and Reddish Brown	Very Stiff	CL	61		[47]			PP = 2.5 tsf
				62					
	Dark Gray			63					
				64					

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**2 of 4**	**AKA-26**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean - some sand, rock fragments	Mottled Gray, Bluish Gray and Reddish Brown	Very Stiff	CL	65					
				66					
-sandy, gravelly	Greenish Gray			67					
				68					
	Bluish Gray			69					
				70					
CLAY, Lean - with silt, some sand and gravel, rock fragments, (conglomerate)	Mottled Gray, Bluish Gray, Reddish Brown	Hard	CL	71		50/3"			
				72					
				73					
				74					
SILT, Gravelly - rock fragments, some clay	Bluish Gray	Hard	ML	75					
				76		50/5"			
CLAY, Lean - with sand lenses fine to medium size gravel, rock fragments	Olive Gray and Greenish Gray	Hard	CL	77					
				78		50/5"			
-very fine grained crystalline rock in clay matrix	Dark Gray to Black					50/4"			
				79					
				80					
				81					
				82					
SILTSTONE - competent bedrock below 82 feet, low hardness, weak, little weathered	Gray to Bluish Gray		BR	83					
				84		50/3"			
				85					
				86					
				87					
				88					
				89		50/1"			
				90					
				91					
-hard, moderately strong, little weathered	Gray to Dark Gray			92		50/2"			
				93					
				94					
				95		50/2"			
				96					
				97					
				98					

(Continued on Next Page)

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**3 of 4**	**AKA-26**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
SILTSTONE - low hardness, weak, little weathered, increased in sand content	Gray to Dark Gray		BR	99					
				100		50/1.5"			
Bottom of boring at 100.3 feet.									

NOTES:

1. Groundwater elevations obscured due to rotary wash drilling method.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Penetration resistance values shown have not been corrected for hammer energy.
5. Elevations were provided by LBNL.
6. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".

DRILL RIG: D51, Rotary Wash	**SURFACE ELEVATION:** 739 feet (see notes)	**LOGGED BY:** AL
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 5" inches	**DATE DRILLED:** 7/1/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
-3" Asphalt Concrete									
CLAY, Lean, Sandy - with gravel	Black and Dark Gray	Stiff	CL	1					
				2					
				3					
				4					
				5					
				6					
				7					
				8					
				9					
-gravelly with some sand	Brown to Dark Brown			10					
				11		[15]			
				12					
				13					
				14					
				15					
				16					
-trace fine gravels	Reddish Brown			17					
				18					
				19					
	Dark Grayish Brown			20					
				21					
				22					
				23					
				24					
CLAY, Lean, Gravelly - with sand lenses, subangular fine gravel	Brown with Bluish Gray, Greenish Gray and Yellowish Brown	Stiff	CL	25					PP = 1.0 tsf
				26		[19]			PP = 1.7 tsf
				27					
				28					
				29					

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**1 of 4**	**AKA-27**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean, Gravelly - with sand lenses, subangular fine gravel	Brown with Bluish Gray, Greenish Gray and Yellowish Brown	Stiff	CL	31 32 33 34					
CLAY, Lean - with fine to coarse gravels, sand lenses, siltstone fragments	Mottled Dark Bluish Gray, Greenish Gray and Brown	Very Stiff	CL	35 36 37 38 39 40 41 42 43 44	X	[26]			PP = 1.75 tsf
-trace fragments of siltstone, sand lense, fine to medium size gravel	Reddish Brown with Bluish Gray	Hard		45 46 47 48 49 50 51 52 53 54	X	[59]			PP = 3.75 tsf PP = 2.75 tsf
CLAY, Lean, Gravelly - with sand and siltstone fragments	Greenish Gray and Bluish Gray	Hard	CL	55 56 57 58 59 60 61 62 63 64	X	[90]			PP = 1.75 tsf PP = >4.5 tsf

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**2 of 4**	**AKA-27**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
		Hard	CL	65		50/1'			
CLAY, Lean - with gravel, sand and siltstone fragments, rock blocks up to 3", conglomerate, sandstone, siltstone	Bluish Gray	Hard	CL	66					
				67					
-basalt and quartz fragments	Brown			68					
-sandy, gravelly, abundant siltstone clasts, occasional quartz, trace sandstone fragments	Brown			69					
				70					
				71					
-highly weathered, clay-lined sandstone 72-74 feet	Gray to Dark Gray			72					
				73					
-74-74.8 feet - potential failure surface, clay rich with trace fine to coarse silty sandstone fragments		Soft		74					LL = 36 PI = 17 -200 = 53.2 Sieve Analysis Torsional Ring Shear (See Appendix A)
				75					
-highly weathered and fractured sandstone in a clay matrix at 76'				76					
-possible weak shears of soft clay at 77'	Greenish Gray to Bluish Gray	Soft		77					
SANDSTONE - competent bedrock below 78 feet, weak, deeply weathered, instensly fractured	Gray to Black		BR	78					
				79					
				80					
SILTSTONE - low hardness, friable, moderately weathered	Gray to Olive Gray		BR	81					
				82					
				83					
				84					
				85					
SANDSTONE - low hardness, friable, moderately to deeply weathered	Gray to Bluish Gray		BR	86					
				87		78			
				88					
				89					
SILTSTONE/CLAYSTONE - with fine sand, low hardness, friable, moderately weathered	Gray to Dark Gray		BR	90		50/3"			
				91					
				92					
				93					
				94					
	Dark Gray			95					
				96		71			
				97					
				98					

(Continued on Next Page)

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**3 of 4**	**AKA-27**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
SILTSTONE/CLAYSTONE - with fine sand, low hardness, friable, moderately weathered	Gray to Dark Gray		BR	99					
				100		50/3.5"			
				101					
				102					
				103					
				104					
-intensely fractured	Gray			105		50/2"			

Bottom of boring at 105.2 feet.

NOTES:

1. Groundwater elevations obscured due to rotary wash drilling method.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Penetration resistance values shown have not been corrected for hammer energy.
5. Elevations were provided by LBNL.
6. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".

DRILL RIG: D30, Rotary Wash	**SURFACE ELEVATION:** 734 feet (see notes)	**LOGGED BY:** AL
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 5" inches	**DATE DRILLED:** 6/30/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
GRAVEL - well-graded, with sand (Base Rock)	Gray	Dense	GW	1, 2, 3					
CLAY, Lean - with silt, some fine to medium size gravel, moist	Mottled Gray, Olive Gray and Brown	Stiff	CL	4, 5, 6, 7, 8, 9	X	[19]			
CLAY, Lean - with fine gravel	Gray to Grayish Brown		CL	10, 11, 12, 13, 14					
-with silt, fine gravel	Mottled Reddish Brown, Gray and Dark Gray	Hard		15, 16	X	[49]			
		Very Stiff		17	X	[47]			
-sandy, some fine gravel	Light Brown			18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29					

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**1 of 4**	**AKA-28**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean, Sandy - with fine gravel and rock fragments	Brown	Very Stiff	CL	31		[28]			
				32					
				33					
				34					
				35					
				36					
	Gray to Greenish Gray			37					
				38					
				39					
				40					
	Bluish Gray			41		[38]			
				42					
				43					
				44					
				45					
				46					
				47					
				48					
				49					
				50					
-decrease on sand	Mottled Greenish Gray and Bluish Gray	Hard		51		[55]			
				52					
				53					
				54					
				55					
	Greenish Gray to Bluish Gray	Very Stiff		56		[29]			
				57					
				58					
				59					
				60					
-with less clay to deeply weathered sandstone/siltstone	Gray to Bluish Gray	Hard		61		[52]			
				62					
				63					
				64					

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**2 of 4**	**AKA-28**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
SANDSTONE to SILTSTONE - competent bedrock below 64 feet, low hardness, friable, moderately weathered, with fractures	Gray to Bluish Gray		BR	65 66 67 68 69		50/5'			
SILTSTONE - with sand, low hardness, friable, moderately weathered	Greenish Gray		BR	70 71 72 73 74 75 76 77 78 79		52			
-blocky	Gray			80 81 82 83 84 85 86 87 88 89 90		86 50/4.5"			

Bottom of boring at 90.9 feet.

NOTES:

1. Groundwater elevations obscured due to rotary wash drilling method.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Penetration resistance values shown have not been corrected for hammer energy.

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EXPLORATORY BORING LOG

HELIOS BUILDING - LINE E BORINGS
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4D	**October 2008**	**3 of 4**	**AKA-28**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									

5. Elevation was estimated based on surface topography and other boring elevations.

SOIL AND ROCK CLASSIFICATION KEYS TO BORINGS
AKA 29, AKA 29A, AKA 30, AKA 31 and AKA 32A

Example soil log header

Project Name and Job Number	WLA William Lettis & Associates, Inc.	SOIL LOG - Boring No.

1 Depth (feet)	2 Sample	3 Sample Type & No.	4 Uncorrected Blows/6 inches	5 Recovery (inches)	6 Water Content	6 Grain Size	6 Atterberg Limits	7 Lithology	8 Soil Type (USCS)	9 Lithology	10 Remarks	11 Instrument.	12 Elevation (feet)

Example rock log header

Project Name and Job Number	WLA William Lettis & Associates, Inc.	ROCK LOG - Boring No.

1 Depth (feet)	7 Lithology	13 Drill Rate (mm/ft)	14 Run No.	15 Recovery / Cut	16 % RQD	17 Weathering	18 Strength	19 In-Situ Testing	20 Discontinuity log	21 Discontinuity Description	9 Lithology	10 Remarks	11 Instrument.	12 Elevation (feet)

Explanation of log fields

1 Depth (feet)	Distance in feet below the borehole collar
2 Sample	See Table 1
3 Sampler Type & No.	Sampler type and sample number for each attempt
4 Uncorrected Blows/6 inches	Number of hammer blows needed to advance SPT sampler six inches
5 Recovery (inches)	Length of soil sample in inches recovered from each attempt
6 Water Content, Grain Size, Atterberg Limits	Results of lab testing data, if applicable. Water content given as percent by weight. For grain size analysis, see Table 2 (below). Atterberg limits include plastic limit (PL), and liquid limit (LL).
7 Lithology	Graphic log using symbols to describe soil and rock lithologies of borehole materials (See Table 2)
8 Soil Type (USCS)	See Table 2
9 Lithology	Lithologic description of samples. Descriptive terms defined on Tables 3 through 5.
10 Remarks	Rig geologist's observations and driller's feedback
11 Instrument.	Piezometers, etc., see Table 6 (if applicable)
12 Elevation (feet)	Elevation in feet referenced to the indicated vertical datum
13 Drill Rate (min/ft)	Time (minutes:seconds) for drill string to advance one foot
14 Run No.	Coring interval number
15 Recovery/Cut	Ratio of sample recovery length to total run length
16 RQD	Rock Quality Designation: percentage of sound, intact core greater than 4 inches in length
17 Weathering	See Table 7
18 Strength	See Table 8
19 In-situ testing	Description and interval of in-situ testing
20 Discontinuity Log	Naturally occurring fractures showing angle relative to core axis
21 Discontinuity Description	See Table 9

BORING LOG KEY

Table 1. Sample symbology

- Auger cuttings
- Soil core
- Grab sample
- Modified california sampler
- Standard Penetration Test (SPT) sampler
- Undisturbed sample

Table 2. Unified soil classification system

Major Divisions		Symbols	Typical Names
Coarse-grained soils (more than half of soil > no. 200 sieve size)	Gravels (More than half of coarse fraction > no. 4 sieve size)	GW	Well-graded gravels or gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels or gravel-sand mixtures, little of no fines
		GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
	Sands (More than half of coarse fraction < no. 4 sieve size)	SW	Well-graded sands or gravelly sands, little or no fines
		SP	Poorly-graded sands or gravelly sands, little or no fines
		SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
Fine-grained soils (more than half of soil <no. 200 sieve size)	Silts and Clays LL = < 50	ML	Inorganic silts and clayey silts of low plasticity, sandy silts, gravelly silts
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, lean clays
		OL	Organic silts and organic silt-clays of low plasticity
	Silts and Clays LL = > 50	MH	Inorganic silts of high plasticity
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic silts and clays of high plasticity
Highly Organic Soils		PT	Peat and other highly organic soils

Table 3. Moisture condition classification scale

Dry	Absence of moisture, dusty, dry to the touch
Damp	Slight moisture content, difficult to mold fines into ball
Moist	Moisture evident but no visible water, fines can be molded into ball
Wet	Visible free water, soil is usually below water table

Table 4 Consistency (fine grained samples)

SPT blow counts	Pocket Pen. (ksf)	Consistency	Field Test
≤2	≤1/4	Very soft	Extruded between fingers when squeezed
2 - 4	1/4 - 1/2	Soft	Molded by light finger pressure
4 - 8	1/2 - 1	Medium stiff	Molded by strong finger pressure
8 - 15	1 - 2	Stiff	Readily indented by thumb but penetrated with great effort
15 - 30	2 - 4	Very stiff	Readily indented by thumbnail
>30	>4	Hard	Indented with difficulty with thumbnail

Density (coarse grained samples)

SPT blow counts	Density
0 - 4	Very loose
4 - 10	Loose
10 - 30	Medium dense
30 - 50	Dense
> 50	Very dense

Table 5. Classification of additional characteristics

Fine-grained components (modified from ASTM 2488-93)

Dry strength		Dilatency		Toughness		Plasticity	
None	Crumbles with mere pressure	None	No visible change	Low	Slight pressure, thread soft and weak	Non-plastic	Thread can't be rolled at any water content
Low	Crumbles with some pressure	Slow	Water appears slowly on surface and disappears slowly upon squeezing	Medium	Medium pressure, thread medium stiff	Low	Thread can barely be rolled, ball can't be formed after rolled
Medium	Crumbles with considerable pressure			High	Considerable pressure, thread very high stiffness	Medium	Thread easily rolled, can't be rerolled
High	Breaks between thumb and hard surface	Rapid	Water appears quickly on surface and disappears quickly			High	Considerable time needed to roll thread, can be rerolled several times, ball can be formed without crumbling when direr than PL
Very High	Can't be broken						

Table 6. Well construction symbology

- Bentonite seal
- Capped riser
- Cement seal
- Filter pack
- No backfill (just pipe)
- Pipe cap
- Slotted pipe
- Slough backfill
- Top cap

Table 7. Rock weathering classification scale

Designation	Symbol	Field Identification	Grade
Fresh	F	No visible sign of rock material weathering: perhaps slight discoloration on major discontinuity surfaces. Rings under hammer impact.	I
Slightly weathered	SW	Rock mass is generally fresh with slight discoloration in rock fabric. Discontinuities are stained and may contain clay. Decomposition extends up to 1 inch into rock.	II
Moderately weathered	MW	Less than 50% of rock is decomposed. Significant portion of rock shows discoloration and weathering effects. Crystals are dull and/or altered. Discontinuities are stained and may contain secondary minerals. Strength is significantly less than fresh rock.	III
Highly weathered	HW	Rock mass is more than 50% decomposed. Rock can be broken by hand or scraped with knife or pick. All discontinuities exhibit secondary mineralization. Surface of core is friable and/or pitted due to washing out of highly altered minerals by drill water.	IV
Completely weathered	CW	Rock mass is completely decomposed but rock fabric and structure may still be evident (saprolite). Specimen is easily crumbled or penetrated with pocket knife or geologic pick.	V
Residual Soil	RS	All rock material is decomposed to soil. Rock fabric and structure completely destroyed. There is a large change in volume, but soil has not been significantly transported.	VI

Modified from Brown (1981)

Table 8. Rock strength classification scale

Term	Hardness Designator/ Grade	Field Identification	Approximate Range of Uniaxial Compressive Strength
Extremely weak	R0	Can be indented with difficulty by thumb nail. May be friable or moldable with finger pressure.	< 150 psi
Very weak	R1	Crumbles under firm blows with point of geologic hammer. Can be pealed by a pocket knife.	150 - 725 psi
Weak	R2	Can be peeled or scraped by a pocket knife with difficulty. Cannot be scratched by fingernail. Shallow indentation made by firm blow of geologic hammer	725 - 3,625 psi
Medium strong	R3	Cannot be scraped or picked with a pocket knife. Specimen can be fractured with a single firm blow of a hammer/geologic pick	3,625 - 7,250 psi
Strong	R4	More than one blow of geologic hammer required to fracture specimen	7,250 - 14,500 psi
Very strong	R5	Specimen requires many hard blow of hammer to fracture or chip. Hammer rebounds after impact	14,500 - 36,250 psi
Extremely strong	R6	Specimen can only be chipped by hammer	> 36,250 psi

Modified from Brown (1981), Hoek (1996)

Table 9. Discontinuity abbreviations

TYPE		SURFACE SHAPE		ROUGHNESS		APERTURE	
be	bedding	pl	planar	po	polished	fi	filled
fa	fault	st	stepped	sm	smooth	he	healed
fo	foliation	wa	wavy	sl	slightly rough	op	open
fz	fracture zone			mo	moderately rough	ti	tight
jt	joint			ro	rough		
mb	mechanical break			st	stepped		
rf	random fracture						
sh	shear						
ve	vein						

AKA 29, AKA 29A, AKA 30, AKA 31 and AKA 32A
EXPLORATORY BORING LOGS

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SOIL TYPE DATA LOG - Boring No. AKA-29

Type and Diameter of Boring: SPT/MC / ~4"	Boring Location (UCB grid coordinates): -928.3N, 3924E		Total Depth: 28.7 feet
Drilling Contractor and Rig: Access / Minuteman	Elevation: 694.1 feet LBNL	Ground Water Depth: Not encountered	Depth to Bedrock: 24.7 feet
Sampling Method: SPT	Sample Driving Hammer/Drop: 140 lb. / 30 inches	No. of Samples: 20	Date Started: 10/30/08
	Borehole Inclination: -90	Logged by: K. Krug	Date Completed: 10/30/08

Reviewed by / Date: K. Krug 11/14/08

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0		SPT 1	4, 6, 8	18/18					CL	CLAY LEAN with sand and gravels; yellow; stiff; dry; large clasts of sandy siltstone; angular clasts 40%; dry clay matrix, no structure; clasts of Orinda Fm		694
1												693
2		SPT 2	7, 8, 9	16.8/18		%< #200=63%	PI=22 LL=38			0' to 5.0' repaired slope	Lab test at 2.5'	692
3		SPT 3	8, 9, 3	12/18							0' to 3.8' Fill	691
4										Soils, gravel	3.8' to 5.0' soils	690
5		SPT 4	5, 3, 6	12/18					CL	CLAY LEAN with gravels; very dark grayish brown (10YR 3/2); damp; little to low plasticity; medium stiff; clasts of silty material, 0.01' diameter, ~30%; some dry, loose Orinda (blue gray siltstone) clasts, (pocket pen= 4.5, TSF) (Qc_1)	5.0' to 6.6' buried soil horizon	689
6		SPT 5	4, 5, 6	18/18						CLAY LEAN - same as above - no gravels (Qc_1)		688
7												687
8		SPT 6	6, 9, 11	12/18							decrease in gravels, increase in plasticity	686
9		SPT 7	3, 5, 7	16.8/18					CL	CLAY LEAN with gravels; very dark grayish brown (10YR 3/2); damp; stiff to very stiff; medium plasticity; very fine grained; gravels 20%, subrounded, 0.01' to 0.05' diameter, rusted; sandstone clasts ~10%, yellow and green in color; Mg nodules; (Qc_1 slope wash material with soil development)	switched to drilling between holes	685
10												684
11		SPT 8	6, 7, 10	18/18							5.0' to 12.0' likely native siltstone clasts (non repaired); Qc1	683
12											abrupt contact	682
13		SPT 9	4, 5, 7	18/18					CH	CLAY FAT with gravel; dark grayish brown (10YR 4/2);damp; medium to high plasticity; stiff-V. stiff; pea-size well rounded clasts of siltstone and sandstone 10% to 5%; yellow-green Orinda Formation clasts, $Mn0_2$ staining; clay rich top and bottom, no shearing, 12.3' to 16.0', (pocket pen=2.5, TSF) (Qc_2)	native, non repaired slope, becomes less dark, changing to olive brown; Qc_2	681
14		SPT 10	6, 7, 10	14.4/18								680
15												

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SOIL TYPE DATA LOG - Boring No. AKA-29

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15		SPT 11	4 6 10	20.4/18						Qc2 (continued from previous page)		679
16									CH	CLAY FAT with gravels; olive brown (2.5Y 4/3); damp; stiff to very stiff; high plasticity; clasts 10-15% well distributed, 0.01' to 0.001' diameter, sandy/silty composition; MnO_2 staining; sand texture in matrix; Qc_3	gradual color change and softening	678
17		SPT 12	7 9 15	18/18							16.0' to 18.0' Pleistocene Qc3	677
18		SPT 13	7 8 12	20.4/18						increase in gravels; 15 - 20%; shale, sandstone, and siltstone; multiple weak soil horizons, (pocket pen= 2.25, TSF).		676
19											fining upwards sequence; 21.0' to 12.0'	675
20		SPT 14	10 12 15	18/18						gravels ~30%; pockets of yellow sand; clay matrix		674
21		SPT 15	7 18 23	18/18						Transition to Rock 21.3' to 22.0'		673
22										CLAYSTONE; olive gray (5Y 4/2); dry; hard; friable, highly broken and weathered, patina on blocky fractured surfaces, RQD is 0%; Great Valley Group/ Qls debris	22.0' to 24.7' translated rock; weathered and crushed with clay zones	672
23		SPT 16	27 29 40	12/18						23.1' to 23.2' abrupt red silty zone		671
24		SPT 17	19 41 50	20.4/18					CL	CLAY LEAN, yellowish olive brown; soft; very wet; grades to crushed siltstone; Qls plane?		670
25										SILTSTONE to SHALE; olive gray (5Y 4/2); dry; hard; friable, highly broken (crushed) and weathered, platy, subhorizontal fracturing with patina on blocky break surfaces, RQD is 0% (Great Valley Group)	Top of Rock at 24.7'	669
26		SPT 18	25 41 52	15.6/18								668
27		SPT 19	24 55	14.4/14.4								667
28		SPT 20	50/4 50/5	6/6								666
29											Final Depth at 28.7'	665
30												

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

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ROCK TYPE DATA LOG - Boring No. AKA-29A

Type and Diameter of Boring Auger, 101 Geobarrel/ ~4"	Boring Location (UCB grid coordinates) -925.8N, 3921.1E		Total Depth 50 feet
Drilling Contractor and Rig Gregg Drilling / CME 850	Elevation 694.1 feet LBNL	Ground Water Depth Not encountered	Depth to Bedrock 24.5 feet
Casing Size and Depth NA	Length of Core Barrel and Bit 7.5 feet / 1.5 feet	No. of Core Boxes 2	Date Started 11/10/08
	Borehole Inclination -90	Logged by K. Krug	Date Completed 11/10/08

Reviewed by / Date K. Krug 11/12/08

Depth (feet)	Lithology	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Discontinuity Log	Discontinuity Description	Lithology	Remarks	Elevation (feet)
0													694
1											Hand Auger to 5.0'		693
2													692
3													691
4													690
5											Drill 5' to 15' - No sampling. See log AKA-29 for Soil Data		689
6													688
7													687
8													686
9													685
10													684
11													683
12													682
13													681
14													680
15													

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ROCK TYPE DATA LOG - Boring No. AKA-29A

Depth (feet)	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Strength	Discontinuity Description	Lithology	Remarks	Elevation (feet)
15	4	Mod. Cal.-1	1.2/1.5			CL	CLAY LEAN, with sand and gravel, brown (10YR 4/3), very stiff, medium to low plasticity, 0.01' to 0.1' diameter gravel, subrounded Orinda clasts, 5%, trace sand (Qc) (Pocket Pen 3.0 TSF)	(lined mod. cal.)	679
	6								
16	11								678
17							16.5' to 20' drilled out - no sample		677
18								Good Water Return, ~95%	676
19									675
20	11	Mod. Cal.-2	1.2/1.5				CLAY to CLAYSTONE, olive brown (2.5Y 4/3), low strength, friable, intensely fractured, blocky with clay lining, heavily weathered, (Pocket Pen 4.5+ tsf)	(lined mod. cal.)	674
	23								
21	35						21.5' to 24.5' very intense fracturing with thin subhorizontal clay seams between crushed blocks of intensly weathered claystone (possible base Qls)		673
22	1.57	3	3.5/3.5	100	R1-R2				672
23	1.17						Alternating clay and hard rock lenses, approximately 0.01' thick, subparallel	23.5'	671
							23.5' to 24.0' hard shale lens, blocky 24.0' to 24.1' clay seam	24'	
24	2.88						24.0' to 24.5' banded claystone, weathered 0.01' clay bands ?	Good Water Return 24.5' T.O.R	670
	7.00								
25	2.00	4	2.5/5.0	50			SHALE, very dark gray (10YR 3/1), weak, friable, heavily weathered, oxidized patina on platy fractures, intensely fractured mechanically in blocky to platy breaks, subhorizontal, pieces are hard R1 to R2 [Great Valley Group]	Max of 400 PSI drilling pressure for run 3 and 4	669
26	1.00								668
27	1.42								667
28	1.22								666
29	2.00								665
30									

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ROCK TYPE DATA LOG - Boring No. AKA-29A

Depth (feet)	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Strength	Discontinuity Description	Lithology	Remarks	Elevation (feet)
30									664
	2.58				R1 to R2			Good Water Return, ~95%	
31							Alternating shale and claystone (Great Valley Group), SHALE is R1 to R2, friable, blocky, broken up by drilling		663
	2.00								
32									662
	5.00	5	3.0/5.0	60				32.5'	
33							CLAYSTONE, dark gray (GLEY1 4/4), moist to wet, FAT clays subhorizontal banding of colors, competent; where claystone present, weak and moist. (pocket pen 2.5 tsf) [Great Valley Group]		661
	5.00								
34							Hard zone, subvertical fractures	34'	660
	4.00								
35							CLAYSTONE, soft and clay-like, blocky, fresh breaks	34.8' 35' to 37.2' Lost to drilling	659
	3.50						SHALE/CLAYSTONE, alternating hard layers (R1) with subvertical fractures, and softer clay rich layers (R0), (Great Valley Group)		
36					R1 to R0				658
	0.67								
37									657
	2.00	6	2.8/5.0	56					
38							38.2' - Pocket Pen - 3.5 tsf	Runs 5 thru 7 - max of 400 PSI drilling pressure	656
	8.13								
39							38.7' Calcite viens and nodules present, 0.001' in diameter		655
	5.65								
40									654
	2.58								
41									653
	1.58								
42									652
	4.50	7	2.5/5.0	50				Samples wet due to drill mud intrusion	
43									651
	4.00								
44									650
	2.08								
45									

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ROCK TYPE DATA LOG - Boring No. AKA-29A

Depth (feet)	Lithology	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Discontinuity Log	Discontinuity Description	Lithology	Remarks	Elevation (feet)
45		5.00									SHALE/CLAYSTONE, R0 to R2, subvertical fractures and subhorizontal partins in clay rich layers, (Great Valley Group)	Good Water Return, ~90%	649
46		2.83					R0 to R2						648
47		2.83	8	4.0/5.0	80						At 47.0', 0.02' thick subhorizontal clay seam separating two blocks of shale/claystone	Run 8 - max 400 PSI drilling pressure	647
48		1.17											646
49		6.00											645
50											Total Depth - 50.0' Grouted upon completion		644
51													643
52													642
53													641
54													640
55													639
56													638
57													637
58													636
59													635
60													

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ROCK TYPE DATA LOG - Boring No. AKA-30

Type and Diameter of Boring 101 Geobarrel / ~4"	Boring Location (UCB grid coordinates) -943.6N, 4035.1E		Total Depth 50 feet
Drilling Contractor and Rig Gregg Drilling / CME D45	Elevation 729.7 feet LBNL	Ground Water Depth Not encountered	Depth to Bedrock 25.8 feet
Casing Size and Depth 6" / 3 feet	Length of Core Barrel and Bit 7.5 feet / 1.5 feet	No. of Core Boxes 3	Date Started 11/7/08
	Borehole Inclination -90	Logged by G. Van Etten	Date Completed 11/7/08

Reviewed by / Date K. Krug 11/17/08

Depth (feet)	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	Discontinuity Description	Lithology	Remarks	Elevation (feet)
0–5								Hand Augered to 5.0 feet		729–725
5–10	7, 15, 22	Mod. Cal. 1	1.5/1.5		MW	R0	CL	CLAY LEAN with sand and gravel; light olive brown (2.5Y 5/4), moist, stiff to very stiff, ~65% clay, ~15% sand, ~15% to 20% 0.01 to 0.005 foot diameter shales and Orinda Fm.clasts, mottled; (pocket pen - 1.25, tsf), reworked Qc, Fill, repaired slope?	5.0'	724–723
5–10	3.00, 3.18, 3.25, 3.05	1	3.1/3.5	89	MW	R0	CL	0.1' transition Changes to dark brown (10YR 3/3), very stiff, oxidized pockets, increase in gravels to 20% to 30%, large weathered blocks of Orinda Fm. with occasional calcite nodules (Pocket Pen - 3.5, 4.5+ tsf)	7.9'	722–721
10–11	14, 20, 28	Mod. Cal. 2	1.0/1.5		MW	R0	CL	Mixed color banding, yellow, green, brown, red, with sand and trace gravels of weathered Orinda Fm. and 0.005 foot diameter angular quartz, colorbands 0.01' to 0.1' thick, subhorizontal (Pocket Pen - 2.0, 2.5 tsf)	No Recovery on Mod. Cal. Sample from 10.0' to 10.5'	720–719
11–15	1.05, 3.27, 3.20, 3.53	2	2.5/3.5	71	MW	R0	CL	mottled clay with 20-25% gravels; gray reduced zones, plastic, damp	LAB test at 13' Liquid limit = 44, plasticity index = 24, %< #200=75	718–715

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ROCK TYPE DATA LOG - Boring No. AKA-30

Depth (feet)	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	Discontinuity Description	Lithology	Remarks	Elevation (feet)
15	8	Mod. Cal. 3	1.5/1.5				CL	CLAY with sand and gravel; very dark grey (2.5YR 3/1), moist, medium stiff to stiff, ~65% clay, ~15% to 5% sand, ~20% to 30% 0.2' to 0.01' diameter Orinda Fm. clasts (Pocket Pen - 3.0 tsf)		714
16	12									
	14									
17	0.92	3	1.6/3.5	46						713
	2.50							(Pocket Pen - 2.0 tsf)		712
18	2.18									711
19	2.07				MW	R0		mottled and mixed with yellowish clasts; soft, plastic, weak, (repaired slope? or debris flows?)		710
20	1.75	4	2.0/5.0	40				19.0' to 25.8' highly mixed zone of fractured rock and very soft clay; Qls debris	Large gravel clasts surrounded by dark brown sand at 20.7'	709
21	1.53							21.5' sandstone clast		708
22	1.52						CL	CLAY LEAN, with sand and gravel, brown (10YR 4/3), damp, medium plasticity, stiff to very stiff 10% sand,10% to 15% clasts of weathered, rounded sandstone ~ 0.1' diameter, (Pocket Pen - 2.5 tsf)		707
23	1.68									706
24	1.55								24.5' Rock clast	705
25	1.60	5	5.0/5.0	100	SW	R0 to R1		Sandstone clast, brown (10YR 4/3), strong R0 to R1, weathered, fine-grained, well cemented, oxidized, very slight reaction to HCl. (Pocket Pen - 3.5 tsf)	25.0'	704
26	1.70				F	R1		CLAY, with gravel, yellowish brown, (10YR5/6), damp, plastic/nonplastic, angular clasts, no clear laminations. Highly mixed zone of siltstone and sandstone with clay; very soft, plastic and weak (landslide basal plane?) (Pocket Pen -2.0+ tsf)	25.8' T.O.R	703
27	1.75									702
28	1.85							SANDSTONE, fine-grained with clay, yellowish brown (10YR 5/6), fresh, very weak,very fine grained, moderately lithified, highly fractured with clay infilling, broken into platy blocks along weathering rinds/patina, high angle fractures, no reaction to HCl. Rock broken into 0.1' pieces due to drilling; (Great Valley Group)		701
29	1.23						29.5' - clay lined 0.001' thick fracture, 65 degree dip, planar, smooth, tight (tectonic)	29.7' - MnO_2 stained clay		700
30										

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ROCK TYPE DATA LOG - Boring No. AKA-30

Depth (feet)	Lithology	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Discontinuity Log	Discontinuity Description	Lithology	Remarks	Elevation (feet)
30		1.88								30.0' to 31.5' - Clay infilled fractures, may be drill mud	SHALE/CLAYSTONE, yellowish brown (10YR 5/6) to dark yellowish brown; fresh; very weak; very fine grained with some sand, moderately lithified, highly fractured due to drilling, with planar joints dipping 30 to 60 degrees, clay infilling fractures, weathering rinds on many surfaces, increased competence of rock at 30.0' [Great Valley Group]		699
31		2.30											698
32		2.37	6	4.6/5.0	92						SHALE/CLAYSTONE, dark gray (N4), fresh, very weak, massive, few clay laminations, abundant joints, dipping 45 degrees, moderately lithified, highly fractured, joints have weathering rinds on planar surfaces, breaking into 0.2' to 0.4' competant pieces [Great Valley Group]		697
33		4.00											696
34		2.88											695
35		2.08											694
36		1.80											693
37		2.92	7	4.6/5.0	92	F	R1						692
38		3.18									37.7' to 38.4' very distinct weathered shale bed soft as clay with bedrock fabric intact, no laminations, weak zone; likely not a slide plane, but a weak claystone layer; very weak; calcium carbonate. (Pocket Pen - 2.5 tsf)		691
39		3.15											690
40		3.18											689
41		3.22									Abundant conchoidal fractures in hard shale; pieces no longer than 0.3'		688
42		4.23	8	4.4/5.0	0								687
43		3.17											686
44		8.33										Driller notes harder rock at 44'	685
45													

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ROCK TYPE DATA LOG - Boring No. AKA-30

Depth (feet)	Lithology	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Discontinuity Log	Discontinuity Description	Lithology	Remarks	Elevation (feet)
45		5.33	6	2.5/5.0	0	F	R1				CLAYSTONE, shaly, dark gray (N4), fresh,very weak R1, massive, few clay laminations, abundant joints, dipping 45 degrees, moderately to well lithified, highly fractured, joints have fresh planar surfaces, breaking into 0.3' or smaller pieces due to drilling [Great Valley Group]		684
46		6.18											683
47		18.72											682
48		15.23											681
49		7.05											680
50											Total Depth 50.0'		679
51													678
52													677
53													676
54													675
55													674
56													673
57													672
58													671
59													670
60													

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ROCK TYPE DATA LOG - Boring No. AKA-31

Type and Diameter of Boring: 101 Geobarrel / ~4"	Boring Location (UCB grid coordinates): -811.2N, 3679.1E		Total Depth: 90 feet
Drilling Contractor and Rig: Gregg / Fraste XL	Elevation: 675.8 feet LBNL	Ground Water Depth: Not encountered	Depth to Bedrock: 76.5 feet
Casing Size and Depth: NA	Length of Core Barrel and Bit: 7.5 feet / 1.5 feet	No. of Core Boxes: 32 samples	Date Started: 11/3/08
	Borehole Inclination: -90	Logged by: G. Van Etten	Date Completed: 11/4/08

Reviewed by / Date: K. Krug 11/17/08

Depth (feet)	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Discontinuity Description	Lithology	Remarks	Elevation (feet)
0									675
1									674
2									673
3							Fill/Qc_1 non-native clasts in clay with gravels	Started drilling at 5.0' after hand augering through the top 5.0'	672
4									671
5	1.08	1	3.4 / 3.0	100		CL	CLAY LEAN with sand and silt; very dark brown (7.5YR 2.5/3); moist/wet; medium stiff;~70% clay, ~20% fine sand, ~10% silt; slightly mottled with weathered sandstone pebble sized clasts, several gravel clasts, trace organics, soft; (Pocket Pen=1.0 tsf) Qc_2	5.8'	670
6	1.33							QC_2	669
7	1.42								668
8	1.28	2	4.5 / 4.0	100	MW		(Pocket Pen=1.5 tsf)		667
9	1.08						grading to more clayey, less sandy; increase in pebbles at 9.0'		666
10	1.17					CL	Steep contact or fracture dipping 50 degrees with color change; becomes dark brown; buried soil horizon to 12.0'		665
11	1.50						Stiff (Pocket Pen=2.0 tsf)		664
12	2.00	3	2.3 / 3.0	77		CL	CLAY with silt and sand; very dark brown (10YR 3/2) with several light brown and red zones; damp; medium stiff; ~60% clay, ~20% silt, ~15% coarse to fine sand, ~5% gravels; weathered greenish sandstone clasts; slightly mottled, poorly sorted, subhorizontal color banding, 1" laminations in organic horizons; fining downwards	12' QC_3	663
13	1.83								662
14	1.27						Banding becomes subhorizontal and multicolored with less gravels, soft at 13 feet Stiff (Pocket Pen=1.0 tsf)		661
15									

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ROCK TYPE DATA LOG - Boring No. AKA-31

Depth (feet)	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Discontinuity Log	Discontinuity Description	Lithology	Remarks	Elevation (feet)
15										CLAY LEAN with silt and sand; v. dark brown (10YR 3/2); medium stiff; ~60% clay, ~20% silt, ~15% coarse to fine sand, ~5% gravels; weathered greenish sandstone clasts; slightly mottled, poorly sorted, subhorizontal color banding; fining downwards; (Pocket Pen=1.5 tsf) Qc3	gradational contact over several feet	
16	1.63	4	3.1/3.0	100					CL		QC_3	660
	2.17										16.5'	659
17	2.27									Sandy Clay, as above; with 1-2" thick soft clay, subhorizontal and plastic; Qc4	16.8' to 16.9' red colored interbed of clay dipping ~10 degrees	658
18	1.58	5	5.2/5.0	100		R0			SC	10-15% clays with Orinda Formation siltstone clast with calcite; massive structure	subangular gravel clast of gabbro	657
19	1.47										QC_4	656
20	1.67									Clasts of sandstone; greenish gray (5G 3/1);large Orinda boulder		655
21	1.83										21.1' well cemented clast dipping 30 degrees	654
22	1.42				MW				CL	CLAY LEAN with silt and sand; very dark brown (10YR 3/2) with several light brown and red zones; damp; medium stiff; 20-25% fine, angular gravel; weathered greenish sandstone and shale clasts; poorly sorted, subhorizontal color banding and mottling; fining downwards; (Pocket Pen=1.75 tsf), Qc4	at 21.6, 0.1' thick light gray clay seam, plastic	653
23	1.77	6	1.9/4.0	48								652
24	1.75									24.4' to 27.0' changes to red (2.5YR 2.5/2); mottling abundant, (Pocket Pen=1.5 tsf)		651
25	2.37										24.9' gravel at bottom of Run 6; bottom 2' washed out	650
26	2.13											649
27	2.03	7	1.4/3.0	47					CL	No reddish mottling; dark gray, gray clay; 10-20% fines with sandstone and shale clasts, no clay seams; Qc5	27'	648
28	1.17											647
29	1.67									(Pocket Pen=1.75 tsf)		646
30												

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ROCK TYPE DATA LOG - Boring No. AKA-31

Depth (feet)	Lithology	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Discontinuity Log	Discontinuity Description	Lithology	Remarks	Elevation (feet)
30		1.43	8	3.5/3.0	100	MW				CL	CLAY LEAN with silt and some sand; very dark brown (10YR 3/2) with several light brown and redzones; damp; medium stiff to stiff; ~60% clay,~20% silt, ~15% coarse to fine sand, ~5%gravels; weathered greenish sandstone clasts; slightly mottled, poorly sorted, subhorizontal color banding; fining downwards		645
31		1.10											644
32		2.17									gravels 15-20%; 0.05' diameter; shale and siltstone, (Pocket Pen=1.25 tsf).	32.4'	643
33		1.75	9	1.7/2.0	95							QC_5	642
34		1.73									34.0' to 34.4' clay 34.4' to 35.2' greenish Orinda clast		641
35		2.08	10	3.6/3.0	100						(Pocket Pen=1.75 tsf)		640
36		2.17									36-36.5' clay with sand and 5% gravels, very soft plastic and grey (slide plane?)		639
37		2.10									CLAY; very dark gray (6YR 4/2); very abrupt upper contact ~45 degrees and clay rich	37' QC_6	638
38		1.67	11	3.0/3.0	100								637
39		2.50									39.0' to 39.4' reddish clay 39.5' planar cemented at 40' sandstone clast dipping ~40 degrees; rounded gabbro clast		636
40		2.37											635
41		2.17	12	4.0/4.0	100						41.0'-41.9' green with many gravels		634
42		1.77									CLAY LEAN with gravels; dark gray (10YR 4/1); damp; stiff; plastic; 10-15% clasts 0.01'-0.005' diameter, subrounded weathered Orinda Fm. and white calcite nodules stiff clay; Qc_7; 43.2' to 44.3' core is completely broken up; mechanical breaks	42' QC_7	633
43		1.58											632
44		1.67											631
45													

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ROCK TYPE DATA LOG - Boring No. AKA-31

Depth (feet)	Lithology	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Discontinuity Log	Discontinuity Description	Lithology	Remarks	Elevation (feet)
45		1.93									CLAY LEAN with silt and sand; very dark brown(10YR 3/2) with some dark greenish gray(5G 3/1) and very dusty red (10R 2.5/2); moist; medium stiff; ~60% clay, ~20% silt,10-15% gravels, 5-10% coarse to finesand; occasional weathered greenish-sandstone clasts; few pebbles; slightly-mottled; poorly sorted	fewer green gravel clasts	630
46		1.75	13	3.1/3.0	100								629
47		1.92											628
48		1.77											627
49		3.33	14	2.4/2.0	100						(Pocket Pen=1.25 tsf)		
											decreasing clast percentage; 5-10%	49.7'	626
50		2.83									Very clay rich gradational contact	50.5'	
											clay becomes dark brown (7.5YR 4/1)	50.7' to 58.0' No Recovery; drill spin at 50.7'	625
51		3.03	15	0.7/3.0	23								624
52		3.17				MW				CL		Qc_8	623
53		3.25											622
54		2.80	16	0.0/2.0	0								621
55		2.92											620
56		3.17	17	0.0/3.0	0								619
57		3.33											618
58		3.42									clay is weak red (2.5YR 4/2); large blocks of Orinda Fm. mixed with Qc containing angular Great Valley shale clasts at 62.0'	58.0' tripped out and put on new, longer, 101 shoe on sampler	617
59		3.17	18	1.2/2.0	60						(Pocket Pen=2.0 tsf)	58.2' sandstone clast that could have plugged hole Qc_9	616
60													

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ROCK TYPE DATA LOG - Boring No. AKA-31

Depth (feet)	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Discontinuity Log	Discontinuity Description	Lithology	Remarks	Elevation (feet)
60												
	2.25	19	2.3/2.0	100						CLAY LEAN with silt and sand; v. dark brown (10YR 3/2) with some dark greenish gray (5G 3/1) and very dusty red (10R 2.5/2); moist; medium stiff-stiff;~60% clay,~20% silt, 10-15% gravels, 5-10% coarse to fine sand; occasional weathered greenish sandstone clasts; few pebbles; slightly mottled 0.2'-0.3' thick; poorly sorted; Qc_9		615
61	3.08											614
62	4.03	20	3.0/3.0	100							62.0' stopped drilling on 10/3/08 at 3:30 due to rain	613
63	3.25								CL	62.9' to 63.2' sandy green interbed		612
64	3.08											611
65	2.67	21	2.2/2.0	100	MW	R0				CLAY LEAN with SAND and SILT; dark greenish gray (5G 3/1) with very dark brown (10YR 3/2); moist; stiff to very stiff; ~60% silt, ~20% clay, ~20% fine sand; trace pebbles; poorly sorted; slightly mottled; sandstone pebbles intermixed, (Pocket Pen = 3.75 tsf)	65.3' gradational contact	610
66	2.72										Qc_{10}	609
67	3.60	22	0.0/2.5	0						Highly variegated clay mixed with reddish brown and gray material	Run 22 no recovery	608
68	2.50											607
69	1.08									SHALE and siltstone; greenish black (5G 2.5/1); damp; medium stiff; silty clay intermixed; intensly fractured in subvertical, planar, blocky pieces with clay on surfaces and heavily crushed zones (landslide debris translated Great Valley Group)	69.5' Contact not directly sampled 69.5' to 70.8' drilled with rock bit on innerbarrel to get past the clast that blocked Run 22	606
70	NA											605
	NA											
71	NA											
	5.33	23	1.2/1.2	100							Approximately 5-8' wide disturbed zone near bedrock contact	604
72	5.17				SW	R0 to R1	Friction angle = 13 degrees Clay fraction = 11%			72.0', 0.4' thick clay seam; soft seam with shale clasts, sheared zone between weathered and bedrock		603
73	6.80	24	1.9/2.0	95					Torsional ring shear 73'		Liquid limit = 33 Plasticity index = 12 %< #200 = 38	602
74	5.63	25	0.0	0							Sieve analysis: gravel 2% Sand 60% Fines 38% Heavily crushed	601
75												

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ROCK TYPE DATA LOG - Boring No. AKA-31

Depth (feet)	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Discontinuity Log	Discontinuity Description	Lithology	Remarks	Elevation (feet)
75	4.33		1.8								Run 25 no recovery	
76	NA											600
	3.17	26	2.3/2.2	100	SW	R0 to R1				Base of Translated Rock, Qls SILTSTONE; black (5Y 2.5/2); damp; medium stiff; very weak; slightly weathered; ~75% siltstone, ~15% silt, ~10% sand; siltstone is shaly and highly fractured into angular clasts; weathering rinds on surfaces (Great Valley Group)	TOR 76.5' inferred contact increase in clay and oxidation	599
77	2.50											598
78	5.50	27	2.4/2.0	100						SILTSTONE; dark gray (N4); fresh; very weak; silty matrix between highly fractured, angular, shaly siltstone clasts; poorly sorted; smooth surfaces; poorly consolidated (Great Valley Group)	78.6' Top of competent rock	597
79	5.53											596
80	4.47	28	3.0/3.0	100								595
81	3.33											594
82	3.93											593
83	6.08	29	2.2/2.0	100								592
84	5.87				F	R1						591
85	5.85	30	2.5/2.5	100								590
86	4.00											589
87	3.33									increase in percentage rock; less silty matrix		
88	4.33	31	0.9/1.0	90								588
	6.17											
89	3.00	32	1.5/1.5	100								587
	7.22										Total Depth at 90.0'	586
90												

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ROCK TYPE DATA LOG - Boring No. AKA-32A

Type and Diameter of Boring: 101 Geobarrel / ~4"	Boring Location (UCB grid coordinates): -760N, 3859.1E		Total Depth: 50 feet
Drilling Contractor and Rig: Gregg / Fraste XL	Elevation: 716.4 feet LBNL	Ground Water Depth: Not encountered	Depth to Bedrock: 24.5 - 34.5 feet
Casing Size and Depth: NA	Length of Core Barrel and Bit: 7.5 feet / 1.5 feet	No. of Core Boxes: 7	Date Started: 11/4/08
	Borehole Inclination: -90	Logged by: G. Van Etten/K. Krug	Date Completed: 11/5/08

Reviewed by / Date: K. Krug 11/14/08

Depth (feet)	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	Discontinuity Description	Lithology	Remarks	Elevation (feet)
34								34.5 driller notes marked increase in downpressure and change in cuttings; Top of Rock 23.5 to 34.5' (TOR not directly sampled)	34.5' average down pressure 800-1000 psi	682
35	5	1	2.1/2.0	100				SHALE, dark olive brown (2.5Y 3/3); damp; newly/intensly fractured on smooth, blocky, and conchoidal surfaces with patina weathering rind; weathered, clay lined, no discernable bedding; weak, friable, R0; MnO_2 staining, no anomolous clay seems (Great Valley Group)	Good water return	681
36	6									680
37	4.8	2	2.9/2.8	100	MW	R0				679
38	9.5						healed, 70 degree dipping, gray, clay filled, weathered fracture	highly weathered siltstone/shale of Great Valley		678
39	2.1						yellow, weathered, gray, clay rich, 60 degree dipping fracture			677
40	4	3	2.2/2.2	100				suphorizontal partings		676
41	3.6							hard layer, increase in fracturing and weathering		675
42	6.3	4	0.8/1.2	0		R2		SHALE, dark olive brown (2.5Y 3/3); fresh; weak; heavily fractured with high angle healed fractures, and 0.1' to 0.3' shale clasts (Great Valley Group)	41.3' to 41.4' soft claystone layer; top of less weathered rock	674
43	1									673
44	5	5	1.2/1.7	0				hard shale; fresh breaks		672
	5							clay lined fractures		
45	5	6	2.3/2.4	100	SW			broken pieces of weathered shale to siltstone		671
46	6.2					R0 to R1		SHALE, very dark gray (2.5Y 2.5/1); damp, weak to extremely weak with soft and hard zones; subhorizontal partings and high angle healed fractures, smooth choncoidal surfaces (patina, clay rich), (Great Valley Group)	45.0' top of competent rock	670
47	1.5								good water return	669
48	7.5	7	2.9/2.7	100			45.0' to 50.0' many clay filled, healed fractures		45.0' to 50.0' many clay filled, healed fractures	668
49	4.3									

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ROCK TYPE DATA LOG - Boring No. AKA-32A

Depth (feet)	Lithology	Drill Rate (min/ft)	Run No.	Recovery / Cut	% RQD	Weathering	Strength	In-Situ Testing	Discontinuity Log	Discontinuity Description	Lithology	Remarks	Elevation (feet)
49		4.3	7	2.9 / 2.7	100	W	R0 to R1				49.0' to 49.2' red brown clay matrix to shale; weathered zone.	47.3' to 50.0' down pressure 500 psi	667
		2									50.0' end of boring; grouted upon completion. 11/5/08 at 10:30 am		
50													666
51													665
52													664
53													663
54													662
55													661
56													660
57													659
58													658
59													657
60													656
61													655
62													654
63													653
64													

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SOIL TYPE DATA LOG - Boring No. AKA-32A

Type and Diameter of Boring 101 Geobarrel / ~4"	Boring Location (UCB grid coordinates) -760N, 3859.1E		Total Depth 50 feet
Drilling Contractor and Rig Gregg / Fraste XL	Elevation 716.4 feet LBNL	Ground Water Depth Not encountered	Depth to Bedrock 24.5-34.5 feet
Sampling Method Auger	Sample Driving Hammer/Drop NA / NA	No. of Samples 7	Date Started 11/4/08
	Borehole Inclination -90	Logged by G. Van Etten/K. Krug	Date Completed 11/5/08

Reviewed by / Date K. Krug 11/14/08

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
0												716
1												715
2												714
3												713
4												712
5											Hand augered from 0' to 5.0'	711
6												710
7												709
8												708
9												707
10											Drilled through with rock bit plugging sampler; no samples	706
11												705
12												704
13												703
14												702
15												

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SOIL TYPE DATA LOG - Boring No. AKA-32A

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
15												701
16												700
17												699
18												698
19												697
20												696
21											clayey, light brown cuttings	695
22												694
23												693
24												692
25											Drilled through with rock bit plugging sampler; no samples	691
26												690
27												689
28												688
29												687
30												

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

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SOIL TYPE DATA LOG - Boring No. AKA-32A

Depth (feet)	Sample	Sample Type & No.	Uncorrected Blows/6 inches	Recovery (inches)	Water Content	Grain Size	Atterberg Limits	Lithology	Soil Type (USCS)	Lithology	Remarks	Elevation (feet)
30												686
31												685
32												684
33											33.0' end of auger drilling on 11/4/08	683
34										See rock log for continued borehole description		682
35												681
36												680
37												679
38												678
39												677
40												676
41												675
42												674
43												673
44												672
45												

Undisturbed sample
SH = Shelby; P = Pitcher; O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California; O = other

Standard Penetration Test (SPT) sampler

SOIL AND ROCK CLASSIFICATION KEYS TO BORINGS
AKA 32 through AKA 44

SOIL CLASSIFICATION CHART

PRIMARY DIVISIONS			SECONDARY DIVISIONS		
			CRITERIA *	GROUP SYMBOL	GROUP NAME
COARSE-GRAINED SOILS MORE THAN 50% RETAINED ON NO.200 SIEVE	GRAVELS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO.4 SIEVE	CLEAN GRAVELS LESS THAN 5% FINES	$Cu \geq 4$ AND $1 \leq Cc \leq 3$ [A]	GW	Well-graded gravel
			$Cu < 4$ AND/OR $1 > Cc > 3$	GP	Poorly-graded gravel
		GRAVELS WITH FINES - MORE THAN 12% FINES	FINES CLASSIFY AS ML OR MH	GM	Silty gravel
			FINES CLASSIFY AS CL OR CH	GC	Clayey gravel
	SANDS 50% OR MORE OF COARSE FRACTION PASSES NO. 4 SIEVE	CLEAN SANDS LESS THAN 5% FINES	$Cu \geq 6$ AND $1 \leq Cc \leq 3$	SW	Well-graded sand
			$Cu < 6$ AND/OR $1 > Cc > 3$	SP	Poorly-graded sand
		SANDS WITH FINES - MORE THAN 12% FINES	FINES CLASSIFY AS ML OR MH	SM	Silty sand
			FINES CLASSIFY AS CL OR CH	SC	Clayey sand
FINE-GRAINED SOILS 50% OR MORE PASSES THE NO.200 SIEVE	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50%	INORGANIC	PI > 7 AND PLOTS ON OR ABOVE "A" LINE	CL	Lean clay
			PI < 4 OR PLOTS BELOW "A" LINE	ML	Silt
		ORGANIC	$\frac{\text{LIQUID LIMIT - OVEN DRIED}}{\text{LIQUID LIMIT - NOT DRIED}} < 0.75$	OL	Organic Clay & Organic Silt
	SILTS AND CLAYS LIQUID LIMIT 50% OR MORE	INORGANIC	PI PLOTS ON OR ABOVE "A" LINE	CH	Fat clay
			PI PLOTS BELOW "A" LINE	MH	Elastic silt
		ORGANIC	$\frac{\text{LIQUID LIMIT - OVEN DRIED}}{\text{LIQUID LIMIT - NOT DRIED}} < 0.75$	OH	Organic Clay & Organic Silt
	HIGHLY ORGANIC SOILS		PRIMARILY ORGANIC MATTER, DARK IN COLOR, AND ORGANIC ODOR	PT	Peat

REFERENCE: Unified Soil Classification System (ASTM D 2487-06)

* Criteria may be done on visual basis, not necessarily based on lab testing

A – $C_u = D_{60}/D_{100}$ & $C_c = (D_{30})^2 / (D_{10} \times D_{60})$

GRAIN SIZES

U. S. STANDARD SERIES SIEVE				CLEAR SQUARE SIEVE OPENINGS			
200	40	10	4	3/4"		3"	12"
SILTS AND CLAYS	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

ABBREVIATIONS

INDEX TESTS

LL - Liquid Limit (%) (ASTM D 4318-05)

PI - Plasticity Index (%) (ASTM D 4318-05)

-200 - Passing No. 200 Sieve (%) (ASTM D 1140-00)

STRENGTH TESTS

PP - Field Pocket Penetrometer test of unconfined compressive strength (tsf)

TV - Field Torvane test of shear strength (psf)

UC - Laboratory unconfined compressive strength (psf) (ASTM D 2166-06)

TXUU - Laboratory unconsolidated, undrained triaxial test of undrained shear strength (psf) (ASTM D 2850-03a)

MISCELLANEOUS

ATOD - At time of drilling

psf/tsf - pounds per square foot / tons per square foot

psi - pounds per square inch (indicates relative force required to advance Shelby tube sampler)

SYMBOLS

Standard Penetration Test Split Spoon (2-inch O.D.)

