APPENDIX G

Geologic Resources Studies

G.1 – Preliminary Engineering Geology Investigation

G.2 – Subsurface Fault Investigation and Development Setback Map

G.3 – Preliminary Soils Engineering Report

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APPENDIX G.1

Preliminary Engineering Geology Investigation

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PRELIMINARY ENGINEERING GEOLOGY INVESTIGATION
FROOM/EL VILLAGGIO SPECIFIC PLAN
APNs: 067-241-030 and -031
SAN LUIS OBISPO AREA
SAN LUIS OBISPO COUNTY, CALIFORNIA

PROJECT SL09734-1

Prepared for

Madonna Froom Ranch
C/o Madonna Construction Company
Post Office Box 3910
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Prepared by

GEOSOLUTIONS, INC.
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April 14, 2017

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San Luis Obispo, California 93401

Subject: **Preliminary Engineering Geology Investigation**
Froom/ El Villaggio Specific Plan, APNs: 067-241-030 and -031
San Luis Obispo area, San Luis Obispo County, California

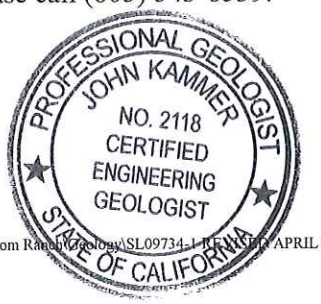
Dear Mr. Madonna:

This Preliminary Engineering Geology Investigation has been prepared for the proposed development to be located on the property referred to as Froom/ El Villaggio Specific Plan located on APN Parcels 067-241-030 and -031, in the San Luis Obispo area, San Luis Obispo County, California. Geologically, the site is generally suitable for the proposed development provided the recommendations in this report are incorporated into the design. As no final site development plans were available for review, only general statements regarding geologic site suitability are presented.

The site is primarily composed of Franciscan Complex units in the western upper topographic regions covered with a veneer of surface soils (colluvium and alluvium). Alluvial sediments are within the eastern lower topographic regions. The property is grossly stable. Ground water in the lower elevation areas is high (up to 1.5 feet from ground surface), the expansion of soils has been measured as up to very high, a small landslide is mapped at the site, and springs are observed at the site. One small area has a potential for rockfall during a seismic event. Based on the consistency and relative density of the in-situ soils, the potential for seismic liquefaction of soils at the Site is low. A subsurface fault study was completed at the site (under a separate report) and the Los Osos fault is mapped through the site with development setbacks applied according to activity. General conclusions and recommendations are included within the report.

GeoSolutions, Inc. appreciates the opportunity to provide technical services to you. Should you have any questions regarding this report, please call (805) 543-8539.

Sincerely,
GeoSolutions, Inc.



John Kammer, C.E.G. #2118
Principal

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APPENDIX A

Boring Logs
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North Wall of Trench T-2a – Lettis Consultants International, Inc.
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PRELIMINARY ENGINEERING GEOLOGY INVESTIGATION
PROPOSED FROOM/EL VILLAGGIO SPECIFIC PLAN
APNS: 067-241-030 AND -031
SAN LUIS OBISPO AREA, CALIFORNIA
PROJECT SL09734-1

1.0 INTRODUCTION

This report presents the results of the preliminary engineering geology investigation for the proposed Froom/El Villaggio Specific Plan to be located at the Madonna – Froom Ranch, located along Los Osos Valley Road, near the junction with Calle Joaquin adjacent to the City of San Luis Obispo, California. APNs are 067-241-030 and 031. See Figure 1: Area Location Map for the general location of the project area.

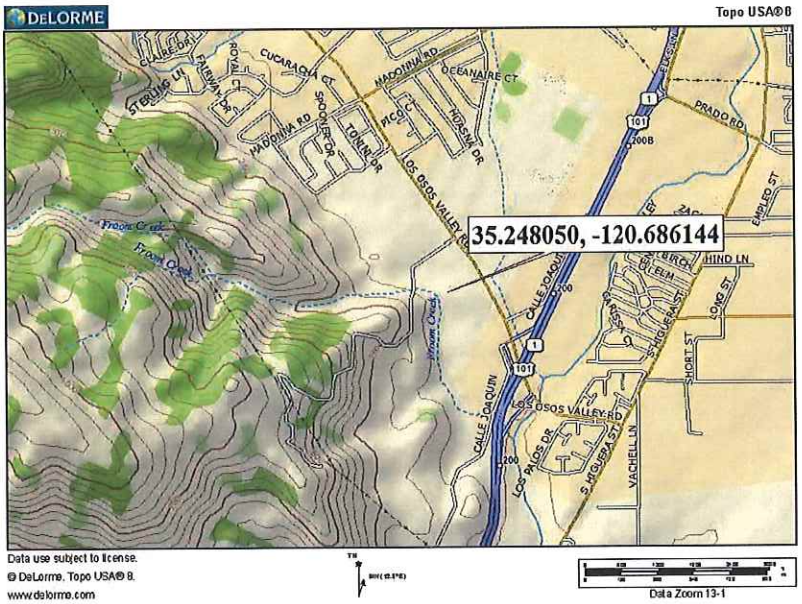

Figure 1: Area Location Map

The proposed development is located at approximately 35.248050 degrees north latitude and approximately -120.686144 degrees west longitude at an elevation of approximately 119 feet (varies) above mean sea level. The nearest intersection is where Los Osos Valley Road intersects Calle Joaquin at the southeast corner of the property. The project properties will hereafter be collectively referred to as the "Site."

The Site is characterized by flat to rolling grasslands with natural drainages which rise to steep, rocky hills at the southwestern portion of the property known as the Irish Hills. The property is approximately "U" shaped with the proposed development within the southern area of the property. The Site is developed with several older ranch buildings and currently utilized for cattle/horse grazing. Surface drainage follows topography to the middle-southern portion of the Site towards Froom Creek that traverses through the property from the northwest. Native grasses, brush, and scattered trees currently vegetate the Site.

The proposed development is to include the construction of residential structures, community buildings, restaurants, fitness centers, parks, roadways, and drainage facilities and associated improvements including but not limited to; sidewalks, site retaining walls, boundary walls, and retention basins. The proposed development is to include the construction of mixed residential and commercial development. The proposed structures are anticipated to be constructed using light wood framing and/or light gauge steel/structural steel.

Plates 1A, 1B, and 1C are a Site Engineering Geologic Maps (Plates 1B and 1C are enlargements of Plate 1A) that depicts local geologic conditions. Plates 1D, 1E, 1F are Fault Setback Maps (Plates 1E and 1F are enlargements of Plate 1D). Plate 2, Site Cross Sections, presents two interpretive sections through the property. Plates 3A, 4, 5A, 6A, and 7A are Regional Geologic Maps (Hall, 1973; PG&E, 2014; Dibblee, 2006; Wiegers, 2011; and Lettis and Hall, 1994), depict geologic conditions in the vicinity of the property. Plates 3B, 5B, 6B and 7B present Geologic Explanations. Plate 8 is a Google image of the project site with current USGS fault lines from KMZ files. Plate 9 is the State of California Special Studies Zone Map in the area. Plate 10 is a PG&E LiDAR image of the area of the subject property. Plate 11 is a Regional Fault Map (Jennings, 2010) that depicts

fault locations in the vicinity of the site. Plate 12 is a Superimposed Fault Map showing a compilation of faults mapped by others. Plate 13A, Historical Seismicity Map and Plate 13B, Historical Seismicity List depict significant historical earthquakes in the region. Plate 14, Landslide Hazards Map (San Luis Obispo County Department of Planning and Building, 1999) depicts the County of San Luis Obispo landslide hazard potential in the vicinity of the Site. Plate 15 is the Flood Insurance Rate Map and Explanations showing the location of the 100-year flood zone in relation to the Site. Plate 16, Geologic Study Area Map (San Luis Obispo County Department of Planning and Building, 1996) depicts the property in relation to the geologic study area. GeoSolutions, Inc. conducted geological reconnaissance mapping, trenching, and drilling from the dates of May 18 to June 7, 2016. This report discusses geologic conditions observed at the Site and provides general engineering geologic recommendations regarding proposed development. This report was prepared in partial accordance with San Luis Obispo County Department of Planning and Building Land Use Ordinance Section 23.07.084 and Guidelines for Engineering Geology Reports, December 2013. The report is in partial conformance of the guidelines as the project is in conceptual planning stages and no final plans have been prepared.

A Subsurface Fault Investigation and Development Setback Map report was prepared (detailed in a separate report) to assess the characteristics of the Los Osos fault through the subject site (GeoSolutions, Inc., April 14, 2017). For the fault investigation, a series of 10 sets of fault trenches (15 individual trenches total) were excavated. The fault at the site exhibited characteristics of active movement (movement within the last 11,000 years before present or Holocene in age, offset in colluvial sediments), Quaternary age (last 2 million years before present) movement, and pre-Quaternary movement (movement prior to 2 million years before present). Development setbacks from the Subsurface Fault Investigation and Development Setback Map report are provided within this Preliminary Engineering Geology Investigation report on Plates 1D, 1E, 1F (where Plates 1E and 1F are enlargements of Plate 1D). Specific recommendations for development setbacks are within the Subsurface Fault Investigation and Development Setback Map report.

2.0 CONCLUSIONS

As no final development plans are prepared, no final statement can be made regarding geologic suitability of the proposed specific development at the site. However, general geologic site characteristics are provided for planning purposes.

2.1 Geologic Conditions

Franciscan Complex formational units of metavolcanic rock, greywacke sandstone, serpentinite, claystone, and chert were encountered near the surface, within borings and trenches, and along slopes in the vicinity of the property. Formational material is limited to the western upper-elevation areas of the site. Surface material in the eastern lower-elevations generally consists of very dark grayish brown sandy clay and dark gray clay encountered approximately from ground surface to various depths depending upon location. Underlying these surface material are formational units assigned to the Franciscan Complex. A total of six exploratory trenches and four soil borings by GeoSolutions, Inc. were conducted at the property for this Preliminary Engineering Geology Investigation. In addition, a fault study was conducted at the site and 15 fault trenches were excavated at the property for the fault study. Based upon observations made during the field investigations, excavation may be by conventional grading equipment in the upper elevation areas although localized hard to very hard rock conditions (chert, serpentite) should be anticipated during grading and underground utility excavation. Soil expansion is very high (ei of 186 for one of the samples) via laboratory testing. Stability of cut and fill slopes in formational units and capability of geology to support structures is considered good if the recommendations within the Soils Engineering Report and this Engineering Geology Report are incorporated into design. Grading,

excavations, and site work (especially subsurface utilities) to be developed in the eastern lower-elevations at the Site should anticipate high-groundwater.

2.2 Landslides, Rockfall, and Liquefaction

Slopes are primarily composed of Franciscan Complex units covered with a veneer of colluvium or alluvium. The western upper-elevation portion of the property is grossly stable. One landslide is mapped by the undersigned at the property although no landslides are mapped at the site on published maps. Slopes at the site appear generally stable. The potential for a non-seismically induced slope instability to affect the proposed development is considered low. The potential for rockfall at the overall site is considered low although one area demarcated on Plate 1A shows a low to moderate potential for rockfall. The liquefaction hazard at the Site is considered low in the upper-elevations of the site. In the lower elevation areas, based on the consistency and relative density of the in-situ soils the potential for seismic liquefaction of soils at the Site is low.

2.3 Seismic

The potential for ground rupture at the Site during ground shaking is considered moderate due to the presence of the Los Osos fault through the site. A fault study (GeoSolutions, Inc., April 14, 2017) was conducted at the site and development setbacks from the trace of the Los Osos fault through the site have been established. Two Site Class's for the proposed structures have been provided; the deepened alluvial deposits in the eastern lower-elevations at the site are Site Class E and the near-surface bedrock in the western upper-elevations are Site Class C. The Seismic Design Category for the proposed structures is D. The subject site is not located within an Earthquake Fault Zone.

2.4 Seismically Induced Hazards

The potential for a tsunami to affect the Site is low due to elevation. Flooding associated with a seismic event is considered low due to the absence of a body of water upslope of the property. Assuming that the recommendations of the Soils Engineering Report are implemented, the potential for seismically induced settlement and differential settlement at the Site is considered to be low. Design a_{max} for the Site is equal to S_{D1}=0.425 g and S_{DS}=0.854 g, for the western upper-portion of the Site (Site Class C) and S_{D1}=0.774g and S_{DS}=0.769 g for the eastern lower-portion of the Site (Site Class E). The potential for ridgetop shattering is considered moderate if structures are located at the top of local ridges or peaks.

2.5 Groundwater and Drainage

Groundwater was encountered during the sub-surface investigation to a depth of 1.5 feet bgs in the eastern lower-elevations of the site. Ground water was not observed in the western upper-elevations of the site although springs were mapped in the upper elevations. Natural surface drainage is directed toward the established drainage at Froom Creek.

2.6 Asbestos

Serpentinite rock was encountered at the site during the surface and subsurface investigation. A composite sample of serpentinite rock was submitted for laboratory analysis for asbestos and chrysotile asbestos was detected. Site disturbance is anticipated to be greater than 1 acre and San Luis Obispo County Air Resource Board dust control measures are recommended to be incorporated into project plans. The California Air Resources Board Section 93105 (California Code of Regulations, Title 17), Asbestos Airborne Toxic Control Measures for Construction, Grading, Quarrying, and Surface Mining Operations (e)(2), Requirements for Construction and Grading Operations state that dust mitigation

measures be initiated at the start and maintained throughout the duration of the construction or grading activity.

3.0 GENERAL RECOMMENDATIONS

It is understood that specific plans are not available so only general recommendations are provided for planning purposes. Recommendations include:

1. It is recommended that the project utilize different seismic design criteria according to general location of proposed development. As there is deepened alluvium in the eastern lower-elevations and near-surface formational material in the western upper-elevations, seismic design criteria may be different according to general area of development.

2. It is recommended that the recommendations within the GeoSolutions, Inc. April 14, 2017 Fault Investigation and Development Setback report be incorporated into design.

3. It is recommended that loose surface rocks in the potential rockfall hazard area be removed or mitigation (small berm, ditch, fence, wall) be established upslope of proposed development to mitigate the potential for rocks to roll toward the development. As development plans become available, mitigation may be incorporated into the design of the development.

4. It is recommended that the soils engineer and engineering geologist review the project plans prior to construction.

5. Difficult digging/excavation conditions should be anticipated due to hard rock conditions in upper western topographic areas at the site within Franciscan Complex material.

6. It is recommended that the recommendations within the project Soils Engineering Report be incorporated into design.

7. It is recommended that the project engineering geologist and soils engineer observe foundation excavations, keyway, and benching excavations and conduct site visits during construction to verify recommendations within this report and the Soils Engineering report.

8. It is recommended that keyways and benches of fill slopes be founded into Franciscan Complex material where possible. It is recommended that keyways and benches follow current Building Code guidelines. Drainage of these keyways will be assessed at time of construction.

9. Foundations for structures are recommended to be in engineered fill, within Franciscan Complex material, or competent native material. There is a potential for differential settlement occurring between foundations supported on two soil materials having different settlement characteristics, such as native soil, formational material, and engineered fill. It is recommended that all of the foundations are founded in equally competent uniform material.

10. Surface drainage is recommended to be controlled to prevent concentrated water-flow on either natural or constructed slopes. Surface drainage gradients should be planned to prevent ponding and promote drainage of surface water away from building foundations, edges of pavements and sidewalks or natural or man-made slopes.

11. Seepage is anticipated along the interface of the surface alluvial/colluvial materials and the underlying formational units. Seepage within formational units should also be anticipated.

Surface drainage facilities (graded swales, gutters, positive grades, etc) are recommended at the base of cut slopes that allow surfacing water to be transferred away from the base of the slope. The project designer is recommended to offer specific design criteria for mitigation of water drainage behind walls and other areas of the site. This is especially imperative upslope of retaining walls for residences. Material such as Akwadrain or Ameridrain or equivalent should to be installed on the wall per manufacturer's specifications. A contractor experienced in this type of installation should be consulted for this work. Drainage from the subsurface should not be connected into conduit from surface drains and should not connect to downspout drainage pipes.

12. Drainage from surface and subsurface areas is recommended to be directed to established drainages.

13. Excavation, fill, and construction activities are recommended to be in accordance with appropriate codes and ordinances of the City of San Luis Obispo. In addition, unusual subsurface conditions encountered during grading such as springs or fill material are recommended to be brought to the attention of the Engineering Geologist and Soils Engineer.

14. It is recommended that numerical slope stability analyses be conducted on permanent soil or rock slopes cut steeper than 2-to-1 (horizontal to vertical). Due to the presence of competent units of the Franciscan Complex in the subsurface, un-retained cut slopes up to 1.5-to-1 (horizontal to vertical) may be considered under the supervision of the Engineering Geologist or Soil Engineer after determining rock quality and performing a stability analysis at that particular location. Locally steeper slopes may be allowed depending on further study and slope stability analysis.

15. The following dust mitigation measures are recommended to be initiated at the start and maintained throughout the duration of the construction or grading activity.

    i. Construction vehicle speed at the work site must be limited to fifteen (15) miles per hour or less;
    ii. Prior to any ground disturbance, sufficient water must be applied to the areas to be disturbed to prevent visible emissions from crossing the property line;
    iii. Areas to be graded or excavated must be kept adequately wetted to prevent visible emissions from crossing the property line;
    iv. Storage piles must be kept adequately wetted, treated with a chemical dust suppressant, or covered when material is not being added to or removed from the pile;
    v. Equipment must be washed down before moving from the property onto a paved public road; and
    vi. Visible track-out on the paved public road must be cleaned using wet sweeping or a HEPA filter equipped vacuum device within twenty-four (24) hours.
    vii. A dust mitigation plan is recommended for the site.

16. Fill slopes designed or constructed steeper than California Building Code requirements (2-to-1 horizontal to vertical) are recommended to be evaluated by a numerical slope stability analysis completed by the project soils engineer.

17. It is recommended that contractors be aware of potential high groundwater in the lower eastern topographic areas. Ground stabilization may be necessary and methods and requirements may be predicated on the depth to groundwater during construction.

4.0 SITE DESCRIPTION

The Froom/El Villaggio Specific Plan is located in the general vicinity of 35.248050 degrees north latitude and 120.686144 degrees west. The property is irregular in shape and 111.39 acres in size. The site is bounded by Los Osos Valley Road to the north-east, the Home Depot / T.J Maxx development to the north-west, a combination of development and open space to the south, and the Irish Hills Natural Reserve open space to the west. The nearest major intersection is where Los Osos Valley Road intersects Highway 101 approximately 500 feet south from the most easterly portion of the property.



Figure 2: View north of the lower elevations at the Site.

The Site is characterized by flat to rolling grassland with an existing irrigation basin which rises to a steep, rocky hill at the westerly edge of the property, known as the Irish Hills Natural Reserve. The Site is currently developed with few farm/ranch buildings and undeveloped amongst most of the southern portion of the site utilized for animal grazing. Annual grasses, shrubs and a few trees currently vegetate the Site. Surface drainage generally follows the topography toward the east primarily toward the Froom Creek drainage. Anticipated cut and fill is not known at this time. The property will hereafter be referred to as the "Site." Elevation varies but lower elevations are approximately 110 feet above sea level. The signing Certified Engineering Geologist conducted site investigation on May 19 and June 7, 2016. Figure 2 shows a general picture of the site from upper elevations of the property looking northeast.

5.0 PURPOSE AND SCOPE

The purpose of this study was to evaluate engineering geologic hazards at the Site and to develop conclusions and recommendations regarding general site development. The scope of this investigation consisted of:

1. Research and review of pertinent published geologic literature, regional faulting and seismicity maps, previous site investigations, aerial photographs, topographic maps, LiDAR imagery, consulting reports, and web-based information as listed in the reference section of this report;

2. A review of regional faulting and seismicity hazards.

3. Meetings with project planners and developer regarding proposed development;

4. A review of landslide potential, surface water and groundwater conditions, and liquefaction hazards.

5. Subsurface investigation including trenching and drilling to determine subsurface conditions.

6. Development of general recommendations for site preparation.

7. Preparation of this report that summarizes our findings, conclusions, and recommendations regarding engineering geology aspects of the project.

6.0 ENGINEERING GEOLOGY INVESTIGATION

6.1 Regional Geology

The site is located in the vicinity of the San Luis Range of the Coast Range Geomorphic Province of California. The Coast Ranges lie between the Pacific Ocean and the Sacramento-San Joaquin Valley and trend northwesterly along the California Coast for approximately 600 miles between Santa Maria and the Oregon border.

6.2 Local Geology

Locally, the site is located along the southwestern flank of the local Santa Lucia Mountain Range and east of the adjacent Irish Hills. The site is generally within Franciscan Complex units and alluvial deposits. Plates 3A, 4, 5A, 6A, and 7A are Regional Geologic Maps of the general vicinity of the Site and Plates 3B, 5B, 6B, and 7B provide descriptions of these Regional Geologic Maps (Hall, 1973; PG&E, 2014; Dibblee, 2006; Wiegers, 2011; and Lettis and Hall, 1994). These authors have generally mapped the site as within Jurassic and Cretaceous age (205-63 mybp) Franciscan Complex units with alluvial material in the lower elevations. Our exploration of the area generally encountered units of the Franciscan Complex and alluvial deposits. Information derived from the subsurface exploration was used to classify subsurface soil and formational units and to supplement geologic mapping.

Subsurface investigation was performed by GeoSolutions, Inc. for this study and consisted of 4 borings and 7 trenches (labeled GST-# for the soil investigation trenches). A fault study was also conducted at the site and a series of 15-fault trenches were excavated to determine subsurface conditions (fault trenches are labeled T-#). Boring depth was to a maximum of 46 feet and trench depth was to a maximum of 25 feet below land surface (bls).

6.2.1 Surficial Units

Drilling was focused on the lower elevations at the property to ascertain the depth and consistency of the subsurface conditions. The surface materials at the Site generally consisted of very dark grayish brown sandy fat CLAY (CH) encountered in a dry and soft to firm condition and dark brown to black sandy CLAY (CH) encountered in a very moist and firm to stiff condition to approximately 45.5 feet bgs. The material in the lower elevations of the site is termed "colluvium" (Qc) and alluvium (Qal). Borings B-1, B-3, and B-4 encountered clay, sandy clay, and/or clayey sand to termination at 10 feet bls. Boring B-2 terminated at approximately 46 feet in hard material interpreted as Franciscan Complex, which is also referred to as competent formational material. Highest groundwater was encountered in boring B-3 at a depth of 1.5 feet. Soft, wet clay was observed in the lower topographic area borings. Generally, the upper topographic areas encountered dense material at depth within the formational unit. Units at the site consist of the following:

Fill - Fill was interpreted at the property in developed areas and is comprised of clay, silt, sand, and gravel.

Colluvium - Colluvial material encountered at the project is assumed Holocene in age. Colluvial material is olive black (5YR 2.5/1), dark gray (10YR4/1), very dark greyish brown (10YR 3/2), black (10YR 2/1) and is interpreted to be resultant from weathering of underlying soil and rock material. Variations in colluvial material occurred according to location. Caliche (calcium carbonate) is observed within this unit. Colluvial deposits within fault trenches T-2A and T-2B

were logged in detail by Lettis Consultants International, Inc. (LCI). Photo logs of the LCI trenches are contained within Appendix A. LCI states the colluvium is "silt with occasional pebble to medium cobbles, Brown (10YR 4/3); clasts are dominantly Franciscan, increasing in size to small boulders to west, angular, fractured, slightly weathered, matrix is eolian silt, with some clay and sparse fine sand; loose, moist, slightly to moderately cohesive; a surface soil sequence is developing in unit." Thickness of this unit varies depending upon location but, in general, is approximately 1 to 3 feet thick as observed within the fault trenches.

Landslide Deposits - Landslide deposits are mapped in a small section of the subject property just south of City of San Luis Obispo property. This material is composed of clay, silt, sand, gravel, and cobbles. Color varies depending upon location but is generally olive brown 2.5Y 4/4. Thickness is unknown but is estimated to be approximately 1 foot to several feet depending upon location. No trenches or borings encountered this material which is interpreted from surface expression.

Stream Deposits – Stream deposits are assumed Holocene in age. Stream deposits were observed in fault trench T-5. This unit is composed of gravel and cobbles in a matrix of sand and silt. This material appears to be derived from Froom Creek drainage. Color was light yellowish brown, 10YR 6/4. Thickness of this unit within the trench is approximately less than one foot but could be thicker depending upon area especially within stream areas. This material is mapped along the Froom Creek drainage that flows through the property

Alluvial Deposits - Alluvial material was encountered within most fault trenches (T-#) during the fault investigation. Generally, alluvium within the fault trenches encompasses that material that underlies colluvium and overlies Franciscan Complex bedrock. Generally, alluvial deposits are comprised of clay, sand; silt, pebbles, cobbles, and boulders (up to 2-feet diameter). Clasts were composed primarily of Franciscan Complex rock and Monterey Formation material that is rounded to subrounded. Caliche was observed within this unit. Most Alluvium is matrix (sand, clay) supported. Color of the unit varied depending upon location. Colors ranged from moderate yellowish brown (10Y 5/4), pale yellow (5Y 7/3), brownish yellow (10YR 6/6), brown (7.5 YR 4/4), pale brown (10 YR 6/3), dark greyish brown (10YR 4/2), dark brown (10YR 3/3), to dark yellowish brown (10YR 4/4).

Trenching to obtain soil samples for soils engineering purposes (trenches labeled GST-#) occurred at the property. Trenches GST-1 and GST-2 encountered reddish brown silty and sandy clay termed colluvium from ground surface to 2 feet bls. Franciscan complex material was below colluvium to total depth of approximately 4.5 feet bls. Trench GST-3 encountered dark brown silty clay with rounded cobbles (to 1-foot diameter) from ground surface to 1.5 bls. This material is interpreted as alluvium. Franciscan complex material was below this alluvium to total depth of 2.5 feet bls. Trench GST-4 encountered a pebbly silty clay interpreted as alluvial deposits from ground surface to total depth of 8 feet bls. Trench GST-5 encountered dark brown silty clay (interpreted as colluvium) from ground surface to 2 feet bls with Franciscan Complex material below. Trench GST-5 encountered dark brown silty clay (interpreted as colluvium) from ground surface to 2 feet bls with Franciscan Complex material below. Trench GST-6 encountered dark brown clay (interpreted as colluvium) from ground surface to 3.5 feet bgs. Trench GST-7 encountered silty sandy clay with cobbles, pebbles, and boulders to a depth of 25 feet bls. This material is interpreted as alluvium.

6.2.2 Formational Units

Hall (1975) describes the Franciscan Complex (KJfmv) as metavolcanic rocks, primarily greenstone (metamorphosed from basalt), and diabase commonly associated with red chert. Hall et al. (1979) describes the Franciscan Complex (KJfmv) as metavolcanic rocks (greenstone), primarily metamorphosed basalt and diabase. Commonly associated with red chert. Locally dark red and extensively sheared. Considered to be tectonic blocks on or within or below Franciscan mélange and probably equivalent to upper part of Jurassic ophiolite. The thickness is unknown but is likely several thousand feet. The Franciscan Complex encountered during the geologic mapping and subsurface investigation included metavolcanic rock, greywacke sandstone, serpentinite, claystone, and chert. The thickness of Franciscan Complex at the Site is unknown. Outcrop of chert, serpentinite, and greywacke sandstone of the Franciscan Complex was observed at the site.

PG&E (6/2014) describes the Franciscan Complex in the following manner:

> *The Cretaceous to Jurassic Franciscan Complex (unit symbol KJf where undifferentiated) in the project area consists of multiple lithologies. The most widespread Franciscan Complex unit is mélange (unit symbol KJfm) with knockers of graywacke (gw); shale (sh); schist (sch); blueschist (bs); conglomerate (cg); metavolcanic rocks (mv); silica carbonate (sc); and green, white, or red chert (ch). Also widespread are mapped bodies of metavolcanic rocks (KJfmv); serpentinite (s); and graywacke (KJfg). In one area—Port San Luis—a mappable body of ophiolite is categorized as part of the Franciscan Complex (KJfo), reflecting its emplacement history and honoring the original age designation of these rocks by Hall (1973a). Lithologic contacts within the Franciscan Complex are almost exclusively faulted. In contrast, unit boundaries between the Franciscan Complex and younger units are a mixture of unconformable contacts and fault contacts. At the surface, the size distribution of sub-units within the Franciscan Complex is considerable, ranging in scale from several meters to several kilometers; it is likely that such a size distribution is present at depth. Within any given sub-unit, the size and density distribution of fracturing and other rock discontinuities is also variable between scales of tens to hundreds of meters. This results in frequent juxtaposition of highly fractured and competent bedrock.*

Structural attitudes were difficult to observe at the Site due to the massive, highly fractured, and weathered composition of the formational unit. No attitudes were obtained at the site. Cross sections A-A' and B-B' presents a subsurface interpretation of the property. Section A-A' is from the upper elevations to the lower elevations. Section B-B' is along the lower elevation portion of the property; Section B-B' is almost exclusively within alluvial deposits with underlying Franciscan Complex bedrock.

As the property is large, variation in rock type should be expected. Franciscan Complex rock at the site varies from fresh to very intensely weathered, very hard to very soft, and massive to slightly bedded (in chert). Fractures within the rock varied depending upon the rock type and location, and varied from moderately to very closely spaced, discontinuous to slightly continuous, fracture ends could be seen in the exposure, openness was tight to moderately wide, filling thickness was no film coating to moderately thin, moderately healed, stepped to smooth roughness, and dry fractures with water flow possible. Hardness of the rock varies; chert and some types of

serpentinite are very hard and may require special excavation techniques. It should be anticipated that utility trenches and cuts may encounter difficult excavation due to rock hardness.

6.3 Surface and Groundwater Conditions

Surface drainage flows approximately east in the upper elevations toward Froom drainage. Froom drainage was dry during our site visits. During the surface and subsurface investigation, the highest groundwater was encountered at 1.5 feet bgs and varies with location. Springs were observed at the property and are noted on the Site Engineering Geology Maps. At least two water wells are known on the property.

7.0 LANDSLIDES

A landslide was mapped at the site but no landslide is represented on published geologic maps. Small surface slumps were also observed on the property. Airphoto analysis does not show indication of large-scale landslide material at the property. Due to the presence of near surface Franciscan Complex units, the non-seismic landslide potential at the Site is considered low.

8.0 FLOODING AND SEVERE EROSION

The site has locations that are within or near the 100-year flood zone based on Federal Emergency Management Agency flood zone maps (Plate 15A).

9.0 ON-SITE SEPTIC SYSTEMS

No septic system is proposed. The project will utilize a community sewer and water system.

10.0 HYDROCOLLAPSE OF ALLUVIAL FAN SOILS

The potential of hydrocollapse of soils is assumed to be moderate if cyclical watering/dewatering of sediments in the lower elevation areas is conducted.

11.0 REGIONAL FAULTING AND SEISMICITY

Similar to the surrounding areas, the Site may be affected by moderate to major earthquakes centered on one of the known large, active faults listed in Table 1 below. Moment magnitudes are expressed, although any significant event on these faults could result in moderate to severe ground shaking at the subject site. The potential for ground failure at the Site during ground shaking is considered moderate due to the likely presence of the Los Osos fault traversing through the site.

TABLE NO. 1 – Holocene Active Faults

Closest Active Faults to Site	Approximate Distance (miles)	Moment Magnitude
Los Osos	1.5	7.0
Hosgri	8	7.5
San Andreas	38	8.0

The closest known active Quaternary age fault is the Los Osos fault approximately located at the property. The closest known active portion of a Holocene age fault is the active Los Osos fault that is located approximately 8,000 feet north-northwest of the Site (Jennings, 2010). Plate 11 is a Regional Fault Map for the area. Plate 7A

depicts the location of the Earthquake Fault Zone in relation to the Madonna Froom site. The San Andreas fault is the most likely active fault to produce ground shaking at the Site although it is not expected to generate the highest ground accelerations because of its distance from the Site.

The potential for ridge-top shattering or ridge-top spreading is considered moderate if structures are located on local ridgelines or peaks. However, obvious evidence of ridge-top spreading, shattered ground, sharply defined scarps, side hill benches, shallow depressions, fissures, sackung, or linear troughs were not observed during the site investigation.

11.1 Los Osos Fault

The Los Osos fault is mapped through the subject property as depicted on Plates 1A – 1F. Lettis and Hall (1994) subdivided the Los Osos fault into four segments, from the northwest to the southwest they are the Estero Bay, Irish Hills, Lopez Reservoir, and Newsom Ridge segments. The Irish Hills segment is about 10 to 12 miles long and extends from the Pacific Ocean near Los Osos eastward to San Luis Creek and includes the study area. This segment of the fault forms the boundary between the Los Osos Valley and the Irish Hills and has documented Holocene offset (PG&E, 1988). P.G. & E. suggests that the Irish Hills segment displays the most well-expressed geomorphic features displacing late Pleistocene and Holocene deposits. A portion of the Irish Hills segment is considered active and has been included within Alquist-Priolo zoning by the State of California (1990). Plate 9 depicts the Earthquake Fault Zone Map (State of California, 1990). Plate 7A depicts the approximate location of the Earthquake Fault Zone in relation to the Madonna Froom site.

The Los Osos fault zone has had a complex history of both strike-slip and dip-slip displacement (Lettis and Hall, 1990). The fault zone is a 50 km long, 2 km wide system of discontinuous, subparallel, and en echelon fault traces extending from Estero Bay on the north to an intersection with the West Huasna fault southeast of San Luis Obispo. Along the coast, the fault zone truncates a flight of marine terraces, indicating a vertical rate of separation across the fault zone of about 0.2 mm/yr. Preliminary results from new geomorphic mapping, interpretation of reprocessed seismic-reflection data, analysis of seismicity data, and structural analysis suggest that the fault zone dips steeply to the southeast (45 to 70 degrees or possibly steeper), and may be primarily an oblique-slip fault, with a significant component of dip slip to accommodate uplift of the range. (PG&E, January, 2011, Shoreline fault study)

A fault study was conducted at the site and referenced herein. The Los Osos fault at the site exhibited characteristics of active movement (movement within the last 11,000 years before present or Holocene in age, offset in colluvial sediments), Quaternary age (last 2 million years before present) movement, and pre-Quaternary movement (movement prior to 2 million years before present). Strike of the fault in several of the trenches is approximately similar. Fault strike in Trench 3A is N50W, in Trench 3B is N60W, in Trench 2B is N42W (to approximately N24W), Trench T-7 is N27W. The fault study recommended development setbacks according to activity of the fault. Fault trench logs are contained in Appendix A.

Jennings 2010, maps the Los Osos fault through the site as "Late Quaternary fault displacement (during past 700,000 years). Geomorphic evidence similar to that described for Holocene faults except features are less distinct. Faulting may be younger, but lack of younger overlying deposits precludes more accurate age classification." An active fault section of the Los Osos fault located approximately 8,000 feet northwest of the subject property is labeled on the Jennings, 2010 map (Plate 11) as "Holocene fault displacement (during past 11,700 years) without historic record. Geomorphic evidence for Holocene faulting includes sag ponds, scarps showing little erosion, or the following features in Holocene age deposits: offset stream courses, linear scarps, shutter ridges, and triangular faceted spurs. Recency of faulting offshore is based on the interpreted age of the youngest strata displaced by faulting". Studies performed by P.G. & E. (1988) indicate that the fault is a zone of

northwest trending high and low angle faults that exhibits a complex history of both strike slip and reverse displacement.

The Los Osos fault is described by PG&E (6-2014) in the following manner:

> *The Los Osos fault zone was characterized by the LTSP (PG&E, 1988) and Lettis and Hall (1994) as a late Quaternary reverse fault that defines the northern and northeastern margin of the San Luis Range.*

The Los Osos fault is characterized in the vicinity of the Madonna Froom areas as:

> *The southeastern most reach of the Los Osos fault zone within the Irish Hills study area—informally named the east reach—is approximately 6 to 7 km long and is located between San Luis Obispo Creek and a point approximately 2 km west-northwest of the intersection of West Foothill Boulevard and Los Osos Valley Road* (A portion of this reach is depicted on Plate 7A of this Madonna Froom report). *This reach includes abrupt scarps and tonal and vegetative lineaments at and near the range front and a linear fault zone within Franciscan Complex serpentinite along the foothills south of the range front (Lettis and Hall, 1994). No systematic lateral deflection of streams crossing the lineaments or bedrock fault traces was noted from LiDAR or field evaluation. Paleoseismic trenches across several lineaments and the bedrock fault zone revealed evidence for late Quaternary faulting along the east reach, although the relationships between faulting, scarp formation, and differential uplift of the Irish Hills relative to the Los Osos Valley were locally unclear and conflicting (Lettis and Hall, 1994). The northeastern-most trench—Ingley trench T-2— crossed a northeast-facing, 6-m-high topographic scarp near Los Osos Valley Road and contained evidence for a gently (22 to 29°) southwest dipping zone of thrust faults within alluvium that shortened and repeated a prominent soil horizon. Slickensides were consistent with dip-slip faulting and a left-lateral component. The faulting exposed here was interpreted to be the range front Los Osos fault. Other trenches upslope of the Ingley trench T-2 were less straightforward. For example, a trench across the bedrock fault zone (Ellsworth trench T-1) exposed evidence for faulted Quaternary gravels along a steeply northeast-dipping fault with southwestside-down vertical separation. Striations and folding of Quaternary strata were consistent with northeast- (valley-) side-up reverse faulting. Trenches across prominent scarps farther downslope (at the Cuesta and Ingley sites) exposed evidence that some scarps were not associated with faulting and thus were most likely erosional (Cuesta trench T-1), some faults offsetting Quaternary alluvium did not have recognizable geomorphic expression (Cuesta trench T-3), and a prominent northeast- (valley-) side-down scarp was underlain by a northeast-dipping fault placing Franciscan Complex mélange in the hanging wall against Quaternary alluvium in the footwall (indicating valley-side up faulting) with slickensides consistent with pure dip slip (Cuesta trenches T-2 and T-3). Other faults with geomorphic expression similarly showed evidence for northeast- (valley-) side-up reverse displacement with Franciscan Complex rocks faulted against late Quaternary deposits (Ingley trench T-1). Lettis and Hall (1994) proposed alternative explanations for the unexpected observations, including scarp formation by erosional (as opposed to tectonic) processes, and normal reactivation of earlier Quaternary reverse faults. The preferred interpretation in general was that deformation observed in trenches in the foothills and near the range front was secondary, hanging-wall deformation above an underlying, southwest-dipping thrust or reverse fault that projected up dip to the range front of the Irish Hills (e.g., such as at Ingley trench T-2). Alternative interpretations to explain the conflicting relationship between the geomorphic scarps and faulting observed in the trenches were proposed with implications for possible changes in dip with depth on an underlying range-front fault (Lettis and Hall, 1994).*
>
> *Although the east reach of the Los Osos fault zone within the Irish Hills segment includes the strongest evidence for a shallow or emergent, southwest-dipping Los Osos reverse fault, the*

absence of a footwall basin, and the lack of a compelling, laterally-continuous fault (or fault scarp) at the surface is also consistent with a mostly blind Los Osos reverse fault or a fold hinge at the range front that is locally broken by discontinuous faults. Interpretations of seismic-reflection data across the east and east-central reaches of the Irish Hills should consider the observations of steep faulting in Franciscan Complex rocks at the surface (particularly the serpentinite-defined fault zone along the foothills sub-parallel to the range front), a locally observed southwest-dipping thrust fault at the range front, possible changes in fault dip with depth beneath the foothills, and alternative hypotheses for active structures that can accommodate differential uplift of the Irish Hills relative to the Los Osos Valley.

Comparing the faulting characteristics from the above description with observed faulting characteristics within fault trenches excavated at the Madonna Froom site, the site generally shows a southwest-dipping fault that is broken by discontinuous faults. Although the Los Osos fault as mapped at the Madonna Froom site exhibited discontinuities (ie, Holocene-active faulted areas and Quaternary age {older} faulted areas (ie fault trenches T-4, T-10B), the study at the Madonna Froom site conservatively recommended a development setback region along the fault.

11.2 Ground Shaking

Estimating the design ground motions at the Site depends on many factors including the distance from the Site to known active faults; the expected magnitude and rate of recurrence of seismic events produced on such faults; the source-to-site ground motion attenuation characteristics; and the Site soil profile characteristics. According to section 1613 of the 2016 CBC (CBSC, 2016), all structures and portions of structures should be designed to resist the effects of seismic loadings caused by earthquake ground motions in accordance with the *ASCE 7 2010 Minimum Design Loads for Buildings and Other Structures*, hereafter referred to as ASCE7-10 (ASCE, 2013). The Site soil profile classification (Site Class) can be determined by the average soil properties in the upper 100 feet of the Site profile and the criteria provided in Table 20.3-1 of ASCE7-10.

Spectral response accelerations, peak ground accelerations, and site coefficients provided in this report were obtained using the computer-based U.S. Seismic Design Map tool available from the United States Geological Survey website (USGS, 2013). This program utilizes the methods developed in the 1997, 2000, 2003, 2008 and 2013 errata editions of the NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures in conjunction with user-inputted Site latitude and longitude coordinates to calculate seismic design parameters and response spectra (both for period and displacement) for soil profile Site Classes A through E.

Site coordinates of 35.24805 degrees north latitude and -120.686144 degrees west longitude were used in the web-based probabilistic seismic hazard analysis (USGS, 2013). Based on the results from the in-situ tests performed during the field investigation, the Site was defined as **Site Class E, Soft Soil** for the eastern lower-elevations of the Site and **Site Class C, Very Dense Soil and Soft Rock profile** for the western upper-elevations of the Site profile per ASCE7-10, Chapter 20. Relevant seismic design parameters obtained from the program area are summarized in Table 2: Seismic Design Parameters.

Table 2: Seismic Design Parameters

Site Class	**E – Soft Clay (lower elevations)** **C – Very dense soil/soft rock (upper elevations**
Seismic Design Category	**Varies**
1-Second Period Design Spectral Response Acceleration, S_{D1}	**0.425 g for western upper elevations** **0.774 g for eastern lower elevations**
Short-Period Design Spectral Response Acceleration, S_{DS}	**0.854 g for western upper elevations** **0.769 g for eastern lower elevations**
Site Specific MCE Peak Ground Acceleration, PGA_M	**0.541 g for western upper elevations** **0.487 g for eastern lower elevations**

11.3 Ground Surface Rupture Due to Faulting

The Alquist-Priolo Earthquake Fault Zoning Act of 1972 requires that the California State Geologist establish Earthquake Fault Zones around the surface traces of active faults and to issue appropriate maps. The subject site is not located within an Earthquake Fault Zone (Jennings, 2010) although an Earthquake Fault Zone is located approximately 8,000 feet north/northwest of the site (see Plate 7A for location of Earthquake Fault Zone in vicinity of subject site).

11.4 Seismically Induced Water Waves and Flooding

Tsunamis and seiches are two types of water waves that are generated by earthquake events. Tsunamis are broad-wavelength ocean waves and seiches are standing waves within confined bodies of water, typically reservoirs. The potential for a tsunami to affect the Site is low due to distance from the ocean. Flooding associated with a seismic event is considered low due to the absence of a body of water upslope of the property.

11.5 Seismically Induced Settlement and Slope Failure

There is a low potential for seismically induced settlement in the western upper topographic areas at the Site based upon the depth to Franciscan Complex units and densities within the subsurface. There is a potential for seismically induced settlement in the eastern lower topographic areas at the Site based upon the depth of the sediments and densities within the subsurface, however, assuming that the recommendations of the Preliminary Soils Engineering Report are implemented, the potential for seismically induced settlement and differential settlement at the Site improvements is considered to be low. The potential for seismically induced slope failure is considered low due to the presence of near-surface Franciscan Complex material within the subsurface on western upper elevations of the property.

12.0 LIQUEFACTION ANALYSIS

In the context of soil mechanics, liquefaction is the process that occurs when the dynamic loading of a soil mass causes the shear strength of the soil mass to rapidly decrease. Liquefaction can occur in saturated cohesionless soils.

The most typical liquefaction-induced failures include consolidation of liquefied soils, surface sand boils, lateral spreading of the ground surface, bearing capacity failures of structural foundations, flotation of buried structures, and differential settlement of above-ground structures.

Liquefiable soils must undergo dynamic loading before liquefaction occurs. Ground motion from an earthquake may induce large-amplitude cyclic reversals of shear stresses within a soil mass. Repetitive lateral and vertical loading and unloading usually results from this process. This process is considered to be dynamic loading. In a liquefiable soil mass, liquefaction may occur as a result of the dynamic loading caused by ground motion produced by an earthquake.

The presence of loose, poorly graded, fine sand material that is saturated by groundwater within an area that is known to be subjected to high intensity earthquakes and long-duration ground motion are the key factors that indicate potentially liquefiable areas and conditions that lead to liquefaction. Based on the consistency and relative density of the in-situ soils the potential for seismic liquefaction of soils at the Site is low.

13.0 GEOLOGIC HAZARDS

13.1 Expansive Soils

The expansion potential of soils vary from medium (ei = 79) to very high (ei = 186).

13.2 Naturally Occurring Asbestos

Serpentinite rock was encountered at the site during the surface and subsurface investigation. Site disturbance is anticipated to be greater than 1 acre and San Luis Obispo County Air Resource Board dust control measures are recommended to be incorporated into project plans. Rock samples were collected from four locations where serpentinite was in outcrop. Laboratory analysis (CARB 435) results show that asbestos containing rocks (chrysotile) are present at the site. Lab results are contained at the end of the report.

13.3 Radon and Other Hazardous Gases

The potential for radon or other hazardous gases is low due to the absence of Monterey formation bedrock and other gas producing formations.

14.0 SUBSIDENCE

Causes of significant land subsidence in California include compaction and decreased void space as a result of reduced pore pressure due to de-watering or withdrawal of oil and gas; hydro-compaction of dry, loose, clayey soils; and oxidation of organic material and subsequent compaction of remaining soil material. Assuming that the recommendations of the Soils Engineering Report are implemented, the potential for subsidence at the Site with respect to development is considered to be low.

15.0 ROCKFALL HAZARD

Plate 1A depicts a line demarcated as a general extent of observed potential for rockfall (rocks observed lying on the surface) as observed during the site reconnaissance by the undersigned. The main criteria for establishment of this line is presence of rocks that were generally 1-foot diameter and composition of generally serpentinite. Loose surface rocks in this area have a potential to roll during a seismic event. Mitigation is offered in the recommendations section of this report and is dependent upon type of development proposed in this area.

Development within or downslope of the potential rockfall hazard may be affected. Slope gradient, rock size, sphericity of rocks, slope roughness, rock exposure dictate propensity of potential for rocks to roll.

16.0 VOLCANIC ERUPTION

Volcanism in California is typically associated with the Cascade Ranges Geomorphic Province in northern California, and the Basin and Range Province on the eastern side of the Sierra Nevada Mountains. Prevailing westerly winds would most likely reduce the chance of ash fallout in the central California coastal area from volcanic activity on the eastern side of the Sierra Nevada. Other hazards generally related to volcanism are not pertinent to the subject site.

17.0 ADDITIONAL SERVICES

The recommendations contained in this report are based on excavated exploratory trenches and borings and on the continuity of the sub-surface conditions encountered. It is assumed that GeoSolutions, Inc. will be retained to perform the following services:

1. Consultation during plan development.

2. Plan review of final grading and drainage documents prior to construction.

3. Additionally, construction observation by the Project Engineering Geologist may be necessary to verify sub-surface conditions during excavation activities.

18.0 LIMITATIONS

1. The recommendations contained in this report are based on Site reconnaissance; review of sub-surface data, and partly on certain plans, information, and data provided to us. Any changes in those plans, information and data will render our recommendations invalid unless we are commissioned to review the changes and to make any necessary modifications and/or additions to recommendations.

2. This report is issued with the understanding that it is the responsibility of the owner or his/her representative to ensure that the information in this report be incorporated into the project plans and recommendations contained herein be brought to the attention of the architect. The owner or his/ her representative is responsible to ensure that the necessary steps are taken to verify that the contractor and subcontractors comply with recommendations in the field.

3. Our recommendations have been made in accordance with the principles and practices generally employed by the engineering professions. This is in lieu of all other warranties, expressed or implied. Reference is made to our Agreement for Professional Services, which contains additional limitations concerning this project.

4. Any person concerned with this project who observes conditions or features of the Site or surrounding area that are different from those described in this report should report them immediately to this office for evaluation as part of an additional scope of work. Should additional evidence become available in the future that would indicate the need for additional study, this firm should be contacted.

5. As of the present date, the findings of this report are valid for the property studied. With the passage of time, changes in the conditions of a property can occur whether they are due to natural

processes or to the works of man on this or adjacent properties. Therefore, this report should not be relied upon after a period of one (1) year without our review nor should it be used or is it applicable for any properties other than those studied. However many events such as floods, earthquakes, grading of the adjacent properties and building and municipal code changes could render sections of this report invalid in less than 1 year.