Modified California Sampler (3-inch O.D.)

Thin-walled Sampler Tube (either Pitcher or Shelby) (3-inch O.D.)

Rock Core

Bag Sample

Groundwater Level

ALAN KROPP & ASSOCIATES

Geotechnical Consultants

KEY TO EXPLORATORY BORING LOGS

HELIOS PROJECT

University of California; Berkeley, California

PROJECT NO.	DATE
2500-4	**December 2008**

CONSOLIDATION OF SEDIMENTARY ROCKS; usually determined from unweathered samples. Largely dependent on cementation.

U = unconsolidated
P = poorly consolidated
M = moderately consolidated
W = well consolidated

BEDDING OF SEDIMENTARY ROCK

Splitting Property	Thickness	Stratification
Massive	Greater than 4.0 feet	Very thick-bedded
Blocky	2.0 to 4.0 feet	Thick-bedded
Slabby	0.2 to 2.0 feet	Thin-bedded
Flaggy	0.05 to 0.2 feet	Very thin-bedded
Shaly or platy	0.01 to 0.05 feet	Laminated
Papery	Less than 0.01 feet	Thinly laminated

FRACTURING

Intensity	Size of Pieces in Feet
Very little fractured	Greater than 4.0 feet
Occasionally fractured	1.0 to 4.0 feet
Moderately fractured	0.5 to 1.0 feet
Closely fractured	0.1 to 0.5 feet
Intensely fractured	0.05 to 0.1 feet
Crushed	Less than 0.05 feet

HARDNESS

1. **Soft** - Reserved for plastic material alone.
2. **Low Hardness** - Can be gouged deeply or carved easily by a knife blade.
3. **Moderately Hard** - Can be readily scratched by a knife blade; scratch leaves a heavy trace of dust and is readily visible after the powder has been blown away.
4. **Hard** - Can be scratched by a knife blade with difficulty; scratch produces little powder and is often faintly visible.
5. **Very Hard** - Cannot be scratched by a knife blade; leaves a metallic streak

STRENGTH

1. **Plastic -** Very low strength.
2. **Friable** - Crumbles easily by rubbing with fingers.
3. **Weak** - An unfractured specimen of such material will crumble under light hammer blows.
4. **Moderately Strong** - Specimen will withstand a few heavy hammer blows before breaking.
5. **Strong** -Specimen will withstand a few heavy ringing hammer blows and will yield with difficulty only dust and small flying fragments.
6. **Very Strong** -Specimen will resist heavy ringing hammer blows and will yield with difficulty only dust and small flying fragments.

WEATHERING - the physical and chemical disintegration and decomposition of rocks and minerals by natural processes such as oxidation, reduction, hydration, solution, carbonation, and freezing and thawing.

D. **Deep** - Moderate to complete mineral decomposition; extensive disintegration; deep and thorough discoloration; many fractures, all extensively coated or filled with oxides, carbonates and/or clay or silt.
M. **Moderate** - Slight change or partial decomposition of minerals; little disintegration; cementation little to unaffected. Moderate to occasionally intense discoloration. Moderately coated fractures.
L. **Little** - No megascopic decomposition of minerals; little or no effect on normal cementation. Slight and intermittent, or localized discoloration. Few stains on fracture surfaces.
F. **Fresh** - Unaffected by weathering agents. No disintegration or discoloration. Fractures usually less numerous than joints.

AKA 32 through AKA 44
EXPLORATORY BORING LOGS

DRILL RIG: D30, Rotary Wash	**SURFACE ELEVATION:** 694 feet (see notes)	**LOGGED BY:** AL
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 5 inches	**DATE DRILLED:** 10/31/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
-2" Asphalt Concrete over 6" Aggregate Base									
GRAVEL, Clayey - fine to coarse gravel with sand	Dark Brown and Black	Medium Dense	GC	1, 2					
FILL									
CLAY, Fat - high plasticity, sandy with some fine gravel, dry	Dark Brown, Yellowish Brown and Reddish Brown	Stiff to Very Stiff	CH	3, 4, 5					PP = 2.75 tsf
-with sand and trace gravel, moist	Reddish Brown and Grayish Brown			6, 7		[21]			PP = 2.5 tsf PP = 3.5 tsf
-medium to high plasticity, with trace sand and trace fine subrounded gravel	Reddish Brown			8, 9, 10		[21]	24	87	PP = 3.0 tsf PP = 1.5 tsf PP = 2.5 tsf
-sandy, with trace fine subrounded gravel and weathered siltstone fragments, wet and soft, very weak material (slide material?)	Reddish Brown and Greenish Brown	Firm to Stiff		11, 12, 13, 14		[15]			PP = 2.0 tsf PP = 1.0 tsf
-with sandstone fragments and weatered cobble	Olive Green and Reddish Brown			15, 16, 17		[30]			
CLAY, Lean - sandy, with fine to coarse gravel and some cobbles of Moraga volcanics	Reddish Brown	Very Stiff	CL	18, 19, 20		[40]			PP = 2.5 tsf PP = 2.0 tsf
-moist to dry				21, 22, 23		[36]			
CLAY, Lean - with silt, some sand, trace fine to medium subrounded gravel, and trace cobble, moist	Greenish Gray to Bluish Gray	Very Stiff	CL	24		23			

(Continued on Next Page)

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 3**	**AKA-32**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean - with silt, some sand, trace fine to medium subrounded gravel, and trace cobble, moist	Greenish Gray to Bluish Gray	Very Stiff	CL	26		[38]	26	101	PP = 4.25 tsf LL = 41 PI = 27 -200 = 87%
CLAY, Lean - low plasticity, with some sand and siltstone and claystone fragments, moist to wet	Bluish Gray	Very Stiff	CL	27					
				28					
				29		[36]			
				30					
				31					
				32					
				33		[29]			PP = 2.75 tsf
CLAY, Lean - with sand, siltstone fragments and medium angular gravel of Moraga volcanics	Bluish Gray to Grayish Brown	Very Stiff to Hard	CL	34					
				35					
	Greenish Gray to Bluish Gray			36					Sieve Analysis (see Appendix E)
				37		[50]	21	108	
				38					
				39					
	Greenish Gray, Black and Reddish Brown			40					
				41		[50]/6"			
-large angular boulder with silty sand (2.5 to 3 feet), gravel and rubble zone with Moraga volcanics and Orinda Formation clasts, very coarse colluvium	Black			42					
				43					
				44					
-gray weak clay zone at 45.5' to 46'				45					
				46		[57]			
-medium to low plasticity, with sand and gravels of Orinda and Moraga		**(TOP OF ROCK)**		47					
SILTSTONE - with clay and some sand, low hardness, friable to weak, moderately weathered, closely fractured, wet (Great Valley Group)	Grayish Brown and Gray		BR	48					
				49					
				50					
				51		[74]			
				52					
				53					

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**2 of 3**	**AKA-32**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
SILTSTONE - with clay and some sand, low hardness, friable to weak, moderately weathered, closely fractured, wet (Great Valley Group)	Grayish Brown and Gray		BR	54 55 56 57		[59]			
SANDSTONE - fine grained, silty and clay rich, low to moderate hardness, friable to weak, little to moderately weathered, well cemented (Great Valley Group)	Bluish Gray		BR	58 59 60		[50]/5"			

Bottom of boring at 60.9 feet.

NOTES:

1. Groundwater elevation is obscured due to rotary wash drilling method.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG
HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING **AKA-32**
2500-4	**December 2008**	**3 of 3**	

DRILL RIG: D45, Rotary Wash	**SURFACE ELEVATION:** 674 feet (see notes)	**LOGGED BY:** AL/GVE
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 5 inches	**DATE DRILLED:** 11/5/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
GRAVEL, Well-Graded - with sand, dry	Light Gray to Brown		GW	1					
CLAY, Lean, Gravelly - some roots, moist	Brown		CL	2, 3					
CLAY, Fat - with fine gravel, some silt, sand, and roots	Mottled Brown and Dark Brown	Firm to Stiff	CH	4, 5, 6, 7					
		Stiff		8, 9			25	100	LL = 52 PI = 34 TXUU 1190 psf (see Appendix E)
				10					PP = 1.25 tsf
				11, 12			23	103	TXUU 1500 psf (see Appendix E) PP = 1.0 tsf
-with rounded sandstone cobbles and sand	Olive Brown to Yellowish Brown	Soft to Firm		13, 14, 15, 16					
CLAY, Lean - with trace gravels of sandstone, shale, and volcanics; massive, damp, medium to low plasticity	Very Dark Gray	Stiff	CL	17, 18, 19					
				20					PP = 1.5 tsf
				21					
-increase in gravels 10-15% -brown soft clay 23.7' to 23.8'				22					PP = 1.75 tsf
				23					PP = 2.25 tsf
	Reddish Brown	Stiff to Very Stiff	CL	24					

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 3**	**AKA-33**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean - with fine grained sand and silt, decomposed organics, 15% gravel (0.01'-.005' diameter), rounded and weathered clasts, moist -sandstone boulder at 25.7 feet	Reddish Brown Dark Yellowish Brown	Stiff to Very Stiff	CL	26 27 28 29 30					PP = 2.7 tsf
CLAY, Lean - with sand and gravel, trace poorly sorted pebbles and fine gravel, moist; 15% gravel	Reddish Brown and Dark Gray	Stiff to Very Stiff	CL	31 32					PP = 3.7 tsf PP = 4.25 tsf
CLAY, Lean - with clasts and lenses of siltstone and clay matrix (Mixed Debris Zone, Potential Qls) -gravelly with sandstone fragments, increase in coarse gravels with soft clay matrix (50% clay; 30% gravel; 20% silt) -with silt and poorly sorted fine grained gravel and friable sandstone fragments	Very Dark Gray Brown Dark Gray	Stiff to Very Stiff **(TOP OF ROCK)**	CL	33 34 35 36 37 38 39 40 41					PP = 2.5 tsf PP = 3.5 tsf
CLAYSTONE - weak, fresh weathering, intensely fractured with zones of rounded pebble to gravel sized clasts (broken from drilling), silty between clasts (top of rock estimated at 41.5' based on poor recovery) -friable to weak claystone, shaley	Dark Gray		BR	42 43 44 45 46 47 48 49 50 51 52 53					

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**2 of 3**	**AKA-33**

DESCRIPTION AND REMARKS (Continued from Previous Page)	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAYSTONE - with silt and poorly sorted fine grained sandstone in fragments due to drilling, friable	Dark Gray		BR	54					
Bottom of boring at 55.0 feet.				55					

NOTES:

1. Groundwater elevation is obscured due to rotary wash drilling method.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG
HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**3 of 3**	**AKA-33**

DRILL RIG: D30, Rotary Wash	**SURFACE ELEVATION:** 653 feet (see notes)	**LOGGED BY:** GH
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 5 inches	**DATE DRILLED:** 11/5/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Fat - plastic, with some coarse sand and medium to coarse gravel, moist (Qc)	Mottled Olive Brown and Reddish Brown	Stiff	CH	1					
				2					
				3					
				4					
				5					
				6			27	97	LL = 63 PI = 40 TXUU 1080 psf (see Appendix E)
				7					
				8					PP = 1.25 tsf
				9					
				10			19	110	TXUU 1990 psf (see Appendix E)
				11					
-with lenses of shale, hard, deeply weathered, intensely fractured with oxidized surfaces below 11'	Greenish Gray			12					PP = 2.25 tsf
				13					
				14					
	Reddish Brown to Dark Gray			15					
				16					
				17					
CLAYSTONE/SHALE - soft with hard lenses, deeply weathered, intensely fractured, moist **(Translated Rock/Qls)**	Dark Greenish Gray			18		30			
SHALE - intensely fractured, oxidized with weak and thin clay lined fractures **(Translated Rock)**	Dark Greenish Gray			19					
				20					
				21					
-soft and weak clay rich shale, slide plane within weathered bedrock **(Qls)**				22		42			
CLAY/CLAYSTONE - soft with hard lenses, deeply weathered, intensely fractured, moist **(Translated Rock)**	Dark Greenish Gray			23					
SHALE - intensely fractured, oxidized with weak and thin clay lined fractures	Dark Greenish Gray			24					

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 2**	**AKA-34**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
(Translated Rock)	Dark Greenish Gray								
SHALE - intensely fractured, oxidized with weak and thin clay lined fractures **(Translated Rock)**	Bluish Gray			26					
		(TOP OF ROCK)		27					LL = 31 PI = 11 Sieve Analysis Torsional Ring Shear Test (see Appendix E)
CLAYSTONE - plastic, clay rich with fine weathered rock fragments, moderately hard to hard, crushed, wet **(Base Slide Plane)**	Bluish Gray		BR	28					
	Dark Gray		BR	29					
SHALE - intensely fractured, oxidized with weak and thin clay lined fractures	Dark Gray		BR	30					
CLAYSTONE - plastic, with fine weathered rock fragments in a soft clay matrix, moderately hard to hard, crushed, wet				31		52			
				32		50/3"			
SHALE/CLAYSTONE - moderately hard to hard, moderately strong, moderately weathered, intensely fractured									

NOTES: Bottom of boring at 32.3 feet.

1. Groundwater elevation is obscured due to rotary wash drilling method.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**2 of 2**	**AKA-34**

DRILL RIG: D30, Rotary Wash	**SURFACE ELEVATION:** 719 feet (see notes)	**LOGGED BY:** AL
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 5 inches	**DATE DRILLED:** 11/6/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Lean, Gravelly - with sand, some silt and roots, moist -2-inches of Asphalt at 1.5 feet	Dark Brown		CL	1 2 3					
CLAYSTONE - silty, weak, deeply weathered, blocky fractures lined with wet clay, moist **(Qc-Debris Mass)**	Yellowish Brown to Olive Gray			4 5 6 7 8 9		[29] 32			PP = >4.5 tsf
SILTSTONE - with some clay, low to moderate hardness, friable, moderately weathered, intensely fractured with oxidized zones **(Qc-Debris Mass)**	Yellowish Brown to Olive Brown			10 11 12		[50]			
-deeply weathered	Reddish Brown			13 14		51			
-with some clay, low hardness, weak to friable, little weathering	Olive Gray to Olive Brown			15		[50]/4" 50/5.5"			
SHALE - weak to friable, little weathering **(Qc-Debris Mass)**	Dark Greenish Gray			16 17 18 19					
-with clay, low hardness, friable, moderately weathered with some oxidized zones **(Base Qc-Debris Hollow)**	Mottled Reddish Brown, Black and Olive Gray	**(TOP OF ROCK)**		20					
SANDSTONE - with claystone pieces, low hardenss, friable to weak, deeply weathered (Great Valley Group)	Yellowish Brown and Olive Gray		BR	21 22 23 24		43			

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
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DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
	Yellowish Brown and Olive Gray		BR	26		[56]			
SHALE/CLAYSTONE - low to moderate hardness, friable (Great Valley Group)	Dark Greenish Gray, Reddish Brown and Gray		BR	27					
				28		32			
				29					
	Mottled Yellowish Brown, Black, Gray and Reddish Brown			30					
				31		[44]			
				32					
				33		45			
				34					
				35					
-with clay lined fractures	Gray			36		[50]/4"			
				37		89			
				38					
				39					
-low hardness, friable to weak, deeply weathered, intensely fractured with oxidized zones	Mottled Brown, Black and Olive Gray			40					
				41		[73]			
	Olive Gray			42					
				43		61			
				44					
-medium plasticity, hard	Gray			45					PP = >4.5 tsf
				46					
				47					
				48					
				49					
-hard, moderately strong, fresh to little weathering, calcite stet at 50 feet	Gray			50					
				51		[88]			
-weaker				52		50/6"			
				53					

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EXPLORATORY BORING LOG

HELIOS PROJECT
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PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**2 of 3**	**AKA-35**

DESCRIPTION AND REMARKS *(Continued from Previous Page)*	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
SILTSTONE - hard, friable, little weathering, closely fractured (Great Valley Group)	Mottled Yellowish Brown and Gray		BR	54					
				55		[50]/4"			
				56		50/6"			
				57					
				58					
				59					
				60		50/6"			
SILTSTONE - hard, moderately strong, little weathering, closely fractured, patina on fracture surface (Great Valley Group)	Gray to Dark Gray		BR	61					
				62					
				63					
				64					
				65					
				66		61			

Bottom of boring at 66.5 feet.

NOTES:

1. Groundwater elevation is obscured due to rotary wash drilling method.
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG
HELIOS PROJECT
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PROJECT NO.	DATE	SHEET	BORING **AKA-35**
2500-4	**December 2008**	**3 of 3**	

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 693 feet (see notes)	**LOGGED BY:** AL
DEPTH TO GROUNDWATER: 21 feet (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 10/29/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Lean - with sand, some gravel and trace roots, dry (FILL)	Yellowish Brown to Grayish Brown	Stiff to Very Stiff	CL	1		[23]	10	96	PP = >4.5 tsf LL = 40 PI = 23 -200 = 68%
-with some fine to medium subangular to subrounded gravel				2					
FILL				3		13			PP = >4.5 tsf
CLAY, Lean - with sand and fine to coarse subangular to subrounded gravel (Qc)	Light Brown with Bluish Gray Yellowish Brown with Olive Gray	Stiff to Very Stiff	CL	4		[36]			
				5					
				6		12			Sieve Analysis (see Appendix E)
-with some silt, sand and gravel, dry to moist	Mottled Brown, Olive Gray and Reddish Brown			7		[40]	16 13	112 109	PP = 3.5 tsf PP = >4.5 tsf
-clay seam: very thin slide plane at 8'				8					
-with sand and some gravel	Mottled Olive Gray, Brown, and Bluish Gray			9		20			PP = 3.25 tsf LL = 37 PI = 21 -200 = 65%
				10		[40]	15	112	
				11					
SILTSTONE - with clay and trace sand, low hardness, friable, deeply weathered, intensely fractured with trace roots, moist **(Translated Rock/Qls)**	Brown with Black and Gray			12		23			
				13		[85]			
-crushed rock w/ ~0.2' of clay (slide plane?)		**(TOP OF ROCK)**		14					
SILTSTONE - oxidized sections (Great Valley Group) with clay and sand, low hardness, friable, deeply weathered, moist	Reddish Brown to Olive Gray		BR	15		42			
				16		[50]/5"			
				17		68			
-moderately hard, weak, moderately weathered, closely fractured	Gray to Dark Gray			18		[93]	10	123	
				19					
-clay rich, friable to weak, moderate to little weathering, dry				20		62			
				21		34			▽
-dry to moist	Dark Gray			22					
				23		48			
				24					

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 2**	**AKA-36**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
SILTSTONE - clay rich, low hardness, friable to weak, little weathering, closely fractured, very wet (Great Valley Group)	Dark Gray		BR	26		62			
				27		50/5.5"			
				28					
				29		95			
Bottom of boring at 30.0 feet.				30					

NOTES:

1. Groundwater was encountered at approximately 21 feet at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG
HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**2 of 2**	**AKA-36**

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 703 feet (see notes)	**LOGGED BY:** DI/AL
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 10/28/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Lean - with silt, some sand and roots, dry (FILL)	Yellowish Brown to Grayish Brown	Firm	CL	1					Sieve Analysis (see Appendix E)
				2		[11]			
		Stiff		3					
				4		8	13	92	
FILL				5		[33]			
SILTSTONE - deeply weathered (Great Valley Group) **(Potential Translated Rock/Qls)**	Brown to Grayish Brown			6					
				7		35			LL = 40 PI = 19 -200 = 68%
				8		[50]/6"	10	119	
				9		97			
-deeply to moderately weathered	Light Grayish Brown to Gray			10					
				11					
				12					
-Brecciated with clay matrix, very weak, potential slide zone		**(TOP OF ROCK)**		13		45			
SILTSTONE - deeply weathered, (Great Valley Group)			BR	14		50/4"			
-low hardness, friable, with oxidized sections	Grayish Brown with Yellowish Brown			15					
				16		107/10"			
				17					
				18					
				19					
-clay rich with calcite	Gray to Dark Gray			20					
				21		100			
				22					
				23					
				24		50/4"			

Bottom of boring at 24.5 feet.

(Continued on Next Page)

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 2**	**AKA-37**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									

NOTES:

1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 704 feet (see notes)	**LOGGED BY:** AL
DEPTH TO GROUNDWATER: 22 feet (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 10/27/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Fat - silty, with some sand and roots, dry (Qc)	Brown to Yellowish Brown	Stiff	CH	1		[14]	12	92	PP = >4.5 tsf LL = 52 PI = 33 -200 = 94% PP = 3.75 tsf
				2					
				3		17			
				4		21			
-with fine rock fragments	Yellowish Brown and Olive Gray	Very Stiff		5					
CLAY, Lean / SILTSTONE - with sand, friable, deeply weathered with oxidized sections, (Great Valley Group) **(Translated Rock/Qls)**	Reddish Brown and Olive Gray			6		36			
				7		78			
				8					
				9					
-with trace sand, friable, moderately to deeply weathered	Gray and Yellowish Brown			10					
				11		50/4.5"			
				12					
	Light Grayish Brown to Gray			13					
				14		50/4.5"			
				15					
				16					
				17					
-moderately weathered				18					
				19		42			
				20					
				21					
CLAY, Lean - with silt/claystone materials crushed, wet, weathered **(Potential Qls Debris/Zone)**	Gray to Dark Gray			22					▽
				23		40			
				24		50/5"			

(Continued on Next Page)

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 2**	**AKA-38**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									
CLAY, Lean / SILTSTONE - with trace sand, friable, little weathering **(Qls Debris)**	Dark Gray			26 27		109/11"			
Bottom of boring at 27.4 feet.									

NOTES:

1. Groundwater was encountered at approximately 22 feet at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG
HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**2 of 2**	**AKA-38**

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 657 feet (see notes)	**LOGGED BY:** DI
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 11/5/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Lean - with silt, some sand and trace gravel	Yellowish Brown to Brown	Firm	CL	1					
				2					LL = 50 PI = 27 -200 = 85% PP = 4.5 tsf Sieve Analysis (see Appendix E)
		Stiff to Very Stiff		3		[14]	16	91	
		(TOP OF ROCK)		4					
SILTSTONE - low hardness, friable, deeply to moderately weathered, clay coatings on blocky fractures (Great Valley Group)	Yellowish Brown to Reddish Brown		BR	5		[34]			
				6		[69]			
				7		[50]/6"	11	113	
				8					
				9		78			
				10		94			

Bottom of boring at 10.5 feet.

NOTES:

1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 1**	**AKA-39**

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 648 feet (see notes)	**LOGGED BY:** DI
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 11/6/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Lean - moderately expansive, with silt, moist to wet	Brown to Dark Brown	Firm	CL	1					
				2		[10]			PP = 3.5 tsf
		Very Stiff		3		[28]			
		(TOP OF ROCK)		4					PP = 4.5 tsf
SILTSTONE/CLAYSTONE - soft hardness, friable, deeply weathered (Great Valley Group)	Yellowish Brown to Grayish Brown		BR	5		[51]	14	100	
				6		[93]			
				7					
				8		54			
				9		83			
				10					
				11		106			

Bottom of boring at 11.0 feet.

NOTES:

1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 1**	**AKA-40**

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 644 feet (see notes)	**LOGGED BY:** GH
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 11/6/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Lean - with weathered sandstone fragments and roots, moist (Qc/Qls)	Brown to Yellowish Brown	Soft	CL						
-silty with some medium gravel		Very Stiff		1		[18]			PP = >4.5 tsf LL = 30 PI = 12 -200 = 54%
-sandy with sandstone and claystone fragments, dry to moist	Yellowish Brown			2			11	108	PP = >4.5 tsf
-quaternary colluvium, coarse grained siltstone and shale clasts within a clay matrix		Very Stiff to Hard		3		[49]			PP = >4.5 tsf
-4' buried surface				4		[56]			PP = >4.5 tsf
				5					PP = >4.5 tsf
				6		[88]			
				7		40			
				8					
				9		63			
				10		60			
				11					
				12		69			
SILTSTONE - with shale clasts, hard, weak to friable, deeply weathered, intensely fractured **(Translated Rock/Qls)**	Dark Grayish Brown			13		77			
CLAYSTONE - with lenses of shale, low hardness, moderately strong, moderately weathered, intensely fractured **(Translated Rock/Qls)**	Grayish Brown			14					
				15		101			
-deeply weathered				16		56			LL = 35 PI = 16 -200 = 62%
-clay rich, friable, crushed	Olive Brown			17					
-**(Base of Qls/Debris Material)**		**(TOP OF ROCK)**		18		59			
CLAYSTONE - moderately strong, little weathering (Great Valley Group)			BR	19		53			
-moderately hard, weak to moderately strong, moderately weathered, intensely fractured	Gray Brown to Gray			20					
-with shale lenses, moderately strong, intensely to closely fractured	Gray Olive Brown			21		58			
-friable, deeply weathered, black seam, crushed				22		50/5" 50/4"			

Bottom of boring at 22.8 feet.

NOTES:

(Continued on Next Page)

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 2**	**AKA-41**

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
(Continued from Previous Page)									

1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 652 feet (see notes)	**LOGGED BY:** GH
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 11/6/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Lean - with sandstone fragments, moist (Qc)	Brown	Firm	CL	1		[6]			PP = 2.25 tsf
-interbedded with sandstone, moderately hard, little weathering	Brown	**(TOP OF ROCK)**		2					PP = >4.5 tsf
SANDSTONE - low hardness, weak, deeply weathered (Great Valley Group)	Yellowish Brown		BR	3		[27]			
CLAYSTONE - clayey with some sand, low hardness, friable, moderately weathered (Great Valley Group)	Yellowish Brown		BR	4		[24]			PP = >4.5 tsf
				5			12	114	PP = >4.5 tsf
-interbedded with gray siltstone at 5.7 feet, low to moderate hardness	Olive Gray			6		[57]			
-friable to weak, intensly weathered, crushed to intensely fractured with clay				7		[50]/5"	14	113	
				8					
-moderately hard, weak, moderate to little weathering, intensely fractured, clay lined	Yellowish Brown			9		40			
	Gray			10		60			
				11		65/6" 50/2.5"			

Bottom of boring at 11.2 feet.

NOTES:

1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 1**	**AKA-42**

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 653 feet (see notes)	**LOGGED BY:** AL
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 11/7/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Lean - with silt and roots, moist (Qc)	Brown	Stiff to Very Stiff **(TOP OF ROCK)**	CL	1		[13]	18	95	PP = 2.25 tsf PP = 3.25 tsf
SILTSTONE - with sand and roots, low hardness, friable, deeply weathered, clay lined fractures (Great Valley Group)	Yellowish Brown		BR	2 3 4		[38] [76]			
SANDSTONE - silty with black clay seams, low hardness, friable, deeply weathered, dry to moist (Great Valley Group)	Yellowish Brown		BR	5 6		[90]/10"	15	87	
SILTSTONE - low hardness, friable, deeply weathered, dry, clay lenses (Great Valley Group)	Yellowish Brown to Grayish Brown		BR	7 8 9 10		44 92/10.5" 92/11" 50/5"			

Bottom of boring at 10.8 feet.

NOTES:

1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 1**	**AKA-43**

AKA BORING LOG BORING LOGS.GPJ AKA_TEMPLATE.GDT 1/29/09

DRILL RIG: Minuteman, Solid Flight Auger	**SURFACE ELEVATION:** 679 feet (see notes)	**LOGGED BY:** AL
DEPTH TO GROUNDWATER: (see notes)	**BORING DIAMETER:** 3.5 inches	**DATE DRILLED:** 11/7/08

DESCRIPTION AND REMARKS	COLOR	CONSISTENCY	SOIL TYPE	DEPTH (ft)	SAMPLER TYPE	SAMPLER BLOW COUNTS	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	OTHER TESTS
CLAY, Lean - with silt and roots, moist (Qc)	Brown	Firm to Very Stiff	CL	1					PP = >4.5 tsf
	Reddish Brown	**(TOP OF ROCK)**		2		[12]			
SILTSTONE - low hardness, friable, deeply weathered (Great Valley Group)	Yellowish Brown		BR	3		[27]	12	100	
-moderately hard, weak, deeply weathered, dry	Olive Gray			4		[72]			
-friable, deeply weathered	Light Brown to Yellowish Brown			5					
-low hardness, friable to weak, deeply weathered				6		[99]/11"			
				7		43			
	Olive Gray			8					
				9		68			
-moderate to little weathering	Olive Brown to Olive Gray			10		43			
Bottom of boring at 11.3 feet.				11		98/10"			

NOTES:

1. No groundwater was encountered at the time of drilling and the boring was backfilled immediately after drilling. (See report for discussion.)
2. Stratification lines represent the approximate boundaries between material types and the transitions may be gradual.
3. Penetration resistance values (blow counts) enclosed in brackets ([ ]) were recorded with a 3.0-inch O.D. Modified California sampler; these are not standard penetration resistance values.
4. Elevations were provided by LBNL (Based on LBNL Datum).
5. Approximate unconfined compressive strength values were recorded in the field using a pocket penetrometer. These values are shown on the logs and are preceded by the symbol "PP".
6. Blow Counts have not been corrected for hammer energy.

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EXPLORATORY BORING LOG

HELIOS PROJECT
University of California; Berkeley, California

PROJECT NO.	DATE	SHEET	BORING
2500-4	**December 2008**	**1 of 1**	**AKA-44**

APPENDIX B

SELECTED BORING LOGS AND TRENCH DATA FROM PREVIOUS REPORTS

Point Data

Used in Sections	GIS ID	Data Source[1]	LBNL Building ID	Original Report[1]	Data Type	Alternate Data ID[2]	Original Data ID
A	14	Dames_Moore_1962_Bld77_LBNL171	77	N/A	Boring	106.17	106
A	15	Dames_Moore_1962_Bld77_LBNL171	77	N/A	Boring	107.17	107
C	28	Dames_Moore_1963_Bld62_LBNL120	62	N/A	Boring	5.120	5
C	30	Dames_Moore_1963_Bld62_LBNL120	62	N/A	Boring	7.120	7
C	35	Geomatrix_1994_EHS_LBNL351	9-EH&S	N/A	Boring	-	4
C	38	Geomatrix_1994_EHS_LBNL351	9-EH&S	N/A	Boring	-	3A
	39	Geomatrix_1994_EHS_LBNL351	9-EH&S	N/A	Boring	-	4A
A	40	Geomatrix_1994_EHS_LBNL351	9-EH&S	N/A	Boring	-	5A
A	41	Geomatrix_1994_EHS_LBNL351	9-EH&S	N/A	Boring	-	6A
B	43	HLA_1979_.138_Bld62_LBNL123	62	HLA_1975_.100	Boring	2.1	2
C	50	HLA_1980_.147_Bld62_72_LBNL127	62-72	HLA_1963_.009_LBNL121	Boring	2.9_2.009	2
C	52	HLA_1980_.147_Bld62_72_LBNL127	62-72	HLA_1963_.009_LBNL121	Boring	2A.9_2A.009	2A
B	65	HLA_1980_.147_LBNL195	72b_75	N/A	Boring	9.147, 9A.147	9, 9A
A	85	HLA_1983_.179_LBNL163	77A	N/A	Boring	9.179	9.179
A	96	HarzaKaldveer_1993_ChickenCreek_LBNL300	C. Cr Parking	N/A	Boring	300.5, PB-5_LBNL300	EB-5
A	181	P_Jordan_2007_NoLBNL_Figure4-2b	31	unofficial	Boring	-	SB31-97-2
A	185	HarzaKaldveer_1995_1993_ChickenCreek_LBNL352	31	N/A	Boring	EB-4	EB31-4_352
D	221	WLA_2008_NoLBNL_job2020	Centennial Drive	Pending 2008	Boring	-	WLA-1
A	384	HarzaKaldveer_1995_1993_ChickenCreek_LBNL352	Chicken Creek	N/A	Boring	5-352	EB-5
B	385	HarzaKaldveer_1995_1993_ChickenCreek_LBNL352	Chicken Creek	N/A	Boring	6-352	EB-6
A and C	387	HarzaKaldveer_1995_1993_ChickenCreek_LBNL352	Chicken Creek	N/A	Boring	8-352	EB-8

Line Data

Used in Sections	GIS ID	Data Source[1]	LBNL Building ID	Original Report[1]	Data Type	Alternate Data ID[2]	Original Data ID
C	3	Geomatrix_1994_EHS_LBNL351	9 -EHS	N/A	Test Pit	-	T1
E	17	Geomatrix_1994_EHS_LBNL351	9 -EHS	N/A	Test Pit	-	T18
B	25	Kleindelder_2002_2003_Bld67_LBNL402pg60	67	N/A	Test Pit	-	TP-1
B	27	Kleindelder_2002_2003_Bld67_LBNL402pg60	67	N/A	Test Pit	-	TP-3
A	32	AKA_2008_Helios_NoLBNL_Survey1930	Helios	Appendix B	Seismic Line	Line 1	Line 1
A	33	AKA_2008_Helios_NoLBNL_Survey1930	Helios	Appendix B	Seismic Line	Line 2	Line 2
A	35	AKA_2008_Helios_NoLBNL_Survey1930	Helios	Appendix B	Seismic Line	Line 4	Line 4

Notes:

1) Most data was obtained directly from the original report in which it was first presented. However, due to information loss, the original reports do not always present the data or locations, and in some cases the reports themselves are no longer on file at LBNL.

2) Represents the previous designation of the data by others.

FOUNDATION INVESTIGATION

PROPOSED MECHANICAL SHOPS, BUILDING 77
LAWRENCE RADIATION LABORATORY
BERKELEY, CALIFORNIA

FOR THE UNIVERSITY OF CALIFORNIA

BLDG. 77

JUN 1 1971

PLANT ENG.
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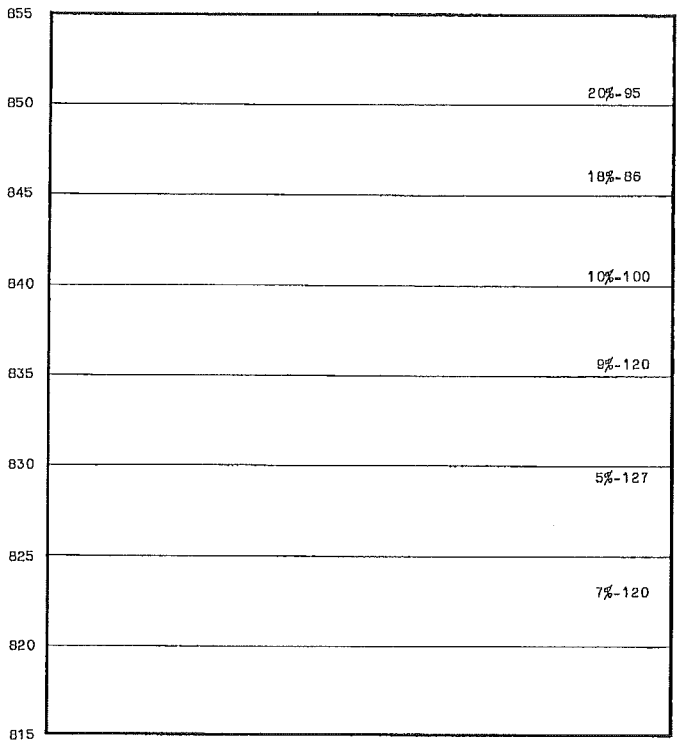
DAMES & MOORE

EARTH SCIENCES

171_00001

BORING 106
DRILLED 12-11-61

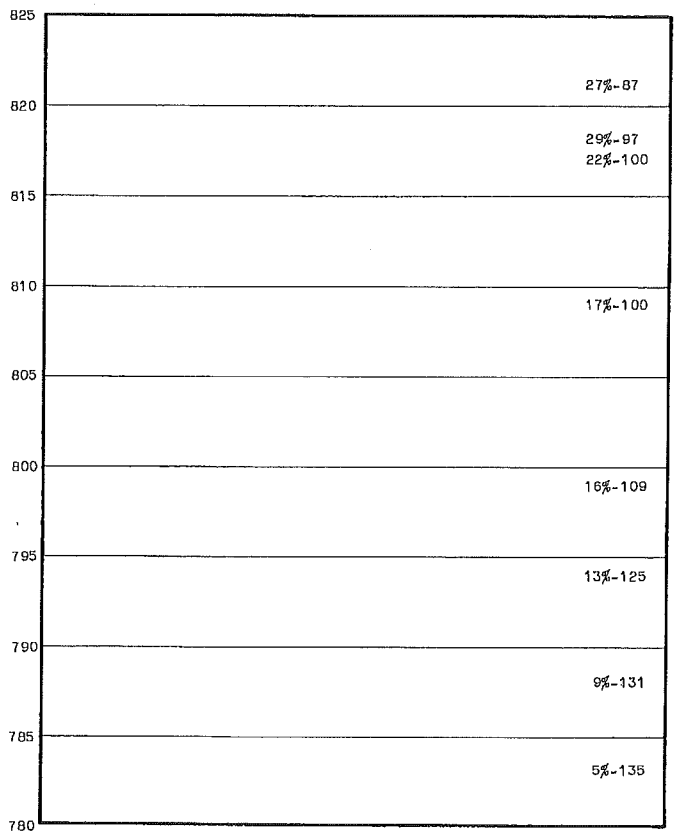
ELEVATION 852.2'



CH	BLACK CLAY WITH ROOTS (TOPSOIL)
CL	LIGHT BROWN SANDY CLAY (WEATHERED SANDSTONE) (MOIST) (FIRM)
	(OCCASIONAL LAYERS OF WEATHERED DARK BROWN SHALE)
CL	YELLOWISH-BROWN SANDY CLAY (WEATHERED SANDSTONE & SHALE) (FIRM)
	(GRADING MORE SANDY & LESS WEATHERED)
	YELLOWISH-BROWN FINE-GRAINED SANDSTONE (FRIABLE) (POORLY CEMENTED)
	(DRILLING HARD)
	(GRADING GRAY)

BORING 107
DRILLED 12-5-61

ELEVATION 822.5'



CL	DARK BROWN CLAY WITH ROCK FRAGMENTS (FILL) (VERY MOIST) (MOD.SOFT) (COMPRESSIBLE)
CH	BLACK CLAY (TOPSOIL)
CL	LIGHT BROWN SANDY CLAY WITH ROCK FRAGMENTS (WEATHERED SANDSTONE & SHALE) (FIRM) (MOIST)
	(GRADING MORE MOIST & MORE ROCK FRAGMENTS)
	LIGHT BROWN FINE-GRAINED SANDSTONE WITH SHALE LENSES (POORLY CEMENTED)
	(GRADING DARK GRAY SHALE WITH SANDSTONE LENSES)
	LIGHT BROWN FINE-GRAINED SANDSTONE (POORLY CEMENTED)
	(GRADING LIGHT BLUISH-GRAY, POORLY CEMENTED)
	RED SHALE WITH THIN GRAY LENSES (SHEARED) (SLICKENSIDED)

LOG OF BORINGS

DAMES & MOORE
SOIL MECHANICS ENGINEERS

BY ____ DATE ____
BY ____ DATE ____
PLATE ____ OF ____

BY ____ DATE ____
CHECKED BY ____ DATE ____

171_00022

BORING #	SURF ELEV:	UC EAST:	UC NORTH:	LOGGED BY:	DATE DRILLED:	PAGE:
SB31-97-2	feet	feet	feet	Preston Jordan	9/3/97	1/3

DEPTH TO GROUNDWATER:	DRILLING CONTRACTOR:	BORING EQUIPMENT:	DRILL RIG:
37.8', 3:15, 9/5	Gregg	6" hollow-stem auger	M-11

DESCRIPTION AND CLASSIFICATION

DESCRIPTION AND REMARKS	SOIL TYPE	DEPTH (FEET)	SAMPLE	Standard Penetration Resistance (Blows/ft)	ambient FID readings (ppm)	REMARKS	Well Construction
SILTY CLAY (CH), dark brown, stiff, moist, thinly laminated, laminae of silt and light brown sand (fill).				all samples taken with 2 inch internal diameter split spoon sampler			
CLAY (CH), black, stiff, dry to moist, well developed blocky structure, rootlets.		5					
CLAY (CL), brown, medium stiff to stiff, moist, poorly developed blocky structure, moderately developed peds, root casts with glay coloration surrounded by orange brown.		10, 15					
SANDY CLAY (CL), dark brownish gray, medium stiff to stiff, saturated, fine sand, minor subangular basaltic gravel.		20, 25, 30, 35		5/ 10/ 8		Bentonite chips	
SANDY CLAY (CL), reddish and purplish brown with green gray and brown sand, medium stiff, saturated, coarse sand consists of sandstone predominantly, gravel instead of sand at some depths.		40		7/ 8/ 10			
SANDY SILT (ML), greenish gray and brown mottled, medium stiff to stiff, saturated, occasional thin beds of angular basaltic gravel.		45, 50		10/ 24/ 28			

LAWRENCE BERKELEY NATIONAL LABORATORY	EXPLORATORY BORING LOG		
	PROJECT # Site Restoration Project	DATE: 10/1/97	BORING # SB31-97-2

BORING #	SURF ELEV:	UC EAST:	UC NORTH:	LOGGED BY:	DATE DRILLED:	PAGE:
SB31-97-2	feet	feet	feet	Preston Jordan	9/3/97	2/3

DEPTH TO GROUNDWATER:	DRILLING CONTRACTOR:	BORING EQUIPMENT:	DRILL RIG:
37.8', 11:30, 9/5	Gregg	6" hollow-stem auger	M-11

DESCRIPTION AND CLASSIFICATION

DESCRIPTION AND REMARKS	SOIL TYPE	DEPTH (FEET)	SAMPLE	Penetration Resistance (Blows/ft)	ambient FID readings (ppm)	REMARKS	Well Construction
SANDY SILT, cont.							
SILTY SAND (SM/ML), purplish gray and brown mottled, dense, saturated, medium to coarse angular sand of basalt, blue gray sandstone, quartzite, and red chert.		55, 60, 65		10/ 18/ 50/5"; 29/ 32/ 45			
GRAVELLY CLAY (CL), brown, stiff, saturated, angular to subround gravel predominantly of gray and blue gray sandstone, minor fine gravel of red chert.		70, 75		17/ 45/ 43		Bentonite chips	
SILTSTONE, black, crushed, weak to moderately strong, moderately hard, little weathered, slickensides pervasive.		80, 85, 90, 95, 100		48/ 50/4"; 28/ 50/5"; 50/5"			
• occasional closely fractured, unsheared zones							

all samples taken with 2 inch internal diameter split spoon sampler

no liners

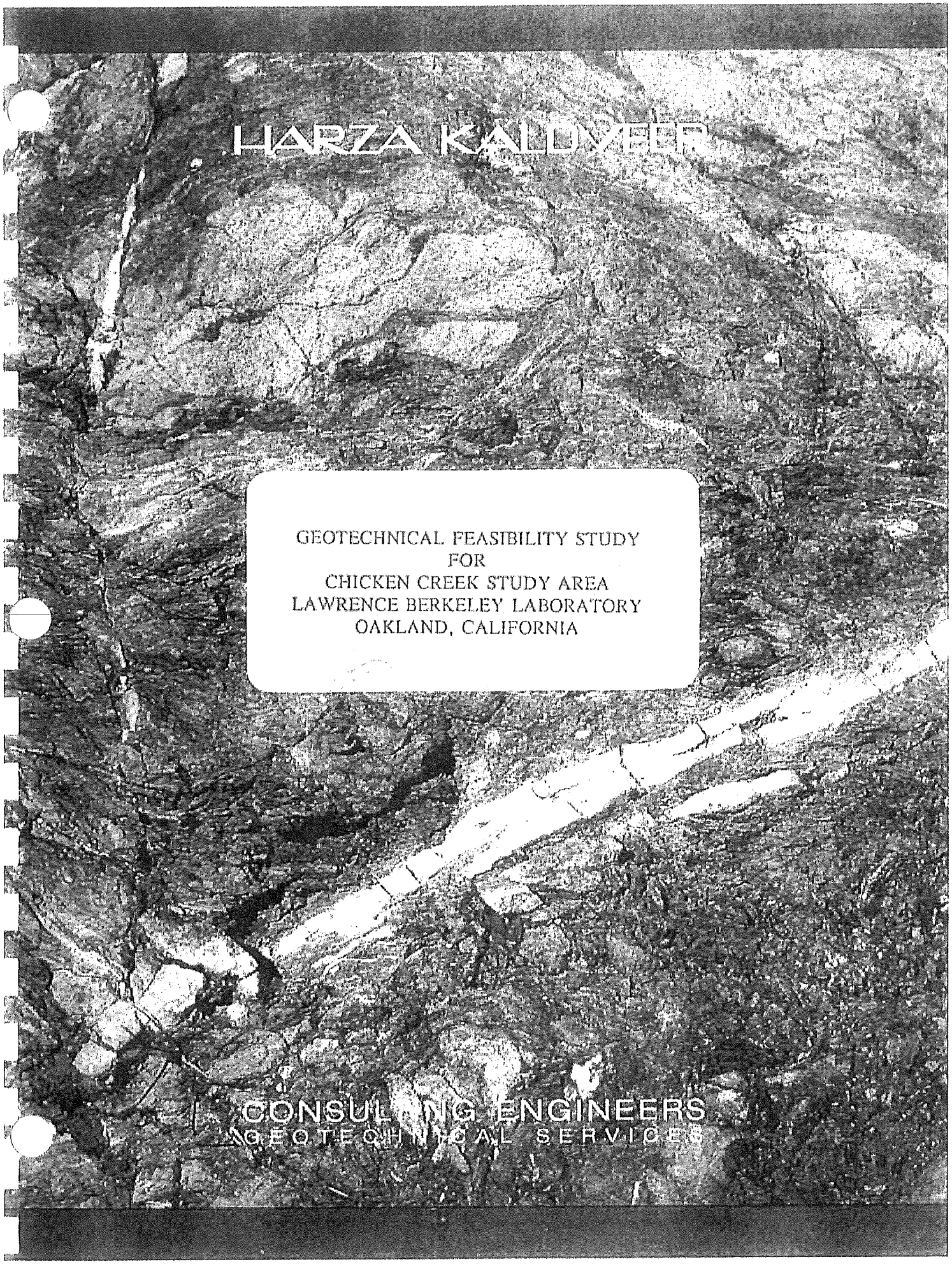
LAWRENCE BERKELEY NATIONAL LABORATORY	EXPLORATORY BORING LOG		
	PROJECT # Site Restoration Project	DATE: 10/1/97	BORING # SB31-97-2

BORING #	SURF ELEV:	UC EAST:	UC NORTH:	LOGGED BY:	DATE DRILLED:	PAGE:
SB31-97-2	feet	feet	feet	Preston Jordan	9/3/97	3/3

DEPTH TO GROUNDWATER:	DRILLING CONTRACTOR:	BORING EQUIPMENT:	DRILL RIG:
37.8', 11:30, 9/5	Gregg	6" hollow-stem auger	M-11

DESCRIPTION AND CLASSIFICATION		DEPTH (FEET)	SAMPLE	Penetration Resistance (Blows/ft)	ambient FID readings (ppm)	REMARKS	Well Construction
DESCRIPTION AND REMARKS	SOIL TYPE						
SILTSTONE, cont.			50/4"	all samples taken with 2 inch internal diameter split spoon sampler		Bentonite chips	
Total Depth = 105.0 feet		105					
		110					
		115					
		120					
		125					
		130					
		135					
		140					
		145					
		150					

LAWRENCE BERKELEY NATIONAL LABORATORY	EXPLORATORY BORING LOG		
	PROJECT # Site Restoration Project	DATE: 10/1/97	BORING # **SB31-97-2**



HARZA KALDVEER

GEOTECHNICAL FEASIBILITY STUDY FOR CHICKEN CREEK STUDY AREA LAWRENCE BERKELEY LABORATORY OAKLAND, CALIFORNIA

CONSULTING ENGINEERS
GEOTECHNICAL SERVICES

DRILL RIG	CME-55, HSA	SURFACE ELEVATION	690 Feet	LOGGED BY	CDT
DEPTH TO GROUND WATER	28-1/2Ft	BORING DIAMETER	8-inch	DATE DRILLED	11/24/93

DESCRIPTION AND CLASSIFICATION: DESCRIPTION AND REMARKS	CONSIST	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT)	WATER CONTENT (%)	DRY DENSITY (PCF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)	OTHER TESTS
COLLUVIUM: CLAY (CL); Brown, silty, some sand (fine- to coarse-grained), damp	Stiff								
(Dark brown, with silt below 5 feet)			5						
(Reddish brown, silty below 8 feet)									
(Some greenish mottling below 10 feet)	Very Stiff		10	X	31				
(Dark brown below 15 feet)			15						
(Trace gravel (fine-grained, subangular) at 20 to 21 1/2 feet)			20	X	41				
			25						
(Some greenish mottling below 30 feet)			30	X	36	23	104	7.1	

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Consulting Engineers

EXPLORATORY BORING LOG

CHICKEN CREEK STUDY AREA
Oakland, California

PROJECT NO.	DATE	BORING NO
K1226-6-2204	January 1994	EB-4

DRILL RIG	CME-55, HSA	SURFACE ELEVATION	690 Feet	LOGGED BY	CDT
DEPTH TO GROUND WATER	28-1/2Ft	BORING DIAMETER	8-inch	DATE DRILLED	11/24/93

DESCRIPTION AND CLASSIFICATION: DESCRIPTION AND REMARKS	CONSIST	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT)	WATER CONTENT (%)	DRY DENSITY (PCF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)	OTHER TESTS
	Very Stiff								
(Reddish brown, trace sand and shale/sandstone fragments at 40 to 41 1/2 feet)			40	X	55	21	106	7.2	
			45						
(Brown, trace gravel (fine-grained, subangular) at 30 to 31 1/2 feet)			50	X	33				
			55						
(Gray, trace sandstone fragments at 60 to 61 1/2 feet)	Hard		60	X	80	17	115	12.5	
ORINDA FORMATION: SHALE; Gray, thinly laminated, crushed to intense fracturing, moderately weathered	Friable		65						

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EXPLORATORY BORING LOG

CHICKEN CREEK STUDY AREA
Oakland, California

PROJECT NO.	DATE	BORING NO
K1226-6-2204	January 1994	EB-4

DRILL RIG	CME-55, HSA	SURFACE ELEVATION	690 Feet	LOGGED BY	CDT
DEPTH TO GROUND WATER	28-1/2Ft	BORING DIAMETER	8-inch	DATE DRILLED	11/24/93

DESCRIPTION AND CLASSIFICATION: DESCRIPTION AND REMARKS	CONSIST	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT)	WATER CONTENT (%)	DRY DENSITY (PCF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)	OTHER TESTS
SHALE; Continued	Friable				50/5"				
			75		50/6"				
(Wet at 75 feet)									

Bottom of Boring = 75.5 Feet

Notes:

1. The stratification lines represent the approximate boundaries between soil types and the transition may be gradual.
2. For an explanation of penetration resistance values, see the first page of Appendix A.
3. Groundwater was not encountered at the time of drilling, but was encountered at a depth of 27 1/2 feet on 12/2/93.
4. The boring was immediately backfilled with native soil upon completion.

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EXPLORATORY BORING LOG

CHICKEN CREEK STUDY AREA
Oakland, California

PROJECT NO.	DATE	BORING NO	EB-4
K1226-6-2204	January 1994		

DRILL RIG	CME-55, HSA	SURFACE ELEVATION	693 Feet	LOGGED BY	CDT
DEPTH TO GROUND WATER	10-1/2Ft	BORING DIAMETER	8-inch	DATE DRILLED	11/30/93

DESCRIPTION AND CLASSIFICATION: DESCRIPTION AND REMARKS	CONSIST	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT)	WATER CONTENT (%)	DRY DENSITY (PCF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)	OTHER TESTS
FILL: CLAY (CL); Dark brown, silty, with sand (fine- to coarse-grained), trace brick and concrete fragments	Stiff								
FILL: CLAY (CL/CH); Olive brown, with silt, some sand (fine- to medium-grained), damp	Stiff		5						
FILL: CLAY (CL); Dark brown, silty, with sand (fine- to coarse-grained), trace gravel (fine-grained, subangular) and brick fragments, damp	Very Stiff		10		57				
COLLUVIUM: CLAY (CL); Yellow brown, silty, sandy (fine- to medium-grained), damp	Very Stiff		15						
ORINDA FORMATION: SHALE; Gray, moderately weathered	Friable								
ORINDA FORMATION: SANDSTONE; Gray and light brown, thinly laminated, crushed, moderate weathering	Friable		20		50/4"				

Bottom of Boring = 20 1/2 Feet

Notes:

1. The stratification lines represent the approximate boundaries between soil types and the transition may be gradual.
2. For an explanation of penetration resistance values, see the first page of Appendix A.
3. Groundwater was encountered at 10.5 feet at the time of drilling.
4. The boring was immediately backfilled with native soil upon completion.