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PLATES

Plates 1A, 1B, 1C - Site Engineering Geologic Map

Plates 1D, 1E, 1F – Fault Setback Maps

Plate 2 – Site Cross Sections

Plate 3A, 3B - Regional Geologic Map, Hall, 1973 and Geologic Explanations

Plate 4 - Regional Geologic Map, PG&E, 2014 and Geologic Explanations

Plate 5A, 5B - Regional Geologic Map, Dibblee, 2006 and Geologic Explanations

Plate 6A, 6B – Regional Geologic Map, Weigers, 2011

Plate 7A, 7B – Lettis & Hall, 1994 and Geologic Explanations

Plate 8 – Google Image with USGS KMZ faulting – 2016

Plate 9 – Special Studies Zone – 1990

Plate 10 – LiDAR Image - 2011

Plate 11 – Regional Fault Map, Jennings, 2010 and Explanations

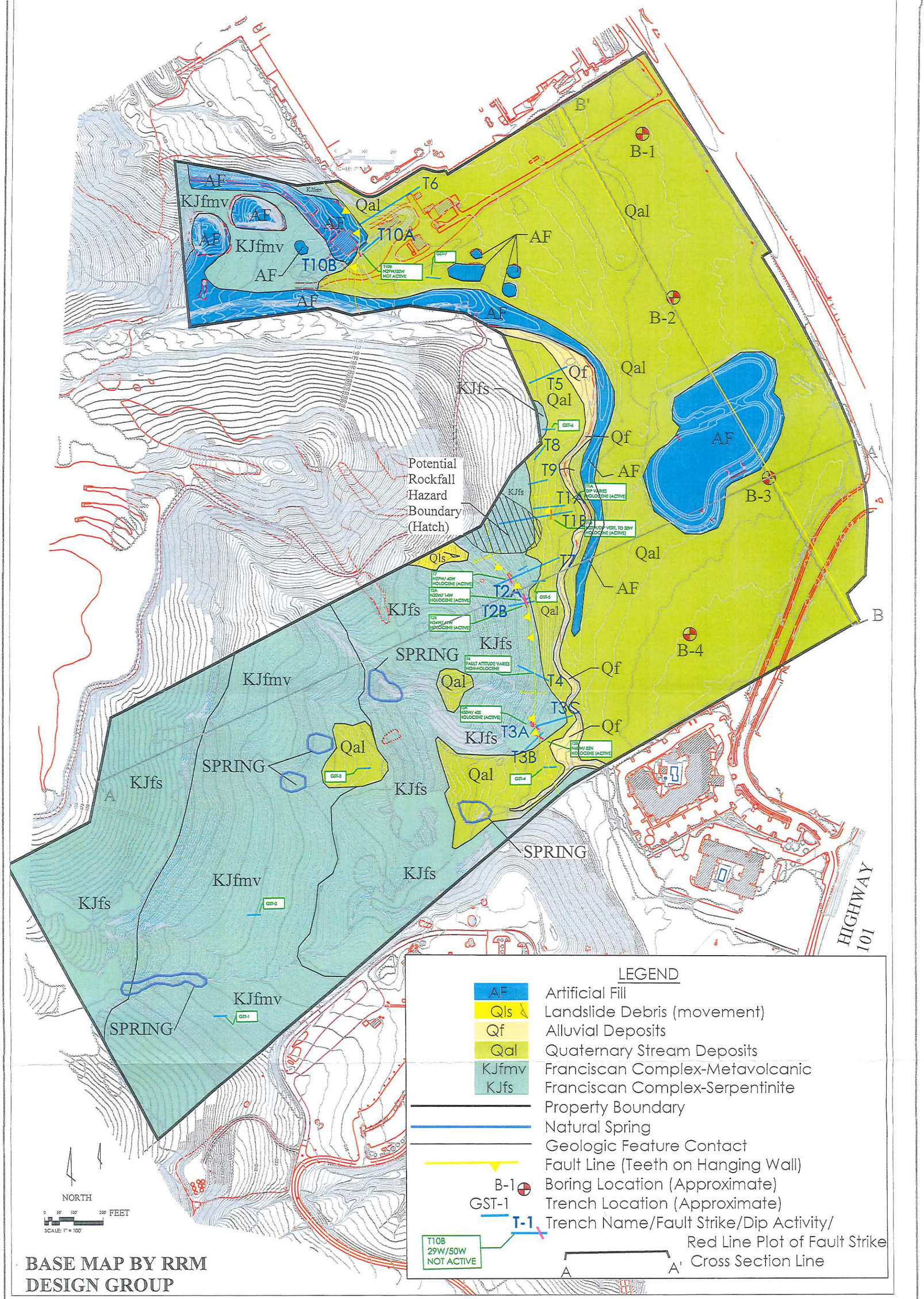
Plate 12 – Superimposed Fault Map

Plate 13A, 13B – Historical Seismicity Map and Historical Seismicity List

Plate 14 – Landslide Hazards Map, San Luis Obispo County Department of Building and Planning, 1999

Plate 15 – Flood Insurance Rate Map, FEMA, 1985 and Explanation

Plate 16 – Geologic Study Area Map and Explanations, San Luis Obispo County Department of Building and Planning, 1993



BASE MAP BY RRM DESIGN GROUP

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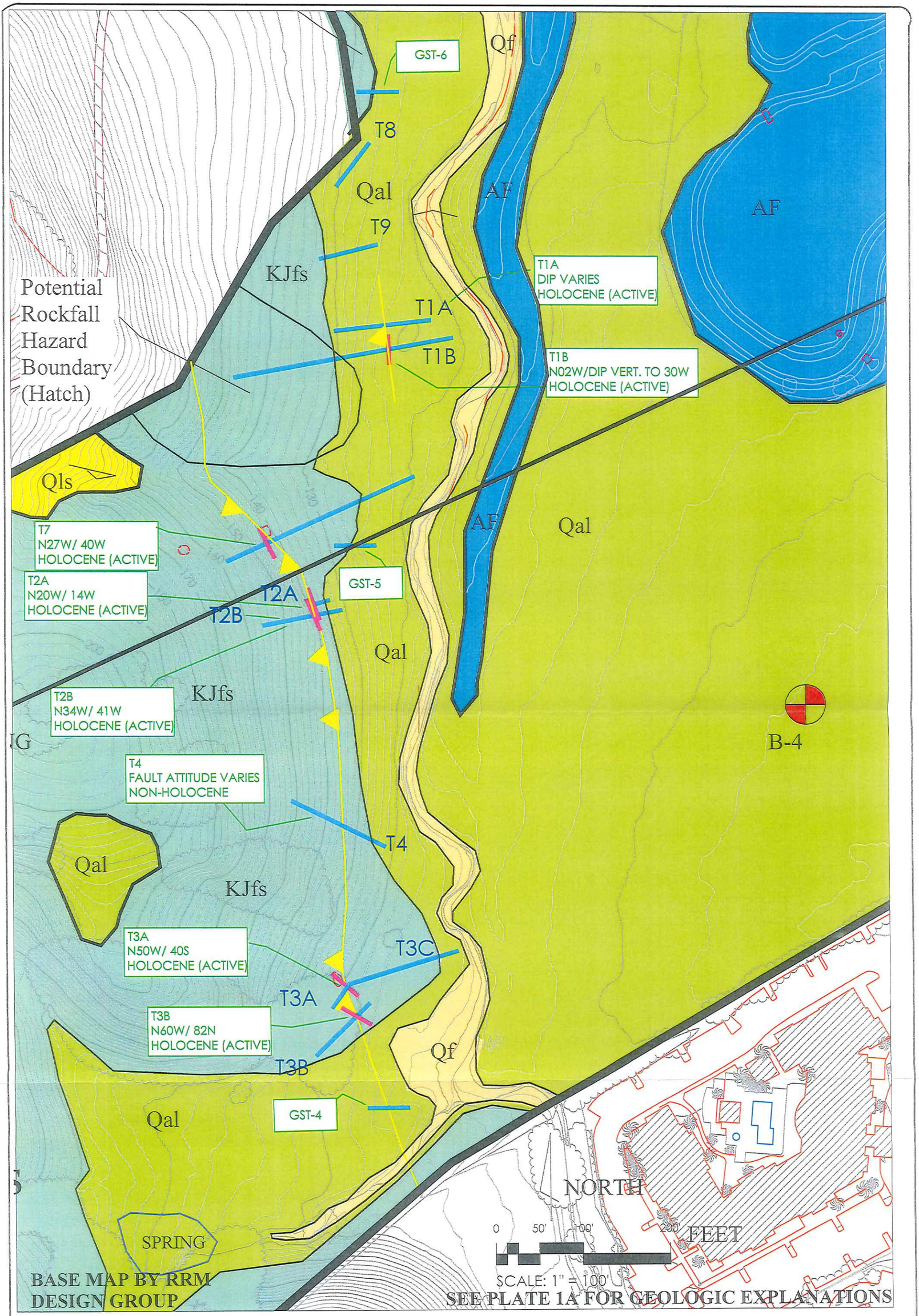
SITE ENGINEERING GEOLOGY MAP

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE 1A

PROJECT SL09734-1



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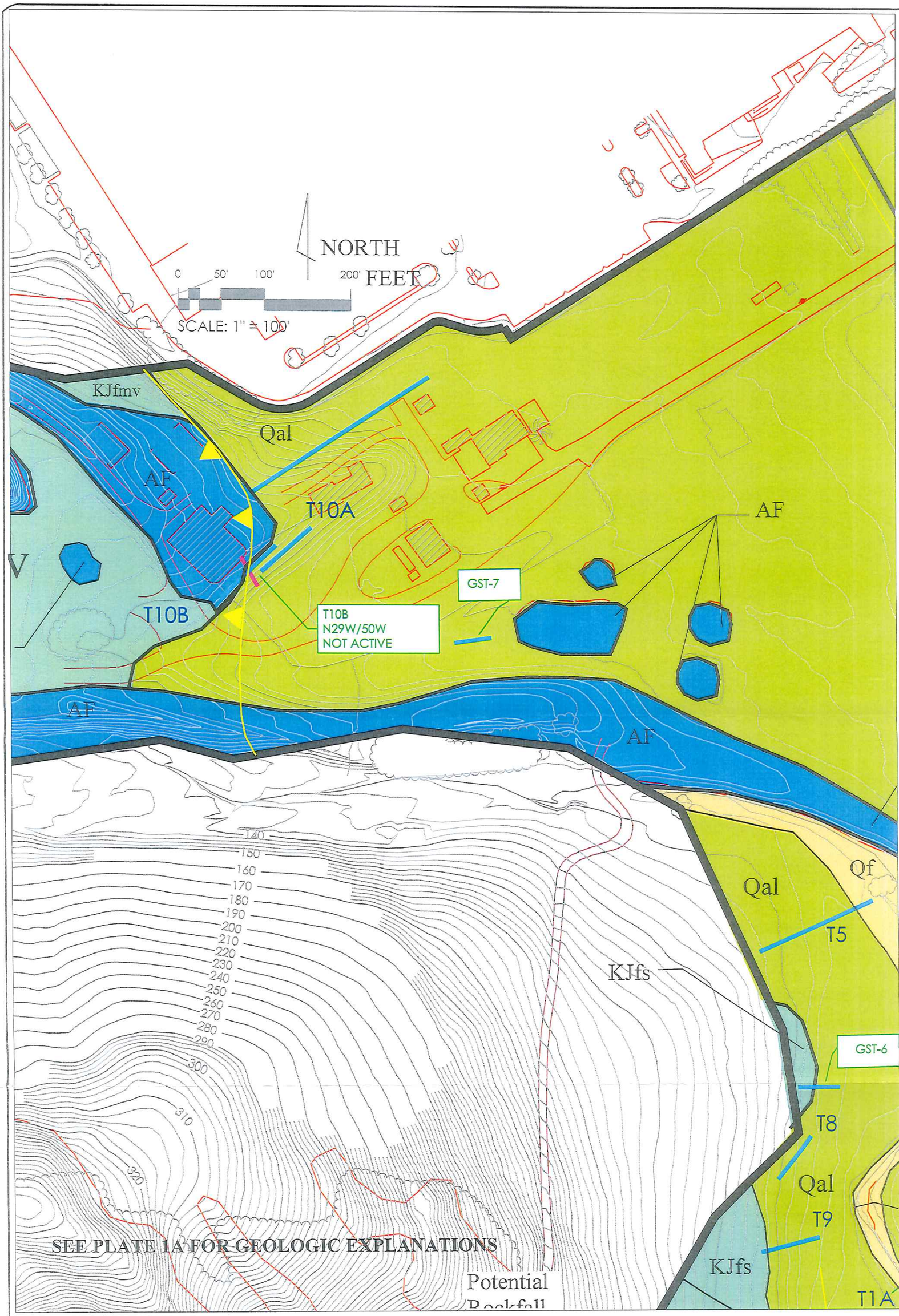
SITE ENGINEERING GEOLOGY MAP

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE
1B

PROJECT
SL09734-1



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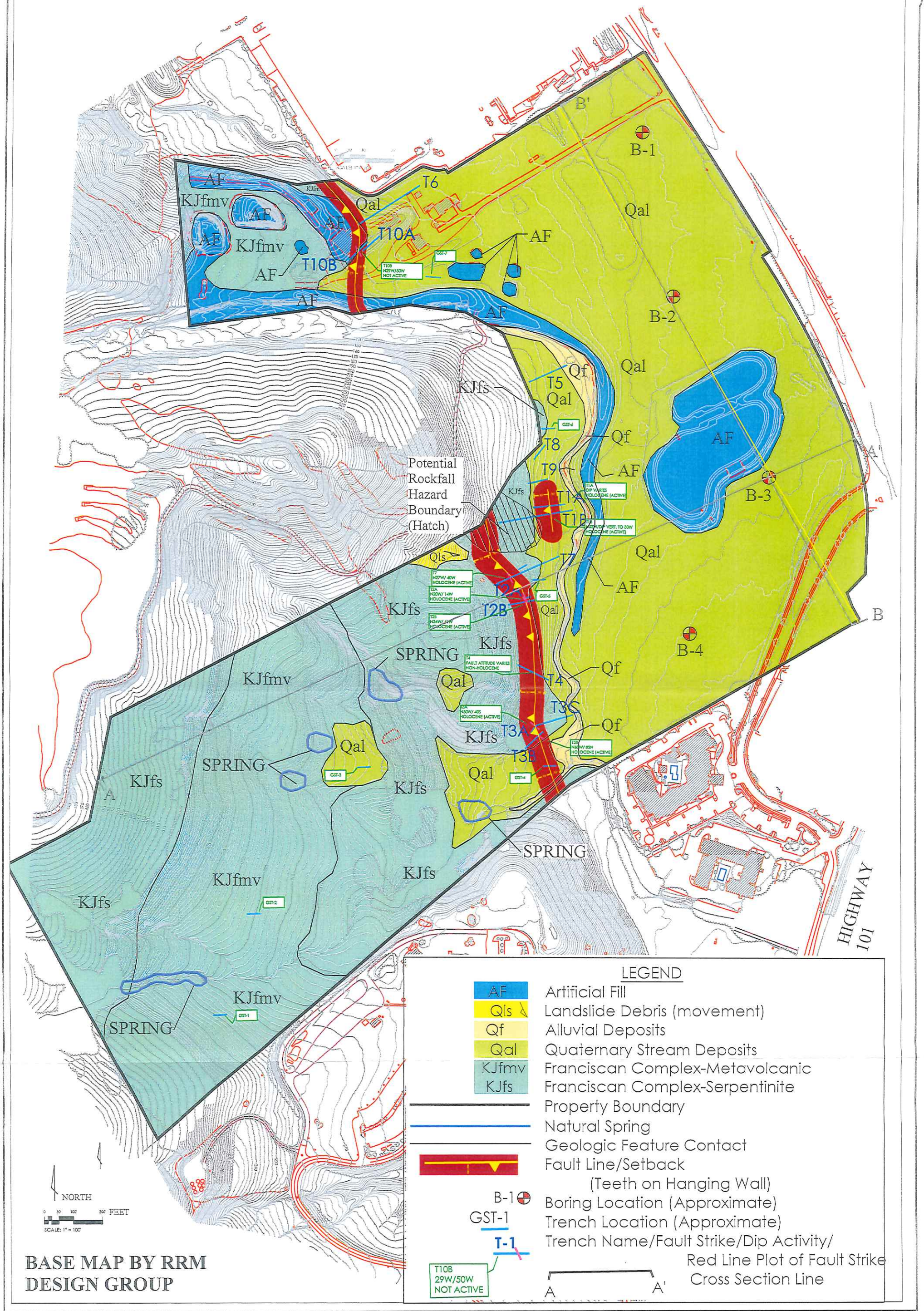
SITE ENGINEERING GEOLOGY MAP

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE
1C

PROJECT
SL09734-1



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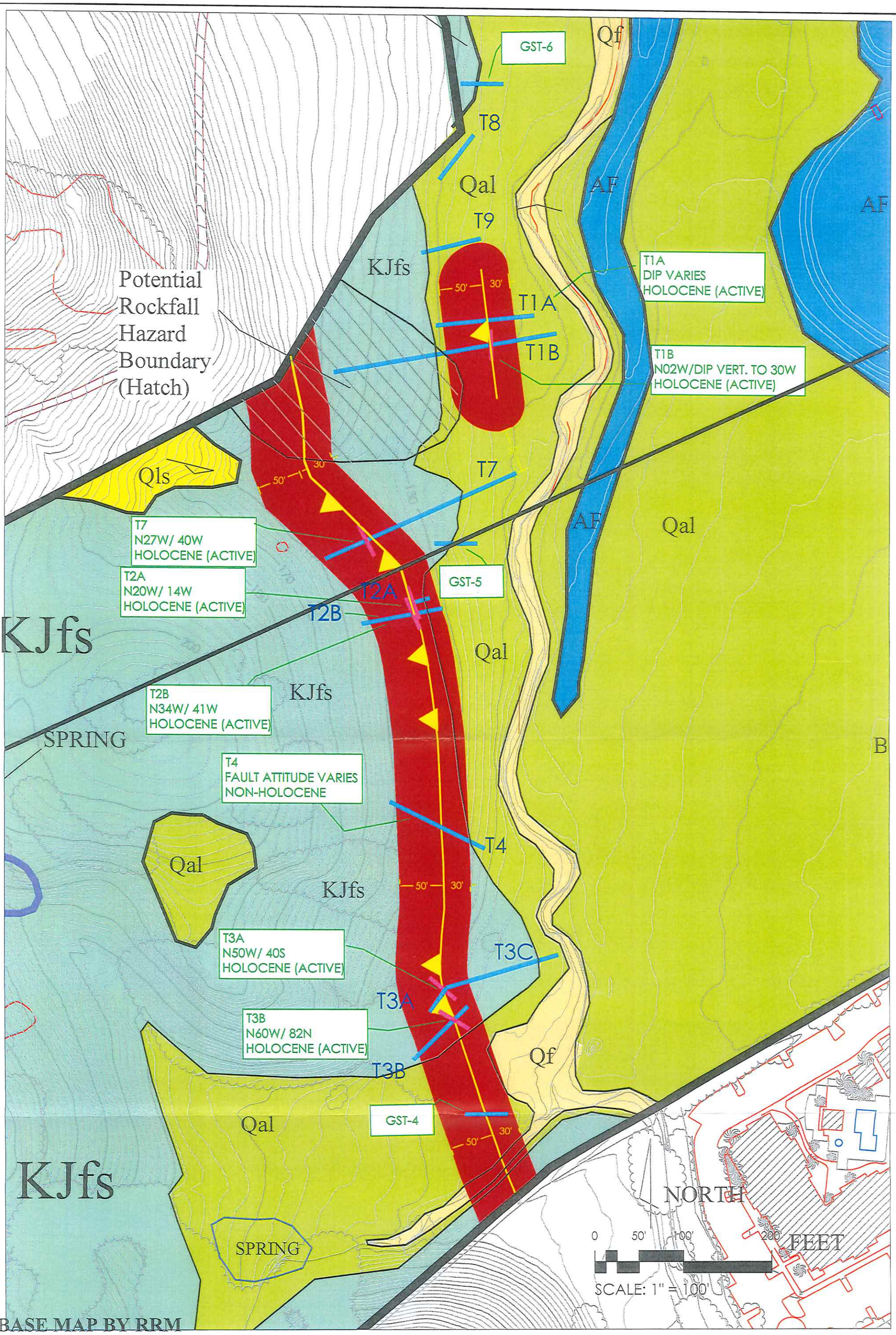
FAULT SETBACK MAP

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE
1D

PROJECT
SL09734-1



BASE MAP BY RRM DESIGN GROUP

SEE PLATE 1D FOR GEOLOGIC EXPLANATIONS

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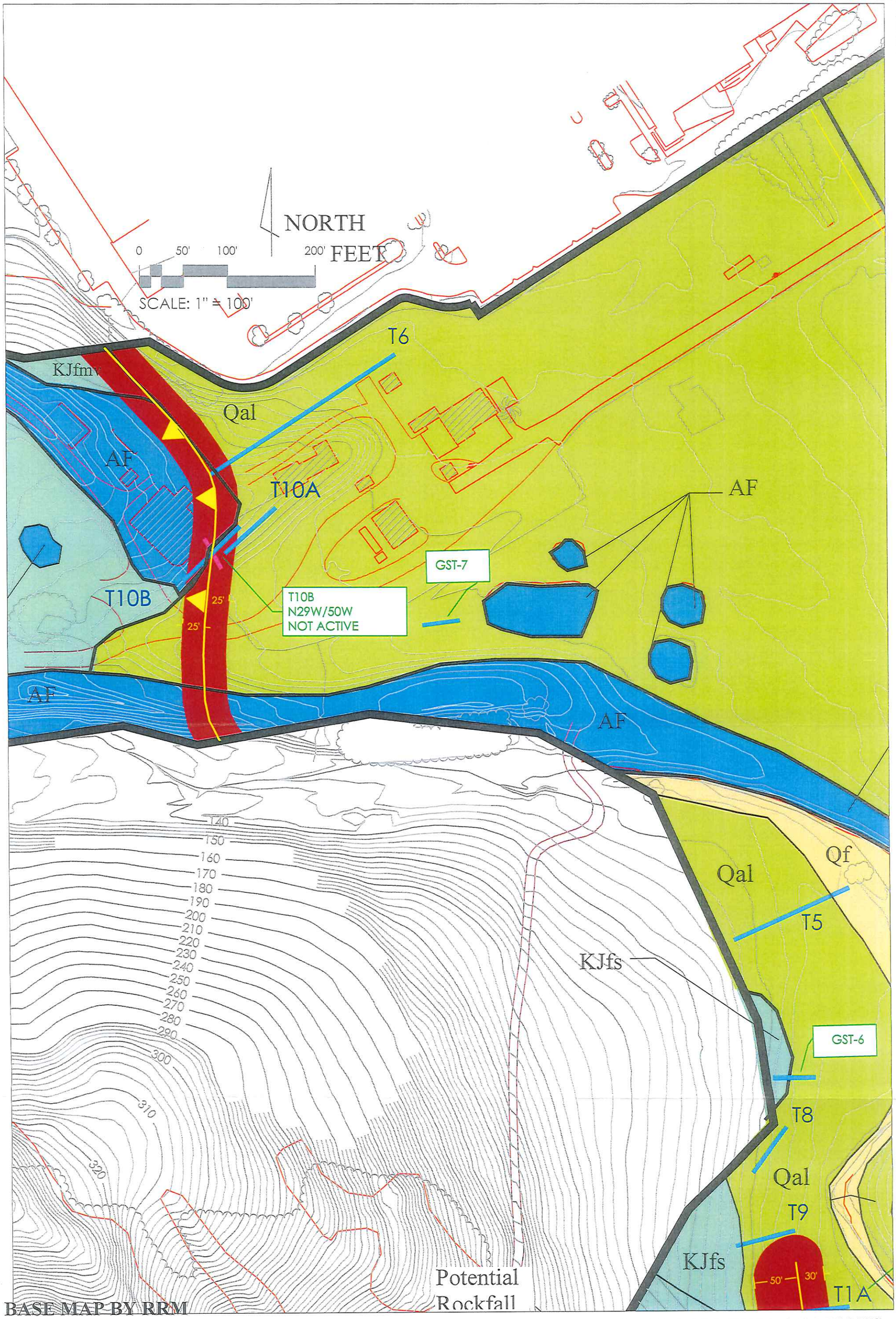
FAULT SETBACK MAP

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE
1E

PROJECT
SL09734-1



BASE MAP BY RRM DESIGN GROUP

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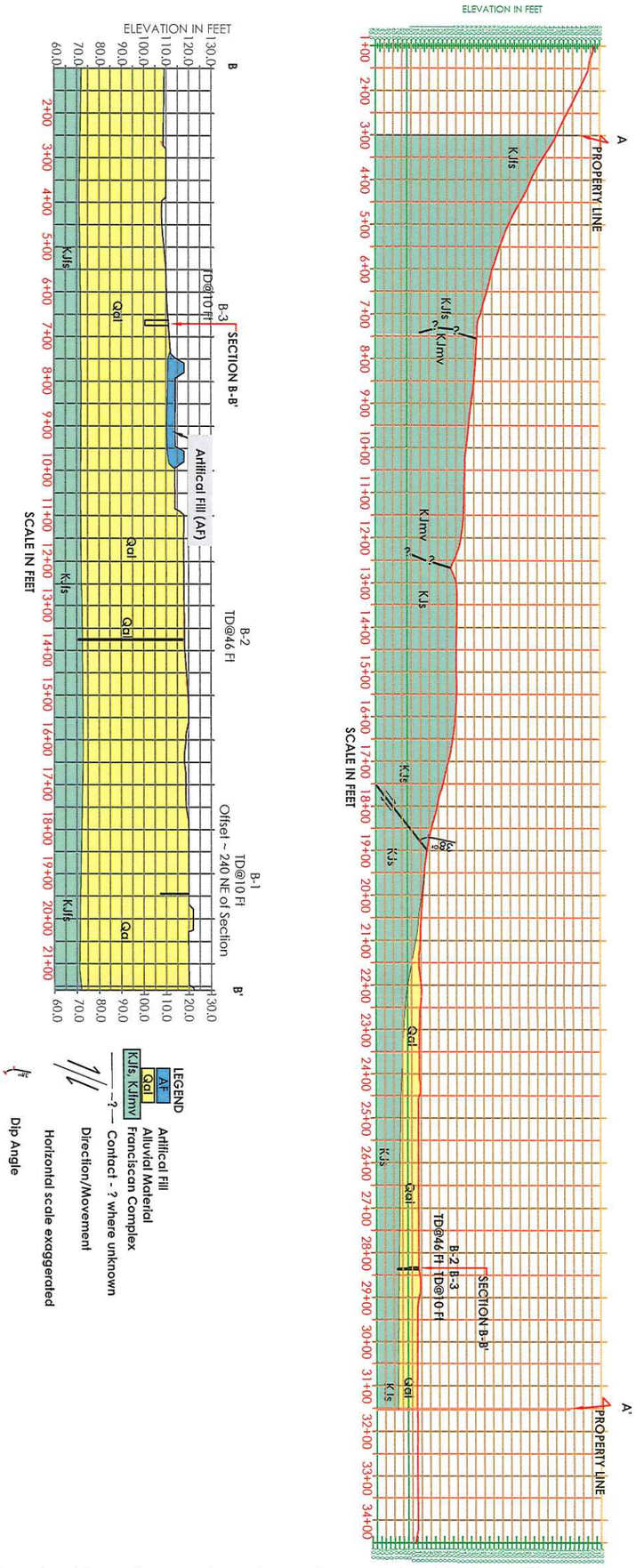
FAULT SETBACK MAP

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE
1F

PROJECT
SL09734-1



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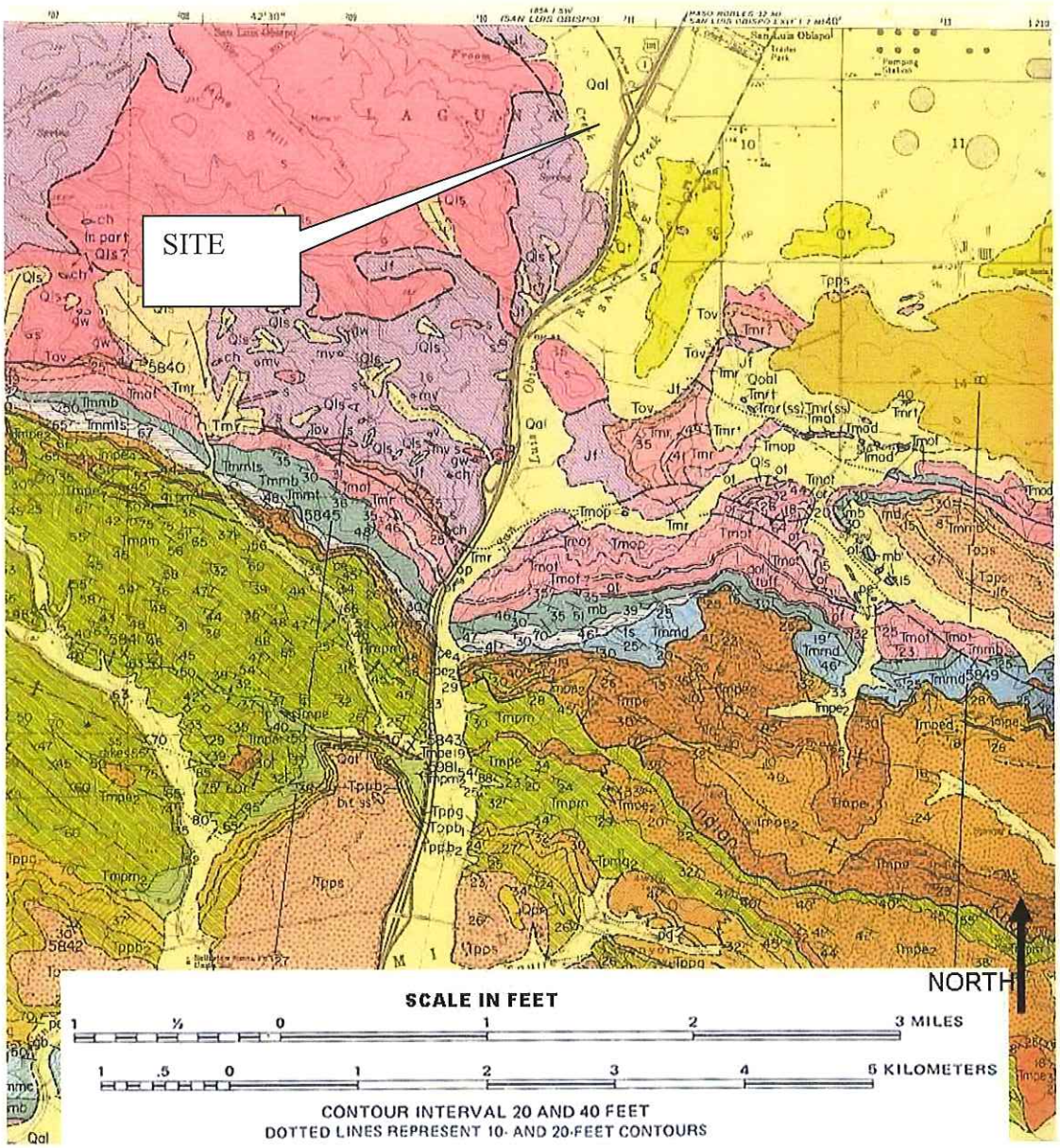
ENGINEERING GEOLOGY CROSS SECTION

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE
2

PROJECT
SL09734-1



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Hall, 1973

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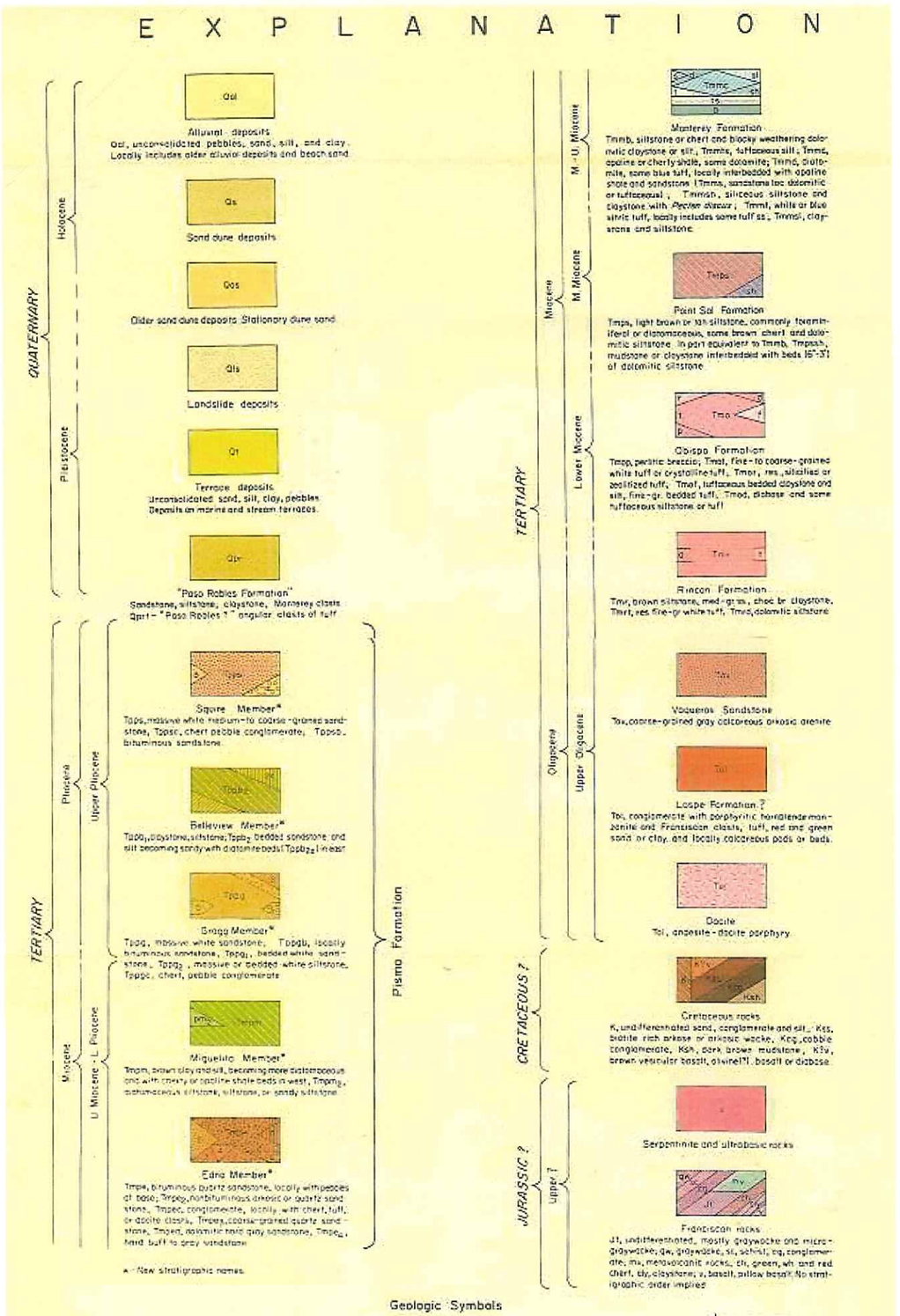
REGIONAL GEOLOGIC MAP

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
3A

PROJECT NO:
SL09734-1

E X P L A N A T I O N



Geologic Symbols

Contact
Dashed where approximately located, queried where inferred, dotted where concealed

Fault
Dashed where approximately located, queried where inferred, dotted where concealed

"Thrust fault"
Dashed where approximately located, saw-teeth on upper plate, dip of fault plane between 30° and 80°

Anticline
Showing trace of axial surface. Dashed where approximately located

Syncline
Showing trace of axial surface. Dashed where approximately located.

46
Strike and dip of bed
Inclined

Strike and dip of bed
Vertical

X 5285
Megafossil locality - U.C.L.A. locality number

Geologic mappable bed symbols
Sandstone — Conglomerate
Siltstone — Tuff

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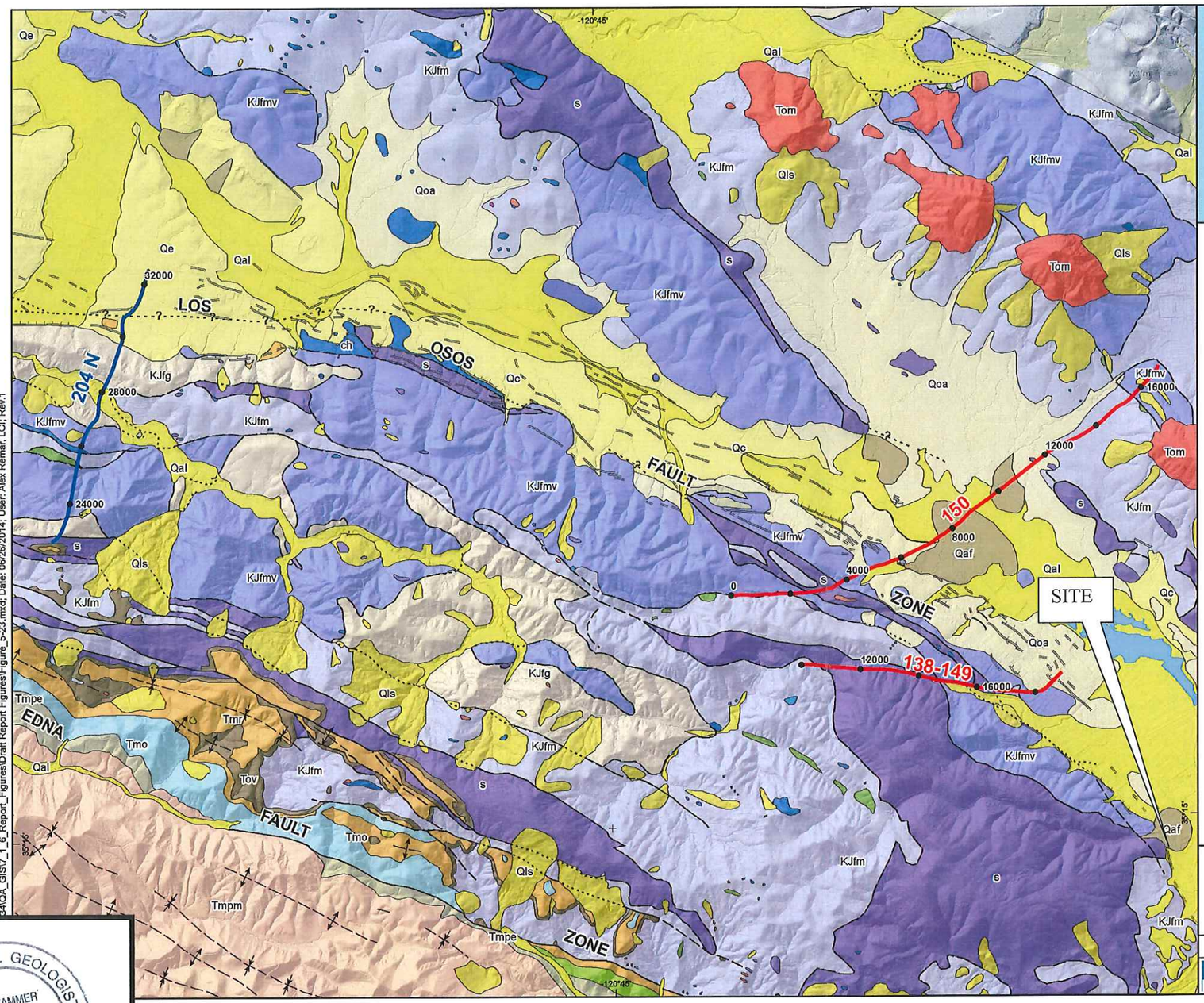
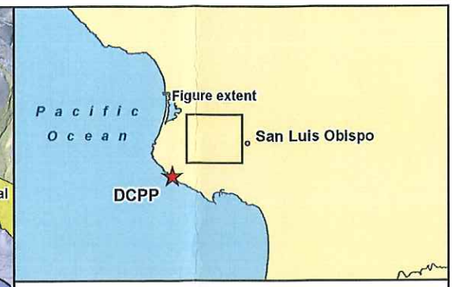
GEOLOGIC EXPLANATIONS

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
3B

PROJECT NO:
SL09734-1





EXPLANATION

- AWD seismic reflection line
- Vibroseis seismic reflection line
- Horizontal distance along seismic line, 2,000 ft. increments

Abbreviated List of Geologic Units

Quaternary continental deposits
- Qe Aeolian deposits
- Qal Alluvial deposits
- Qm Marine terrace deposits

Neogene marine deposits
- Tpps Pismo Formation, Squire Member
- Tmpm Pismo Formation, Miguelito Member
- Tmpe Pismo Formation, Edna Member
- Tmm Monterey Formation
- Tmod Obispo Formation, diabase
- Tmo Obispo Formation, undifferentiated

Continued
- Tmr Rincon Formation
- Tov Vaqueros Sandstone

Mesozoic basement
- Ks Cretaceous sandstone
- KJf Franciscan Complex, undifferentiated
- KJfm Franciscan Complex, melange
- s Franciscan Complex, serpentine
- KJg Franciscan Complex, graywacke sandstone
- KJfmv Franciscan Complex, metavolcanic rocks
- KJfo Franciscan Complex, ophiolite

Geologic Structures

Solid where known; dashed where approximate; dotted where concealed; queried where uncertain. Ticks on lineaments indicate facing direction of topographic scarps.

- Syncline
- Anticline
- Fault
- Lineament

Note: See Plate 1 for full list of geologic units and symbols.

N

0 0.5 1 mi.
0 1 2 km

Map projection and scale: WGS 84 / UTM Zone 10N, 1:40,061

Key Seismic Lines Imaging the Los Osos Fault

2011 ONSIP

Pacific Gas and Electric Company | Figure **5-23**

Ch7.GEO.DCPP.TR.14.03 R0

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PLATE 4

PROJECT NO: SL09734-1

REGIONAL GEOLOGY MAP AND EXPLANATIONS

PG&E, 2014
FROOM/EI VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

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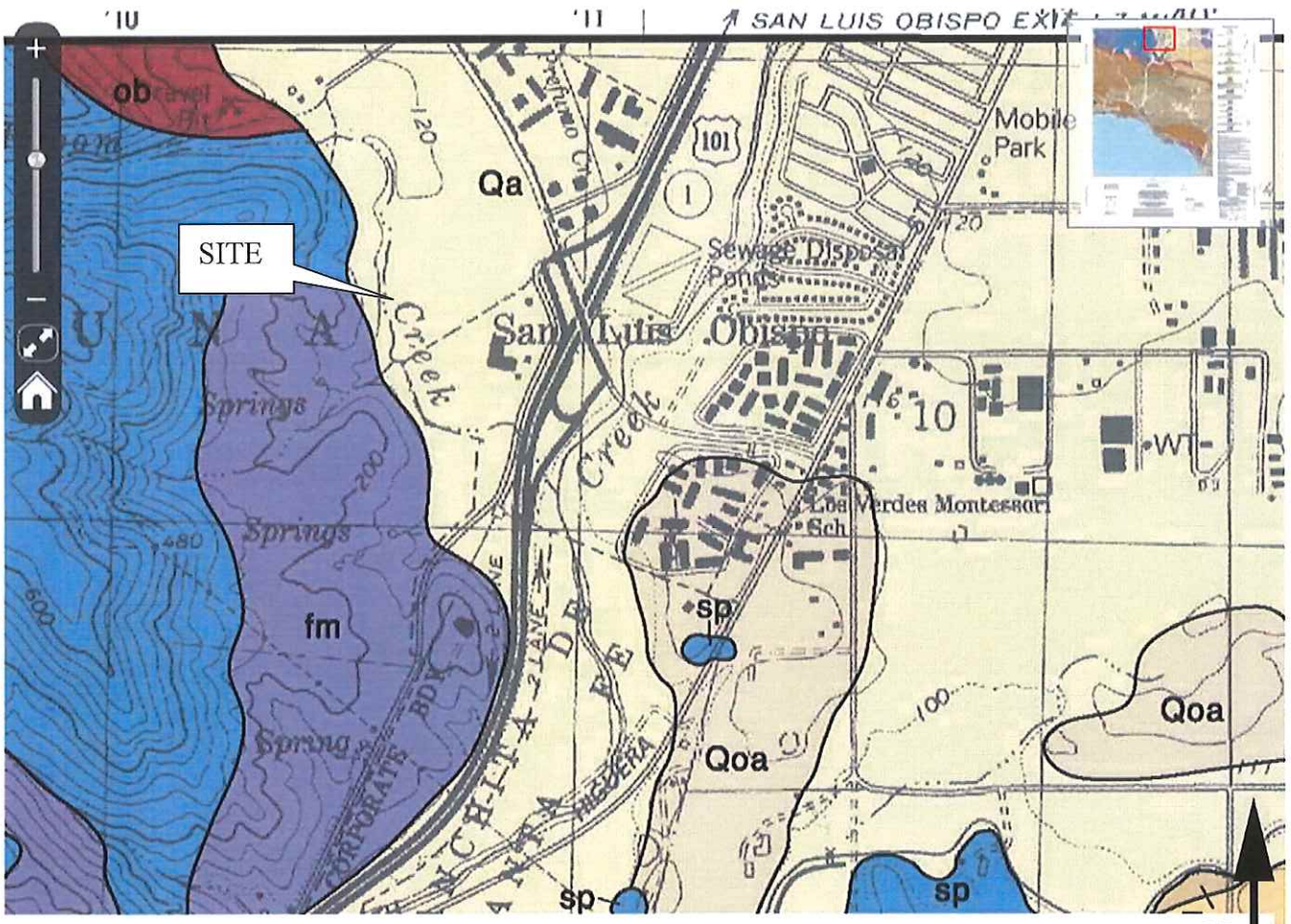
...34\QA_GIS\7_1_6_Report_Figures\Draft Report Figures\Figure_5-23.mxd; Date: 06/26/2014; User: Alex Remar, LCI; Rev.1

Dibblee, T.W., and Minch, J.A., 2006, Geologic map of the Pismo Beach quadrangle, San Luis Obispo County, California: Dibblee Geological Foundation, Dibblee Foundation Map DF-212, scale 1:24,000

View Product Description Page



SCALE 1:24000

1/2 0 1 MILE

1000 2000 3000 4000 5000 6000 7000 FEET

.5 0 1 KILOMETER

PISMO BEACH QUADRANGLE

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REGIONAL GEOLOGIC MAP

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
5A

PROJECT NO:
SL09734-1

PISMO BEACH MAP (DF-212)

LEGEND

Qa | Qbs

SURFICIAL SEDIMENTS
Qa *Alluvial gravel, sand and clay*
Qbs *Beach sand*

Qls

LANDSLIDE RUBBLE

Qos | Qoa

OLDER ALLUVIUM
Qos *Sand of older stabilized dunes, dissected*
Qoa *Dissected gravel and sand*

— *UNCONFORMITY* —

QTp

PASO ROBLES FORMATION
Of Hall, 1973; Valley sediments, weakly indurated, may be older alluvium **(Qoa)**; *age, Pliocene to Pleistocene*
QTp *Older alluvial gravel sand and clay with siliceous shale pebbles, undeformed but dissected*

— *UNCONFORMITY* —

Tsw

SQUIRE SANDSTONE
Squire Member of Pismo Formation of Hall, 1973; designated herein as a formation because of major unconformity at base; age, Pliocene
Tsw *Sandstone, white to gray-white, fine to medium grained, arkosic, friable; equivalent to Careaga Sandstone of Santa Maria basin*

— *UNCONFORMITY* —

Tpsb | Tp | Tps

PISMO FORMATION
Marine; age, late Miocene, possibly early Pliocene, Mohnian and Delmontian Stages
Tps *Sandstone, light gray, friable, quartzose (Edna Member of Hall south of Morro Bay)*
Tpsb *Sandstone, similar to* **Tps**, *but bituminous*
Tp *Claystone to siltstone, gray, weathered tan, vaguely bedded, includes sandstone, similar to* **Tps**, *in north area*

— *UNCONFORMITY* —

Tmm
Tm
Tml

MONTEREY FORMATION
Marine biogenic; age, middle to late Miocene
Tmm *Siliceous shale, white-weathered, thin-bedded, platy, porcelaneous to cherty; age, upper Miocene, Mohnian Stage; assigned by Hall, 1973, to Pismo formation as part of Miguelito Member in west area*
Tm *Siliceous shale, thin-bedded, platy, white-weathered, porcelaneous to cherty in upper part; age, upper to middle Miocene, Mohnian Stage*
Tml *Lower part (Point Sal formation of Hall, 1973), shale, cream-white-weathered, thin-bedded, fissile; includes thin calcareous layers, mostly at base; age, middle Miocene, Luisian-Relizian Stages*

Tot | Top | Tov

OBISPO FORMATION
Pyroclastic-volcanic rocks, lithified; age, early middle Miocene, Saucesian-Relizian Stages
Tot *Tuff and tuff breccia, white to creamy-white, locally silicified or zeolitized to coherent rock*
Top *Perlitic glass and breccia*
Tov *Volcanic rocks, mostly basalt but includes some dark gray andesitic rock, mostly in upper part, not differentiated; basalt, black fine-grained, massive to vaguely bedded, somewhat incoherent where weathered, locally vesicular, composed of plagioclase feldspar and mafic minerals including olivine, locally incudes diabase sills and dikes*

Tr

RINCON SHALE
Marine clastic; age, Oligocene-early Miocene, Zemorrian-Saucesian Stages
Tr *Clay shale, gray, crumbly*

Tvq

VAQUEROS SANDSTONE
Marine clastic; age, early Miocene or late Oligocene, Zemorrian Stage
Tvq *Sandstone, light gray, locally calcareous*

sp

SERPENTINITE
sp *Bluish-green, severly fractured, with shiny slickensides, hydrothermally metamorphosed from intrusive rocks, such as ultramafic, peridotite*

ob

DIABASE
Assigned to Franciscan Rocks by Hall, 1973, 1975, but may be part of Coast Range Ophiolite Complex; associated with **sp**
ob *Diabase, black, fine-grained, massive, of calcic plagioclase and mafic minerals; includes basalt, minor chert; structurally overlies? Franciscan Assemblage*

fm | fg

FRANCISCAN ROCKS
Marine, eugeosynclinal sedimentary and volcanic rocks; age, Jurassic and Cretaceous
fm *Pervasively sheared melange, primarily dark claystone and graywacke sandstone, includes blocks of graywacke, chert, greenstone and glaucophane schist*
fg *Greenstone (meta-basalt)*

Holocene
Pleistocene
QUATERNARY
Pliocene
Miocene
TERTIARY
CENOZOIC
Jurassic & Cretaceous
MESOZOIC

GEOLOGIC SYMBOLS

not all symbols shown on each map

FORMATION CONTACT *dashed where inferred or indefinite, dotted where concealed*
MEMBER CONTACT *between units of a formation* ····· **Prominent bed**
CONTACT BETWEEN SURFICIAL SEDIMENTS *located only approximately in places*

FAULT: *Dashed where indefinite or inferred, dotted where concealed, queried where existence is doubtful. Parallel arrows indicate inferred relative lateral movement. Relative vertical movement is shown by U/D (U=upthrown side, D=downthrown side). Short arrow indicates dip of fault plane. Sawteeth are on upper plate of low angle thrust fault.*

FOLDS: *overturned* — **ANTICLINE** — **SYNCLINE**
arrow on axial trace of fold indicates direction of plunge; dotted where concealed by surficial sediments

Strike and dip of sedimentary rocks: inclined | inclined (approximate) | overturned | horizontal | vertical

Strike and dip of metamorphic or igneous rock foliation or flow banding or compositional layers: inclined | inclined (approximate) | vertical | overturned

OTHER SYMBOLS: Direction of landslide movement | outline of water bodies shown on map | water well | oil well | springs

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REGIONAL GEOLOGIC MAP

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
5B

PROJECT NO:
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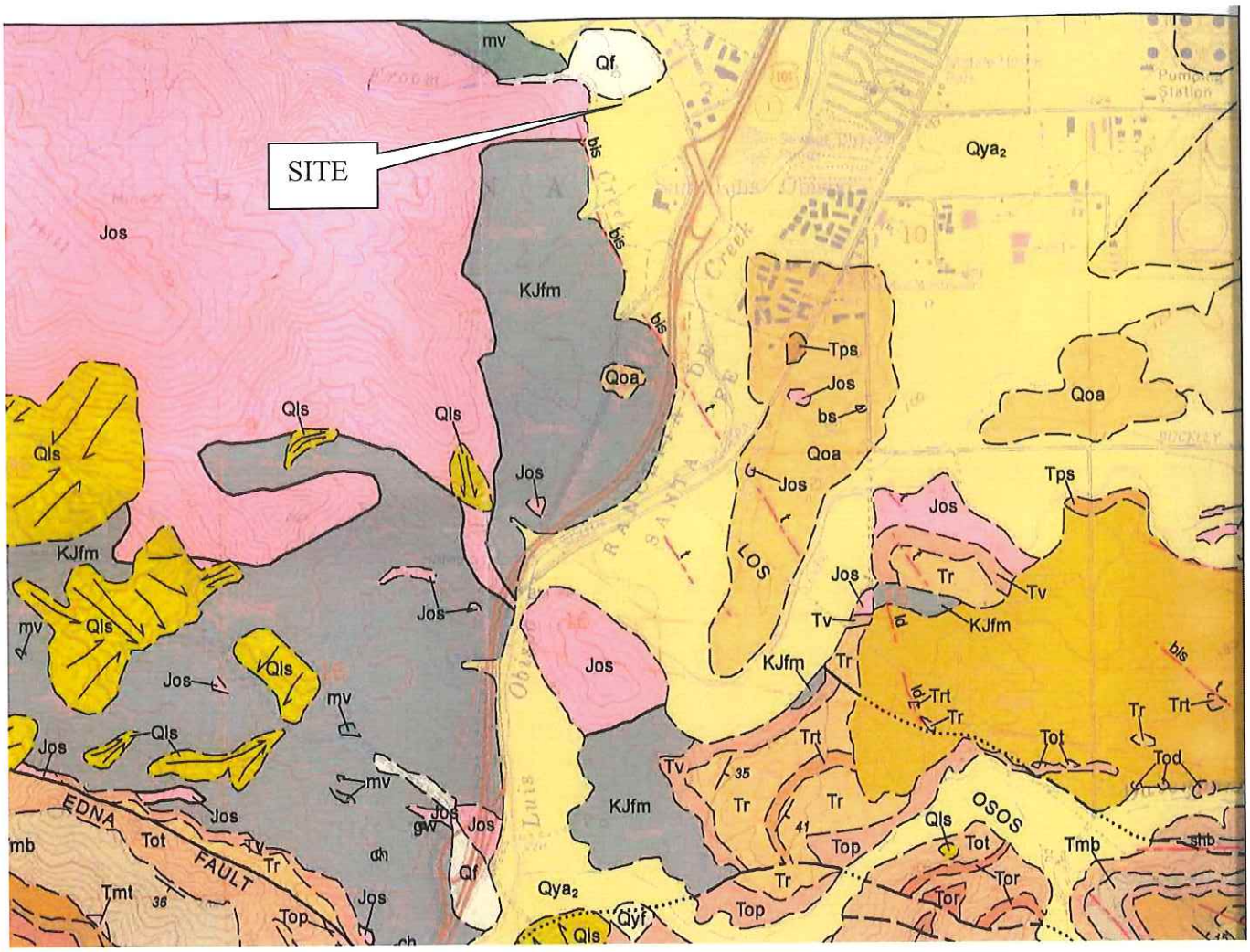

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REGIONAL GEOLOGIC MAP

(Wiegers, 2011)
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
6A

PROJECT NO:
SL09734-1

DESCRIPTION OF MAP UNITS

QUATERNARY DEPOSITS

Very Young Surficial Deposits

Qa **Alluvial flood-plain deposits (late Holocene)** - Active and recently active flood-plain deposits. Consists of unconsolidated sandy, silty, and clay-bearing alluvium.