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EXPLORATORY BORING LOG

CHICKEN CREEK STUDY AREA
Oakland, California

PROJECT NO.	DATE	BORING NO
K1226-6-2204	January 1994	EB-6

DRILL RIG	CME-55, HSA	SURFACE ELEVATION	618 Feet	LOGGED BY	CDT
DEPTH TO GROUND WATER	Not Enc.	BORING DIAMETER	8-inch	DATE DRILLED	12/1/93

DESCRIPTION AND CLASSIFICATION			DEPTH	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT)	WATER CONTENT (%)	DRY DENSITY (PCF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)	OTHER TESTS
DESCRIPTION AND REMARKS	CONSIST	SOIL TYPE	(FEET)						
COLLUVIUM: CLAY (CL); Brown, silty, some sand (fine- to coarse-grained)	Very Stiff								
(Trace gravel in cuttings at 5 to 10 feet)			5						
			10						
			15						
(Reddish brown with gray mottling, trace gravel (fine-grained, subrounded) and sandstone fragments at 20 to 21 1/2 feet)	Hard		20		64				
			25						

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EXPLORATORY BORING LOG

CHICKEN CREEK STUDY AREA
Oakland, California

PROJECT NO.	DATE	BORING NO	EB-8
K1226-6-2204	January 1994		

DRILL RIG	CME-55, HSA	SURFACE ELEVATION	618 Feet	LOGGED BY	CDT
DEPTH TO GROUND WATER	Not Enc.	BORING DIAMETER	8-inch	DATE DRILLED	12/1/93

DESCRIPTION AND CLASSIFICATION: DESCRIPTION AND REMARKS	CONSIST	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT)	WATER CONTENT (%)	DRY DENSITY (PCF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)	OTHER TESTS
COLLUVIUM: CLAY (CL); Continued	Hard		35						
(Brown, some gray sandstone fragments and lenses below 40 feet)			40		57				
			45						
(Slickenside at 50 feet)			50		35				
			55						

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Consulting Engineers

EXPLORATORY BORING LOG

CHICKEN CREEK STUDY AREA
Oakland, California

PROJECT NO.	DATE	BORING NO	EB-8
K1226-6-2204	January 1994		

DRILL RIG	CME-55, HSA	SURFACE ELEVATION	618 Feet	LOGGED BY	CDT
DEPTH TO GROUND WATER	Not Enc.	BORING DIAMETER	8-inch	DATE DRILLED	12/1/93

DESCRIPTION AND CLASSIFICATION			DEPTH	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT)	WATER CONTENT (%)	DRY DENSITY (PCF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)	OTHER TESTS
DESCRIPTION AND REMARKS	CONSIST	SOIL TYPE	(FEET)						
(Gray with brown mottling, abundant sandstone fragments, moist below 60 feet)	Very Stiff				31				
			65						
ORINDA FORMATION: SANDSTONE; Gray, thinly laminated, crushed, little to moderate weathering	Moderate Hardness								
			70		50/3"				
Bottom of Boring = 70.25 Feet Notes: 1. The stratification lines represent the approximate boundaries between soil types and the transition may be gradual. 2. For an explanation of penetration resistance values, see the first page of Appendix A. 3. Groundwater was not encountered at the time of drilling. 4. The boring was immediately backfilled with native soil upon completion.									

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Consulting Engineers

EXPLORATORY BORING LOG

CHICKEN CREEK STUDY AREA
Oakland, California

PROJECT NO.	DATE	BORING NO
K1226-6-2204	January 1994	EB-8

-Reviewed Log-

SOIL LOG - Boring No. WLA - 1

Centennial Drive Road Assesment
WLA project #2020

WLA

Type and Diameter of Boring: Single Slight and Hand Auger 4.5" diam.	Boring Location: Uphill side of rd, near pole at F hill, 0.5' in lane from white line, 30.5' from top of hill		Total Depth: 34.5'
Drilling Contractor and Rig: Northstar Drilling, Truck mounted Mobile B-24	Elevation and Datum: 577 - Pending Survey	Ground Water Depth: —	Depth to Bedrock: ~32.8'
Sampling Method: Modified California (4.5" x 2"), SPT.	Sample Driving Hammer/Drop: —	No. of Samples: 20 (in 4 boxes)	Date Started: 8/13/08
	Borehole Inclination: Vert. (-90°)	Logged by: K.D. Krug	Date Completed: 8/13/08

Reviewed by/Date: Krug 9/19/08, Krug & Baldwin 9/12/08

(TSF) Pocket Pen (9/12/08)

Depth (feet)	Drilling Rate (min/foot)	Sampler Type	Sample No	Uncorrected Blows/6 inches	Feet Recovered	Pocket Pen Tonnage (TSF)	Graphic Log	Lithology	Remarks	In-situ test	Elevation (feet)
0–1		Auger / Cuttings; 1) - hand sample		1	1	1		Asphalt; Gravels - Fill road grading material	0.3'		
1–2								SANDY GRAVELY CLAY, olive Brown (2.5Y R 4/3), Dry, very Loose, gravels 10-25% ~ .1-.05' diam., subangular, No strength, low Plasticity, organics (roots)	? 1.0'; 1.5' - more gravels difficult Augering		
2–3				1	1	1		Increasing gravels ~30% of non-native origin. Soils more Yellow-Brown	Fill		
3–4		Hand		1	1	1		CLAY rich cuttings	? 4.2' Colluvium		
4.5 med; 5–6			26	6, 9, 8	1.4/1.5	93%		CLAY w/ SAND and GRAVELS, olive brown (2.5YR 4/4), Very Stiff, high dry strength, medium toughness, low plasticity, gravels 5-10% - .1-.05' diam. subrounded composed of sandstone currently the [illegible] Hard gravels ~.1-.2' Sandstone clasts.	6.0' gravel; 6.5		
6–7			3	10, 14, 17	1.35/1.5	90%		Return to previous			
7–8								Increase in gravels (10-15%), higher % of granite rocks & light clasts, clasts have weathered rinds, at base of sample col (0.3' diam.), siltstone and [illegible] sample.	7.4' Increased clasts		
8–9	5.4		4	16, 20, 29	1.5/1.5	100%		Dry; Harder Siltstone clasts. → 9.1.5' Red (10R 5/6) clasts Silty - 0.05' diameter			
9–10			5	16, 23, 24	1.5/1.5	100%		CLAY w/ SAND and GRAVEL, Dark Brown (10YR 3/3), Moist, Hard, Med. toughness, high stiffness, med. plasticity, [illegible] clasts/gravel ~.05 - 0.1' diam composed of sandy material ~5%, well distributed (across smaller clasts), Mod Staining.	9.5 (cleaned out Boring - Last contact) Color change		Qc1? Fill? Qc2?
10–11	4.5										
11–12			6	28, 35, 46	1.5/1.5	100%		Along Fed. Interface; Subvert Silty lenses, Yellowish Brown (10YR 5/4), 0.2' long and vertical.	Bor 1 ↕ Bor 2		
12–13	4.5		7	10, 15, 20	1.5/1.5	100%		greyish clay provides matrix between "clasts" in portion of matrix (i.e. the brown matrix w/ ↑ silty lenses of sub-vert).	13' ~~1.5'~~ ↑ silty lenses of sub-vert.		
13–14								~~Slow Increase~~			
14–15			8	11, 12	1.5/1.5	100%		→ Large Sandy/Silty clasts (Yellow-white) ↑ 15%. → Grey clay intermixed w light olive Brown (2.5YR 5/6)			Qc2? Qc3? 2

Page 1 of 3

- Revised Log -

SOIL LOG - Boring No. WLA-1

Centennial Drive Road Assesment
WLA project #2020

WLA

* Based on Fining Upward Seq.

Depth (feet)	Drilling Rate (min/foot)	Sampler Type	Sample No.	Uncorrected Blows/6 inches	Feet Recovered	Pocket Pen/ Torvane (TSF)	Graphic Log	Lithology	Remarks	In-situ Testing	Elevation (feet)
15		SPT	8	14	1.5/1.5			See Previous page	→ Introduce Pink clasts .05' diam		
16		SPT	9	14, 19, 27	1.5/1.5	→ 100%		CLAY w/ SANDY GRAVEL, Olive Brown (2.5YR 4/3), Hard, Dry, Low Plasticity, gravels 5-10% composed of .01' diam. clasts fine grained sandstone (or ash?), red clasts present down down now, MnO staining. * Grey-Sh "Mingled CLAY" more dominant ~15% of matrix.			
17		SPT	10	30, 36, 45	1.5/1.5	→ 100%		Stringers of Grey CLAY now cont. through ~.01' thick (sub vert. core. (root holes?) Fewer "red" clasts & clasts overall	7.4' Clay Saturated.		
18		SPT	11	13, 21, 34	1.5/1.5	→ 100%		Matrix GRADATIONAL to Yellowish Brown (10YR 5/4)	[Clean Out Boring @ 18.5]		Qc 3 / Qc 4
19		SPT	12	11, 17, 18	1.5/1.5	→ 100%		Increase of Sand/Siltstone clasts ~15% Occasional angular crystalline clasts ↑ Loss of Density, NO "Grey clay" ↑	Note: "Old" Hole Always. Box 2 ↑ ↓ Box 3		Qc 3 / Qc 4
20		SPT	13	30, 13, 16	1.5/1.5	→ 100%		Silty CLAY w/ Sand and gravel, Brown (10YR 4/3), Dry, Dense, Clasts of crystalline rock w/ bright red coating 5-10%, Sandstone 3-5%, clasts ~.1 to .2' diam, Sub-angular and very pressed. Moraga.	20.0' End/Base LS?		
21		SPT	14	12, 38	1.1/1.1	→ 100%		More Clay Matrix Supported	[Cleaned out Boring @ 21.5]		
22		SPT	15	50	1.5/1.5	→ 100%		G.W. - rusted clast/shales? - talus: Moraga			
23								rock - Silt w/ 25% gravels - rusting present	23.9' (obstruction)		
24								loose and wet → Concretion?			
24.1' / 24.4'								? ? ? ?	24.8'? [Cleaned out Boring 24.4'-25.0']		Qc 4 / Qc 5
25	½ hr	NO SAMPLE									
26		SPT	16	45, 24, 50	1.3/1.3	→ 100%		SANDY CLAY w/ gravel, Olive Brown (10YR 4/3), Wet-Damp, Hard, Med-Hi Plasticity, Gravels ~25% .01-.1' diam. Sub-angular, Sand 5-10% intermixed w/ clays.			
26.3'								→ Mottled Clay Iteration including, Wet Strong Brown (7.5YR 5/6), Clay in Stronger structure.			
27	½ hr	NO SAMPLE						? ? ? ? ? ?	[26.3' to 27.2' Cleaned out Boring]		
27.2'		SPT	17	22, 23, 25	1.7/1.5	→ 100%		Dark Brown (7.5YR 3/2) Dark Yellowish Brown (10YR 4/4) - no more red clasts. Gravelly SILT, more to little matrix intermixed, Loose and gravelly, Wet.			
28.7'								rock - Shales, S.S. - Sandy Zone	Box 3 ↑ ↓ Box 4		
29		SPT	18	13, 14, 18	1.5/1.5	→ 100%		SILTY GRAVELS w/ SAND, Dark Yellow to Brownish Yellow (10YR 4/4), Increase in gravel size ~.1 to .2', Sub-angular ~70% clasts, Matrix made of Sand, Silt, and some clays. Red colored rock/gravel	29.8'		
30								* Percent of large gravel Sand ↑ to 30% of matrix			

Undisturbed sample
S = Shelby, P = Pitcher, O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California, O = other

Standard Penetration Test (SPT) sampler

– Reviewed Log –

SOIL LOG - Boring No. WLA-1

Centennial Drive Road Assesment
WLA project #2020

WLA

Depth (feet)	Drilling Rate (min/foot)	Sampler Type	Sample No.	Uncorrected Blows/6 inches	Feet Recovered	Pocket Pen/ Torvane (TSF)	Graphic Log	Lithology	Remarks	In-situ Testing	Elevation (feet)
30	-	MC	18	18	-	-					
30.25				12				SILTY CLAY w/ Sand and Gravel, mottled matrix color – to altered by clast mixing, sands intermixed w/ gravels subangular to angular, 0.01 in – 2' diam.; shale, chert, sandstone, unknowns. Loose – Dry – Nonplastic – Organics			
31	4	50%	19	25	1.5/1.5	100%			31.2' weathered TOR? – ?		
				24				Large hard sandstone rocks			
32	½hr	NO SAMPLE					?		[Cleaned Boring 31.7' to 32']		
32.1	4	4" MC		13	9/9	100%		SANDY CLAY w/ Gravel/clasts, Dark Brown (7.5YR 3/1), Dry – Damp, Low Plasticity, Mottled/poorly sorted composition 10% Sand, 15% gravels angular			
33				50/5"				Sandstone pieces 1&2 strong	32.8' TOR? – – – [Cleaned 33 to 33.5']		
	½hr	NO SAMPLE					?				
34	½ hour	NO SAMPLE					?		[Drilled out to 34.5]		
								END Boring @ 34.5' bgs			
								→ grouted upon completion ←			
35											
36											
37											
38											
39											
40											
41											
42											
43											
44											
45											

SPT @ 32' = 50/5"

SPT @ 33.5' = 50/0"

SPT @ 34.5' 50/0"

Undisturbed sample
S = Shelby, P = Pitcher, O = other

Driven (2.5 to 3.0 inch) with liners
MC = Modified California, O = other

Standard Penetration Test (SPT) sampler

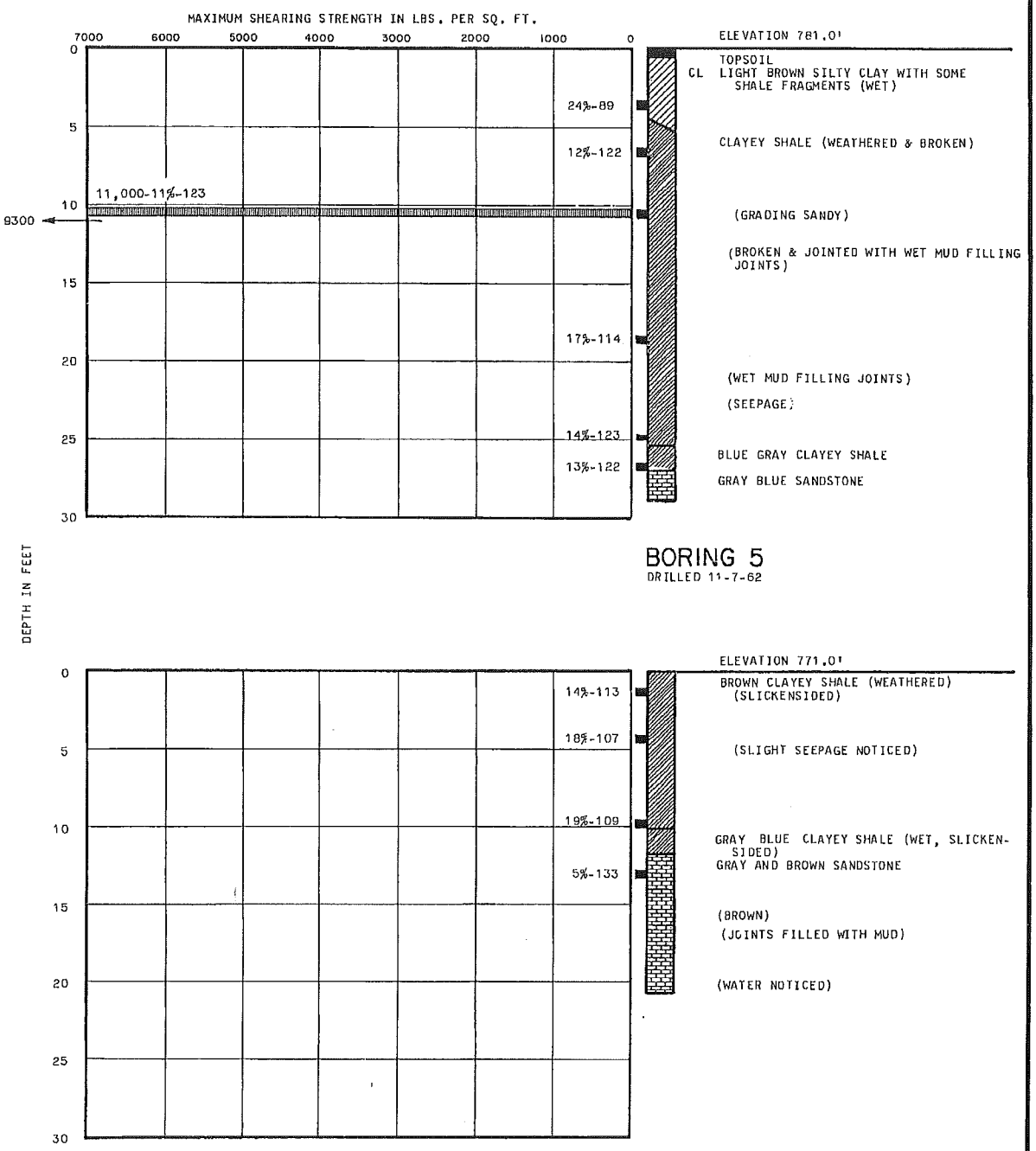
FOUNDATION INVESTIGATION

PROPOSED INORGANIC MATERIAL LABORATORY
(BUILDING 62)
LAWRENCE RADIATION LABORATORY
BERKELEY, CALIFORNIA

FOR THE UNIVERSITY OF CALIFORNIA

DAMES & MOORE

EARTH SCIENCES



LOG OF BORINGS

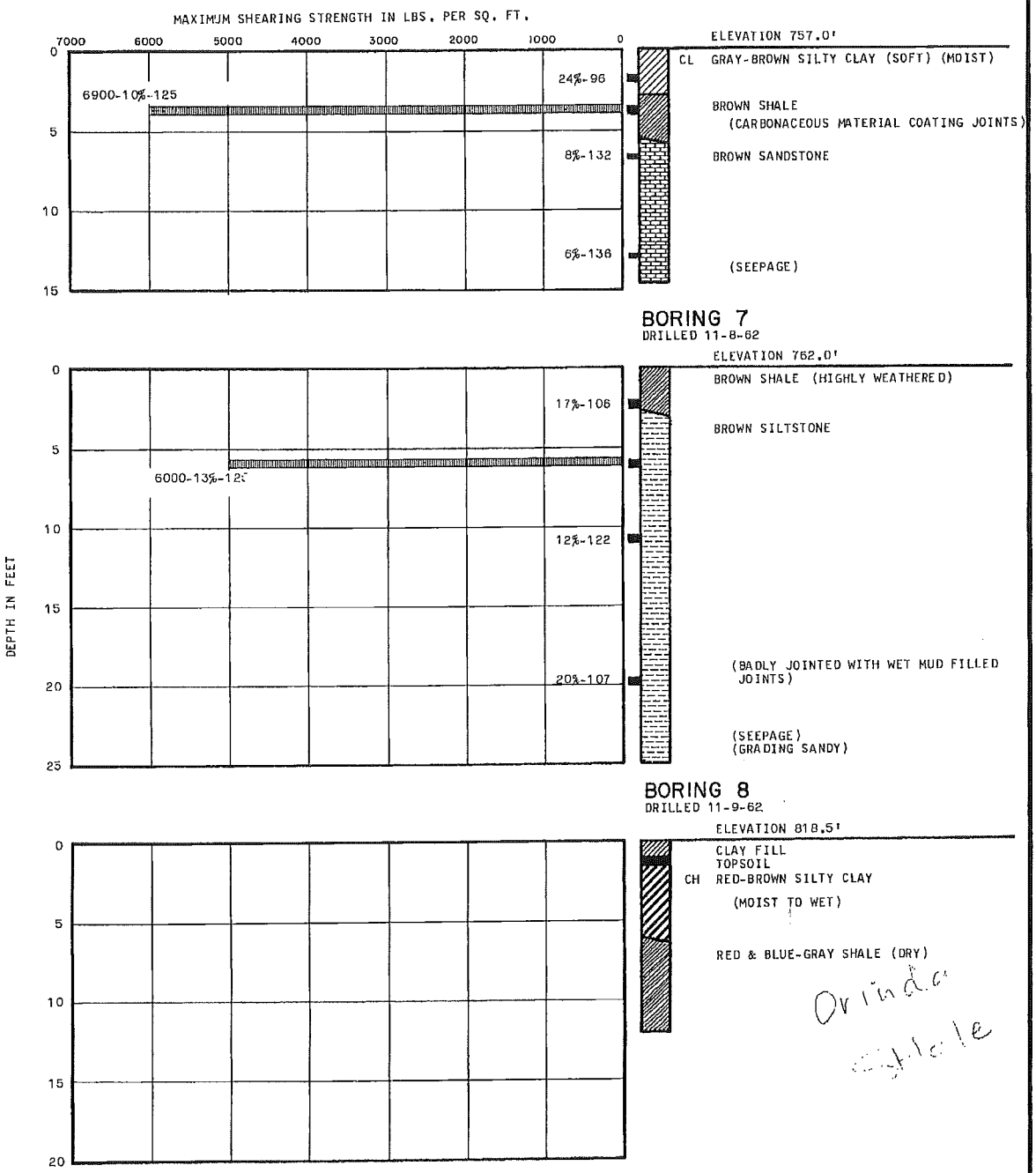
DAMES & MOORE
SOIL MECHANICS ENGINEERS

PLATE A1 C

REVISIONS
BY DATE
BY DATE
PLATE OF

FILE 234-085
UNIV. OF CALIF.
BY HST DATE 11-21-62
CHECKED BY DATE

120_00018



LOG OF BORINGS

DAMES & MOORE
SOIL MECHANICS ENGINEERS

PLATE A1D

REVISIONS
BY ____ DATE ____
BY ____ DATE ____
PLATE ____ OF ____

FILE 234-085
UNIV. OF CALIF.
BY NCT DATE 11-21-62
CHECKED BY ____ DATE ____

351

GEOMATRIX

GEOTECHNICAL STUDY FOR THE ENVIRONMENTAL HEALTH AND SAFETY BUILDING

Strawberry Canyon Facility
Berkeley, California

Lower Chicken Creek Area Soils INFO
S. Blair

Prepared for

University of California
Planning, Design and Construction
2000 Carleton Street
Berkeley, California 94720

April 1994
Project No. 2501

Geomatrix Consultants

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 3A

BORING LOCATION: See Figure 1

DATE STARTED: 10/25/93 | DATE FINISHED: 10/26/93

DRILLING METHOD: 6-inch continuous flight auger

HAMMER WEIGHT: 155 lbs. | DROP: 27 inches

SAMPLER: 2-inch modified California and SPT

NOTES:
Logged by: A. Thomas
Drilling Equipment: ---
Drilling Contractor: Garrett Enterprises

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION (Surface Elevation: 641±)	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				SANDY CLAY (CL) Stiff, brown, moist, with small pebbles [Fill?]			
1							
2							
3							
4							
5							
6	1		12	No recovery			
7							
				SANDY CLAY (CL) Very stiff, brown, moist			
8							
9							
10							
11	2		29		22	103	---
12							
13							
14				(Orinda/Moraga Colluvium)			
15							

gt-1-88

Project No. 2501 | Geomatrix Consultants | Figure A-4

351_00056

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 3A (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				SANDY CLAY (CL) (continued)			
16	3		27		21	104	3140
17							
18							
19							
20							
21	4		22		23	106	4570
22							
23				SANDY CLAY (CL) Very stiff, mottled gray, green, and brown, with subangular and subrounded pebbles			
24							
25							
26	5		46		17	115	6130
27							
28				(Mixed Orinda/Moraga and Cretaceous Colluvium)			
29							
30							
31	6		33		18	115	2600
32							

gt-2-88

Project No. 2501 | Geomatrix Consultants | Figure A-4 (cont'd.)

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 3A (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				SANDY CLAY (CL) (continued)			
33							
34				SANDY CLAY (CL) Very stiff to hard, dark gray, moist, with shale and sandstone fragments			
35	7		41	▽ 10/27/93 1:30 pm	16	115	3100
36							
37							
38							
39							
40				(Cretaceous Colluvium)			
41							
42							
43							
44				SHALE Hard, blue-gray			
45	8		100/2"				
	9		100/2.5"				
46				Bottom of boring at 45.5 feet			
47							
48							
49							

gt-2-88

Project No. 2501 | Geomatrix Consultants | Figure A-4 (cont'd.)

351_00058

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING Strawberry Canyon Facility Berkeley, California	# Log of Boring No. 4A

BORING LOCATION: See Figure 1

DATE STARTED: 11/18/93	DATE FINISHED: 11/18/93	NOTES: Logged by: D. Wells Drilling Equipment: Mobile B-61 Drilling Contractor: West Hazmat Drilling Corp.
DRILLING METHOD: 7-inch hollow stem auger		
HAMMER WEIGHT: 140 lbs.	DROP: 30 inches	
SAMPLER: Continuous core and 2-inch modified California		

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION Surface Elevation: 658±	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				FILL Aggregate base material with asphalt and concrete pieces			
1				SILTY CLAY (CL) Stiff, dark brown (10YR 4/3), moist, with fine to coarse sand and small round pebbles			
2							
3							
4							
5							
6				(Orinda/Moraga Colluvium)			
7							
8					23	103	---
9							
10				Very dark grayish brown (2.5Y 4/2)			
11				Sandy clay (CL), stiff, mottled to olive brown (2.5Y 4/4), medium plastic			
12							
13				Multicolored large Orinda type sandstone fragments (2-inch) (rounded pebbles)			
14							
15							

gt-1-88

Project No. 2501	Geomatrix Consultants	Figure A-5

351_00059

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 4A (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
16			24	SILTY CLAY (CL) (continued)	24	103	---
17							
18							
19				SANDY CLAY (CL) Very stiff, mottled brown (10YR 5/3) to yellowish brown (10YR 5/8), moist, with sand and clasts of weathered Cretaceous shale and Orinda-type sandstone			
20							
21							
22							
23				(Mixed Orinda/Cretaceous Colluvium)			
24							
25				SANDY CLAY (CL) Very stiff, dark brown (10YR 3/3), moist, with sand and abundant fragments of Cretaceous shale			
26				1/2-hour after drilling (Cretaceous Colluvium)			
27				HIGHLY WEATHERED SHALE			
28							
29							
30	2		50 / 5.5"	Fresh unweathered gray shale, wet	---	---	---
31				Bottom of boring at 30.5 feet			
32							

gt-2-88

Project No. 2501 | Geomatrix Consultants | Figure A-5 (cont'd.)

351_00060

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 5A

BORING LOCATION: See Figure 1

DATE STARTED: 11/18/93 | DATE FINISHED: 11/18/93

DRILLING METHOD: 7-inch hollow stem auger

HAMMER WEIGHT: --- | DROP: ---

SAMPLER: Continuous core

NOTES:
Logged by: D. Wells
Drilling Equipment: Mobile B-61
Drilling Contractor: West Hazmat Drilling Corp.

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION (Surface Elevation: 607±)	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				GRAVELLY FILL			
1							
2							
3				SANDY CLAY (CL) Stiff, reddish brown (5YR 4/3) and light gray (5Y 7/1), with small subrounded pebbles			
4							
5				(Recovered 2 feet)			
6							
7				Light gray (5Y 7/1), highly weathered Orinda sandstone clasts, with roots			
8				Approximately horizontal bedding laminations/planes			
9							
10				(Recovered 2.3 feet)			
11				(Orinda/Moraga Colluvium)			
12				Pale olive (5Y 6/3), fine to coarse sand and subrounded to rounded quartz sand and basalt pebbles			
13							
14							
15							

gt-1-88

Project No. 2501 | Geomatrix Consultants | Figure A-6

351_00061

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 5A (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				(Recovered 4.2 feet)			
				SANDY CLAY (CL) (continued)			
16				Dark reddish gray (5YR 4/2)			
17							
18				Horizontal laminations -- bedding planes			
19							
20				(Recovered 3 feet)			
21				Clasts of pale olive (5Y 6/3) sandstone			
22				(Orinda/Moraga Colluvium)			
23							
24					12	127	---
25				(Recovered 4.5 feet)			
				Less clay			
26							
27				More clay			
28							
29							
30				(Recovered 4.2 feet)			
31							
32							

gt-2-88

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 5A (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				SANDY CLAY (CL) (continued)			
				Varicolored dark brown (7.5YR 4/2)			
33							
34					16	111	---
				Subhorizontal bedding planes			
35				(Recovered 4 feet)			
36							
37							
38				(Orinda/Moraga Colluvium)			
39							
40				(Recovered 3 feet)			
41							
42							
43							
44							
45				CLAYEY SAND (SC) Dense, dark gray (5Y 4/1), with angular basalt fragments			
46				SANDY CLAY (CL) Very stiff, dark gray, (5Y 4/1), moist, with sand and subangular basalt fragments			
47				(Recovered 4.2 feet)			
48				(Mixed Orinda/Moraga and Cretaceous Colluvium)			
49					15	110	---

gt-2-88

Project No. 2501 | Geomatrix Consultants | Figure A-6 (cont'd.)

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 5A (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				SANDY CLAY (CL) (continued)			
50				(Recovered 1 foot)			
51							
52				(Mixed Orinda/Moraga and Cretaceous Colluvium)			
53							
54							
55				(Recovered 3 feet)			
56							
57							
58							
59							
60				(Recovered 5 feet)			
61							
62				WEATHERED SHALE Moderately hard, dark gray			
63							
64							
65				Fresh unweathered dark gray (N-4) shale			
66							

gt-2-88

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 5A (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				SHALE Fresh unweathered dark gray (N-4)			
67							
68							
69							
70				Bottom of boring at 70 feet. Dry ATD			
71							
72							
73							
74							
75							
76							
77							
78							
79							
80							
81							
82							
83							

gt-2-88

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING Strawberry Canyon Facility Berkeley, California	# Log of Boring No. 6A

BORING LOCATION: See Figure 1

DATE STARTED: 11/22/93	DATE FINISHED: 11/22/93	NOTES: Logged by: D. Wells Drilling Equipment: Mobile B-61 Drilling Contractor: West Hazmat Drilling Corp.
DRILLING METHOD: 7-inch hollow stem auger		
HAMMER WEIGHT: 140 lbs.	DROP: 30 inches	
SAMPLER: Continuous core and 2-inch modified California		

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION Surface Elevation: 587±	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				FILL Sand and gravel			
1				(Recovered 3.25 feet)			
				SANDY CLAY (CL) Stiff, reddish brown (5Y 4/3), fine to coarse sand, with highly weathered fragments of feldspars, sandstone, and quartz			
2							
3							
4							
5				2-inch thick olive (5Y 4/3), medium to coarse sand. (Recovered 5 feet)			
6				Abundant rock fragments			
7				Very stiff			
8				(Orinda/Moraga Colluvium)			
9							
10				(Recovered 5 feet)			
11							
12							
13							
14							
15							

gt-1-88

Project No. 2501	Geomatrix Consultants	Figure A-7

351_00066

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 6A (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				SANDY CLAY (CL) (continued)			
				(Recovered 4 feet)			
16				Interbedded clasts of light gray (5Y 7/2) clayey sand			
17							
18							
19				Abundant sandstone fragments			
20				Very stiff to hard			
21	1		65	Occasional 0.5 to 2-inch thick interbeds of light gray (5Y 7/2), medium coarse sand	15	115	8980
22				(Recovered 3.5 feet)			
23				(Orinda/Moraga Colluvium)			
24							
25				(Recovered 3.2 feet)			
26							
27				CLAYEY SAND (SC) Dense, olive (5Y 4/3), medium to coarse sand mixed with dark reddish brown sand, abundant rock fragments (subangular to subrounded), angular basalt gravel at 29 feet			
28							
29				SANDY CLAY (CL) Hard, dark reddish brown (5YR 3/3) with olive, medium coarse sand and fragments of Cretaceous sandstone, basalt, and feldspar			
30				(Recovered 3.8 feet)			
31							
32							

gt-2-88

PROJECT: U.C. ENVIRONMENTAL HEALTH & SAFETY BUILDING
Strawberry Canyon Facility
Berkeley, California

Log of Boring No. 6A (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				SANDY CLAY (CL) (continued)			
33				Harder drilling at 32.5 feet			
				Large clasts of Cretaceous sandstone (2 inches)			
34				(Recovered 5 feet)			
35				At 35 feet a thick bed of dark greenish gray (5G 4/1), fine to medium sand with red-purple rock fragments			
36				SANDY CLAY (CL) Hard, greenish gray (5BG 5/1), medium clayey sand mixed with dark brown (7.5YR 4/2) clayey sand, with subangular Cretaceous sandstone fragments, basalt, feldspar(?), and quartz(?)			
37							
38							
				Dark brown (10YR 3/3) medium sand (1-inch thick) at 38.8 feet	17	131	---
39				Dark gray (5Y 4/1) medium clayey sand with fragments of Cretaceous sandstone at 39.5 feet			
40							
41	1		28	(Mixed Orinda and Cretaceous Colluvium) (Recovered 3.5 feet)	23	100	4190
42				Dark gray (5Y 4/1) medium sand with abundant fragments of subangular Cretaceous sandstone (to 0.5 inches), quartz (1-inch clast), and basaltic sandstone (1-inch clast)			
43							
44							
45				SANDSTONE Moderately hard, dark gray (N4) to greenish gray (5GB 5/1)			
46				Bottom of boring at 46 feet. Auger refusal. No water ATD			
47							
48							
49							

gt-2-88

Project No. 2501 | Geomatrix Consultants | Figure A-7 (cont'd.)

351_00068

PROJECT: U.C. WASTE FACILITY
Poultry Husbandry Site
Berkeley, California

Log of Boring No. 4

BORING LOCATION: See Figure 1

DATE STARTED: 10/14/92 | DATE FINISHED: 10/14/92

NOTES: Drilling contractor: Garrett Enterprises
Logged by: C. H. Crocker

DRILLING METHOD: 6" diameter solid stem auger

HAMMER WEIGHT: 155 lbs | DROP: 27 inches

SAMPLER: 2" I. D. modified California

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION (Surface Elevation: 624±)	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Uncont. Comp. Str. (psf)
				Broken asphalt			
1	1		38	SANDY CLAY (CL) Very stiff, reddish brown (5YR 4/3), moist, fine to coarse sand, with trace fine gravel	15	111	---
2							
3							
4							
5							
6	2		46	SANDY SILT (SM) Hard, olive (5Y 4/3), moist, fine to medium sand	16	106	---
7							
8							
9							
10							
11				SANDY CLAY (CL) Hard, reddish brown (5YR 4/3), moist, fine to coarse sand, with trace fine weathered shale fragments			
12							
13							
14	3		40/6"		20	119	9370
15							

gi-1-88

Project No. 2179.01 | Geomatrix Consultants | Figure A-10

351_00094

PROJECT: U.C. WASTE FACILITY
Poultry Husbandry Site
Berkeley, California

Log of Boring No. 4 (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
				SANDY CLAY (CL) (continued)			
16							
17							
18							
19				Harder drilling			
20							
21							
22							
23				Color change to dark brown (7.5YR 3/2)			
24	4		70		15	110	9380
25							
26							
27							
28							
29							
30							
31							
32							

gt-2-88

Project No. 2179.01 | Geomatrix Consultants | Figure A-11

351_00095

PROJECT: U.C. WASTE FACILITY
Poultry Husbandry Site
Berkeley, California

Log of Boring No. 4 (cont'd.)

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS: Moisture Content (%)	LABORATORY TESTS: Dry Density (pcf)	LABORATORY TESTS: Unconf. Comp. Str. (psf)
33				SANDY CLAY (CL) (continued)			
34	5		64	Coarse gravel clast of indurated sandstone/shale within sandy clay matrix	---	---	---
35							
36							
37							
38							
39							
40							
41							
42							
43				Wet			
44	6		56	CLAYEY SAND (SC) Very dense, dark greenish gray (5GY 4/1), wet	---	---	---
45							
46							
47							
48				SANDY CLAY (CL) hard, very dark gray (5Y 3/1), moist, fine to coarse sand, with trace fine gravel			
49							

gt-2-88

Project No. 2179.01 | Geomatrix Consultants | Figure A-12

351_00096

PROJECT: U.C. WASTE FACILITY
Poultry Husbandry Site
Berkeley, California

Log of Boring No. 4 (cont'd.)

DEPTH (feet)	SAMPLES Sample No.	SAMPLES Sample	SAMPLES Blows/Foot	MATERIAL DESCRIPTION	LABORATORY TESTS Moisture Content (%)	LABORATORY TESTS Dry Density (pcf)	LABORATORY TESTS Unconf. Comp. Str. (psf)
				SANDY CLAY (CL) (continued)			
50				SHALE Well indurated			
51							
52							
53							
	7		50/3"		---	---	---
54				Bottom of boring at 53.75 feet			
55							
56							
57							
58							
59							
60							
61							
62							
63							
64							
65							
66							

gt-2-88

Project No. 2179.01 | Geomatrix Consultants | Figure A-13

(123)

Geo file Y-File

UNIVERSITY OF CALIFORNIA C. McClure
LAWRENCE BERKELEY LAB (w/encl)

AUG 31 1979
79-B-2614
PLANT ENGINEERING

HARDING-LAWSON ASSOCIATES
ENGINEERS, GEOLOGISTS AND GEOPHYSICISTS
55 MITCHELL BOULEVARD, P.O. BOX 3030,
SAN RAFAEL, CALIFORNIA 94902 415/472-1400 TELEX 340523

May 22, 1979

2000,138.01

MBT Associates
631 Clay
San Francisco, California 94111

Attention: Mr. Jack Boyce

Gentlemen:

Preliminary Geotechnical Evaluation
Alternative Sites - Building 62 Addition
Lawrence Berkeley Laboratory

This letter presents our preliminary geotechnical evaluation of your four alternative site locations for the proposed addition to Building 62 at Lawrence Berkeley Laboratory (LBL) as shown on your site plans of May 1979, copies of which are attached. We had previously described the general soil and geologic conditions of the site vicinity in our report to LBL dated February 8, 1979 (No. 2000,138.01). As discussed with you in our recent meeting, our general conclusion is that the site vicinity is geotechnically suitable for the planned addition; however, siting on or close to the west slope will require slope stabilization measures due to the presence of landslide deposits.

Alternative 1

This plan is for a three-story structure to be located on the ridge upslope from Building 62. Based on our knowledge of the site conditions and review of three test borings drilled several years ago, this site is underlain by relatively thin clay soils over weakly consolidated siltstone, claystone and sandstone bedrock. The bedrock should provide suitable foundation support; most structures at LBL are supported in this type bedrock. No slope reconstruction measures would be necessary unless grading includes the slope area to the northwest. Generally, excavation of the bedrock will not be difficult; however, temporary cut slopes may be required and their design will be determined from a soil and foundation investigation which would require five test borings to depths from 20 to 50 feet.

LOG OF BORING 2

Equipment: Flight Auger

Elevation: 797 Date: 4/10/75

Shear Strength (lbs/sq ft)	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample	Description	
	21.3	97	0		BROWN GRAVELLY CLAY (CL) stiff, wet	FILL
					MOTTLED DARK BROWN & YELLOW SILTY CLAY (CL) stiff, wet	FILL
			5		GRAY-BROWN CONGLOMERATE moderately hard, strong, little weathered	ORINDA FORMATION
			10		LIGHT GREEN-GRAY SANDY SILTSTONE - low hardness, moderately strong, little weathered	ORINDA FORMATION
					water level 4/16/75	ORINDA FORMATION
			15		RED-BROWN CLAYSTONE low hardness, friable, little weathered	ORINDA FORMATION
					GRAY CLAYSTONE intensely fractured, low hardness, weak, little weathered, with occasional slickensides	ORINDA FORMATION
			20		BLUE-GRAY SILTY SANDSTONE low hardness, weak, fresh	ORINDA FORMATION
			25		BROWN CLAYSTONE low hardness, weak	ORINDA FORMATION
					LIGHT GRAY SANDSTONE low hardness, moderately strong, fresh	ORINDA FORMATION
			30			ORINDA FORMATION
			35			ORINDA FORMATION
	11.6	128	45		change to strong	ORINDA FORMATION

HARDING - LAWSON ASSOCIATES

Consulting Engineers and Geologists

Job No 2000,100.01 Appr. LEL Date 5/29/75

LOG OF BORING 2

Building 62 Addition

Lawrence Berkeley Laboratory

PLATE 3

123_00020

(127)

JK

PLANT ENGINEERING

FOUNDATION INVESTIGATION
HEMICAL AND MATERIALS SCIENCE LABORATORY
ND ATOMIC RESOLUTION MICROSCOPE BUILDING
LAWRENCE BERKELEY LABORATORY
BERKELEY, CALIFORNIA

147.01

HARDING-LAWSON ASSOCIATES

Shear Strength (lbs/sq ft) | Moisture Content (%) | Dry Density (pcf) | Depth (ft) | Sample

LOG OF 1

Equipment Hand Auger
Elevation 766.5 feet Date 1963

0
Dark Blue-Gray Shale, highly sheared and slickensided, (weak, wet)

5
Grading firmer with gray sandstone hard, refusal at 4.8'

10

LOG OF 1A

Equipment 14 inch Auger
Elevation 772 feet Date 1963

0
Light Brown Fine Sandstone and Siltstone, highly decomposed and fractured (damp to moist)

5
Blue-Gray Sandstone-Shale, highly decomposed and fractured with abundant slickensides (moist)

Light Gray Sandstone, hard, fractured (moist)
Refusal, very hard

10

LOG OF 2

Equipment Hand Auger
Elevation 766.5 feet Date 1963

0
Dark Blue Gray Shale, highly sheared and slickensided with gray clay seams (weak, wet)
Grading firmer (with clay seams)

5

10

HARDING - LAWSON ASSOCIATES
Consulting Engineers and Geologists

Job No. 2000,009.01 Appr: HL Date 12/31/79

LOG OF 1, 1A, and 2
Lawrence Radiation Laboratory
Building 62
Berkeley, California

PLATE 1

127_00043

LOG OF BORING 2A

Equipment 18 inch Auger

Elevation 772 feet Date 1963

Shear Strength (lbs/sq ft)	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample	
			0		Brown Sandy Clay (CL) with abundant siltstone and sandstone fragments moderately firm to firm, moist
			5		grading to siltstone, fractured and decomposed, moist Blue-Gray Shale, highly fractured, decomposed with abundant slickensides, (moderately firm, moist)
			10		
			15		with some hard gray sandstone (firm) wet with soft wet clay seams
			20		
			25		Gray, Thin Laminated Fine Sandstone and Siltstone, (hard, wet)
			30		
			35		
			40		

HARDING-LAWSON ASSOCIATES

Consulting Engineers and Geologists

Job No. 2000,009.01 Appr: [illegible] Date 12/31/79

LOG OF BORING 2A

Lawrence Radiation Laboratory

Building 62

Berkeley, California

PLATE 2

127_00044

HARDING-LAWSON ASSOCIATES
ENGINEERS, GEOLOGISTS AND GEOPHYSICISTS

7655 REDWOOD BOULEVARD
P.O. BOX 578
NOVATO, CALIFORNIA 94947 415/892-0821, Telex No. 340523

ALASKA
CALIFORNIA
HAWAII
ILLINOIS
NEVADA
TEXAS
WASHINGTON, D.C.
SAUDI ARABIA
NIGERIA

JO #127308
CMSL & ARM
62 72

file (letter only)
c: blair
~~[illegible]~~/eng file
Klein
McClure

July 16, 1980

2000,147.01

Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, California 94720

UNIVERSITY OF CALIFORNIA
LAWRENCE BERKELEY LAB
JUL 18 1980
PLANT ENGINEERING

195

Attention: Mr. Steve Blair,
Plant Engineering

Gentlemen:

Report
Supplemental Exploration
Chemical and Materials Science
Laboratory Building
Lawrence Berkeley Laboratory

This report presents the results of our supplemental exploration for the proposed Chemicals and Materials Science Laboratory Building. Our foundation investigation report for this project was submitted on January 3, 1980.

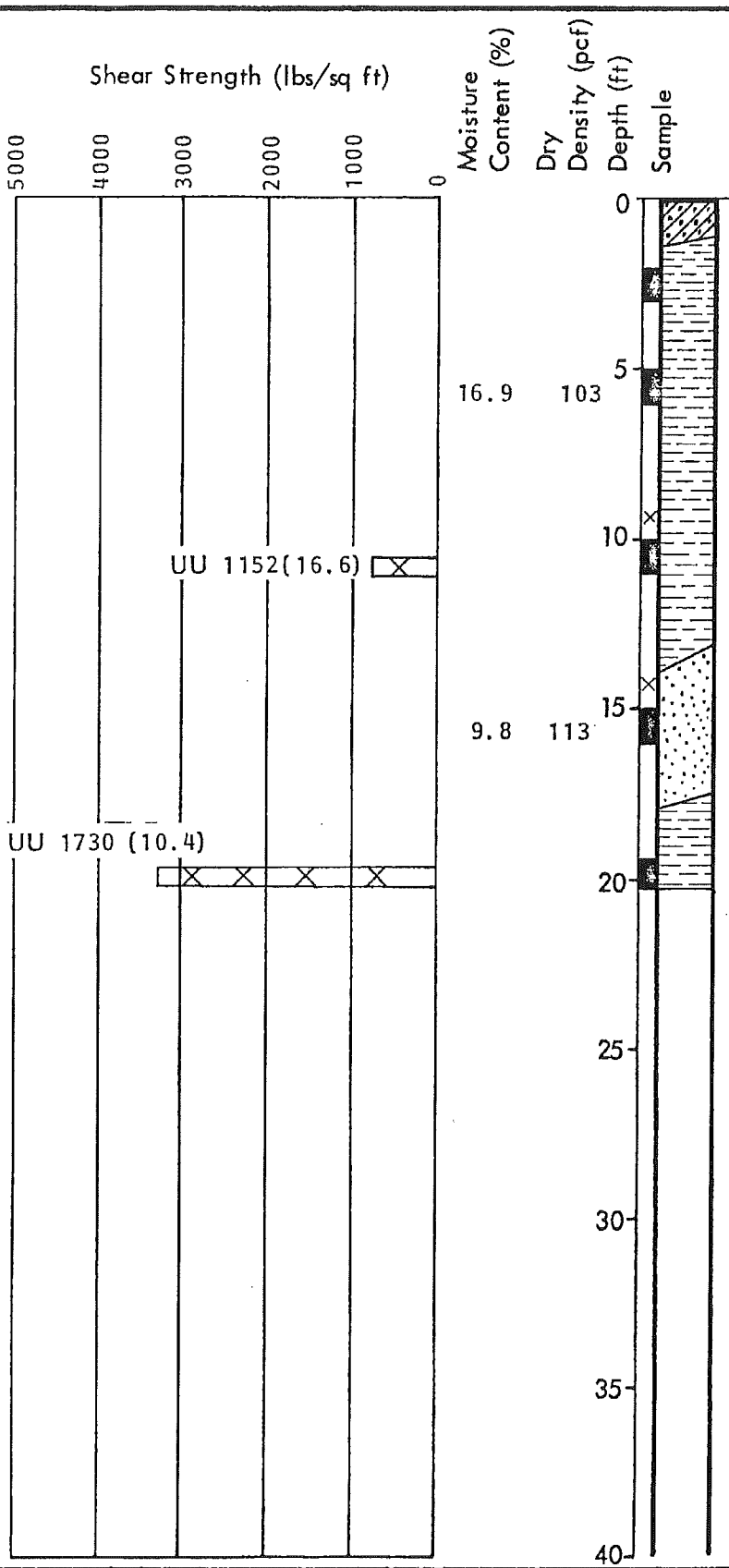
Since that time the building location and configuration have been changed. As shown on Plate A, it is now located about 20 to 30 feet west and about 50 feet southwest of the former location.

The CMSL building will consist of a three-story reinforced concrete frame structure approximately 95 by 105 feet in plan dimension with a ground floor elevation of 788 feet (LBL Datum). There also will be a wing to the south of the main building which will house an auditorium, administration and a mechanical room in the basement at Elevation 773. The new plan requires cuts and fills as high as 30 and 12 feet, respectively. The cut on the north side of the building is to be retained with a free-standing retaining wall. We understand that column and wall dead plus live loads will be as much as 300 kips and 10 kips per foot, respectively. The purpose of the supplemental exploration was to obtain additional subsurface information in areas where the building is now planned and which was not explored previously.

LOG OF BORING 9.147

Equipment 8" Hollow Auger

Elevation 757.5 feet Date 5/27/80



DARK BROWN GRAVELLY SANDY CLAY (CL) - very stiff, moist

GRAY-BROWN SHALE
low to moderately hard, weak, moderately weathered
intensely fractured with clay fracture fillings, occasionally sheared

sheared at 14 feet

GRAY SANDSTONE
low hardness, weak, intensely fractured

DARK GRAY SHALE
sheared, low hardness, weak
little weathered

Cretaceous

HARDING-LAWSON ASSOCIATES
Consulting Engineers and Geologists

Job No. 2000,147.01 Appr: SCK Date 7/14/80

LOG OF BORING 9.147
CMSL Building
Lawrence Berkeley Laboratory

PLATE **B**

195_00005

Harding Lawson Associates

Engineers, Geologists
& Geophysicists

HLA

GEOTECHNICAL INVESTIGATION
ENGINEERING AND
TECHNICAL SUPPORT FACILITY
BUILDING 77A
LAWRENCE BERKELEY LABORATORY
BERKELEY, CALIFORNIA

HLA Job No. 2000,179.01

Equipment 3" Flight Auger

Elevation 855 feet Date 9-21-83

Laboratory Tests	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Core Recovery (%)	Cored Interval	Depth (ft)	Sample	
		12.6	97			0		MOTTLED RED-BROWN AND AND LIGHT GRAY CLAYEY SILT (ML)- medium stiff, dry, with abundant gravel
								becoming moist below 4'
						5		
						10		BROWN SANDY SILTSTONE intensely fractured to crushed, friable, low hardness, weathered
		10.7	106					
						15		(No Free Water Encountered)
						20		
						25		
						30		
						35		
						40		

FILL

ORINDA FORMATION

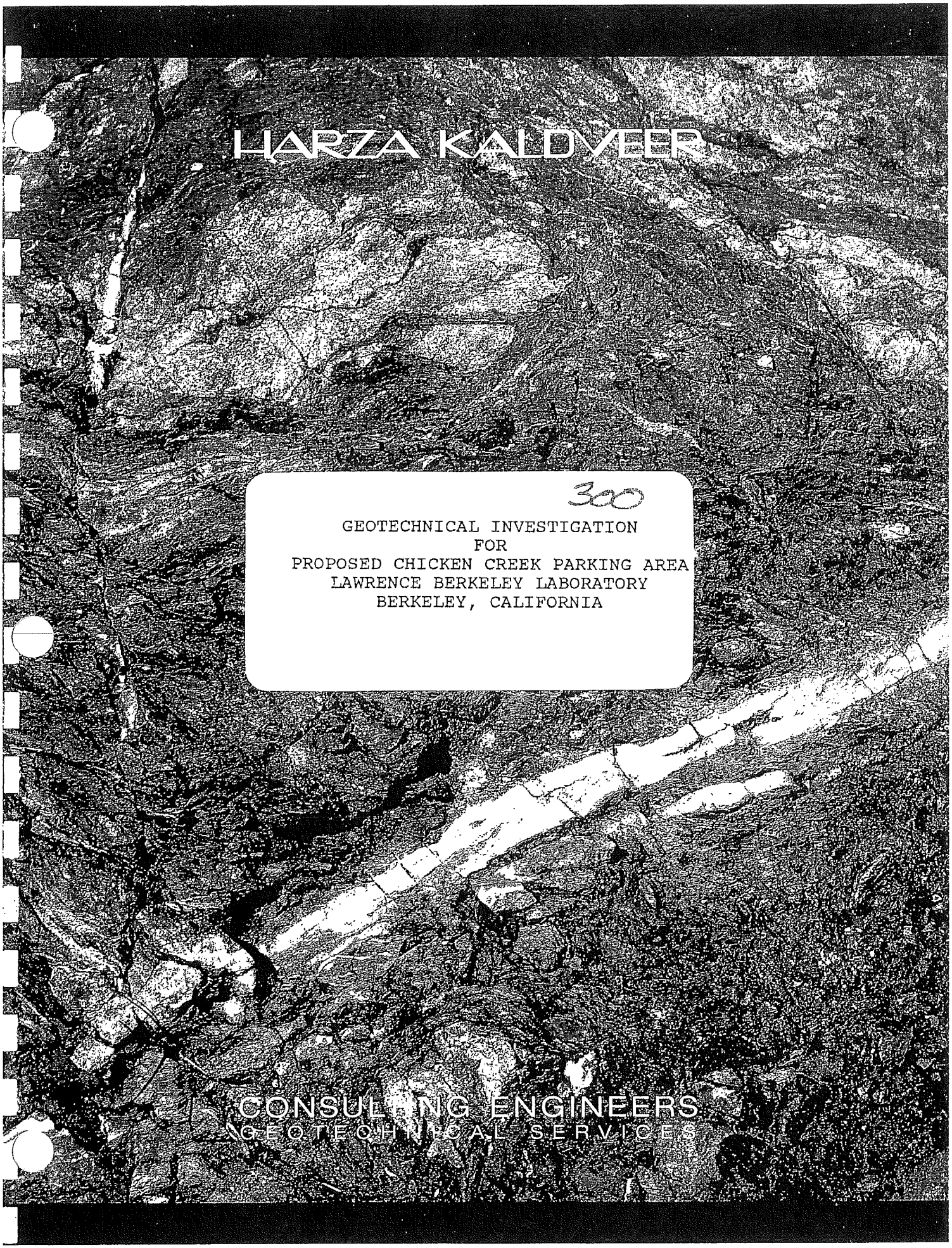
Harding Lawson Associates
Engineers Geologists
& Geophysicists

Log of Boring 9 - 179
LBL Building 77A
Berkeley, California

PLATE **10**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
DMR	2000,179.01	C. Storall	10/83		

163_00025



HARZA KALDVEER

300

GEOTECHNICAL INVESTIGATION
FOR
PROPOSED CHICKEN CREEK PARKING AREA
LAWRENCE BERKELEY LABORATORY
BERKELEY, CALIFORNIA

CONSULTING ENGINEERS
GEOTECHNICAL SERVICES

DRILL RIG	CME-75, CFA	SURFACE ELEVATION	760 Feet	LOGGED BY	CDT
DEPTH TO GROUNDWATER	Not Enc.	BORING DIAMETER	6-inch	DATE DRILLED	4/22/93

DESCRIPTION AND CLASSIFICATION: DESCRIPTION AND REMARKS	CONSIST	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT)	WATER CONTENT (%)	DRY DENSITY (PCF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)	OTHER TESTS
2" old AC									
COLLUVIUM: CLAY (CL), dark brown with black mottling, with silt and sand (fine- to coarse-grained), damp (trace rootlets in upper 2 feet)	Stiff			X	10	24	88	1.5	
(black CH lense at 6 feet) (trace gravel at 6 to 6-1/2 feet)	Very Stiff		5	X	18	31	88		PI=45%,LL=67 Passing #200 Sieve=90%
(some sand, no gravel below 10 feet)	Hard		10	X	37				
	Very Stiff		15	X	27				
(cuttings moist at 20 to 21-1/2 feet)			20	X	25				
COLLUVIUM (CL/CH), gray gray, medium plasticity, some silt and sand (fine- to medium-grained), trace organics, moist	Very Stiff		25	X	18				
			30	X	21				

HARZA KALDVEER
Consulting Engineers

EXPLORATORY BORING LOG

PROPOSED CHICKEN CREEK PARKING AREA - LBL
Berkeley, California

PROJECT NO.	DATE	BORING NO	EB-5
K1226-4-1864	July 1993		

DRILL RIG	CME-75, CFA	SURFACE ELEVATION	760 Feet	LOGGED BY	CDT
DEPTH TO GROUNDWATER	Not Enc.	BORING DIAMETER	6-inch	DATE DRILLED	4/22/93

DESCRIPTION AND CLASSIFICATION: DESCRIPTION AND REMARKS	CONSIST	SOIL TYPE	DEPTH (FEET)	SAMPLER	PENETRATION RESISTANCE (BLOWS/FT)	WATER CONTENT (%)	DRY DENSITY (PCF)	UNCONFINED COMPRESSIVE STRENGTH (KSF)	OTHER TESTS
COLLUVIUM (CL/CH) (continued) (trace gravel at 35 to 36-1/2 feet)	Very Stiff				24				
COLLUVIUM: CLAY (CL), brown, silty, some sand (medium- to coarse-grained), damp (grayish-blue sandstone/siltstone interbedded at 40 to 41-1/2 feet)	Hard		40		39				
(blue at 46 to 46-1/2 feet)			45		68				
(blue sandstone/siltstone interbedded, trace gravel at 50 to 51-1/2 feet)			50		54				
(blue sandstone in shoe)			55		75/11'				
Bottom of Boring = 56-1/2 Feet									

Notes:
1. The stratification lines represent the approximate boundaries between soil types and the transition may be gradual.
2. For an explanation of penetration resistance values, see the first page of Appendix A.
3. Groundwater was not encountered at the time of drilling.
4. The boring was backfilled with native soil cuttings immediately upon completion.
5. PI = Plasticity Index, LL = Liquid Limit.