Qf **Alluvial fan deposits (late Holocene)** – Small active alluvial fans at the mouths of steep mountain streams. Consists of cobbles, gravel, sand, and silt.

Qb **Beach sand (late Holocene)** – Unconsolidated beach deposits consisting mostly of fine- to medium-grained well-sorted sand.

Qd **Dune sand (late Holocene)** – Unconsolidated, well-sorted white to brown windblown sand. Forms active dunes behind modern beaches.

Qls **Landslide deposits (Holocene)** – Highly fragmented to largely coherent landslide deposits.

Young Surficial Deposits

Qye **Young eolian deposits (Holocene to late Pleistocene)** – Stationary sand dune deposits. Well-sorted white to brown windblown sand.

Qya **Young alluvial valley deposits, undivided (Holocene to late Pleistocene)** – Unconsolidated sand, silt, and clay-bearing alluvium deposited on flood-plains and along valley floors. Locally divided by relative age (2 = youngest, 1 = oldest). Surfaces on young deposits are undissected and lack soil development. Surfaces on older deposits are slightly dissected and display weak soil development:

Qya_2 **Young alluvial valley deposits, Unit 2**

Qya_1 **Young alluvial valley deposits, Unit 1**

Old Surficial Deposits

Qoa **Old alluvial valley deposits (late to middle Pleistocene)** – Fluvial sediments preserved above active flood plains and channels. These deposits are moderately consolidated, slightly dissected and capped by moderate to well-developed pedogenic soils. Consists of relatively thin deposits of gravel, sand, silt and clay-bearing alluvium overlying eroded bedrock surfaces and older sediments. Forms low rounded topographic rises in San Luis Obispo Valley. Locally perched on isolated strath terraces.

Qop_{1-3} **Old paralic deposits (late to middle Pleistocene)** – Marine terrace deposits consisting of beach and nearshore sands and gravels covered by colluvium and alluvium. These deposits rest on emergent wave-cut platforms preserved by regional uplift. Marine deposits consist of well-sorted sand and gravel locally containing fossils and shell fragments. Overlying non-marine cover consists of poorly-sorted sand, silt, gravel and clay deposited by slope wash and alluvial processes. Divided by relative age (3 = youngest, 1 = oldest). Estimated ages of deposits are as follows (Hanson and others, 1994):

Qop_3 **Old paralic deposits, Unit 3 – 80 ka**

Qop_2 **Old paralic deposits, Unit 2 – 120 ka**

Qop_1 **Old paralic deposits, Unit 1 – 210 ka - 430 ka**

Old Surficial Deposits

Qvoa **Very old alluvial valley and pediment deposits (middle to early Pleistocene)** – Tan silt and fine sand deposited on a gently sloping pediment surface extending down the northeast side of the San Luis Range into San Luis Obispo Valley. Mapped as Paso Robles Formation by Hall (1973). Lacks channel conglomerates. Much of the unit appears gradational with underlying sandstone of the Squire Member of the Pismo Formation (Tps) and may in part be residual soil developed on that unit (Nilchman, 1988).

Qvop **Very old paralic deposits (middle to early Pleistocene)** – Marine terrace deposits consisting of beach and near shore sands and gravels covered by colluvium and alluvium. These deposits rest on emergent wave-cut platforms preserved by regional uplift. Well preserved terraces are found about 400 feet above sea level on slopes north and northwest of Pismo Beach. These terraces are estimated to be older than 560 ka (Hanson and others, 1994).

TERTIARY AND OLDER ROCKS

Pismo Formation (lower Pliocene to upper Miocene)

Tps **Squire member** – Massive, white, calcareous, fine- to medium-grained, quartzose to arkosic, silty sandstone. Sand grains subrounded to subangular; 75-80% quartz, 15-20% feldspar, less than 15% mafic minerals (Hall, 1973). Contains lenses of white, well-rounded pebbles and cobbles of Monterey and Obispo Formation clasts north of Edna Fault. Basal conglomerate of rounded chert and basalt cobbles near mouth of San Luis Obispo Creek. Bioturbated with greenish glauconitic sand coatings and clay and silt interbeds in footwall of Wilmar Avenue Fault at Pismo Beach (Nitchman, 1988). **Tpsc** - Conglomerate of rounded chert pebbles near middle of unit on north side of Edna Fault.

Tpb **Bellevlew member** – Light-gray, bedded, resistant sandstone and interbedded siltstone. Sandstone medium-grained; 60% quartz, 30% feldspar, locally 15% rock fragments (Hall, 1973). **Tpbc** - Interbedded, buff claystone, siltstone and fine-grained sandstone. Claystone speroidally fractured. Sandstone beds locally fossiliferous. **Tpbd** - Well-bedded diatomaceous siltstone, claystone and silty diatomite.

Tpgs **Gregg member** – Massive, white, buff-weathering sandstone, soft to resistant, medium-grained; 65% quartz, 30% feldspar, clay 4%, mafic minerals 1% (Hall, 1973). **Tpgs** – Well-bedded sandstone, beds 2 inches to 2 feet thick. **Tpgf** – Massive buff siltstone. **Tpgb** – Locally bituminous sandstone. **Tbgc** – Chert pebble conglomerate. **Tpgd** – Diatomaceous siltstone.

Tpm **Miguelito member** – Brown to buff interbedded siltstone and claystone, moderately resistant, well-bedded, beds generally 2 to 4 inches thick. Locally includes beds and lenses of siliceous and dolomitic siltstone and friable, locally bituminous sandstone (Hall, 1973). Opaline and porcelaneous shale is present in the western part of the map area. **Tpms** – Poorly bedded siltstone, diatomaceous siltstone and sandy siltstone. The Miguelito Member consists of basinal mudstones in the west and south parts of the map area that interfinger with coeval inner shelf sandstones of the Edna member to the east.

Tpet **Edna member** – Buff, massive arkosic to quartzose sandstone, fine- to coarse-grained; quartz 80-95%, feldspar less than 5-15% (Hall, 1973). **Tpeb** – Bituminous sandstone zones within Tpe. Oil can be seen leaking from exposures near Price Canyon Oil Field and oily sandstones are exposed on the ridge north of Shell Beach. **Tpec** – Basal conglomerate and/or breccia with clasts ½-inch to several feet in diameter of Monterey chert, dacite and Franciscan debris. Clasts commonly angular and poorly sorted but locally rounded and well-sorted. Basal conglomerate overlying Monterey Formation well exposed at Shell Beach. **Tpes** – Massive medium- to coarse-grained pebbly sandstone, locally calcareous and fossiliferous. **Tped** – Fine-grained dolomitic sandstone.

SYMBOL EXPLANATION

Contact between map units - Solid where accurately located, dashed where approximately located, dotted where concealed.

Fault - Solid where accurately located, dashed where approximately located, dotted where concealed. U = upthrown block; D = downthrown block.

Thrust fault - Solid where accurately located, dashed where approximately located, dotted where concealed. Barbs on upper plate.

Synclinal axis - Solid where accurately located, dashed where approximately located, dotted where concealed. Arrow shows plunge direction.

Anticlinal axis - Solid where accurately located, dashed where approximately located, dotted where concealed. Arrow shows plunge direction.

Aerial photo lineaments (Lettis and Hall, 1994). Dashed where less distinct, queried where questionable. Hachures indicate topographic scarp and direction of slope. t = tonal contrast; v = vegetative lineament; ld = linear drainage.

Strike and dip of bedding plane.

Tmt **Monterey Formation (upper to middle Miocene)** – Bedded, resistant chert, color varies from white and gray to brown and reddish-brown, weathering to chalky white. Brittle, conchoidal fracturing, commonly sheared, beds ½ to 6-inches thick, commonly laminated, locally interbedded with diatomite (Hall,1973). **Tmd** – White to buff diatomite with minor tuff, opaline chert and tuffaceous sandstone. **Tmts** – Tuffaceous siltstone, locally interbedded with dolomitic siltstone and opaline chert. **Tmt** – White to blue-gray tuff, very fine- to coarse-grained, locally includes virtic tuff and tuffaceous sandstone. **Tms** – Brown to white siltstone with some claystone. **Tmb** – Tan to yellowish-white siltstone and dolomitic claystone locally tuffaceous or interbedded with chert.

Tof **Obispo Formation (lower Miocene)** – Coarse-grained tuff with subangular clasts of pumice (5%-50%), perlite (5%-15%), white to dark-gray glass shards (20%) and feldspar (5%) in a vitric ashy matrix; commonly altered to montmorillonite (Hall, 1973). Type locality along San Luis Obispo Creek. Locally contains clasts of reddish- brown tuffaceous mudstone. **Top** – Perlite breccia. Patchy white and gray, weathering to dark-gray, contains subangular perlite and pumice clasts 2 to 8 inches in diameter in a tuffaceous matrix. **Tor** – Resistant, hard, fine-grained, zeolized tuff. Forms resistant cliffs at Fossil Point near Avila Beach and resistant outcrops and an ancient sea stack along State Route 1 at Pismo Beach. **Tof** – Yellow to brown tuffaceous siltstone and claystone. **Tod** – Diabase dikes and sills. Exposed locally in cliffs at Pismo Beach.

Tr **Rincon Shale (Oligocene and lower Miocene)** – Dark-brown to orange-brown siltstone and claystone, poorly to well-bedded, weathers white to light-brown. Locally contains yellowish, fine-grained quartzose sandstone. **Trt** – White to buff rhyolitic vitric tuff. Contains quartz and feldspar crystals in a fine-grained ash matrix (Hall, 1973).

Tv **Vaqueros Sandstone (Oligocene)** – Gray to brown, medium- to coarse-grained sandstone and conglomerate, poorly to well-indurated. Conglomerate clasts typically black and green chert. Sandstone grains well-rounded to subrounded with a typical composition of 40% to 60% quartz, 5% to 15% feldspar, 30% to 50% rock fragments (Hall, 1973). Contains fossiliferous zones with broken mollusk shells and large oysters.

KJfm **Franciscan Complex mélange (Cretaceous to Jurassic)** – Chaotic mixture of fragmented rock masses embedded in a penetratively sheared matrix of argillite and crushed metasandstone. Individual rock masses contained in the matrix range from less than a meter to kilometers in scale. Blocks large enough to be shown on map include high grade blueschist (bs), greenstone (mv), pillow basalt (v), graywacke (gw) and chert (ch). Penetrative deformation of matrix postdates metamorphism of enclosed rock masses.

Jos **Serpentinized ultramafic rocks** – Pervasively sheared serpentinite occurring as lenticular fault-bounded bodies in Franciscan mélange. Considered to be dismembered bodies of the Coast Range Ophiolite tectonically interleaved with mélange during subduction. Locally, hydrothermally altered to silica-carbonate rock.

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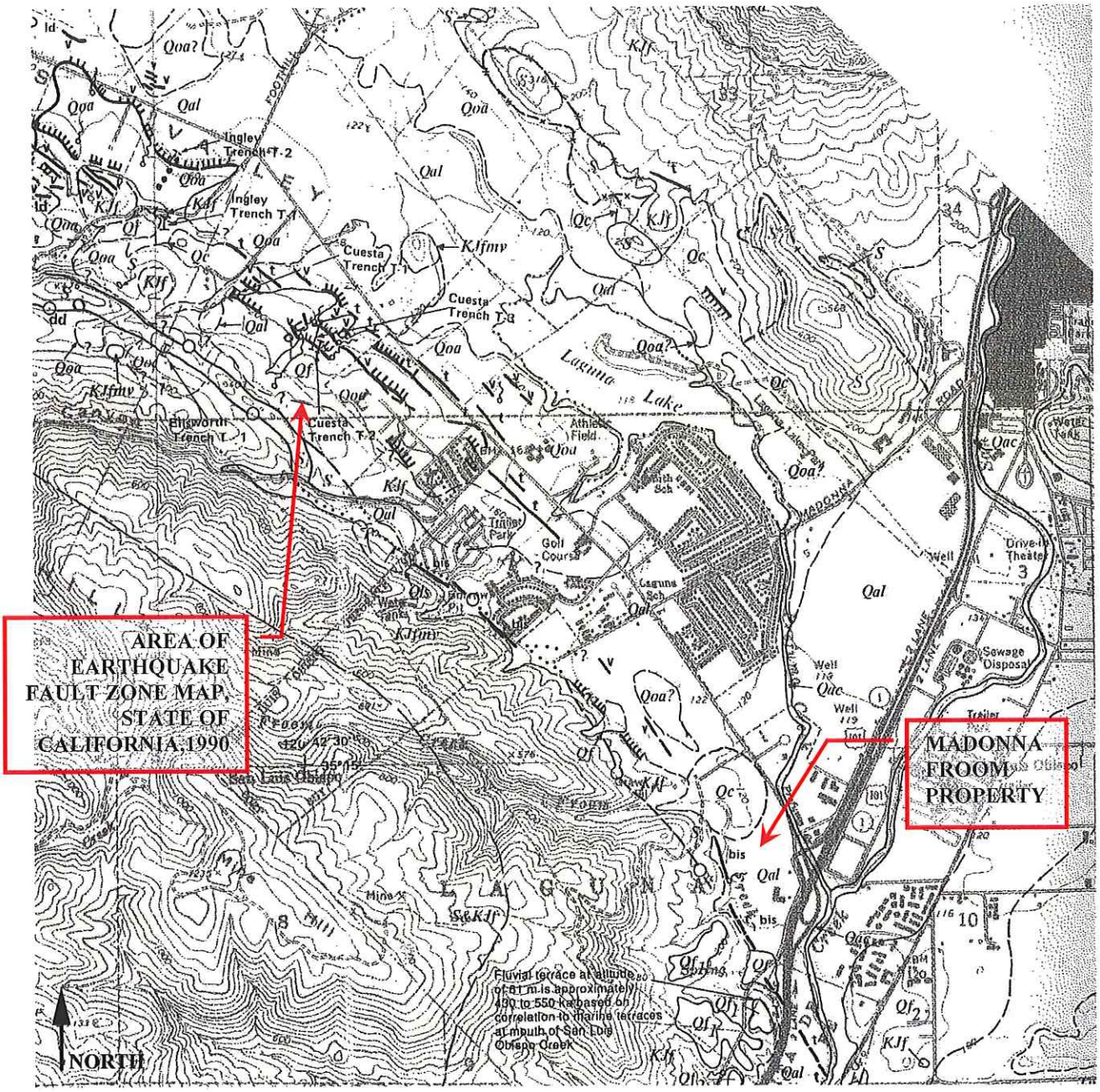
GEOLOGIC EXPLANATIONS

WIEGERS, 2011
FROOM/EI VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
6B

PROJECT NO:
SL09734-1



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REGIONAL GEOLOGIC MAP

(Lettis and Hall, 1994)
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
7A

PROJECT NO:
SL09734-1

EXPLANATION

MAP SYMBOLS

- Fault — Long dash where approximately located; short dash where concealed but location is well constrained; dotted where inferred; U = up/D = down and arrows indicate relative sense of displacement; small arrow and number indicate dip of fault plane exposed in outcrop
- Aerial photo lineament —Dashed where less distinct; probable fault; tc = tonal contrast, vl = vegetation lineament, ld = linear drainage, bls = break in slope, shb = side hill bench. Hachures on topographically downside of a scarp
- Shear zone in bedrock
- Strick and dip of bedding
- Marine terrace strandline — Solid where well constrained; double dot-dash where buried or less well constrained; dotted where eroded; queried where uncertain; altitude of shoreline angle in meters
- Contact — Dashed where approximately located, dotted where buried and inferred
- SR-8 Seismic refraction survey line
- T-1 Trench
- SP-T-5 Soil pit
- EP-16 Exploration pit
- 28 Borehole — Completed as part of Long-Term Seismic Program (PG&E, 1988)
- Qal/Qmlf; 34 Subsurface stratigraphy and altitude (meters) of the top of bedrock. See description of map units for explanation of Quaternary and bedrock symbols
- Landslide, arrow indicates direction of movement
- Spring
- Relict sea stack
- KH-42-A Location of dated fossil sample
- 14C-KH-5C Location of radiocarbon sample
- TL-1a Location of sample for thermoluminescence analysis

DESCRIPTION OF MAP UNITS

- Q_b Beach deposit — Modern beach sands, unconsolidated
- Q_e Eolian deposit (Holocene and late Pleistocene) — Includes unconsolidated active sand dunes, and slightly to weakly cemented inactive dune sand on elevated marine terraces that has been stabilized by vegetation and soil development
- Q_c Colluvium (Holocene and Pleistocene) — Unconsolidated, poorly sorted sand, gravel, silt, and clay deposited as a result of hillslope processes
- Q_f Fluvial and alluvial deposits (Holocene and Pleistocene) undifferentiated — Unconsolidated cobble-pebble gravel, sand, silt, and clay
- Q_t Stream terrace deposit (Holocene and late Pleistocene) — Undifferentiated

Oak Knoll Creek

Qt_1	active	Qt_4	2.5 - 3.8 ka
Qt_2	historical	Qt_5	5.5 to 7.9 ka
Qt_3	2.25 ± 0.75 ka	Qt_6	Late Pleistocene to early Holocene
Qt_{4a}	2.25 ± 0.75 ka		

- Q_{es} Estuarine deposit (Pleistocene)— Silty clay interbedded with thin layers of fine- to coarse-grained sand; dark gray; contains abundant charcoal, wood, and disseminated organic material
- Q_{oa} Older alluvium (middle to late Pleistocene) — Unconsolidated, weakly to moderately stratified, moderately to poorly sorted gravel, sand, silt, and clay deposited in fluvial channels and alluvial fans overlying marine wave-cut platforms; presently undergoing dissection
- Q_m Marine deposit (middle to late Pleistocene) — Unconsolided boulders, cobbles and sand, well- to moderately sorted clasts are typically subrounded to rounded and consist of Jurassic ophiolite, Franciscan Complex and Monterey lithologies

Bedrock outrops (Note: Bedrock geology is not mapped in detail)

- c Careaga Sandstone (Pliocene and Pleistocene?) — Loosely consolidated to well-cemented, poorly bedded, medium- to coarse-grained sandstone and conglomerate; shell debris as much as 20% of rock (modified from Hall et al., 1979)
- m Monterey Formation (middle and late Miocene) — Diatomaceous shale, porcelaneous shale, diatomite, silty sandstone, and opaline and cherty shale (modified from Hall et al., 1979)
- ps Point Sal Formation (middle Miocene) — Light brown siltsone, diatomaceous siltstone, and dolomite siltstone (modified from Hall et al., 1979)
- t Lospe Formation (Oligocene) — Includes green and red conglomerate, sandstone, and silty claystone (modified from Hall et al., 1979)
- r Tuff (age uncertain)
- Franciscan Complex (Cretaceous or Jurassic) — includes:
- f Graywacke, shale, chert, and melange
- mv Metavolcanic rock
- bs Blueschist
- s Serpentinite (Jurassic?)
- x Undifferentiated bedrock
- x_p Subscript p indicates presence of pholad borings on wave-cut platform

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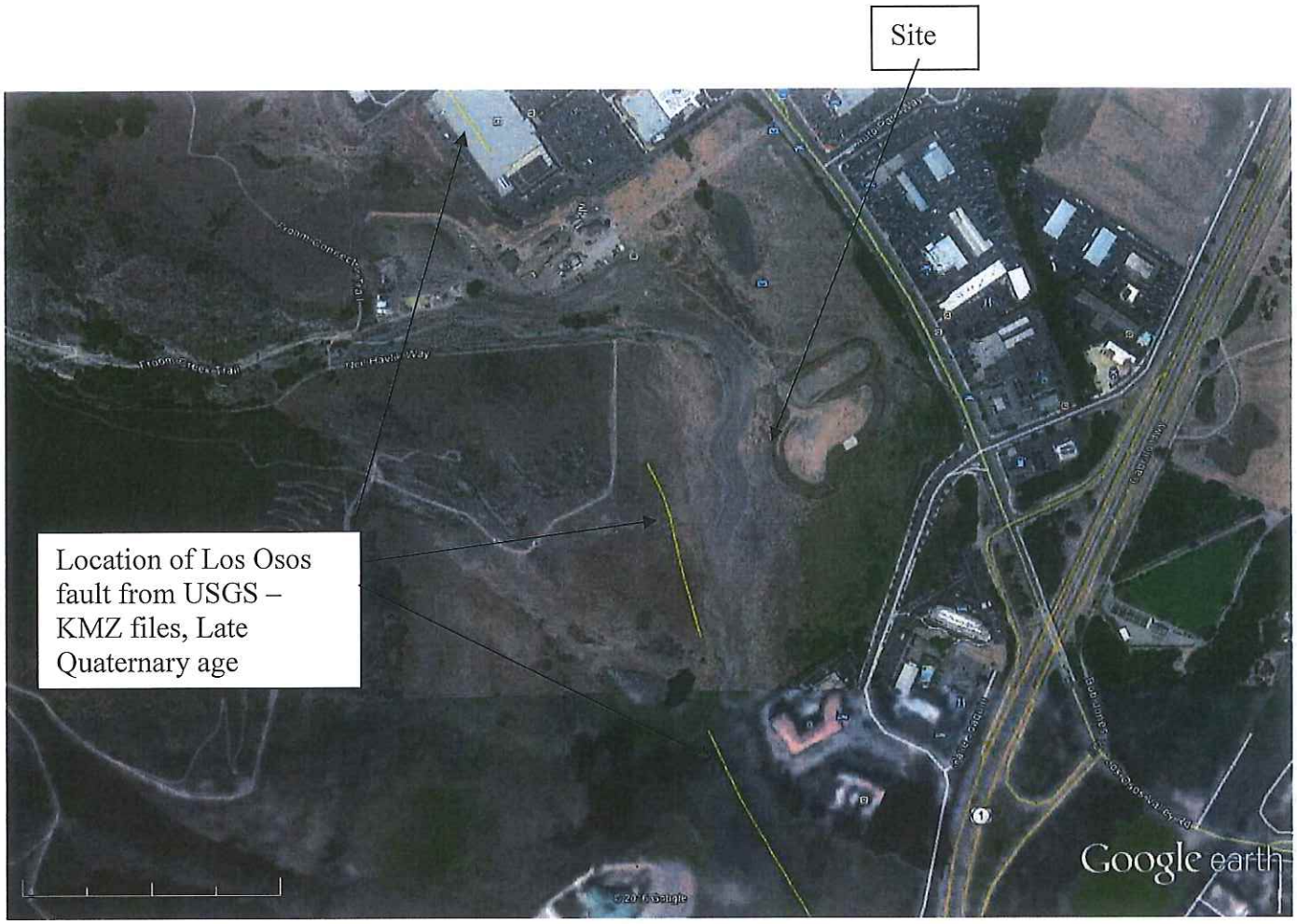
GEOLOGIC EXPLANATIONS

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
7B

PROJECT NO:
SL09734-1



Google earth

feet 2000
meters 700

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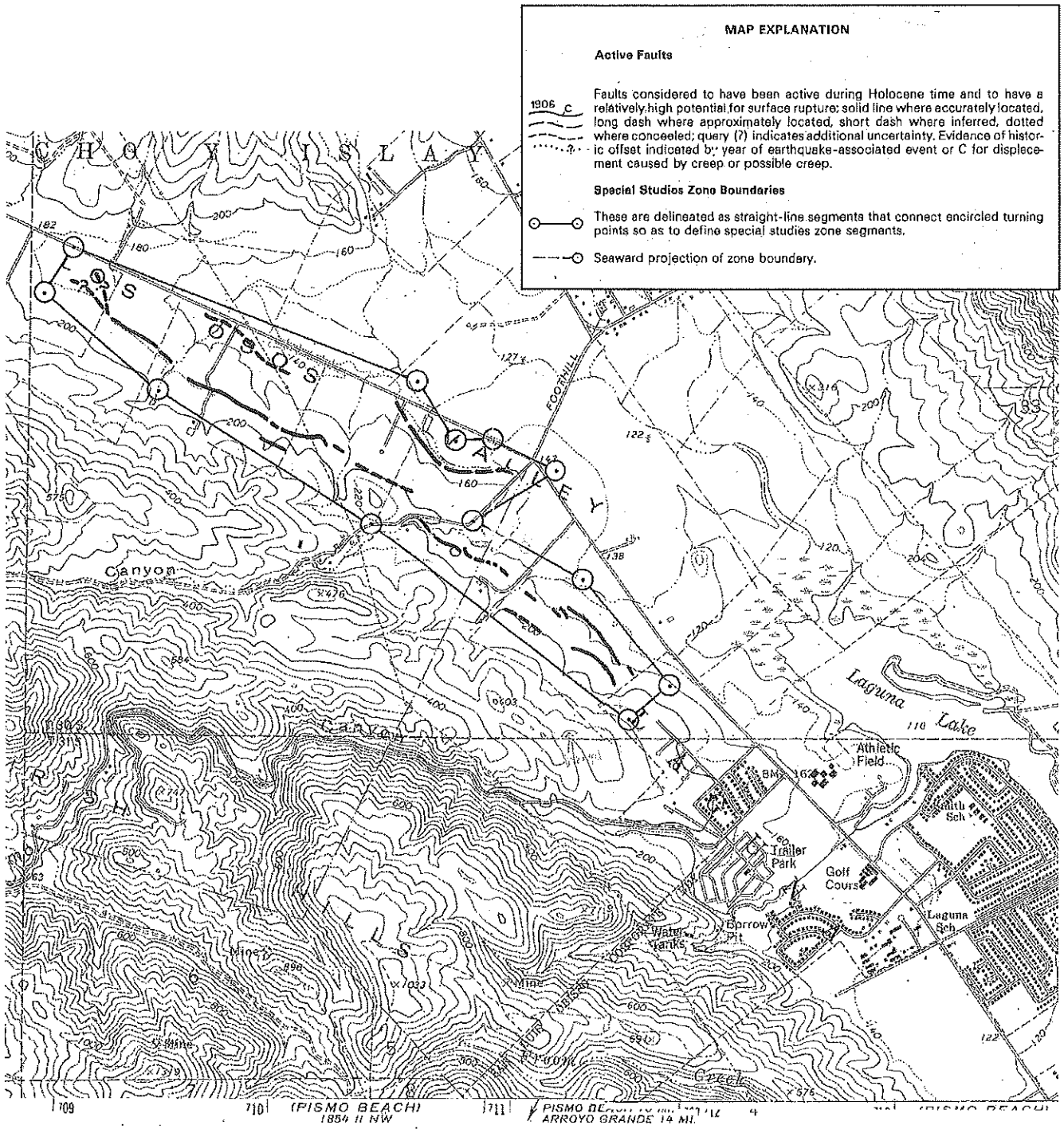
GOOGLE IMAGE WITH USGS KMZ FAULTING

Date: 2016
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
8

PROJECT NO:
SL09734-1



SCALE 1:24 000

½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

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EARTHQUAKE FAULT ZONES MAP

(STATE OF CALIFORNIA, JANUARY 1, 1990)
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
9

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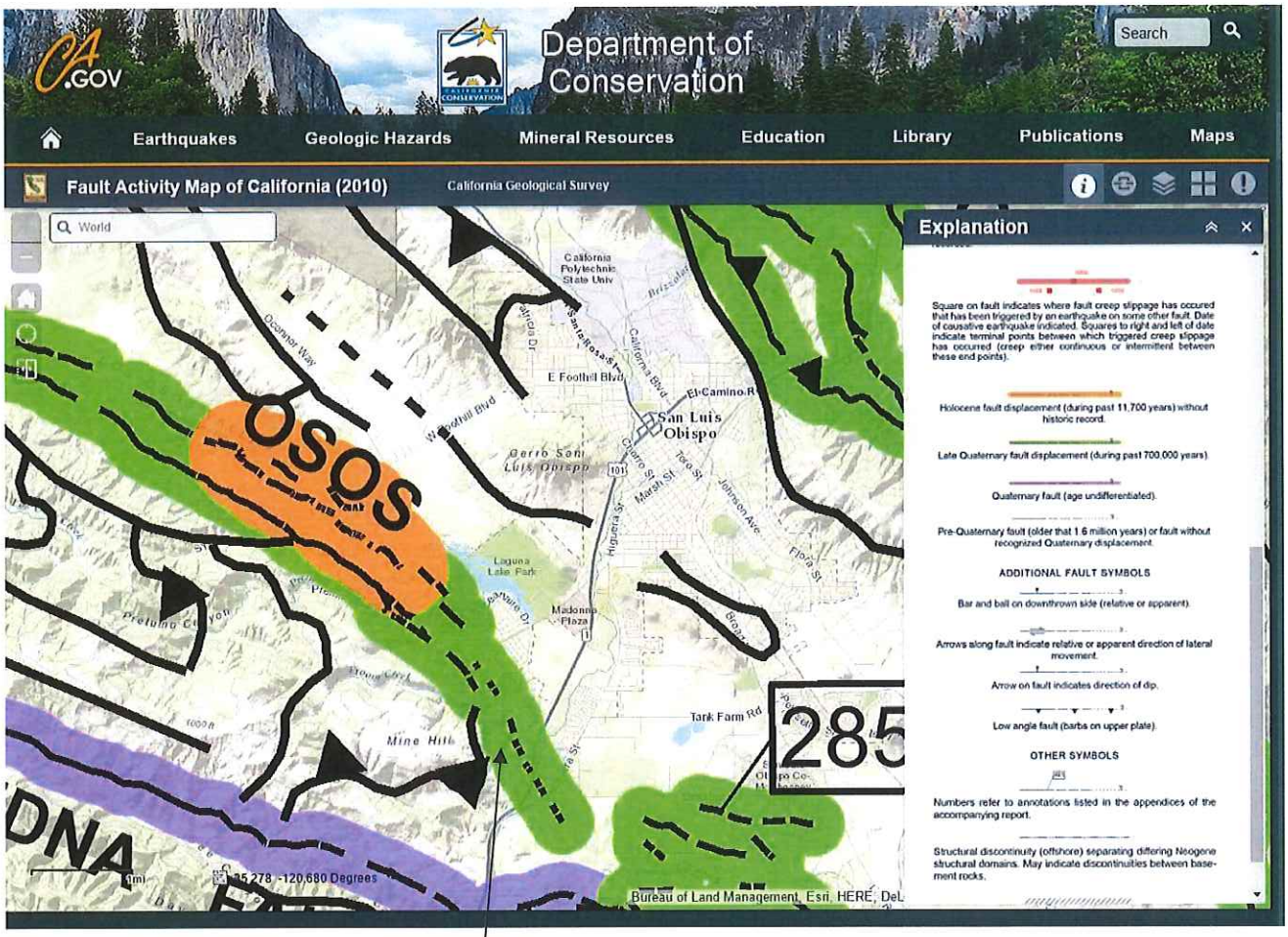
LiDAR Image 2011

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
10

PROJECT NO:
SL09734-1



SITE

NORTH

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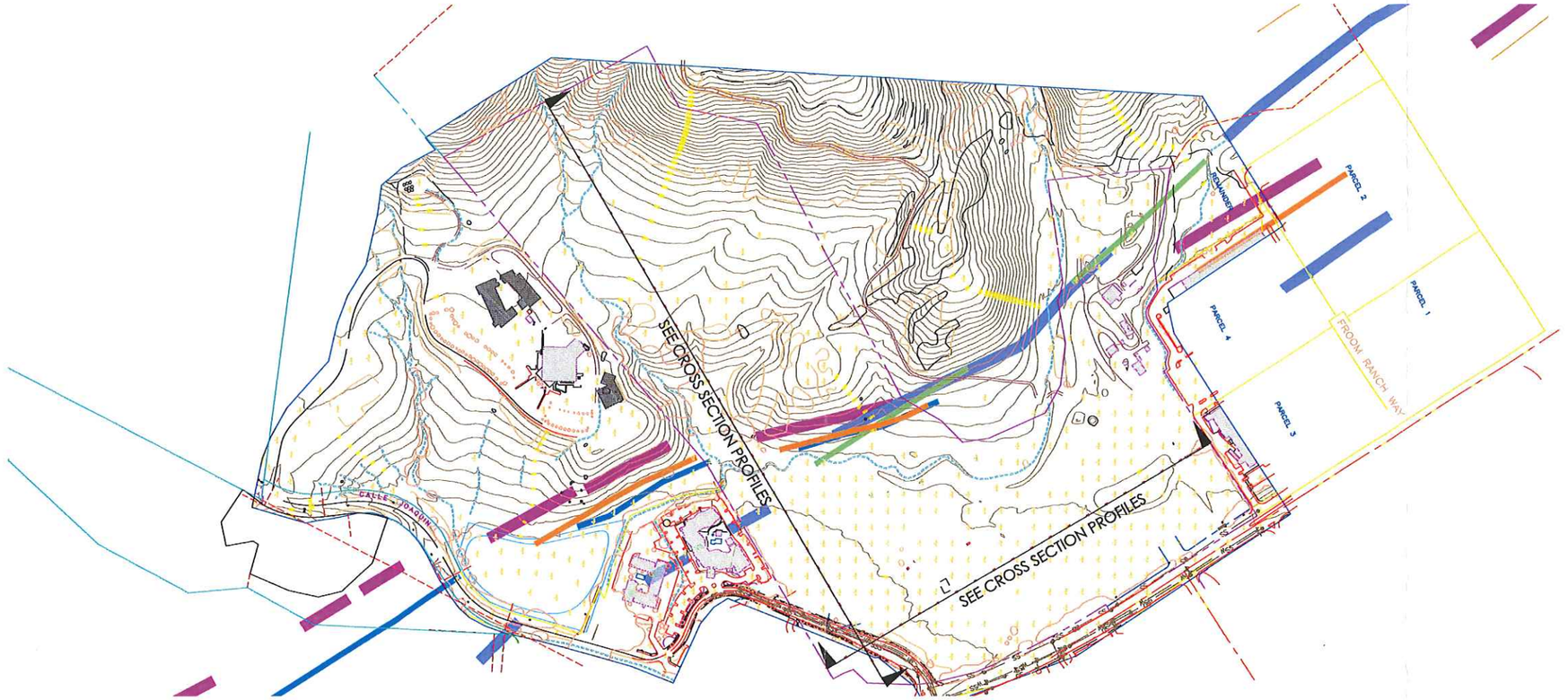
REGIONAL FAULT MAP AND EXPLANATIONS

Jennings, 2010
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
11

PROJECT NO:
SL09734-1



LEGEND

- Plate 3: Hall 1973
- Plate 4: PG&E 2014
- Plate 6: Wiegers, 2011
- Plate 7; Lettis & Hall, 1994
- Plate 8 - KMZ-USGS 2016

Froom Ranch

FROOM CREEK FAULT LINE EXHIBIT

SCALE: 1" = 250'

Exhibit
June 23, 2016

rrm design group

FAULT LOCATIONS AS APPROXIMATELY MAPPED BY OTHERS

RRM DESIGN, 2016
FROOM/EI VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
12

PROJECT NO:
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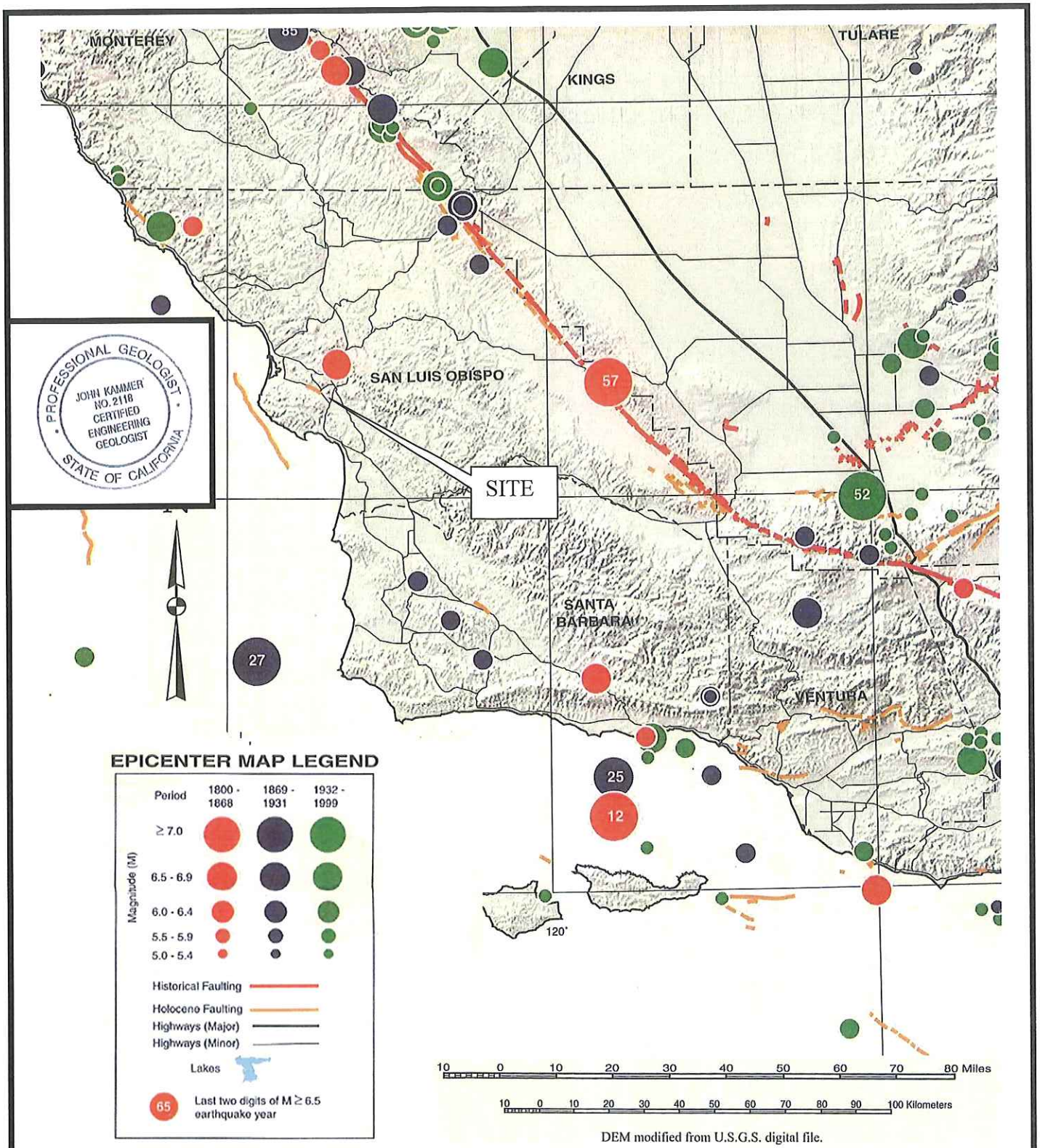

T. TOPPOZADA, D BRANUM, M PETERSEN, C HALLSTROM, C. CRAMER, M. REICHLE, 2000

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HISTORICAL SEISMICITY MAP

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
13A

PROJECT NO:
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Significant Earthquakes That May Have Affected the Site in the Last 200 Years

DATE			TIME (GMT)	LATITUDE	LONGITUDE	MAG	LOCATION
Year	mth	day	hr	(N)	(W)		
1812	12	21	19:00	34 12.00	119 54.00	7.0	Santa Barbara Channel
1830	?	?		35 3	120 6	5.0	San Luis Obispo area (?)
1853	2	1		35 6	121 1	5.0	San Simeon area (?)
1857	1	9	16:00	35 42.00	120 18.00	8.25	Great Fort Tejon earthquake
1866	7	15	06:30	37 30.00	121 18.00	6.0	W. San Joaquin Valley
1881	2	2	00:11	36 0.	120 30.00	5.75	Parkfield
1881	4	10	10:00	37 24.00	121 24.00	6.0	W. San Joaquin Valley
1882	3	6	21:45	36 54	121 12.	5.75	Hollister
1883	9	5	12:30	34 12.00	119 54.00	6.25	Santa Barbara Channel
1885	3	31		36 7	121 3	5.5	San Andreas Fault (?)
1885	4	2		36 8	121 4	5.4	San Andreas Fault (?)
1885	4	12		36 4	121 0	6.2	San Andreas Fault (?)
1892	4	21	17:43	38 30.00	121 54.00	6.25	Winters
1892	11	13		36 8	121 5	5.5	San Andreas Fault (?)
1892	11	13	12:45	36 48.00	121 30.00	5.75	Hollister
1897	6	20	20:14	37 0.	121 30.00	6.25	Gilroy
1899	7	22		34 2	117 4	5.5	San Andreas Fault (?)
1899	7	22		34 3	117 5	6.5	San Andreas Fault (?)
1901	3	3	07:45	36 0.	120 30.00	6.4	Parkfield
1901	3	3		36 0	120 5	5.5	Parkfield Area
1902	7	28		34 75	120 33	5.4	Los Alamos area
1902	12	12		34 76	120 37	5.0	Los Alamos area
1906	4	18	13:12	37 42.00	122 30.00	8.25	Great 1906 earthquake
1907	9	20		34 2	117 1	6.0	San Andreas Fault (?)
1910	3	11	06:52	36 54.00	121 48.00	5.8	Watsonville
1910	12	31		36 8	121 4	5.0	Hollister Area
1913	10	20		35 12	120 58	5.0	Arroyo Grande area
1915	1	20		34 73	120 23	5.8	Los Alamos area
1916	8	6		36 7	121 3	5.5	Paicines area
1916	10	23	02:44	34 54.00	118 54.00	5.3	Tejon Pass region
1916	10	23		34 6	118 9	6.0	Tejon Pass Area
1916	10	23		34 7	119 0	5.5	Tejon Pass Area
1916	12	1		35 18	120 73	5.0	Avila area
1917	7	9		35 25	120 48	5.0	Lopez Canyon area
1919	2	16		35 0	119 0	5.0	Tejon Pass Area
1922	3	10	11:21	6 0.	120 30.00	6.3	Parkfield
1922	3	10		35 75	120 25	6.5	Cholame Valley Area
1922	8	18		35 75	120 3	5.0	Cholame Valley Area
1925	6	29	14:42	34 18.00	119 48.00	6.3	Santa Barbara
1926	7	25		36 6	120 8	5.0	Idria area
1926	12	27		36 2	120 3	5.0	Coalinga area
1927	11	4	13:50	34 42.00	120 48.00	7.3	SW of Lompoc
1932	2	26		36 0	121 0	5.0	San Ardo area
1934	6	8	04:47	36 0	120 30.00	6.0	Parkfield
1934	6	5		35 80	120 33	5.0	Parkfield Area
1934	6	8		35 80	120 33	6.0	Parkfield Area
1934	12	24		35 93	120 48	5.0	Parkfield Area
1939	6	24		36 80	121 45	5.5	Hollister Area
1939	9	21		34 87	118 93	5.2	Cuddy Valley Area
1939	12	28		35 80	120 33	5.0	Parkfield Area