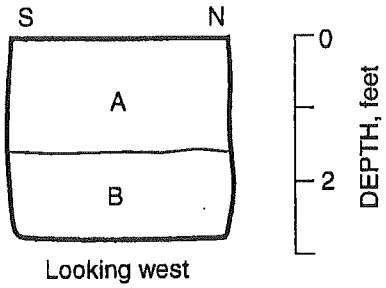
HARZA KALDVEER
Consulting Engineers

EXPLORATORY BORING LOG

PROPOSED CHICKEN CREEK PARKING AREA - LBL
Berkeley, California

PROJECT NO.	DATE	BORING NO
K1226-4-1864	July 1993	EB-5

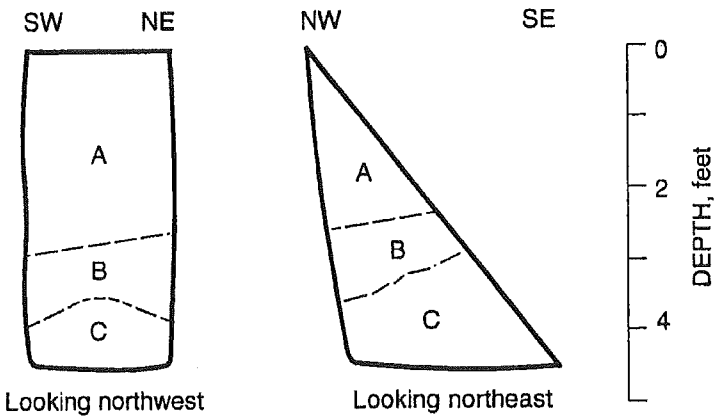
EXCAVATION T1



A Soil with shale fragments

B Weathered/fractured shale with some clay

EXCAVATION T2



A Very stiff, dry clay with shale fragments

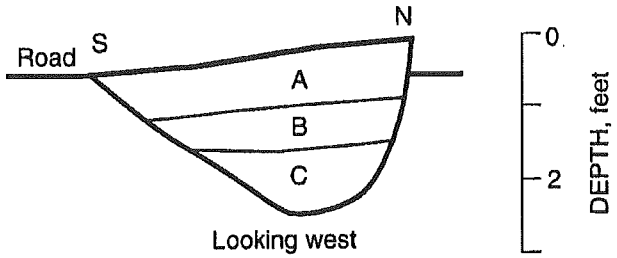
B Weathered yellow-brown shale and clay

C Hard, brown, dry, blocky shale

Joints:
N65°W35°NE
N65°W40°NE
N68°W50°NE

GEOMATRIX	LOGS OF EXPLORATORY EXCAVATIONS U.C. EH&S Building Strawberry Canyon Facility Berkeley, California	Figure B-1 Project No. 2501

EXCAVATION T18

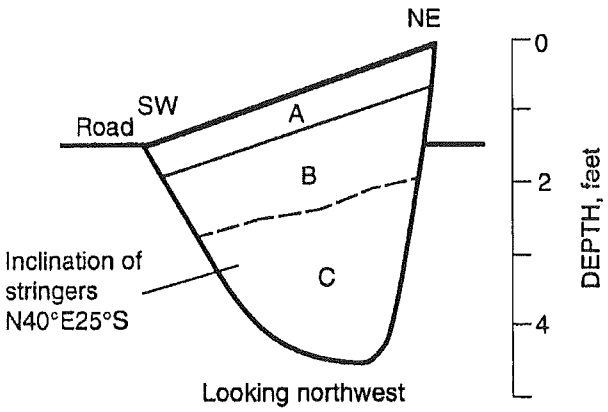


A Clay fill with road base

B Sandy clay colluvium, with sandstone fragments

C Hard, dry, yellow-brown sandstone (Orinda type)

EXCAVATION T19

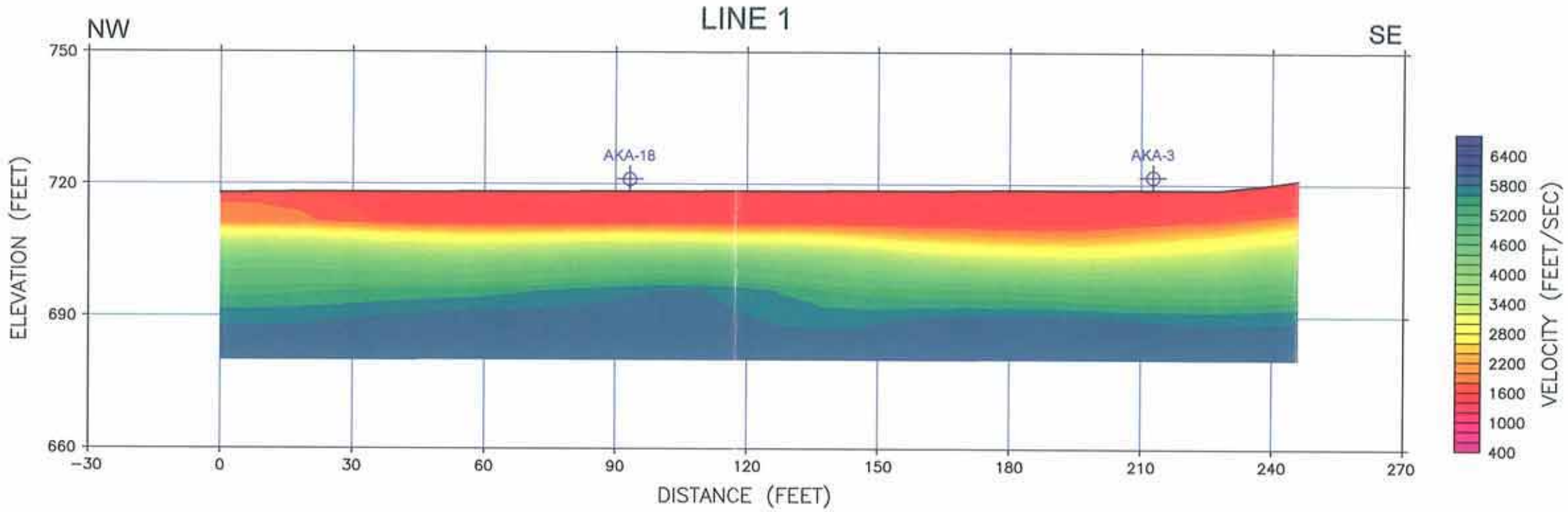


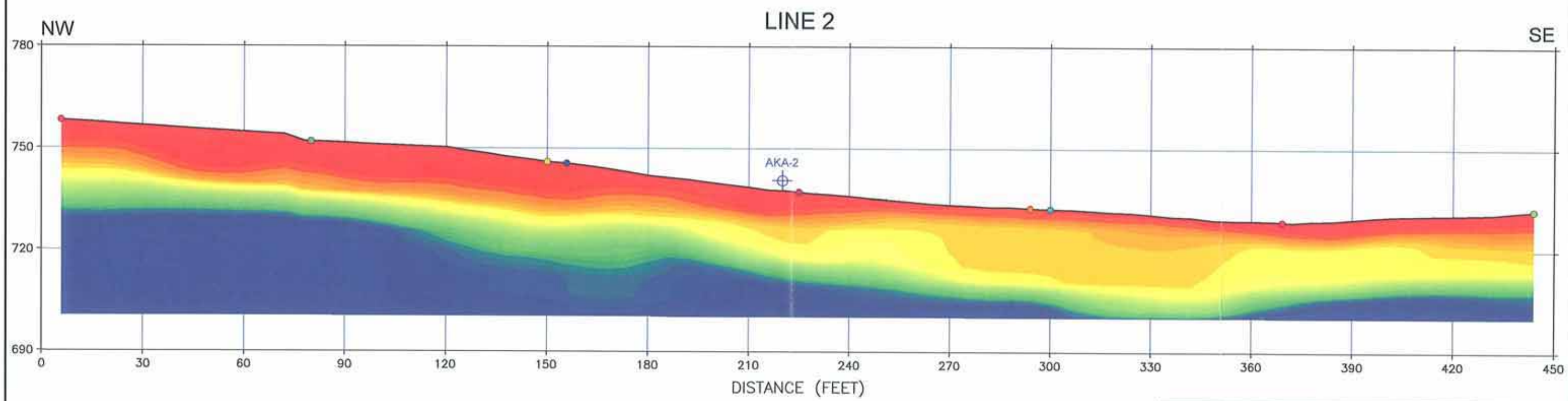
A Black clay

B Red clay, highly weathered colluvium

C Hard, red, colluvium with green sand stringers, discontinuous round basalt boulder (12" x 12") and Orinda type conglomerate boulder (6" x 8") (not blocky colluvium)

GEOMATRIX	LOGS OF EXPLORATORY EXCAVATIONS U.C. EH&S Building Strawberry Canyon Facility Berkeley, California	Figure B-10 Project No. 2501





LEGEND	
⌖	APPROXIMATE BORING LOCATION (PER ALAN KROPP & ASSOCIATES, INC.)

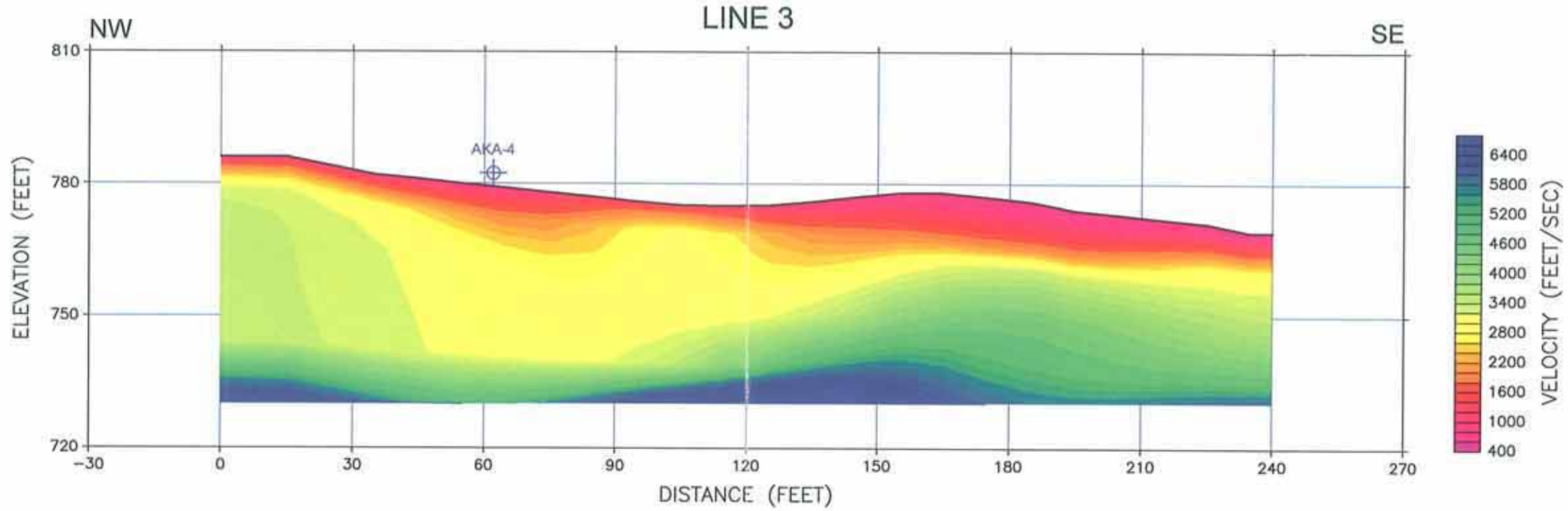
SCALE
0 15 30 60
(1 inch = 30 feet)

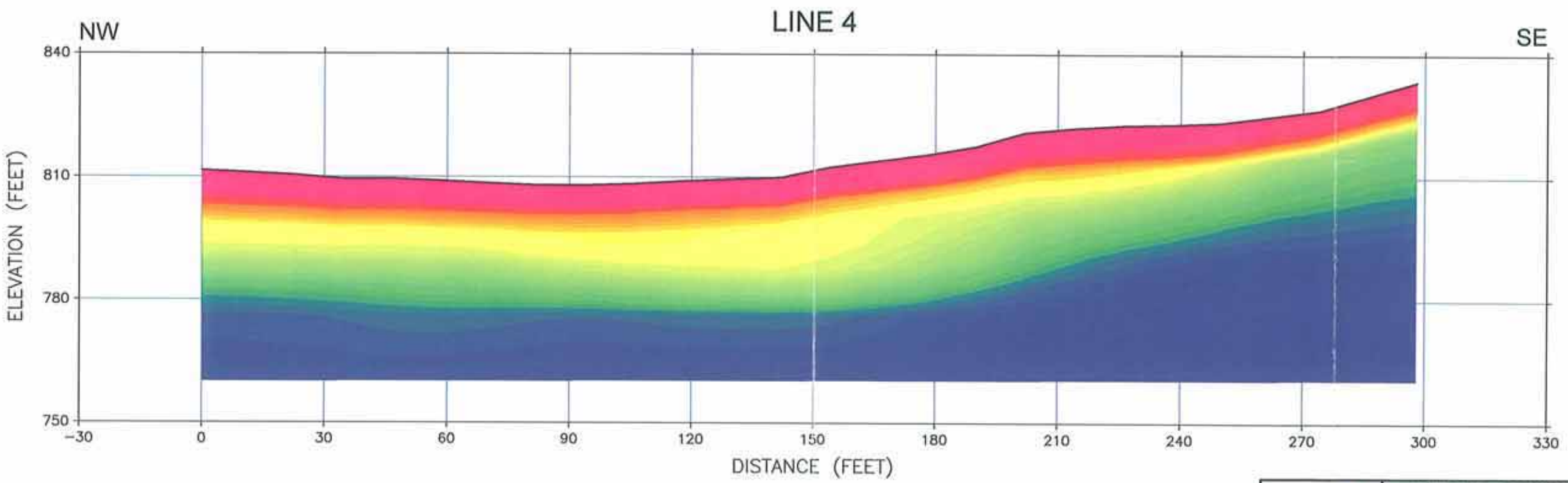
NORCAL

SEISMIC REFRACTION PROFILES
LINES 1 & 2
LBL SITE

LOCATION: BERKELEY, CALIFORNIA
CLIENT: ALAN KROPP & ASSOCIATES, INC.
NORCAL GEOPHYSICAL CONSULTANTS INC.
JOB #: 07-778.03
DATE: OCT. 2007
DRAWN BY: G.RANDALL
APPROVED BY: OSB

PLATE 2





LEGEND	
⌖	APPROXIMATE BORING LOCATION (PER ALAN KROPP & ASSOCIATES, INC.)

SCALE
0 15 30 60
(1 inch = 30 feet)

NORCAL

SEISMIC REFRACTION PROFILES
LINES 3 & 4
LBL SITE

LOCATION: BERKELEY, CALIFORNIA
CLIENT: ALAN KROPP & ASSOCIATES, INC.
NORCAL GEOPHYSICAL CONSULTANTS INC.
JOB #: 07-778.03
DATE: OCT. 2007
DRAWN BY: G.RANDALL
APPROVED BY: OSB

PLATE 3

402

BERKELEY LAB

MOLECULAR FOUNDRY PROJECT

Date: November 7, 2003

To: David Bleiman, Rutherford & Chekene
Fred Angliss, LBNL

From: Marissa Smithwick
Molecular Foundry Project Administrator

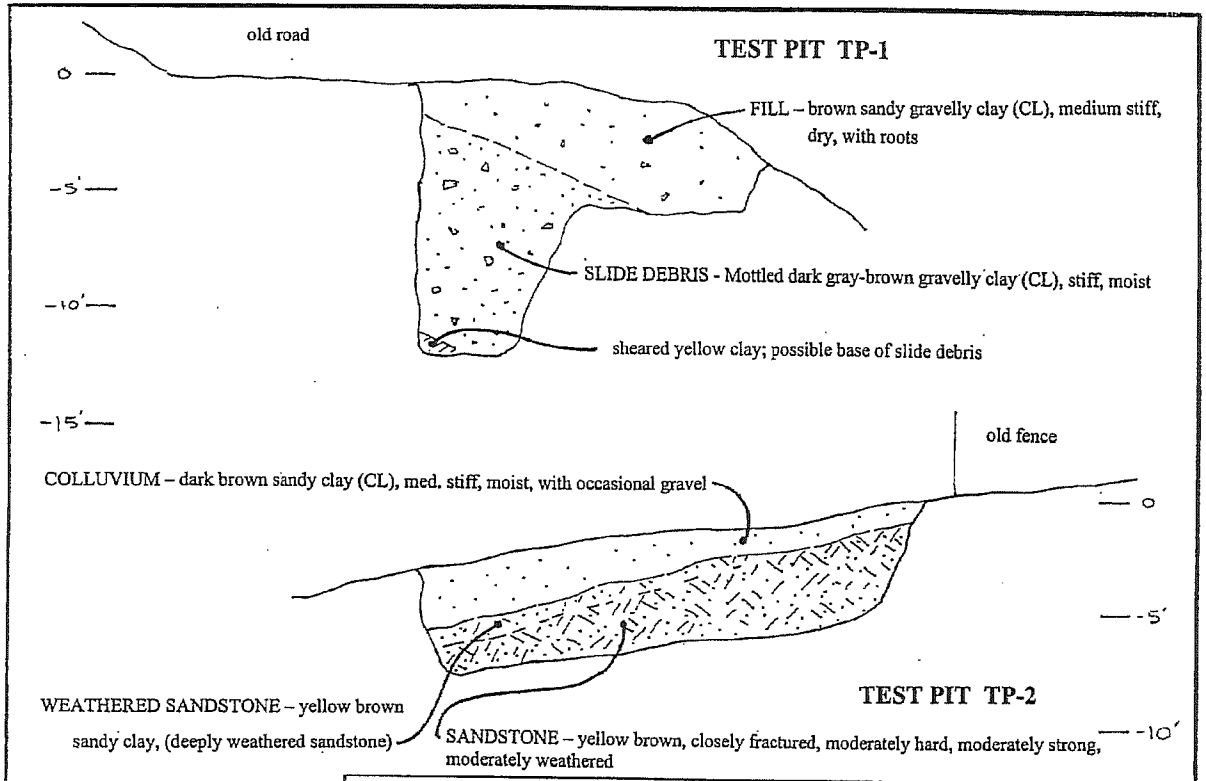
Subject: Molecular Foundry Geotechnical Investigation – Aggregate

Attached please find the aggregate geotechnical investigation report from Kleinfelder, dated 10/30/03, for the Molecular Foundry project. This report is provided for your reference.

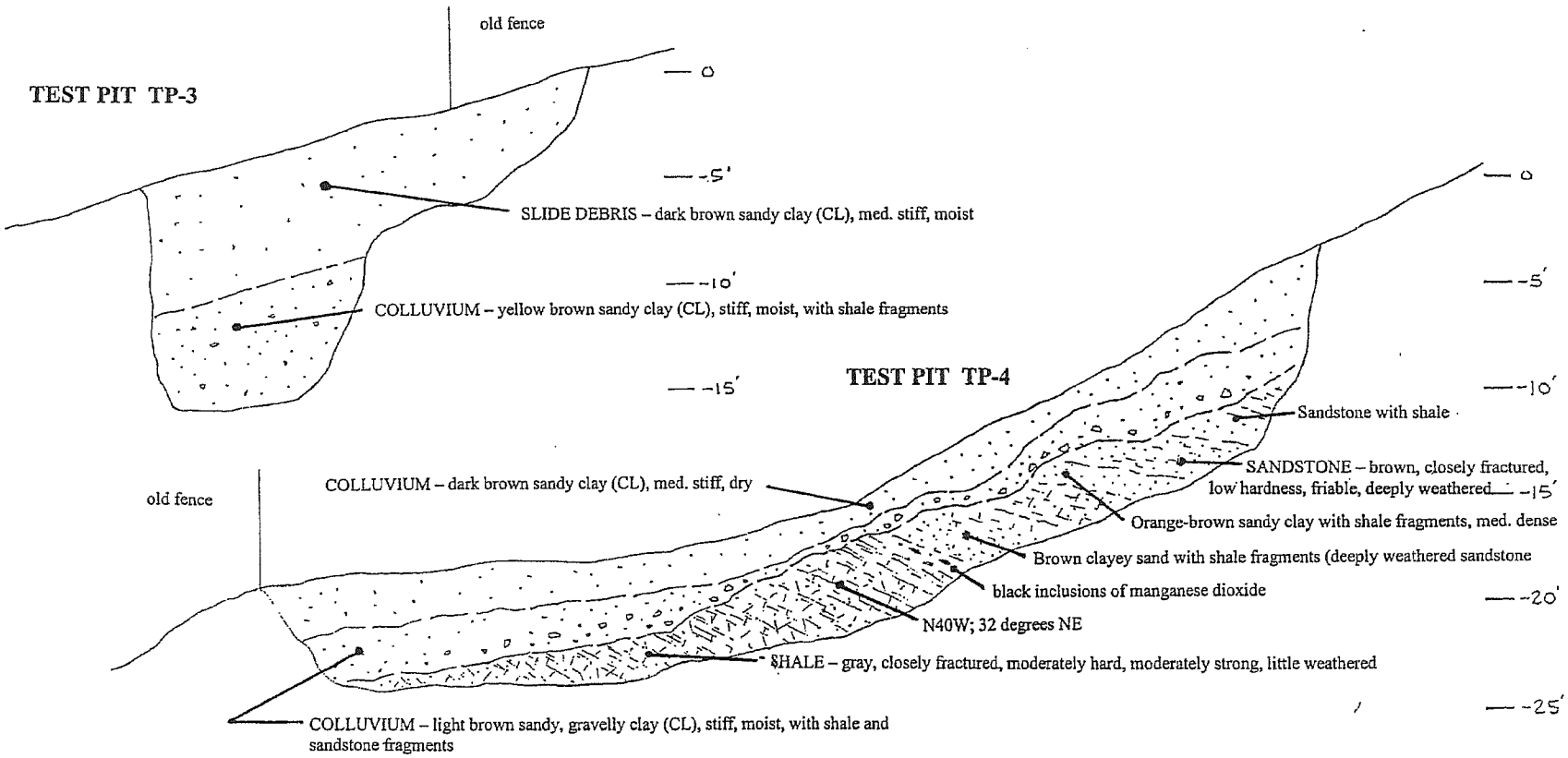
Please let me know if you have any questions.

Cc: Suzanne Napier, SmithGroup Inc.
Mike Detata, Rudolph & Sletten
File: 1.3.3.3.2

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY
ONE CYCLOTRON ROAD • BERKELEY CA 94720
510-486-6088 • 510-486-4101 FAX



KLEINFELDER PROJECT NO. 20258	LOGS OF TEST PITS TP-1 and TP-2 Molecular Foundry Project Lawrence Berkeley National Laboratory Berkeley, California	PLATE 2



KLEINFELDER

PROJECT NO. 20258

LOGS OF TEST PITS TP-3 and TP-4
Molecular Foundry Project
Lawrence Berkeley National Laboratory
Berkeley, California

PLATE 3

M-7

402_00062

APPENDIX C

DOWNHOLE GEOPHYSICAL DATA

NORCAL GEOPHYSICAL CONSULTANTS, INC.

December 8, 2008

Mr. Wayne Magnusen
Alan Kropp and Associates
2140 Shattuck Avenue, Suite 910
Berkeley, CA 94704

Subject: P-and S-Wave Borehole Suspension Logging Report
Helios Building Area
Lawrence Berkeley Laboratory
Berkeley, CA
NORCAL Job No. 08-778.05B

Mr. Magnusen:

This report presents the findings of a borehole geophysical survey performed by NORCAL Geophysical Consultants, Inc. The survey was performed in one borehole designated as AKA-35. Boring AKA-35 was situated on a access road downslope of the Helios Building.

The geophysical survey consisted of measuring the subsurface distribution of compressional (P-) and shear (S-) seismic velocity using a downhole suspension velocity logging system. The field work was performed on November 6, 2008 by NORCAL geophysicist, William Henrich.

1.0 PURPOSE

The purpose of the seismic suspension logging survey was to measure the distribution of P-wave and S-wave velocities below the hillside. These data will aid in evaluating foundation characteristics for a tower expansion off of the existing Helios Building.

2.0 METHODOLOGY

We used an OYO-Robertson Model 3403 digital suspension logging system to measure downhole compressional (P-) and shear (S-) velocities. The suspension logging system consists of a control console, four-conductor winch and downhole probe. The probe is equipped with a dipole seismic energy source located near the base of the probe and a pair of geophones (detectors) located at the upper end. A schematic showing the probe configuration and equipment attachments is shown in Appendix A. The distance

321A BLODGETT STREET • COTATI, CA 94931 • TELEPHONE (707) 796-7170 • FAX (707) 796-7175
www.norcalgeophysical.com

from the energy source to the first geophone was 7.02 feet (2.13 meters). The in-line distance between the geophone pair is 3.28 feet (1.0 meter). Each geophone contains one horizontal and one vertical oriented element. The horizontal phone elements preferentially record the shear wave. The vertical geophone elements record first arriving P-wave energy.

Suspension seismic data are collected at discrete depths in a fluid-filled borehole. At each measurement depth, the energy source is activated via commands from the surface control console. This activation causes a metal solenoid to strike a plate (anvil) mounted inside the probe housing. This energy transmits through the fluid to the borehole wall which produces a seismic wave ("flexure") in the adjacent formation. As this wave propagates radially in the formation away from the source, a seismic interaction between the seismic wave and the borehole wall creates tube waves together with a compressional P-wave that travels up the borehole to the two recording geophones.

P-wave arrival times are identified as the first break on the vertical geophone seismic records. Tube wave arrivals are later arriving seismic events and are recorded on the horizontal geophones. The identification of the tube wave arrival times are facilitated by recording seismic records from two opposite directions of solenoid impacts. By superimposing these two seismic records, the onset of the tube wave/S-wave arrival time is usually identified as a higher amplitude and phase reversal event. The velocity of the tube wave is very close (90 percent) to that of the S-wave. Hence, we report tube wave velocities as seismic S-wave velocities.

When assembled, the suspension logging tool measures approximately 19 feet in length. The measuring point of the tool is taken at the center of the pair of geophones. This measuring point is approximately 11 feet from the bottom of the probe. Therefore, the maximum depth of our survey will always be reported 11 feet from the total depth of the borehole.

4.0 DATA ACQUISITION

The boreholes were drilled with a rotary core method using a five-inch diameter drill bit. Total depth of Boring AKA-35 was 67 feet below ground surface (bgs).

We measured seismic suspension velocities at one-half to two-foot intervals beginning at 15 feet below ground surface down to the bottom of each well. At each measurement station, we cycled the energy source to fire 3 to 5 times in succession into each geophone element. This cycling stacks seismic records to achieve better signal to noise ratios. We also recorded S-wave data using a 1.2 KHz low pass filter.

This filtering reduces high frequency interference from the onset of earlier arriving P-wave modes. The downhole tool did not encounter any obstructions and as a result, we were afforded more time to record additional measurement stations up the boring such that the final sampling interval was one-half to one foot over critical borehole sections.

5.0 DATA ANALYSIS

Seismic P- and S-wave velocities were calculated with the interpretation computer software Glog SUS, Version 1.12 published by Oyo Corporation (2000). A typical interpreted seismic record is presented in Appendix B. This record shows six geophone traces. Traces H1 and H2 are horizontal geophone elements which are preferentially aligned to record S-waves. H1 is the geophone nearest to the source, H2 is the farthest from the source. V1 and V2 are the vertical geophone elements which are preferentially aligned to record P-waves. The horizontal geophone elements (H1 and H2) show a total of four S-wave arrival times; two arrival times identified at each geophone are referenced as "up" and "down" breaks. The "up" and "down" breaks are the result of two separate and oppositely directed (180 degrees) solenoid impacts by the energy source. As the example record illustrates, these opposing impacts produce amplitude phase reversals which identifies the on set of the S-wave energy. All seismic records were analyzed for P- and S- arrival time in this manner. Seismic velocities are calculated by dividing the geophone spacing interval (1 meter) by the interpreted interval travel times in microseconds to yield seismic velocities in meters per second. Two S-wave velocities are calculated at each depth measurement station. We averaged the results of two S-wave interval velocities and presented a single S-wave value at each measurement station.

The interval velocity calculation method is the preferred reduction technique, however, we have noticed problems as some first arrival times (first breaks) within a set of measured waveforms are not always in phase. These mismatches cause significant velocity deviations at some depth measurement stations when compared to nearest neighbors. To help flag these mismatches we performed direct velocities calculations from the arrival times. That is, we divide the travel distance from the source to the detectors by the arrival times (see report graphic regarding the probe geometry). These direct arrival times velocities are compared to the interval velocities. When we see velocity discrepancies we reinterpret arrival times in the Glog-SUS program so that the interval velocities approximately correspond to the direct velocity calculation. It should be noted that the direct velocity calculation though useful can not substitute for an interval velocity because the delay times due to instrumental and probe standoff are not known precisely.

6.0 RESULTS

The results of our velocity interpretation are graphically presented on Plate 1. The P- and S-wave velocities were converted to English units in feet per second (fps). Note, the horizontal velocity scale for the S-wave velocity is one half value that of the P-wave velocity scale. The reason for this more sensitive S-wave scale is to show small magnitude velocities variations with depth.

7.0 INTERPRETATION

Our analysis showed the subsurface P-wave and S-wave velocities ranged from 5300 to 6400 and 850 to1850 feet per second (fps), respectively. According to the geological logs these velocity ranges represent sandstone and shale bedrock in various states of weathering and consolidation. It should be noted that the lower velocity measurement limit of the suspension logging technique with respect to first arriving P-waves is about 5000 fps. This is due to the fact that the tool operates in a fluid column that has an intrinsic compressional P-wave velocity of approximately 5000 fps. P-wave energy emitted by the source will travel up the borehole fluid column and arrive at the geophone detectors as direct arrivals thereby muting any slower P-wave velocity modes excited in the lower velocity geologic materials between the source and detectors. In Boring AKA-35, bedrock formation P-wave velocities which exceeded the fluid velocity were observed beginning at 46 feet bgs. Since the P-wave velocities in geologic materials are greatly effected by saturation, this 44 foot depth may correspond to the depth of the local water table.

S-wave velocities are not subject to the above P-wave limitation and provide a useful comparative velocity profile of the subsurface. Low S-wave velocities less than 1000 fps usually indicate unconsolidated alluvium or highly weathered bedrock. These S-wave velocities are confined to depths between 12 and 14 feet (see Plate 1). The S-wave profile shows a near consistent 1200 fps velocity beginning at 16 down to 28 feet bgs and suggesting a geologic unit of relatively low shear rigidity. Just below 28 feet, the S-wave increases in a step-wise manner at 28.5 feet to 1600 fps. Higher S-wave velocities above 1600 fps usually indicate a change in rock properties or change in lithology. According to the preliminary geologic log this velocity change closely corresponds to bedrock change from an upper highly weathered sandstone to a harder, less weathered shale at 26.5 feet bgs.

8.0 STANDARD CARE AND WARRANTY

The scope of NORCAL's services for this project consisted of using downhole geophysical methods to characterize the subsurface. The accuracy of our findings is subject to specific site conditions and limitations inherent to the techniques used. We performed our services in a manner consistent with the standard of care ordinarily exercised by members of the profession currently employing similar methods. No warranty, with respect to the performance of services or products delivered under this agreement, expressed or implied, is made by NORCAL.

We appreciate having the opportunity to provide you with this information.

Respectfully,

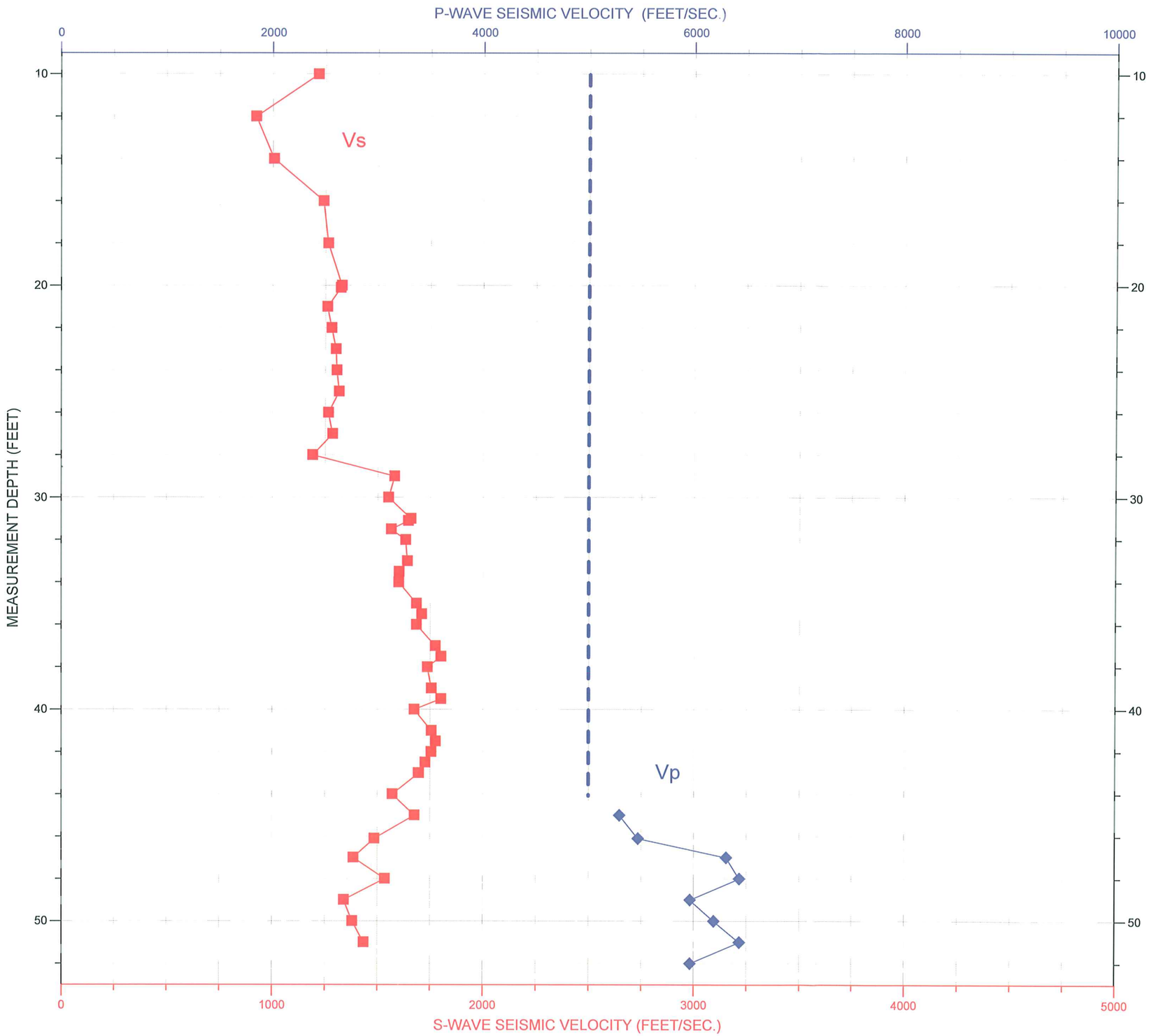
NORCAL Geophysical Consultants, Inc.

William J. Henrich
Geophysicist, GP-893

Attachments: PLATE 1: Suspension P- and S-wave Velocity Profile

Appendix A: Suspension Logging Probe and System Schematic
Appendix B: Example Seismic Suspension Record

WJH/tt



NOTE: P-wave velocity of bedrock less than the fluid velocity is not detectable above 44 feet bgs.

BOREHOLE FLUID VELOCITY

P- & S-WAVE VELOCITIES

Vp interval

Vs interval

NORCAL

BORING AKA-35
SUSPENSION P- & S-WAVE VELOCITY PROFILE
LAWRENCE-BERKELEY NATIONAL LAB

LOCATION: BERKELEY, CALIFORNIA

CLIENT: ALAN KROPP & ASSOCIATES

JOB #: 08-778.05B

NORCAL GEOPHYSICAL CONSULTANTS INC.

DATE: DEC. 2008

DRAWN BY: G. RANDALL

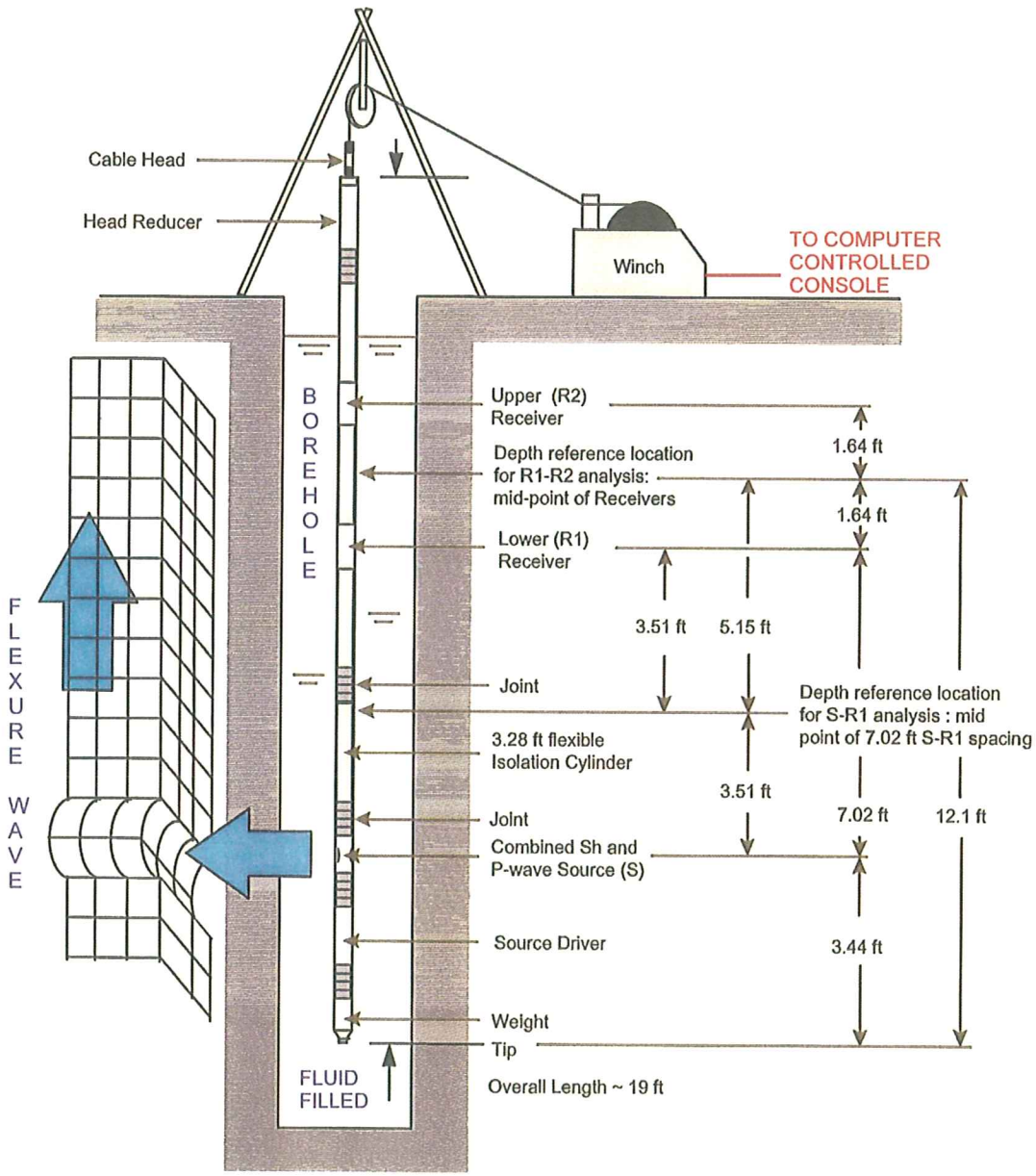
APPROVED BY: WJH

PLATE 1

APPENDIX A

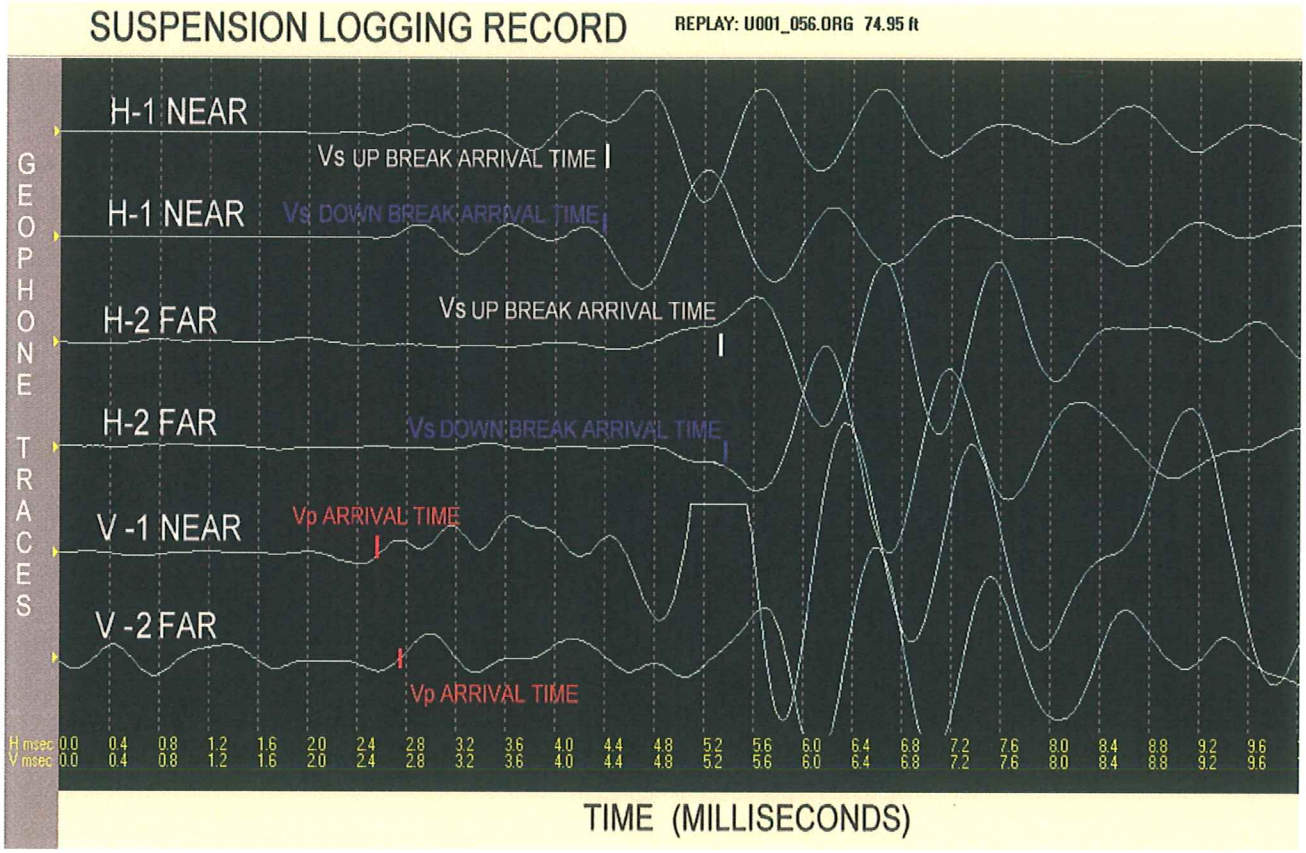
Suspension Logging Probe and System Schematic

SUSPENSION LOGGING PROBE AND EQUIPMENT CONFIGURATION



Appendix B:

Example Seismic Suspension Record


SUSPENSION LOGGING RECORD
REPLAY: U001_056.ORG 74.95 ft
GEOPHONE TRACES
H-1 NEAR
Vs UP BREAK ARRIVAL TIME
H-1 NEAR
Vs DOWN BREAK ARRIVAL TIME
H-2 FAR
Vs UP BREAK ARRIVAL TIME
H-2 FAR
Vs DOWN BREAK ARRIVAL TIME
V -1 NEAR
Vp ARRIVAL TIME
V -2 FAR
Vp ARRIVAL TIME
H msec 0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0 4.4 4.8 5.2 5.6 6.0 6.4 6.8 7.2 7.6 8.0 8.4 8.8 9.2 9.6
V msec 0.0 0.4 0.8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 4.0 4.4 4.8 5.2 5.6 6.0 6.4 6.8 7.2 7.6 8.0 8.4 8.8 9.2 9.6
TIME (MILLISECONDS)

NORCAL

NORCAL GEOPHYSICAL CONSULTANTS, INC.

BHTV
DUAL INDUCTION
NATURAL GAMMA
CALIPER

COMPANY	WILLIAM LETTIS ASSOCIATES
WELL ID	AKA-2
FIELD	HELIOS
COUNTRY	USA STATE CA

CO ALAMEDA
WELL AKA-2
FLD LBL
CTY BERKELEY
STE CALIFORNIA
FILING No

LOCATION
LBL
HELIOS

SEC TWP RGE

OTHER SERVICES
SUSPENSION LOGGING
P- AND S-WAVE

PERMANENT DATUM ELEVATION NA K.B.

LOG MEAS. FROM GROUND SURFACE ABOVE PERM. DATUM D.F.

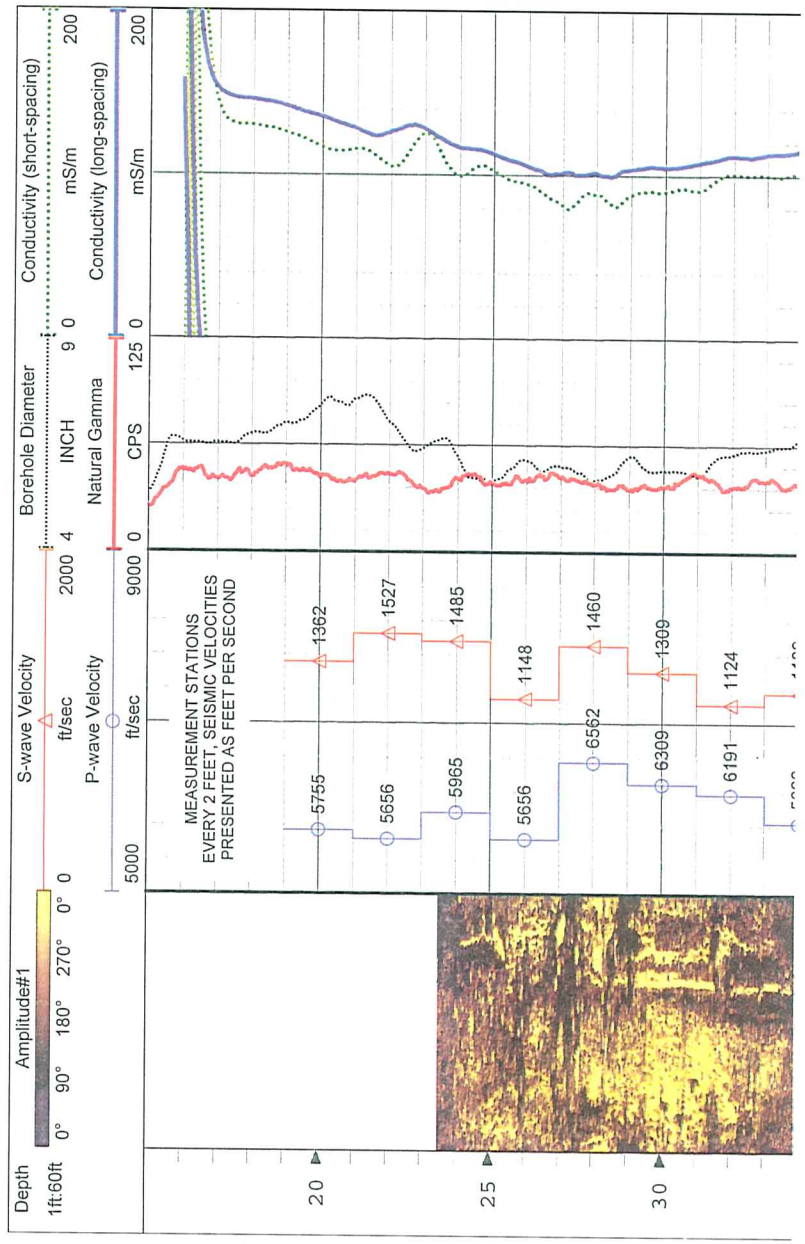
DRILLING MEAS. FROM GROUND SURFACE G.L.