DATE			TIME (GMT)	LATITUDE	LONGITUDE	MAG	LOCATION
Year	mth	day	hr	(N)	(W)		
1941	7	1	07:50	34 22.00	119 35.00	5.9	Carpenteria
1951	7	29		36 58	121 18	5.0	Southeast of Mulberry
1952	7	21	11:52	35 0.	119 1.00	7.7	Kern County earthquake
1952	11	22	07:46	35 44.00	121 12.00	6.0	Bryson
1955	11	02		35 96	120 92	5.1	San Ardo area
1956	11	16		35 95	120 47	5.0	Southwest of Coalinga
1960	1	20		36 78	121 43	5.0	South of Hollister
1966	6	28	04:26	36 0.	120 30.00	6.0	Parkfield
1966	6	28		120 50		5.1	Parkfield Sequence
1966	6	28		35 95	120 50	5.5	Parkfield Sequence
1970	9	12		34 27	117 54	5.4	Lytle Creek Area
1971	2	9	14:00	34 25.00	118 24.00	6.5	San Fernando
1972	2	24		36 58	121 21	5.0	Southeast of Hollister
1980	5	29		34 94	120 78	2.1	Orcutt Frontal Fault
1981	9	4	15:50	33 40.00	119 7.00	5.9	N. of Santa Barbara Island
1982	10	25		36 32	120 52	5.4	New Idria area
1983	5	2	23:42	36 14.00	120 19.00	6.5	Coalinga
1983	7	22	00:23	36 14.00	120 25.00	5.7	Coalinga
1983	8	29		35 84	121 34	5.4	San Simeon area
1984	1	23		36 35	121 91	5.2	Point Sur area
1984	4	24	21:15	37 19.00	121 39.00	6.1	Morgan Hill
1985	8	4	12:10	36 8.00	120 10.00	5.9	North Kettleman Hills
1989	10	18	00:04	37 2.19	121 52.98	7.1	Loma Prieta
2003	12	22	19:16	35 41.98	121 5.84	6.5	San Simeon
2004	09	28	10:15	35 8.15	120 3.74	6.0	Parkfield

S:\Misc Drawings\Geology\locallargefaults.doc

S:\Misc Drawings\Geology\locallargefaults.doc

San Luis Obispo County Department of Planning and Building, December 1999) Safety Element

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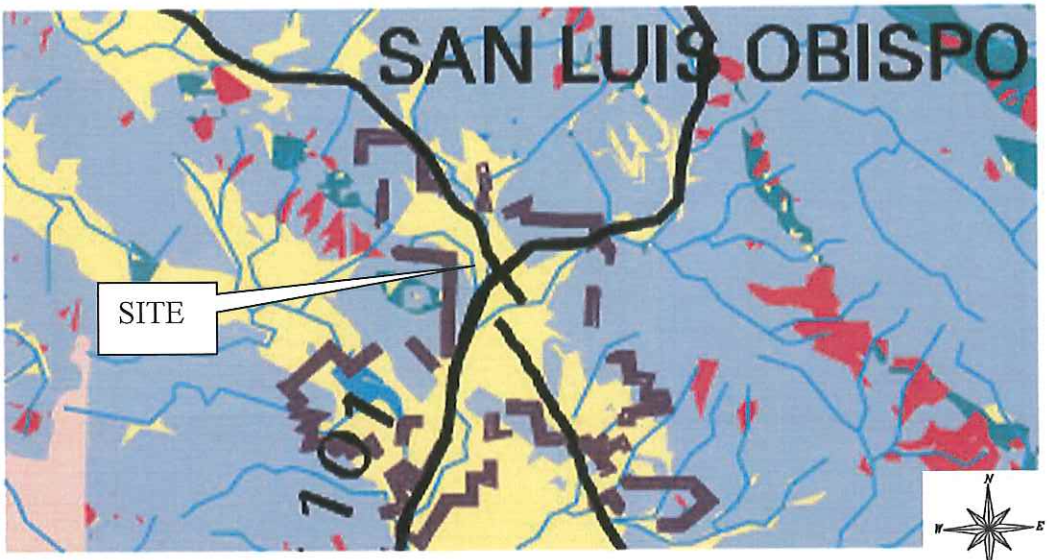
HISTORICAL SEISMCITY LIST

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
13B

PROJECT NO:
SL09734-1



SCALE" 5000'

0' **5000'**

- County Boundary
- City Boundaries
- Highways
- Rivers, Lakes, and Streams

LANDSLIDE POTENTIAL

- Very High — Existing Mapped Landslide (Qls, Qlsa)
- High Potential — Franciscan and Other Potentially Unstable Rocks (KJfme, KJfmv, KJt, KJfg, Tm, s, Tr, KJs, K) and/or Slope Gradient > 50%
- Moderate Potential — Formations Known to Have Localized Areas of Instability (QTp, Ka, K) and/or Slope Gradient > 20%
- Low Potential — Slope Gradient < 20%
- No Landslide Data

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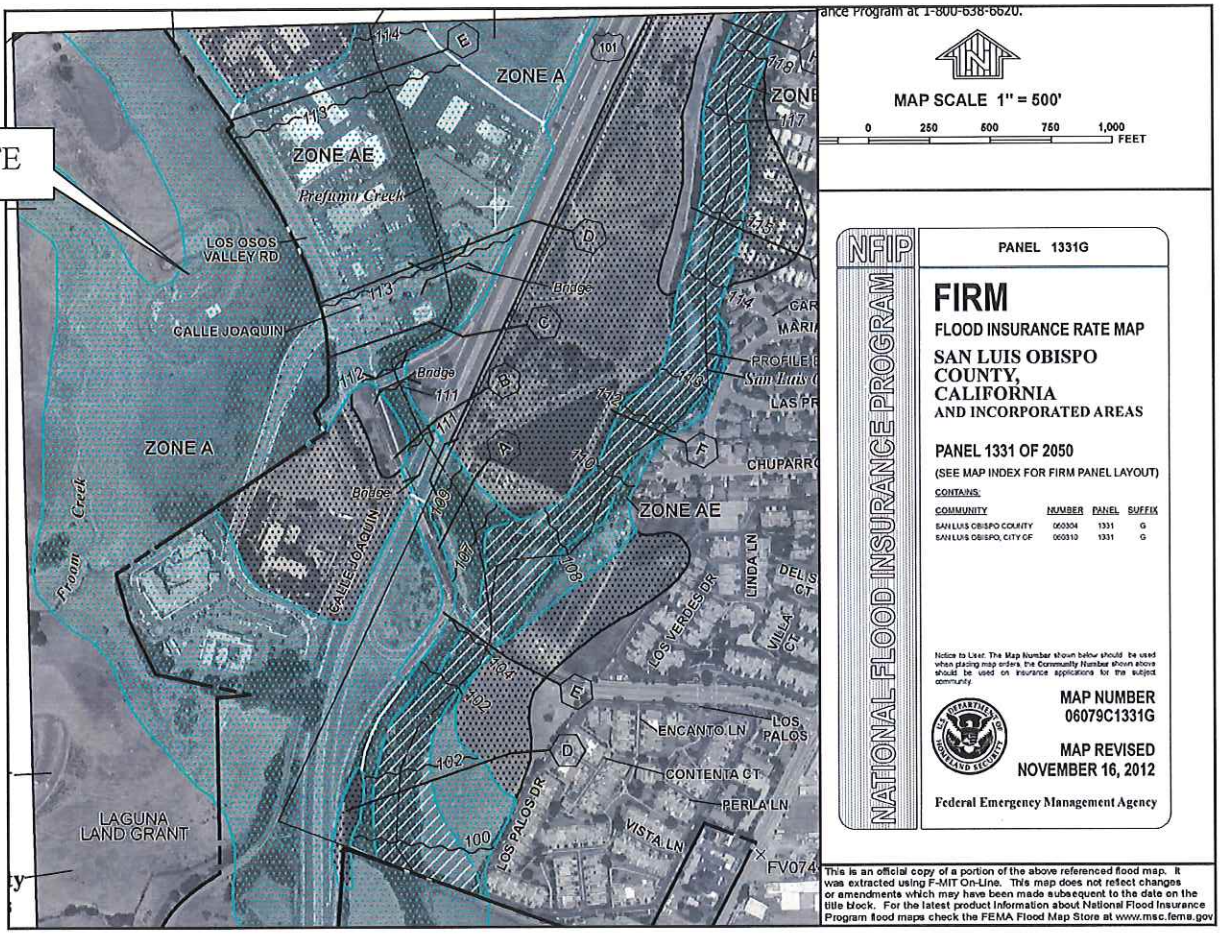
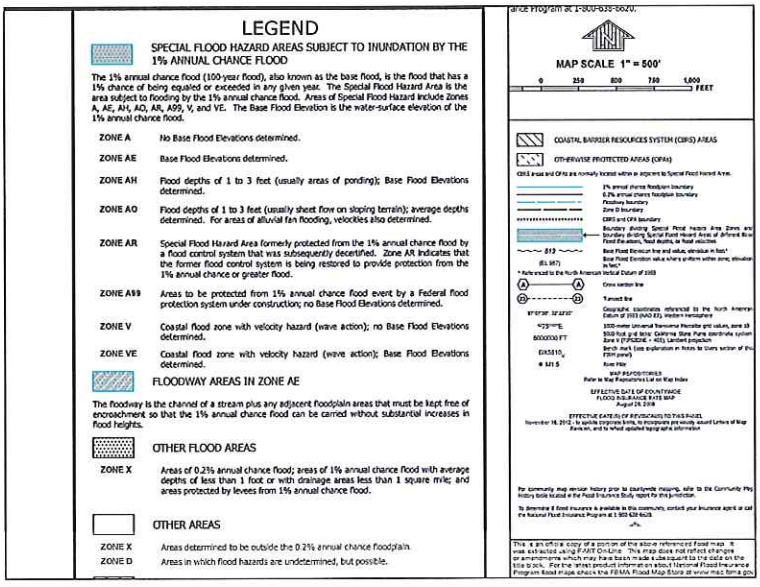
LANDSLIDE HAZARDS MAP

COUNTY OF SAN LUIS OBISPO DEPARTMENT OF BUILDING AND PLANNING, 1999
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
14

PROJECT NO:
SL09734-1





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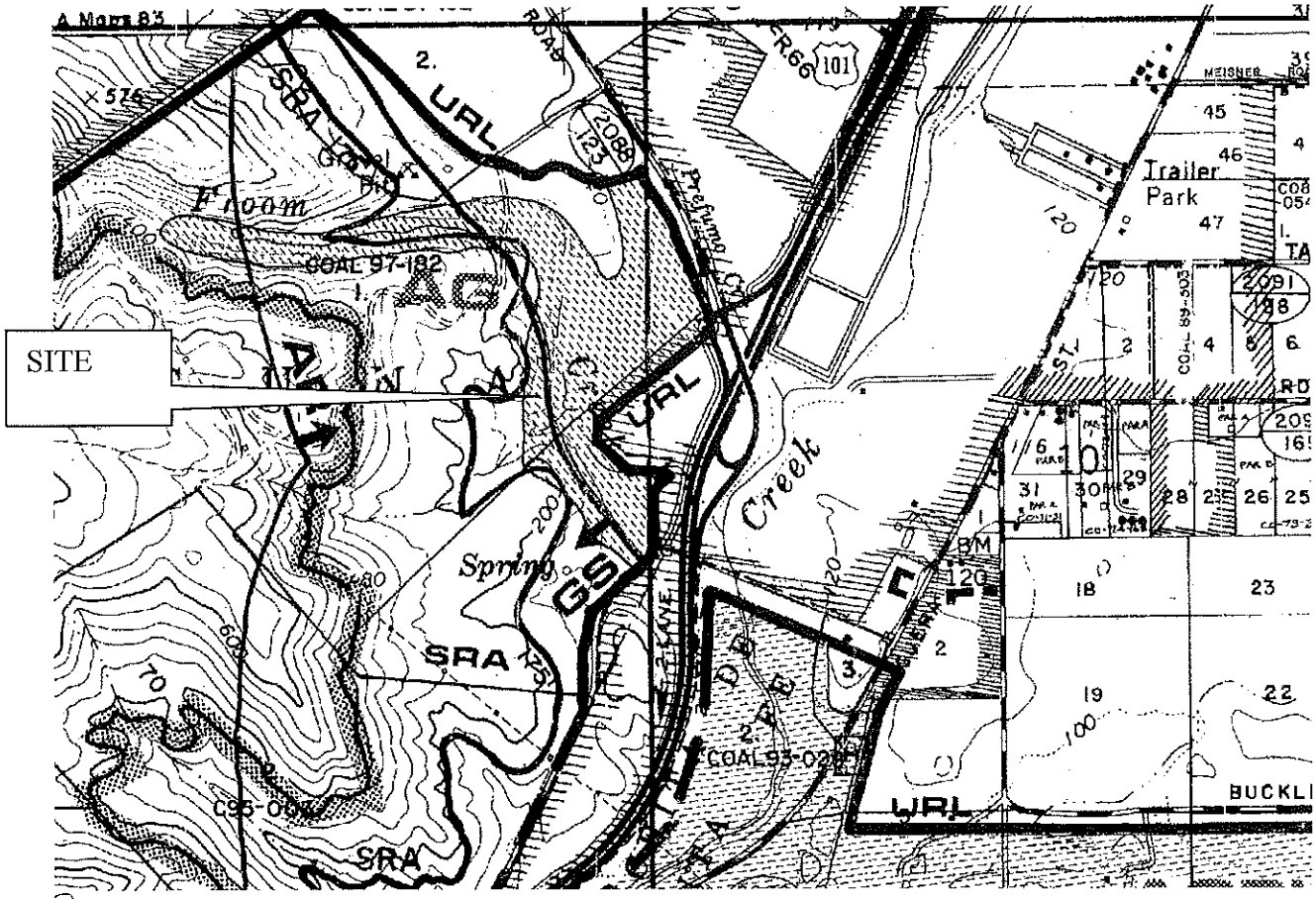
FLOOD INSURANCE RATE MAP

FEMA201985 AND EXPOLANATIONS
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
15

PROJECT NO:
SL09734-1



San Luis Obispo County Department of Building and Planning, 1996

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GEOLOGIC STUDY AREA MAP AND EXPLANTIONS

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
16

PROJECT NO:
SL09734-1

APPENDIX A

Boring logs

GST-# Trench logs

Fault Trench Logs

Laboratory Data

Asbestos Lab Results

Report – Soil Stratigraphic Assessments – Earth Consultants International

North Wall of Trench T-2a – Lettis Consultants International, Inc.

Photo Log of Trench T-2B North Wall - Lettis Consultants International, Inc.

Photo Log of Trench T-2A South Wall - Lettis Consultants International, Inc.

USGS Design Maps Summary Report

GeoSolutions, Inc.

220 High Street, San Luis Obispo, CA 93401
1021 West Tama Lane, Suite 105
Santa Maria, CA 93454

BORING LOG

BORING NO. **B-1**

JOB NO. **SL09734-1**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 18, 2016**	SAMPLING METHOD:	**SPT and CA**
LOGGED BY:	**GTV**	HOLE ELEVATION:	**Not Recorded**

▼ Depth of Groundwater: **Not Encountered** Boring Terminated At: **10.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	CLAYEY SAND: very dark grayish brown, dry	CH											
-1				A			28.7				107	79.6	31
-2	stiff			SPT	6	9							
-3	SANDY CLAY: dark brown, dry	CH											
-4													
-5	stiff			CA	8	8		110					
-6													
-7													
-8	stiff												
-9				SPT	9	9							
-10													
-11													
-12													
-13													
-14													
-15													
-16													
-17													
-18													
-19													
-20													

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BORING LOG

BORING NO. **B-2**

JOB NO. **SL09734-1**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 19, 2016**	SAMPLING METHOD:	**SPT**
LOGGED BY:	**GTV**	HOLE ELEVATION:	**Not Recorded**

▼ Depth of Groundwater: **4.0 Feet** Boring Terminated At: **46.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	CLAYEY SAND: very dark grayish brown, dry	CH											
-2	SANDY CLAY: dark brown, dry	CH											
-4	firm			SPT	5	7							
-6	SANDY CLAY: dark olive brown, very moist	CH											
-8	stiff			SPT	8	8							
-10	SANDY CLAY: black, very moist	CH											
-13	stiff			SPT	16	15							
-16	SANDY CLAY: dark olive brown, with gravel, coarse grained	CH											
-18	stiff			SPT	5	4							
-23													

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BORING LOG

BORING NO (cont). **B-2**

JOB NO. **SL09734-1**

▼ Depth of Groundwater: **4.0 Feet** Boring Terminated At: **46.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	(N) 60	FRICTION ANGLE (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINE CONTENTS	PLASTICITY INDEX (PI)
-25	SANDY CLAY: dark yellowish brown, saturated very stiff	CH		SPT	21	16							
-45	very sticky												
-46	FRANCISCAN COMPLEX: serpentinite & melange, meta volcanic, very weathered			SPT	50/1"								

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BORING LOG

BORING NO. **B-3**

JOB NO. **SL09734-1**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 18, 2016**	SAMPLING METHOD:	**SPT and CA**
LOGGED BY:	**GTV**	HOLE ELEVATION:	**Not Recorded**

▼ Depth of Groundwater: **1.5 Feet** Boring Terminated At: **10.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	FAT CLAY: very dark grayish brown, dry	CH		B							186	94.7	48
-1													
-2	firm			SPT	4	6							
-3	SANDY CLAY: dark olive brown, very moist	CH											
-4													
-5	firm			CA	6	6							
-6													
-7													
-8	soft												
-9				SPT	2	2							
-10													
-11													
-12													
-13													
-14													
-15													
-16													
-17													
-18													
-19													
-20													

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BORING LOG

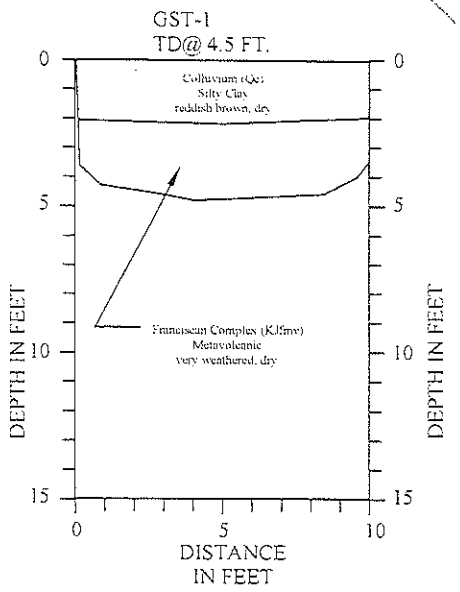
BORING NO. **B-4**

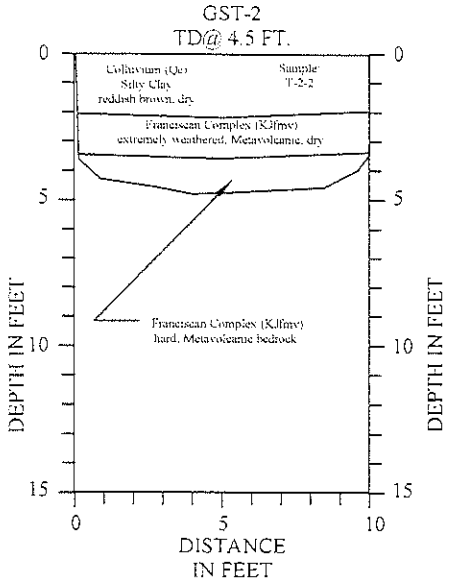
JOB NO. **SL09734-1**

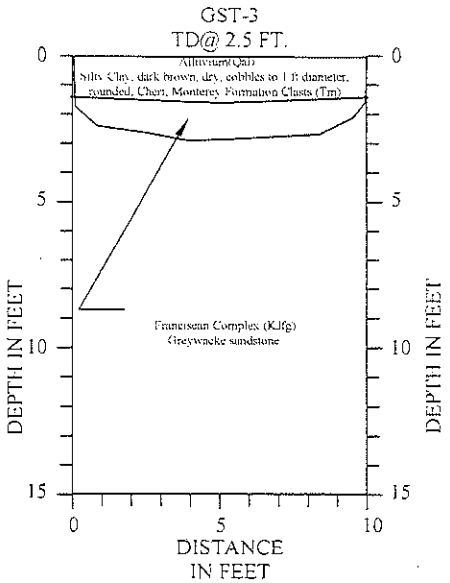
PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 18, 2016**	SAMPLING METHOD:	**CA and SPT**
LOGGED BY:	**GTV**	HOLE ELEVATION:	**Not Recorded**

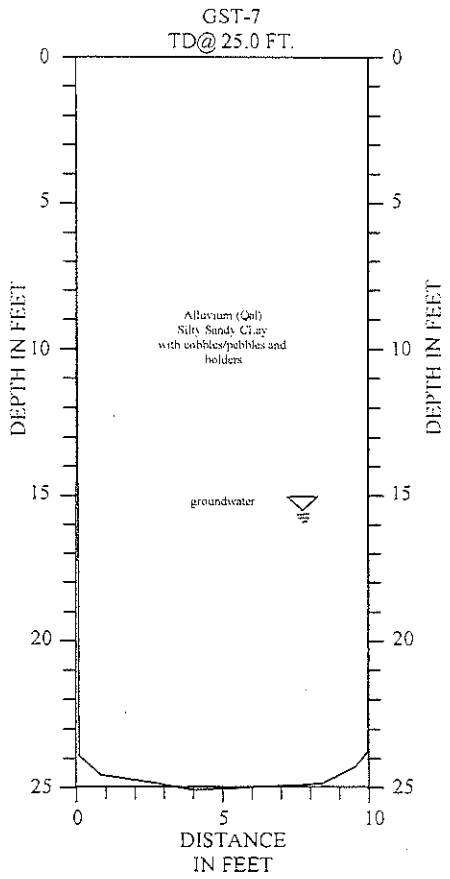
▼ Depth of Groundwater: **2.5 Feet** Boring Terminated At: **10.0 Feet**

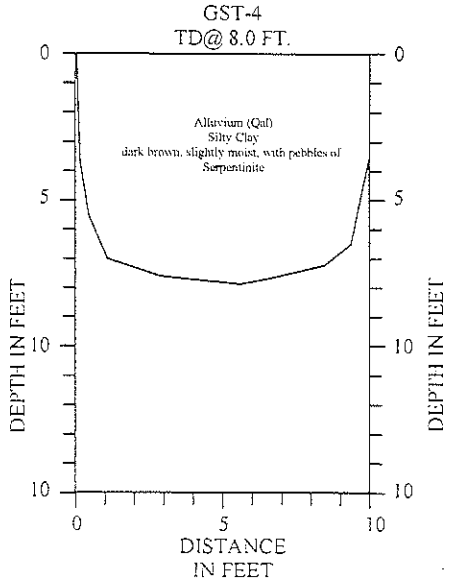
DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	CLAYEY SAND: very dark brown, very moist	CH											
-1	soft												
-2													
-3													
-4													
-5	SANDY CLAY: dark brown, very moist	CH		CA	3	3							
-6													
-7													
-8													
-9	firm			SPT	6	6							
-10													
-11													
-12													
-13													
-14													
-15													
-16													
-17													
-18													
-19													
-20													

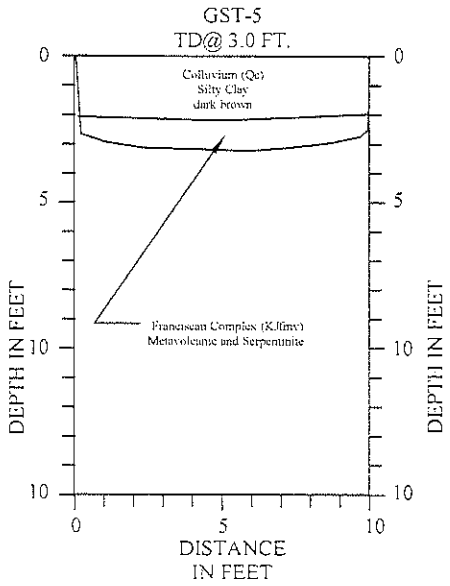


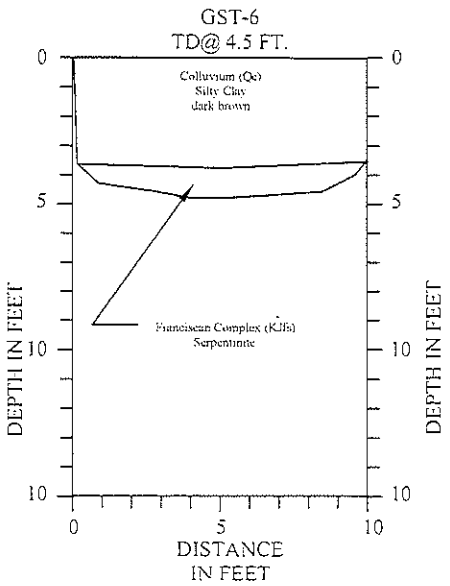












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STATE OF CALIFORNIA

TRENCHING LOGS

MADONNA - FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

LOGS
1

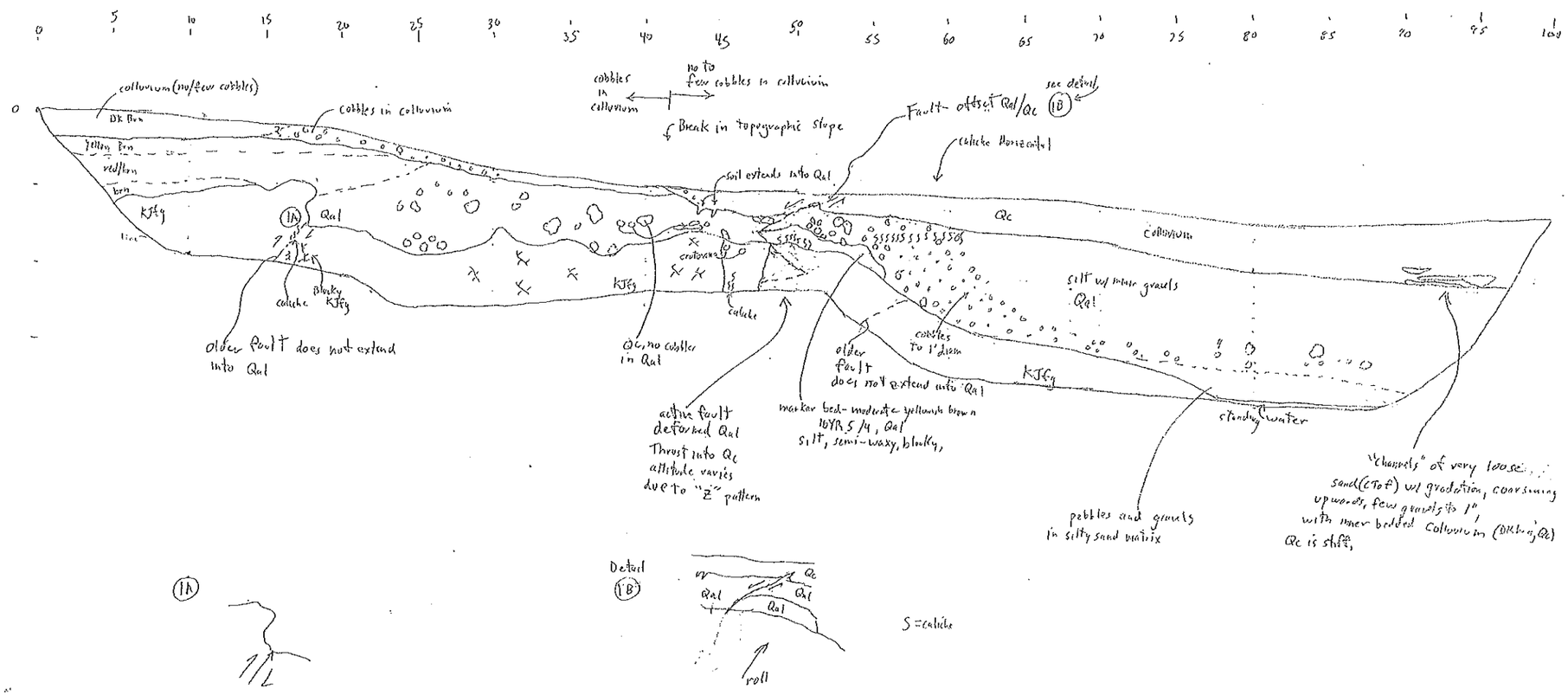
PROJECT
SL09734-1

T1-A

→ N89E

View of North wall

SCALE IN FEET



1A

Detail 1B

S = caliche

TRENCH T1-A

Notes- Fault at 50-55' offset Qal and Qc

- on both sides of trench- offset Qal and Qc at this location

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
- Contact between units
- Fault with arrows showing movement direction, dashed where sheared
- Cobbles
- Pebbles and gravel, coarse sand
- Fractures
- Caliche

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TRENCH LOG T1-A

A

1" = 5'

T1-B

NW wall

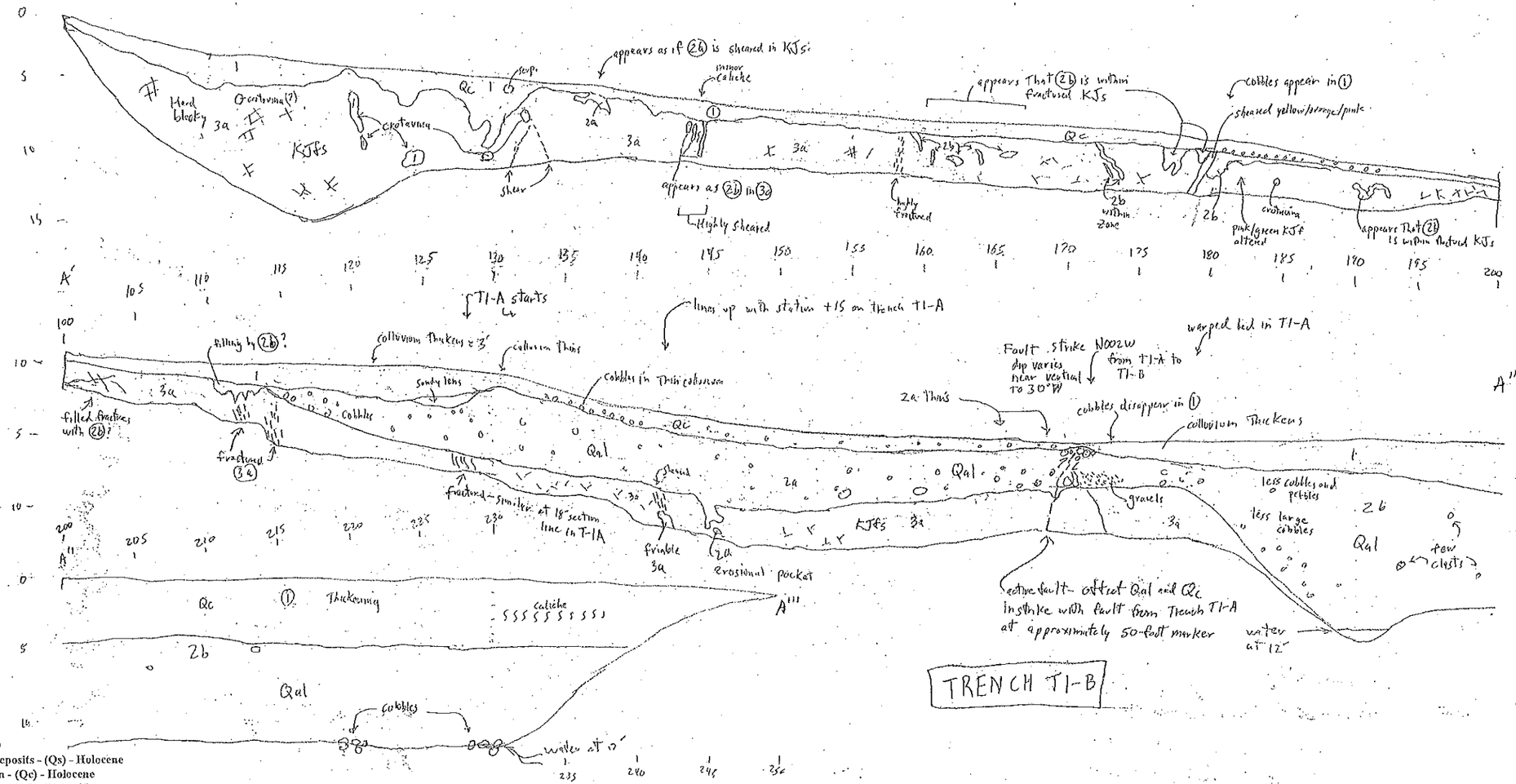
N75E

Fault Trenching - FROOM RANCH

A'

SCALE IN FEET

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100



TRENCH T1-B

LEGEND

Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic

——— Contact between units
T/L Fault with arrows showing movement direction, dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
SSS Caliche

(1) - colluvium - Dark brown, silty clay, few cobbles, Qc
(2a) - older Alluvium - silty sandy clay with pebbles, cobbles, boulders to 2' diam, rounded to subrounded, clasts are Franciscan complex, Qal
(2b) - older Alluvium - silty clay with minor cobbles and pebbles, Qal
(3) - Franciscan complex, KJfm/s
3a - serpentinite
3b - metavolcanic
3c - greywacke/melange

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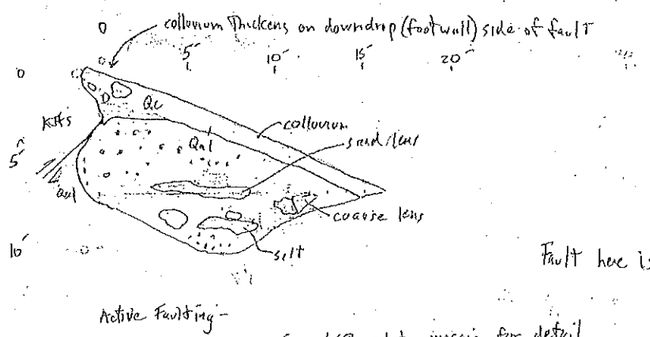
TRENCH LOG
T-1B

T-2A

SCALE IN FEET



Fault here is N 20W/14W

Active Faulting -

See LCI photo mosaic for detail

Trench T-2A

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
— Contact between units
Fault with arrows showing movement direction
dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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TRENCH LOG
T2-A

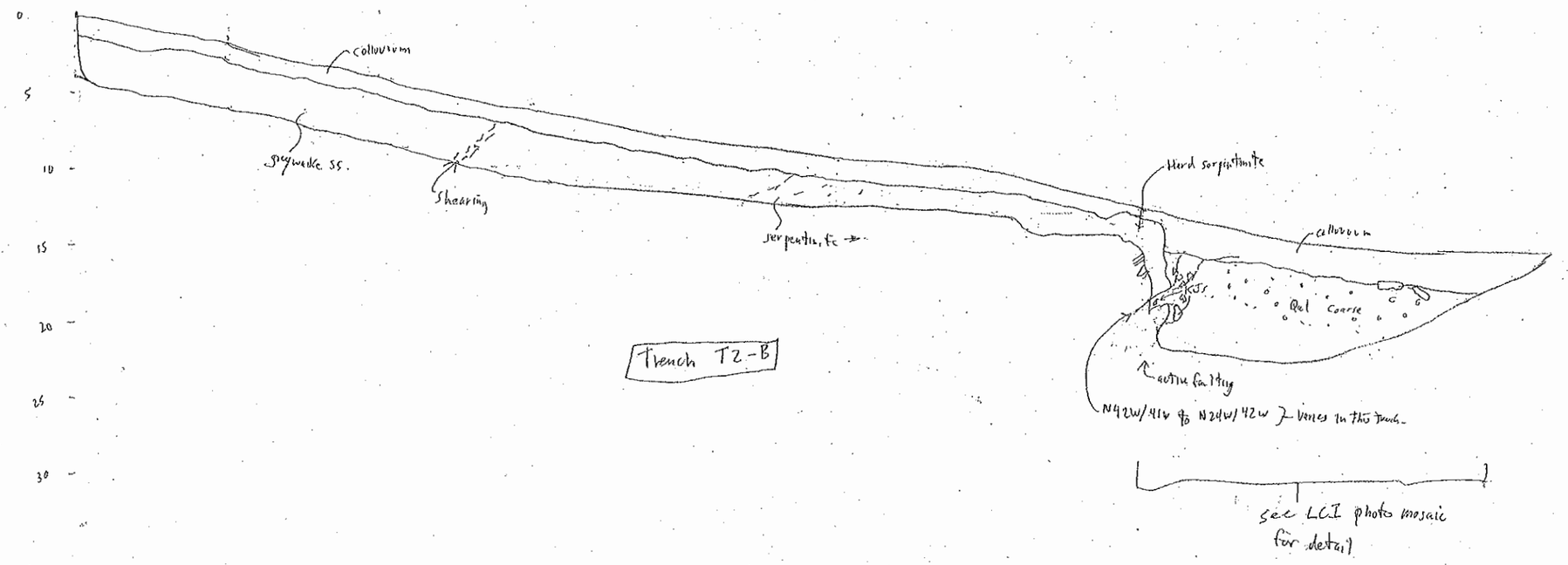
T2-B

N70E →

North wall

SCALE IN FEET

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100



Trench T2-B

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
——— Contact between units
Fault with arrows showing movement direction dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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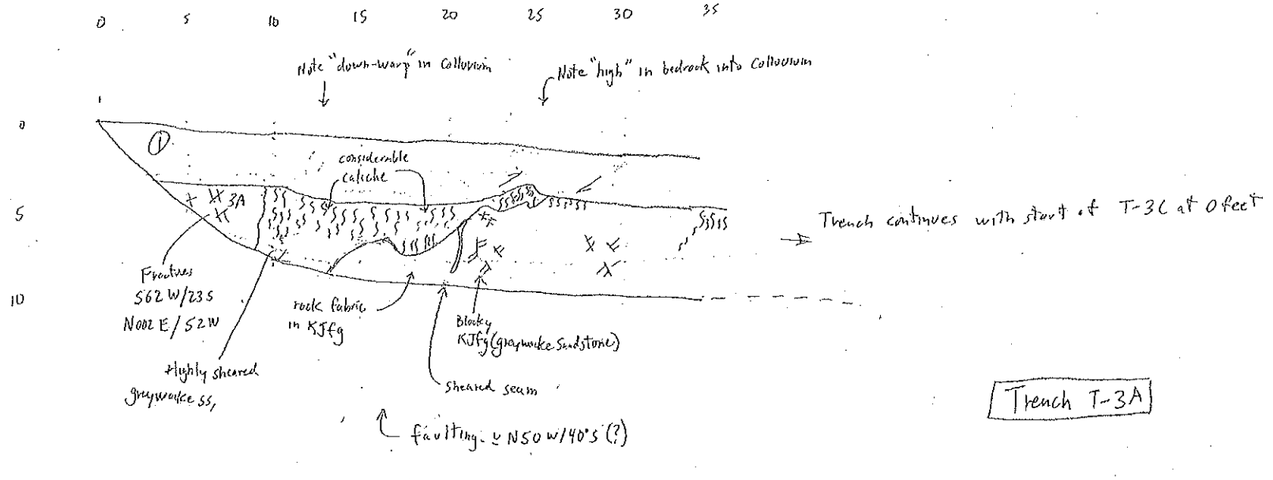
TRENCH LOG T2-B

Trench T-3A

N54E →

SCALE IN FEET

0 5 10 15 20 25 30 35



Trench T-3A

This area coincides with Fault in Trench T-3B

apparent

← Fault Zone →

Notes- Bedrock "High" suggests recent fault displaces Franciscan complex and overlying colluvium
- Bedrock underlying colluvium - no alluvium
- fault appears as Thrust (Reverse)

S = caliche

① - Colluvium -

② - not in Trench - Older Alluvium

③ Franciscan Complex -
3A - Blocky
3B - Pale Olive 10Y 6/2

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, grewacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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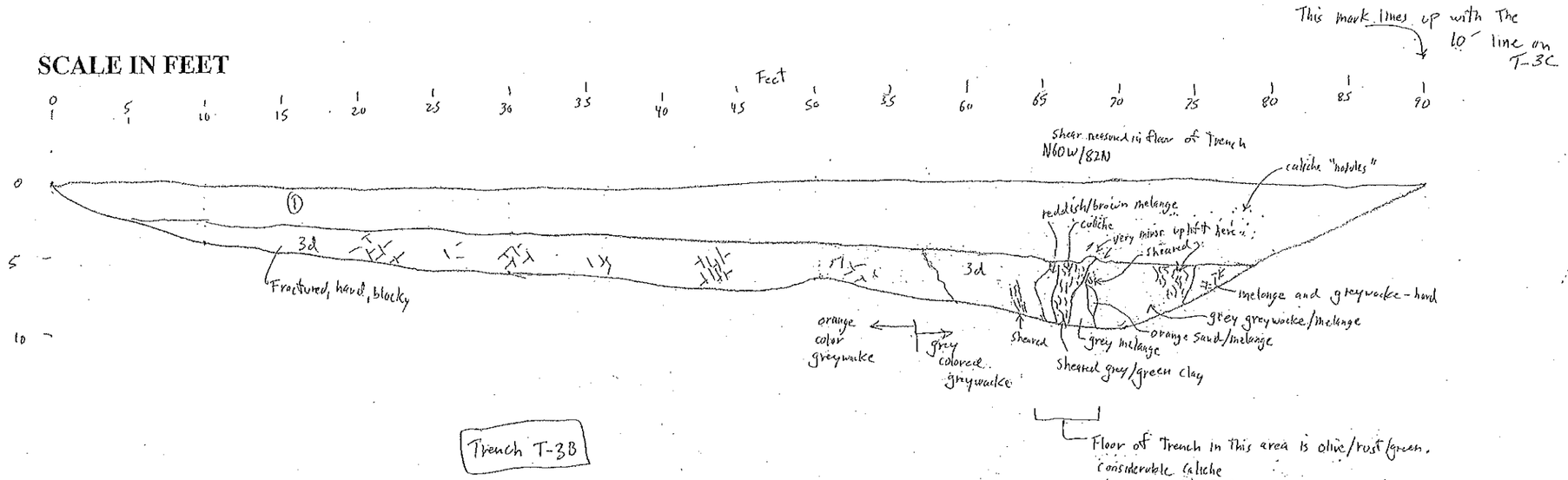
TRENCH LOG T3-A

T-3B N55E Trench

This mark lines up with the 10' line on T-3C

SCALE IN FEET



Trench T-3B

Floor of Trench in this area is olive/rust/green.
Considerable caliche
Sheared, weak, friable,
From floor of Trench, attitude of shear zone is N60W/82N;
Movement is apparent only on west side of fault in Trench floor

① - colluvium - Dark gray 10YR 4/1 - clay, v. stiff

② Franciscan Complex

3d - greywacke sandstone, blocky

Notes –
1) only Franciscan complex overlain by colluvium, No alluvium
2) Fault orientation in bottom of Trench.
3) Very minor uplift of KJfg with colluvium at station 68 feet
4) Fault is dying south of here compared to north into T-3A
5) bedrock dives deep south of here due to creek

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction, dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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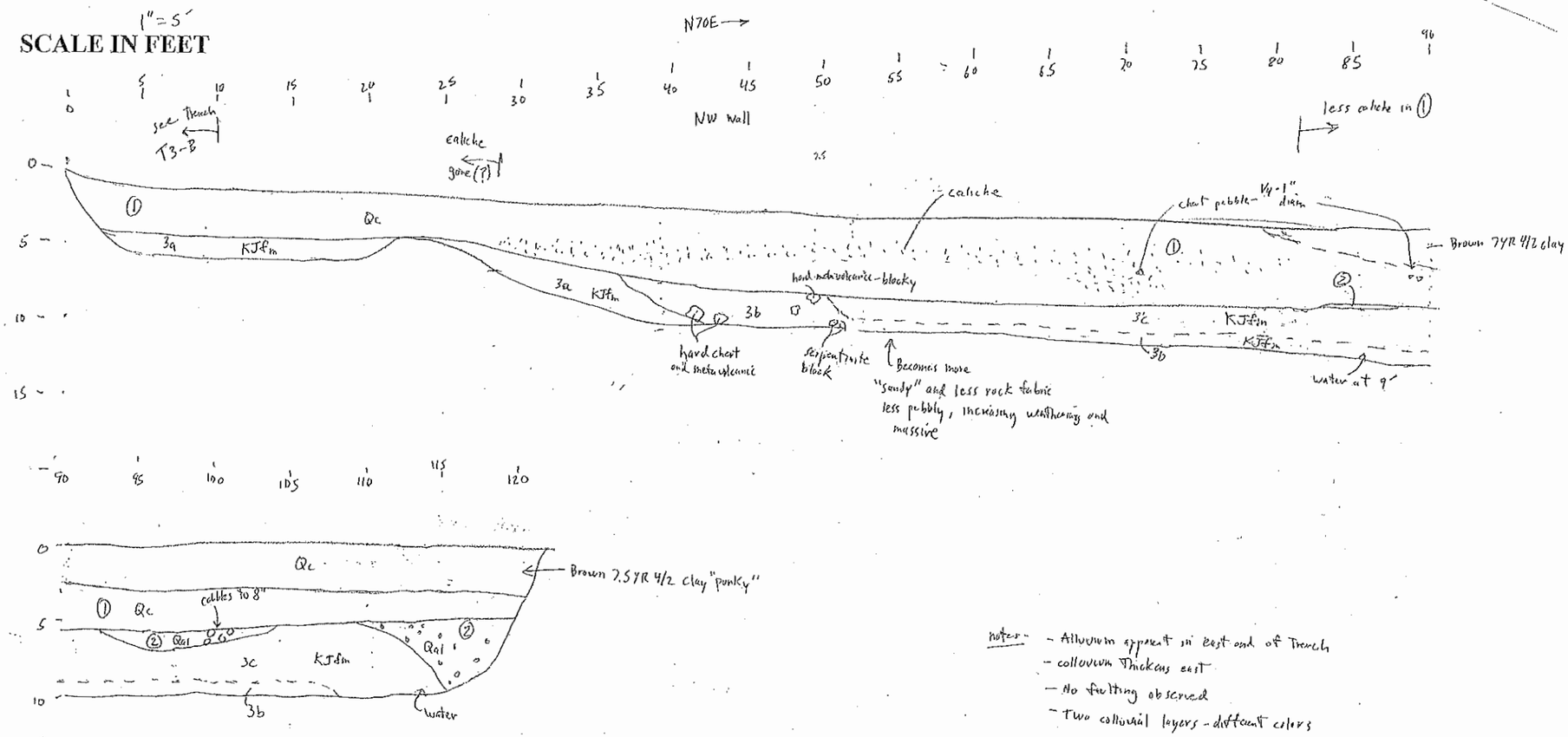
TRENCH LOG T3-B

Fault TRENCH T3-C

SCALE IN FEET 1"=5'



notes -
- Alluvium apparent at east end of Trench
- colluvium thickens east
- No faulting observed
- Two colluvial layers - different colors

Trench T3-C

(1) - Olive Black 5YR2.5/1 silty clay - Colluvium - dry, deep dessication cracks to 3.5 feet, caliche "nodules", very stiff

(2) older Alluvium - clay, sand, silt, pebbles, cobbles - Monterey Fm clasts, red sandstone, serpentinite, rounded to semi-rounded, altered basalt, matrix is Pale Yellow (5Y 7/3) to Brownish Yellow (10YR 6/6).

(3) Franciscan Complex -

(3a) greywacke/melange - yellowish gray 5Y7/2 hard, rock fabric.

(3b) - melange/greywacke - yellowish gray 5Y 7/2 slight "pebbly" appearance, faint rock fabric, moderately hard.

(3c) greywacke/melange - yellowish gray 5Y 7/2 weathered, soft,

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
— Contact between units
Fault with arrows showing movement direction, dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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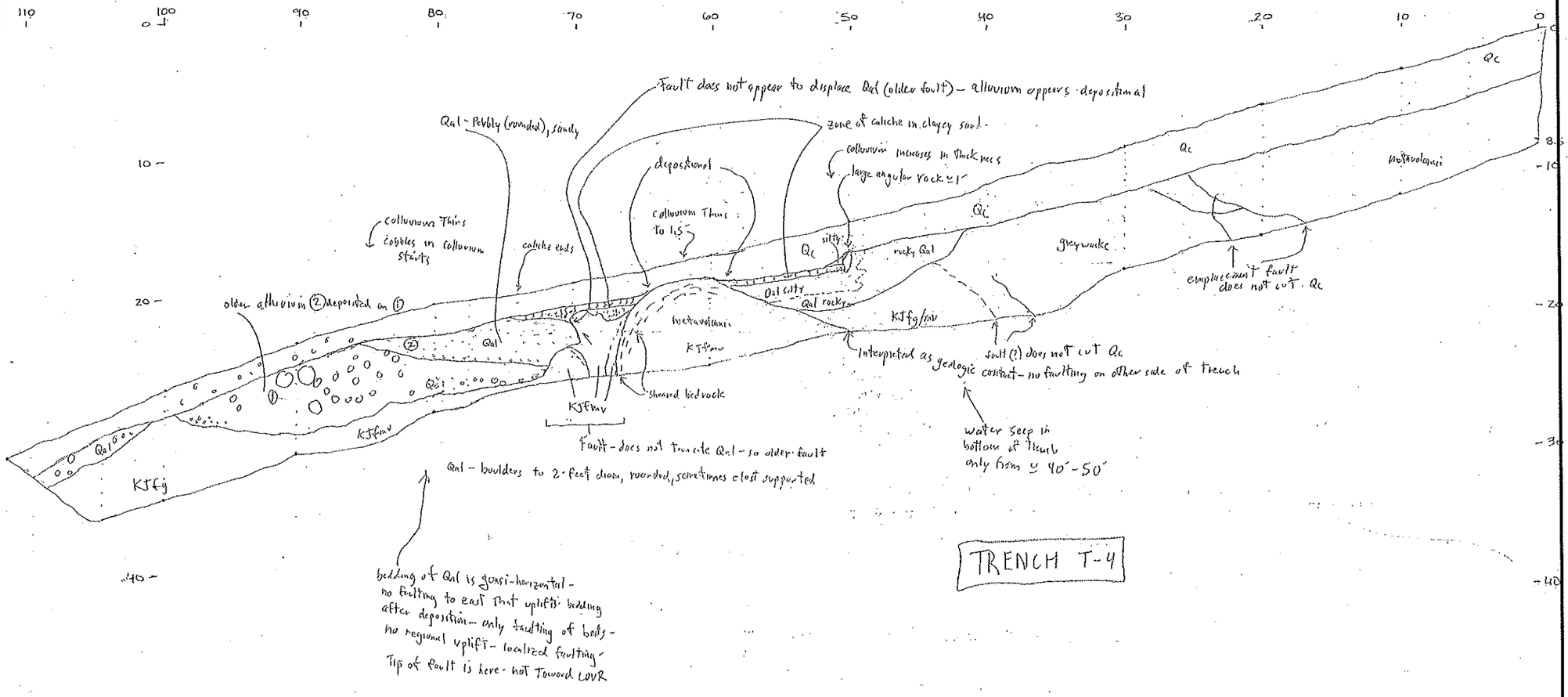
TRENCH LOG T3-C

T-4 South wall
Trench N58W orientation

SCALE IN FEET



TRENCH T-4

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic
melange, grewacke sandstone, serpentinite, metavolcanic
Contact between units
Fault with arrows showing movement direction
dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

Notes
- 1 event of faulting - one older (does not cut Qal), ~70°
- That main faulting is here in trench, not in flats of Trench (no tilting of Qal) - eastern limits found -
- striations on bedrock, N33E ~ 55° in trench

Bedding of older Qal semi Horizontal - no faulting east of here that would indicate more uplift east.

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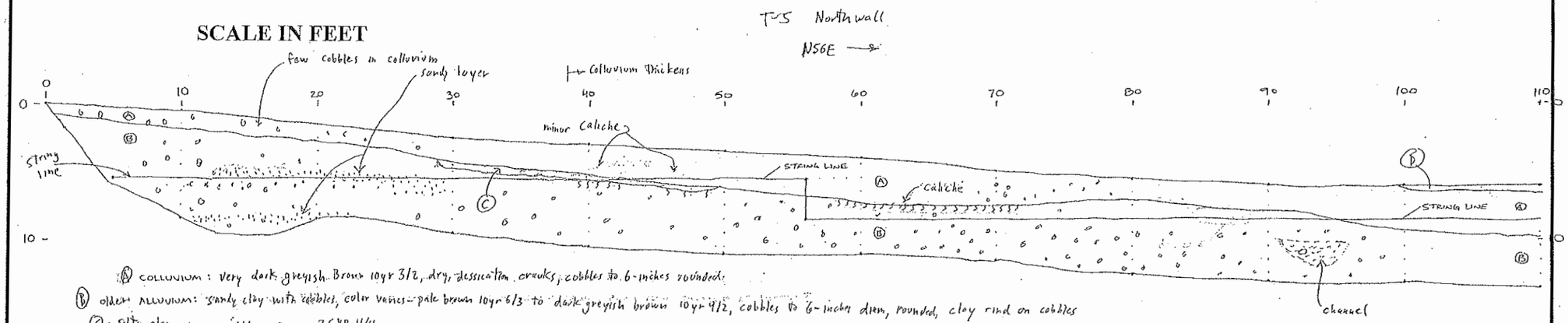
TRENCH LOG
T-4

T-5 Northwall

N56E →

SCALE IN FEET

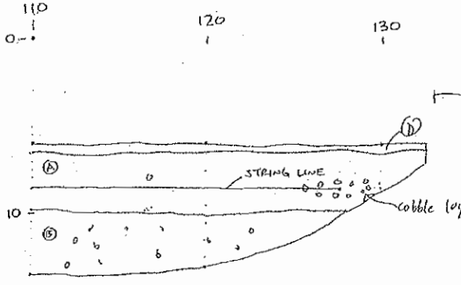


Ⓐ colluvium: very dark greyish Brown 10yr 3/2, dry, dessication cracks, cobbles to 6-inches rounded.

Ⓑ older alluvium: sandy clay with cobbles, color varies - pale brown 10yr 6/3 to dark greyish brown 10yr 4/2, cobbles to 6-inches diam, rounded, clay rind on cobbles

Ⓒ - silty clay - minor pebbles - Brown 7.5YR 4/4

Ⓓ - recent stream - overbank deposits, gravel and cobbles in loose sand, light yellowish brown 10YR 6/4



Notes- No fault seen
- Horizontal units
- older alluvium - clay rinds on clasts, red soil in Ⓒ

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
- Contact between units
- Fault with arrows showing movement direction, dashed where sheared
- Cobbles
- Pebbles and gravel, coarse sand
- Fractures
- Caliche

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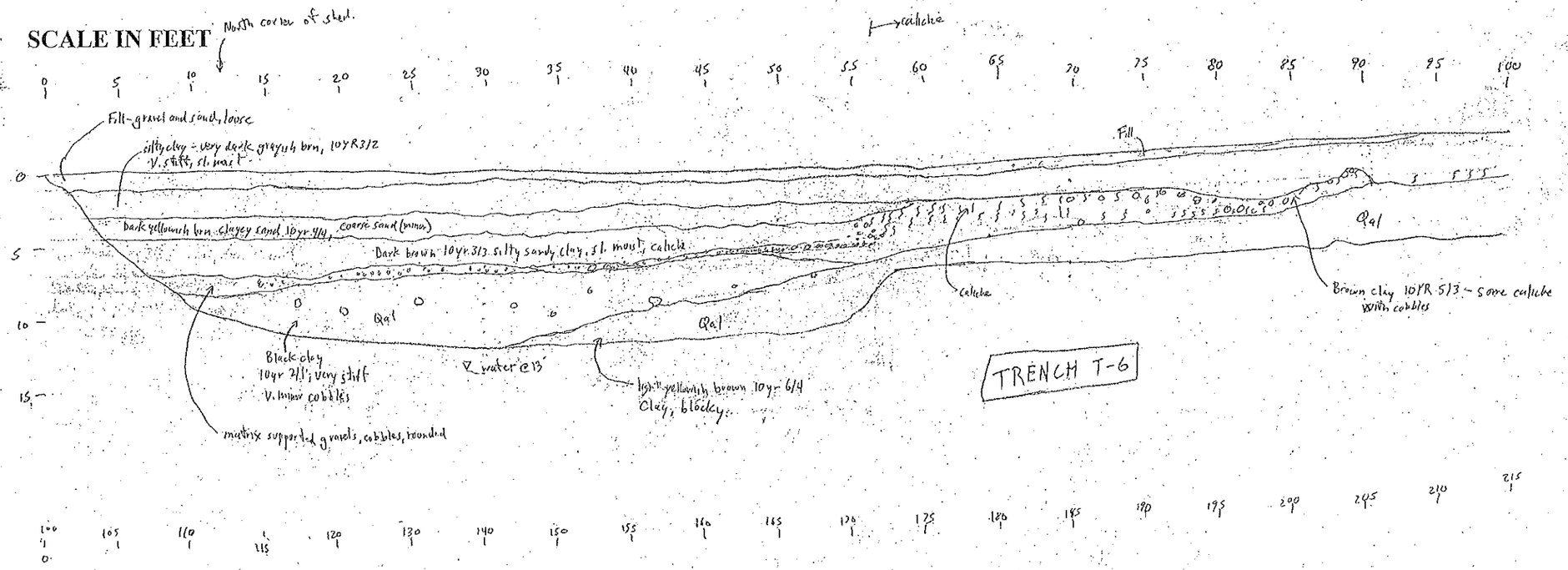
TRENCH LOG
T-5

T-6

South wall

← N58°E

SCALE IN FEET



LEGEND

Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, grewacke sandstone, serpentinite, metavolcanic

—— Contact between units
Fault with arrows showing movement direction, dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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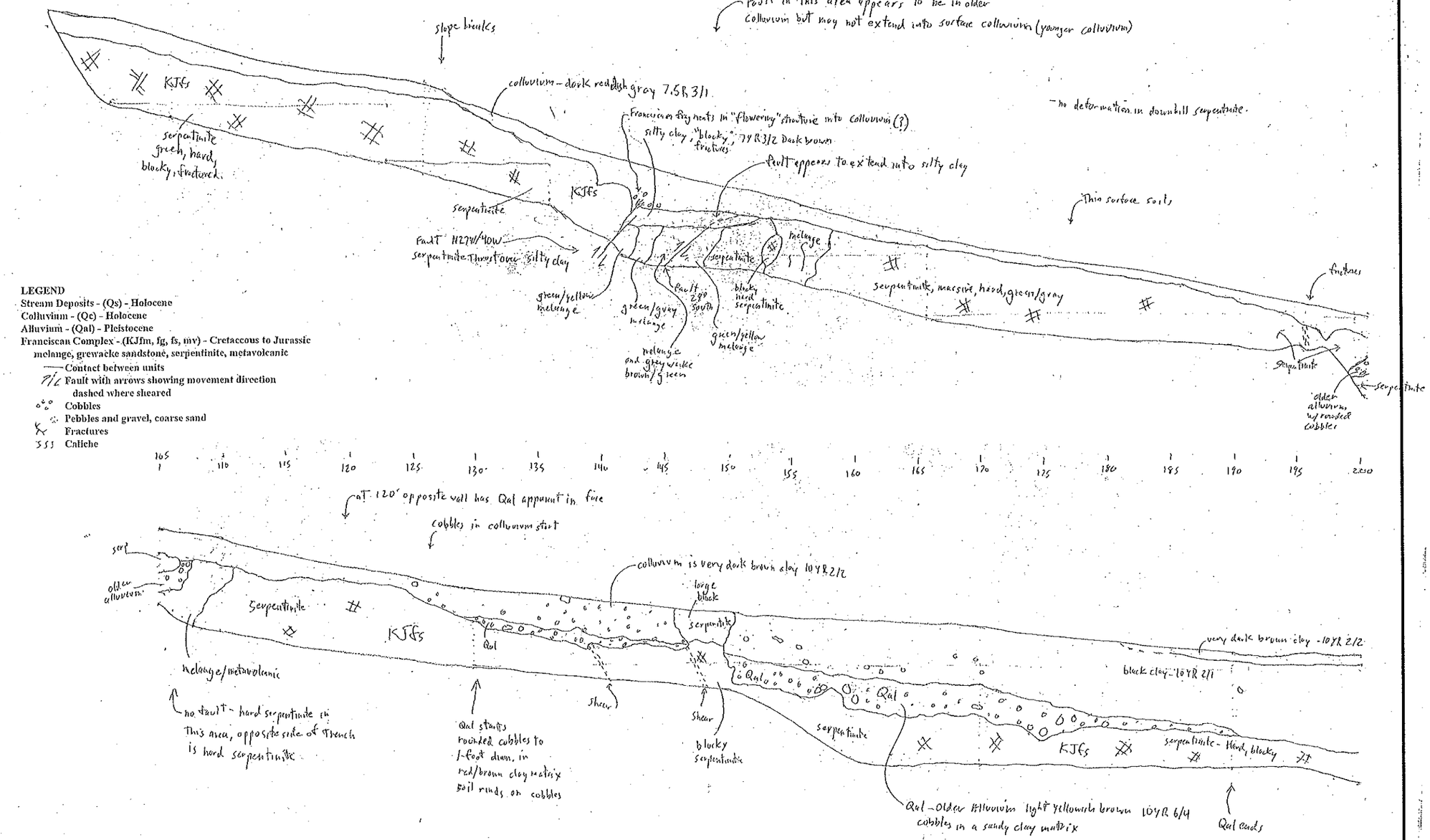
TRENCH LOG T-6

North wall T-7 N63E→

SCALE IN FEET

Feet: 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105



Feet: 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200

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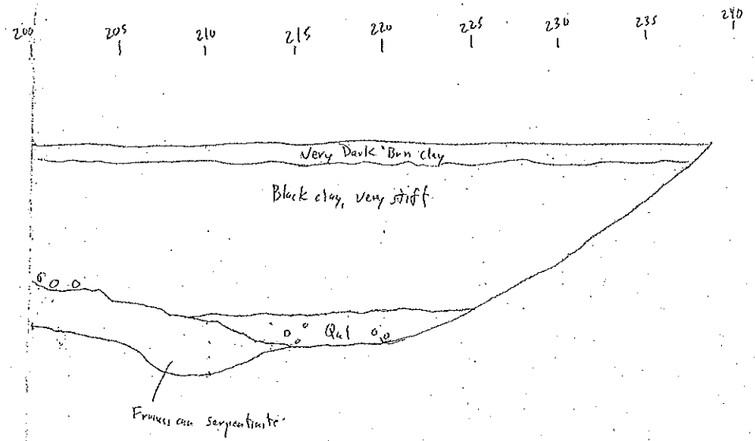
TRENCH LOG T-7

T-7 (continued)

SCALE IN FEET



LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
Contact between units
Fault with arrows showing movement direction dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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TRENCH LOG
T-7

T-8 adjacent to property corner

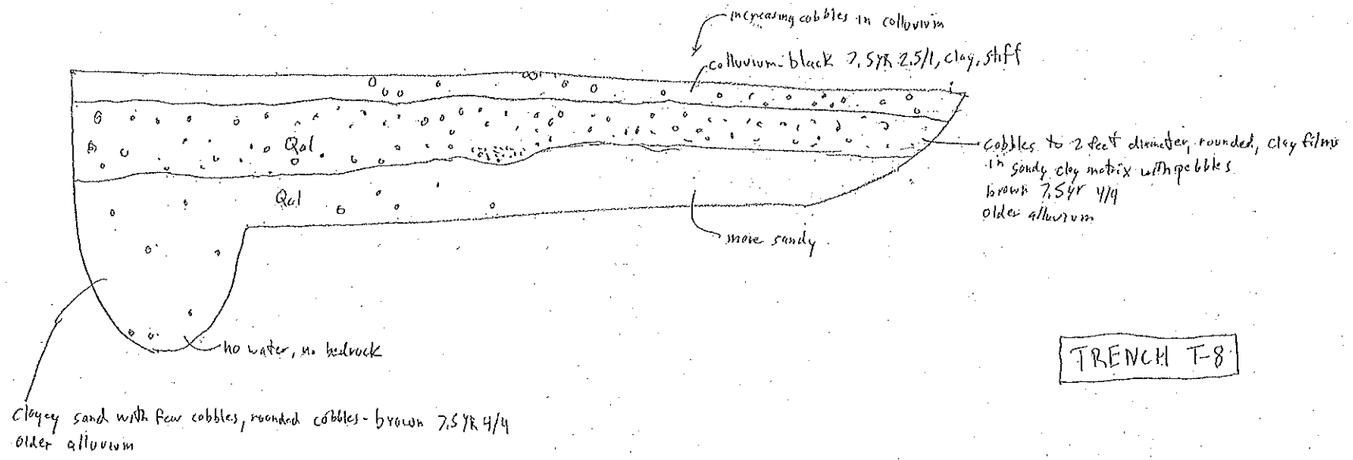
N38E →

1698

property corner

SCALE IN FEET

0 5 10 15 20 25 30 35 40 45 50



TRENCH T-8

Notes: - No faulting characteristics
- excavated to clear homes to North/Northeast along property line

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction, dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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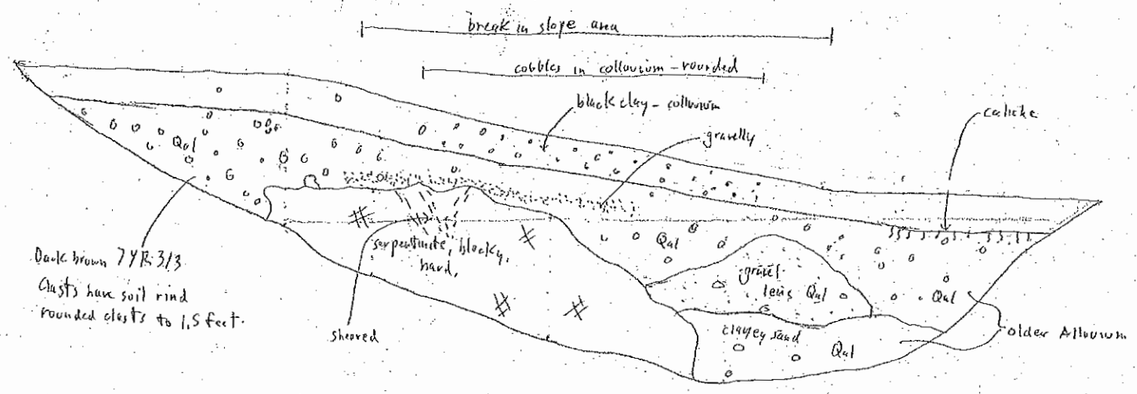
TRENCH LOG T-8

T-9 between T1A + T-8

N75E →

SCALE IN FEET

0 5 10 15 20 25 30 35 40 45 50 55 60



TRENCH T-9

Notes:
- no faulting observed
- fault in T-1A does not extend here.

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction, dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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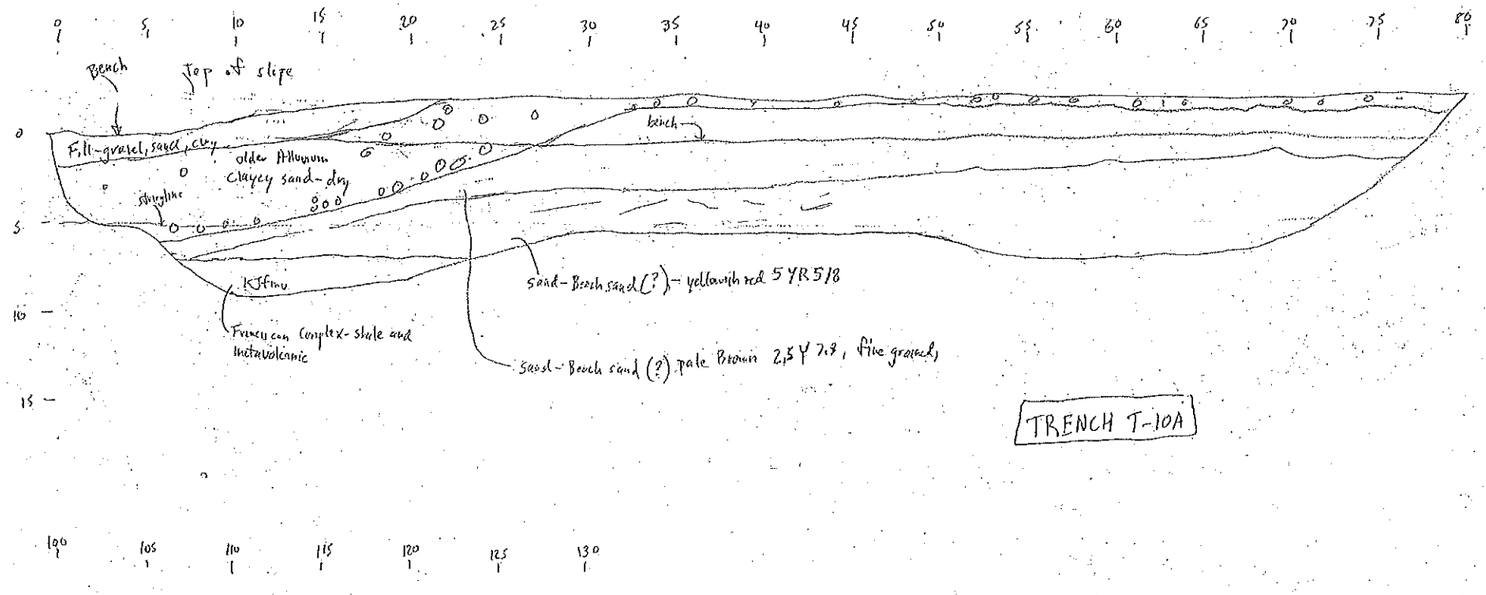
TRENCH LOG T-9

T-10A

N48E →

lower slope below bench

SCALE IN FEET



TRENCH T-10A

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, grewacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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TRENCH LOG
T10-A

T-10B

South side of Barn

North wall

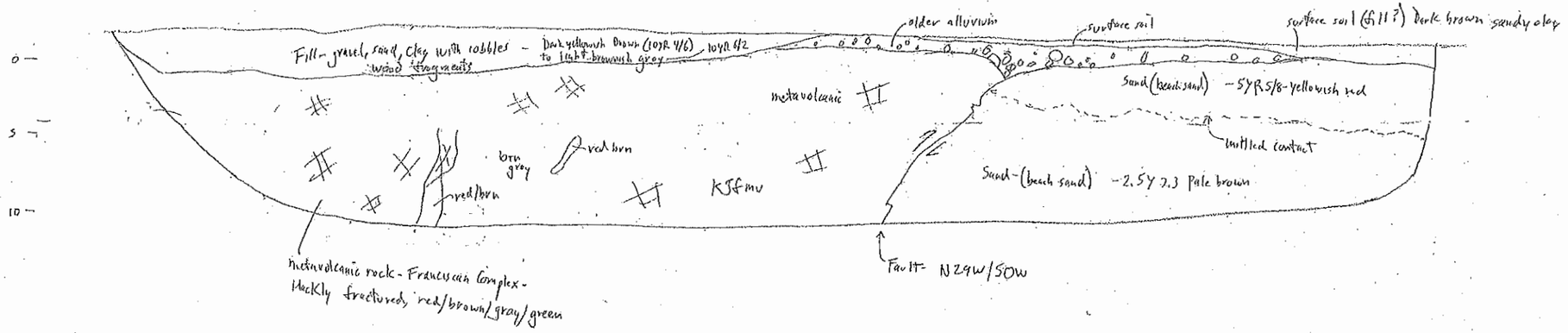
start of "0" at lower Trench T-10A

SCALE IN FEET

west end of Barn

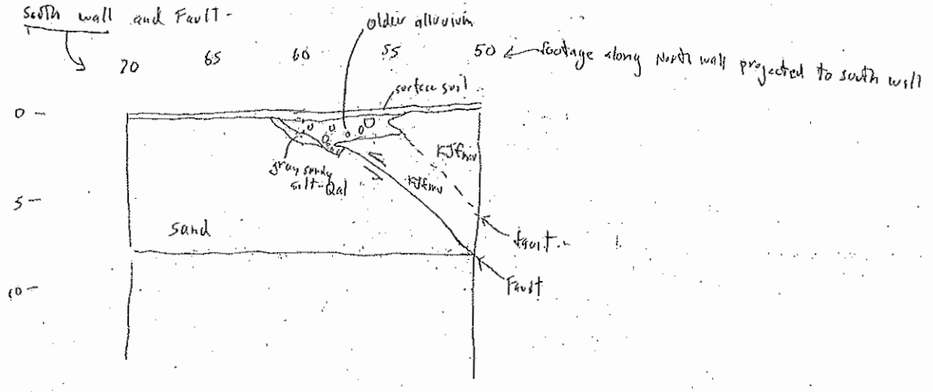
east end of Barn

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 89



TRENCH 10B

Sketch of South wall and Fault -



LEGEND

Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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San Luis Obispo, California 93401 info@geosolutions.net

TRENCH LOG
T0-B

GeoSolutions, Inc. **SOILS REPORT** **(805) 543-8539**

Project:	Madonna Froom Ranch			Date Tested:	June 3, 2016
Client:				Project #:	SL09734-1
Sample:	A	Depth:	1.0 Foot	Lab #:	16516
Location:	B-1			Sample Date:	May 18, 2016
				Sampled By:	GV/TG

Soil Classification
ASTM D2487, D2488

Result: Very Dark Grayish Brown Sandy Fat CLAY

Specification: CH

Sieve Analysis
ASTM D422

Sieve Size	Percent Passing	Project Specifications
3"		
2"		
1 1/2"		
1"		
3/4"		
No. 4	93	
No. 8	90	
No. 16	89	
No. 30	87	
No. 50	84	
No. 100	82	
No. 200	79.6	

Sand Equivalent Cal 217

1		SE
2		
3		
4		

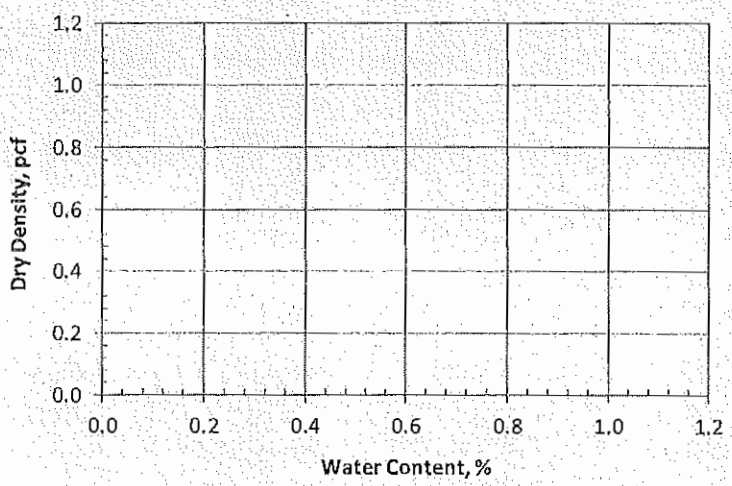
Plasticity Index
ASTM D4318

Liquid Limit:	54
Plastic Limit:	23
Plasticity Index:	31

Expansion Index
ASTM D4829

Expansion Index:	107
Expansion Potential:	High
Initial Saturation, %:	50

Laboratory Maximum Density
ASTM D1557



Mold ID	n/a	Mold Diameter, ins.	4.00
No. of Layers	5	Weight of Rammer, lbs.	10.00
No. of Blows	25		

Estimated Specific Gravity for 100% Saturation Curve =

Trial #	1	2	3	4
Water Content:				
Dry Density:				

Maximum Dry Density, pcf:	
Optimum Water Content, %:	

Moisture-Density ASTM D2937, **Moisture Content** ASTM D2216

Sample	Depth (ft)	Water Content (%)	Dry Density (pcf)	Relative Density	Sample Description
B-1	2.5	38.5			Dark Olive Gray Sandy CLAY
B-2	2.5	27.4			Dark Olive Gray Sandy CLAY

Report By: Aaron Eichman

GeoSolutions, Inc.	SOILS REPORT	(805) 543-8539

Project:	Madonna Froom Ranch			Date Tested:	June 8, 2016
Client:				Project #:	SL09734-1
Sample:	B	Depth:	1.0 Foot	Lab #:	16516
Location:	B-3			Sample Date:	May 18, 2016
				Sampled By:	GV/TG

Soil Classification
ASTM D2487, D2488

Result:	Dark Gray Fat CLAY
Specification:	CH

Sieve Analysis
ASTM D422

Sieve Size	Percent Passing	Project Specifications
3"		
2"		
1 1/2"		
1"		
3/4"		
No. 4	100	
No. 8	100	
No. 16	100	
No. 30	99	
No. 50	98	
No. 100	96	
No. 200	94.7	

Sand Equivalent Cal 217

1		SE
2		
3		
4		

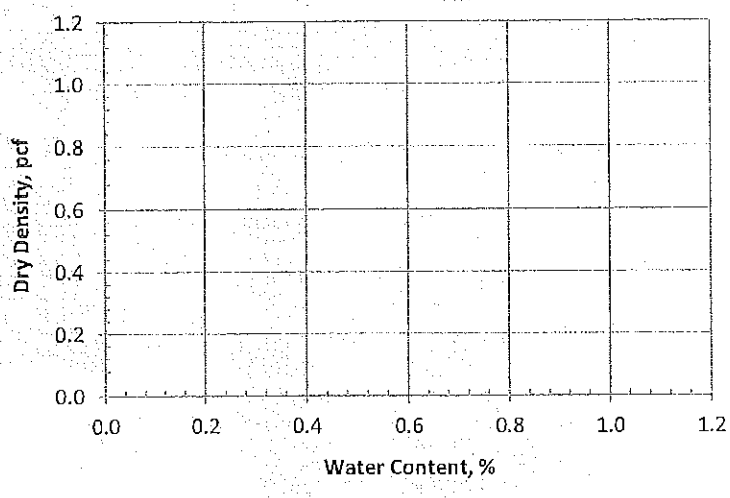
Plasticity Index
ASTM D4318

Liquid Limit:	84
Plastic Limit:	36
Plasticity Index:	48

Expansion Index
ASTM D4829

Expansion Index:	186
Expansion Potential:	Very High
Initial Saturation, %:	50

Laboratory Maximum Density
ASTM D1557



Mold ID	n/a	Mold Diameter, ins.	4.00
No. of Layers	5	Weight of Rammer, lbs.	10.00
No. of Blows	25		

Estimated Specific Gravity for 100% Saturation Curve =

Trial #	1	2	3	4
Water Content:				
Dry Density:				

Maximum Dry Density, pcf:	
Optimum Water Content, %:	

Moisture-Density ASTM D2937, **Moisture Content** ASTM D2216

Sample	Depth (ft)	Water Content (%)	Dry Density (pcf)	Relative Density	Sample Description

Report By: Aaron Eichman

GeoSolutions, Inc. | **SOILS REPORT** | **(805) 543-8539**

Project:	Madonna Froom Ranch			Date Tested:	June 9, 2016
Client:				Project #:	SL09734-1
Sample:	C	Depth:	2.0 Feet	Lab #:	16516
Location:	T-2			Sample Date:	May 18, 2016
				Sampled By:	GV/TG

Soil Classification
ASTM D2487, D2488

Result: Dark Reddish Brown Sandy Fat CLAY

Specification: CH

Sieve Analysis
ASTM D422

Sieve Size	Percent Passing	Project Specifications
3"		
2"		
1 1/2"		
1"		
3/4"		
No. 4		
No. 8		
No. 16		
No. 30		
No. 50		
No. 100		
No. 200		

Sand Equivalent Cal 217

1		SE
2		
3		
4		

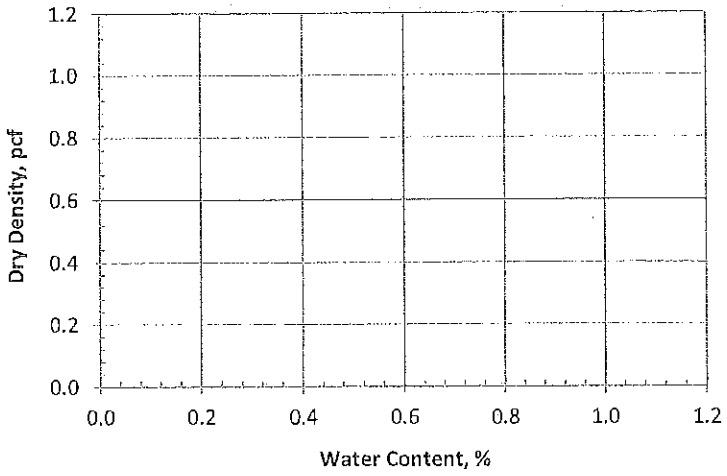
Plasticity Index
ASTM D4318

Liquid Limit:	65
Plastic Limit:	23
Plasticity Index:	42

Expansion Index
ASTM D4829

Expansion Index:	79
Expansion Potential:	Medium
Initial Saturation, %:	50

Laboratory Maximum Density
ASTM D1557



Mold ID	n/a	Mold Diameter, ins.	4.00
No. of Layers	5	Weight of Rammer, lbs.	10.00
No. of Blows	25		

Estimated Specific Gravity for 100% Saturation Curve =

Trial #	1	2	3	4
Water Content:				
Dry Density:				

Maximum Dry Density, pcf:	
Optimum Water Content, %:	

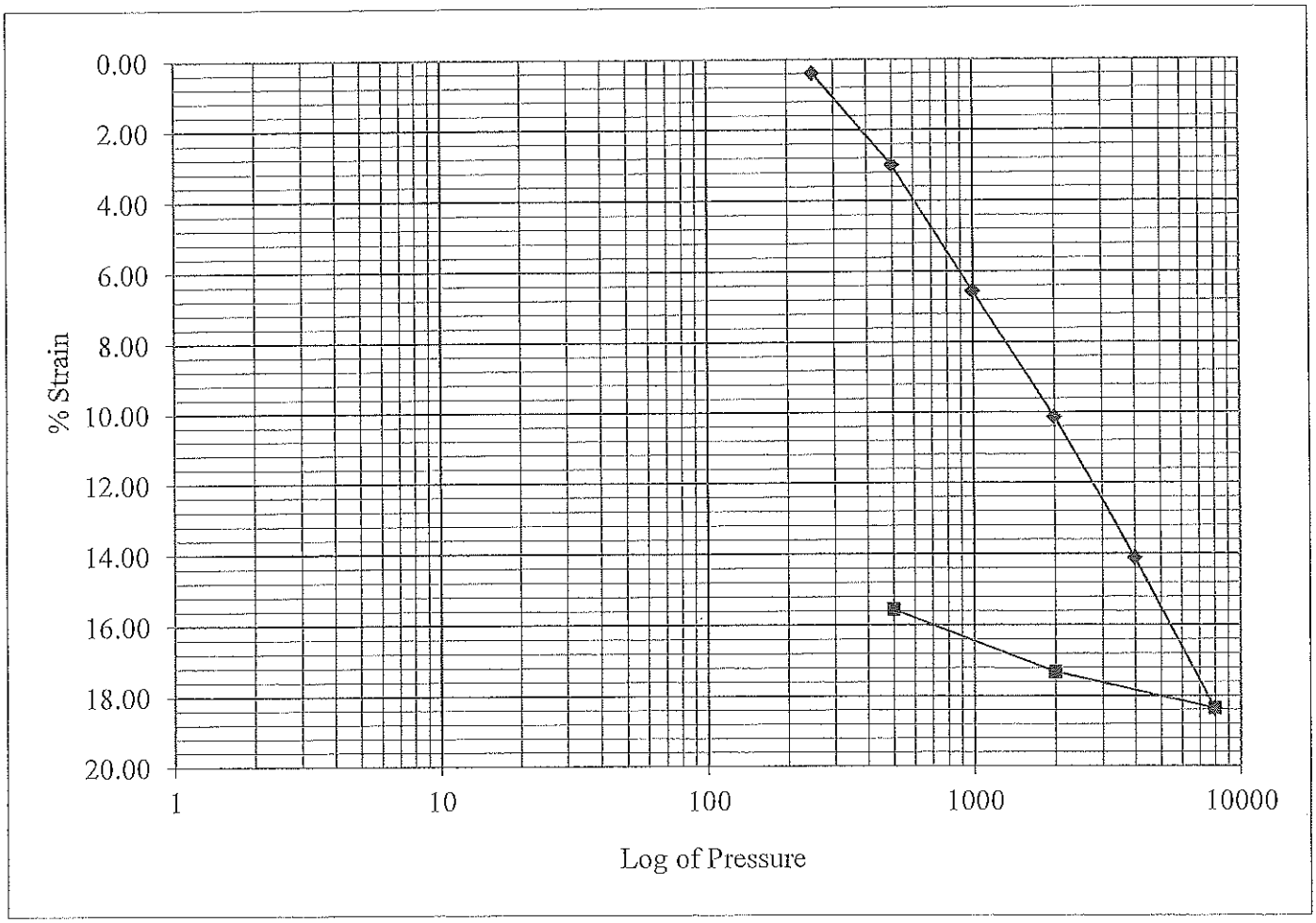
Moisture-Density ASTM D2937, **Moisture Content** ASTM D2216

Sample	Depth (ft)	Water Content (%)	Dry Density (pcf)	Relative Density	Sample Description

Report By: Aaron Eichman

GeoSolutions, Inc.	CONSOLIDATION REPORT D2435-11	(805) 543-8539

Project:	Madonna Froom Ranch			Date Tested:	6/7/2016
Client:				Project #:	SL09734-1
Sample:	B-1 @ 5'	Depth:	5.0 Feet	Lab #:	16516
Location:	B-1			Sample Date:	5/18/2016
Material:	Very Dark Grayish Brown Sandy CLAY			Sampled By:	GV/TG



Applied Pressure (psf)	% Strain
250	0.38
500	2.99
1000	6.55
2000	10.12
4000	14.11
8000	18.35
2000	17.32
500	15.56

Compression Index, Cc
0.165
Recompression Index, Cr
0.017

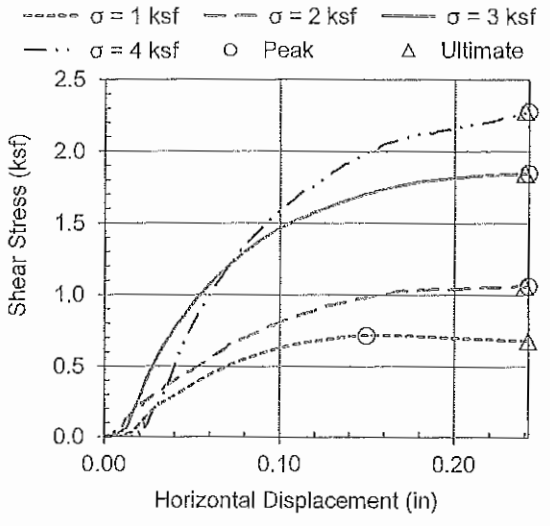
Report By: Aaron Eichman

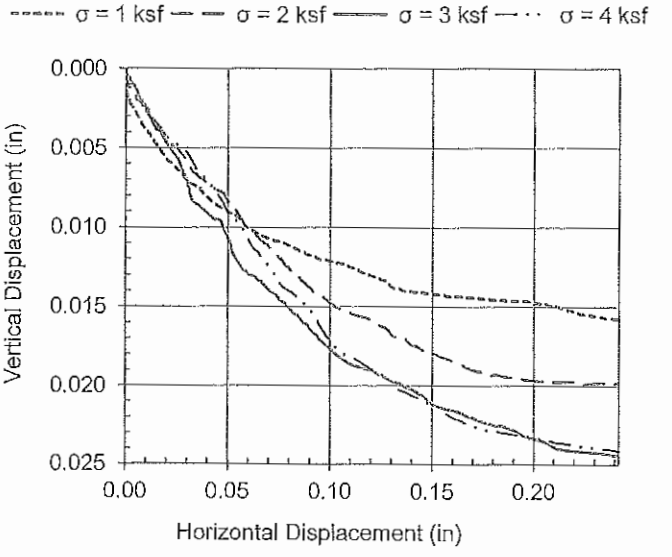
GeoSolutions, Inc. | **DIRECT SHEAR TEST SUMMARY REPORT (ASTM D3080)** | **(805) 543-8539**

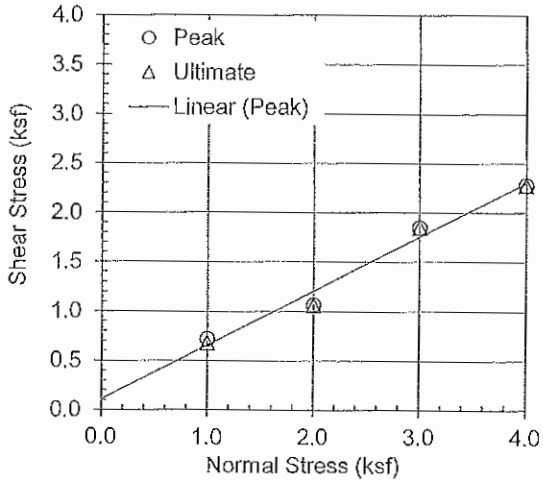
Project:	Madonna Froom Ranch			Project No.:	SL09734-1
Client:				Date Tested:	6/9/2016
Sample No.:	B-1 @ 5'	Depth:	5.0 Feet	Lab No.:	16516
Location:	B-1			Checked By:	AE

MATERIAL DESCRIPTION	LL	PL	PI	% passing No. 200	Gs *	Sample Type
Very Dark Grayish Brown Sandy CLAY	nm	nm	nm	nm	2.4	in-situ (rings)

* Gs = assumed; nm = not measured







Angle of Internal Friction, ϕ_{peak} (degrees):	28.7
Cohesion, C_{peak} (psf)	110

Initial Conditions	Specimen No. 1	2	3	4
Dry Density	92.3	90.3	87.4	95.7
Water Content (%)	25.8	25.8	25.8	25.8
Diameter (in)	2.42	2.42	2.42	2.42
Sample Height (in)	1.00	1.00	1.00	1.00

Test Data	Specimen No. 1	2	3	4
Normal Stress (ksf)	1.00	2.00	3.00	4.00
Peak Shear Stress (ksf)	0.72	1.06	1.85	2.28
Horiz. Displacenent at Peak Shear (in)	0.15	0.24	0.24	0.24
Ultimate Shear Stress (ksf)	0.68	1.06	1.85	2.28
Horiz. Displ. at Ult. Shear (in)	0.24	0.24	0.24	0.24
Rate of Deformation (in/min)	0.002	0.002	0.002	0.002

Remarks:

Samples were not saturated prior to shearing

Forensic Analytical LABORATORIES

Final Report

Bulk Asbestos Material Analysis

(Air Resources Board Method 435, June 6, 1991)

GeoSolutions, Inc.
John Kammer
220 High St.

San Luis Obispo, CA 93401

Client ID: 4947
Report Number: N008330
Date Received: 06/20/16
Date Analyzed: 06/27/16
Date Printed: 06/27/16

Job ID/Site: SL9734-1 - Froem Ranch

PLM Report Number: N/A

FALI Job ID: 4947
Total Samples Submitted: 1
Total Samples Analyzed: 1

Sample Preparation and Analysis:

Samples were analyzed by the Air Resources Board's Method 435, Determination of Asbestos Content of Serpentine Aggregate. Samples were ground to 200 particle size in the laboratory. Approximately 1 pint was retained for analysis. Samples were prepared for observation according to the guidelines of Exception I and Exception II as defined by the 435 Method. Samples which contained less than 10% asbestos were prepared for observation according to the point count technique as defined by the 435 Method. This analysis was performed with a standard cross-hair reticle.

Sample ID	Lab Number	Layer Description
Rock 1	11777123	**Grey/Green Stones**

Point Count Results:

Number of asbestos points counted:	0
Number of non-empty points:	400
Matrix percentage of entire	100
Percent asbestos in matrix:	**< 0.25**
Visual estimation percentage:	<1
Asbestos type(s) detected:	Chrysotile

Comment: Asbestos was detected but no points were counted due to counting criteria. Therefore quantitation deemed to be < 0.25%.

Tad Thrower

Tad Thrower, Laboratory Supervisor, Hayward Laboratory

Note: Limit of Quantification (LOQ) = 0.25%. Trace denotes the presence of asbestos below the LOQ. ND = None Detected.

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3777 Depot Road, Suite 409, Hayward, CA 94545 / Telephone: (510) 887-8828 (800) 827-FASI / Fax: (510) 887-4218

Forensic Analytical LABORATORIES

Analysis Request Form (COC)

Client Name & Address: Client No.: [illegible] [illegible] San Luis Obispo, CA 93401	PO / Job#: [illegible] Date: 6/15/16 Turn Around Time: Same Day / 1Day / 2Day / 3Day / 4Day / 5Day ☐ PCM: ☐ NIOSH 7400A / ☐ NIOSH 7400B ☐ Rotameter ☐ PLM: ☐ Standard / ☐ Point Count 400 / 1000 / ☒ CARB 435
Contact: [illegible] Phone: [illegible] E-mail: [illegible]	☐ TEM Air: ☐ AHERA / ☐ Yamate2 / ☐ NIOSH 7402 ☐ TEM Bulk: ☐ Quantitative / ☐ Qualitative / ☐ Chatfield ☐ TEM Water: ☐ Potable / ☐ Non-Potable / ☐ Weight % ☐ TEM Microvac: ☐ Qual / ☐ D5755(str/area) / ☐ D5756(str/mass)
Site Name: [illegible] Ranch Site Location:	☐ IAQ Particle Identification (PLM LAB) ☐ PLM Opaques/Soot ☐ Particle Identification (TEM LAB) ☐ Special Project ☐ Metals Analysis Matrix: Method: Analytes:
Comments: CARB 435 Standard Turnaround	☐ Silica in Air ☐ w/Gravimetry

Sample ID	Date / Time	Sample Location / Description	FOR AIR SAMPLES ONLY				Sample Area / Air Volume
			Type	Time On/Off	Avg LPM	Total Time	
Rock 1	6/15/16	Multiple locations	[A] [P] [C]				
			[A] [P] [C]				
			[A] [P] [C]				
			[A] [P] [C]				
			[A] [P] [C]				
			[A] [P] [C]				
			[A] [P] [C]				
			[A] [P] [C]				
			[A] [P] [C]				
			[A] [P] [C]				

Sampled By: [illegible] Date/Time: 6/15/16 Shipped Via: ☐ FedEx ☐ UPS ☐ US Mail ☐ Courier ☐ Drop Off ☐ Other:

Relinquished By: [illegible] Date / Time: 6/15/16	Relinquished By: Date / Time:	Relinquished By: Date / Time:
Received By: Date / Time: Condition Acceptable? ☐ Yes ☐ No	Received By: Date / Time: Condition Acceptable? ☐ Yes ☐ No	Received By: Date / Time: Condition Acceptable? ☐ Yes ☐ No

RECEIVED JUN 20 2016

November 18, 2016
ECI Project No. 3613

Earth Consultants International

To: **Pacific Gas & Electric Company**
Geosciences Department
245 Market Street, MC N4C
San Francisco, California 94105

Attention: **Dr. Chris Madugo, Senior Geologist**

Subject: **Report - Soil Stratigraphic Assessments in Support of a Study to Characterize the Activity of Strands of the Los Osos Fault Exposed in Trenches Along the Los Osos Valley Road, in San Luis Obispo, California**

1.0 INTRODUCTION

We are pleased to present this report describing our findings of a soil stratigraphic study that we conducted at your request for a site along Los Osos Valley Road, in San Luis Obispo, California. The purpose of our study was to estimate the age of the soils observed in trenches excavated by others. These trenches exposed strands of the Los Osos fault, and we were asked to provide assistance in characterizing the age of the soils involved in the faulting to better understand the recency of activity of the faults exposed, and if possible, their earthquake recurrence. Determination of the age of the faults exposed will be conducted by others using our soils data and observations regarding how the faults interact with various surface and buried soils that we identified in two trenches.

1.1 SCOPE OF WORK

The specific tasks that we conducted as part of this study are described below. More detailed information regarding the methodology we used to describe the soils, calculate the soil indices, and estimate the ages of the soils is provided in the following sections.

- We reviewed photos and photomosaics of the trench exposures and discussed our preliminary impressions with you and the project team via telephone and video conferencing.
- We compiled, reviewed and analyzed several soil chronosequences and soil profiles developed in coastal areas of central and southern California and the Baja Peninsula, Mexico, that were described and dated by others. If soil descriptions were provided in the sources used, we calculated their Soil Development Indices (SDI) and Mean Horizon Indices (MHI) in an effort to develop soil chronofunctions appropriate for the San Luis Obispo location. The references used are listed in Appendix A.
- We traveled to/from the Los Osos Valley trenching site in San Luis Obispo, where we reviewed the trench exposures still open, discussed with you the stratigraphy observed

in the trenches, and photographed and collected soil samples from four separate soil profiles. We also collected samples of unaltered or slightly altered alluvium from the walls of the active wash near the east side of the property to use as proxies for the soils' parent materials.

- Back in our office, we completed the soil profile descriptions. These are presented in Appendix B.
- We calculated the SDIs and MHIs for the profiles that we described in the field and compared them to the indices of the soils described and dated by others that we had analyzed and compiled as part of our desktop study. Using the chronofunctions developed from the soils data analyzed, we estimated a range of ages for the soils at the site. The soil age estimates computed were then vetted for reasonableness based on topographic and geomorphic position, and geological context.
- We prepared this report summarizing the work completed.

2.0 METHODOLOGY USED FOR SOIL-STRATIGRAPHIC ANALYSES

2.1 BACKGROUND

The term soil as used herein refers to a natural body of mineral and/or organic material consisting of layers (or horizons) that are different from the underlying or original geologic (parent) material in their "morphological, physical, chemical and mineralogical properties and their biological characteristics" (Birkeland, 1984). These differences are the result of weathering and the effects of five main soil-forming factors: parent material, climate, slope or topography, organisms, and time (Jenny, 1941). Time is an important factor because the longer a geologic deposit is exposed to the effects of weathering and soil formation, the better developed the soil characteristics generally become. We take advantage of this when using soils to estimate the age of the deposits.