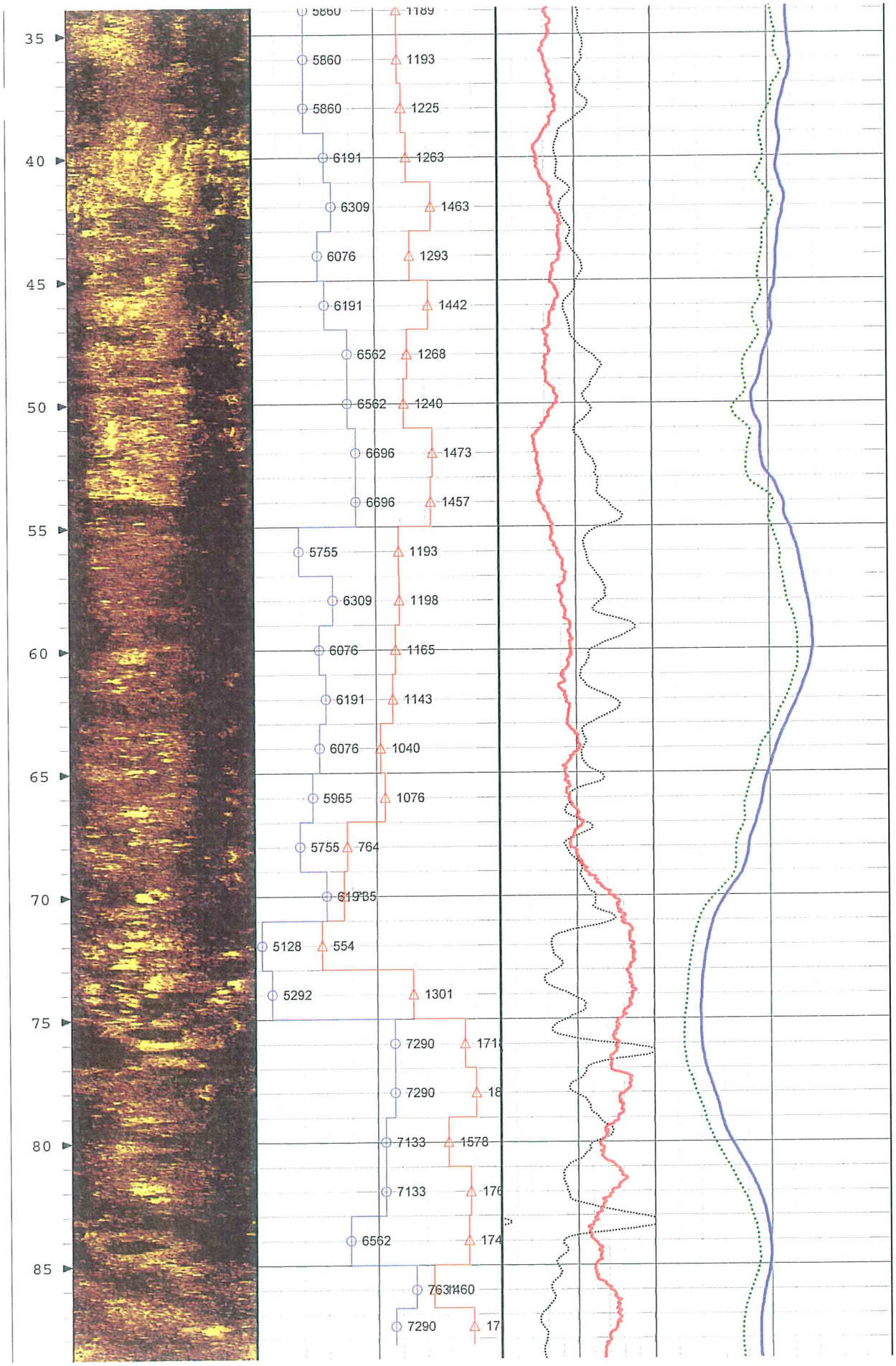
DATE	14 Sep 2007	TYPE FLUID IN HOLE	WATER
RUN No	1	SALINITY	
TYPE LOG	GAMMA-DUAL INDUCT BHTV	DENSITY	
DEPTH-DRILLER	102	LEVEL	19
DEPTH-LOGGER	101	MAX. REC. TEMP.	
BTM LOGGED INTERVAL	101		
TOP LOGGED INTERVAL	7		
OPERATING RIG TIME	4 HOURS		
RECORDED BY	W HENRICH		
WITNESSED BY	KATE KRUG		

RUN	BOREHOLE RECORD			CASING RECORD			
NO.	BIT	FROM	TO	SIZE	WGT.	FROM	TO
1	4.9	15	102	5.5	STEEL	0	15

NOTES

VELOCITIES CALCULATED WITH GLOG-SUSP V. 1.12

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40
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75
80
85
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5860 1193
5860 1225
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6076 1293
6191 1442
6562 1268
6562 1240
6696 1473
6696 1457
5755 1193
6309 1198
6076 1165
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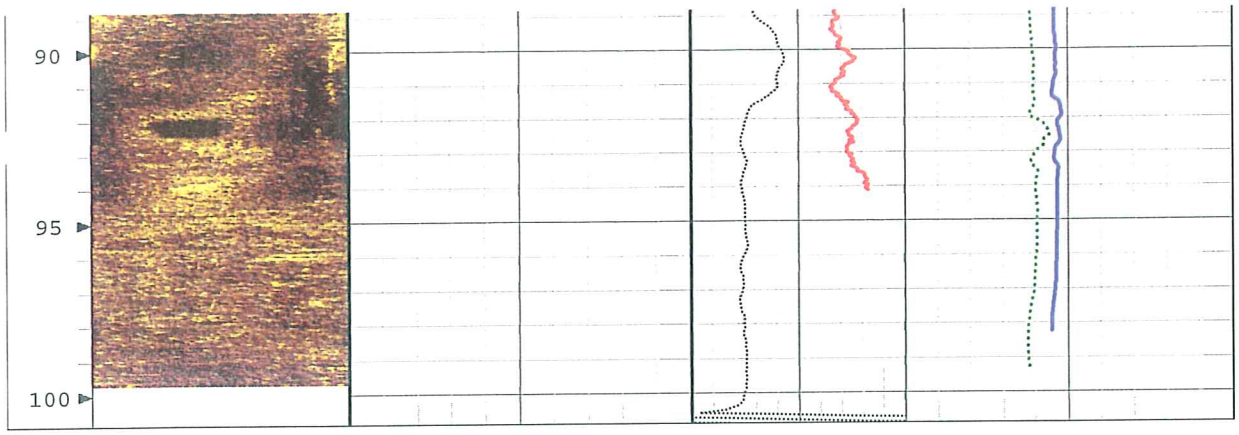
7133
6562
7290


90
95
100

APPENDIX D

SEISMIC SURVEY DATA & REPORT

NORCAL GEOPHYSICAL CONSULTANTS, INC.

October 19, 2007

Mr. Wayne Magnusen
Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA 94704

Subject: Seismic Surveys
Helios Building Project, Lawrence Berkeley National Labs
Berkeley, CA
NORCAL Job # 07-778.03

Dear Mr. Magnusen:

This report presents the findings of a seismic refraction (SR) and multi-channel analysis of surface waves (MASW) survey performed by NORCAL Geophysical Consultants, Inc. at Lawrence Berkeley National labs in Berkeley, CA. The survey was performed on September 25 and 26, 2007 by NORCAL Professional Geophysicists Donald J. Kirker and Sierra Boyd, and geophysical technician Travis Black. Logistical support was provided by Wayne Magnusen of Alan Kropp & Associates and Kate Krug of William Lettis & Associates, Inc.

SITE DESCRIPTION

Lawrence Berkeley National Labs (LBL) is located in the foothills above the University of California's Berkeley campus and conducts research across a wide spectrum of scientific disciplines. Currently, LBL is planning to construct a new research facility, called the Helios Project, on the slopes below the National Center for Electron Microscopy (NCEM). As part of this project, William Lettis & Associates has drilled numerous borings throughout the area.

The SR and MASW surveys, as specified by Alan Kropp & Associates, Inc., were conducted along five profiles, designated as Lines 1 through 5 on Plate 1. The profiles were positioned along various roadways above and below the NCEM. The survey area is characterized by a relatively steep, broad drainage that has been crossed by many roads and LBL structures. The cuts and fills associated with these features have masked portions of the natural surface topography of the area.

Geologic data obtained from William Lettis & Associates borings AKA-2, AKA-3, AKA-4, and AKA-18, (borings in close proximity to Lines 1 through 3) indicate that the local geology is very heterogenous, consisting of clay with interbedded sand and gravel (colluvium) overlying claystone, siltstone, and/or sandstone. In addition, other site information indicates that a possible landslide has been mapped by others within the survey area.

Borehole geophysical surveys were also conducted by NORCAL in boring AKA-2. The results of this survey, submitted to William Lettis & Associates on September 3, 2007, indicate that compressional (P) wave velocities (Vp) range from 5,100 ft/s to over 7,000 ft/s from a depth of 19 to 88 feet.

321A BLODGETT STREET • COTATI, CA 94931 • TELEPHONE (707) 796-7170 • FAX (707) 796-7175
www.norcalgeophysical.com

PURPOSE

The purpose of the SR survey was to measure compressional (P-) wave velocities along Lines 1 through 5 to aid in determining the thickness of overburden and the depth and excavation characteristics (rippability) of the bedrock. The purpose of the MASW survey was to measure shear (S-) wave velocities along Line 2 where a building is proposed. We understand that Alan Kropp & Associates, Inc. will use the SR and MASW information as part of their geotechnical evaluation for the construction of the proposed Helios Project. Additionally, the results will also be used to assess whether there is a localized zone of low velocity material that may be related to the approximate limits of the mapped landslide debris.

METHODOLOGY

SR Survey

The SR method is used to determine the seismic velocity of compressional P-waves in subsurface materials. The seismic velocity of P-waves in fill, sediments, and rock are dependent on physical properties such as compaction, density, hardness, and induration. However, other factors such as bedding, fracturing, and saturation also effect seismic velocity. Typically, low velocities are indicative of loose soil, poorly compacted fill material, and poorly to semi-consolidated sediments. Higher velocities are indicative of consolidated or dense sediments, highly compacted fill, and moderate to highly weathered and fractured bedrock. The highest velocities are measured in unweathered rock with few fractures.

MASW Survey

The MASW method is used to determine the seismic velocity of shear S-waves in subsurface materials. When seismic waves are generated at or near the ground surface, both body and surface waves are generated. Body waves consist of both compressional (P) and shear (S) waves. Surface waves, commonly referred to as ground roll in seismic surveys, account for more than two-thirds of the energy produced by vertical seismic energy sources. As a result, surface waves are the most prominent signal on multi-channel seismic records. In addition, surface waves have dispersion properties that body waves lack. That is, different wavelengths have different penetration depths and, therefore, propagate at different velocities. By analyzing the dispersion of surface waves it is possible to obtain a near-surface S-wave velocity profile. Since S-wave velocity is directly proportional to shear modulus, this provides a direct indication in the variation of stiffness (or rigidity) of subsurface materials. A more detailed description of the SR and MASW methodologies is provided in Appendix A.

FIELD INVESTIGATIONS

Data Acquisition

SR Survey

We obtained SR data along Lines 1 through 5, as designated by Alan Kropp & Associates. Line 1 measured 246 feet long and consisted of one spread. Line 2 measured 444 feet long and consisted of three spreads positioned end-on-end. Lines 3 through 5 measured 240, 298, and 296 feet long, respectively, and each consisted of one spread. Each spread comprised 24 geophones and three shot points distributed in a collinear array. The geophones were coupled to the ground surface at 6 to 12 foot intervals. Two of the shot points were located 5 to 12 feet beyond the end geophones, and the third shot point was positioned in the center of the spread.

MASW Survey

We collected MASW data along Line 2 using roll-along techniques similar to those used in seismic reflection surveys. Our procedure was to distribute 48-geophones along the line at 6-ft intervals in a collinear array (spread). We then generated surface waves at shot points distributed at 12-ft intervals along the traverse. For each shot point, the signals from 24 contiguous geophones were selected using a roll box and were recorded using a 24-channel seismograph.

We began the survey with geophones 1 through 24 active, and the shot point positioned 24-ft from the first geophone. After recording the data (shot gather) we moved the shot point 12-ft along the line and used the roll box to activate geophones 3 through 26. We continued in this manner, moving both the shot point and the active 24-geophone array 12-ft at a time until the last 24 geophones in the array were active. We then picked up the first 24 geophones and moved them to the end of the array and continued the data acquisition to cover the total length of each profile.

Energy Source and Instrumentation

We produced seismic energy at each shot point by using a Digipulse AWD-200 accelerated weight drop mounted on an all-terrain vehicle. The AWD-200 consists of a vertically mounted, cylindrically shaped, 200 lb. weight that is accelerated by a gas filled piston onto an aluminum plate on the ground surface. An accelerometer attached to the strike plate transmits a triggering pulse to the seismograph each time the weight strikes the plate. This energy was stacked by impacting the plate numerous times until the delineation of seismic wave arrival times could be made.

We detected the seismic energy produced by the AWD-200 using ***Oyo Geospace*** geophones with a natural frequency of 8-Hz. We used an ***I/O*** Rota-long switch box to activate the appropriate 24-geophones for each shot. The detected seismic signals were digitized and recorded using a ***Geometrics Geode*** 24-channel distributed array seismograph connected to a field computer. The data were recorded on the computers internal hard drive and stored for future processing.

Data Analysis

SR Survey

The seismic refraction data were processed using the program ***Seisimager*** by ***Geometrics***. This software is used to pick the "first-arrival" times on each seismic trace (the time when energy from the shot is first detected at the geophone). These arrivals are given initial layer assignments and interpreted using the time-term technique. The results of this interpretation is used as the starting model for a tomographic inversion procedure that iterates the velocity model to minimize differences between the observed and modeled arrival times. The tomographic inversion method of processing is designed to detect vertical and lateral seismic velocity gradients within the subsurface. These gradients, which can be significant, would be masked by traditional layer-based refraction interpretation.

MASW Survey

We processed the surface wave data using the software package ***SurfSeis*** which was developed by the University of Kansas. The data from each shot point was processed to develop a dispersion curve representing variations in Rayleigh wave velocity with frequency. Each dispersion curve was then inverted to compute a 1D model representing Vs versus depth beneath the center of the 24-geophone array used to record the respective data. We then used the software package ***Surfer***, by Golden Software, to collate and contour all of the 1D models. This resulted in a 2D cross-section illustrating variations in Vs with depth and distance beneath the seismic line.

The 2D cross-section described above does not cover the entire length of the geophone array. This is because the 1D Vs models comprising the section are plotted beneath the center of their respective 24-geophone arrays. As a result, there is no coverage beneath the outermost 12-geophones at either end of each seismic line.

RESULTS AND INTERPRETATION

The results of the seismic surveys are presented by the SR and MASW seismic velocity cross-sections on Plates 2 through 5. Plates 2 through 4 are the seismic refraction profiles for Lines 1 through 5, and Plate 5 is the MASW profile for Line 2. The vertical axis represents elevation (above mean sea level) and the horizontal axis represents distance. Each profile is color contoured to better illustrate the respective variations in compressional (P) wave velocities (Vp) and shear (S) wave velocities (Vs). The values are indicated by the velocity scale shown on each plate.

SR Survey

The profiles shown on Plates 2 through 4 indicate seismic velocities ranging from 400 to over 6,000 ft/s. Along each seismic line, the contours (shaded blue to red) indicate a gradual increase in velocity with depth. To assist in our interpretation of these velocities, we reviewed the William Lettis & Associates borehole logs from borings AKA-2, AKA-3, AKA-4, and AKA-18. They are located in close proximity to Lines 1 through 3, as shown on Plate 1. Geologic data obtained from these borings indicate that the local geology consists of fill and clay with interbedded sand and gravel (colluvium) overlying bedrock at depths of 28 to 64 feet. These borings also indicate that bedrock is highly variable. Due to the heterogeneity of the colluvium and highly weathered and fractured bedrock, the determination of a coherent bedrock interface is difficult. In some borings, rock is relatively shallow and consists of claystone and siltstone. In others, rock is deeper and consists of sandstone.

The profiles on Plates 2 through 4 show that low velocities of 400 to 2,800 ft/s (red to yellow) comprise a 6 to 30 foot thick surficial layer. Velocities in this range are consistent with surficial soils and unconsolidated sediments, and represent the fill and colluvium defined in the geologic borehole logs. Moderate velocities of 2,800 to 5,600 ft/s (green shading) are consistent with colluvium and highly weathered bedrock. The range of velocities within this zone are influenced by varying degrees of compaction and consolidation of the sediments and weathering of the bedrock. The deeper layer (blue) exhibits velocities of 5,600 to over 6,400 ft/s at depths of 21 to 50 feet that are most likely indicative of less weathered bedrock.

Borehole Geophysical Survey Correlation

As noted above, a borehole geophysical survey was conducted in borehole AKA-2 along Line 2. The results of this survey defined compressional (P) wave velocities (Vp) of 5,600 ft/s to over 5,900 ft/s from depths of 19 to 27 feet. From 27 to 38 feet (the depth of the SR profile at that point), velocities increase to over 6,500 ft/s. These depth and velocity ranges generally corroborate the SR velocity variations shown along Line 2 (Plate 2) and support the interpretation that these velocities are indicative of bedrock.

MASW Survey

The MASW cross-section along Line 2 (Plate 5) generally indicates Vs velocities that increase with depth. The cross-section shows an anomalous zone of very low velocity material (shaded red) near the surface along the northwest half of the line. This zone is surrounded by higher velocities (light to dark green). Since Vs velocities are indicative of material strength, the anomalous zone may represent material associated with a possible landslide. The moderate velocities surrounding this zone probably represent colluvium. The high velocities (blue) at depth are indicative of the sandstone bedrock described in the AKA-2 borehole log.

EXCAVATION CHARACTERISTICS (Rippability)

Seismic velocity charts relating seismic velocity and excavation characteristics have been developed from field tests by others. These charts list the seismic velocity of various types of rock and their relative ease of excavation using different types of rippers. Caterpillar Tractor Company publishes a performance manual that lists ripper performance charts for the D8L, D9L, and D11L tractors. The following information in Table B was obtained from a performance chart for a D9L Ripper:

Table B: D9L Ripper Performance Chart

PERFORMANCE	ROCK TYPE	VELOCITY RANGE (ft/s)
Rippable	Sedimentary	< 6,400 to 7,800
	Igneous	< 6,700 to 7,600
	Metamorphic	< 7,200 to 7,300
Marginally Rippable	Sedimentary	6,400 to 9,700
	Igneous	6,700 to 8,600
	Metamorphic	7,200 to 9,200
Non-rippable	Sedimentary	> 8,600 to 9,700
	Igneous	> 8,000 to 8,700
	Metamorphic	> 9,000 to 9,200

Based on the highest seismic velocities measured, and their comparisons with the above table, the interpreted bedrock along Lines 1 through 5 is consistent with rock that is rippable.

This information should only be used as a general guide, however, as many other factors should also be considered. These factors include rock jointing and fracture patterns, the experience of the equipment operator, and the equipment and excavation methods selected. Also, the computed velocities measured along each profile are an average for each layer. Therefore, there may be localized zones within each layer where the velocities may be higher or lower than indicated. Since the accuracy of our findings is subject to these limitations, it should be noted that subsurface conditions may vary slightly from those depicted in the final results. A more detailed discussion of the limitations with regard to the seismic refraction method is presented in Appendix A.

STANDARD CARE AND WARRANTY

The scope of NORCAL's services for this project consisted of using geophysical methods to characterize the subsurface. The accuracy of our findings is subject to specific site conditions and limitations inherent to the techniques used. We performed our services in a manner consistent with the standard of care ordinarily exercised by members of the profession currently employing similar methods. No warranty, with respect to the performance of services or products delivered under this agreement, expressed or implied, is made by NORCAL.

We appreciate having the opportunity to provide you with this information.

Respectfully,

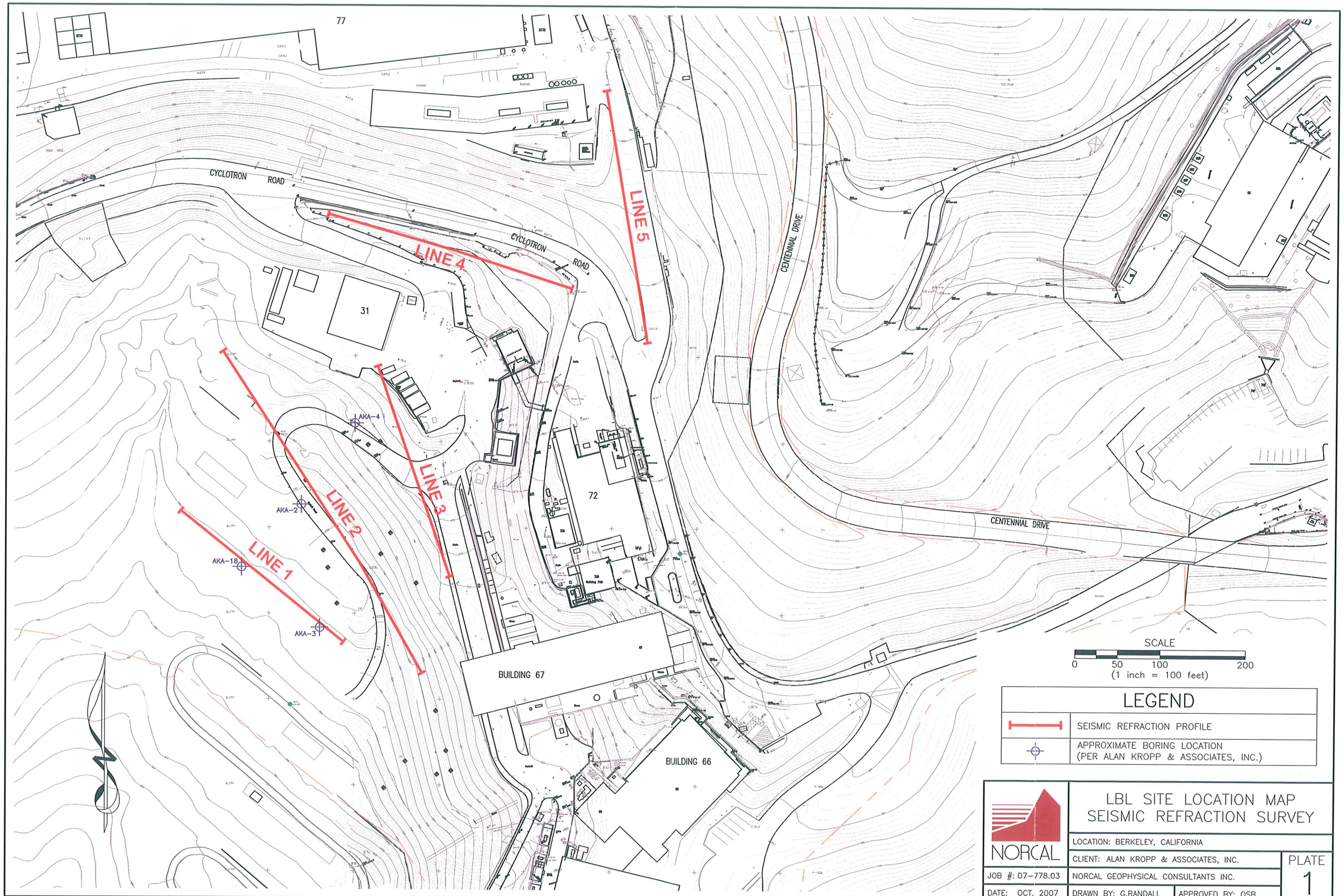
NORCAL Geophysical Consultants, Inc.

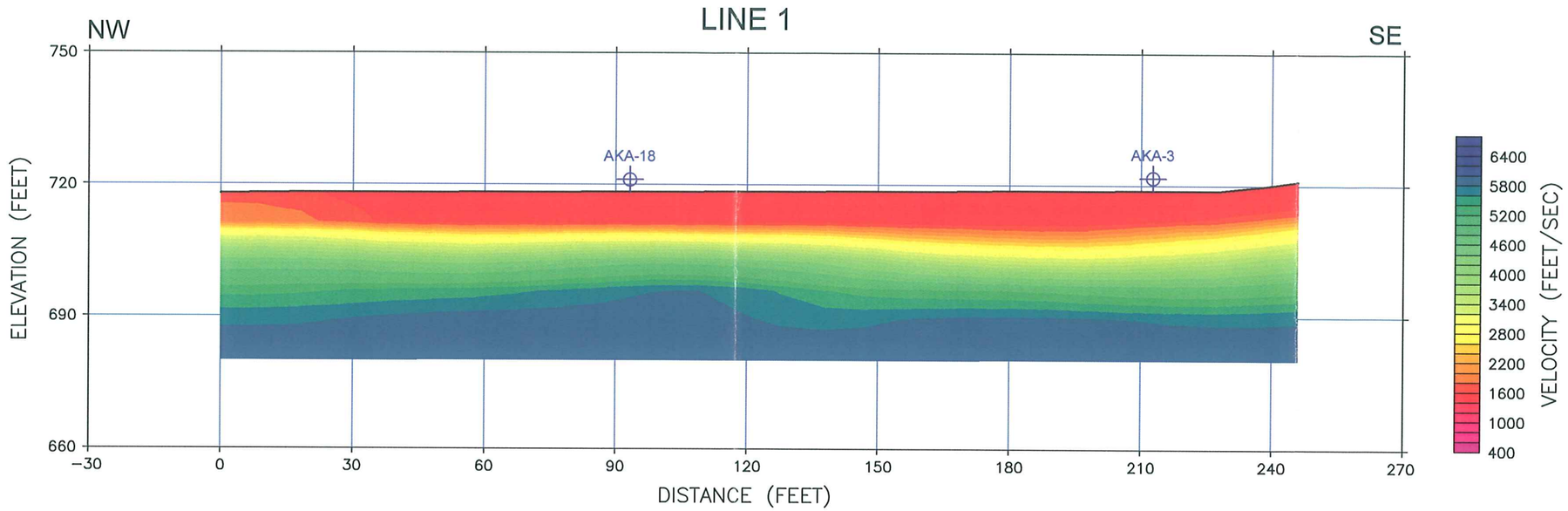
Donald J. Kirker

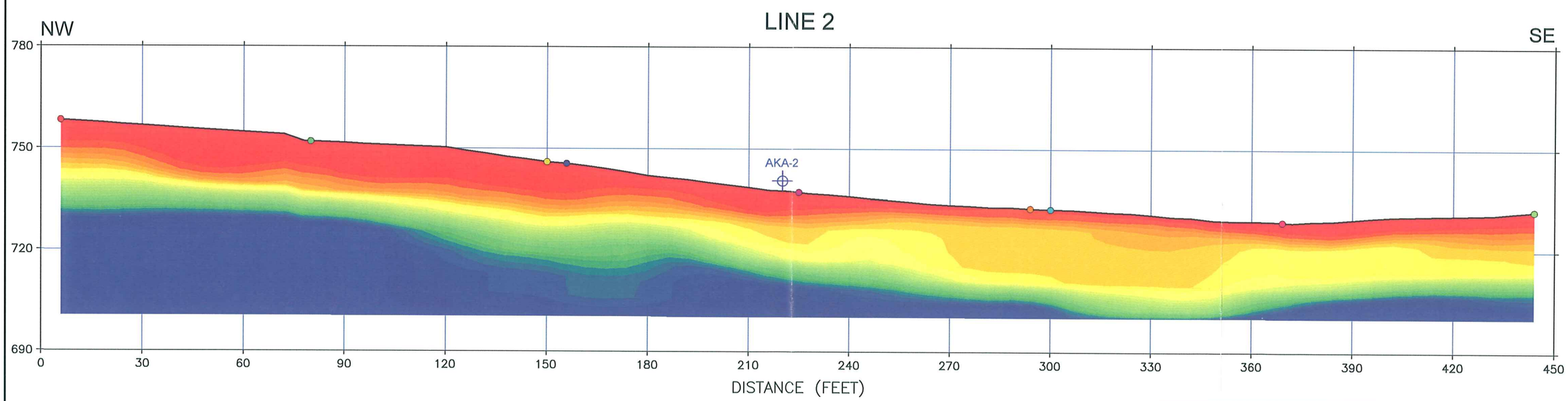
Donald J. Kirker
Geophysicist, GP-997

DJK/tt

Enclosures: Plates 1 through 5
Appendix A Seismic Surveys


77
CYCLOTRON ROAD
CYCLOTRON ROAD
CENTENNIAL DRIVE
CENTENNIAL DRIVE
LINE 1
LINE 2
LINE 3
LINE 4
LINE 5
AKA-1B
AKA-2
AKA-3
AKA-4
31
72
BUILDING 67
BUILDING 66
SCALE
0 50 100 200
(1 inch = 100 feet)
LEGEND
SEISMIC REFRACTION PROFILE
APPROXIMATE BORING LOCATION
(PER ALAN KROPP & ASSOCIATES, INC.)
NORCAL
LBL SITE LOCATION MAP
SEISMIC REFRACTION SURVEY
LOCATION: BERKELEY, CALIFORNIA
CLIENT: ALAN KROPP & ASSOCIATES, INC.
NORCAL GEOPHYSICAL CONSULTANTS INC.
JOB #: 07-778.03
DATE: OCT. 2007
DRAWN BY: G.RANDALL
APPROVED BY: OSB
PLATE
1





LEGEND	
⌖	APPROXIMATE BORING LOCATION (PER ALAN KROPP & ASSOCIATES, INC.)

SCALE

0 15 30 60

(1 inch = 30 feet)

NORCAL

SEISMIC REFRACTION PROFILES
LINES 1 & 2
LBL SITE

LOCATION: BERKELEY, CALIFORNIA

CLIENT: ALAN KROPP & ASSOCIATES, INC.

JOB #: 07-778.03

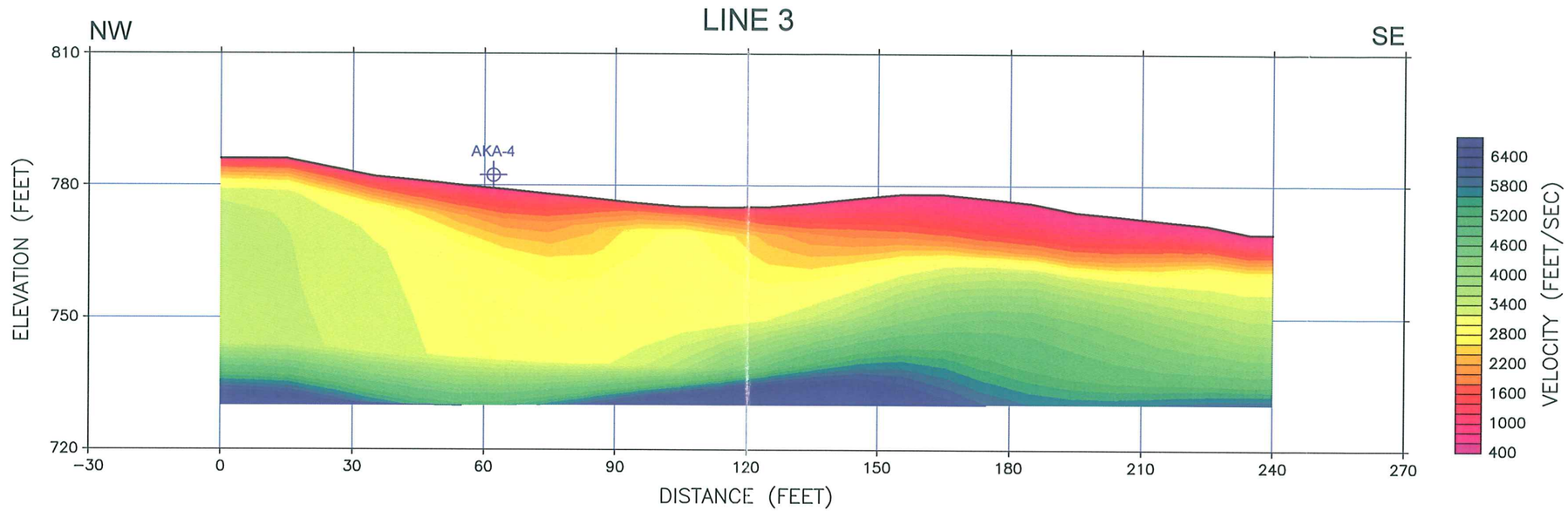
NORCAL GEOPHYSICAL CONSULTANTS INC.

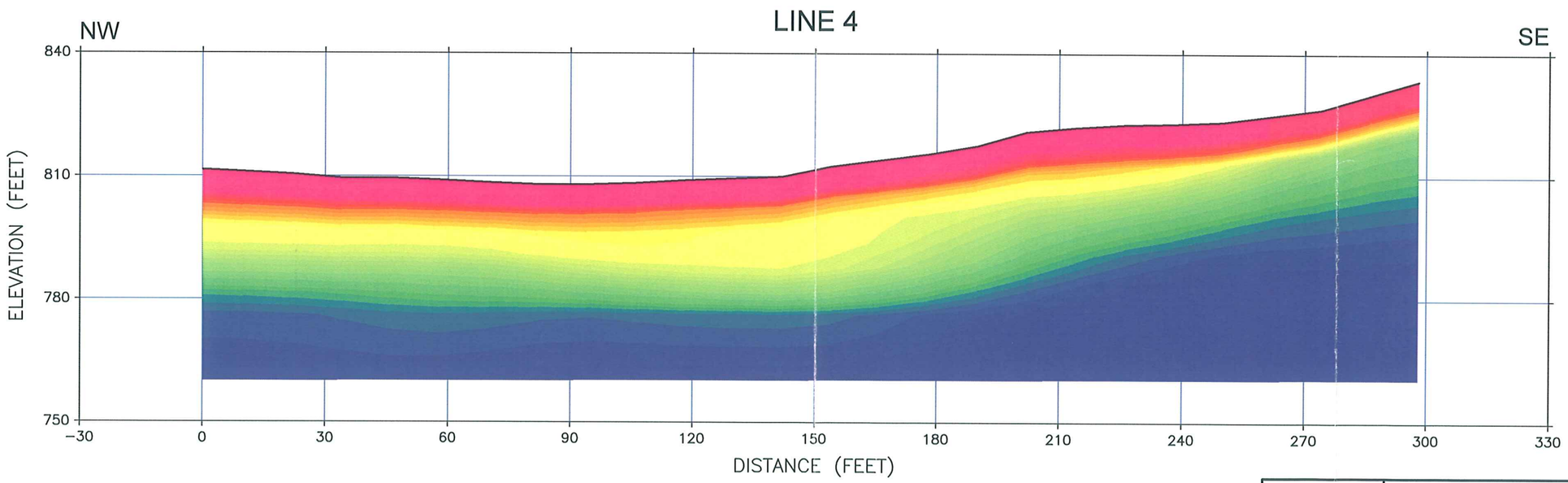
DATE: OCT. 2007

DRAWN BY: G.RANDALL

APPROVED BY: OSB

PLATE 2





LEGEND

⊕	APPROXIMATE BORING LOCATION (PER ALAN KROPP & ASSOCIATES, INC.)

SCALE

0 15 30 60

(1 inch = 30 feet)

NORCAL

SEISMIC REFRACTION PROFILES
LINES 3 & 4
LBL SITE

LOCATION: BERKELEY, CALIFORNIA

CLIENT: ALAN KROPP & ASSOCIATES, INC.

JOB #: 07-778.03

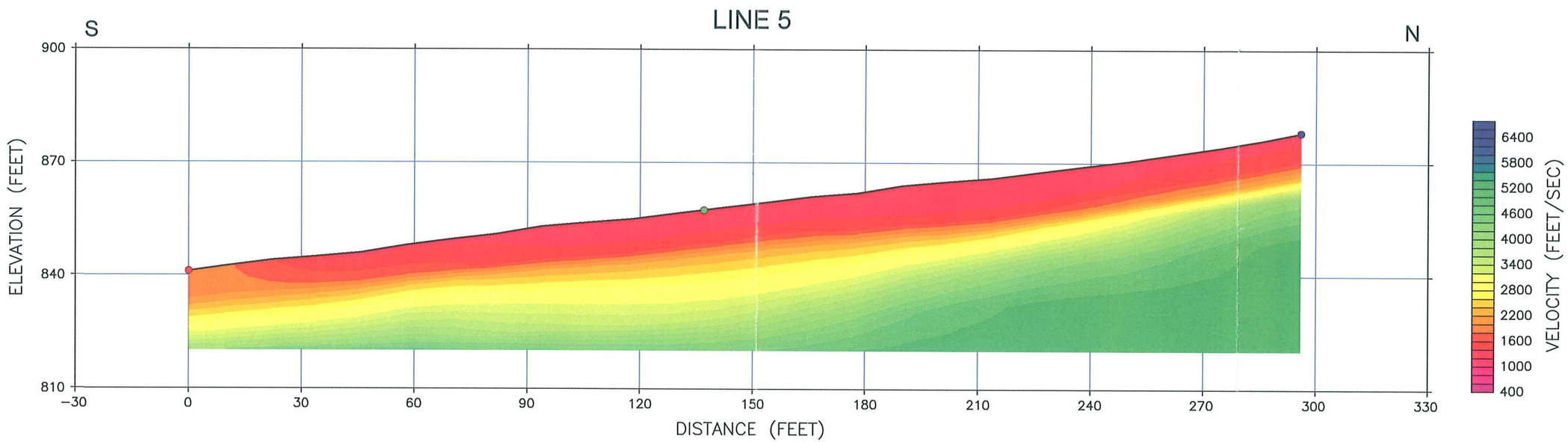
NORCAL GEOPHYSICAL CONSULTANTS INC.

DATE: OCT. 2007

DRAWN BY: G.RANDALL

APPROVED BY: OSB

PLATE 3



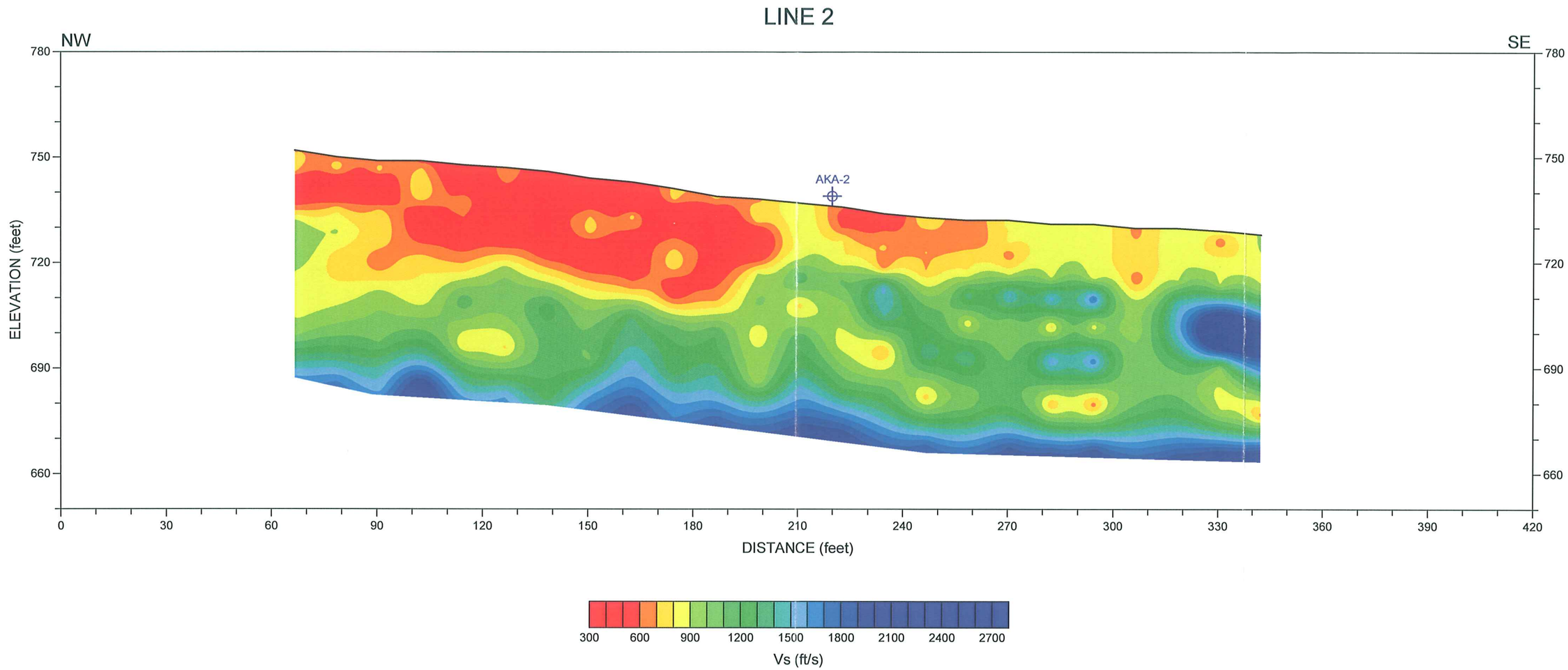
SCALE
0 15 30 60
(1 inch = 30 feet)

NORCAL

SEISMIC REFRACTION PROFILE
LINE 5
LBL SITE

LOCATION: BERKELEY, CALIFORNIA
CLIENT: ALAN KROPP & ASSOCIATES, INC.
NORCAL GEOPHYSICAL CONSULTANTS INC.
JOB #: 07-778.03
DATE: OCT. 2007
DRAWN BY: G.RANDALL
APPROVED BY: OSB

PLATE 4



SCALE

0 30 60

(1 inch = 30 feet)

LEGEND	
⌖	APPROXIMATE BORING LOCATION (PER ALAN DROPP & ASSOCIATES, INC.)

NORCAL

SEISMIC MASW PROFILE
LINE 2
LBL SITE

LOCATION: BERKELEY, CALIFORNIA

CLIENT: ALAN KROPP

JOB #: 07-778.03

NORCAL GEOPHYSICAL CONSULTANTS INC.

DATE: OCT. 2007

DRAWN BY: G.RANDALL

APPROVED BY: DJB

PLATE 5

Appendix A

SEISMIC SURVEYS

Appendix A

SEISMIC REFRACTION (SR)

Methodology

The seismic refraction method provides information regarding the seismic velocity structure of the subsurface. An impulsive (mechanical or explosive) source is used to produce compressional (P) wave seismic energy. The P-waves propagate into the earth and are refracted along interfaces caused by an increase in velocity. A portion of the P-wave energy is refracted back to the surface where it is detected by sensors (geophones) that are coupled to the ground surface in a collinear array (spread). The detected signals are recorded on a multi-channel seismograph and are analyzed to determine the shot point-to-geophone travel times. These data can be used along with the corresponding shot point-to-geophone distances to determine the depth, thickness, and velocity of subsurface seismic layers.

The seismic refraction technique is based on several assumptions. Paramount among these are:

1) that seismic velocity increases with depth, and,
2) that the velocity of each seismic layer is uniform over the length of the given spread.

In cases where these assumptions do not hold, the accuracy of the technique decreases. For example, if a low velocity layer occurs between two layers of higher velocity, the low velocity layer will not be detected and the depth to the underlying high velocity layer will be erroneously large. Also, if the velocity of a seismic layer varies laterally within a spread, those variations will be interpreted as fluctuations in the elevation of the underlying seismic layer.

Instrumentation

Data acquisition is initiated along each SR line by producing seismic energy using a mechanical source. Mechanical sources produce energy by impacting a metal strike plate on the ground surface with either a 12-16 pound sledge hammer or an accelerated weight drop. The resulting seismic wave forms are recorded using a Geometrics 24-channel engineering seismograph and Mark Products geophones with a natural frequency of 10 Hz. The data are recorded on hard copy records (seismograms) as well as on computer disks for future processing. The seismograms display the amount of time it takes for a compression (P) wave to travel from a given shot point to each geophone in a spread.

Data Analysis

The seismic data are downloaded to a computer and processed using the program ***Seisimager*** by Geometrics, Inc. This is an interactive program that is used to determine the shot point to geophone travel times, and to compute a 2D model based on those times. Once the travel times for a given line are determined, the programs time-term algorithm are used to compute a preliminary 2D seismic model. This model is then used as input for the programs tomographic

routine. Using this procedure, the program divides the starting model into a network of cells and assigns velocities to those cells based on the starting model. The program then traces the refracted seismic travel paths through those cells and computes the associated travel times. It then compares the computed travel times with the measured times and adjusts the velocities of the appropriate cells to improve the fit. The software is programmed to continue this procedure for twenty iterations. Typically, at the end of the twenty iterations the travel times associated with the computed model match the observed travel times to an accuracy of one milli-second (mS) or better. Once a satisfactory model is computed, the software contours the model velocities to produce seismic velocity vs. depth and distance cross-sections (profiles).

Limitations

In general, there are limitations unique to the SR method. These limitations are primarily based on assumptions that are made by the data analysis routine. First, the data analysis routine assumes that the velocities along the length of each spread are uniform. If there are localized zones within each layer where the velocities are higher or lower than indicated, the analysis routine will interpret these zones as changes in the surface topography of the underlying layer. A zone of higher velocity material would be interpreted as a low in the surface of the underlying layer. Zones of lower velocity material would be interpreted as a high in the underlying layer.

Second, the data analysis routine assumes that the velocity of subsurface materials increase with depth. Therefore, if a layer exhibits velocities that are slower than those of the material above it, the slower layer will not be resolved. Also, a velocity layer may simply be too thin to be detected. Due to these and other limitations inherent to the SR method, the results of the SR survey should be considered only as approximations of the subsurface conditions. The actual conditions may vary locally.

1-D MULTI-CHANNEL ANALYSIS OF SURFACE WAVES (MASW)

Methodology

When seismic waves are generated at or near the ground surface, both body and surface waves are generated. Body waves consist of both compressional (P) and shear (S) waves. Surface waves (e.g., Rayleigh, Love, etc.) propagate at velocities that are proportional to shear wave velocity (Vs). If a vertical energy source is used, Rayleigh type surface waves are produced. These are commonly referred to as ground roll in seismic surveys. Rayleigh waves are retrograde elliptical and travel at approximately 0.9 times the velocity of S-waves.

MASW data are gathered in much the same way as high-resolution reflection data. Seismic energy - generated by vertical impacts on the ground surface - are detected by an array of closely spaced geophones. The primary differences are that the surface wave technique requires an energy source that is capable of producing ground roll and geophones that are capable of detecting low frequency (<10 Hz) signals.

Surface waves account for more than two-thirds of the energy produced by vertical seismic energy sources. As a result, surface waves are the most prominent signal on multi-channel seismic records. In addition, surface waves have dispersion properties that body waves lack. That is, different wavelengths have different penetration depths and, therefore, propagate at different velocities. By analyzing the dispersion of surface waves it is possible to obtain a near-surface S-wave velocity profile. Since S-wave velocity is directly proportional to shear modulus, this provides a direct indication in the variation of stiffness (or rigidity) of subsurface materials.

Data Acquisition

The spectral analysis of surface waves (SASW) is not a new technique. This method has been used by engineers and geophysicists for many years. However, the conventional method involves using two receivers (geophones) to record multiple impacts at a fixed point. The survey is initiated with the geophones at close proximity to the impact (shot) point. With succeeding impacts the geophones are moved further and further away. This is done so that the surface wave can be sampled at numerous locations. The data from all of the geophone locations are then analyzed to determine the variation in the velocity of the surface wave with respect to frequency. This results in what is referred to as a dispersion curve. With this technique, it may take several hours to obtain a dispersion curve at a single point.

Recent advances in computer software and processing techniques developed by researchers at the University of Kansas have made it possible to analyze surface waves using a large number of shot points and receivers. This is referred to as the multi-channel surface wave (MASW) technique. Dispersion curves at dozens of points distributed along a profile can now be obtained with MASW in the same amount of time it previously took to obtain a single dispersion curve using SASW. The surface wave data are gathered in much the same way as high resolution seismic reflection data. Seismic waves generated by vertical impacts on the ground surface are detected by an array of closely spaced geophones (spread). The energy source and the geophones are sequentially moved along a profile as the survey progresses.

Data Analysis

We analyze MASW data using the computer program ***Surfseis***, which was developed at the University of Kansas. The software analyzes the data by identifying the ground-roll portion of the seismic wave traces, computing the frequency and velocity of the wavelets, and constructing a dispersion curve representing the variation in surface wave velocity versus frequency. The program then inverts the dispersion curve to compute a one-dimensional (1D) layered model indicating shear-wave velocity (Vs) versus depth beneath the center of the geophone array for each shot gather. In all cases the MASW modeling was iterated until the dispersion curve generated from the S-wave velocity model closely matched that calculated from the shot gathers. The 1D models inverted from all four shot gathers were then entered into a spread sheet which computed average Vs versus depth values.

The inversion of the dispersion curve into a shear wave velocity profile is a non-unique process. By default, the software will produce a shear wave profile containing 10 distinct subsurface velocity intervals at various depths. To help resolve the non-uniqueness of the solution, the results from the P-wave refraction survey were used to guide the positioning of the layering in the S-wave velocity profile, particularly at shallow depths where MASW resolution is lacking. In most cases this suitably resolved the shallow velocity interfaces and resulted in a close fit between the modeled and observed dispersion curves. Typically, the MASW technique resolves velocity interfaces at greater depths than the refraction analysis given the 138-ft geophone spread length. Therefore, the models shown on Plates 2 through 11 and listed in Table 1, indicate Vs at greater depths than Vp. Furthermore, the MASW technique is capable of resolving velocity reversals (decrease in velocity with depth) that cannot be detected by the refraction method.