Soil development occurs on stable geomorphic surfaces (a stable surface is one that is not being significantly impacted by deposition or erosion). Soil development typically starts to occur as soon as a surface stops being eroded or deposited on. Therefore, in some environments, such as an alluvial plain or alluvial fan, it is common to find several weakly to moderately developed buried soils that rest one upon the other, sometimes separated by unaltered or only slightly altered sediments (the parent material). The soils represent periods of sub-aerial weathering and soil formation that occurred in between periods of alluvial erosion and deposition.

In these environments, the age of the primary, unaltered deposits is estimated by summing the age of the individual soils, including the surface soil and the buried soils that overlie the section of interest. It is important to recognize, however, that the soil-age estimates will provide a minimum age for the parent material, as the estimated ages do not account for the length of time it took for the sediments to be deposited. Furthermore, if portions of soil horizons, or even entire soil horizons, have been removed (truncated) from the area by erosion, the age estimates will not capture that erosional period of time. Nevertheless, if these limitations are recognized, soils can provide useful information on the age and geological history of a constructional surface, such as an alluvial or marine terrace or alluvial fan. This is especially true for sediments that 1) do not contain suitable datable materials such charcoal, 2) whose age extends beyond the useful range of radiocarbon

dating, 3) that are too coarse-grained or too clayey to date using Optically Stimulated Luminescence, and 4) cannot be dated by some other absolute dating method. In these cases, soil-age estimations are particularly useful.

2.2 SOIL DESCRIPTIONS

For this project we described four soil profiles; three in trench T-1A and one in trench T-2A. Three of these profiles include a surface soil and two underlying buried soils. The last profile we described is a soil developed in a fining-upward section of fine-grained sediments that were deposited in a low spot that appears to have formed as a result of movement on the adjacent fault. These sediments are referred to here as "ponded deposits." Lastly, we also collected and described samples of unweathered to slightly weathered alluvium from the active channel near the eastern portion of the site. These alluvial deposits are considered representative of the parent materials for the soils described in the trenches.

The descriptions were made using a combination of the characteristics and nomenclature established by the Soil Survey Staff (1975, 1992), the National Soil Survey Center (2012), and Birkeland (1984, 1999). Colors of the soil horizons were recorded by comparing the color of the matrix and clay films, both in the dry and wet states, to color chips in a Munsell Soil Color Chart.

Other characteristics that we recorded include: 1) texture or grain-size distribution, 2) structure (whether the soil mass breaks into distinctive peds, or is single-grained), 3) the amount, distribution and thickness of translocated clay forming films or stains on the soil ped faces and clasts, in pores, between sand grains (called bridges), around clasts, and in clast pockets, 4) the looseness or induration of the soil peds when dry and moist, and 5) the stickiness and plasticity of the wet soil. The sharpness and relief characteristics of the contact (or boundary) between horizons were also noted.

Finally, we also noted and qualitatively described the content, size, angularity or roundness, predominant composition and degree of weathering of the clasts found mixed with the finer-grained soil matrix. The clast weathering stages used follow the nomenclature defined by Tinsley and others (1982)[1], who found a positive correlation between the age of a deposit and the degree of weathering of the clasts therein. The complete soil descriptions for all profiles are provided in Appendix B.

2.3 SOIL INDICES AND DEVELOPMENT COMPARISONS

To estimate the age of geologic deposits using soil-stratigraphic techniques we rely on a comparison of the characteristics of the soils in question with those of other soils

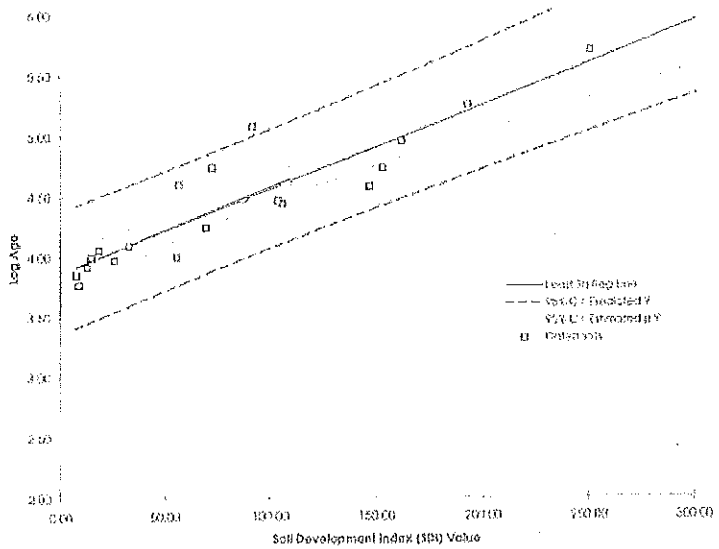
[1] Stage 1: Unweathered bedrock, rings sharply to blow of hammer.
Stage 2: Slightly weathered bedrock, incipient to moderate surface pitting, fractured, with oxidation rinds greater than 1-2 mm in thickness, yields moderate ring to blow of hammer.
Stage 3:Substantially weathered bedrock, surface highly pitted, strongly fractured, mafic minerals and feldspars may be strongly altered, clasts can be broken with difficulty by hand, dull sound to blow of hammer.
Stage 4: Very strongly weathered bedrock, easily disaggregated by hand into grus; very dull sound when struck with hammer.

developed in similar parent materials and climate conditions that have been dated using both absolute and relative dating methods. For this quantitative comparison, the characteristics of the soils are assigned numerical values that are then used to calculate the soils' degree of development. We used two of these quantitative methods for this study: Harden's (1982) Soil Development Index (SDI), and Ponti's (1985) Maximum Horizon Index (MHI). Both SDI and MHI values have been shown to be useful relative indicators of soil age, with older, better developed soils typically having higher SDI and MHI values (Harden, 1982; Harden and Taylor, 1983; Rockwell et al., 1984; Rockwell et al., 1990; Bornyasz and Rockwell, 1997).

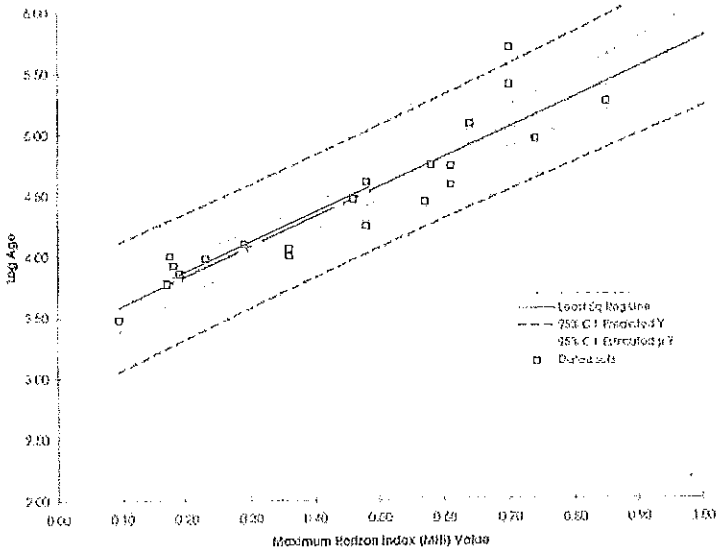
In these quantitative assessments, the characteristics of the soil are "subtracted" from the characteristics of the parent material to develop an empirical estimate of the length of time that a geologic deposit has been subjected to the effects of weathering and soil formation. Field studies have shown that all other conditions being equal, a soil developed in fine-grained sediments appears better developed, with increased horizonation and illuviation, than a coarse-grained soil of similar age (Rockwell et al., 1985). We accounted for these differences when estimating the age of these soils as follows: For the coarse-grained buried soils we used the gravelly loamy sand alluvium that we collected from the active channel as parent material. For the fine-grained surface soils and the ponded deposits, we used sandy loam alluvium as the parent material. The descriptions of these alluvial parent materials are included in Appendix B, at the end.

To obtain minimum age estimates for the soils in the profiles described, we compared the soils' SDI and MHI values with the chronofunctions presented in Dolan et al. (1997; see Graphs 1 and 2 below), which are based on the chronosequences of the Ventura Basin by Rockwell (1983) and Rockwell et al. (1985), the Merced Valley by Harden (1982), and Cajon Pass by McFadden and Weldon (1987). Since two of these chronosequences (Merced Valley and Cajon Pass) developed in inland areas of southern California not exposed to coastal fog, and are thus unlike the coastal area of San Luis Obispo where the site is located, we also compiled, reviewed and analyzed four additional soil chronosequences developed in coastal areas of central and southern California (Rockwell et al., 1994; Muhs, 1982), and in the Baja Peninsula in Mexico (Rockwell et al., 1993). Coastal soils typically develop faster than inland soils because sodium input from sea spray and coastal fog helps to deflocculate (disperse) the clay minerals (Shlemon, 1978; Shlemon and Hamilton, 1979; Birkeland, 1984), and the moisture provided by the fog helps to translocate (mobilize) the clay fraction down the sediment section. As a result, argillic (Bt) soil horizons tend to form faster in this environment than in more inland areas not subject to these fluxes. The properties of these soils were quantified using both the Harden (1982) and Ponti (1985) methods to develop soil indices that we then plotted as a function of time to develop chronofunctions that would theoretically be more representative of the site than some of the chronosequences used for the soil age regressions used by Dolan et al. (1987).

Graph 1: Soil Development Index vs Log Age Regression published by Dolan et al. (1997) and used in this study to estimate the age of the Los Osos Valley Soils



Graph 2: Maximum Horizon Index vs Log Age Regression published by Dolan et al (1997) and used in this study to estimate the age of the Los Osos Valley Soils



The age estimates calculated using soil-stratigraphic methods provide the approximate minimum length of time that a soil was exposed to soil-forming processes when at the ground surface. In areas where the surface soil is underlain by one or more buried soils,

the age of the buried soils and the underlying sediments is best estimated by adding the age of the overlying, surface soil to the amount of time that each of the now-buried soils was exposed to soil-forming processes prior to burial. This method is considered to provide a minimum age for the sediments that the soils developed in because the age estimates do not account for the length of time it took for the sediments to be deposited, nor do they include any soils (or portions of soil horizons) since removed by erosion that are no longer present in the record.

Finally, and of significant note, the age estimates obtained by applying these chronofunctions need to be evaluated and reconciled with other criteria that also provide general information on the possible age of the sediments. These criteria include but are not limited to geomorphic position and the region's Quaternary history, including glacial and interglacial events that defined whether the processes of incision, backfill, or soil formation predominated.

3.0 FINDINGS

3.1 SUMMARIZED SOIL PROFILE DESCRIPTIONS

Three of the soil profiles that we described in trenches T-1a and T-2a are relatively similar in appearance and stratigraphic position. All three of these profiles have a surface soil and two buried soils (Soil Profile 3 in Trench T-2a has an additional truncated soil that is buried under a low-angle fault). Characteristics of each of these soils are summarized below. For the complete soil descriptions, refer to Appendix B.

Surface Soil: ABt1/ABt2 in Profile 1; A1/A2/Bt in Profile 2; A1/A2/Btj in Profile 3
The surface soil consists of organic-rich silty clay to silty clay loam that is very dark gray and dark brown when dry, and black, very dark brown and very dark grayish brown when moist (10YR to 7.5YR hues). The section is between 43 and 58 cm thick, and has characteristics of both A and Bt horizons, with structure that ranges from granular within the root zone to strong subangular blocky below. Clay films in the argillic section vary from few to common thin to continuous thick on ped faces, coating clasts and lining clast pockets. Sand grains are common, but fine gravel-sized clasts are few and scattered throughout.

This deposit is distinctly finer-grained than the underlying buried soils, with only a few scattered gravel-sized clasts, and a high concentration of silt. We suggest that it was deposited primarily by eolian processes, either as coastal fog fallout over a long period of time (Keller et al., 1981), or as a paleodune emplaced during a marine regression, typically during and after a falling sea level (Orme, 1990). Orme (1990) mapped several paleodune deposits in the study area and to the south, including several that "feather out at 300 m against the San Luis Range (Irish Hills)." Although Orme (1990) did not map dune deposits in the immediate site vicinity, he indicated that Pleistocene eolian deposits in the region are buried under predominantly fluvial sequences, resulting in complex stratigraphic sections that require additional research. In the Santa Maria and Santa Ynez valley south of Pismo Beach, Orme (1990) mapped several late Quaternary dune deposits more than 30 km inland, including paleodune sediments that nearly wrap around the Casmalia Hills. These observations indicate that it is plausible for similar paleodune sediments to occur in the site vicinity. Burke et al. (2016) have studied sediments with similar characteristics in

coastal northern California, and suggest that these eolian sediments were deposited during the last glacial maximum, 20-30ka.

First Buried Soil: 2Btkb/3Btb/4BCb in Profile 1; 2Btkb in Profile 2; 2Btb1/2Btb2 in Profile 3
In two of the profiles described, the first buried soil is defined by, or includes a calcium carbonate-rich argillic horizon (Btk) with Stage I to II calcium carbonate as coatings on ped faces, lining pores, in veins, and as nodules (Machette, 1985). San Luis Obispo's current climatic environment (annual average precipitation of 48.3 cm and temperature of 15.2°C) is not conducive to the formation of Stage I-II calcium carbonate morphology. These calcic horizons therefore most likely formed when this area was drier and warmer than today, sometime during the Pleistocene.

This buried soil is a relatively thin, partly truncated soil that varies in thickness between 39 and 64 cm. Although these are minimum thicknesses, as the A horizons are not preserved, and the argillic horizons appear to be truncated, the better-preserved section in Profile 1 is still thin, suggesting that this buried soil was formed during a dry period, limiting the effective depth of translocated clay. The horizons observed have a silty clay to silty clay loam texture, with visibly more gravel than the surface soil described above, and moderate to strong subangular blocky to prismatic structure. Color hues are generally in the 7.5YR to 10YR range, with low chromas that are the result of overprinting by (leaching from) the overlying organic-rich surface soil. The clay films are well developed, described as moderately thick to thick and common to continuous on ped faces, coating clasts and on clast pockets. All of these characteristics indicate a relatively long period of exposure to soil-forming processes. In the trench walls that we reviewed, the contact between this first buried soil and the underlying buried soil is locally defined by a stoneline consisting of rounded to subrounded pebbles and cobbles, suggesting a hiatus of deposition between the deeper buried soil and the overlying deposit.

Second Buried Soil: 5Btb2/5Btb3/5Btb4/6Btb5/6btb6 in Profile 1; 3Btb1/4Btb2/5Btlam1b/5Btlam2b in Profile 2; 3Btb3/4Btb4 in Profile 3
In Profiles 1 and 2, this second buried soil ranges in thickness from 133 to 151 cm. These are minimum thicknesses as the A horizons for these soils are not preserved, and the overlying argillic horizons are most likely truncated.

The thickness of the second buried soil in Profile 3 is unknown, as the bottom of the soil is truncated by a low-angle fault, although its original thickness could be reconstructed if we are correct in our assessment that the buried soil below is part of a repeated section. In the area where we described our soil profile, the fault zone appears to be enhanced by translocated clay, whereas farther east, closer to what was the slope face prior to burial, the fault tip is obscured by soil development. This suggests that the faulting event represented by this low-angle fault occurred when the deposit was still being exposed to pedogenesis, prior to burial by the overlying alluvial fan deposits. However, at Station 1.2 the fault plane removed the bottom section from the zone of pedogenic influence.

These now-buried soils developed in coarse-grained parent materials that include many scattered clasts several inches in diameter, yet the texture of the soils ranges from silty clay to sandy clay, indicating significant chemical weathering of the original parent material and/or accumulation and translocation of wind-transported silt over a lengthy period of

time. The thickness and distribution of pedogenic clay down the entire profile also indicates that these soils formed during a former wetter climate, most likely during a major interglacial. Color hues are in the 7.5YR range, with 7.5YR clay films. Clay films on ped faces are found preferentially in the upper argillic horizon; the lower argillic horizons have clay films on clast pockets and coating clasts. These clay films vary from common and thin to continuous and thick.

Soil buried under fault in Profile 3: 5Btb5/5Btb6/6Btb7/7BCb
This is a coarsening-downward soil profile that ranges from sandy clay at the top to loam at the bottom. The profile is at a minimum 67 cm thick at Station 1.2, where we described it, but thickens eastward, away from the low-angle fault described above (at Station 3, the profile was at least 119 cm thick). The bottom of this soil profile extends below the depth of the trench, so these thicknesses are minimum values.

Colors also vary with depth from brown to dark brown (7.5YR 5/3 to 3/3) at the top, to light yellowish brown to brown (10YR 6/4 to 4/4) at the bottom. Clay films in the upper sandy clay and sandy clay loam sections include many moderately thick on ped faces, and many to continuous moderately thick to thick coating clasts and lining clast pockets. The soil formed in an originally coarse-grained deposit that includes many subrounded to subangular Franciscan Formation-type clasts up to 3 inches (7.5 cm) in diameter weathered to Stages 2 to 4.

This soil appears to represent a repeated section of the overlying second buried soil described above. As we suggested above, this lower buried soil appears to have been removed from the effective depth of pedogenic influence by the faulting event, with continued accumulation of translocated clay after the faulting occurring predominantly in the overlying soil and along the fault plane itself. To the east, closer to the slope face, continued soil development, possibly enhanced by bioturbation, obscured the fault plane so that it is no longer visible in that area. In the area where we described the soil, the deposit below the fault was removed from the effective depth of soil formation such that physical and chemical weathering of the sand fraction and/or influx of eolian silt ceased. This explains why this profile is sandier than the soil above. If this argument is correct, the estimated age of the entire section in this area is not represented by the sum of the time it took for the surface soil and each of the underlying three buried soils to form. Instead, the age of the entire section is best represented by the sum of the time it took for the surface soil and each of the first two buried soils to form, plus the difference in age between the second and third buried soils.

Soil developed in the Ponded Deposits west of the fault in Trench T-1a: Btb1/Btb2/Btb3/2Bt4b
This soil developed in what is interpreted to have been a fining-upward sequence of clean, well-sorted sand deposited in a topographic low-spot that developed uphill from the fault exposed in the trench, presumably as a result of the most recent earthquake event on the fault. If this is the case, then estimating the age of this soil would help establish the timing of when this fault trace last moved. This soil is overlain by a 51-cm thick surface soil comparable to that described in Profile 1.
The entire profile is 61 cm thick and includes four argillic soil horizons that vary in texture from clay at the top, to silty clay to sandy clay in the middle, and sandy loam to sandy clay

loam at the bottom. The upper horizons have 7.5YR hues and low chromas, whereas the lower horizons have 10-7.5YR hues. Clay films are common in the upper three horizons, with few thick and common to many thin to moderately thick on ped faces, common thin to moderately thick coating clasts, and common moderately thick lining clast pockets.

3.2 REGIONAL SOIL INDICES USED FOR COMPARISON PURPOSES

As discussed above, we compiled, reviewed and analyzed several soil chronosequences that have been described by others. In particular, we looked for soils developed in coastal areas of California and the Baja Peninsula that are exposed to marine fog and thus sodium influx, on the premise that the soils at the site have been similarly exposed to these conditions, and as a result have developed more quickly than other soils from more inland areas that formed in similar parent materials.

To that end we found and analyzed data for four coastal soil chronosequences. These include 1) soils formed on marine terraces in the nearby San Simeon area described by Rockwell et al. (1994), 2) soils that formed on marine terraces on San Clemente Island described by Muhs (1982), 3) soils that formed on marine terraces in the Punta Banda area of the Baja Peninsula (Rockwell et al., 1987 and 1989, based on the summary by Rockwell et al., 1993), and 4) soils developed on alluvial terraces in the Valle Agua Blanca area, also in the Baja Peninsula, Mexico (Rockwell et al., 1993).

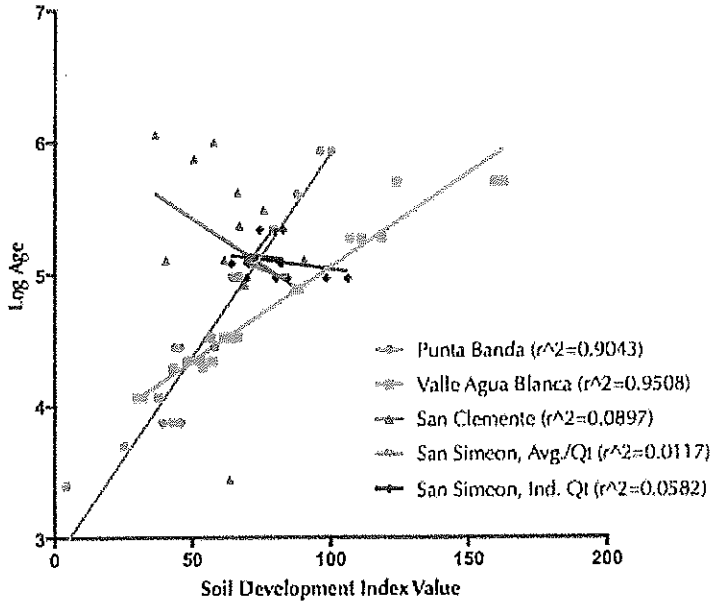
For the San Simeon and San Clemente soils, we took the soil descriptions provided in those sources and calculated their soil indices (SDI and MHI) normalized to a total depth of 200 cm. The Rockwell et al. (1993) publication covering the Punta Banda and Valley Agua Blanca soils did not include individual soil descriptions, but they did provide the SDI and MHI values and age estimates for the various profiles that they described. It is important to note, however, that the soil indices that Rockwell et al. (1993) calculated and published for the Valle Agua Blanca profiles were normalized to a depth of 250 cm, and we have assumed that the same is true for the Punta Banda soils, although Rockwell et al. (1993) do not say so. This is not expected to have an impact on the MHI vs soil age regression curves, as the diagnostic, better developed horizon that provides the MHI value is typically going to be found in the upper 200 cm, and MHI values are independent of overall profile thickness, but the published SDIs for these soils will be higher than the SDIs normalized to a depth of 200 cm. As a result, theoretically, a soil age regression plot generated with SDIs normalized to 250 cm will yield lower age estimates than a regression generated with the same soil data but normalized to 200 cm.

Our analysis shows that there are significant differences among the soil indices developed for these four soil chronosequences. These differences are illustrated in Graphs 3 and 4 below. Graph 3 shows the Soil Development Index (SDI) versus Log Age for the four individual soil chronosequences analyzed for this study, and Graph 4 shows the Mean Horizon Index (MHI) versus Log Age for the same set of soil profiles. The Punta Banda, Valle Agua Blanca, San Clemente, and San Simeon soils data are included in both graphs, with each dataset shown in a different color.

The San Simeon data we analyzed includes twelve soil profiles described from what Rockwell et al. (1994) interpreted as three separate marine terraces (Qt5a, Qt5e, and Qt7). Although the number of profiles is relatively large, the ages of these samples are limited to

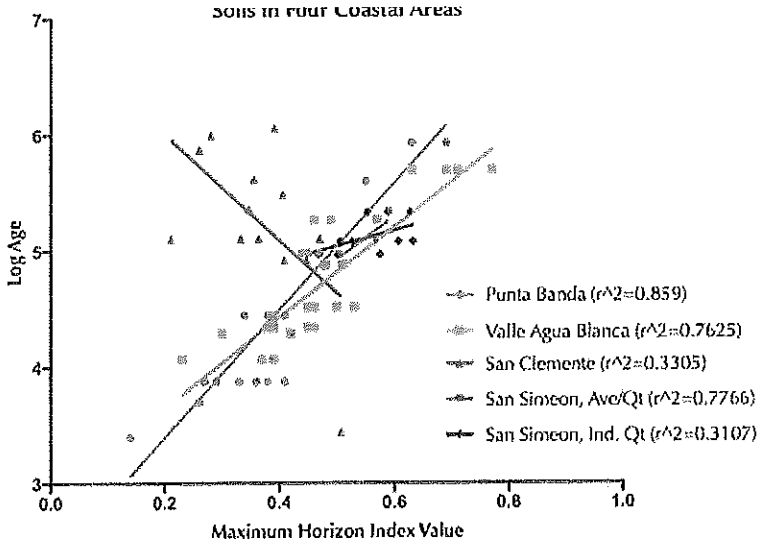
three values, resulting in a fairly limited data set on the graphs used for our analyses. We opted to show and analyze the San Simeon soils data in two different ways: 1) as an average of the SDI and MHI values for each terrace (pink dataset on Graphs 3 and 4), and 2) as individual SDI and MHI values (black dataset).

Graph 3: Soil Development Index (SDI) vs Log Age for Soils in Four Coastal Areas in California and Baja California

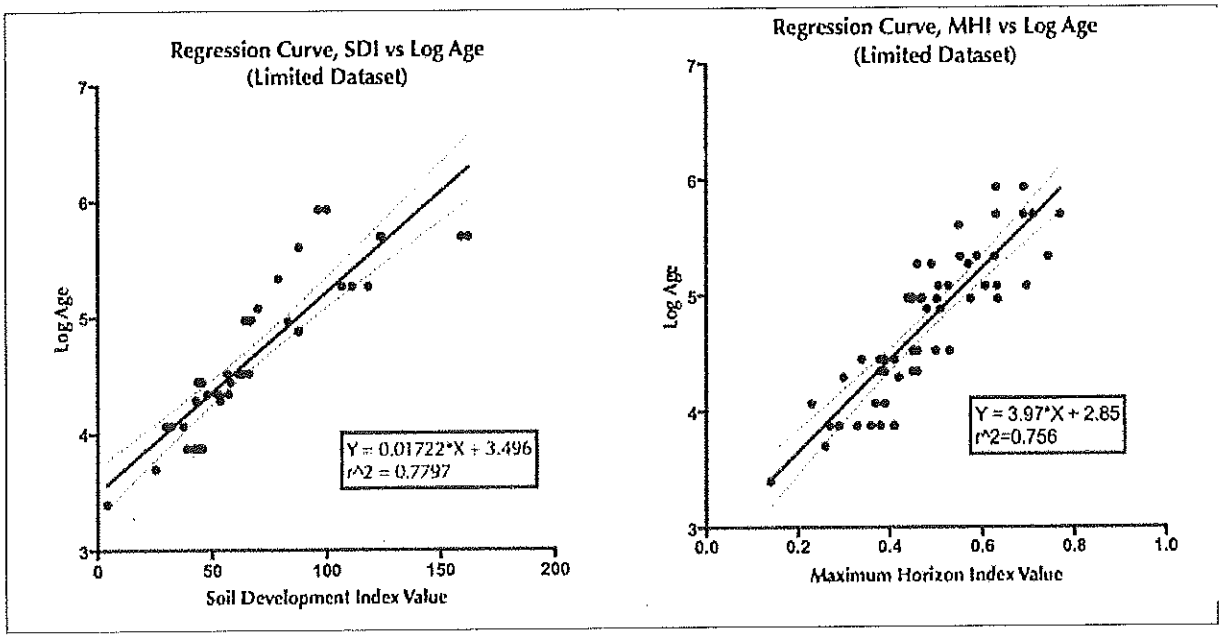


The curves show that the San Clemente soils yield a linear regression solution with a negative slope, meaning that the youngest soils display the strongest soil characteristics. Because this result is contrary to most observations that show an increase in soil indices with increasing age, we chose to not use the San Clemente data to generate the chronofunctions shown in Graphs 5 and 6. Although not as obvious, the Soil Development Indices (SDI) calculated for the San Simeon soils also yield negative slopes (see Graph 3). This may be a function of the relatively small age data set; it is possible that if a larger spread of soils of different ages were available in the region, and these were described and analyzed, the combined results would result in a direct correlation between SDI and log soil age (meaning a positive slope for the linear regression equation). For the purposes of this project, however, we chose to not use the individual San Simeon SDI values to generate the chronofunction shown on Graph 5. Interestingly, the averaged MHI values for each terrace in the San Simeon area plot as expected, with a positive slope (see pink line in Graph 4). As a result, we kept and used the San Simeon average MHI values in generating the combined MHI vs Log Age chronofunction shown in Graph 6.

Graph 4: Maximum Horizon Index (MHI) vs Log Age for Soils in Four Coastal Areas in California and Baja California



Graphs 5 (left) and 6 (right): Chronofunctions Developed for this Study
Using the Punta Banda, Valle Agua Blanca and Average San Simeon Soils Data (MHI only)
Graph 5 shows the Soil Development Index vs Log Age, and
Graph 6 shows the Mean Horizon Index vs Log Age
These functions were used to calculate estimated ages for the soils in this study, with the results presented under the column "Combined PB, VAB and SSavg" in Table 1



3.3 ESTIMATED SOIL AGES BASED ON SOIL INDICES

For our final analysis we used four separate soil chronofunctions to estimate the ages of the soils described for this study. These chronofunctions include the Dolan et al. (1997) SDI

and MHI vs Log Age regressions shown on Graphs 1 and 2, and the limited combined data from the coastal soils shown on Graphs 5 and 6. We also used the chronofunctions calculated for the Punta Banda and Valle Agua Blanca soil indices, since these soil chronosequences generated fairly robust linear regressions (see Graphs 3 and 4).

The results of these analyses are summarized in Table 1. The values presented in Table 1 represent the length of time that each of the soils in a given profile was exposed to soil forming processes when that soil was at the ground surface. As discussed previously, all other conditions being equal, coastal soils are expected to develop faster than inland soils. Thus, we expected that the chronofunctions developed for the Punta Banda, Valle Agua Blanca and the combined coastal soils data would yield younger ages for the Los Osos Valley soils than the values obtained using the Dolan et al. (1997) regressions. However, as Table 1 shows, this is not the case. With the exception of the surface soil from Profile 3, the Dolan et al. (1997) regressions generally returned significantly younger ages than the other chronofunctions.

Table 1: Soil Development Age Estimates Calculated for the Soil Profiles Described for This Study

Soil	MHI	SDI (n=200cm)	Mean Length of Time Soil Was Exposed to at the Surface, based on the Following Soil Chronofunctions:			
			Dolan et al. (1997) (Avg / Min)	Combined PB, VAB, SSavg* (this study)	Punta Banda (this study)	Agua Blanca (this study)
Soil Profile 1, Surface Soil	0.5164		40,793 / 14,014	79,440	135,019	76,116
		93.52	32,857 / 10,658	127,766	515,799	91,326
Soil Profile 1, Buried Soil 1	0.4814		33,513 / 11,376	57,698	86,784	55,573
		93.63	32,916 / 10,677	128,324	519,838	91,657
Soil Profile 1 Buried Soil 2	0.4093		22,348 / 7,402	29,848	34,900	29,061
		72.67	23,524 / 7,576	55,894	117,623	46,054
Soil Profile 2, Surface Soil	0.3591		16,851 / 5,488	18,863	18,508	18,504
		71.18	22,970 / 7,393	52,689	105,836	43,856
Soil Profile 2, Buried Soil 1	0.4505		28,163 / 9,462	43,488	58,713	42,081
		90.09	31,099 / 10,076	111,519	404,456	81,599
Soil Profile 2, Buried Soil 2	0.4409		26,683 / 8,936	39,833	52,004	38,600
		57.4	18,418 / 5,900	30,508	39,840	27,894
Soil Profile 3, Surface Soil	0.2866		11,212 / 3,563	9,724	7,407	9,643
		56.7	18,214 / 5,833	29,674	37,913	27,261
Soil Profile 3, Buried Soil 1	0.5206		41,767 / 14,369	82,550	142,379	79,046
		75.11	24,462 / 7,884	61,574	139,842	49,896
Soil Profile 3, Buried Soil 2	0.4146		23,017 / 7,639	31,322	37,305	30,472
		59.07	18,918 / 6,063	32,598	44,852	29,468
Soil Profile 3, Buried Soil 3	0.4260		24,550 / 8,177	34,785	43,122	33,783
		41.41	14,255 / 4,541	16,183	12,822	16,500
Ponded Deposits	0.4255		24,482 / 8,153	34,628	42,853	33,633
		58.5	18,746 / 6,007	31,868	43,070	28,920

Abbreviations: MHI = Maximum Horizon Index; SDI = Soil Development Index; PB = Punta Banda; VAB = Valley Agua Blanca; SSavg = San Simeon, terrace average

The Dolan et al. (1997) soil age regressions include curves that capture 95% of the data used to generate the chronofunction. We typically use these curves to calculate the minimum and maximum age values for a given soil index, and on Table 1 we present both the median and minimum age values calculated using the Dolan et al. (1997) regressions. The chronofunctions that we generated for this study, such as those shown on Graphs 5 and 6, include 95% confidence interval (CI) envelopes around the median that delineate the area where the linear regression equation that best fits the data is likely to be located. These 95% CI envelopes, however, do not capture 95% of the data used, and are thus not comparable to the envelopes shown on the Dolan et al. (1997) graphs. Because we did not develop similar envelopes to capture 95% of the data used, all other values on Table 1 represent median age estimates. Given that the Dolan et al. (1997) regressions generally returned the youngest ages for the soils described for this study, it is our opinion that the minimum soil development age estimates we calculated with these chronofunctions represent the absolute minimum ages possible for these deposits.

4.0 DISCUSSION and SUMMARY OF RESULTS

Given that the surface soil described in Profiles 1, 2 and 3 is thought to have developed on eolian sediments that were most likely deposited during the last glacial maximum, approximately 20-30ka, the soil development age estimates calculated using the Dolan et al. (1997) regressions appear provide the best age estimates for these surface soils. Furthermore, and as discussed extensively above, the soil age regressions in Dolan et al. (1997) return the youngest age estimates for the soils we described in the trenches. Since these soils are thought to be exposed to coastal fog, and are thus likely to have formed faster than inland soils, the youngest ages seem to be most appropriate for this site.

Table 2 summarizes our preferred ages for the soils described for this study. Our preferred age for the surface soil is constrained between the minimum age returned by the Dolan et al. (1997) regressions, and the age of the eolian sediments that this soil formed. Assuming that these eolian sediments began to be deposited when sea level fell during the last glacial maximum, the soil cannot be more than about 18,000 years old. Thus, even though the soil regressions returned ages significantly older than 18,000 years, we opted to cap the age of the surface soil in all exposures to 18,000 years.

For the buried soils, we chose to give a range of possible development ages that stretch from the lowest average age returned by the regressions to the "middle of the road" values that do not extend into the 100,000s. In particular, we chose to ignore the high age estimates returned by the Punta Banda SDI regressions.

To obtain the total minimum age for a given profile, the development age estimates for all of the soils in that profile were added together, except for Profile 3, where the second buried soil was truncated by faulting, and the third buried soil likely represents a repeated section of the second buried soil. In this case, we suggest that the age of the entire profile is best represented by the sum of the estimated time the surface soil and each of the first two buried soils were exposed to pedogenic processes, plus the difference in soil-development age between the second and third buried soils. Finally, the age of the ponded deposits is determined by adding the length of time that these sediments are thought to have been exposed to soil-forming processes before burial,

plus the age of the overlying surface soil developed in eolian deposits. We used our preferred age of the surface soil from Profile 1, for this calculation. Additional discussion regarding the age of these soils based on their geologic history is provided in the paragraphs below.

Table 2: Preferred Age Estimates for the Soils and Soil Profiles Described for this Study

Soil	Preferred Development Age of Individual Soil	Preferred Age of Profile
Soil Profile 1, Surface Soil	11,000 - 18,000	
Soil Profile 1, Buried Soil 1	33,000 - 87,000	
Soil Profile 1, Buried Soil 2	22,000 – 35,000	66,000 – 140,000
Soil Profile 2, Surface Soil	16,000 – 18,000	
Soil Profile 2, Buried Soil 1	28,000 – 59,000	
Soil Profile 2, Buried Soil 2	18,000 – 40,000	62,000 – 117,000
Soil Profile 3, Surface Soil	7,000 – 18,000	
Soil Profile 3, Buried Soil 1	25,000 – 83,000	
Soil Profile 3, Buried Soil 2	19,000 – 45,000	
Soil Profile 3, Buried Soil 3	13,000 – 43,000	57,000 – 148,000
Ponded Deposits	19,000 – 43,000	30,000 – 61,000

The first buried soil represents the stable ground surface before the last glacial maxima exposed the continental shelf, facilitating burial by the eolian sediments in which the surface soil formed. This paleo surface was composed of alluvial and alluvial fan deposits that were graded to a more distant coastline than today's, probably the MIS 3 coastline of 30-60 ka, but not impossibly the MIS 5a at 75-85 ka (especially considering that this soil appears to have formed during a dry and warm climate, such as MIS 5a).

The second buried soil is locally separated from the overlying soil by a stoneline, implying at least some erosional lowering of the second soil's ground surface before and while undergoing pedogenic weathering. These deposits could be MIS 5e, with surface stabilization occurring during MIS 5c, or they could be as old as MIS 7 with the surface lowering during MIS 6 and pedogenic development occurring during the MIS 5 intervals.

To conclude, therefore, the surface soil is a latest Pleistocene to early Holocene soil developed on late Pleistocene (MIS 2 - 20-30 ka) eolian sands. Those sands blanket a paleosurface that formed during MIS 3 (30-50 ka) that is most likely composed of MIS 4 (60-80 ka) sediments, which in turn overlie an MIS 5 (80-120 ka) paleosol developed upon older alluvial sediments. This would be the youngest age interpretation for all the units.

We hope that the information provided above helps you and team in further characterizing the earthquake history of this segment of the Los Osos fault. Thank you for the opportunity to assist you on this project. Should you have any questions regarding the above, please do not hesitate to contact the undersigned at (714) 412-2654.

Respectfully submitted,
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APPENDIX B: SOIL DESCRIPTIONS

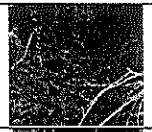
Profile No. 1: Trench T-1A, at about Station 66, on the North Wall

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
0 - 0.75 (0 - 23)	23		ABt1	Surface Soil	SILTY CLAY; very dark gray (10YR 3/1) with very dark grayish brown (10YR 3/2) clay films when dry, black (10YR 2/1) with black (10YR 2/1) clay films when moist; strong medium angular blocky soil structure; extremely hard when dry, very firm when moist, very sticky and very plastic when wet; continuous thick clay films on ped faces, common to many moderately thick clay films coating clasts, many thick clay films lining clast pockets; many fine and common medium roots; scattered fine gravel; clear wavy lower boundary.
0.75 - 1.41 (23 - 43)	20		ABt2		SILTY CLAY; very dark gray and dark brown (10YR3/1 and 10YR 3/3) when dry, black and very dark brown (10YR 2/1 and 7.5YR 2.5/3) when moist; strong medium angular blocky soil structure; extremely hard when dry, firm when moist, very sticky and very plastic when wet; continuous thick clay films on ped faces, many moderately thick and common thick clay films coating clasts, continuous thick clay films lining clast pockets; common fine roots; mix of A and Bt material; scattered fine gravel; clear wavy lower boundary.
1.41 - 1.97 (43 - 60)	17		2Btkb	Buried Soil 1	SILTY CLAY LOAM; dark brown (7.5YR 3/3) when dry, dark brown (7.5YR 3/2) when moist; moderate fine subangular blocky to granular soil structure; hard to very hard when dry, very firm when moist, sticky and plastic when wet; few thick and many to continuous moderately thick clay films on ped faces, common moderately thick clay films coating clasts, few moderately thick clay films lining clast pockets; few to common fine roots; moderately thick calcium carbonate coatings on ped faces and as veins; clear irregular lower boundary.
1.97 - 2.72 (60 - 83)	23		3Btb		SILTY CLAY; brown (7.5YR 4/4) with dark brown (7.5YR 3/2) clay films when dry, dark brown (7.5YR 3/3) with very dark brown (7.5YR 2.5/2) clay films when moist; moderate fine to coarse angular blocky soil structure; extremely hard when dry, firm when moist, very sticky and very plastic when wet; few thick and many moderately thick clay films on ped faces, common moderately thick clay films coating clasts, many moderately thick clay films lining clast pockets, few thin clay films lining pores; common fine gravel; common medium pores; abrupt smooth to wavy lower boundary.

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
2.72 - 3.51 (83 - 107)	24		4BCb		SILTY CLAY; brown (7.5YR 4/4) with dark brown (7.5YR 3/2) clay films when dry, dark brown (7.5 3/3) with dark brown (7.5YR 3/2) clay films when moist; moderate fine to medium subangular blocky soil structure breaking to moderate fine granular and single-grained; hard when dry, firm when moist, sticky and plastic when wet; few moderately thick and common thin clay films on ped faces, common moderately thick and many thin clay films coating clasts, common moderately thick clay films lining clast pockets; with pockets of clay; developed on a different sedimentary unit with scattered subangular and angular cobbles, common subangular coarse gravel, and more fine to medium sand than units above; abrupt wavy lower boundary.
3.51 - 4.04 (107 - 123)	16		5Btb2	Buried Soil 2	SILTY CLAY; brown (7.5YR 4/4) with dark brown ((7.5YR 3/3 clay films when dry, brown (7.5YR 4/3) with dark brown (7.5YR 3/2) clay films when moist; strong medium to coarse subangular blocky breaking to strong fine prismatic soil structure; very hard when dry, firm when moist, very sticky and very plastic when wet; common thin and few moderately thick clay films on ped faces, many moderately thick clay films coating clasts, common moderately thick clay films lining clast pockets, common thin clay films lining pores; scattered subangular pebbles; few to common fine gravel; clear wavy lower boundary.
4.04 - 4.76 (123 - 145)	22		5Btb3		SILTY CLAY; brown (7.5YR 5/4) with brown (7.5YR 4/3) clay films when dry, brown (7.5YR 4/4) when moist; moderate fine subangular blocky soil structure breaking to single-grained; hard when dry, firm when moist, sticky and very plastic when wet; common to continuous thick clay films coating clast pockets, continuous thin and common moderately thick clay films lining clast pockets; soil developed on a matrix-supported fine-grained mudflow deposit with scattered clasts up to 10 cm in diameter, common subangular pebbles and gravel; clear irregular lower boundary.
4.76 - 6.07 (145 - 185)	40		5Btb4		SILTY CLAY to SANDY CLAY; brown (7.5YR 5/4) when dry, brown (7.5YR 4/4) when moist; moderate fine to medium subangular blocky soil structure breaking to granular and single-grained; very hard when dry, firm when moist, very sticky and very plastic when wet; common to many moderately thick clay films coating clasts, continuous thick clay films lining clast pockets; common clasts greater than 10 cm at Stage 2 clast-weathering; common fine gravel and common angular to subrounded pebbles; localized iron oxide staining; clear irregular lower boundary.

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
6.07 - 7.19 (185 - 219)	34		6Btb5		SANDY CLAY; brown (7.5YR 4/4) when dry, brown (7.5YR 4/3) when moist; weak medium subangular blocky soil structure breaking to single-grained; hard when dry, firm when moist, sticky and very plastic when wet; continuous moderately thick clay films on clast pockets, many thin and common moderately thick clay films coating clasts, clay films on rock fractures; soil developed on a clast-supported, coarser-grained mudflow deposit with clasts 10 -25 cm in diameter, common subangular to subrounded cobbles and common fine gravel; most clasts at Stage 2 clast weathering, a few at Stage 3; gradual irregular lower boundary.
7.19 - 8.46 (219 - 258)	39		6Btb6		SANDY CLAY; brown (7.5YR 5/4) when dry, brown (7.5YR 4/4) when moist; moderate fine to medium subangular blocky soil structure; slightly hard to hard and fragic when dry, firm when moist, sticky and very plastic when wet; common thin clay films on ped faces, common moderately thick clay films coating clasts, common thin clay films lining clast pockets, continuous thick clay films on clast pockets; common angular to subangular pebbles, common fine gravel; abrupt smooth to wavy lower boundary to serpentinite bedrock of the Franciscan Formation below, to the bottom of the trench at a depth of 302 cm.

Profile No. 2: Trench T-1A, at about Station 3, on the South Wall

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
0 - 0.72 (0 - 22)	22		A1	Surface Soil	SILTY CLAY; dark brown (7.5YR 3/2) when dry, black (7.5YR 2.5/1) when moist; moderate fine to coarse granular soil structure; extremely hard when dry, extremely firm when moist, sticky and plastic when wet; many roots and rootlets; clear wavy lower boundary.
0.72 - 1.38 (22 - 42)	20		A2		SILTY CLAY; very dark gray (7.5YR 3/1) when dry, black (7.5YR 2.5/1) when moist; moderate fine to medium subangular blocky to granular soil structure; extremely hard when dry, firm when moist, very sticky and very plastic when wet; many roots; common to many medium sand grains and fine gravels; clear to gradual and wavy lower boundary.
1.38 - 1.90 (42 - 58)	16		Bt		SILTY CLAY; very dark gray (7.5YR 3/1) when dry, black (7.5YR 2.5/1) when moist; moderate fine to medium subangular blocky to granular soil structure; very hard when dry, firm when moist, very sticky and very plastic when wet; common thin clay films on ped faces, few thin clay films coating clasts; common fine roots; many visible sand grains and fine gravels; clear to gradual wavy lower boundary.
1.90 - 3.08 (58 - 94)	36		2Btkb	Buried Soil 1	SILTY CLAY; very dark gray (7.5YR 3/1) with brown (7.5YR 4/3) clay films when dry, black (7.5YR 2.5/1) with brown (7.5YR 4/3) clay films when moist; strong medium to coarse prismatic breaking to strong medium subangular blocky soil structure; very hard to extremely hard when dry, very firm when moist, very sticky and very plastic when wet; common to many moderately thick and few thin clay films on ped faces, many thin and few moderately thick clay films coating clasts, common thin clay films lining clast pockets; many rootlets; Stage I to II calcium carbonate lining pores and as nodules; common visible sand grains and small pebbles; abrupt wavy lower boundary on a stoneline of rounded to subrounded pebbles to cobbles.

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
3.08 - 4.30 (94 - 131)	37		3Btb1	Buried Soil 2	SANDY CLAY; brown (7.5YR 4/4) with dark brown (7.5YR 3/4) clay films when dry, brown (7.5YR 4/3) with dark brown (7.5YR 3/3) clay films when moist; weak fine to medium subangular blocky soil structure breaking to single-grained; slightly hard and fragic when dry, friable when moist, slightly sticky and slightly plastic when wet; few thin clay films on ped faces, common to many moderately thick clay films coating clasts, many thin clay films lining clast pockets; sand fraction is predominantly medium- to coarse-grained; many fine gravels and common pebbles weathered to clast-weathering Stages 2 to 3; zones of increased clay content; gradual wavy lower boundary.
4.30 - 5.09 (131 - 155)	24		4Btb2		Clast-supported cobbly SANDY CLAY; brown (7.5YR 4/4) with dark brown (7.5YR 3/4) clay films when dry, dark brown (7.5YR 3/3) with dark brown (7.5YR ¾) clay films when moist; weak fine subangular blocky soil structure breaking to single-grained; slightly hard when dry, friable when moist, non-sticky to slightly sticky and plastic when wet; many to continuous moderately thick clay films coating clasts, many to continuous moderately thick clay films lining clast pockets; with fine gravel and pebbles up to 2.5-inches (5 cm) in diameter, felsic, subrounded to subangular, weathered to clast-weathering Stages 2 to 3; sand fraction is predominantly medium to coarse grained; clear wavy lower boundary on a stoneline.
5.09 - 6.27 (155 - 191)	36		$5Bt_{lam}1b$		SANDY CLAY; dark brown (7.5YR 3/4) with dark brown (7.5YR 3/3 clay films and Bt lamellae when dry, dark brown (7.5YR 3/4) with dark brown (7.5YR 3/3) clay films and Bt lamellae when moist; single-grained; slightly hard and fragic when dry, friable when moist, non-sticky and slightly plastic when wet (Bt lam material); many to continuous moderately thick to thick clay films coating clasts, many moderately thick clay films lining clast pockets; the gravel and pebbles are finer grained than above, subangular to subrounded, weathered to clast weathering Stages 2 to 3; Bt lamellae and zones of increased clay are redder in color but still single-grained; gradual wavy lower boundary.

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
6.27 - 7.45 (191 - 227)	36		$5Bt_{lam}2b$		SANDY CLAY LOAM; dark brown (7.5YR 3/4) with dark brown (7.5YR 3/3) clay films and Bt lamellae when dry, very dark brown (7.5YR 2.5/3) with dark brown (7.5YR 3/3) clay films and Bt lamellae when moist; single-grained; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many moderately thick clay films coating clasts, many to continuous moderately thick clay films lining clast pockets; sand fraction is medium- to coarse-grained; fine gravel and pebbles to 1-inch (2.5 cm) in diameter, rounded to subangular, weathered to clast-weathering Stages 2 to 3; clear wavy lower boundary with another clast-supported mudflow unit with little soil development. This lower mudflow deposit was not described. Below the mudflow deposit was bedrock of the Franciscan Formation.

Profile No. 3: Trench T-2A, at about Station 1.2, on the North Wall

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designation		LCI's Geologic Unit Name	Description
0 - 0.59 (0 - 18)	18		A1	Surface Soil	Unit 7	SILTY CLAY LOAM; dark grayish brown (10YR 4/2) when dry, very dark grayish brown (10YR 3/2) when moist; moderate to strong coarse subangular blocky breaking to strong fine to medium granular soil structure; hard when dry, firm when moist, non-sticky to slightly sticky and slightly plastic when wet; common fine roots; scattered coarse sand to fine gravel; common fine to coarse pores; gradual wavy lower boundary.
0.59 - 1.64 (18 - 50)	32		A2/Btj			SILTY CLAY LOAM; dark grayish brown (10YR 4/2) with brown (10YR 4/3) clay films when dry, very dark brown (10YR 2/2) when moist; strong coarse subangular blocky breaking to moderate fine granular soil structure and single-grained; slightly hard to hard when dry, firm when moist, sticky and plastic when wet; few thin clay films on ped faces; many roots; scattered coarse sand to fine gravel; common fine to coarse pores; clear smooth lower boundary.
1.64 - 2.46 (50 - 75)	25		2Btb1	Buried Soil 1	Unit 5	SILTY CLAY; dark grayish brown (10YR4/2) with brown (10YR 4/3) clay films when dry, very dark grayish brown (10YR 3/2) when moist; moderate coarse subangular blocky soil structure; hard when dry, firm when moist, very sticky and plastic when wet; few thin clay films in pores, many thick clay films coating clasts, many moderately thick clay films lining clast pockets; few fine roots; scattered coarse sand to fine gravel; clasts are weathered to weathering Stages 3 to 4; clear wavy lower boundary.
2.46 - 2.92 (75 - 89)	14		2Btb2		Unit 3	SILTY CLAY; dark grayish brown (10YR 4/2) when dry, dark brown (10YR 3/3) with very dark grayish brown (10YR 3/2) clay films when moist; strong medium prismatic soil structure; very hard when dry, very firm when moist, very sticky and very plastic when wet; continuous thick clay films on ped faces, many moderately thick clay films coating clasts; common coarse sand and fine gravel, clasts are weathered to Stage 3 to 4; few fine roots; clear wavy to irregular lower boundary defined by a stoneline.

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designation		LCI's Geologic Unit Name	Description
2.92 - 3.64 (89 - 111)	22		3Btb3	Buried Soil 2		Gravelly SILTY CLAY; brown (7.5YR 4/3) with brown (7.5YR 4/2) clay films when dry, brown (10YR 4/3) with very dark grayish brown (10YR 3/2) clay films when moist; strong coarse angular blocky breaking to strong fine to medium angular blocky soil structure at the top and strong fine angular blocky soil structure at the bottom; very hard when dry, extremely firm when moist, very sticky and very plastic when wet; common moderately thick clay films on ped faces; many moderately thick clay films coating clasts, continuous moderately thick clay films lining clast pockets; many scattered fine-gravel-sized angular to subangular clasts of Franciscan Formation bedrock weathered to Stage2 to 3; abrupt to clear wavy lower boundary.
3.64 - 4.53 (111 - 138)	27		4Btb4			SILTY CLAY LOAM; brown to yellowish brown (7.5-10YR 5/4) with brown (7.5YR 5/4) clay films when dry, dark yellowish brown (10YR 4/4) when moist; moderate fine to medium subangular blocky soil structure breaking to single-grained; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; common moderately thick clay films on ped faces, continuous moderately thick clay films coating clasts, continuous moderately thick to thick clay films lining clast pockets; scattered clasts weathering to Stage3 to 4; abrupt smooth lower boundary defined by a **fault**.
4.53 – 4.79 (138 – 146)	30 cm thick at Station 3+00, where sample was collected		5Btb5	Buried Soil 3	Unit 3	SANDY CLAY; brown (7.5YR 5/3) with brown (7.5YR 4/3) clay films when dry, dark brown (7.5YR 3/3) with dark brown (7.5YR 3/3) clay films when moist; weak fine subangular blocky soil structure breaking to single-grained; hard to very hard when dry, very firm when moist, sticky and plastic when wet; many moderately thick clay films on ped faces, many moderately thick clay films coating clasts, continuous moderately thick to thick clay films coating clast pockets; many scattered subrounded to subangular clasts up to 3 inches (7.5 cm) in diameter consisting predominantly of Franciscan Formation bedrock weathered to Stage 3 to 4, chert clasts weathered to Stage 1; gradual wavy lower boundary.

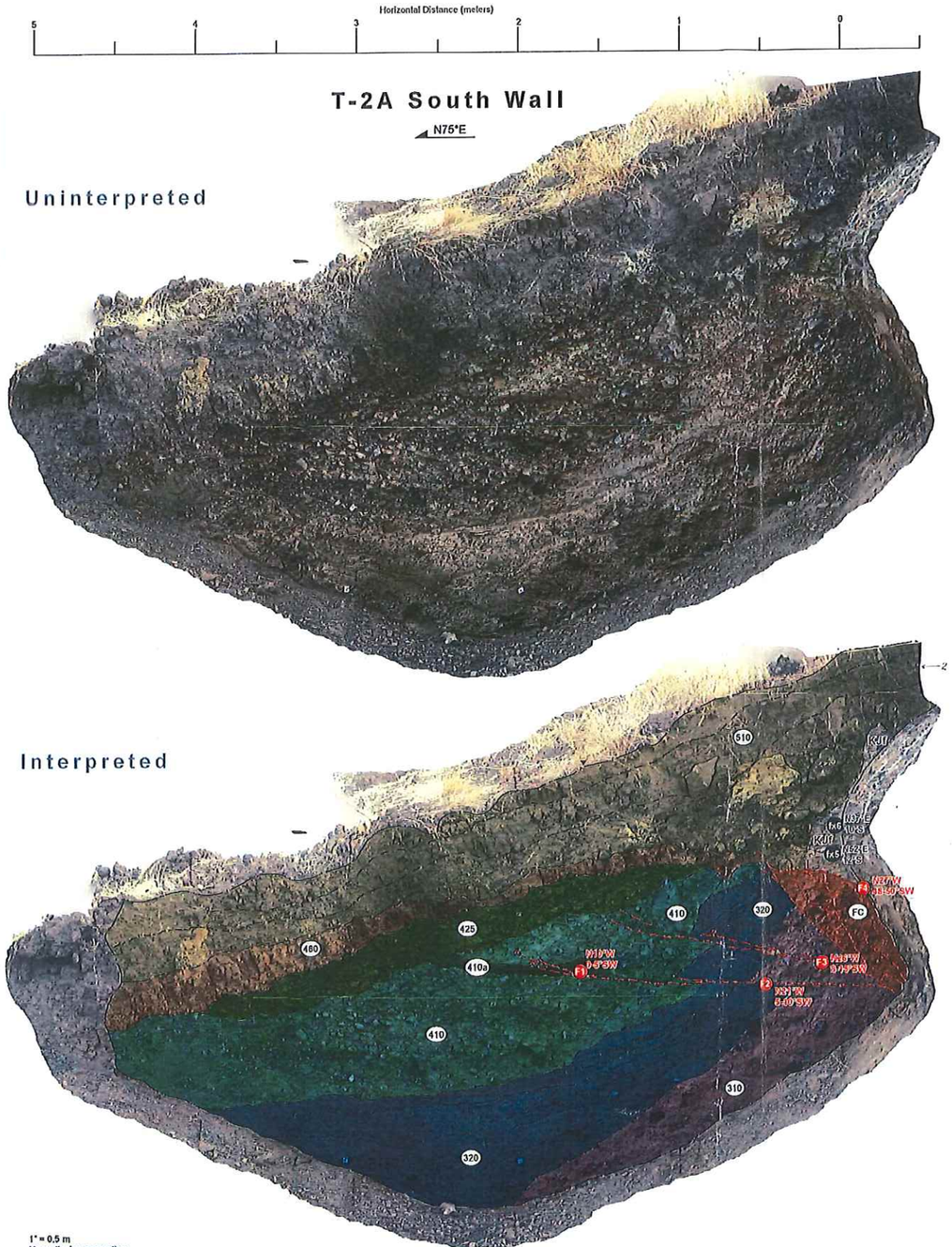
Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designation	LCI's Geologic Unit Name	Description
	30 cm thick at Station 3+00, where sample was collected		5Btb6		SANDY CLAY LOAM; brown (10YR 4/3) when dry and crushed, dark brown (7.5YR 4/3) when moist; weak fine subangular blocky soil structure breaking to single-grained; slightly hard when dry, very friable to friable when moist, sticky and plastic when wet; many moderately thick clay films on ped faces, continuous moderately thick and common thick clay films coating clasts, common thick clay films lining clast pockets; scattered clasts predominantly of Franciscan Formation bedrock that range from fine gravel to 3 inches (7.5 cm) in diameter, subrounded to subangular and broken, weathered to Stages 2 to 4; abrupt wavy lower boundary.
4.79-5.54 (146-169)	23		6Btb7	**Unit 2**	SANDY LOAM; yellowish brown (10YR 5/4) with (7.5YR 5/4) clay films when dry, brown (7.5YR 4/3) when moist; massive breaking to weak to moderate fine subangular blocky soil structure; slightly hard when dry, friable when moist, non-sticky and slightly plastic when wet; few to common thin clay films on ped faces, common moderately thick and many thin clay films coating clasts, many moderately thick clay films lining clast pockets; indurated; common fine to medium gravel, common matrix-supported, subangular to subrounded gravel and pebbles predominantly of Franciscan Formation bedrock, weathered to Stages 2 - 4, less Stage 4 weathered clasts than horizon above; clear wavy lower boundary.
5.54 - 6.73 (169 - 205)	36		7BCb	**Unit 1**	LOAM; light yellowish brown (10YR 6/4 when dry, brown (10YR 4/4) when moist; massive breaking to moderate fine subangular blocky soil structure; hard when dry, friable when moist, non-sticky and slightly plastic when wet; indurated; few scattered fine gravel up to 2 inches (5 cm) in diameter consisting predominantly of Franciscan Formation bedrock weathered to Stage 3; many manganese oxide stains on parting surfaces; fractured; lower boundary not observed.

Ponded Deposit Profile West of Profile 2 in Trench T-1A

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon Designation	Description
1.67- 2.30 (51-70)	19		Btb1	CLAY; dark brown (7.5YR 3/2) with very dark brown (7.5YR 2.5/2) and very dark gray (7.5YR 3/1) clay films when dry, dark brown (7.5YR 3/2) with dark brown (7.5YR 3/3) and black (7.5YR 2.5/1) clay films when moist; strong coarse angular blocky soil structure; very hard when dry, very firm to extremely firm when moist, very sticky and very plastic when wet; many thin and common moderately thick to thick clay films on ped faces, common moderately thick clay films coating clasts, many moderately thick clay films lining clast pockets; many fine rootlets; scattered visible coarse sand grains; clear irregular lower boundary.
2.30 - 2.99 (70 - 91)	21		Btb2	SILTY CLAY to CLAY; dark brown (7.5YR 3/2) and very dark gray (7.5YR 3/1) when dry, dark brown (7.5YR 3/3) and black (7.5YR 2.5/1) when moist; strong very coarse prismatic breaking to strong coarse angular blocky soil structure; extremely hard when dry, firm to very firm when moist, very sticky and very plastic when wet; common to many moderately thick and few thick clay films on ped faces, common thin to moderately thick clay films coating clasts, common moderately thick clay films lining clast pockets; common fine rootlets; scattered visible medium to coarse sand grains; clear irregular lower boundary.
2.99 - 3.31 (91 - 101)	10		Btb3	SILTY CLAY to SANDY CLAY; dark brown (10YR 3/3) and black (10YR 2/1) with dark brown (7.5YR 3/2) clay films when dry, dark brown (10YR 3/3) and black (10YR 2/1) with dark brown (7.5YR 3/3) clay films when moist; moderate medium subangular blocky soil structure; very hard to extremely hard when dry, extremely firm when moist, sticky and very plastic when wet; many thin to moderately thick clay films on ped faces, common thin clay films bridging grains, common thin clay films in pores; few fine rootlets; some fine pores; clear wavy lower boundary.
3.31 - 3.67 (101 - 112)	11		2Btb4	SANDY LOAM to SANDY CLAY LOAM; dark yellowish brown (10YR 3/6) with dark yellowish brown to dark reddish brown (10-7.5YR 3/4) clay films when dry, dark brown (10YR 3/3) with dark brown (10YR 3/3) clay films when moist; few peds with increased clay have very weak fine subangular blocky soil structure breaking to single-grained, most section is single-grained; slightly hard when dry, friable when moist, non-sticky and slightly plastic when wet; common thin and few moderately thick clay films coating clasts; few scattered subangular gravel to small pebbles; abrupt wavy lower boundary to a cobbly gravel unit below.

Samples of Alluvium Collected from Wall of the Modern-Day Incised Channel (Parent Material)

Designation	Photo (not to scale)	Description
Sandy Channel section		LOAM; brown (10YR 5/3) when dry, dark brown (10YR 3/3) when moist; moderate fine subangular blocky soil structure; slightly hard when dry, friable to firm when moist, non-sticky and slightly plastic when wet; common fine pores; common fine rootlets; visible medium to coarse sand grains.
Gravelly Channel section		Gravelly to Stony LOAMY SAND; brown (10YR 4/3) when dry, dark brown (10YR 3/3) when moist; single-grained; loose when dry and moist, non-sticky and non-plastic when wet; many subangular fine gravel, pebbles and cobbles up to 4 inches (10 cm) in diameter; predominantly mafic; sand fraction is fine- to coarse-grained.



EXPLANATION:

510 — Unit 510- Silt with occasional pebbles to medium cobbles. Brown (10YR 4/3); clasts are dominantly Franciscan, increasing in size to small boulders to west, angular, fractured, slightly weathered; matrix is eolian silt, with some clay and sparse fine sand; loose, moist, slightly to moderately cohesive; a surface soil sequence is developing in unit: upper 5 to 15 cm is an Ap/AB horizon with weak granular structure, middle 10 to 20 cm is an A/Btj with weak angular blocky to prismatic structure, and the basal 20 cm is a Btss, similar to Unit 480, with a weak small angular blocky structure; basal contact is clear and smooth. Holocene to modern slope colluvium with stable soil.

480 — Unit 480 - Massive clayey silt with sparse small pebbles. Very dark brown to dark grayish brown (10YR 4/2 to 3/2); matrix is completely eolian silt and pedogenic clay, prominently desiccated; tough, dry to slightly moist, indurated; deep clay soil development of a strong medium to large prismatic to angular blocky structure, discontinuous clay coatings on peds exhibit soil slickensides, soil is a Btss, structural soil fractures are normal to upper and lower contact orientations which suggests unit was not eroded after soil formation; common root filaments, occasional small krotovina, few small pores; basal contact is wavy and clear. Pleistocene eolian silt with strong argillaceous soil.

425 — Unit 425 - Poorly sorted gravel. Unit is of similar composition to subjacent Unit 410 yet displays different internal bedding; darker than Unit 410, brown to dark brown (10YR 4/3 to 3/3); unit is more cohesive, with more matrix than below, and increased soil development, moderate Bt, moderate small angular blocky soil structure throughout; diffuse beds match slope angle, dip east, contrary to Unit 410; basal contact is sharp, smooth. Slope Pleistocene Qc locally sourced from Unit 410.

410a — Unit 410a - Silty sand. Brown (10YR 4/3); massive, coarse to medium sand, well sorted, some silt imparts a "dirty" appearance to otherwise clean quartz sand; no bedding, loose, slightly cohesive; fines upward and laterally to east into silty clay, may reflect ponding of previously moving water; single grained structure to very weak sub-angular blocky structure, some desiccation cracking indicative of clay content, may contain weakly developed Bt; basal contact is concave, may be channelized, clear, smooth; a single low angle fault continues through unit from Unit 410, coarser sand is concentrated at fault. Pleistocene fluvial deposit.

410 — Unit 410 - Poorly sorted gravel of diverse provenance. Clasts are composed of reddish brown chert (2.5YR 4/3), pale yellow greenstone (5Y 7/4), completely weathered yellowish brown volcanic rocks (10YR 5/6), matrix is brown (10YR 4/3); clasts are angular to sub angular, with >50% spill; matrix is loose, slightly moist, friable, increased clay content may indicate moderately developed Bt horizon in upper 30 cm, clay films discontinuous over clasts, weak to moderate small sub-angular blocky soil structure in matrix; no roots, few to common small pores; diffuse beds are defined by slight changes in clast size, from coarse sand matrix dominated areas to small cobble clast supported areas, beds dip to west; basal contact dips to east, flattens to east, may be warped, contact is clear, wavy to smooth; Unit is faulted at least once, possibly twice, from faults extending from Unit 320. Pleistocene bedded alluvium.

320 — Unit 320 - Bedded silts and moderate to fine sand. Silt beds are pale yellow (2.5Y 7/3), coarser layers are very pale yellow (10YR 7/4); bedding is defined by coarsening of matrix with discontinuous layers of coarse sand to granules of Franciscan ultramafic rocks, silt is massive; bedding is diffuse, wavy, 5 to 20 cm wide, and appears synformally warped near west end of trench; beds appear to fine upward, with sand concentrated at the base; silt layers are moderately cohesive, friable, slightly hard, sporadic desiccation cracking indicates slight clay content; coarser layers are looser, single grain structure, with discontinuous layers of granules; sporadic sub-vertical white filaments are formed in desiccation cracks, not carbonate, may reflect translocated light colored clay from KJfm uphill; no roots, few small pores; basal contact is very diffuse, defined by change in color and texture over 5 to 10 cm; Unit is faulted at least once, possibly twice between stations 0 and 1. Pleistocene slope colluvium.

310 — Unit 310 - Coarse sandy silt with sparse medium cobbles. Light yellow brown (10YR 6/4 to 2.5Y 6/3); Clasts are angular to sub angular, fractured, slightly weathered, all ultramafic Franciscan rock, well sorted throughout; loose, dry, friable; slight granular soil structure, Bw/C soil; very weakly discontinuously bedded, few small pores, no roots. Pleistocene single source colluvium.

FC — Unit FC - Silty gravel with pedogenic clay. Brown (10YR 4/3); clasts are all Franciscan, deeply to slightly weathered depending on Franciscan rock type; clasts are angular, highly fractured; where fractured rock appear unweathered; moist, cohesive, slightly tough, slightly hard; weak medium sub-angular blocky structure throughout, very weakly expressed Bt, yet clay development is extensive, may reflect post-depositional movement of unit; basal contact is buried, western contact is moderately west dipping fault. Colluvial wedge material.

KJf — Franciscan melange and serpentinite (Cretaceous/Jurassic)

Contact
Dashed where approximate;
Queried where uncertain

Bedding
Dashed where approximate;
Queried where uncertain

Trench base and corners

Fault (Active)
Dashed where approximate;
Queried where uncertain

F2 N10°W 0.5°SW — Fault Attitude

F6 N37°E 10°S — Foliation Attitude

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Photo Log of Trench T-2A South Wall

PG&E Los Osos Fault Trench Evaluation

LCI Leidis Consultants International, Inc. | Plate 2

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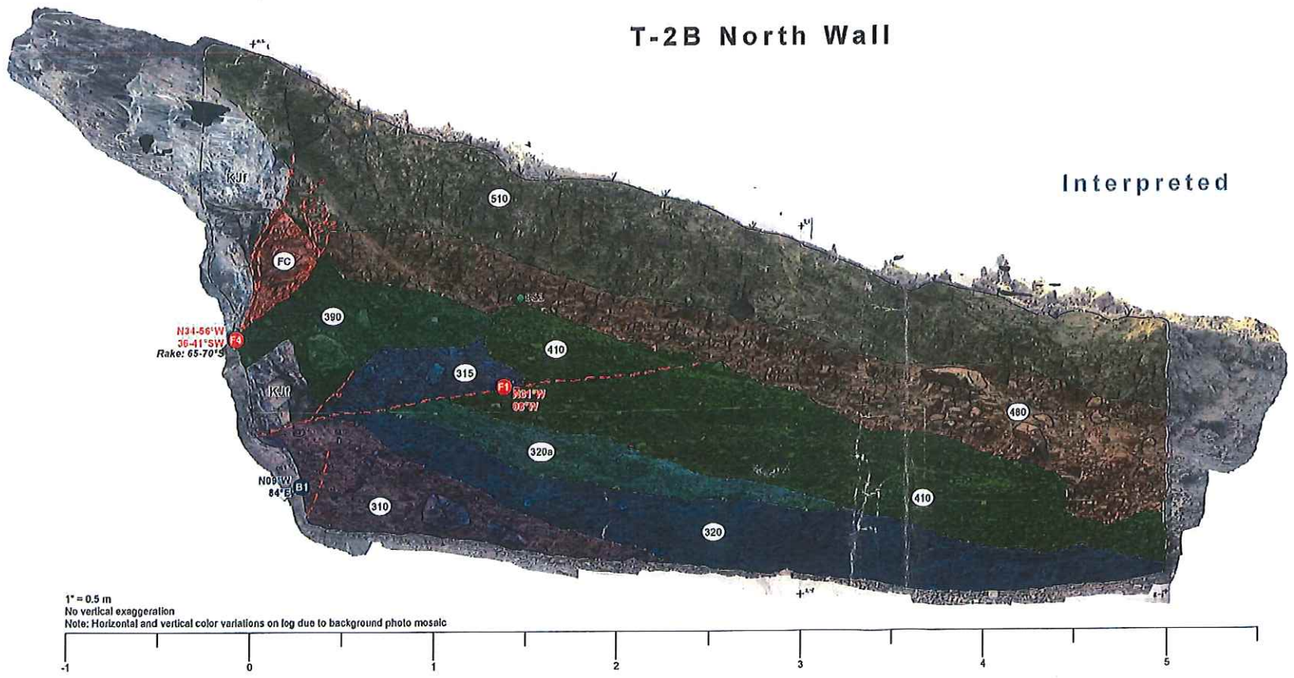
North wall of Trench T-2a detailing exposed stratigraphy and locations of pedologic study of ECI (2016)



1" = 0.5 m
No vertical exaggeration
Note: Horizontal and vertical color variations on log due to background photo mosaic

EXPLANATION:

510 — **Unit 510 - Silt with occasional pebble to medium cobbles. Brown (10YR 4/3); clasts are dominantly Franciscan, increasing in size to small boulders to west, angular, fractured, slightly weathered; matrix is eolian silt, with some clay and sparse fine sand; loose, moist, slightly to moderately cohesive; a surface soil sequence is developing in unit: upper 5-15 cm is an Ap/AB horizon with weak granular structure, middle 10-20 cm is an A/Btj with weak angular blocky to prismatic structure, and the basal 20 cm is a Btss, similar to Unit 480, with a weak small angular blocky structure; basal contact is clear and smooth. Holocene to modern slope colluvium with stable soil.**

480 — **Unit 480 - Massive clayey silt with sparse small pebbles. Very dark brown to dark grayish brown (10YR 4/2 to 3/2); matrix is completely eolian silt and clay, prominently desiccated; tough, dry to slightly moist, indurated; deep clay soil development of a strong medium to large prismatic to angular blocky structure, discontinuous clay coatings on peds exhibit soil slickensides, soil is a Btss, structural soil fractures are normal to upper and lower contact orientations which suggests unit was not eroded after soil formation; common root filaments, occasional small krotovina, few small pores; basal contact is wavy and clear. Pleistocene eolian silt with strong argillaceous soil.**

410 — **Unit 410 - Sandy gravel with clay. Dark reddish brown (5YR 3/3); clasts are angular to sub-angular, up to 20% chert, unweathered, rest serpentine and other Franciscan ultramafics, appear weathered in situ; fine silt matrix has been pedogenically altered with addition of clay; as in T-2a, fine lens of fine material is less obvious at station 2.5, this lens has well developed Bt, with strong small angular blocky structure; bedding is diffuse, weakly stratified; basal contact is sharp, clear. Pleistocene alluvium of Froom Creek.**

390 — **Unit 390 - Sandy clay with gravel and cobbles. Dark brown (7.5YR 3/2); clasts are angular to sub-angular, all Franciscan serpentine, clasts are slightly weathered, fractured, along fracture faces, appear not weathered; very dense, cohesive, moist; well-developed Bt throughout, strong small to medium angular blocky soil structure is formed in matrix; basal contact is wavy and diffuse, unclear locally, possibly due to soil overprinting; unit bounded by faults on east and west, coarsens to west, upper contact dips east imparting wedge morphology to unit. Pleistocene scarp-derived colluvium.**

320a — **Unit 320a - Silty sand with gravel. Strong brown (7.5YR 5/6 to 4/6); sand is fine to coarse, gravel composed of small to medium pebbles, angular to sub-rounded, 5-10% chert, trace meta-volcanic clasts which appear completely rusted, rest serpentine; basal contact is wavy and clear over 1-2 cm. Pleistocene alluvium.**

320 — **Unit 320- Sandy silt with gravel. Dark yellowish brown (10YR 4/6) to pale yellow (2.5Y 7/4); Matrix similar to Unit 310, fewer large clasts, gravel content down to less than 5%; basal contact is clear, smooth to wavy over 2 to 3 cm. Pleistocene colluvium.**

315 — **Unit 315 - Sandy silt with abundant gravel and sparse cobbles. Strong brown (7.5YR 4/6); similar to Unit 1; clasts all serpentine, angular; prominent soil structure from above unit developed throughout, weak to moderate sub-angular blocky structure localized to upper 20 cm; basal contact is low angle fault, unit bounded by faulting west. Pleistocene pedogenically altered colluvium.**

310 — **Unit 310 - Sandy silt with gravel and few cobbles to boulders. Dark yellowish brown (10YR 4/6) to pale yellow (2.5Y 7/4); sand is fine to medium, moderately sorting, massive, gravel is angular to sub-angular, cobbles to boulders are slightly to moderately weathered, fractured, clasts are all serpentine; basal contact is buried. Pleistocene colluvium**

FC — **Unit FC - Silty gravel with pedogenic clay. Brown (10YR 4/3); clasts are all Franciscan, deeply to slightly weathered depending on Franciscan rock type; clasts are angular, highly fractured; where fractured rock appear unweathered; moist, cohesive, slightly tough, slightly hard; weak medium sub-angular blocky structure throughout, very weakly expressed Bt, yet clay development is extensive, may reflect post-depositional movement of unit; basal contact is buried, western contact is moderately west dipping fault. Colluvial wedge material.**

KJf — **Franciscan melange and serpentinite (Cretaceous/Jurassic)**

Contact
Dashed where approximate;
Queried where uncertain

Bedding
Dashed where approximate;
Queried where uncertain

Trench base and corners

Fault (Active)
Dashed where approximate;
Queried where uncertain

F1 N31°W 08°W — Fault Attitude

B1 N09°W 84°E — Bedrock ?

BS2 — Bag Sample

DRAFT

Photo Log of Trench T-2B North Wall

PG&E Los Osos Fault Trench Evaluation

LCI Leftis Consultants International, Inc. | Plate 3

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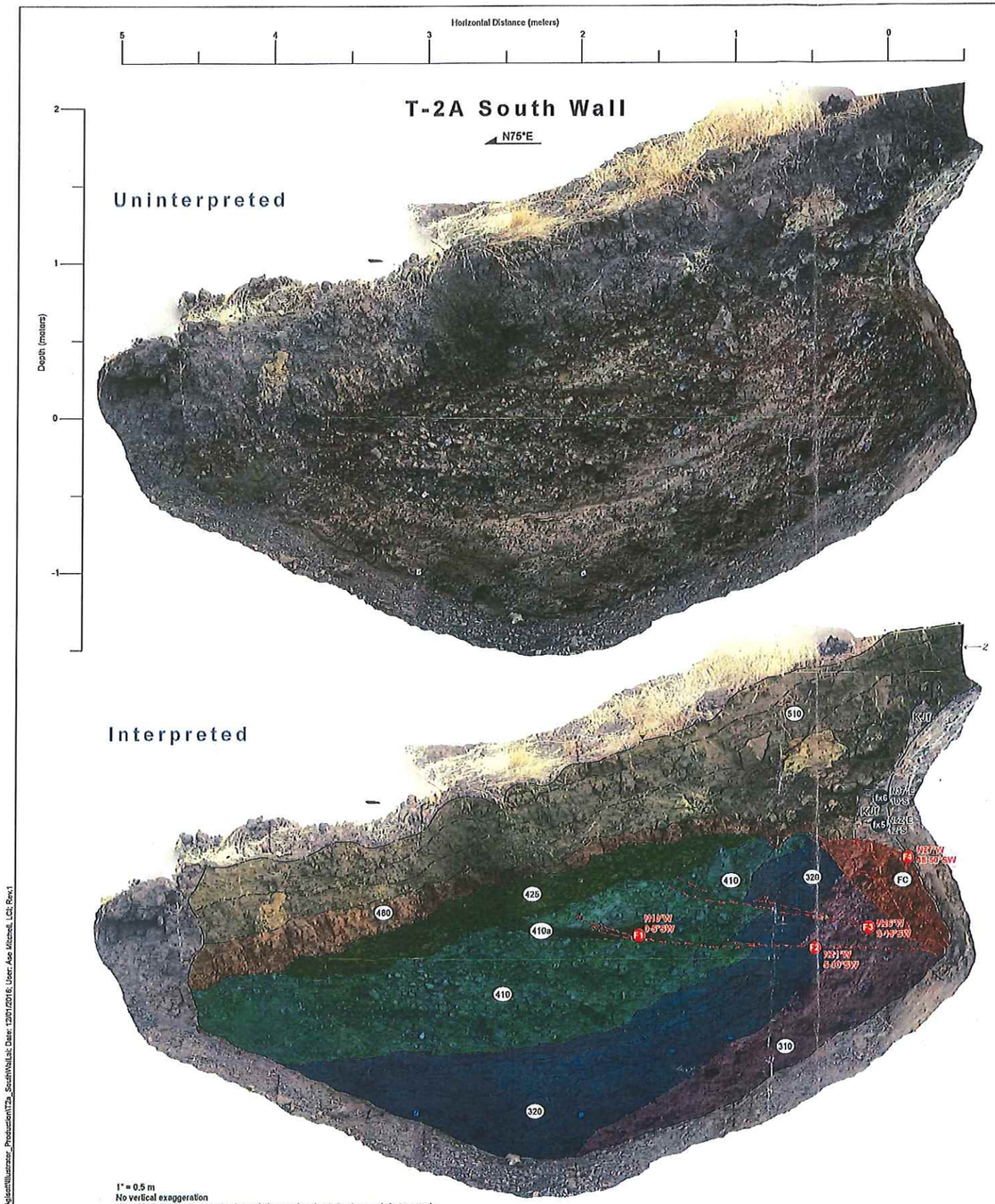

EXPLANATION:

510 — Unit 510- Silt with occasional pebbles to medium cobbles. Brown (10YR 4/3); clasts are dominantly Franciscan, increasing in size to small boulders to west, angular, fractured, slightly weathered; matrix is eolian silt, with some clay and sparse fine sand; loose, moist, slightly to moderately cohesive; a surface soil sequence is developing in unit: upper 5 to 15 cm is an Ap/AB horizon with weak granular structure, middle 10 to 20 cm is an A/Btj with weak angular blocky to prismatic structure, and the basal 20 cm is a Btss, similar to Unit 480, with a weak small angular blocky structure; basal contact is clear and smooth. Holocene to modern slope colluvium with stable soil.

480 — Unit 480 - Massive clayey silt with sparse small pebbles. Very dark brown to dark grayish brown (10YR 4/2 to 3/2); matrix is completely eolian silt and pedogenic clay, prominently desiccated; tough, dry to slightly moist, indurated; deep clay soil development of a strong medium to large prismatic to angular blocky structure, discontinuous clay coatings on peds exhibit soil slickensides, soil is a Btss, structural soil fractures are normal to upper and lower contact orientations which suggests unit was not eroded after soil formation; common root filaments, occasional small krotovina, few small pores; basal contact is wavy and clear. Pleistocene eolian silt with strong argillaceous soil.

425 — Unit 425 - Poorly sorted gravel. Unit is of similar composition to subjacent Unit 410 yet displays different internal bedding; darker than Unit 410, brown to dark brown (10YR 4/3 to 3/3); unit is more cohesive, with more matrix than below, and increased soil development, moderate Bt, moderate small angular blocky soil structure throughout; diffuse beds match slope angle, dip east, contrary to Unit 410; basal contact is sharp, smooth. Slope Pleistocene Qc locally sourced from Unit 410.

410a — Unit 410a - Silty sand. Brown (10YR 4/3); massive, coarse to medium sand, well sorted, some silt imparts a "dirty" appearance to otherwise clean quartz sand; no bedding, loose, slightly cohesive; fines upward and laterally to east into silty clay, may reflect ponding of previously moving water; single grained structure to very weak sub-angular blocky structure, some desiccation cracking indicative of clay content, may contain weakly developed Bt; basal contact is concave, may be channelized, clear, smooth; a single low angle fault continues through unit from Unit 410, coarser sand is concentrated at fault. Pleistocene fluvial deposit.

410 — Unit 410 - Poorly sorted gravel of diverse provenance. Clasts are composed of reddish brown chert (2.5YR 4/3), pale yellow greenstone (5Y 7/4), completely weathered yellowish brown volcanic rocks (10YR 5/6), matrix is brown (10YR 4/3); clasts are angular to sub angular, with >50% split; matrix is loose, slightly moist, friable, increased clay content may indicate moderately developed Bt horizon in upper 30 cm, clay films discontinuous over clasts, weak to moderate small sub-angular blocky soil structure in matrix; no roots, few to common small pores; diffuse beds are defined by slight changes in clast size, from coarse sand matrix dominated areas to small cobble clast supported areas, beds dip to west; basal contact dips to east, flattens to east, may be warped, contact is clear, wavy to smooth; Unit is faulted at least once, possibly twice, from faults extending from Unit 320. Pleistocene bedded alluvium.

320 — Unit 320 - Bedded silts and moderate to fine sand. Silt beds are pale yellow (2.5Y 7/3), coarser layers are very pale yellow (10YR 7/4); bedding is defined by coarsening of matrix with discontinuous layers of coarse sand to granules of Franciscan ultramafic rocks, silt is massive; bedding is diffuse, wavy, 5 to 20 cm wide, and appears synformally warped near west end of trench; beds appear to fine upward, with sand concentrated at the base; silt layers are moderately cohesive, friable, slightly hard, sporadic desiccation cracking indicates slight clay content; coarser layers are looser, single grain structure, with discontinuous layers of granules; sporadic sub-vertical white filaments are formed in desiccation cracks, not carbonate, may reflect translocated light colored clay from KJfm uphill; no roots, few small pores; basal contact is very diffuse, defined by change in color and texture over 5 to 10 cm; Unit is faulted at least once, possibly twice between stations 0 and 1. Pleistocene slope colluvium.

310 — Unit 310 - Coarse sandy silt with sparse medium cobbles. Light yellow brown (10YR 6/4 to 2.5Y 6/3); Clasts are angular to sub angular, fractured, slightly weathered, all ultramafic Franciscan rock, well sorted throughout; loose, dry, friable; slight granular soil structure, Bw/C soil; very weakly discontinuously bedded, few small pores, no roots. Pleistocene single source colluvium.

FC — Unit FC - Silty gravel with pedogenic clay. Brown (10YR 4/3); clasts are all Franciscan, deeply to slightly weathered depending on Franciscan rock type; clasts are angular, highly fractured; where fractured rock appear unweathered; moist, cohesive, slightly tough, slightly hard; weak medium sub-angular blocky structure throughout, very weakly expressed Bt, yet clay development is extensive, may reflect post-depositional movement of unit; basal contact is buried, western contact is moderately west dipping fault. Colluvial wedge material.

KJf — Franciscan melange and serpentinite (Cretaceous/Jurassic)

Contact
Dashed where approximate;
Queried where uncertain

Bedding
Dashed where approximate;
Queried where uncertain

Trench base and corners

Fault (Active)
Dashed where approximate;
Queried where uncertain

F1 N10°W 0.5°SW — Fault Attitude

FA N37°E 10°S — Foliation Attitude

DRAFT

Photo Log of Trench T-2A South Wall

PG&E Los Osos Fault Trench Evaluation

Leftis Consultants International, Inc. | Plate 2

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USGS Design Maps Summary Report

User-Specified Input

Report Title Froom Ranch - Lower Site
Tue June 21, 2016 23:48:46 UTC

Building Code Reference Document ASCE 7-10 Standard
(which utilizes USGS hazard data available in 2008)

Site Coordinates 35.24805°N, 120.68614°W

Site Soil Classification Site Class E – "Soft Clay Soil"

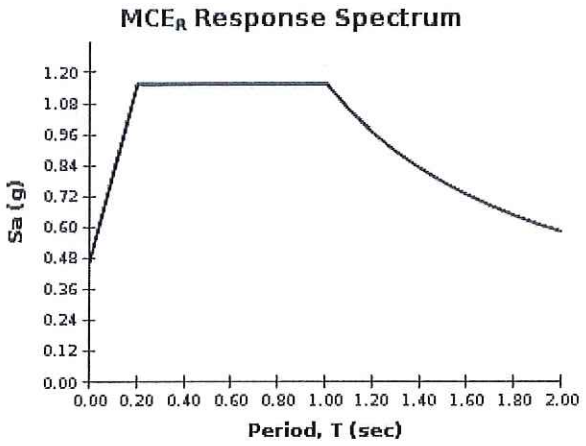
Risk Category I/II/III

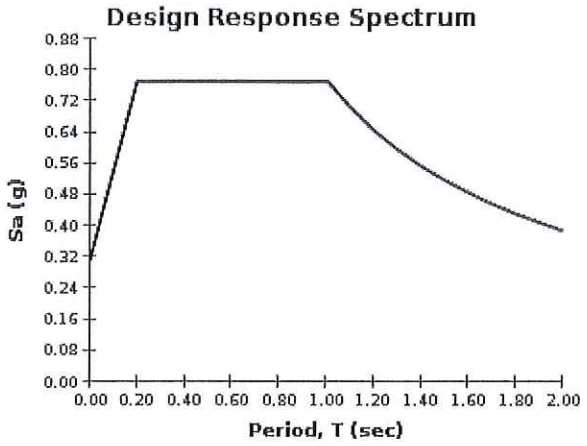


USGS-Provided Output

S_S =	1.281 g	S_{MS} =	1.153 g	S_{DS} =	0.769 g
S_1 =	0.484 g	S_{M1} =	1.162 g	S_{D1} =	0.774 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.





For PGA_M, T_L, C_{RS}, and C_{R1} values, please view the detailed report.

Although this information is a product of the U.S. Geological Survey, we provide no warranty, expressed or implied, as to the accuracy of the data contained therein. This tool is not a substitute for technical subject-matter knowledge.

USGS Design Maps Detailed Report

ASCE 7-10 Standard (35.24805°N, 120.68614°W)

Site Class E – "Soft Clay Soil", Risk Category I/II/III

Section 11.4.1 — Mapped Acceleration Parameters

Note: Ground motion values provided below are for the direction of maximum horizontal spectral response acceleration. They have been converted from corresponding geometric mean ground motions computed by the USGS by applying factors of 1.1 (to obtain S_S) and 1.3 (to obtain S_1). Maps in the 2010 ASCE-7 Standard are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 11.4.3.

From Figure 22-1 [1] $S_S = 1.281$ g

From Figure 22-2 [2] $S_1 = 0.484$ g

Section 11.4.2 — Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class E, based on the site soil properties in accordance with Chapter 20.

Table 20.3-1 Site Classification

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard Rock	>5,000 ft/s	N/A	N/A
B. Rock	2,500 to 5,000 ft/s	N/A	N/A
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff Soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the characteristics: • Plasticity index PI > 20, • Moisture content $w \geq 40\%$, and • Undrained shear strength $\bar{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Section 11.4.3 — Site Coefficients and Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameters

Table 11.4-1: Site Coefficient F_a

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at Short Period				
	$S_S \le 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \ge 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_S

For Site Class = E and S_S = 1.281 g, F_a = 0.900

Table 11.4-2: Site Coefficient F_v

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at 1-s Period				
	$S_1 \le 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \ge 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_1

For Site Class = E and S_1 = 0.484 g, F_v = 2.400

Equation (11.4-1): $S_{MS} = F_a S_S = 0.900 \times 1.281 = 1.153$ g

Equation (11.4-2): $S_{M1} = F_v S_1 = 2.400 \times 0.484 = 1.162$ g

Section 11.4.4 — Design Spectral Acceleration Parameters

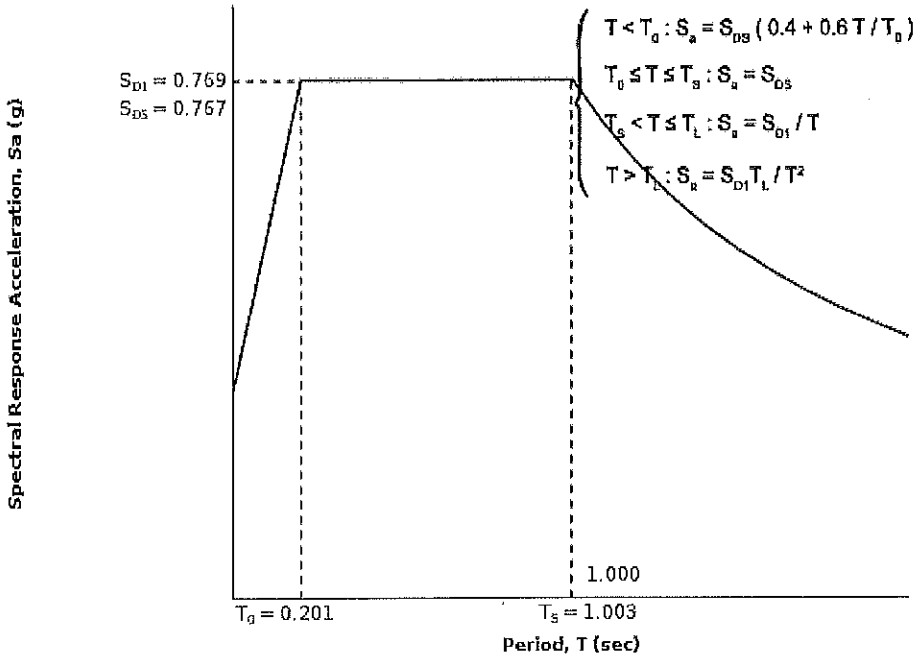
Equation (11.4-3): $S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3} \times 1.153 = 0.769$ g

Equation (11.4-4): $S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3} \times 1.162 = 0.774$ g

Section 11.4.5 — Design Response Spectrum

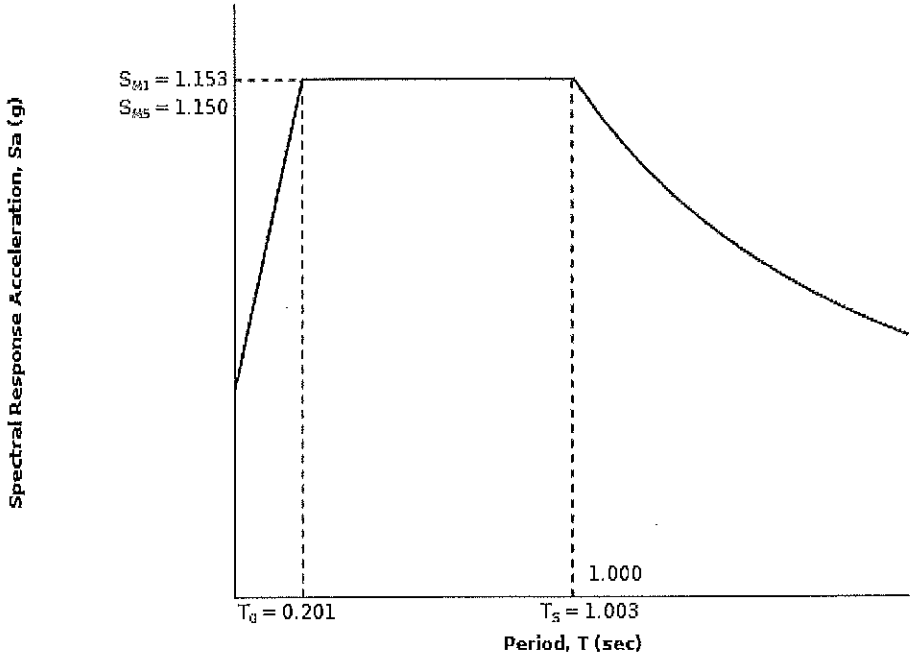
From Figure 22-12 [3] $T_L = 8$ seconds

Figure 11.4-1: Design Response Spectrum



Section 11.4.6 — Risk-Targeted Maximum Considered Earthquake (MCE_R) Response Spectrum

The MCE_R Response Spectrum is determined by multiplying the design response spectrum above by 1.5.



Section 11.6 — Seismic Design Category

Table 11.6-1 Seismic Design Category Based on Short Period Response Acceleration Parameter

VALUE OF S_{DS}	RISK CATEGORY		
	I or II	III	IV
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D	D	D

For Risk Category = I and S_{DS} = 0.769 g, Seismic Design Category = D

Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

VALUE OF S_{D1}	RISK CATEGORY		
	I or II	III	IV
$S_{D1} < 0.067g$	A	A	A
$0.067g \le S_{D1} < 0.133g$	B	B	C
$0.133g \le S_{D1} < 0.20g$	C	C	D
$0.20g \le S_{D1}$	D	D	D

For Risk Category = I and S_{D1} = 0.774 g, Seismic Design Category = D

Note: When S_1 is greater than or equal to 0.75g, the Seismic Design Category is **E** for buildings in Risk Categories I, II, and III, and **F** for those in Risk Category IV, irrespective of the above.

Seismic Design Category ≡ "the more severe design category in accordance with Table 11.6-1 or 11.6-2" = D

Note: See Section 11.6 for alternative approaches to calculating Seismic Design Category.

References

1. *Figure 22-1*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-1.pdf
2. *Figure 22-2*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-2.pdf
3. *Figure 22-12*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-12.pdf
4. *Figure 22-7*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-7.pdf
5. *Figure 22-17*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-17.pdf
6. *Figure 22-18*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-18.pdf

Section 11.8.3 — Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

From Figure 22-7 [4] PGA = 0.541

Equation (11.8-1): $PGA_M = F_{PGA}PGA = 0.900 \times 0.541 = 0.487$ g

Table 11.8-1: Site Coefficient F_{PGA}

Site Class	Mapped MCE Geometric Mean Peak Ground Acceleration, PGA				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of PGA

For Site Class = E and PGA = 0.541 g, F_{PGA} = 0.900

Section 21.2.1.1 — Method 1 (from Chapter 21 - Site-Specific Ground Motion Procedures for Seismic Design)

From Figure 22-17 [5] C_{RS} = 0.902

From Figure 22-18 [6] C_{R1} = 0.939

USGS Design Maps Summary Report

User–Specified Input

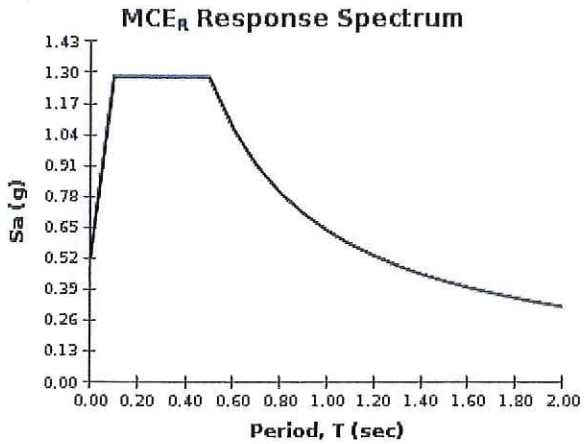
Report Title	Froom Ranch - Upper Site Tue June 21, 2016 23:46:53 UTC
Building Code Reference Document	ASCE 7-10 Standard (which utilizes USGS hazard data available in 2008)
Site Coordinates	35.24805°N, 120.68614°W
Site Soil Classification	Site Class C – "Very Dense Soil and Soft Rock"
Risk Category	I/II/III

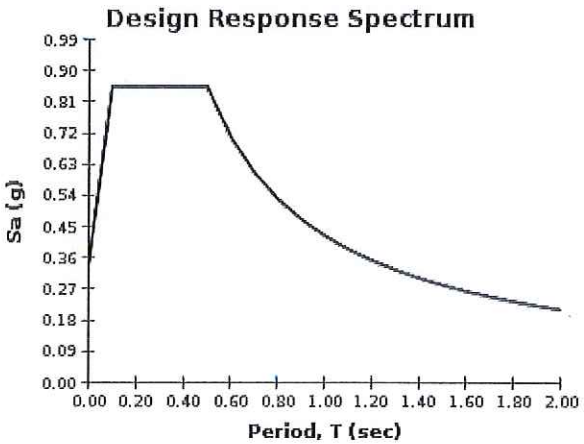


USGS–Provided Output

S_S =	1.281 g	S_{MS} =	1.281 g	S_{DS} =	0.854 g
S_1 =	0.484 g	S_{M1} =	0.637 g	S_{D1} =	0.425 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.





For PGA_M, T_L, C_{RS}, and C_{R1} values, please view the detailed report.

Although this information is a product of the U.S. Geological Survey, we provide no warranty, expressed or implied, as to the accuracy of the data contained therein. This tool is not a substitute for technical subject-matter knowledge.