APPENDIX E

LABORATORY TEST DATA

MOISTURE-DENSITY TESTS				
Boring	Sample Depth (ft)	Moisture Content (%)	Dry Density (pcf)	Moist Density (pcf)
5	2.0	9	115	126
5	6.5	17	115	135
5	16.5	16	113	131
6	2.0	15	94	108
6	6.0	24	101	125
6	7.0	19	108	129
6	12.0	20	110	132
7	1.5	11	106	117
7	11.5	15	117	134
7	21.5	19	107	127
8	6.5	33	90	119
8	12.0	26	102	127
8	17.0	24	102	126
8	21.5	20	112	134
8	27.0	17	116	136
9	6.5	23	102	125
11	9.5	15	116	134
11	29.0	15	120	138
12	1.5	20	105	126
13	2.0	15	90	104
13	5.0	24	90	112
13	9.5	24	99	123
14	5.0	10	119	131
16	2.0	17	98	115
16	5.0	20	103	123
16	9.5	17	113	133
16	15.0	21	108	131
16	20.0	25	104	130
16	25.0	18	116	138
16	30.0	22	109	132
16	34.5	19	114	135
17	3.0	20	101	121
17	7.0	21	93	113
17	13.5	24	97	121
17	29.0	28	92	118
20	10.0	9	-	-
32	26	26	101	127
32	9	24	87	108
32	37	21	108	131
33	10	25	100	125
33	11.5	23	103	127
34	8.5	27	97	123
34	12	19	110	131
36	1.5	10	96	106
36	7	16	112	130
36	7.5	13	109	123
36	10.5	15	112	129
36	18.5	10	123	135
37	2	13	-	-
37	5	13	92	104
37	7.5	10	119	131
38	1.5	12	92	103
39	3.5	16	91	106
39	8	11	113	125

MOISTURE-DENSITY TESTS (continued)				
Boring	Sample Depth (ft)	Moisture Content (%)	Dry Density (pcf)	Moist Density (pcf)
40	5	14	100	114
41	2.5	11	108	120
42	5	12	114	128
42	7	14	113	129
43	1	18	95	112
43	5.5	15	87	100
44	3	12	100	112

ATTERBERG LIMITS TESTS				
Boring	Sample Depth (ft)	Liquid Limit (LL)	Plasticity Index (PI)	%<#200
2	64	38	15	
5*	6.5	37	23	55
5	16	36	18	-
6*	7	36	20	60
7	6.5	31	14	-
7	26.5	53	37	-
8	6.5	76	51	-
11*	9	39	22	75
11	29.5	39	20	-
12	1.5	46	25	-
12	4.5	42	21	-
13	4.5	50	36	-
13	9.5	55	40	-
14	5	35	16	-
16	9.5	52	36	-
25*	69.5	38	18	72
27*	74.5	36	17	53
29*	2.5	38	22	63
30*	13	44	24	75
31*	73	33	12	38
32*	26	41	27	87
33*	10	52	34	-
34*	8.5	63	40	-
34*	27	31	11	55
36*	1.5	40	23	68
36*	10	37	21	65
37*	7.5	40	19	68
38*	1.5	52	33	94
39*	3.5	50	27	85
41*	2.5	30	12	54
41*	17.5	35	16	62

SIEVE ANALYSES				
Boring	Sample Depth (ft)	% Gravel	% Sand	% Fines
11*	5	3	12	85
20*	10	2	16	82
25*	69.5	1	27	72
27*	74.5	8	39	53
31*	73	2	60	38
32*	37	15	26	59
34*	27	0	45	55
36*	7	19	25	57
37*	2	0	11	89
39*	5	1	15	84

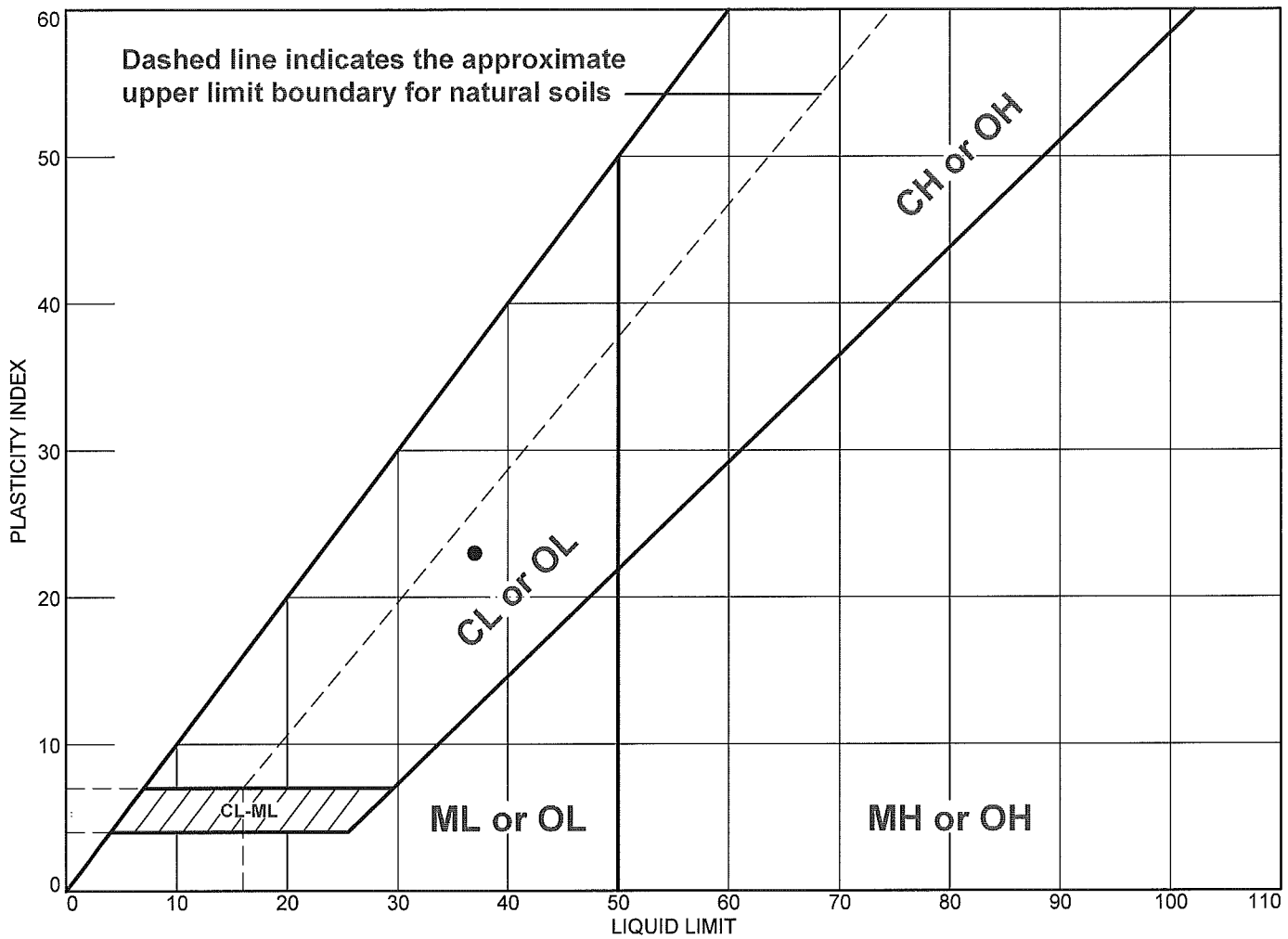
TRIAXIAL UNCONSOLIDATED-UNDRAINED SHEAR STRENGTH TESTS			
Boring	**Sample Depth (ft)**	**Cell Pressure (psf)**	**Shear Strength (psf)**
33*	10	1500	1190
33*	11.5	1500	1500
34*	8.5	1500	1080
34*	11.5	1500	1990

DRAINED RESIDUAL TORSIONAL RING SHEAR TESTS			
Boring	**Sample**	**Secant Friction Angle (degrees)**	**Clay Fraction (%)**
2*	64	27	-
25*	69.5	19	23
27*	74.5	19	17
31*	73	13	11
34*	27	18	11

CORROSIVITY TEST SUMMARY		
Boring	**Sample**	**Test Type**
35*	26	Caltrans Suite
36*	6.5	Caltrans Suite
37*	4	Caltrans Suite

* Laboratory Data Sheets Attached

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Dark Yellowish Brown CLAY, Lean- sandy, some gravel	37	14	23	77.9	55.1	CL

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

● **Source of Sample:** AKA-5 **Depth:** 6' - 6.5'

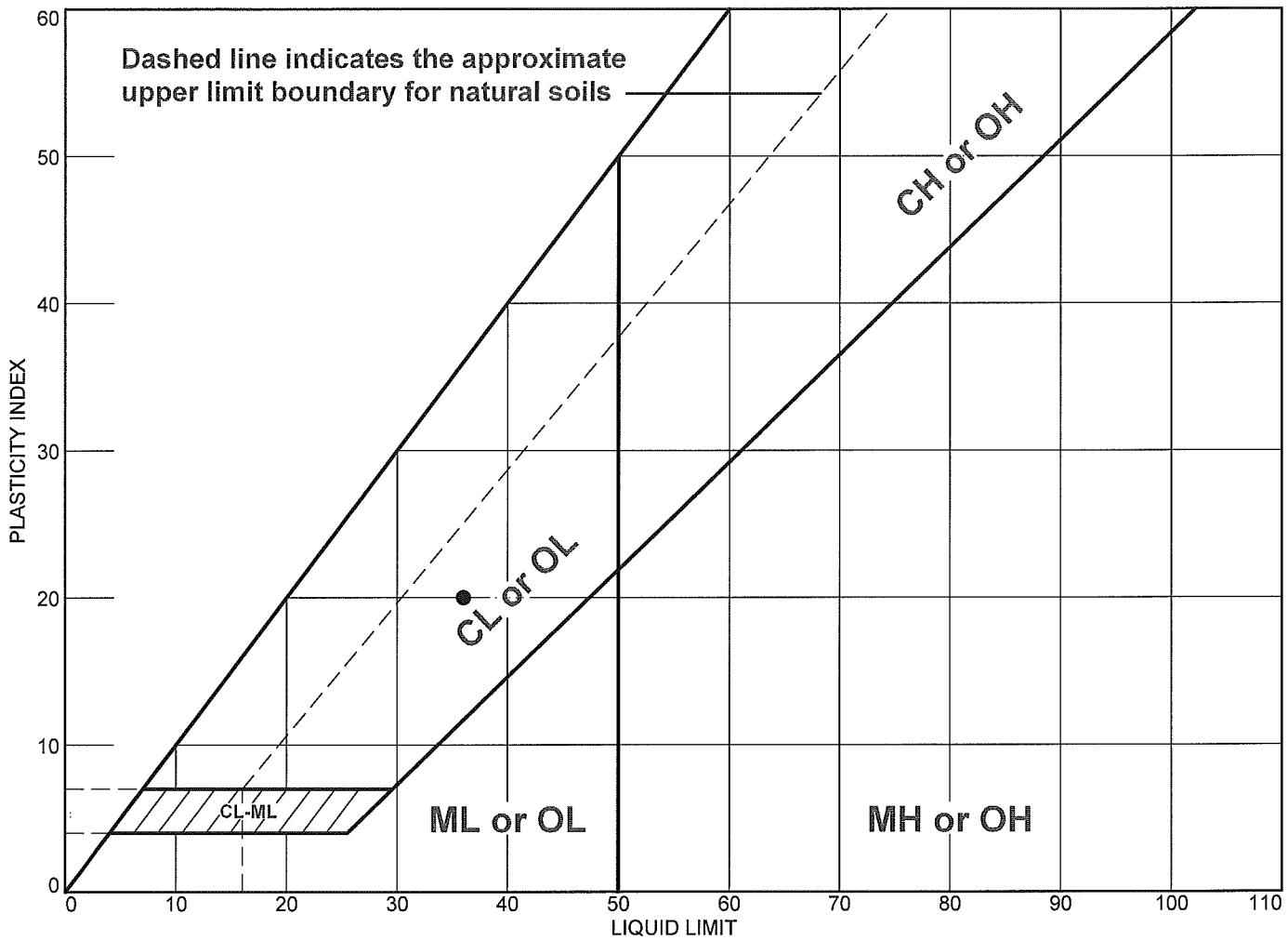
Remarks:

Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA

Figure

Tested By: AL

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Yellowish Brown CLAY, Lean- sandy, some gravel	36	16	20	91.3	60.2	CL

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

● **Source of Sample:** AKA-6 **Depth:** 6.5' - 7'

Remarks:

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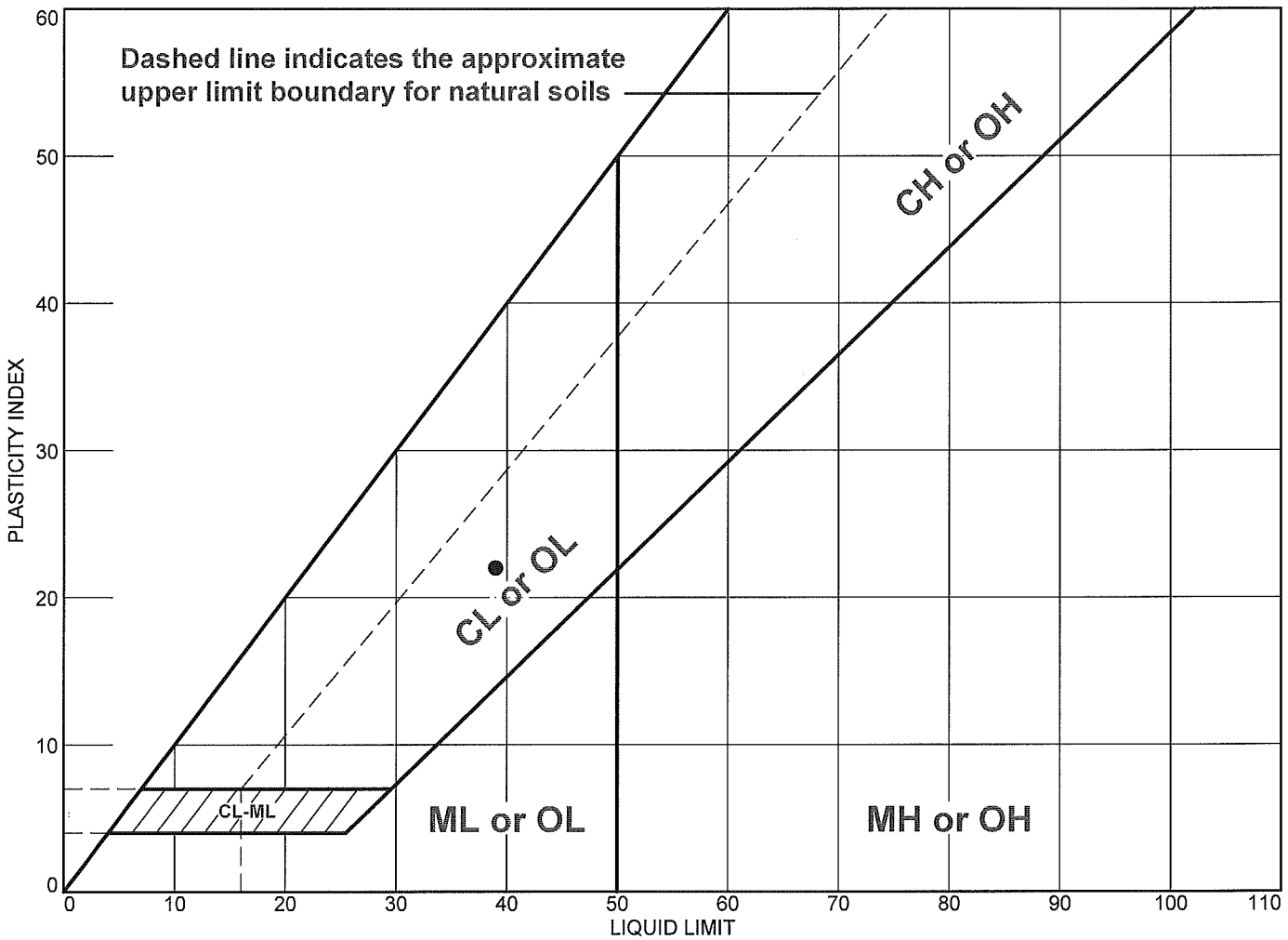
Berkeley, CA

Figure

Tested By: AL

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Brown to Yellowish Brown CLAYSTONE- moderately weathered, very weak, moderately fractured	39	17	22	99.7	75.1	CL

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

● **Source of Sample:** AKA-11 **Depth:** 8.5' - 9'

Remarks:

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Berkeley, CA

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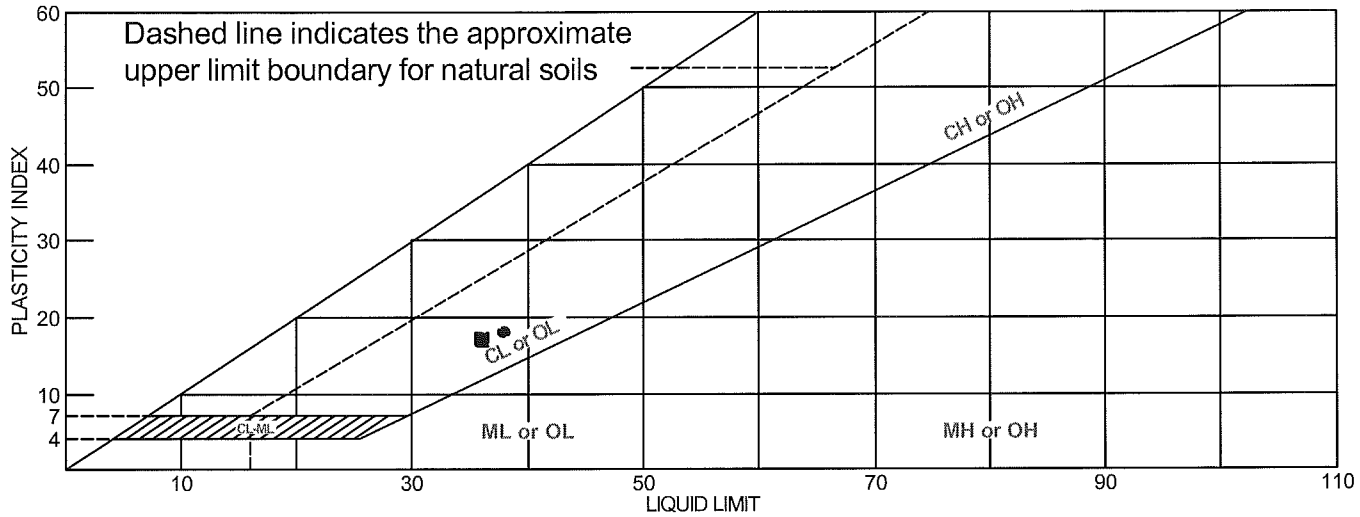
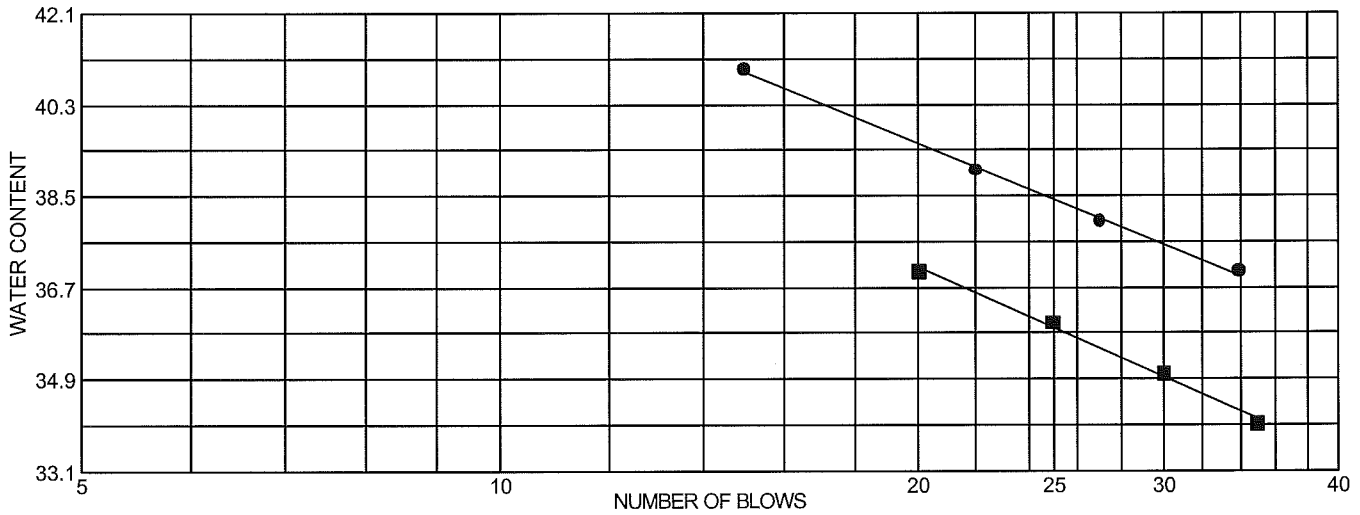
Tested By: AL

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Gray Lean CLAY w/ Sand	38	20	18	89.4	72.2	CL
■	Gray Sandy Lean CLAY	36	19	17	76.1	53.2	CL

Project No. 254-120 **Client:** Alan Kropp & Associates

Project: Helios Project Line E - 2500-4D

● **Source:** AKA-25 **Elev./Depth:** 69-69.5'

■ **Source:** AKA-27 **Elev./Depth:** 74-74.8'

Remarks:

●

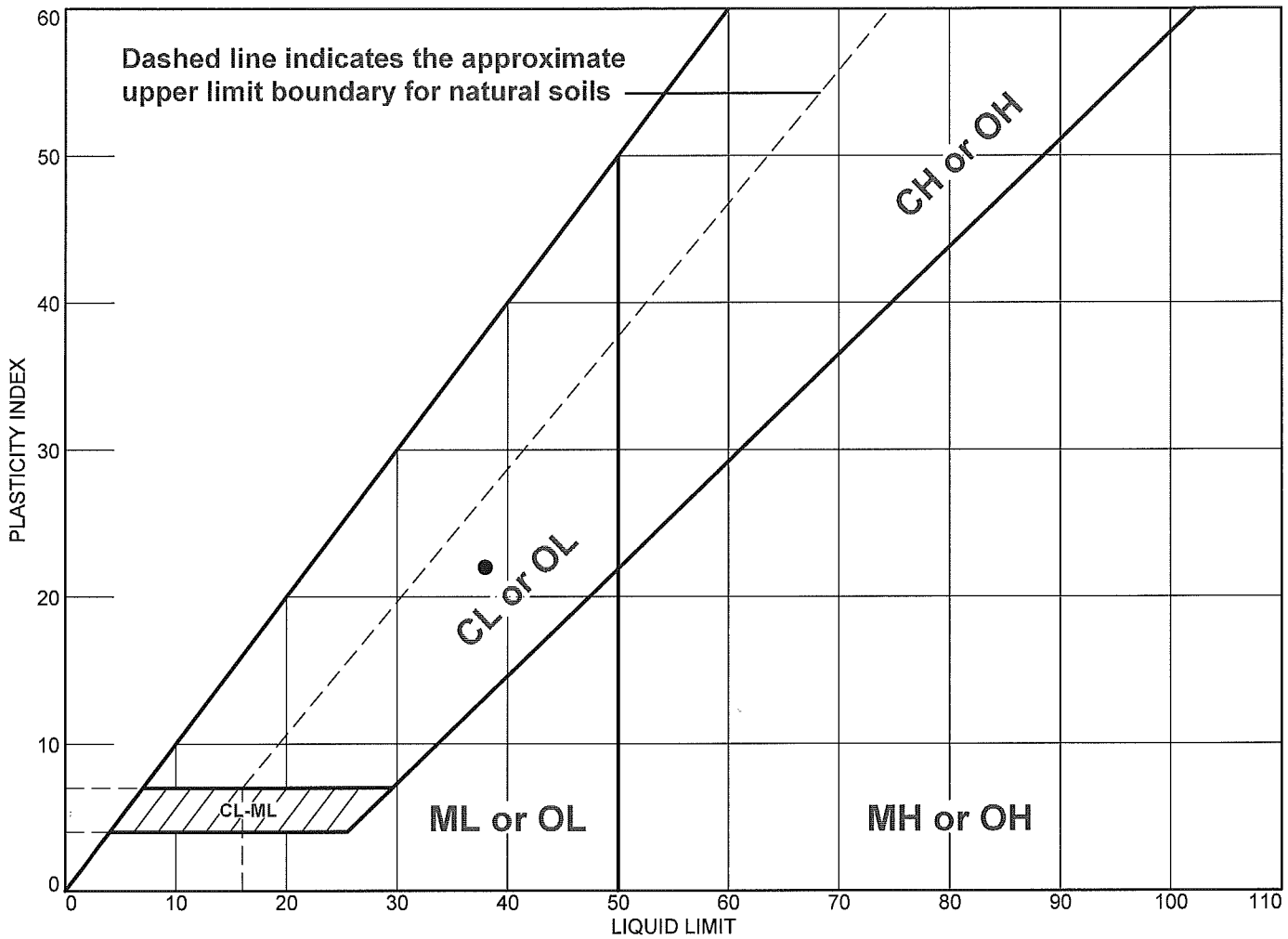
■

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Yellowish Brown CLAY, Lean - with sand and gravel	38	16	22	76.4	62.7	CL

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

● **Source of Sample:** AKA-29 **Depth:** 2' - 2.5'

Remarks:

Alan Kropp & Associates, Inc.
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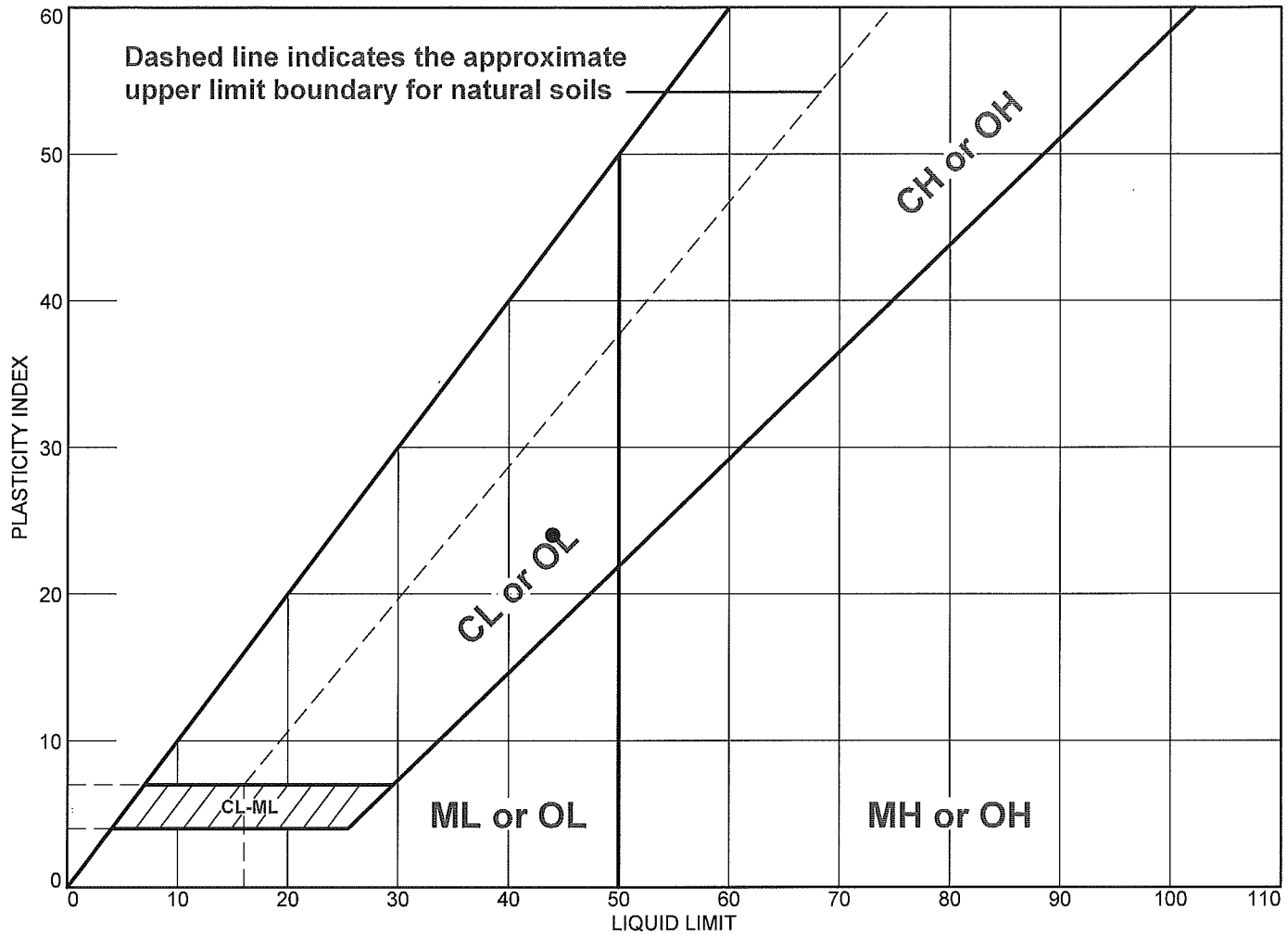
Berkeley, CA

Figure

Tested By: GH/AL

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Grayish Brown CLAY, Lean - with sand, trace gravel	44	20	24	89.2	75.2	CL

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

● **Source of Sample:** AKA-30 **Depth:** 12.5' - 13'

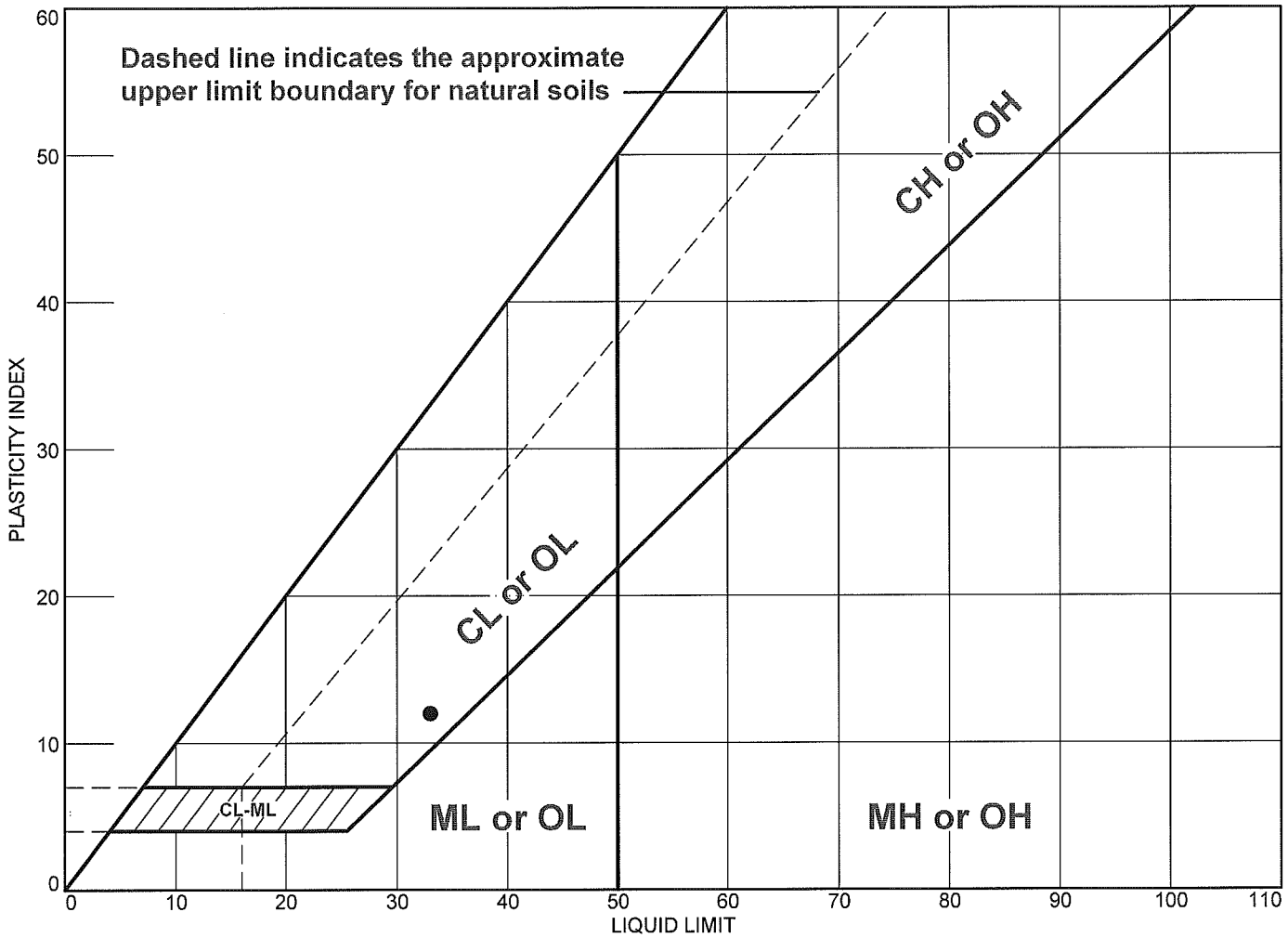
Remarks:

Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA

Figure

Tested By: AL

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Gray SAND- Lean Clayey	33	21	12	51.6	37.9	SC

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

● **Source of Sample:** AKA-31 **Depth:** 72.4' - 73'

Remarks:

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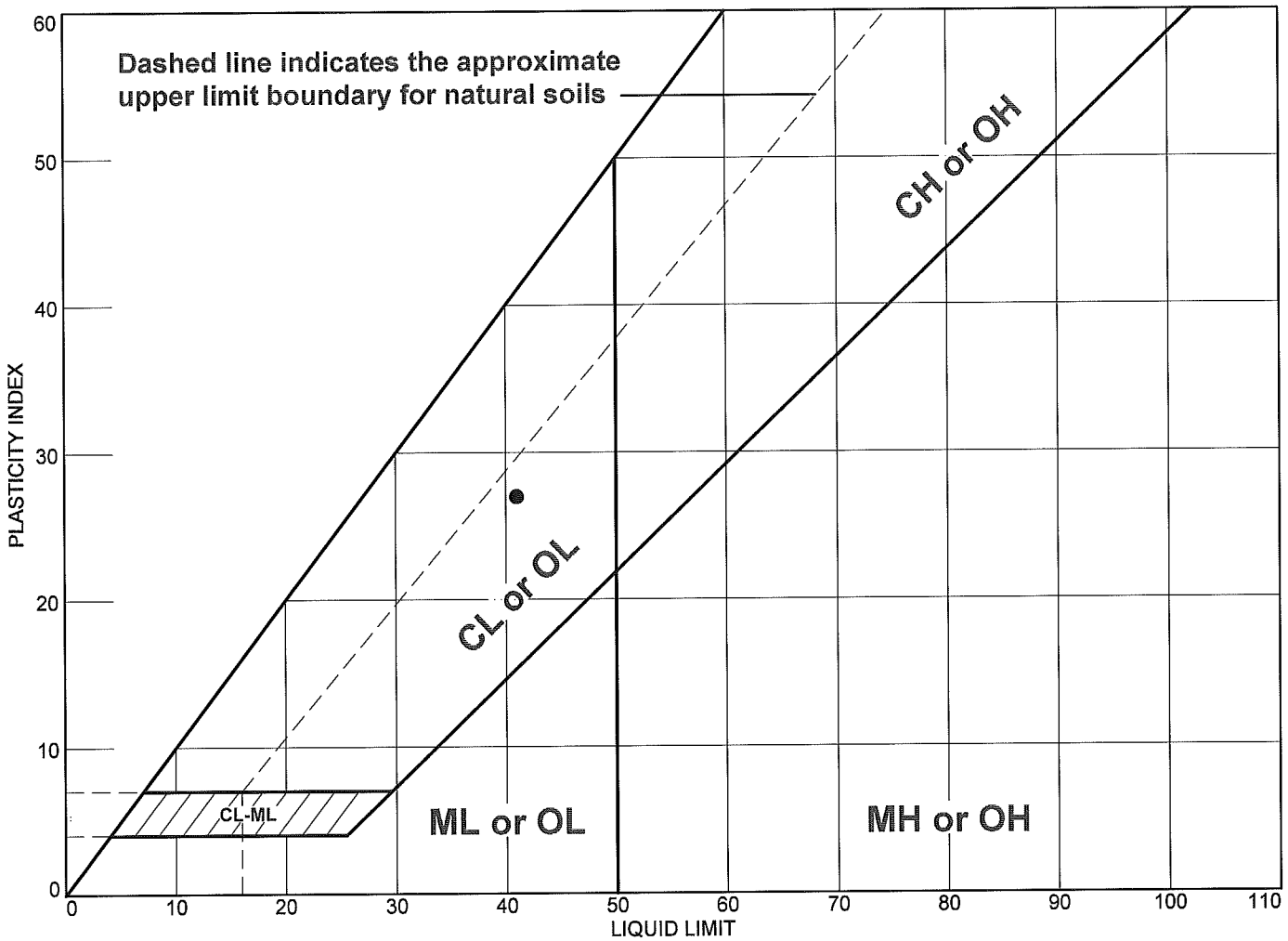
Berkeley, CA

Figure

Tested By: Cooper Testing

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Greenish Gray CLAY, Lean- with silt, some sand	41	14	27	96.8	87.1	CL

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

● **Source of Sample:** AKA-32 **Depth:** 25.8' - 26.3'

Remarks:

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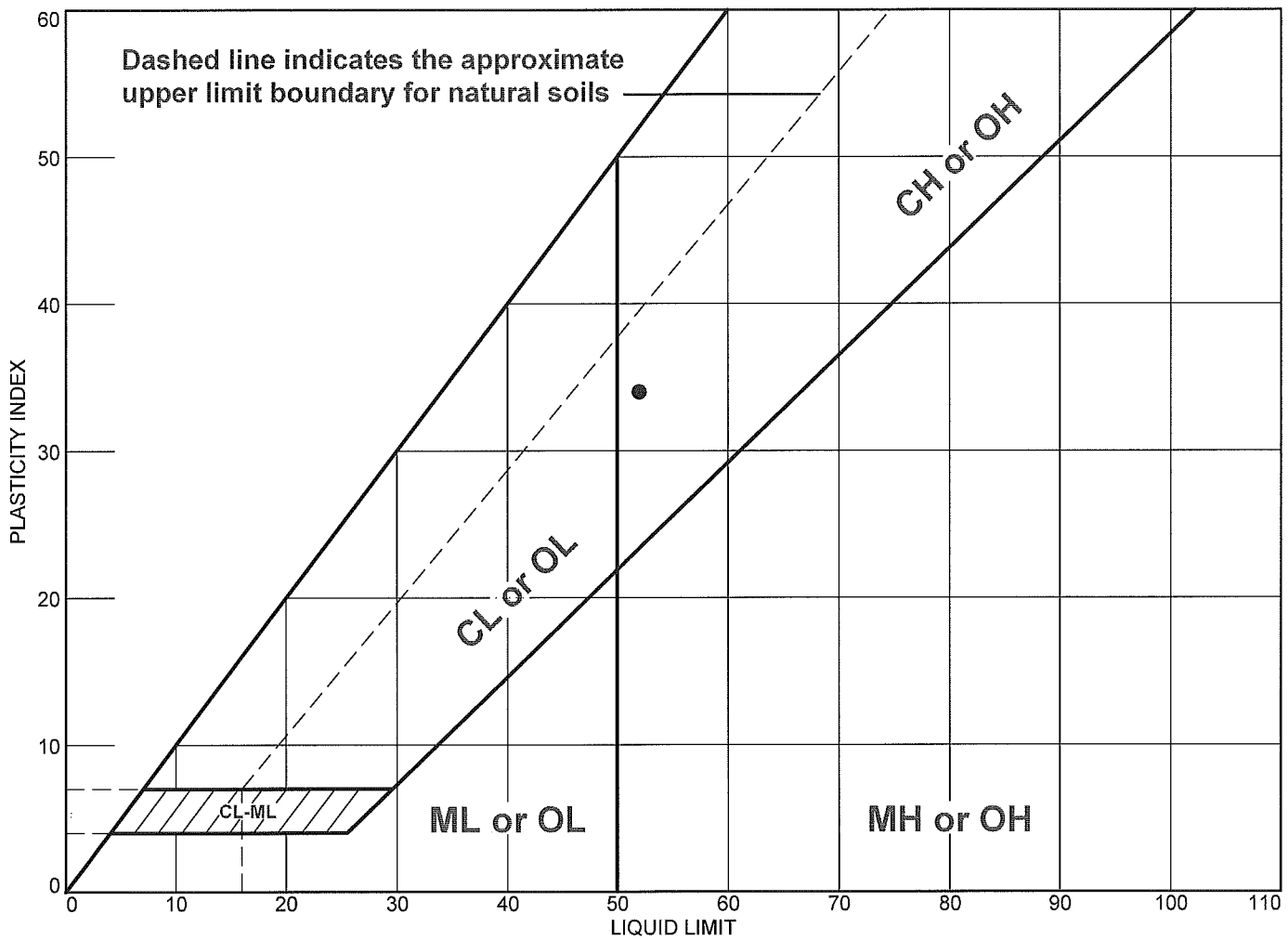
Berkeley, CA

Figure

Tested By: AL

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Brown CLAY, Fat- with fine gravel, some silt, sand and roots	52	18	34			CH

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

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● **Source of Sample:** AKA-33 **Depth:** 8' - 10'

Remarks:

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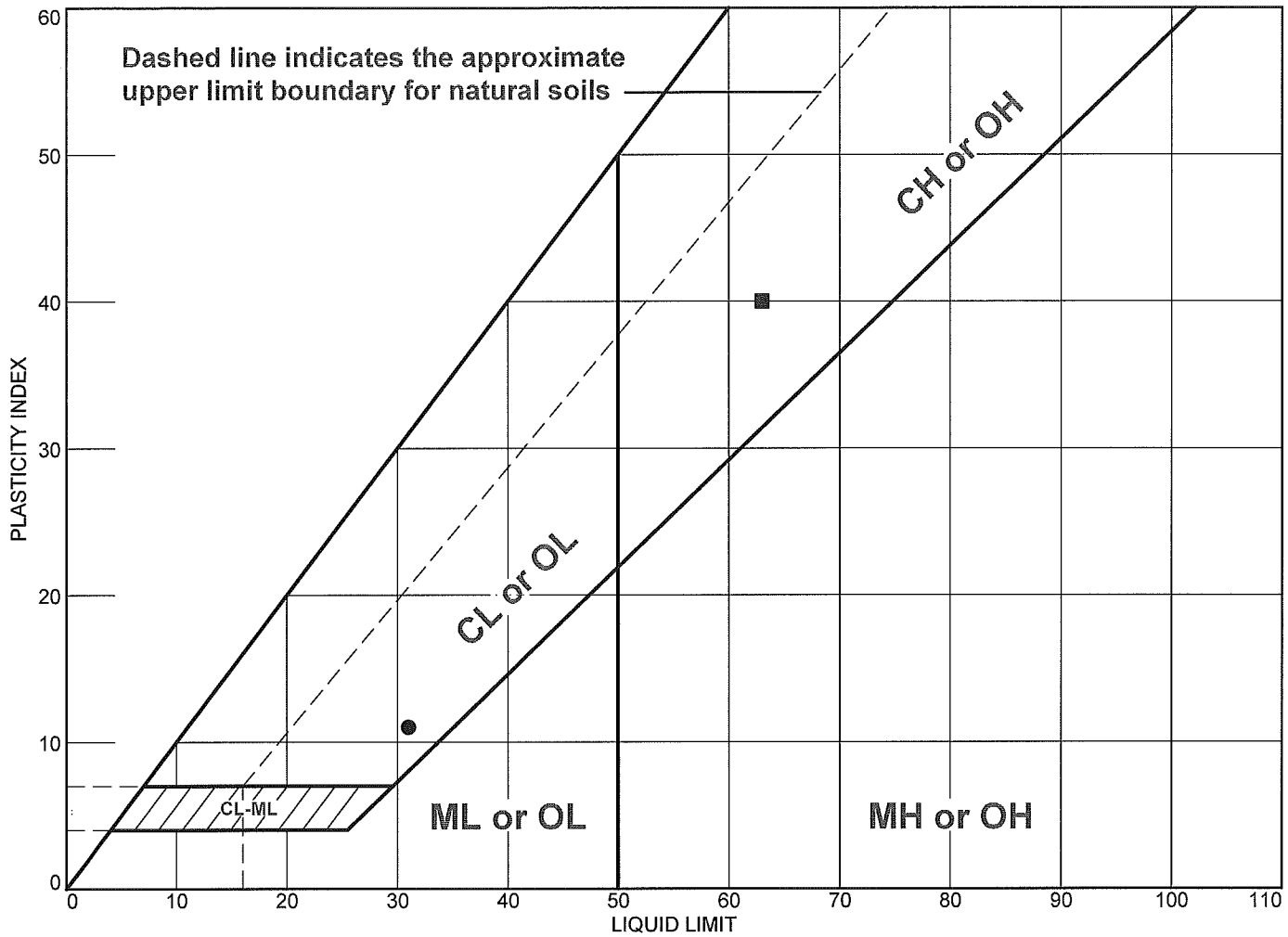
Figure

Tested By: Cooper Testing

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Bluish Gray CLAYSTONE- plastic, clay rich, with weathered rock fragments, moderately hard to hard	31	20	11	65.1	54.8	CL
■	Olive Brown and Reddish Brown CLAY, Fat- some sand and gravel	63	23	40			CH

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

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● **Source of Sample:** AKA-34 **Depth:** 26.5' - 27'

■ **Source of Sample:** AKA-34 **Depth:** 6' - 8.6'

Remarks:

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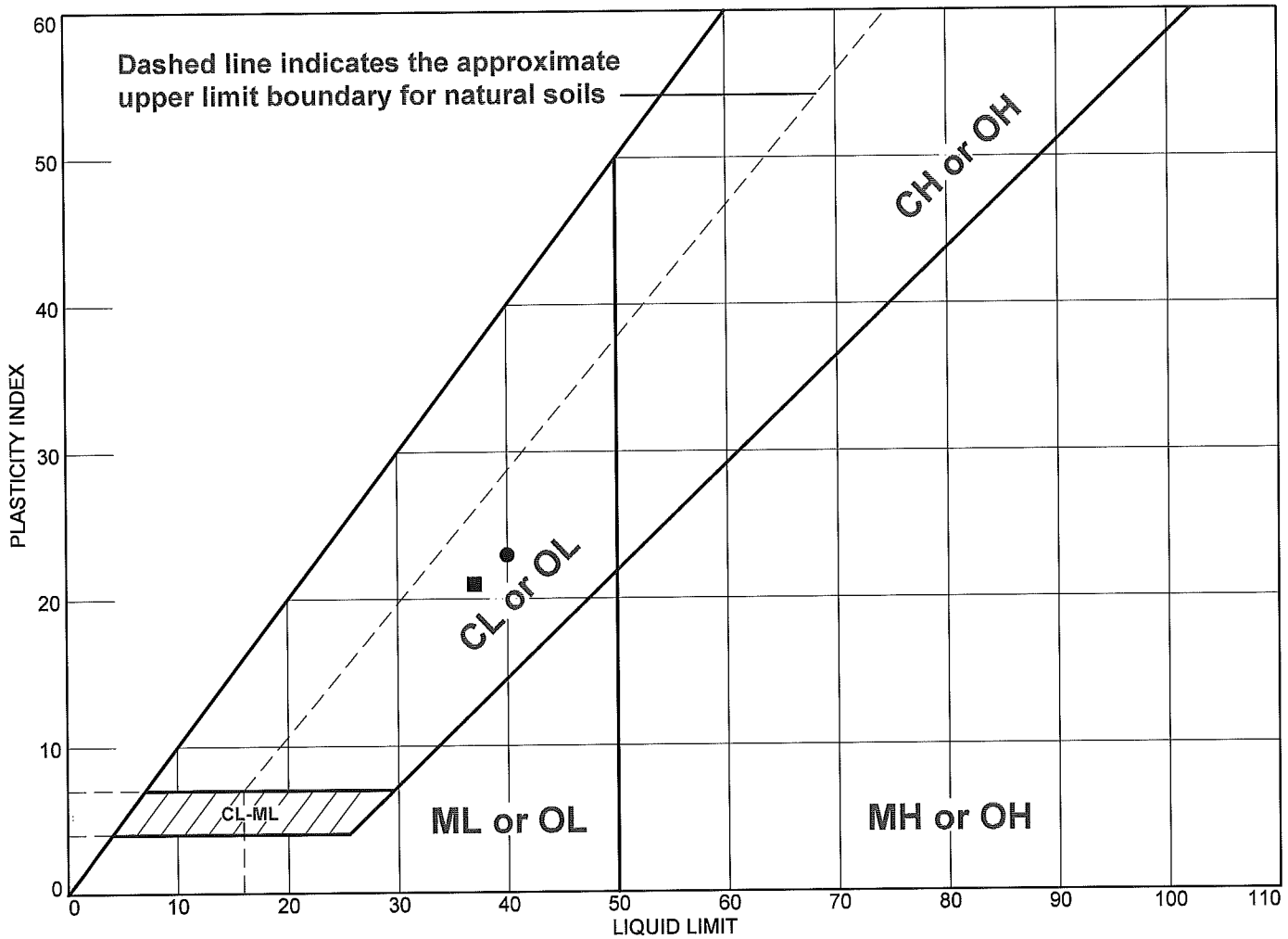
Berkeley, CA

Figure

Tested By: Cooper Testing

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Grayish Brown CLAY, Lean- with sand, some gravel and trace roots	40	17	23	82.0	68.3	CL
■	Mottled Olive Gray, Brown and Bluish Gray CLAY, Lean- with sand and some gravel	37	16	21	81.6	65.3	CL

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

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● **Source of Sample:** AKA-36 **Depth:** 1' - 1.5'

■ **Source of Sample:** AKA-36 **Depth:** 9.5' - 10'

Remarks:

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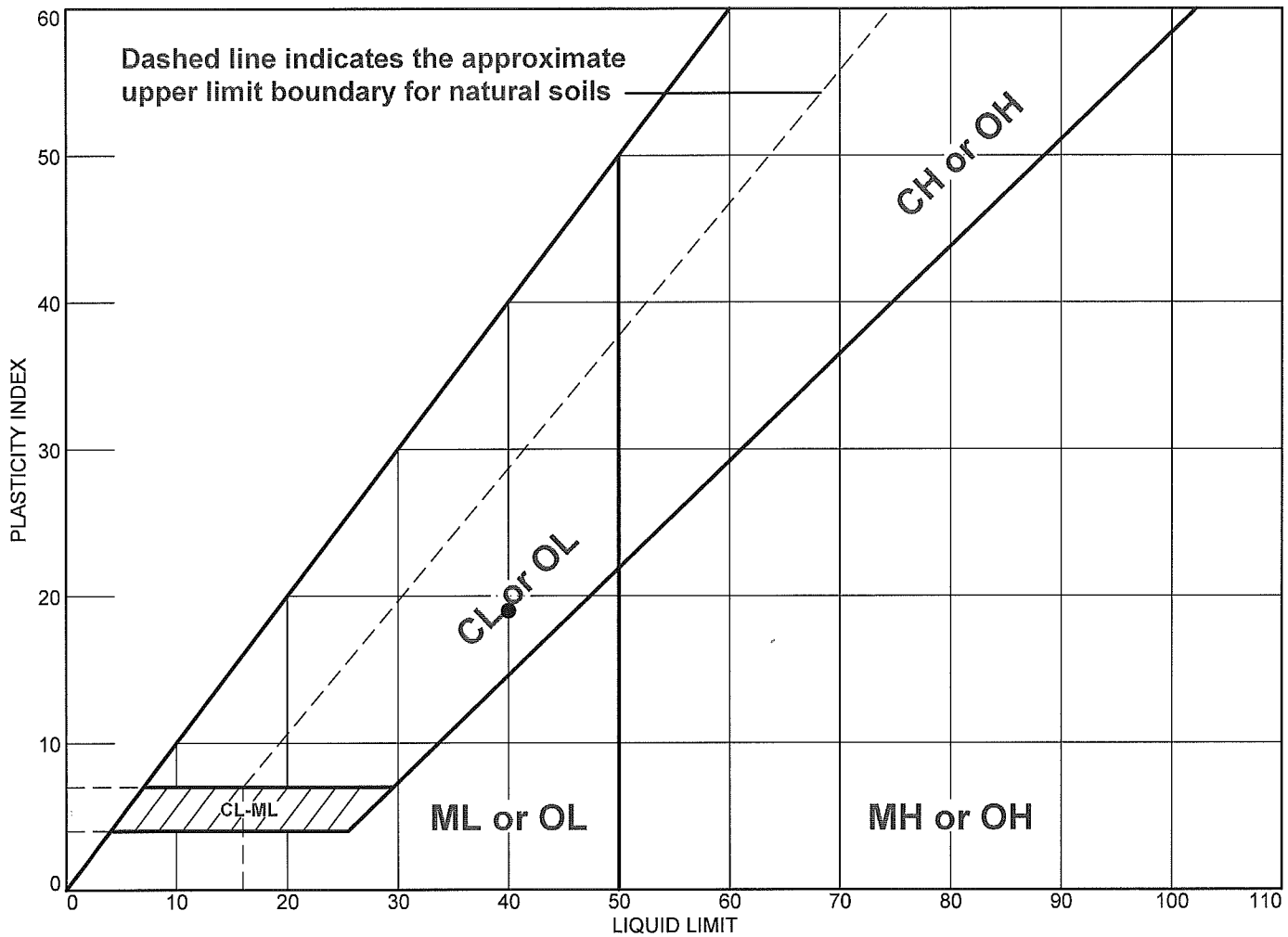
Berkeley, CA

Figure

Tested By: AL

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Yellowish Brown to Gray SILTSTONE	40	21	19	75.9	67.8	CL

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

● **Source of Sample:** AKA-37 **Depth:** 7' - 7.5'

Remarks:

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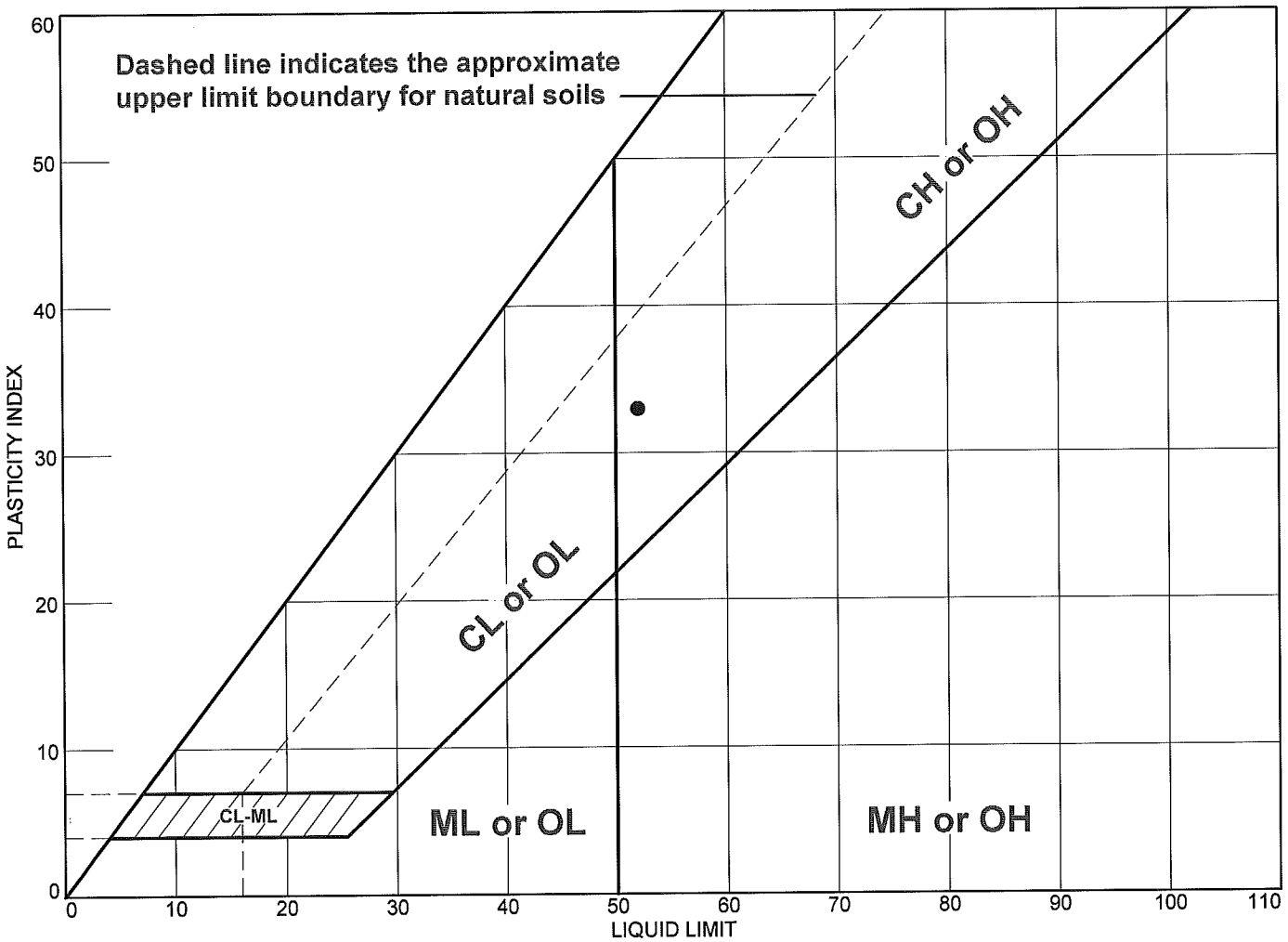
Berkeley, CA

Figure

Tested By: AL

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Brown to Yellowish Brown CLAY, Lean- silty, with some sand and roots	52	19	33	98.6	93.6	CH

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

● **Source of Sample:** AKA-38 **Depth:** 1' - 1.5'

Remarks:

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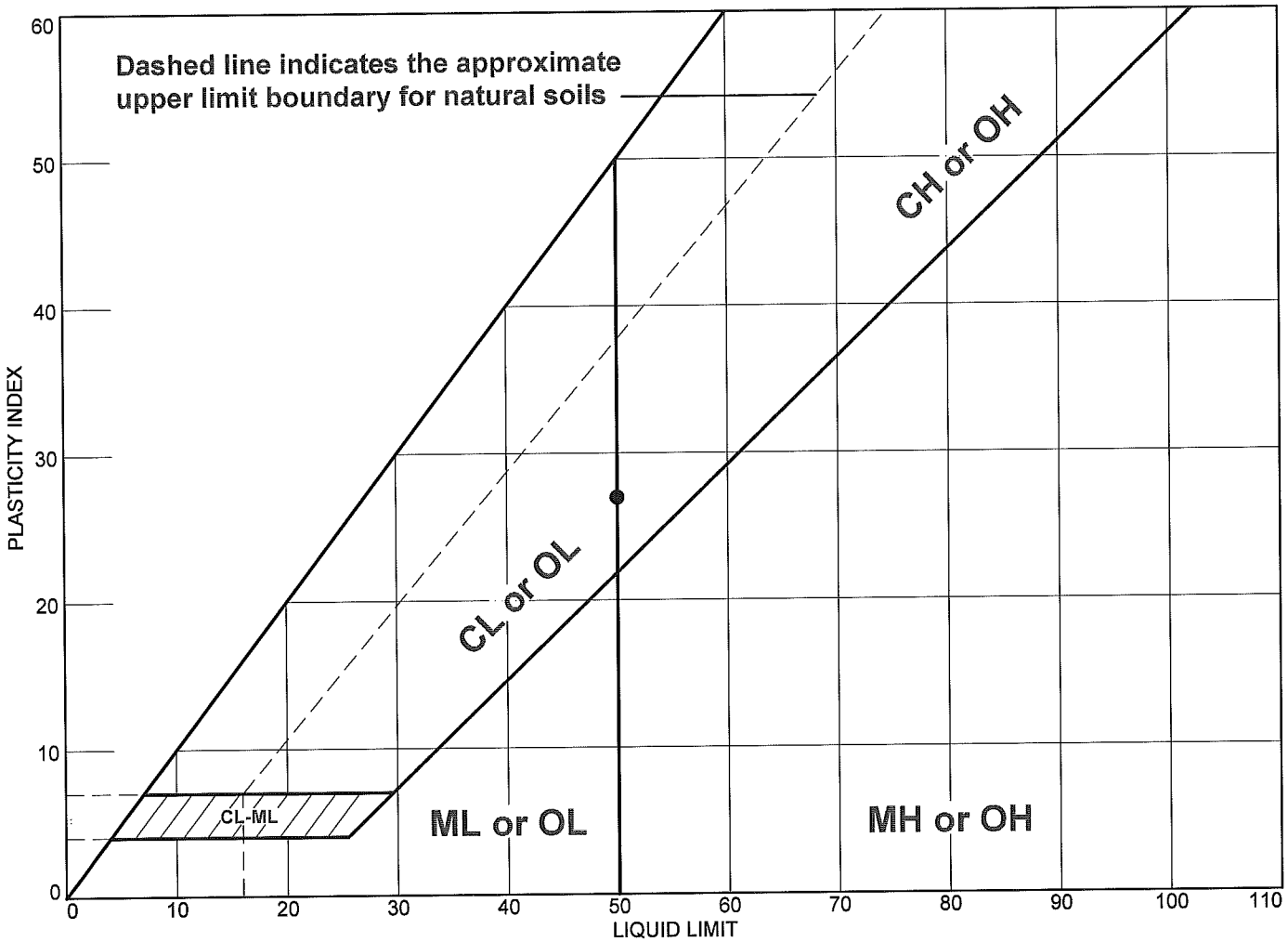
Figure

Tested By: AL

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Yellowish Brown to Brown CLAY, Lean- with silt, some sand	50	23	27	89.1	85.0	CH

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

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● **Source of Sample:** AKA-39 **Depth:** 3' - 3.5'

Remarks:

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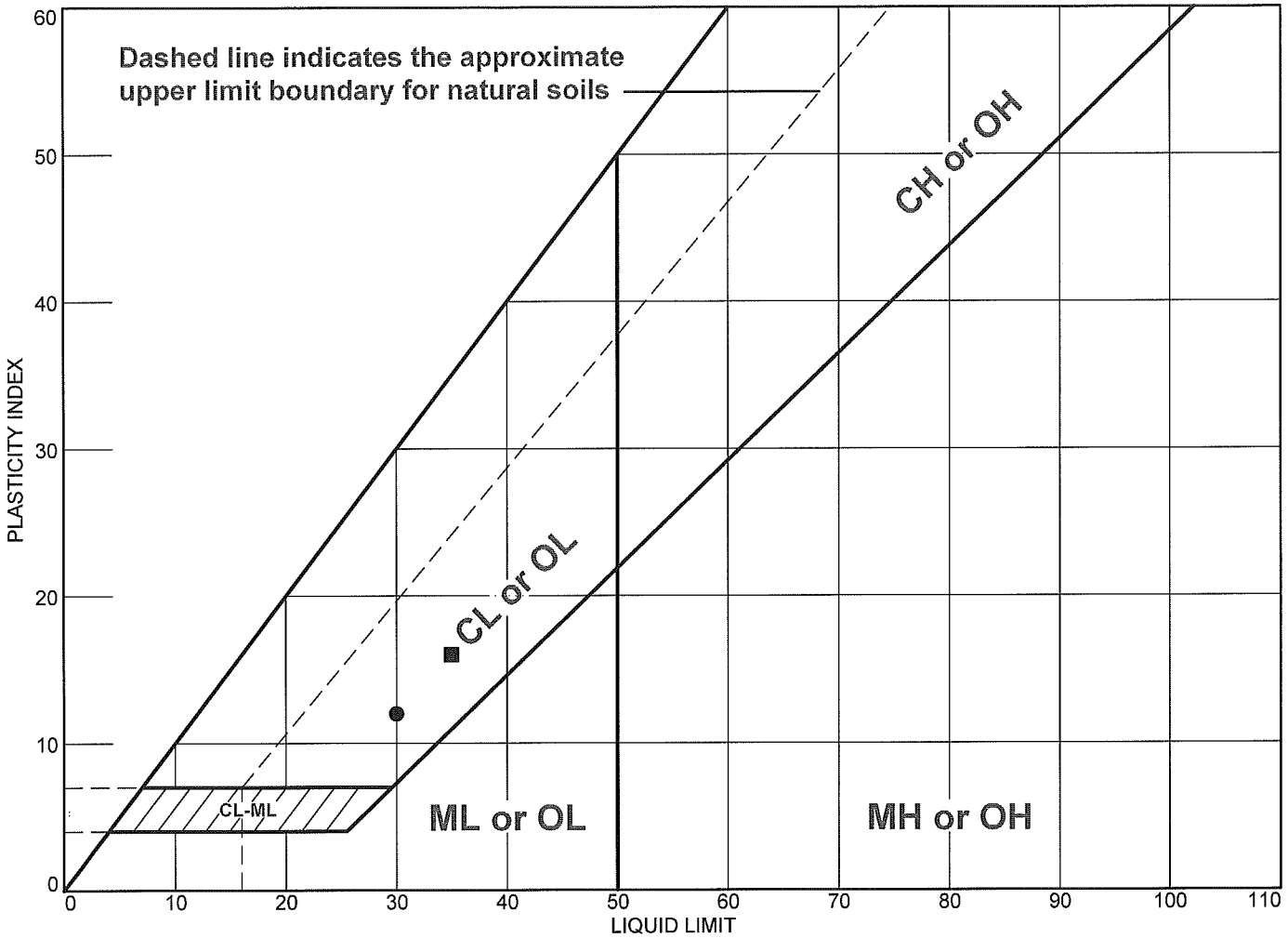
Figure

Tested By: AL

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Brown to Yellowish Brown CLAY, Lean - with weathered sandstone fragments	30	18	12	93.3	54.0	CL
■	Grayish Brown CLAYSTONE - with lenses of shale, clay rich, friable, deeply weathered, crushed	35	19	16	72.7	61.6	CL

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

● **Source of Sample:** AKA-41 **Depth:** 2.25' - 2.7'

■ **Source of Sample:** AKA-41 **Depth:** 17' - 17.5'

Remarks:

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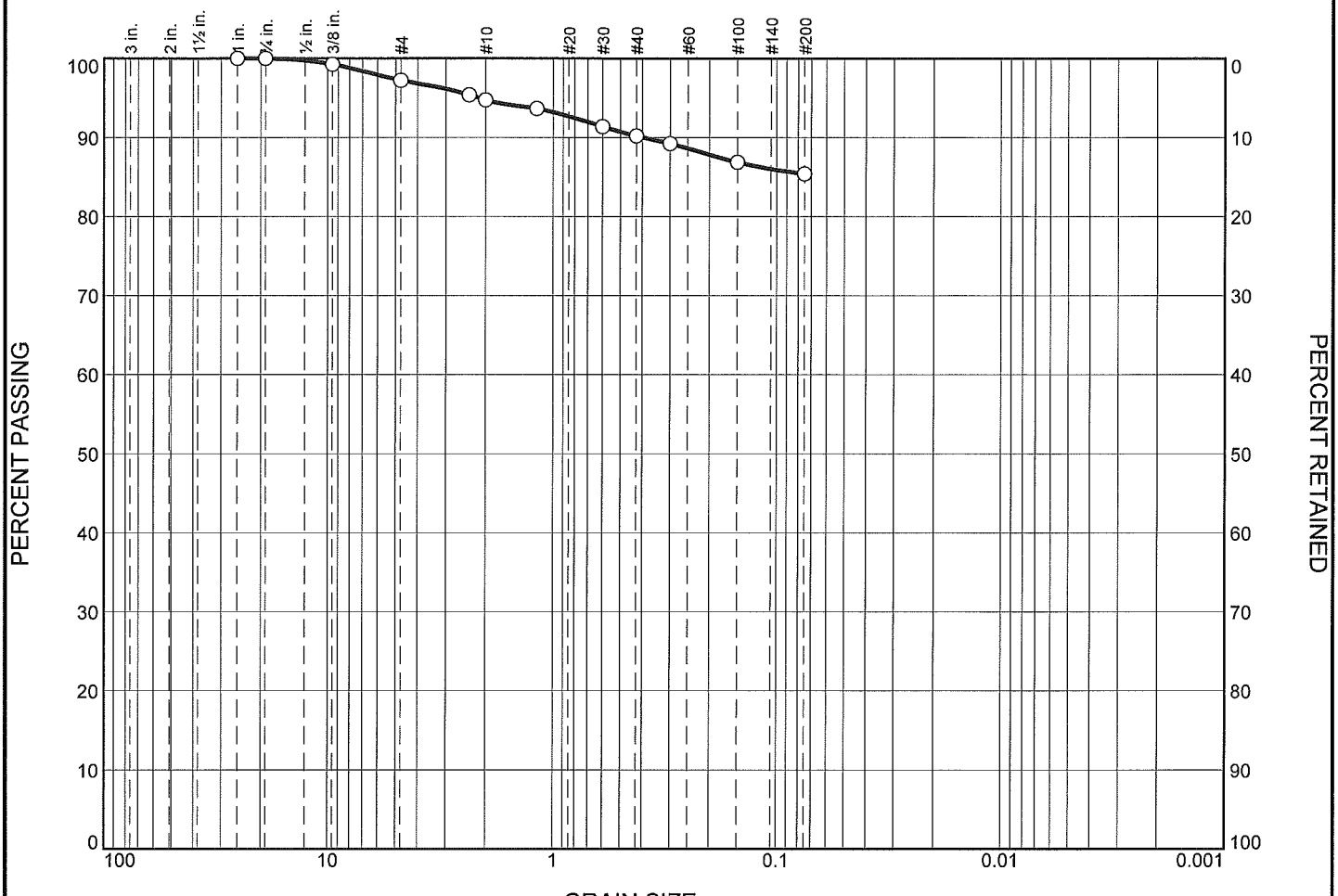
Berkeley, CA

Figure

Tested By: AL

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	2.8	2.4	4.6	4.8	85.4	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○										

Material Description	USCS	AASHTO
○ Olive Brown CLAY, Fat- some sand, trace gravel	CH	

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

○ **Source of Sample:** AKA-11 **Depth:** 4.5' - 5'

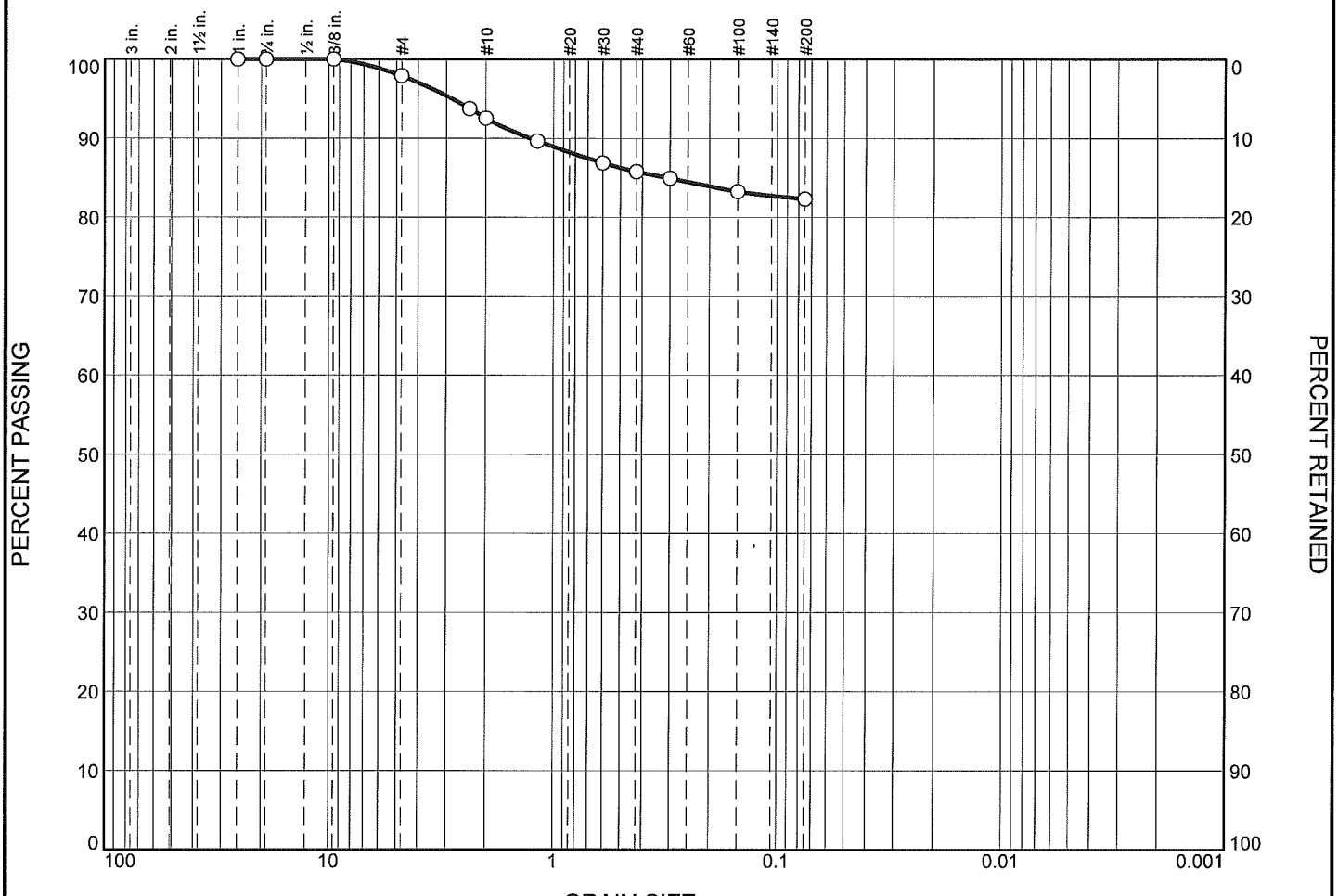
Remarks:

Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA

Figure

Tested By: AL

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	2.1	5.4	6.7	3.5	82.3	

	Colloids	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○				0.3077							

Material Description	USCS	AASHTO
○ Yellowish Brown CLAY, Lean - with silt, some sand, trace gravel, moist	CL	

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

○ **Source of Sample:** AKA-20 **Depth:** 9.5' - 10'

Date: ○

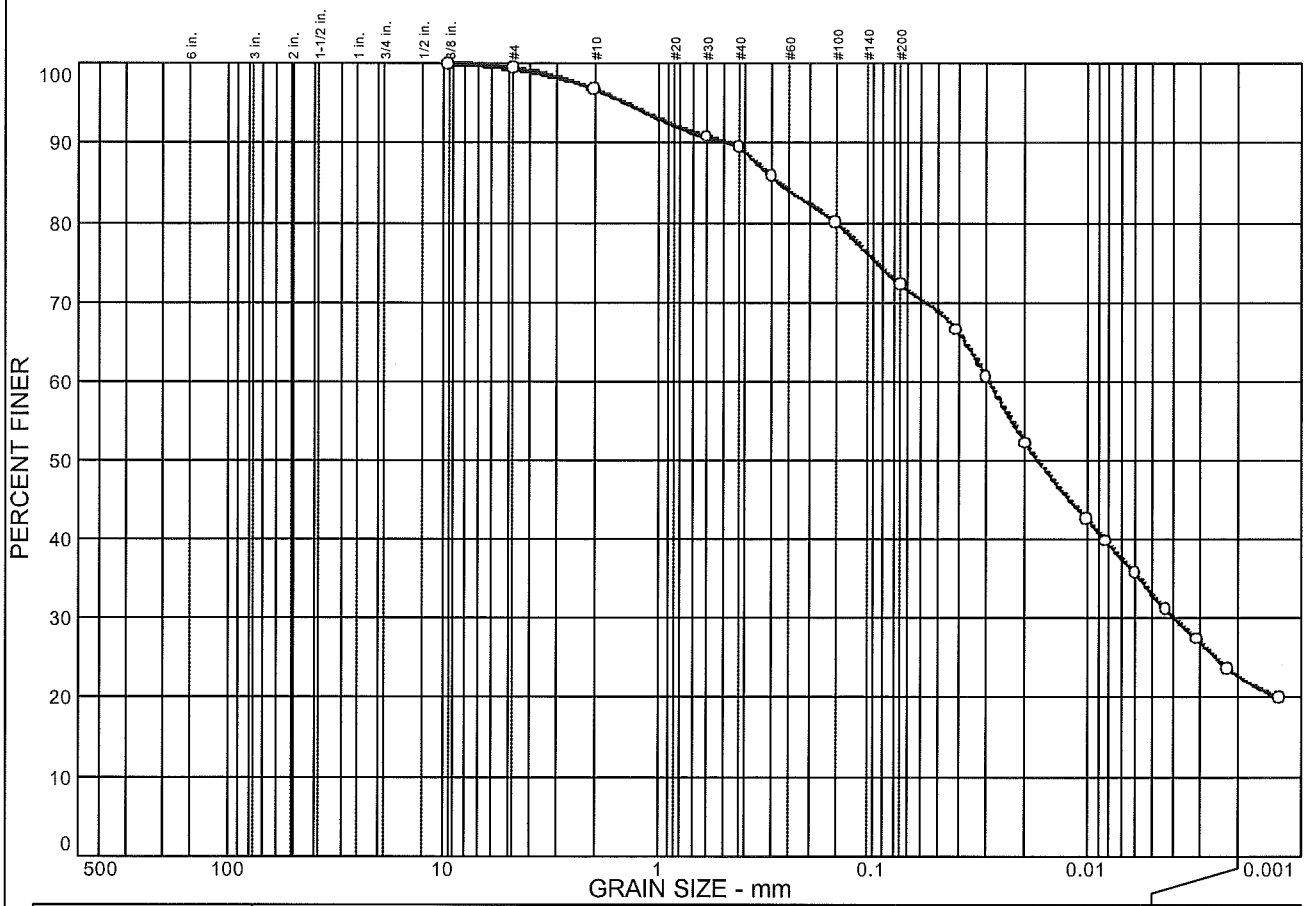
Remarks:

Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA

Figure

Tested By: AL

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	0.6	27.2	49.4	22.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
#4	99.4		
#10	96.8		
#30	90.8		
#40	89.4		
#50	85.8		
#100	80.0		
#200	72.2		
0.0412 mm.	66.5		
0.0299 mm.	60.5		
0.0196 mm.	52.2		
0.0102 mm.	42.6		
0.0083 mm.	39.8		
0.0060 mm.	35.7		
0.0043 mm.	31.1		
0.0031 mm.	27.4		
0.0022 mm.	23.7		
0.0013 mm.	20.0		

* (no specification provided)

Soil Description

Gray Lean CLAY w/ Sand

Atterberg Limits

PL= 20 LL= 38 PI= 18

Coefficients

D_{85}= 0.276 D_{60}= 0.0292 D_{50}= 0.0172
D_{30}= 0.0039 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO=

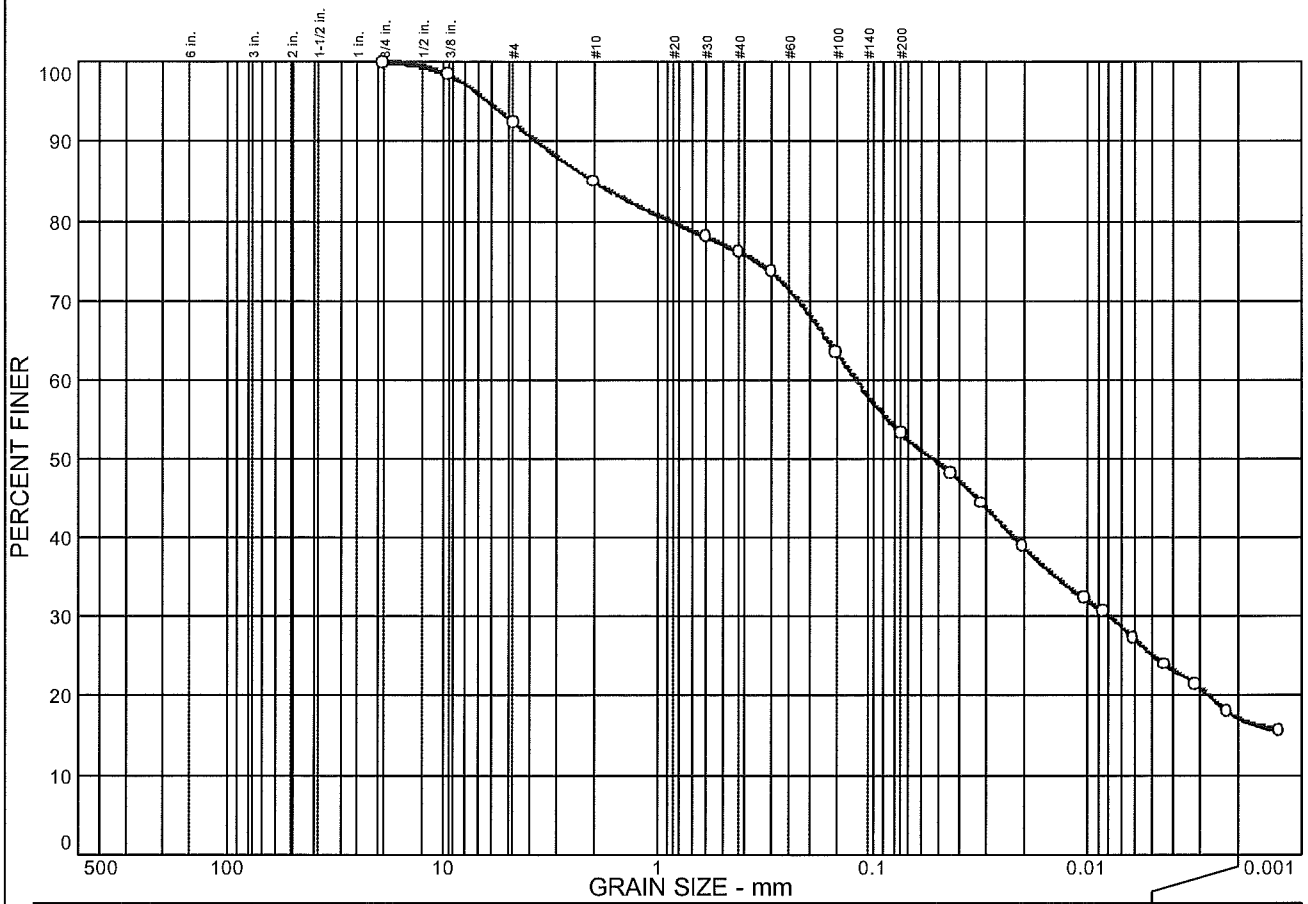
Remarks

Sample No.: **Source of Sample:** AKA-25 **Date:**
Location: **Elev./Depth:** 69-69.5'

COOPER TESTING LABORATORY

Client: Alan Kropp & Associates
Project: Helios Project Line E - 2500-4D
Project No: 254-120 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	7.6	39.2	36.0	17.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
3/8 in.	98.4		
#4	92.4		
#10	85.0		
#30	78.0		
#40	76.1		
#50	73.6		
#100	63.5		
#200	53.2		
0.0436 mm.	48.2		
0.0314 mm.	44.4		
0.0203 mm.	39.0		
0.0104 mm.	32.3		
0.0084 mm.	30.6		
0.0061 mm.	27.3		
0.0044 mm.	24.0		
0.0031 mm.	21.5		
0.0022 mm.	18.1		
0.0013 mm.	15.6		

* (no specification provided)

Soil Description

Gray Sandy Lean CLAY

Atterberg Limits

PL= 19 LL= 36 PI= 17

Coefficients

D_{85}= 2.00 D_{60}= 0.122 D_{50}= 0.0531
D_{30}= 0.0079 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= CL AASHTO=

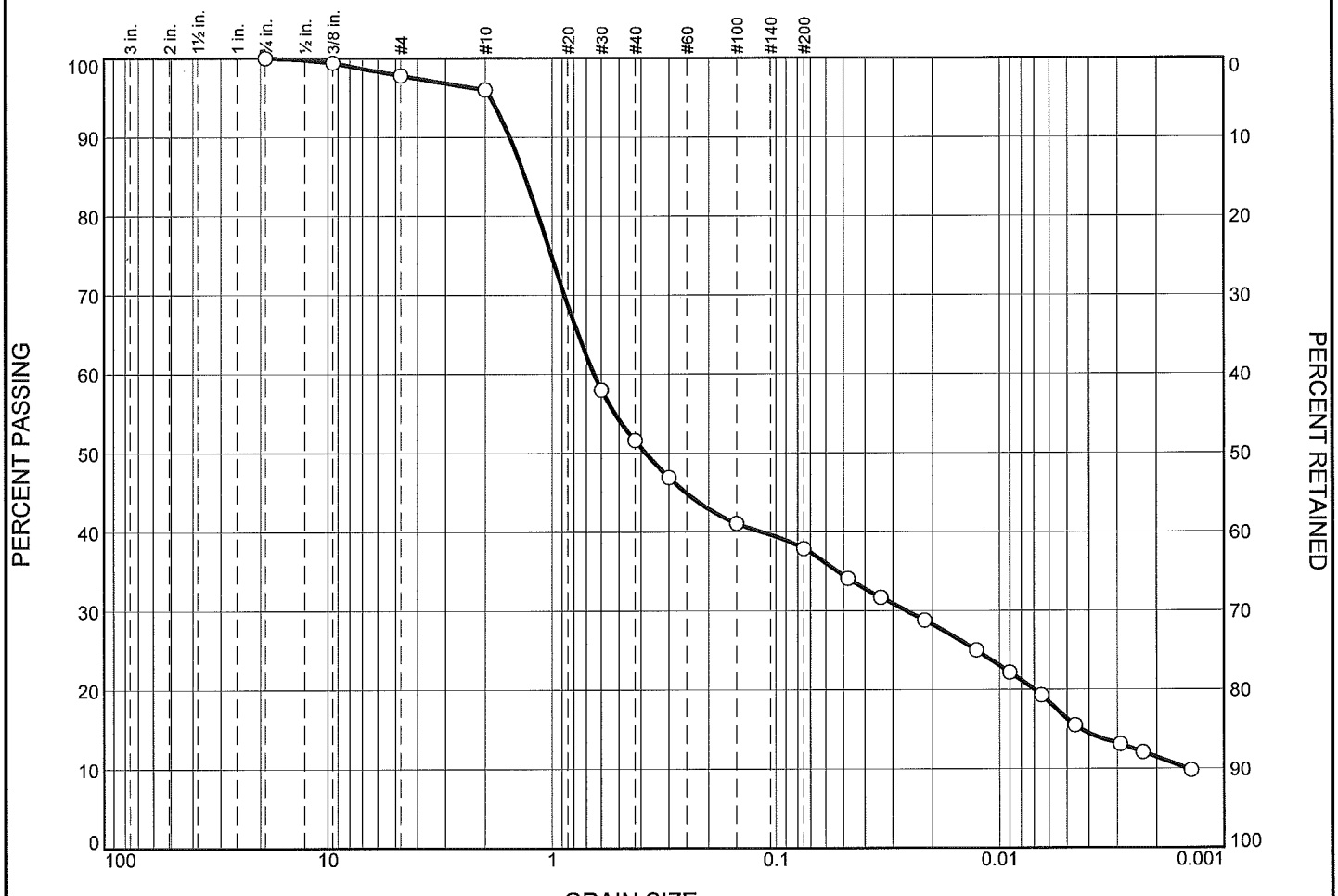
Remarks

Sample No.: **Source of Sample:** AKA-27 **Date:**
Location: **Elev./Depth:** 74-74.8'

COOPER TESTING LABORATORY

Client: Alan Kropp & Associates
Project: Helios Project Line E - 2500-4D
Project No: 254-120 **Figure**

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	2.2	1.8	44.4	13.7	21.6	16.3

☒	Colloids	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○		33	21	1.3259	0.6475	0.3807	0.0261	0.0043	0.0015	0.72	443.16

Material Description	USCS	AASHTO
○ Gray SAND- Lean Clayey	SC	A-6(1)

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

○ **Source of Sample:** AKA-31 **Depth:** 72.4' - 73'

Date: ○

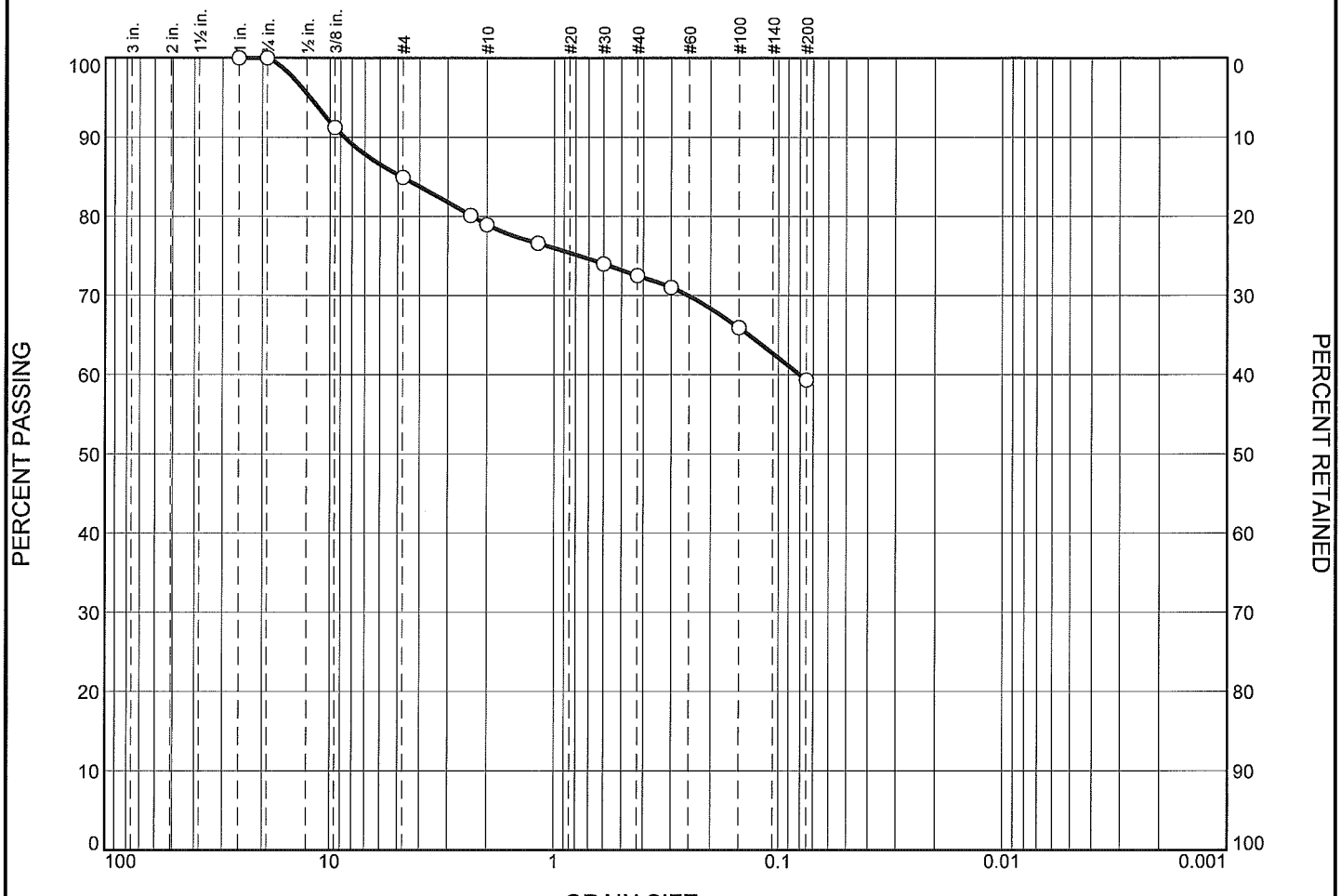
Remarks:

Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA

Figure

Tested By: Cooper Testing

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	15.1	5.9	6.5	13.2	59.3	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			4.8180	0.0802						

Material Description	USCS	AASHTO
○ Greenish Gray CLAY, Lean- with sand, siltstone fragments and gravel of Moraga volcanics	CL	

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

○ **Source of Sample:** AKA-32 **Depth:** 36.3' - 37'

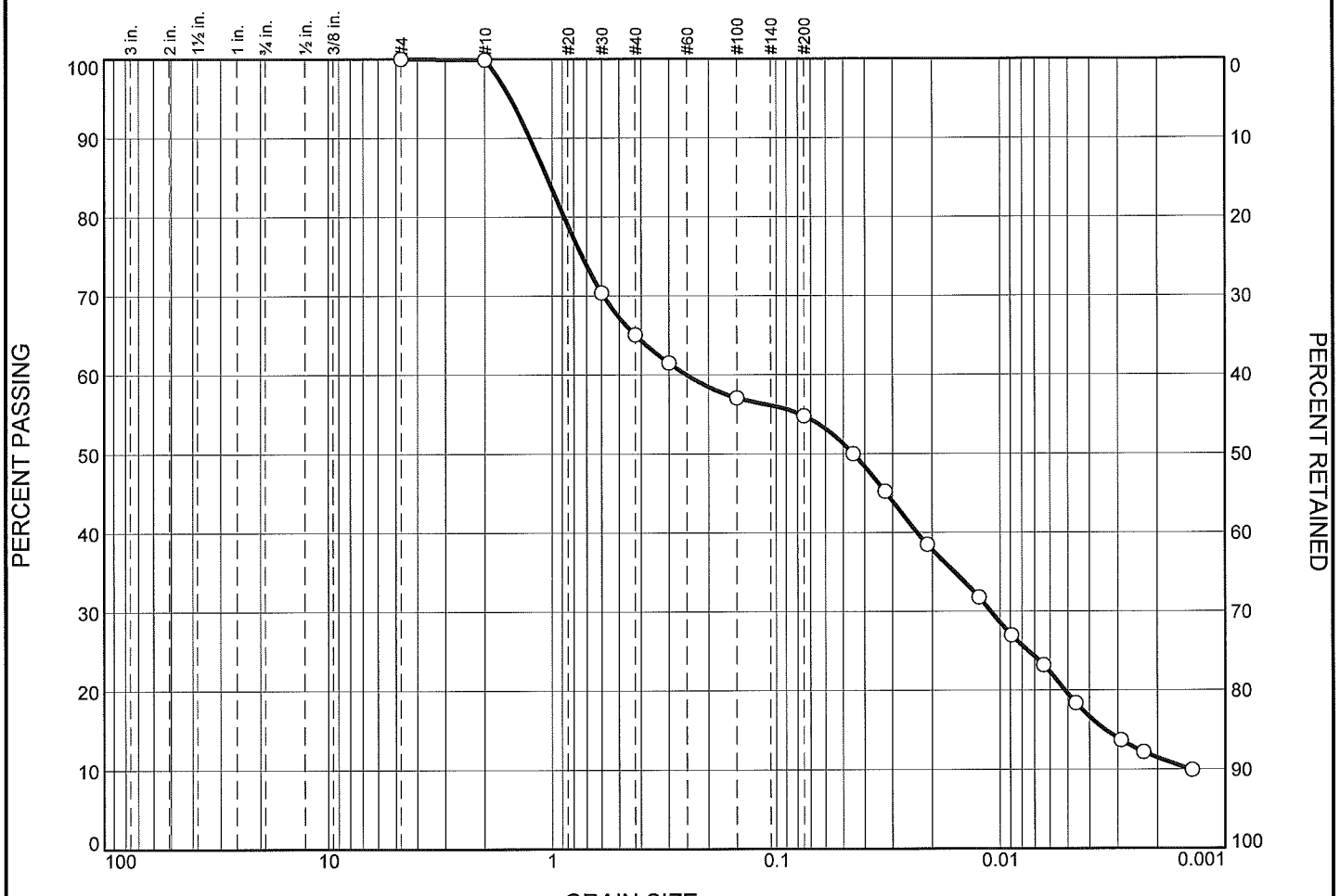
Remarks:

Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA

Figure

Tested By: AL

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	0.1	34.8	10.3	35.2	19.6

	Colloids	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○				1.0515	0.2502	0.0450	0.0110	0.0034	0.0014	0.34	174.43

Material Description	USCS	AASHTO
○ Bluish Gray CLAYSTONE- plastic, clay rich, with weathered rock fragments, moderately hard to hard	CL	

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

○ **Source of Sample:** AKA-34 **Depth:** 26.5' - 27'

Date: ○

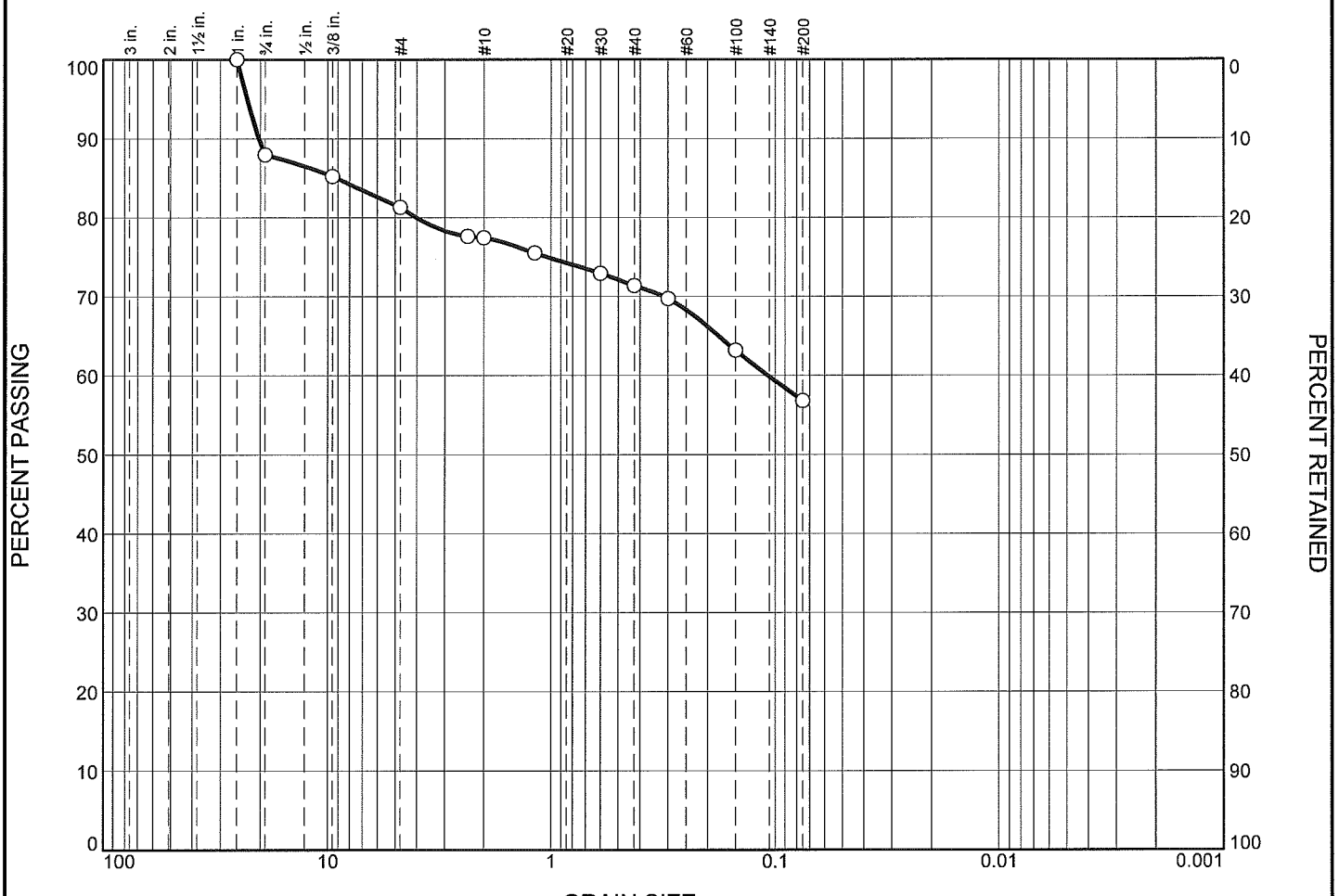
Remarks:

Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA

Figure

Tested By: Cooper Testing

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	12.1	6.6	3.9	6.0	14.6	56.8	

	Colloids	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○				9.1611	0.1074						

Material Description	USCS	AASHTO
○ Mottled Brown, Olive Gray, Olive Brown CLAY, Lean- with sand and gravel	CL	

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

○ **Source of Sample:** AKA-36 **Depth:** 6.9' - 7.4'

Date: ○

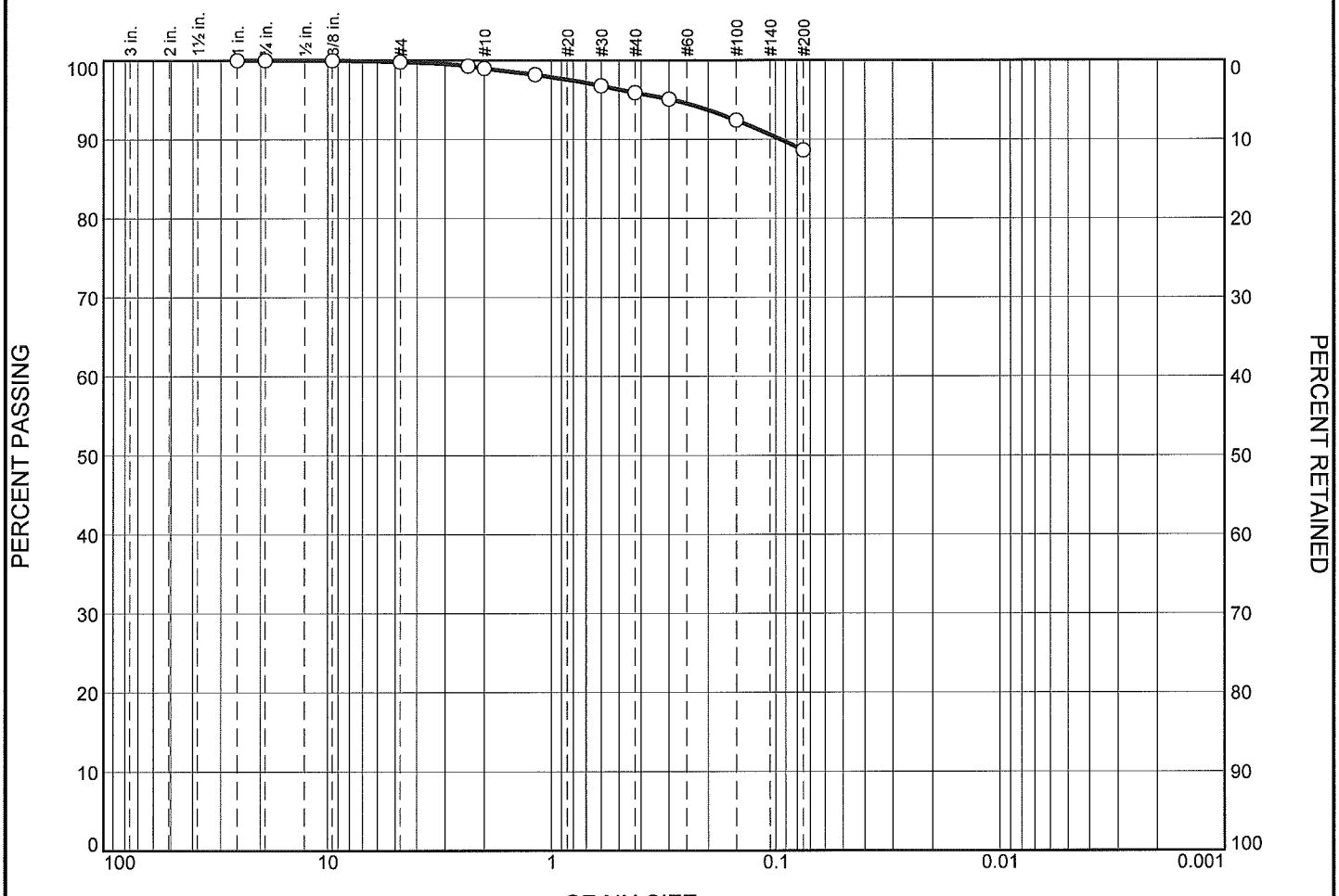
Remarks:

Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA

Figure

Tested By: AL

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.2	0.8	3.1	7.2	88.7	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○										

Material Description	USCS	AASHTO
○ Yellowish Brown to Grayish Brown CLAY, Lean- with silt, some sand and roots	CL	

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

○ **Source of Sample:** AKA-37 **Depth:** 1.5' - 2'

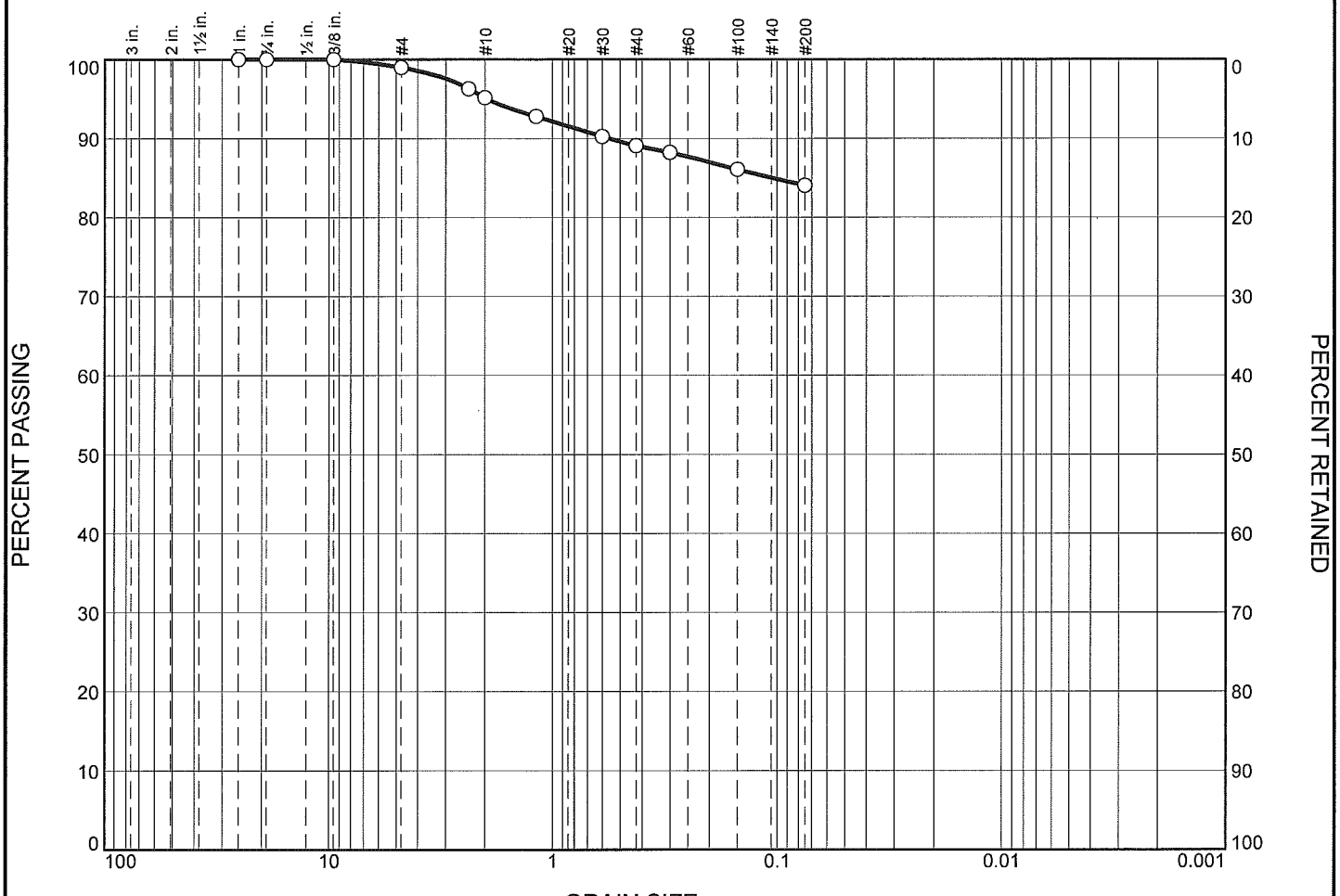
Remarks:

Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA

Figure

Tested By: AL

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	1.0	3.8	6.1	5.1	84.0	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	50	23	0.1053							

Material Description	USCS	AASHTO
○ Yellowish Brown to Brown CLAY, Lean- with silt, some sand and trace gravel	CL	A-7-6(24)

Project No. 2500-4 **Client:** Lawrence Berkeley National Laboratory

Project: HELIOS PROJECT

Lawrence Berkeley National Laboratory; Berkeley, California

○ **Source of Sample:** AKA-39 **Depth:** 3' - 3.5'

Remarks:

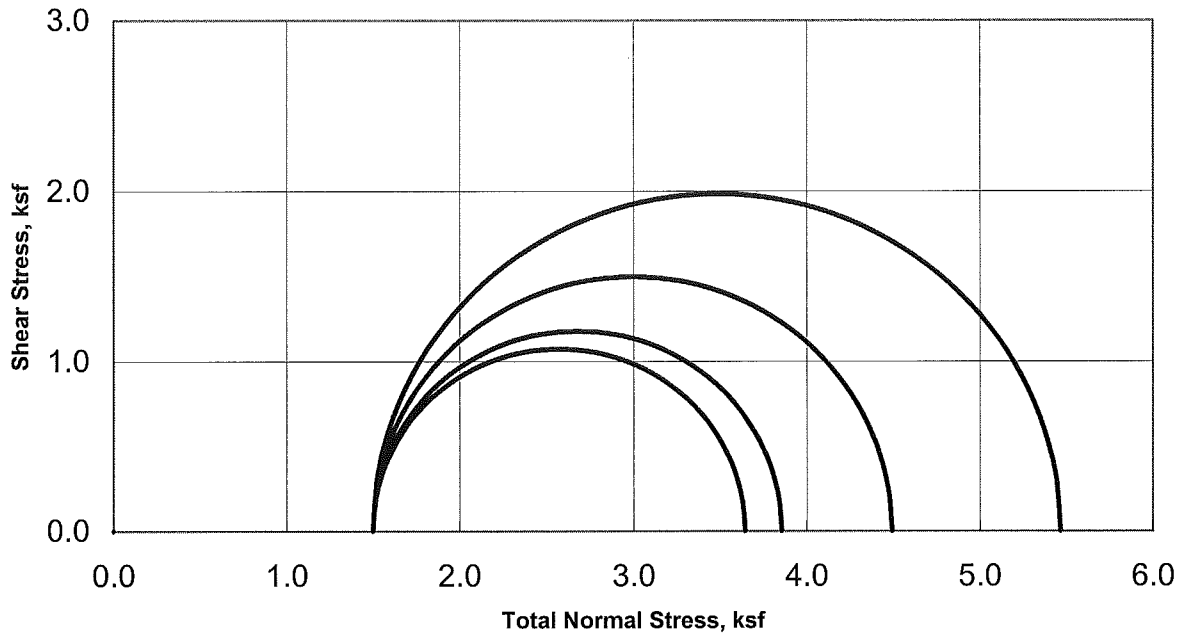
Alan Kropp & Associates, Inc.
2140 Shattuck Avenue, Suite 910
Berkeley, CA

Figure

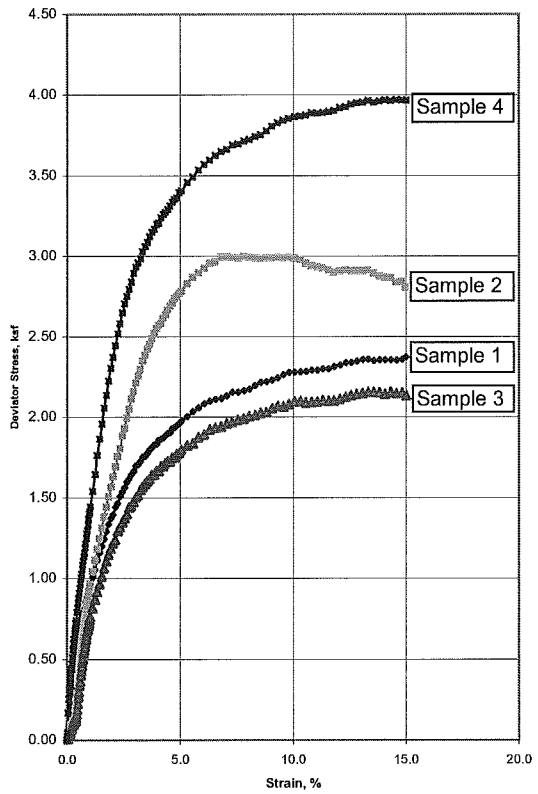
Tested By: AL

Unconsolidated-Undrained Triaxial Test

ASTM D-2850



Stress-Strain Curves



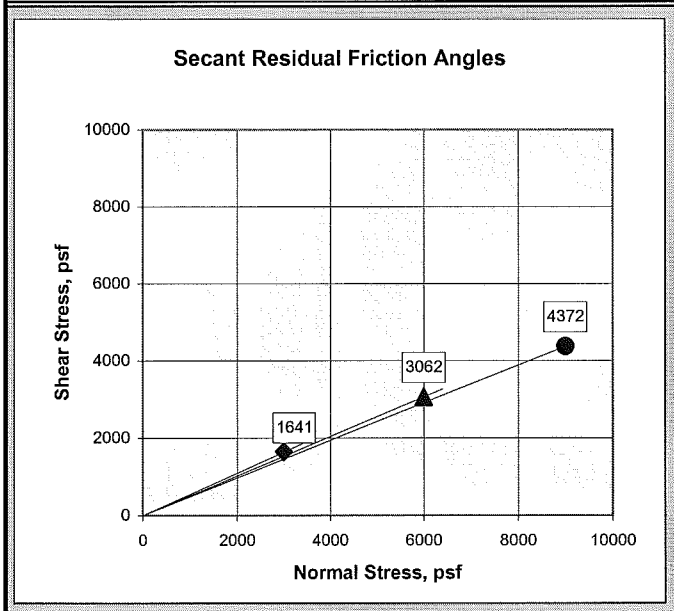
Sample Data				
	1	2	3	4
Moisture %	25.1	23.4	27.2	19.1
Dry Den,pcf	99.9	103.1	96.6	110.4
Void Ratio	0.688	0.634	0.744	0.526
Saturation %	98.7	99.8	98.6	98.2
Height in	5.98	5.99	5.98	6.00
Diameter in	2.85	2.84	2.86	2.86
Cell psi	10.4	10.4	10.4	10.4
Strain %	15.00	7.10	13.30	14.10
Deviator, ksf	2.372	2.998	2.156	3.970
Rate %/min	1.00	1.00	1.00	1.00
in/min	0.060	0.060	0.060	0.060
Job No.:	254-121			
Client:	Alan Kropp & Associates			
Project:	Helios Project- 2500-4			
Boring:	AKA-33	AKA-33	AKA-34	AKA-34
Sample:				
Depth ft:	8-10	10-11.7	6-8.6	10-11.7

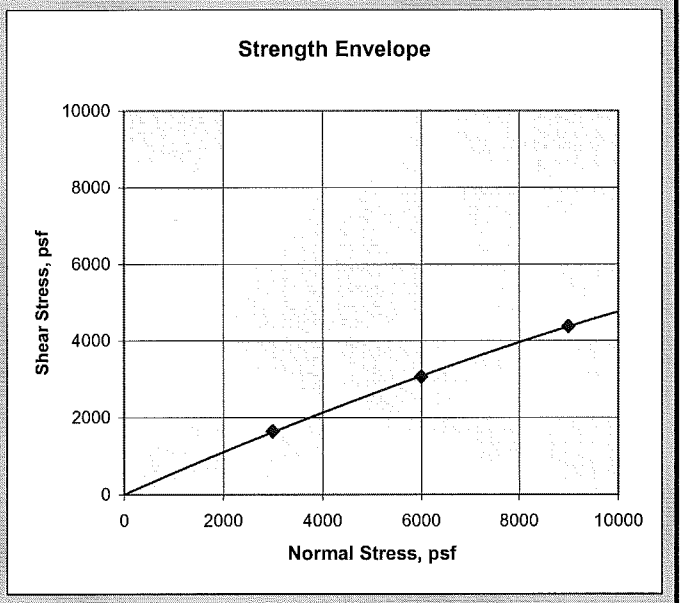
Visual Soil Description	
Sample #	
1 & 2	CLAY, Fat - with fine gravel, some silt, sand, and roots
3 & 4	CLAY, Fat- plastic, with some coarse sand and medium to coarse gravel, moist

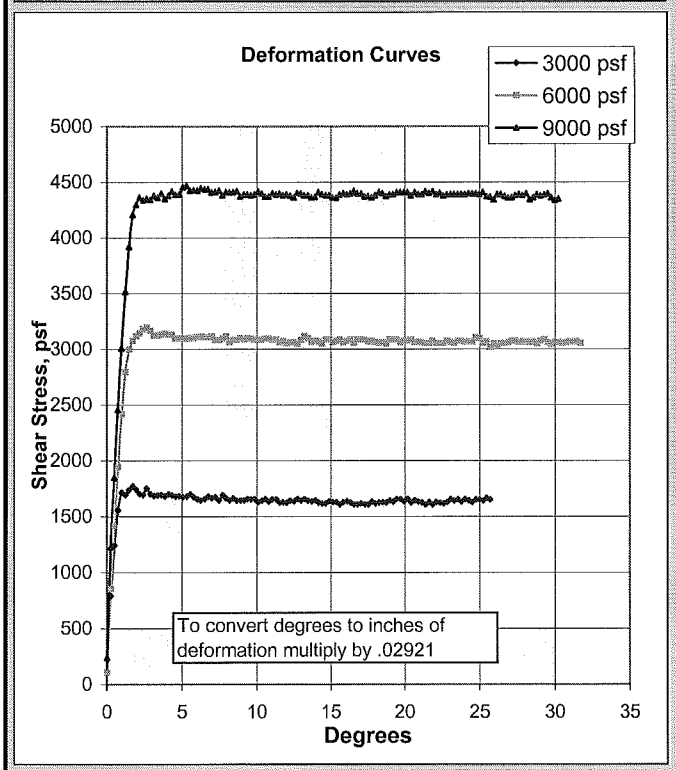
Remarks:

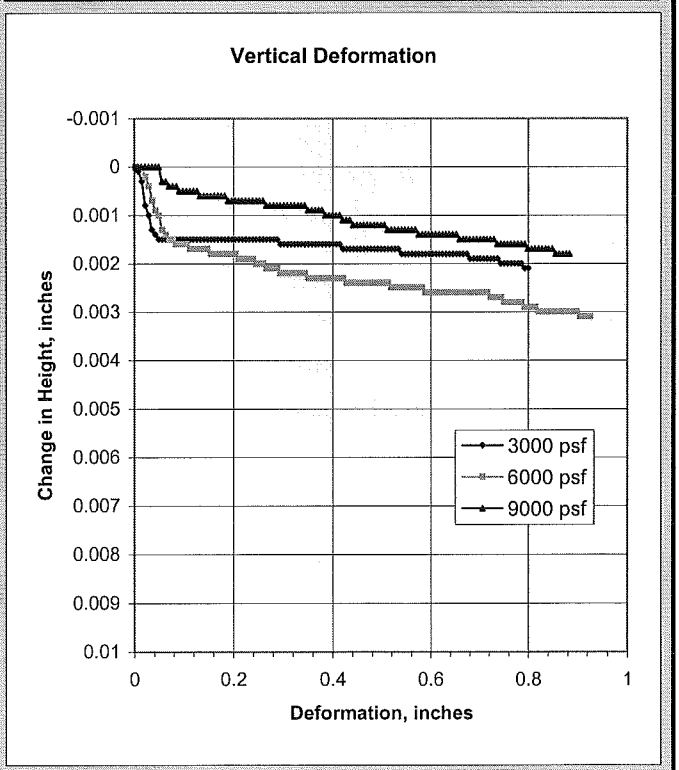
Drained, Residual Torsional Ring Shear Test ASTM D 6467

Job No.:	254-106	**Boring:**	AKA - 2	**Date:**	11/12/2007	**Undisturbed:**	
Client:	Alan Kropp & Associates	**Sample:**		**By:**	PJ	**Peak:**	
Project:	Helios Project	**Depth:**	64	**Checked:**	DC	**Residual:**	
Soil Type:	Greenish Gray CLAY, Lean, Sandy			**Clay, %:**		**Fully Softened:**	X
Remarks:	A small friction correction was applied to each point.			**LL:**	38	**Peak:**	
Normal Stress, psf	3000	6000	9000	**PL:**	23	**Residual:**	X
Secant Phi, deg.	29	27	26				



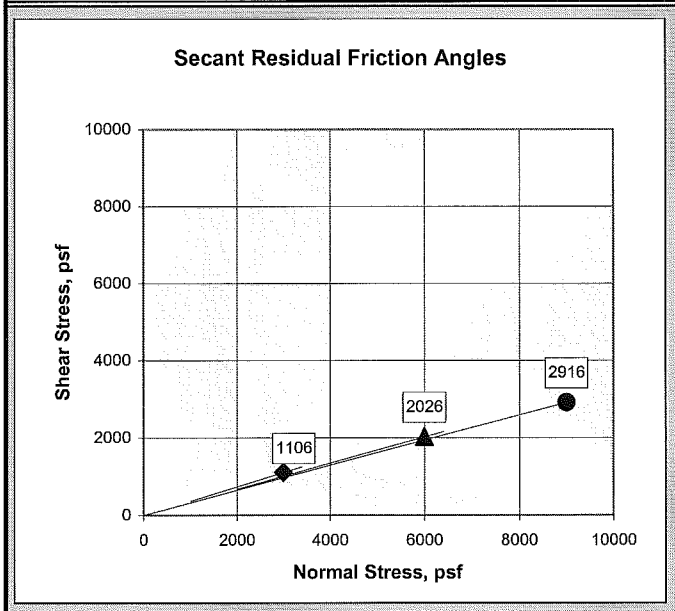


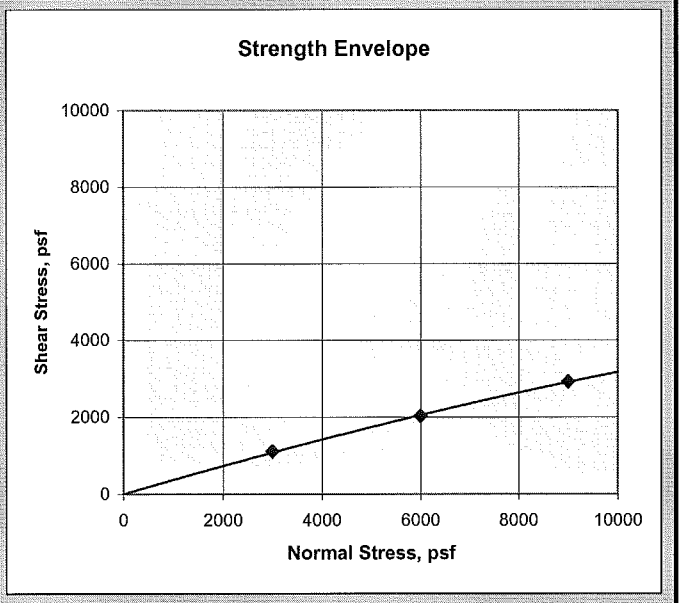


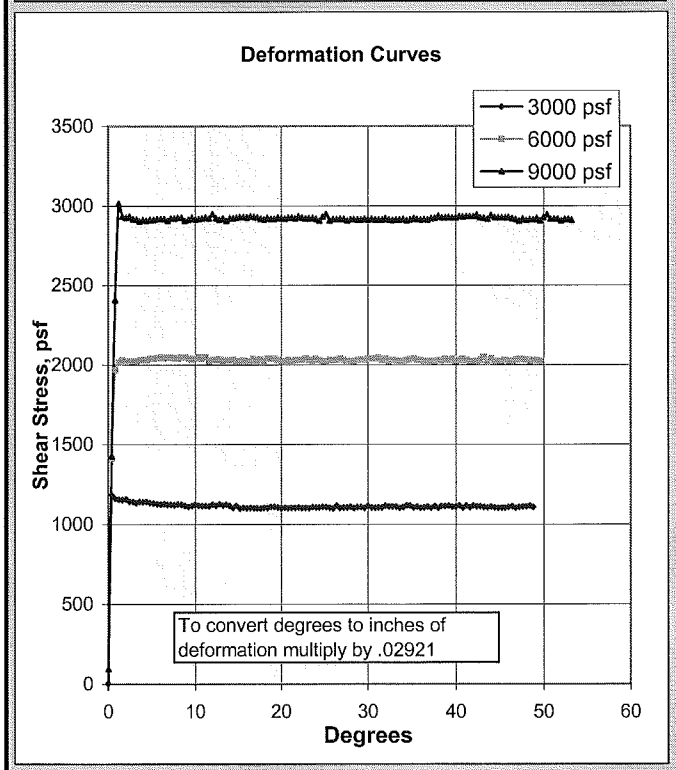


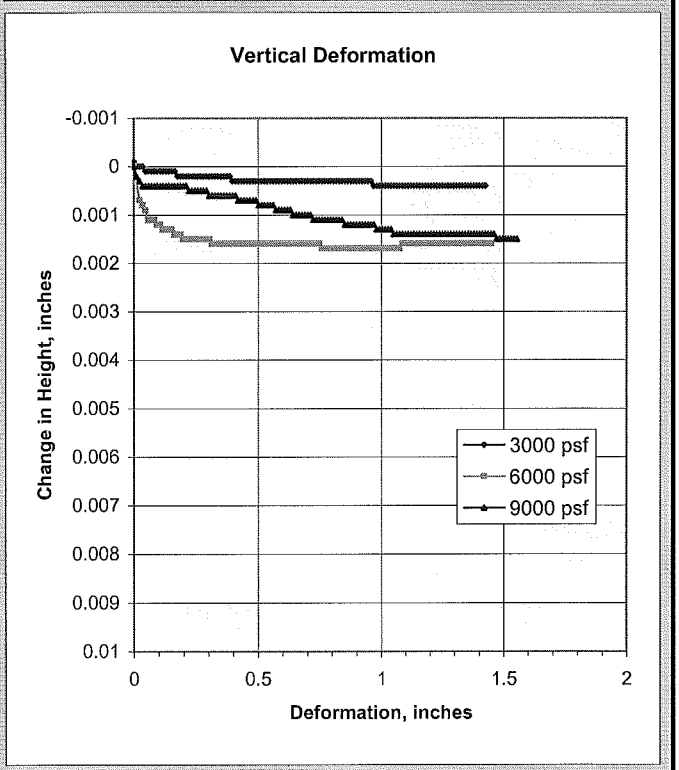
Drained, Residual Torsional Ring Shear Test ASTM D 6467

Job No.:	254-120a	**Boring:**	AKA 25	**Date:**	10/6/2008	**Undisturbed:**	
Client:	Alaln Kropp & Assoc.	**Sample:**		**By:**	PJ	**Peak:**	
Project:	2500-4D	**Depth:**	69 - 69.5	**Checked:**	DC	**Residual:**	
Soil Type:	Gray Lean CLAY w/ Sand			**Clay, %:**	23	**Fully Softened:**	X
Remarks:	A small friction correction was applied to each point.			**LL:**	38	**Peak:**	
Normal Stress, psf	3000	6000	9000	**PL:**	20	**Residual:**	X
Secant Phi, deg.	20	19	18				



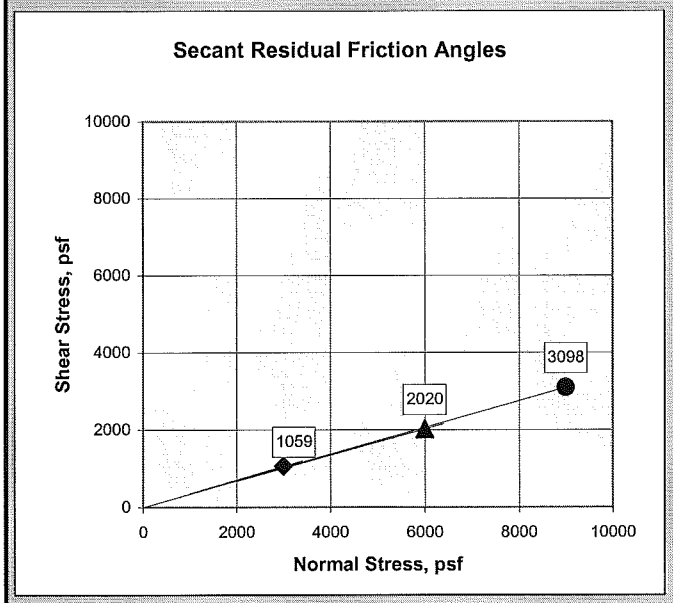


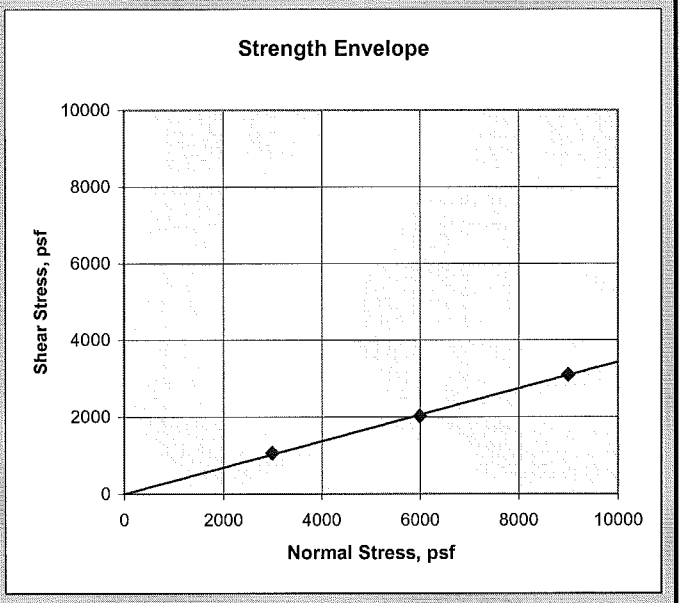


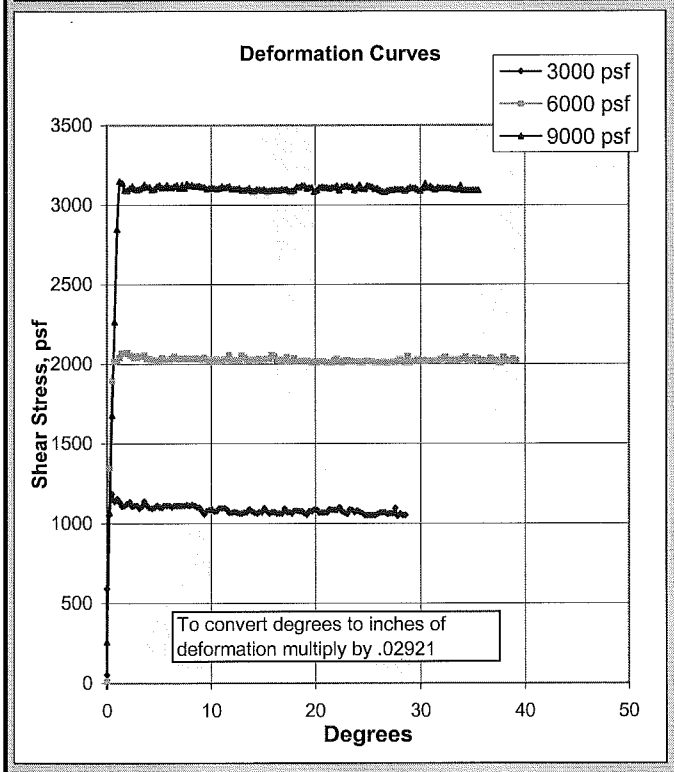


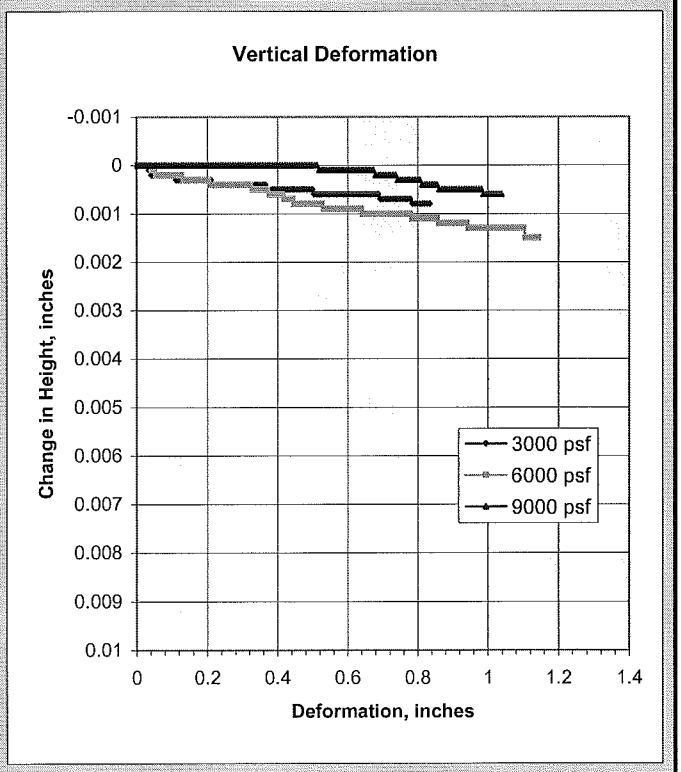
Drained, Residual Torsional Ring Shear Test ASTM D 6467

Job No.:	254-120b	**Boring:**	AKA 27	**Date:**	10/6/2008	**Undisturbed:**	
Client:	Alan Kropp & Assoc.	**Sample:**		**By:**	PJ	**Peak:**	
Project:	2500-4D	**Depth:**	74 - 74.8	**Checked:**	DC	**Residual:**	
Soil Type:	Gray Sandy Lean CLAY			**Clay, %:**	17	**Fully Softened:**	X
Remarks:	A small friction correction was applied to each point.			**LL:**	36	**Peak:**	
Normal Stress, psf	3000	6000	9000	**PL:**	19	**Residual:**	X
Secant Phi, deg.	19	19	19				



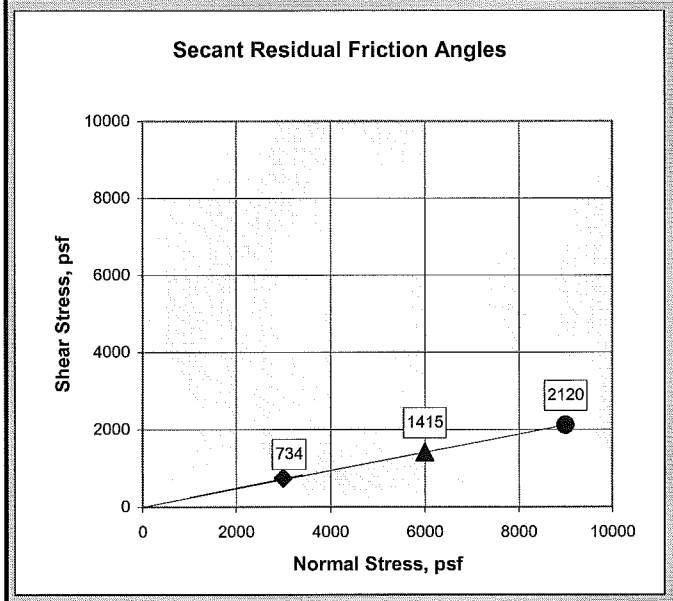


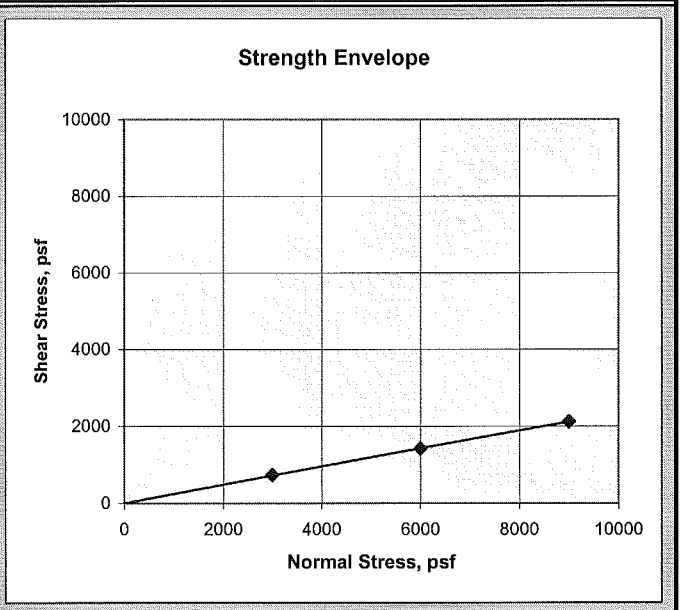


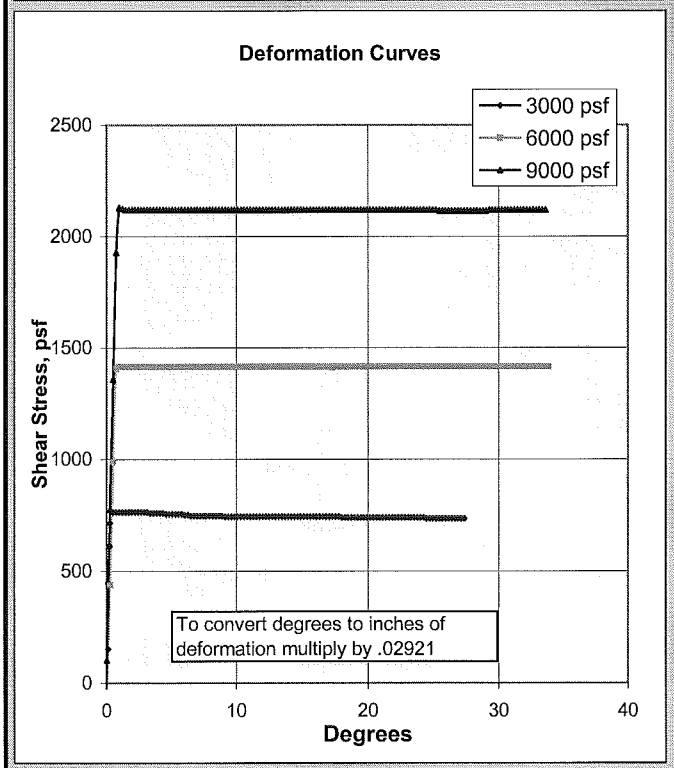


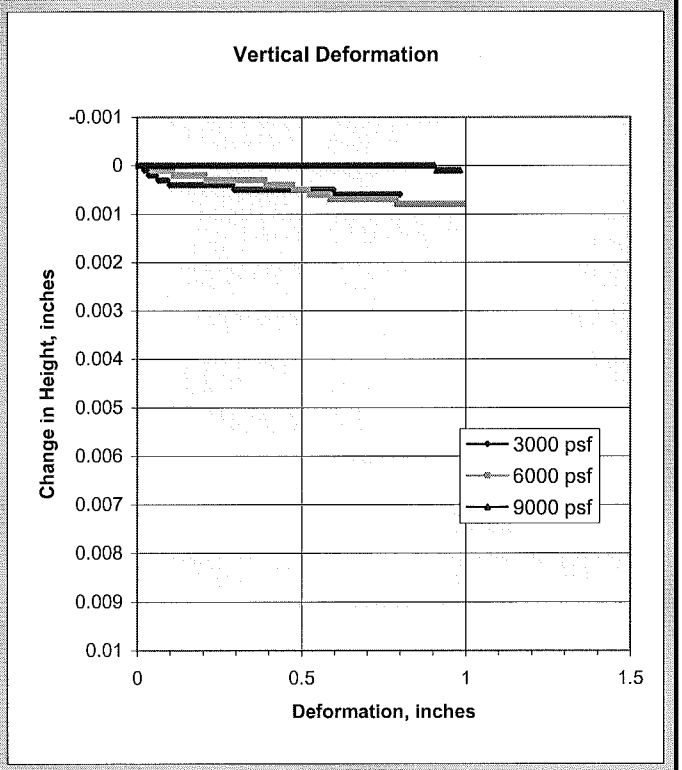
Drained, Residual Torsional Ring Shear Test ASTM D 6467

Job No.:	254-121a	**Boring:**	AKA-31	**Date:**	11/24/2008	**Undisturbed:**	
Client:	Alan Kropp & Assoc.	**Sample:**		**By:**	PJ	**Peak:**	
Project:	Helios Project	**Depth:**	72.4-73	**Checked:**	DC	**Residual:**	
Soil Type:	Gray CLAY, Lean with Sand and Claystone/Siltstone Frags			**Clay, %:**	11	**Fully Softened:**	X
Remarks:	A small friction correction was applied to each point.			**LL:**	33	**Peak:**	
Normal Stress, psf	3000	6000	9000	**PL:**	21	**Residual:**	X
Secant Phi, deg.	14	13	13				



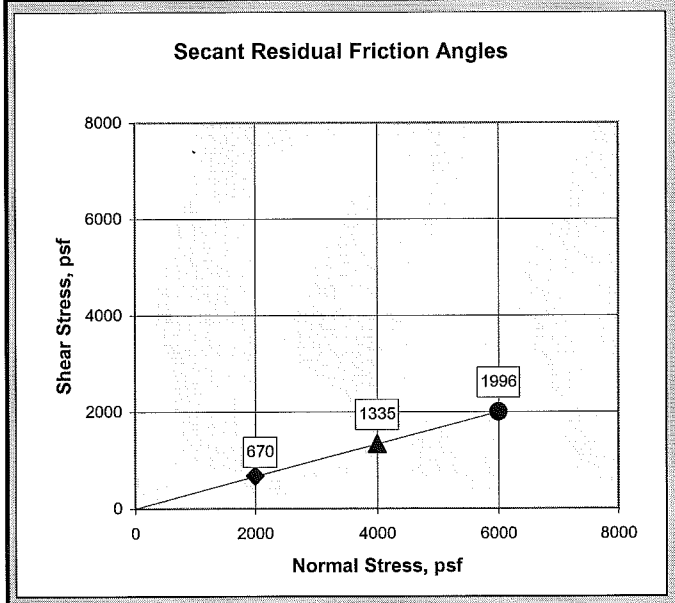


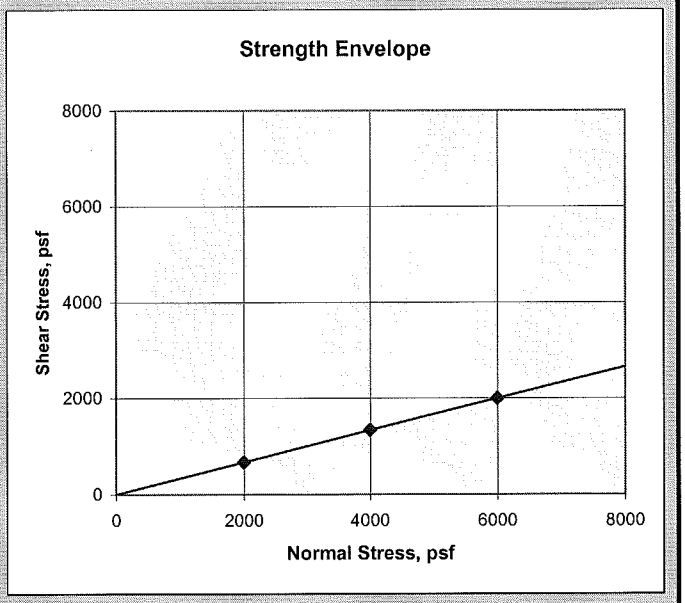


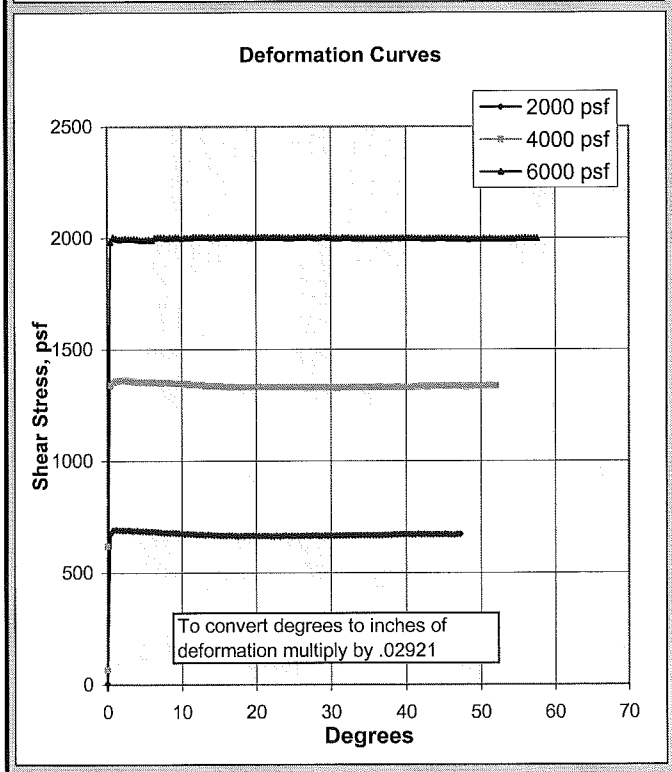


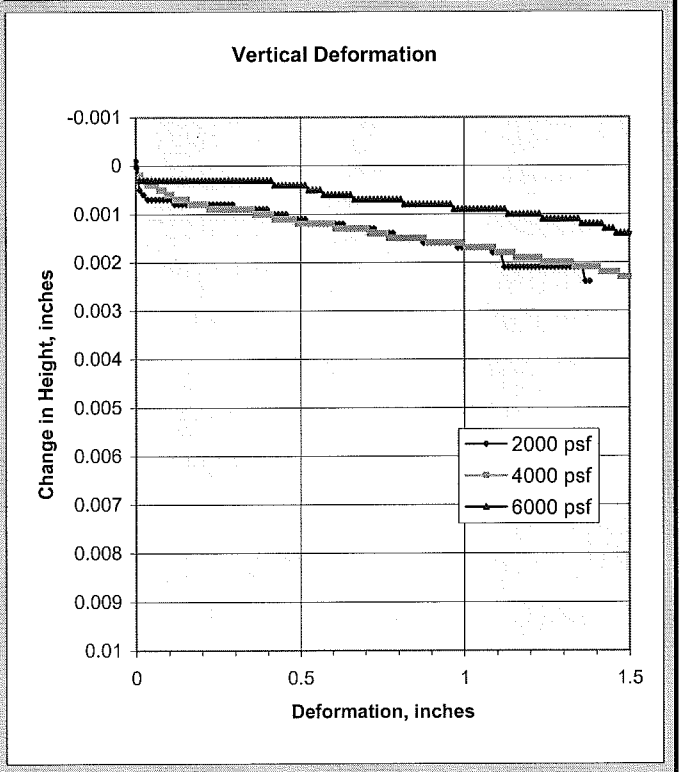
Drained, Residual Torsional Ring Shear Test ASTM D 6467

Job No.:	254-121b	**Boring:**	AKA-34	**Date:**	11/24/2008	**Undisturbed:**	
Client:	Alan Kropp & Assoc.	**Sample:**		**By:**	PJ	**Peak:**	
Project:	Helios Project	**Depth:**	26.5 - 27	**Checked:**	DC	**Residual:**	
Soil Type:	Brown CLAY, Lean Sandy			**Clay, %:**	11	**Fully Softened:**	X
Remarks:	A small friction correction was applied to each point			**LL:**	31	**Peak:**	
Normal Stress, psf	2000	4000	6000	**PL:**	20	**Residual:**	X
Secant Phi, deg.	19	18	18				









Corrosivity Test Summary

COOPER TESTING LABORATORY

CTL # 254-121 **Date:** 11/21/2008 **Tested By:** PJ **Checked:** PJ

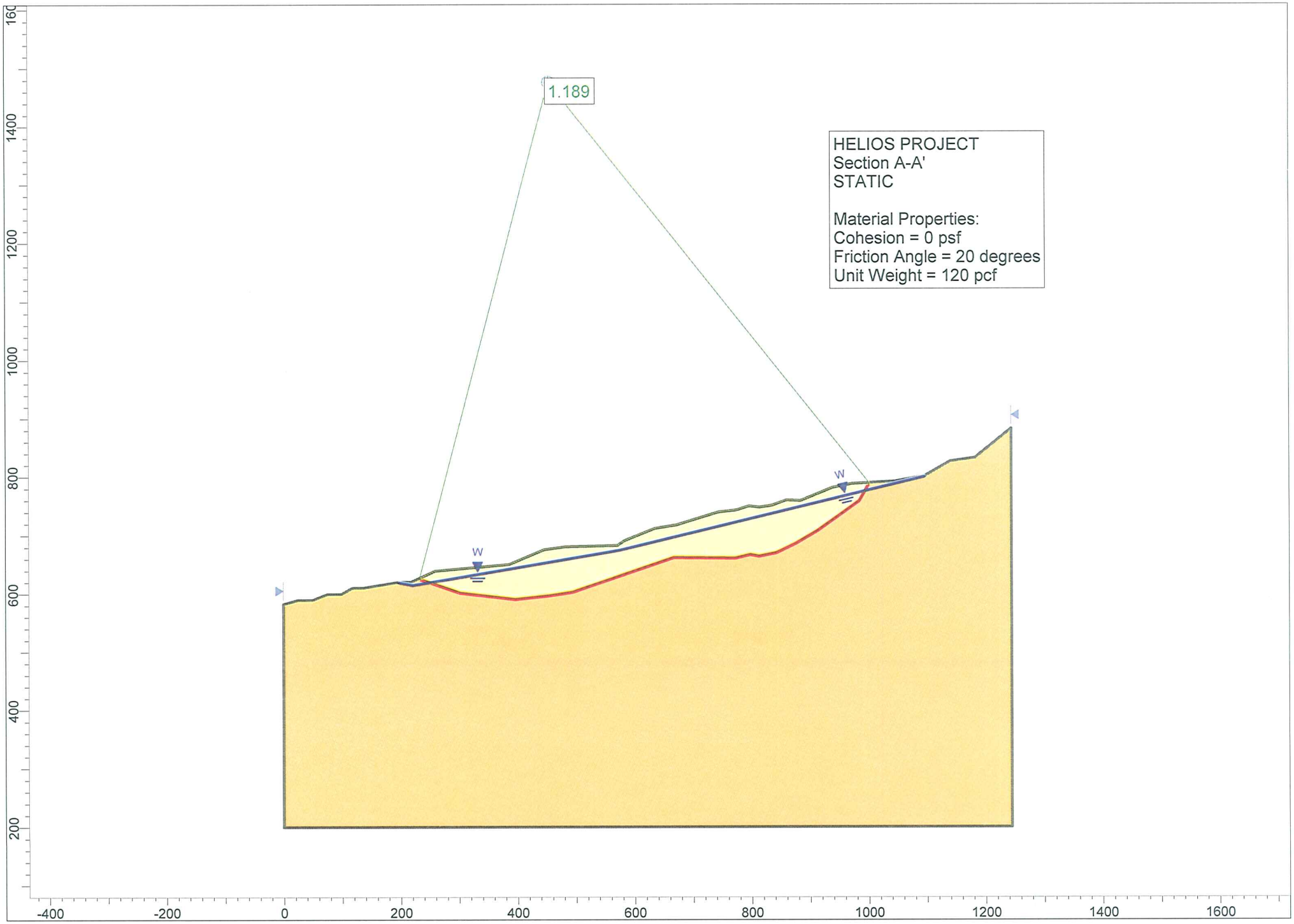
Client: Alan Kropp & Associates **Project:** Helios Project **Proj. No:** 2500-4

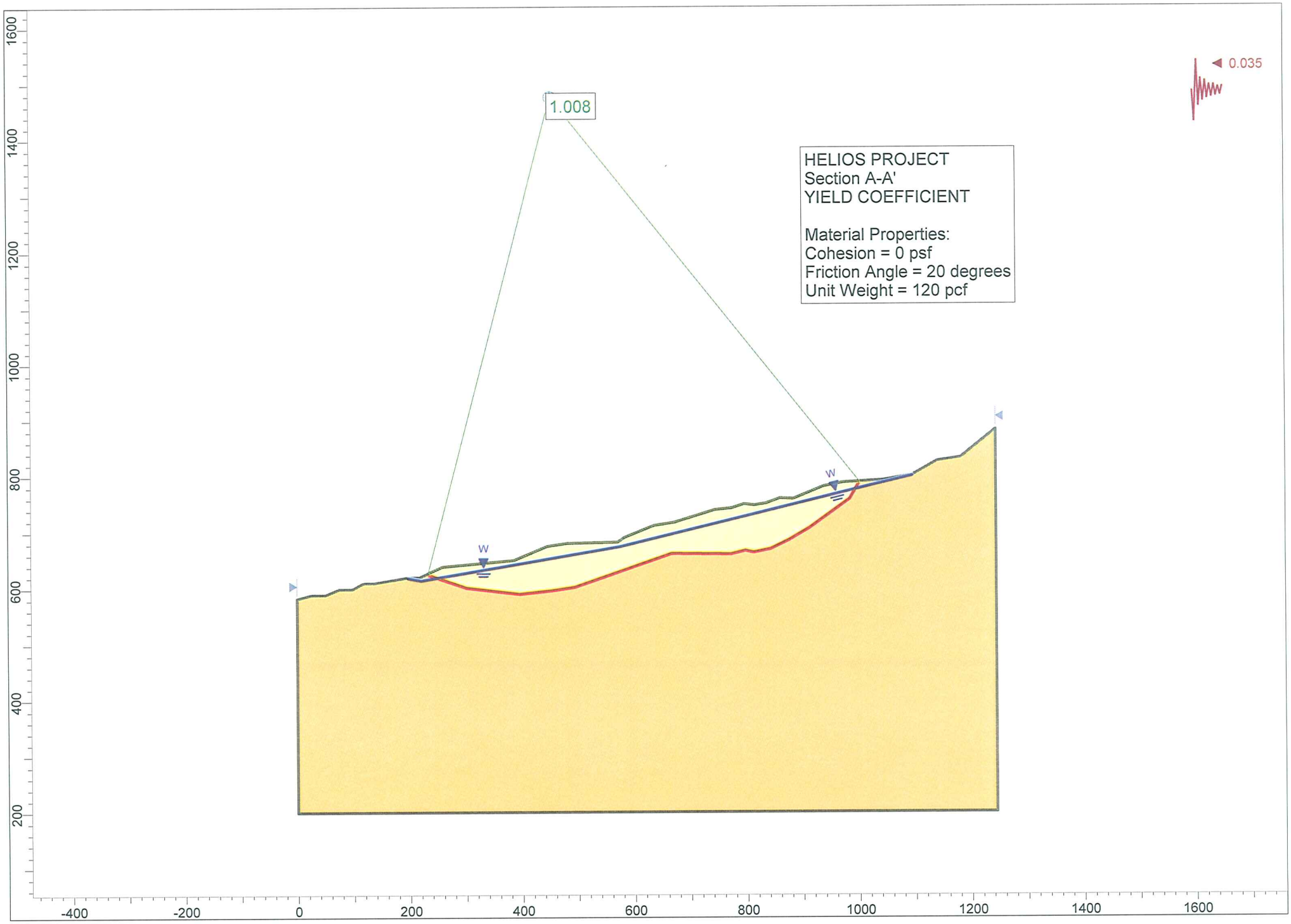
Remarks:

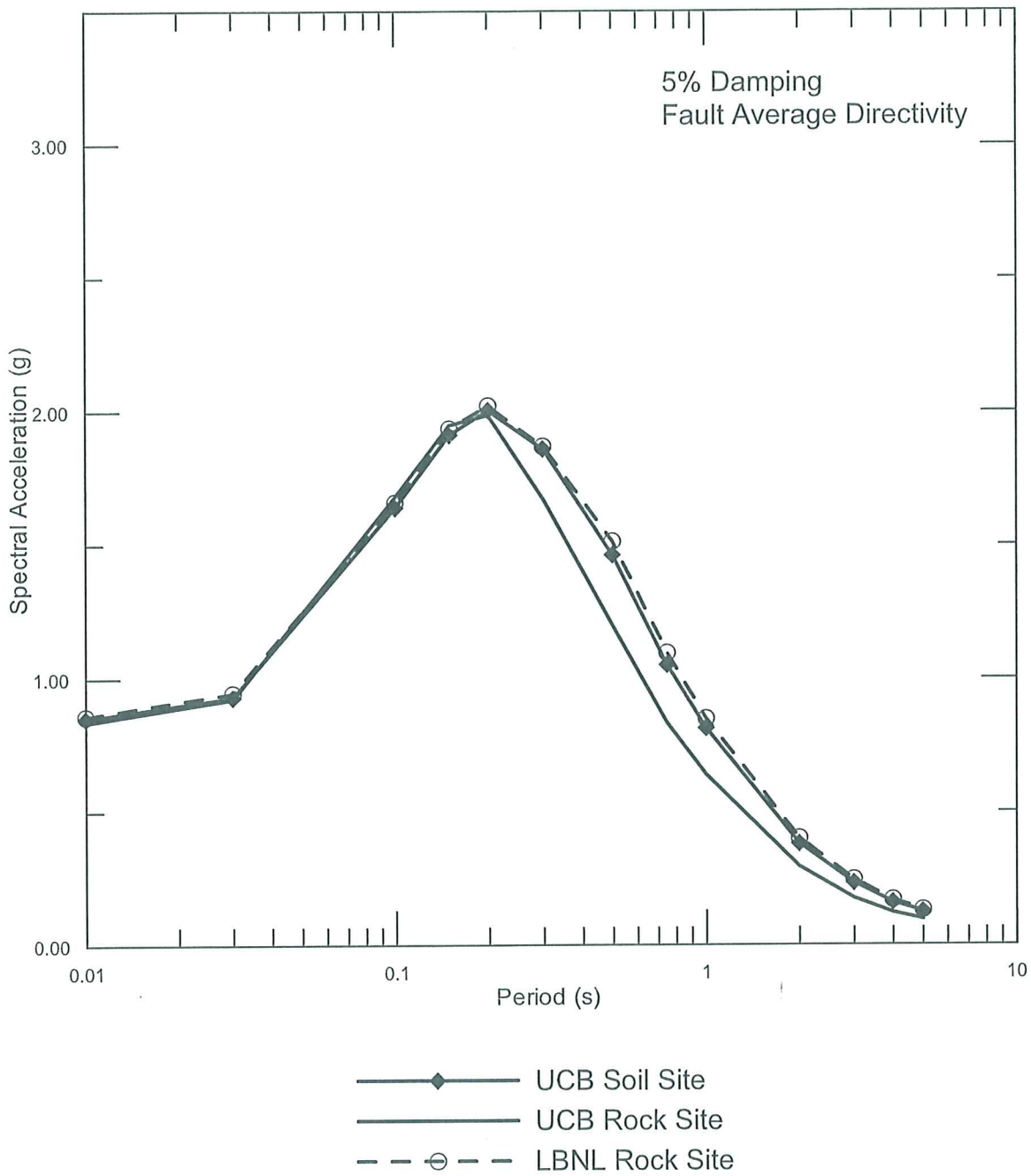
Sample Location or ID			Resistivity @ 15.5 °C (Ohm-cm)			Chloride	Sulfate		pH	ORP	Moisture	Soil Visual Description
Boring	Sample, No.	Depth, ft.	As Rec.	Minimum	Saturated	mg/kg	mg/kg	%		(Redox)	As Received	
						Dry Wt.	Dry Wt.	Dry Wt.		mv	%	
			ASTM G57	Cal 643	ASTM G57	Cal 422-mod.	Cal 417-mod.	Cal 417-mod.	Cal 643	SM 2580B	ASTM D2216	
AKA-35	-	25.5 - 26	-	2977	-	2	<5	<0.0005	6.8	-	14.5	Brown CLAY w/ Gravel
AKA-36	-	6 - 6.5	-	1238	-	8	65	0.0065	8.3	-	15.2	Brown Sandy CLAY
AKA-37	-	3 - 4	-	1856	-	<2	9	0.0009	6.0	-	13.8	Brown Sandy CLAY

APPENDIX F

SLOPE STABILITY ANALYSES


1.189
HELIOS PROJECT
Section A-A'
STATIC
Material Properties:
Cohesion = 0 psf
Friction Angle = 20 degrees
Unit Weight = 120 pcf
W
W
-400
-200
0
200
400
600
800
1000
1200
1400
1600
200
400
600
800
1000
1200
1400
160


1.008
HELIOS PROJECT
Section A-A'
YIELD COEFFICIENT
Material Properties:
Cohesion = 0 psf
Friction Angle = 20 degrees
Unit Weight = 120 pcf
0.035
W
W
1600
1400
1200
1000
800
600
400
200
-400
-200
0
200
400
600
800
1000
1200
1400
1600



URS	Project No.18940836 UCB Berkeley, CA	HORIZONTAL UHS AT 475-YEAR RETURN PERIOD FOR UCB, UCB ROCK SITE AND LBNL	Figure 24

Simplified Procedure for Estimating Earthquake Induced Deviatoric Slope Displacements
by Jonathan D. Bray and Thaleia Travasarou
Journal of Geotechnical and Geonvironmental Engineering, ASCE, V. 133(4), pp. 381-392, April 2007

SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET

Input Parameters			
Yield Coefficient (ky)	0.035		Based on pseudostatic analysis
Initial Fundamental Period (Ts)	0.25	seconds	1D: Ts=4H/Vs 2D: Ts=2.6H/Vs
Degraded Period (1.5Ts)	0.37	seconds	
Moment Magnitude (Mw)	7.1		
Spectral Acceleration (Sa(1.5Ts))	1.74	g	

Additional Input Parameters		
Probability of Exceedance #1 (P1)	84	%
Probability of Exceedance #2 (P2)	50	%
Probability of Exceedance #3 (P3)	16	%
Displacement Threshold (d_threshold)	15	cm

Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	270.73	cm	eq. (5) or (6)
Standard Deviation of Non-Zero Seismic D	0.66		

Results			
Probability of Negligible Displ. (P(D=0))	0.000		eq. (3)
D1	140.44	cm	calc. using eq. (7)
D2	270.73	cm	calc. using eq. (7)
D3	521.90	cm	calc. using eq. (7)
P(D>d_threshold)	1.000		eq. (7)

Notes

1. Values highlighted in blue are input parameters
2. Probability of Exceedance is the desired probability of exceeding a particular displacement value.
3. Displacements D1, D2, and D3 correspond to P1, P2, and P3, respectively.
   (e.g., the probability of exceeding displacement D1 is P1)
4. Calculated seismic displacements are due to deviatoric deformation only (add in volumetrically induced movement).
5. ky may range between 0.01 and 0.5, Ts between 0 and 2 s, Sa between 0.002 and 2.7 g, M between 4.5 and 9
6. Rigid slope is assumed for Ts < 0.05 s
7. When a value for D is not calculated, D is < 1cm
8. ky may be estimated using the simplified equations shown below.
9. Examples of how Ts is estimated are shown below.
10. Vs = weighted avg. shear wave velocity for the sliding mass, e.g., for 2 layers, Vs = [(h1)(Vs1) + (h2)(Vs2)]/(h1 + h2)

HELIOS
AKA Project # 2400-4

Simplified Procedure for Estimating Earthquake Induced Deviatoric Slope Displacements
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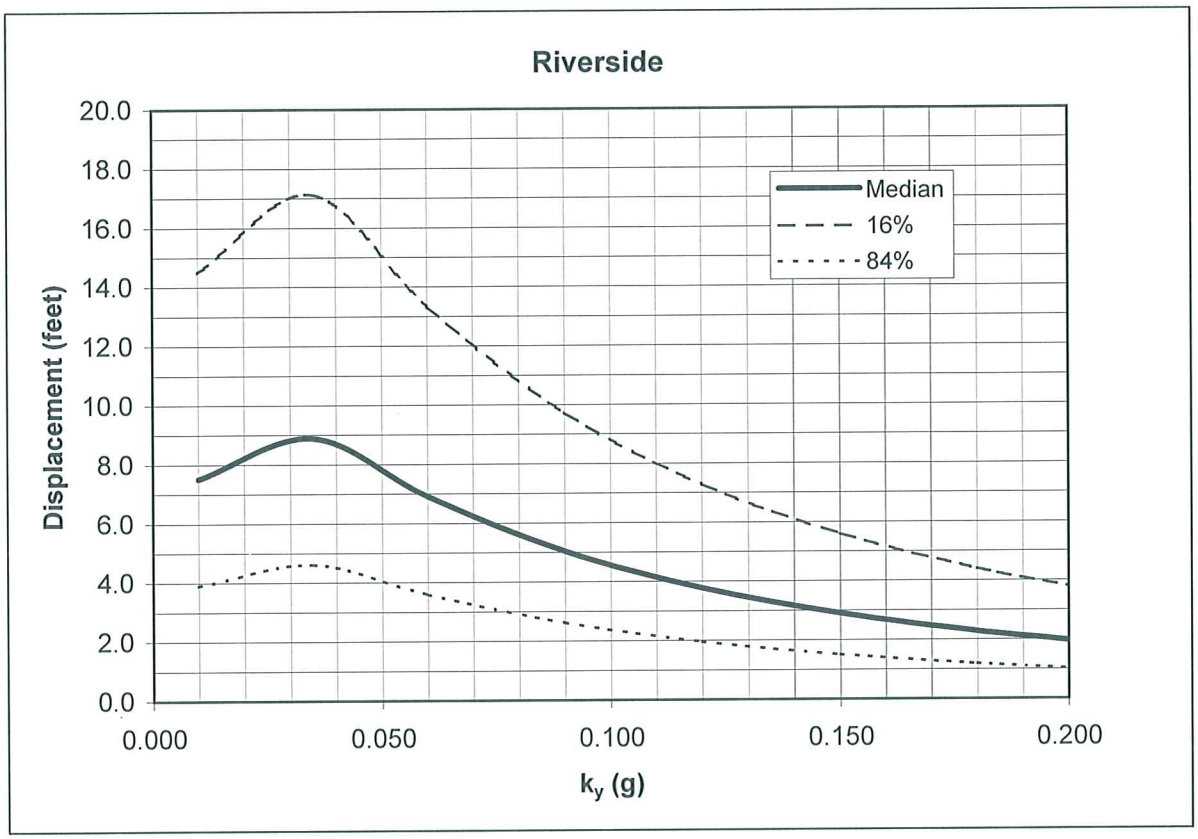
ky	Dmedian (cm)	D3 (cm)	D1 (cm)	Dmedian (ft)	D3 (ft)	D1 (ft)
0.010	229.1	441.6	118.8	7.52	14.49	3.90
0.035	270.7	521.9	140.4	8.88	17.12	4.61
0.060	210.9	406.6	109.4	6.92	13.34	3.59
0.090	153.9	296.6	79.8	5.05	9.73	2.62
0.120	115.1	221.9	59.7	3.78	7.28	1.96
0.150	88.5	170.6	45.9	2.90	5.60	1.51
0.180	69.6	134.2	36.1	2.28	4.40	1.19
0.200	60.0	115.7	31.1	1.97	3.80	1.02