USGS Design Maps Detailed Report

ASCE 7-10 Standard (35.24805°N, 120.68614°W)

Site Class C – "Very Dense Soil and Soft Rock", Risk Category I/II/III

Section 11.4.1 — Mapped Acceleration Parameters

Note: Ground motion values provided below are for the direction of maximum horizontal spectral response acceleration. They have been converted from corresponding geometric mean ground motions computed by the USGS by applying factors of 1.1 (to obtain S_S) and 1.3 (to obtain S_1). Maps in the 2010 ASCE-7 Standard are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 11.4.3.

From Figure 22-1 [1] $S_S = 1.281$ g

From Figure 22-2 [2] $S_1 = 0.484$ g

Section 11.4.2 — Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class C, based on the site soil properties in accordance with Chapter 20.

Table 20.3–1 Site Classification

Site Class	$\overline{v}_s$	$\overline{N}$ or $\overline{N}_{ch}$	$\overline{s}_u$
A. Hard Rock	>5,000 ft/s	N/A	N/A
B. Rock	2,500 to 5,000 ft/s	N/A	N/A
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff Soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the characteristics: • Plasticity index PI > 20, • Moisture content $w \geq 40\%$, and • Undrained shear strength $\overline{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Section 11.4.3 — Site Coefficients and Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameters

Table 11.4-1: Site Coefficient F_a

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at Short Period				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_S

For Site Class = C and S_S = 1.281 g, F_a = 1.000

Table 11.4-2: Site Coefficient F_v

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at 1-s Period				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_1

For Site Class = C and S_1 = 0.484 g, F_v = 1.316

Equation (11.4-1): $S_{MS} = F_a S_S = 1.000 \times 1.281 = 1.281$ g

Equation (11.4-2): $S_{M1} = F_v S_1 = 1.316 \times 0.484 = 0.637$ g

Section 11.4.4 — Design Spectral Acceleration Parameters

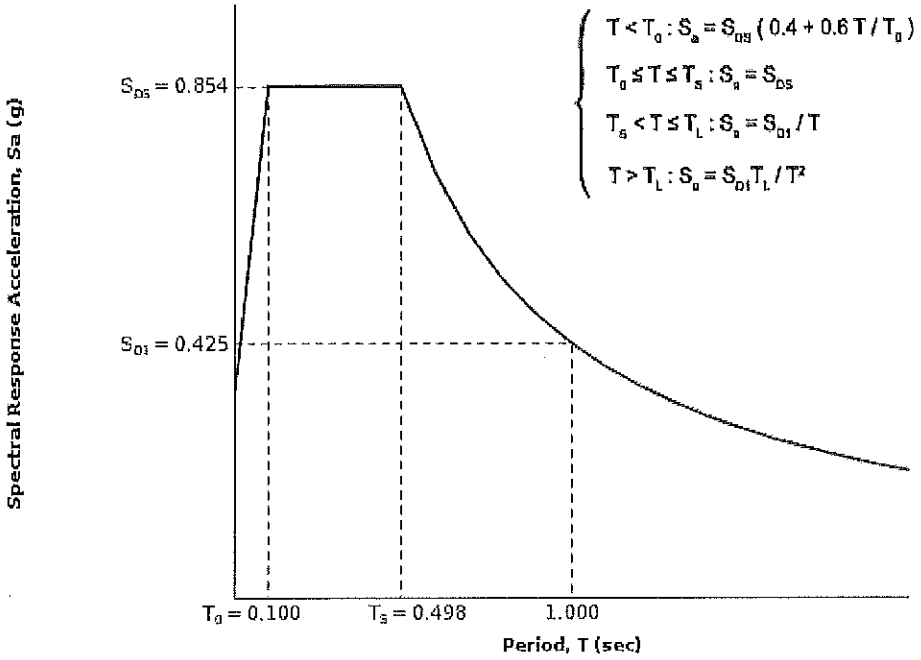
Equation (11.4-3): $S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3} \times 1.281 = 0.854$ g

Equation (11.4-4): $S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3} \times 0.637 = 0.425$ g

Section 11.4.5 — Design Response Spectrum

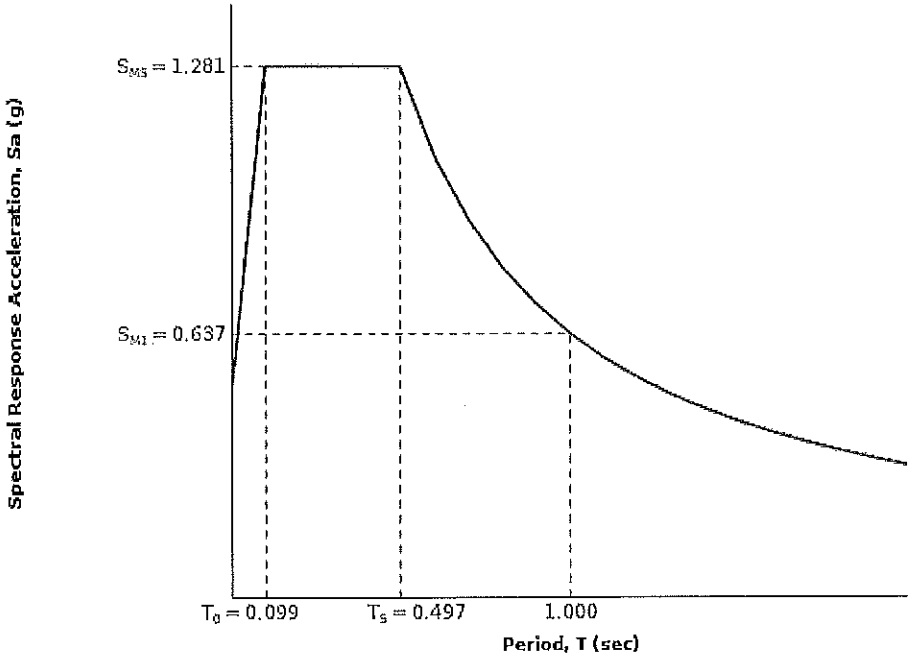
From Figure 22-12 [3] $T_L = 8$ seconds

Figure 11.4-1: Design Response Spectrum



Section 11.4.6 — Risk-Targeted Maximum Considered Earthquake (MCE_R) Response Spectrum

The MCE_R Response Spectrum is determined by multiplying the design response spectrum above by 1.5.



Section 11.8.3 — Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

From Figure 22-7 [4] PGA = 0.541

Equation (11.8-1): $PGA_M = F_{PGA}PGA = 1.000 \times 0.541 = 0.541$ g

Table 11.8-1: Site Coefficient F_{PGA}

Site Class	Mapped MCE Geometric Mean Peak Ground Acceleration, PGA				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of PGA

For Site Class = C and PGA = 0.541 g, F_{PGA} = 1.000

Section 21.2.1.1 — Method 1 (from Chapter 21 - Site-Specific Ground Motion Procedures for Seismic Design)

From Figure 22-17 [5] C_{RS} = 0.902

From Figure 22-18 [6] C_{R1} = 0.939

Section 11.6 — Seismic Design Category

Table 11.6-1 Seismic Design Category Based on Short Period Response Acceleration Parameter

VALUE OF S_{DS}	RISK CATEGORY		
	I or II	III	IV
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D	D	D

For Risk Category = I and S_{DS} = 0.854 g, Seismic Design Category = D

Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

VALUE OF S_{D1}	RISK CATEGORY		
	I or II	III	IV
$S_{D1} < 0.067g$	A	A	A
$0.067g \le S_{D1} < 0.133g$	B	B	C
$0.133g \le S_{D1} < 0.20g$	C	C	D
$0.20g \le S_{D1}$	D	D	D

For Risk Category = I and S_{D1} = 0.425 g, Seismic Design Category = D

Note: When S_1 is greater than or equal to 0.75g, the Seismic Design Category is **E** for buildings in Risk Categories I, II, and III, and **F** for those in Risk Category IV, irrespective of the above.

Seismic Design Category ≡ "the more severe design category in accordance with Table 11.6-1 or 11.6-2" = D

Note: See Section 11.6 for alternative approaches to calculating Seismic Design Category.

References

1. *Figure 22-1*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-1.pdf
2. *Figure 22-2*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-2.pdf
3. *Figure 22-12*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-12.pdf
4. *Figure 22-7*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-7.pdf
5. *Figure 22-17*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-17.pdf
6. *Figure 22-18*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-18.pdf

APPENDIX G.2

Subsurface Fault Investigation and Development Setback Map

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SUBSURFACE FAULT INVESTIGATION AND DEVELOPMENT SETBACK MAP
PROPOSED MADONNA FROOM SPECIFIC PLAN AREA
APNs: 067-241-030 and -031
SAN LUIS OBISPO AREA
SAN LUIS OBISPO COUNTY, CALIFORNIA

PROJECT SL09734-2

Prepared for

Madonna Froom Ranch
C/o Madonna Construction Company, Inc.
Post Office Box 5310
San Luis Obispo, California 93403

Prepared by

GEOSOLUTIONS, INC.
220 HIGH STREET
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April 14, 2017

GeoSolutions, INC.

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April 14, 2017

John Madonna
c/o Madonna Construction Company, Inc.
Post Office Box 5310
San Luis Obispo, California 93403

Subject: Subsurface Fault Investigation and Development Setback Map
Madonna Froom Specific Plan Area – APNs: 067-241-030 and -031
San Luis Obispo area, San Luis Obispo County, California

Dear Mr. Madonna:

A subsurface fault investigation has been conducted for the proposed Madonna Froom Specific Plan Area development to be located on APNs 067-241-030 and -031, in the San Luis Obispo area, San Luis Obispo County, California. The Los Osos fault has been located at the proposed development by use of trenches, surface topographic expression, utilization of aerial photographs, and previous geologic mapping by other authors. Development setbacks have been established based upon characteristics of faulting; active faulting is interpreted along portions of the Los Osos fault at the site. The site is primarily composed of Franciscan Complex units in the upper (western) topographic regions covered with a veneer of surface soils (colluvium and alluvium). Alluvial sediments are within the (eastern) lower topographic regions. Recommended development setbacks from the Los Osos fault are provided within the report.

GeoSolutions, Inc. appreciates the opportunity to provide technical services to you. Should you have any questions regarding this report, please call (805) 543-8539.

Sincerely,

GeoSolutions, Inc.



John Kammer, C.E.G. #2118

Principal

\\Nas-c1-df-18\s\SL09500-SL09999\SL09734-2 - FROOM EL VILLAGGIO SPECIFIC PLAN -FAULT\Geology\sl9734-2 final fault rpt april 14.docx

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Photo Log of Trench T-2B North Wall - Lettis Consultants International, Inc.
Photo Log of Trench T-2A South Wall - Lettis Consultants International, Inc.
Earth Consultants International – November 18, 2016 report
Earth Systems Pacific, February 28, 2000 – Portion of report
Earth Systems Consultants – October 29, 1997 – Portion of report
GeoSolutions, Inc., - January 27, 2000 – Portion of report
Earth Systems Consultants – October 7, 1997 – Portion of report

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SUBSURFACE FAULT INVESTIGATION AND DEVELOPMENT SETBACK MAP
PROPOSED MADONNA FROOM SPECIFIC PLAN AREA
APNs: 067-241-030 and -031
SAN LUIS OBISPO AREA, CALIFORNIA
PROJECT SL09734-2

I. INTRODUCTION and PURPOSE

This Subsurface Fault Investigation and Development Setback Map presents geologic site conditions and discussion of the Los Osos fault through the proposed Madonna Froom Specific Plan Area, APNs 067-241-030 and 031, San Luis Obispo Area, California. A GeoSolutions, Inc. Preliminary Engineering Geology Report (April 14, 2017) recommended a fault study be conducted for the site. Reference geologic maps and reporting data depict strands of the Los Osos fault trending through a portion of the proposed development. The purpose of this study was to locate the trace of the Los Osos fault through the site and establish development setbacks from the fault. This report details the fault investigation and provides development setbacks for the property. Plates 1A, 1B, and 1C are a Site Engineering Geologic Maps (Plates 1B and 1C are enlargements of Plate 1A) that depicts local geologic conditions. Plates 1D, 1E, 1F are Fault Setback Maps (Plates 1E and 1F are enlargements of Plate 1D). Plate 1G presents geologic cross sections of the property. The Los Osos fault is a reverse fault that dips to the southwest beneath the Irish Hills that extends south from the community of Los Osos to near Lopez Lake in San Luis Obispo County. Approximately 8,000 feet northwest of the proposed project, the Los Osos fault is mapped as Holocene active as defined by the State of California (State of California, January 1, 1990). Plate 2 depicts the Earthquake Fault Zone map and Plate 3A and 3B (Lettis and Hall, 1994) depicts the location of the Earthquake Fault Zone map in relation to the Madonna Froom site.

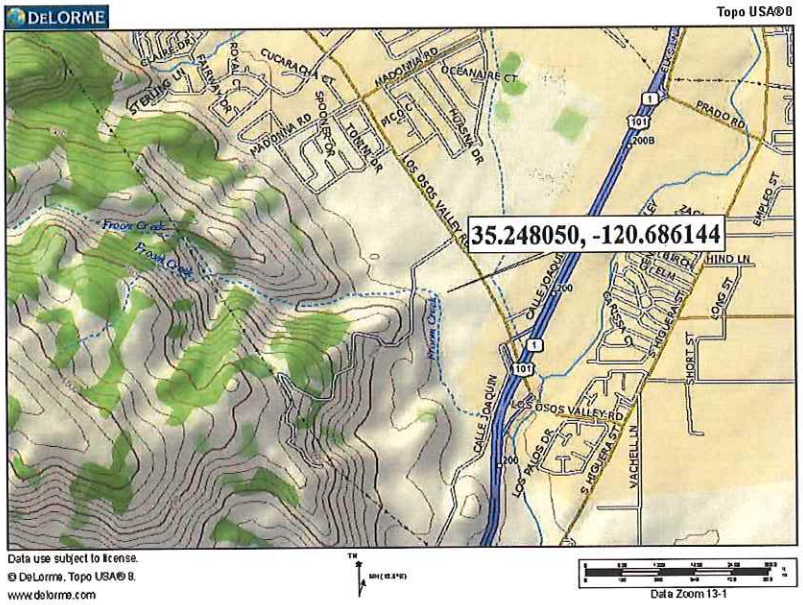

Figure 1: Area Location Map

I.1 Proposed Development

The proposed development is to include residential structures, apartments, high-density residential, some commercial development, a hotel, independent senior living and assisted living, recreational facilities, restaurants, movie theaters, and 51 percent of the project as open space. The proposed structures are anticipated to be constructed using light wood framing and/or light gauge steel/structural steel.

II. SCOPE OF WORK

This Subsurface Fanlt Investigation and Development Setback Map report is a supplement to the Preliminary Engineering Geology Investigation (GeoSolutions, Inc., April, 14, 2017) for the proposed development. The scope of services for this investigation included the following tasks:

1. Research and review of pertinent published geologic literature, regional faulting and seismicity maps, previous site investigations, aerial photographs, topographic maps, LiDAR imagery, consulting reports, and web-based information as listed in the reference section of this report.

2. Research at County of San Luis Obispo and City of San Luis Obispo for soil report data and geologic reports of adjacent properties to the Madonna Froom site.

3. Geologic surface mapping of the property.

4. Trenching of 10 sets of fault trenches (15 individual trenches total) to aid in defining the location of the Los Osos fault through the subject site. Location of trenches was based upon lineaments from published documents, topographic anomalies, potential areas proposed for development, and geologic mapping that suggest faulting.

5. Field logging of trenches and interpretation and evaluation of the exposures.

6. Soil stratigraphic assessment to estimate the age of soils observed in Trenches T-1A and T-2A by Earth Consultants International.

7. Meetings, discussions, and review of open fault trenches with Earth Consultants International, Lettis Consultants International Inc., and Pacific Gas and Electric geologists at the site.

8. Meetings with project planners and developer regarding proposed development.

9. Preparation of this report summarizing the findings of the investigation and providing recommendations regarding development.

III. PREVIOUS STUDIES

The scope of work for this study was based in part on upon past published geologic maps and reports both on-site and off-site. Previous studies include:

1. Previous published geologic maps have identified traces of the Los Osos fault through the site as depicted on Plate 4, Superimposed Fault Map. Fault traces from Hall, 1973 (Plates 5A-5B); PG&E, 2014 (Plate 6); Wiegers, 2011 (Plates 7A-7B); and KMZ-USGS (Plate 8), 2016 were superimposed on Plate 4. It should be understood that differences in map scales and line-widths from previous geologic maps are "best fit" as rectified to Plate 4. Fault trench locations for this study were established to intersect these published fault locations. The Los Osos fault depicted on Jennings, 2010 (Plate 9),was not added to Plate 4 because the fault on Jennings, 2010 could not be accurately positioned due to large scale differences between the two maps. A Regional Geologic Map from Dibblee, 2006, (Plates 10A-10B) did not show faulting at the site.

2. A previous fault investigation within the vicinity of the Earthquake Fault Zone area located approximately 8,000 feet north of the subject property was conducted by Earth Systems Pacific, February 28, 2000. Plate 3A depicts the location of this study. Several fault trenches were excavated for this study. The report stated "The faults encountered on the subject site were determined to be Pleistocene to late Pleistocene age, which are not considered to be active, as defined by the State. Although these faults are not active, there is a potential for differential (horizontal and vertical) movement and ground cracking to occur along these faults during strong ground shaking from an earthquake event". The report also stated "Based on the above criteria, it is recommended that buildings be set back a minimum of 25 feet from secondary antithetic thrust fault on the hanging wall block (up-thrown)..., and 10 feet on the foot wall." "For the high-angle fault that crosses Lots 31..., buildings should have a minimum setback of 10 feet on each side of the fault." A portion of this report is contained within Appendix A at the end of this report.

3. A fault investigation was conducted at the Home Depot store (prior termed "Eagle Hardware and Garden") located immediately north of the Madonna Froom Specific Plan Area (Earth Systems Consultants, October 29, 1997). Plate 3A depicts the location of the Earth Systems Consultants, 1997 study area. One 473-foot long fault trench was excavated for the Eagle Hardware site. The report stated "The soil units exhibit structures and contact relationships which suggest that they were deposited as alluvial "overbank" flood plain deposits by low energy currents of the ancestral Prefumo Creek. Occasional buried channels were observed which consisted of unconsolidated, light brown sandy gravel. These channels were often discontinuous and irregularly shaped." Also, "A charcoal sample was collected and aged dated to 2,650 years (+/- 50 years) before present. This soil date generally correlates with a soil date of 2,516 before present from the PG&E Cuesta Trench T-3. The PG&E trench was located south of Los Osos Valley Road approximately 1.25 miles west of the site, in the same alluvial valley." The report concluded "There was no physical evidence in the subject trench that would suggest the presence of faulting within the proposed building area. Soil layers were generally horizontal, continuous and unbroken. In view of the continuous and unbroken condition of these soils, and that the age of the soils encountered on the subject site pre-date the soils encountered by PG&E, it is concluded that the fault features mapped by PG&E do not extend into the zone investigated. Based upon the above, we are of the opinion that no active faults cross or are within 50 feet of the proposed building area. Therefore, based upon the current level of knowledge, the potential for fault-related ground rupture to occur in the proposed building areas is considered to be low". A portion of this report is contained within Appendix A at the end of this report.

   The conclusion that no faulting was observed from the offsite fault investigation at Eagle Hardware and Garden has been noted for that portion of trench T-6 (Madonna Froom site) that has been logged and infers that the location of the Los Osos fault in the northern portion of the Madonna Froom site is constrained to the location as mapped on Plate 1A. There is a geologic contact at this very northern portion of the Madonna Froom site that has Franciscan Complex thrust over Older Alluvium (as also mapped in trench T-10b). The Los Osos fault appears to be well constrained in this northern portion of the Madonna Froom site as mapped on Plate 1A.

4. A fault investigation was conducted on the then vacant parcel at the southwest corner of Los Osos Valley Road and Madonna Road in San Luis Obispo (GeoSolutions, Inc, January 27, 2000). See Plate 3A for location of this study. A vegetation lineament of the Los Osos fault

as depicted on Lettis and Hall, 1994 was mapped at the vacant parcel. A fault investigation was conducted to verify absence or presence of the fault at the site. A 505-foot long trench was excavated to an average depth of 15-feet. The trench exposed alluvial deposits and subunits were mapped. The report concluded "No evidence of faulting was identified with a 505-footlong fault trench excavated at the site. The vegetation lineament published on the Lettis and Hall, 1994 map coincides with a subsurface, sedimentary channel feature in the vicinity of the 253- to 300- foot trench markers. It is our opinion that the vegetation lineament from the Lettis and Hall, 1994 geologic map indicates a subsurface sedimentary channel feature and not a splay of the Los Osos fault." A portion of this report is contained within Appendix A at the end of this report.

5. A "Geologic and Soils Study, De Vaul Ranch" was conducted by Earth Systems Consultants, dated October 7, 1997. See Plate 3A for location of this study. A series of 18 trenches were excavated at this property to "determine if any potentially fault-related features could be discerned in the areas slated for development" (no map was supplied in the report depicting location of the trenches). The report concluded "At this time, the site is not located within an Earthquake Fault Zone. There was no physical evidence in any of the trenches that would suggest the presence of faulting within the proposed development area. Soil layers were generally horizontal, continuous and unbroken except in Trench 8 (outside the development area), where evidence of strike-slip and/or reverse faulting was observed. No evidence of the underlying thrust fault was encountered in any of the trenches." A portion of this report is contained within Appendix A at the end of this report.

6. A Preliminary Engineering Geology Investigation (GeoSolutions, Inc., April 14, 2017) was conducted for the subject property (Madonna Froom) which identified general geologic characteristics of the property. As part of that investigation, trenching to obtain soil samples for soils engineering purposes (trenches labeled GST-# on Plate 1A-1F) occurred at the property. Trenches GST-1 and GST-2 encountered reddish brown silty and sandy clay termed colluvium from ground surface to 2 feet bls. Franciscan complex material was below colluvium to total depth of approximately 4.5 feet bls. Trench GST-3 encountered dark brown silty clay with rounded cobbles (to 1-foot diameter) from ground surface to 1.5 bls. This material is interpreted as alluvium. Franciscan complex material was below this alluvium to total depth of 2.5 feet bls. Trench GST-4 encountered a pebbly silty clay interpreted as alluvial deposits from ground surface to total depth of 8 feet bls. Trench GST-5 encountered dark brown silty clay (interpreted as colluvium) from ground surface to 2 feet bls with Franciscan Complex material below. Trench GST-5 encountered dark brown silty clay (interpreted as colluvium) from ground surface to 2 feet bls with Franciscan Complex material below. Trench GST-6 encountered dark brown clay (interpreted as colluvium) from ground surface to 3.5 feet bgs. Trench GST-7 encountered silty sandy clay with cobbles, pebbles, and boulders to a depth of 25 feet bls. This material is interpreted as alluvium. Logs associated with these trenches are within Appendix A of this fault report. The purpose of these GST-# trenches was to obtain soil samples and not necessarily to observe faulting characteristics.

IV. METHODOLOGY

For this fault investigation, a series of 10 sets of fault trenches (15 individual trenches total) were excavated at the site to locate the Los Osos fault. Fault trenching was conducted from July to September, 2016 and was directed to determine both presence and absence of faulting in certain areas. Trenches varied in length from approximately 16 feet long (Trench T-2A) to 250 feet long (Trench T-1B). Trench depth varied from approximately 3 feet deep to approximately 15 feet deep. One side wall (predominantly the north wall) was detailed in a drawn cross-section (sections provided in Appendix A). Scale of the sections are one-inch equals 5 feet. Trenches were also still-photographed. Trenches were

benched and excavated utilizing a LC320 and LC350 track hoe. Following excavation of the trenches, the sidewalls of the trenches were cleaned with a hand-held hoe and brush to expose geologic conditions. Level lines were created within the trenches to aid in elevation scale. Fault trenches and fault locations were located utilizing a Trimble Geo XH 6000 with an accuracy of 6-inches. Trenches were backfilled with onsite materials.

Trenches at the project site were excavated in areas where previous authors have mapped potential fault traces (Plate 4), where surface topographic and geomorphic features (such as break in slope) on a LiDAR Image (2011) (Plate 11) or aerial images suggested lineaments and anomalies, and where strike of a known fault in one trench was extended to another portion of the site. Trenching at the site was planned to intersect these features.

Geologic units were demarcated based on lithology, structure, color, and texture. Lithologic differences were the main criteria for differentiation of units within the trench logs. This is especially apparent within the alluvial deposits within the exposed trench sidewalls. Bedrock shears, discontinuities, and disrupted units were observed. Geologic units mapped at the site included fill, recent stream deposits, landslide material, recent surface soils (termed colluvium), Older Alluvial deposits, Aeolian sands, and Franciscan Complex rock. Those areas not proposed for development were not investigated for presence of faulting at the site.

V. ENVIRONMENTAL SETTING and GEOLOGY

The proposed development is located at approximately 35.248050 degrees north latitude and approximately -120.686144 degrees west longitude at an elevation of approximately 119 feet (varies) above mean sea level. The nearest intersection is where Los Osos Valley Road intersects Calle Joaquin at the southeast corner of the property. The project properties will hereafter be collectively referred to as the "Site."

The Site is characterized by flat to rolling grasslands with natural drainages which rise to steep, rocky hills at the southwestern portion of the property known as the Irish Hills. The property is approximately "U" shaped with the proposed development scattered in portions of the property. The Site is currently developed with several older ranch buildings that are over 100 years old. The property has past use and current use for cattle/horse grazing. Native grasses, brush, and scattered trees currently vegetate the Site.

Geomorphically, the eastern portion of the site is flat lying and has been altered in the past by grading. Froom creek exits the local mountain front and has deposited younger alluvial sediments in the flat lying area of the property. West of the flat lying area, the Irish Hills rise as a steep mountain front. Variations in topography are controlled in part by geologic composition. Steeper portions of the property are composed of hard serpentinite with metavolcanic rock and older alluvium usually forming less-steep areas. Breaks in slope, tonal features in vegetation and geology, and linear features were reviewed for potential indications of Quaternary faulting. From this study, it was found that a break in slope was sometimes indicative of recent faulting, mainly in the area of Trenches T-2A, T-2B, and T-7 although there was a break in slope in the vicinity of trench T-9 and no fault was observed within this trench. The Los Osos fault at the site was located near the base of the local topographic change from the flat portion of the property to the local mountain front. On the north portion of the property, the vicinity of the fault has been altered by the Froom drainage exiting the mountains and by man due to grading. Nuance in topographic changes were difficult to assess in the northern section of the property due mainly to past grading.

V.I Regional Geology

The site is located in the vicinity of the San Luis Range of the Coast Range Geomorphic Province of California. The Coast Ranges lie between the Pacific Ocean and the Sacramento-San Joaquin Valley and trend northwesterly along the California Coast for approximately 600 miles between Santa Maria and the Oregon border. Plates

V.II Site Geology

Locally, the site is located along the southwestern flank of the local Santa Lucia Mountain Range and east of the adjacent Irish Hills. The site is generally within Franciscan Complex units and alluvial deposits. Plates 3A, 5A, 6, 7A, and 10A are Regional Geologic Maps of the general vicinity of the Site and Plates 3B, 5B, 7B, and 10B provide descriptions of these Regional Geologic Maps. These authors have generally mapped the site as within Jurassic and Cretaceous age (205-63 mybp) Franciscan Complex units with alluvial material in the lower elevations. Our exploration of the area encountered units of the Franciscan Complex and alluvial deposits. Information derived from the subsurface exploration was used to classify subsurface soil and formational units and to supplement geologic mapping. Plates 1A-1F are engineering geologic maps of the site. Cross sections A-A' and B-B' are presented on Plate 1G. Cross section A-A' utilized an apparent dip (38 degrees) of the Los Osos fault calculated from a dip of 40W from trench T-7.

The following are geologic conditions as interpreted within fault trenches excavated.

ARTIFICIAL FILL (Af)– Artificial fill was observed in the northwestern portion of the property in the vicinity of Trench T-10A, T-10B, and T-6. Fill was composed of dark yellowish brown (10YR4/6) to light brownish gray (10YR 6/2) sand and clay with gravel, cobbles, with timber fragments. Thickness of fill in trenches ranges from approximately 3 feet and less but could be several feet depending upon area. Fill also mapped along the levees adjacent to Froom Creek through the property.

LANDSLIDE DEPOSITS (Qls) – Landslide deposits are mapped in a small section of the property just south of City of San Luis Obispo open space property. This material is composed of clay, silt, sand, gravel, and cobbles. Color varies depending upon location but is generally olive brown 2.5Y 4/4. Thickness is unknown but is estimated to be approximately 1-foot to several feet depending upon location. No trenches or borings encountered this material which is interpreted from surface expression.

STREAM DEPOSITS (Qf) – Assumed Holocene in age. Stream deposits were observed in Trench T-5. This unit is composed of gravel and cobbles in a matrix of sand and silt. This material appears to be derived from Froom Creek drainage. Color was light yellowish brown, 10YR 6/4. Thickness of this unit within the trench is approximately less than one foot but could be thicker depending upon area especially within stream areas. This material is mapped along the Froom drainage that flows through the property.

COLLUVIUM (Qc) – Assumed Holocene in age. This colluvial material is olive black (5YR 2.5/1), dark gray (10YR4/1), very dark greyish brown (10YR 3/2), black (10YR 2/1) and is interpreted to be resultant from weathering of underlying soil and rock material. Variations in colluvial material occurred according to location. Caliche (calcium carbonate) is observed within this unit. Colluvial deposits within Trenches T-2A and T-2B were logged in detail by Lettis Consultants International, Inc. (LCI). Photo logs of the LCI trenches are contained within Appendix A. LCI states the colluvium is "silt with occasional pebble to medium cobbles, Brown (10YR 4/3); clasts are dominantly Franciscan, increasing in size to small boulders to west, angular, fractured, slightly weathered, matrix is eolian silt,

with some clay and sparse fine sand; loose, moist, slightly to moderately cohesive; a surface soil sequence is developing in unit." Thickness of this unit varies depending upon location but, in general, is approximately 1 to 3 feet thick as observed within the trenches. Colluvium within Trench T-3C thickens toward the east at approximately 5 feet.

ALLUVIUM (Qal, Includes Older Alluvium on trench logs) – Pleistocene in age. Alluvial material was found within most trenches during the fault investigation. Generally, alluvium herein encompasses that material that underlies colluvium and overlies Franciscan Complex bedrock. Generally, alluvial deposits are comprised of clay, sand, silt, pebbles, cobbles, and boulders (up to 2-feet diameter). Clasts were composed primarily of Franciscan Complex rock and minor Monterey Formation shale material that is rounded to subrounded. Caliche was observed within this unit. Most Alluvium is matrix (sand, clay) supported. Color of the unit varied depending upon location. Colors ranged from moderate yellowish brown (10Y 5/4), pale yellow (5Y 7/3), brownish yellow (10YR 6/6), brown (7.5 YR 4/4), pale brown (10 YR 6/3), dark greyish brown (10YR 4/2), dark brown (10YR 3/3), to dark yellowish brown (10YR 4/4). Thickness of alluvium varies depending upon location but in general varies from 1 to 5 feet as observed within the fault trenches. To the east, the alluvium thickens and in boring B-2 at the site; alluvial sediments were encountered to a depth of approximately 45.5 feet deep in boring B-2.

Alluvial deposits within Trenches T-2A and T-2B were logged in detail by Lettis Consultants International, Inc. (LCI). Photo logs and detailed descriptions of the LCI trenches are contained within Appendix A. Units described by LCI include Pleistocene eolian silt, fluvial deposits, bedded alluvium, and slope colluvium.

FRANCISCAN COMPLEX (KJfs, KJmv, KJfg)- Cretaceous to Jurassic in age. This unit is the basement rock at the project. Types of Franciscan Complex observed at the site included serpentinite, greywacke sandstone, chert, mélange, claystone, and metavolcanic rock. Franciscan Complex rock at the site varies from fresh to very intensely weathered, very hard to very soft, and massive to slightly bedded (in chert). Fractures within the rock varied depending upon the rock type and location, and varied from moderately to very closely spaced, discontinuous to slightly continuous, fracture ends could be seen in the exposure, openness was tight to moderately wide, filling thickness was no film coating to moderately thin, moderately healed, stepped to smooth roughness, and dry fractures with water flow possible. Hardness of the rock varies; chert and some types of serpentinite are very hard. Structural attitudes were difficult to observe at the Site due to the massive, highly fractured, and weathered composition of the formational unit. Thickness of the Franciscan Complex is several thousand feet thick. Emplacement faults (old faults juxtaposing different types of Franciscan material against Franciscan material) are common within the Franciscan Complex

PG&E (6/2014) describes the Franciscan Complex in the following manner:

> *The Cretaceous to Jurassic Franciscan Complex (unit symbol KJf where undifferentiated) in the project area consists of multiple lithologies. The most widespread Franciscan Complex unit is mélange (unit symbol KJfm) with knockers of graywacke (gw); shale (sh); schist (sch); blueschist (bs); conglomerate (cg); metavolcanic rocks (mv); silica carbonate (sc); and green, white, or red chert (ch). Also widespread are mapped bodies of metavolcanic rocks (KJfmv); serpentinite (s); and graywacke (KJfg). In one area—Port San Luis—a mappable body of ophiolite is categorized as part of the Franciscan Complex (KJfo), reflecting its emplacement history and honoring the original age designation of these rocks by Hall (1973a). Lithologic contacts within the Franciscan Complex are almost exclusively faulted. In contrast, unit boundaries between the Franciscan Complex and younger units are a*

mixture of unconformable contacts and fault contacts. At the surface, the size distribution of sub-units within the Franciscan Complex is considerable, ranging in scale from several meters to several kilometers; it is likely that such a size distribution is present at depth. Within any given sub-unit, the size and density distribution of fracturing and other rock discontinuities is also variable between scales of tens to hundreds of meters. This results in frequent juxtaposition of highly fractured and competent bedrock.

VI. LOS OSOS FAULT

The Los Osos fault is mapped through the subject property as depicted on Plates 1A – 1F. Lettis and Hall (1994) subdivided the Los Osos fault into four segments, from the northwest to the southwest they are the Estero Bay, Irish Hills, Lopez Reservoir, and Newsom Ridge segments; Plate 12 depicts the location of these four segments (Lettis and Hall, 1994). The Irish Hills segment is about 10 to 12 miles long and extends from the Pacific Ocean near Los Osos eastward to San Luis Creek and includes the study area. This segment of the fault forms the boundary between the Los Osos Valley and the Irish Hills and has documented Holocene offset (PG&E, 1988). P.G. & E. suggests that the Irish Hills segment displays the most well-expressed geomorphic features displacing late Pleistocene and Holocene deposits. A portion of the Irish Hills segment is considered active and has been included within Alquist-Priolo zoning by the State of California (1990). Plate 2 depicts the Earthquake Fault Zone Map (State of California, 1990) and Plate 3A depicts the relation of the Earthquake Fault Zone map area to the Madonna Froom site.

The fault zone has had a complex history of both strike-slip and dip-slip displacement (Lettis and Hall, 1990). The fault zone is a 50 km long, 2 km wide system of discontinuous, subparallel, and en echelon fault traces extending from Estero Bay on the north to an intersection with the West Huasna fault southeast of San Luis Obispo. Along the coast, the fault zone truncates a flight of marine terraces, indicating a vertical rate of separation across the fault zone of about 0.2 mm/yr. Preliminary results from new geomorphic mapping, interpretation of reprocessed seismic-reflection data, analysis of seismicity data, and structural analysis suggest that the fault zone dips steeply to the southeast (45 to 70 degrees or possibly steeper), and may be primarily an oblique-slip fault, with a significant component of dip slip to accommodate uplift of the range. (PG&E, January, 2011, Shoreline fault study)

The fault encountered during this investigation exhibited characteristics of active movement (movement within the last 11,000 years before present or Holocene in age, offset in colluvial sediments), Quaternary age (last 2 million years before present) movement, and pre-Quaternary movement (movement prior to 2 million years before present).

Strike of the fault in several of the trenches is approximately similar. Fault strike in Trench 3A is N50W, in Trench 3B is N60W, in Trench 2B is N42W (to approximately N24W), Trench T-7 is N27W. Strike of faulting is plotted on Plates 1B, 1C, 1E, and 1F.

Jennings 2010, maps the Los Osos fault through the site as "Late Quaternary fault displacement (during past 700,000 years). Geomorphic evidence similar to that described for Holocene faults except features are less distinct. Faulting may be younger, but lack of younger overlying deposits precludes more accurate age classification." An active fault section of the Los Osos fault located approximately 8,000 feet northwest of the subject property is labeled on the Jennings, 2010 map (Plate 9) as "Holocene fault displacement (during past 11,700 years) without historic record. Geomorphic evidence for Holocene faulting includes sag ponds, scarps showing little erosion, or the following features in Holocene age deposits: offset stream courses, linear scarps, shutter ridges, and triangular faceted spurs. Recency of faulting offshore is based on the interpreted age of the youngest strata displaced by faulting". This portion of Holocene faulting depicted on Jennings, 2010 is similar to the location of the Earthquake Fault

Zone Map depicted on Plates 2 and 3A of this report (State of California, 1990). Studies performed by P.G. & E. (1988) indicate that the fault is a zone of northwest trending high and low angle faults that exhibits a complex history of both strike slip and reverse displacement.

The Los Osos fault is described by PG&E (6-2014) in the following manner:

> *The Los Osos fault zone was characterized by the LTSP (PG&E, 1988) and Lettis and Hall (1994) as a late Quaternary reverse fault that defines the northern and northeastern margin of the San Luis Range.*

The Los Osos fault is characterized in the vicinity of the Madonna Froom areas as (PG&E, 6-2014):

> *The southeastern most reach of the Los Osos fault zone within the Irish Hills study area—informally named the east reach—is approximately 6 to 7 km long and is located between San Luis Obispo Creek and a point approximately 2 km west-northwest of the intersection of West Foothill Boulevard and Los Osos Valley Road* (A portion of this reach is depicted on Plate 3A of this Madonna Froom report). *This reach includes abrupt scarps and tonal and vegetative lineaments at and near the range front and a linear fault zone within Franciscan Complex serpentinite along the foothills south of the range front (Lettis and Hall, 1994). No systematic lateral deflection of streams crossing the lineaments or bedrock fault traces was noted from LiDAR or field evaluation. Paleoseismic trenches across several lineaments and the bedrock fault zone revealed evidence for late Quaternary faulting along the east reach, although the relationships between faulting, scarp formation, and differential uplift of the Irish Hills relative to the Los Osos Valley were locally unclear and conflicting (Lettis and Hall, 1994). The northeastern-most trench—Ingley trench T-2— crossed a northeast-facing, 6-m-high topographic scarp near Los Osos Valley Road and contained evidence for a gently (22 to 29°) southwest dipping zone of thrust faults within alluvium that shortened and repeated a prominent soil horizon. Slickensides were consistent with dip-slip faulting and a left-lateral component. The faulting exposed here was interpreted to be the range front Los Osos fault. Other trenches upslope of the Ingley trench T-2 were less straightforward. For example, a trench across the bedrock fault zone (Ellsworth trench T-1) exposed evidence for faulted Quaternary gravels along a steeply northeast-dipping fault with southwestside-down vertical separation. Striations and folding of Quaternary strata were consistent with northeast- (valley-) side-up reverse faulting. Trenches across prominent scarps farther downslope (at the Cuesta and Ingley sites) exposed evidence that some scarps were not associated with faulting and thus were most likely erosional (Cuesta trench T-1), some faults offsetting Quaternary alluvium did not have recognizable geomorphic expression (Cuesta trench T-3), and a prominent northeast- (valley-) side-down scarp was underlain by a northeast-dipping fault placing Franciscan Complex mélange in the hanging wall against Quaternary alluvium in the footwall (indicating valley-side up faulting) with slickensides consistent with pure dip slip (Cuesta trenches T-2 and T-3). Other faults with geomorphic expression similarly showed evidence for northeast- (valley-) side-up reverse displacement with Franciscan Complex rocks faulted against late Quaternary deposits (Ingley trench T-1). Lettis and Hall (1994) proposed alternative explanations for the unexpected observations, including scarp formation by erosional (as opposed to tectonic) processes, and normal reactivation of earlier Quaternary reverse faults. The preferred interpretation in general was that deformation observed in trenches in the foothills and near the range*

front was secondary, hanging-wall deformation above an underlying, southwest-dipping thrust or reverse fault that projected up dip to the range front of the Irish Hills (e.g., such as at Ingley trench T-2). Alternative interpretations to explain the conflicting relationship between the geomorphic scarps and faulting observed in the trenches were proposed with implications for possible changes in dip with depth on an underlying range-front fault (Lettis and Hall, 1994).

Although the east reach of the Los Osos fault zone within the Irish Hills segment includes the strongest evidence for a shallow or emergent, southwest-dipping Los Osos reverse fault, the absence of a footwall basin, and the lack of a compelling, laterally-continuous fault (or fault scarp) at the surface is also consistent with a mostly blind Los Osos reverse fault or a fold hinge at the range front that is locally broken by discontinuous faults. Interpretations of seismic-reflection data across the east and east-central reaches of the Irish Hills should consider the observations of steep faulting in Franciscan Complex rocks at the surface (particularly the serpentinite-defined fault zone along the foothills sub-parallel to the range front), a locally observed southwest-dipping thrust fault at the range front, possible changes in fault dip with depth beneath the foothills, and alternative hypotheses for active structures that can accommodate differential uplift of the Irish Hills relative to the Los Osos Valley.

Comparing the faulting characteristics from the above description with observed faulting characteristics within trenches excavated at the Madonna Froom site, the site generally shows a southwest-dipping fault that is broken by discontinuous faults. Although the Los Osos fault as mapped at the Madonna Froom site exhibited discontinuities (ie, Holocene-active faulted areas and Quaternary age {older} faulted areas (ie trenches T-4, T-10B), the study at the Madonna Froom site conservatively recommended a development setback region along the fault.

Plate 2 depicts the Earthquake Fault Zone map for the area located approximately 8,000 feet northwest of the subject site. Plate 13 is data from USGS – KMZ files as depicted on a Google Earth Image for this Earthquake Fault Zone area. Plate 3A, Lettis and Hall, 1994 depicts the Los Osos fault in the area of the Madonna Froom area. These maps shows discontinuous characteristics of the Los Osos fault in the vicinity of the proposed project which is similar to the faulting characteristics identified in the fault investigation at the Madonna Froom Specific Plan area.

VII. ESTIMATED AGES OF UNITS

Estimates on the age of the soils developed in colluvium and alluvial deposits were conducted by Earth Consultants International, Inc., (ECI, November 18, 2016) in conjunction with PG&E (see Appendix A for document). No charcoal was identified in the soils for absolute age dating. Pedologoic age-dating techniques are based on four soil profiles described in trenches T-1A andT-2A; three from Trench T-1A and one from Trench T-2A. The locations of these profiles are shown on logs developed by LCI in Appendix A. As described in the November 18, 2016 document,

Three of these profiles include a surface soil and two underlying buried soils. The last profile we described is a soil developed in a fining-upward section of fine-grained sediments that were deposited in a low spot that appears to have formed as a result of movement on the adjacent fault. These sediment are referred to here as "ponded deposits". Lastly, we also collected and described samples of unweathered to slightly weathered alluvium from the active channel

near the eastern portion of the site. These alluvial deposits are considered representative of the parent materials for the soils described in the trenches.

Given that the surface soil described in Profiles 1, 2 and 3 is thought to have developed on eolian sediments that were most likely deposited during the last glacial maximum, approximately 20-30ka, the soil development age estimates calculated using the Dolan et al. (1997) regressions appear provide the best age estimates for these surface soils. Furthermore, and as discussed extensively above, the soil age regressions in Dolan et al. (1997) return the youngest age estimates for the soils we described in the trenches. Since these soils are thought to be exposed to coastal fog, and are thus likely to have formed faster than inland soils, the youngest ages seem to be most appropriate for this site.

Table 2 (shown below) *summarizes our preferred ages for the soils described for this study. Our preferred age for the surface soil is constrained between the minimum age returned by the Dolan et al. (1997) regressions, and the age of the eolian sediments that this soil formed. Assuming that these eolian sediments began to be deposited when sea level fell during the last glacial maximum, the soil cannot be more than about 18,000 years old. Thus, even though the soil regressions returned ages significantly older than 18,000 years, we opted to cap the age of the surface soil in all exposures to 18,000 years.*

For the buried soils, we chose to give a range of possible development ages that stretch from the lowest average age returned by the regressions to the "middle of the road" values that do not extend into the 100,000s.

Table 2: Preferred Age Estimates for the Soils and Soil Profiles Described for this Study

Soil	*Preferred Development Age of Individual Soil*	*Preferred Age of Profile*
Soil Profile 1, Surface Soil	*11,000 - 18,000*	
Soil Profile 1, Buried Soil 1	*33,000 - 87,000*	
Soil Profile 1, Buried Soil 2	*22,000 – 35,000*	*66,000 – 140,000*
Soil Profile 2, Surface Soil	*16,000 – 18,000*	
Soil Profile 2, Buried Soil 1	*28,000 – 59,000*	
Soil Profile 2, Buried Soil 2	*18,000 – 40,000*	*62,000 – 117,000*
Soil Profile 3, Surface Soil	*7,000 – 18,000*	
Soil Profile 3, Buried Soil 1	*25,000 – 83,000*	
Soil Profile 3, Buried Soil 2	*19,000 – 45,000*	
Soil Profile 3, Buried Soil 3	*13,000 – 43,000*	*57,000 – 148,000*
Ponded Deposits	*19,000 – 43,000*	*30,000 – 61,000*

To conclude, therefore, the surface soil is a latest Pleistocene to early Holocene soil developed on late Pleistocene (MIS 2 - 20-30 ka) eolian sands. Those sands blanket a paleosurface that formed during MIS 3 (30-50 ka) that is most likely composed of MIS 4 (60-80 ka) sediments, which in turn overlie an MIS 5 (80-120 ka) paleosol developed upon older alluvial sediments. This would be the youngest age interpretation for all the units.

Based on an initial pedologic (soil) analysis of the surficial deposits exposed in a few of the trenches at the Madonna-Froom Specific Plan Area, the surface soil (colluvium) is estimated to be latest Pleistocene to early Holocene in age, and overlies deeper alluvial and colluvial deposits likely pre-Holocene in age. From the information presented by ECI, all exposures of surface soils on the older slopes are

considered less than 18,000 years old (latest Pleistocene to early Holocene). For the lower sediments, a range of ages from 30,000, 60,000, and 80,000 years old are the youngest age of these sediments. Several of these older alluvial and colluvial deposits are clearly faulted. It should be understood that soil ages are not absolute ages and that the soil descriptions do not necessarily apply to all soils encountered in the trenches. Some trenches may be within younger sediments and on younger geomorphic surfaces that do not comply with the interpreted geologic model of ECI (2016).

VIII. FAULT TRENCHING

The following is a discussion of general faulting characteristics observed within trenches and topography at the site. In this discussion, footage markers are referred to as along the trench profiles as measured from one end (typically west end) of the trench in the section line.

Trench T-1A – Plate T-1A, Trench length approximately 100 feet – **Assumed Recent faulting.**

Trench T-1A was excavated to intercept a break in slope between the flatter alluvial deposits in the east and a change (increase) in topography toward the west. There is assumed recent faulting between station 50-55 (foot) region of the section where faulting appears to have deformed older alluvium (Qal) and thrust a minor portion of Qal over colluvium with deformation in colluvium (approximately 1-2 inches of Qal deformation thrust over colluvium). Assumed active fault in this location. There is evidence for an older fault (non-Holocene) near station 15-20. Fault orientation is varied due to complex and irregular pattern of faulting at station 50-55. Strike of inferred Holocene fault is approximately N02W from offset in south wall of trench. The fault in this trench is assumed to not be main trace of Los Osos fault as the fault is discontinuous to the north of T-1A and south beyond trench T—1B.

Building setback zone is 50-feet west from station 50-55 which encompasses older emplacement fault within Franciscan Complex units. Building setback zone on the east side of station 50-55 is 30 feet which encompasses minor tilting in older alluvium but no recent faulting was observed beyond station 50-55.

Trench T-1B – Plate T-1B. Trench length approximately 250 feet – **Assumed Recent faulting**

Trench T-1B was excavated to intercept the fault in Trench T-1A, to observe faulting attitude and characteristics compared to T-1A, and to extend the length of subsurface investigation toward the west beyond the termination of T-1A. There is assumed recent faulting in station 170-175 region where faulting appears to have deformed older alluvium (Qal) and offset a minor portion of Qal and colluvium. Station 170-175 is along fault strike with the faulting interpreted at station 50 of Trench T-1A, as mentioned above. Strike of fault between the two trenches was approximately N02W. Assumed active fault in this location. Some shears evident in Franciscan Complex from approximate station 30 – 140 but these shears do not extend into the overlying alluvium or colluvium. The fault in this trench is assumed to not be main trace of Los Osos fault as the fault is discontinuous to the north of T-1A and south beyond trench T—1B.

Building setback zone is 50-feet west from station 170-175, similar to T-1A although similar deformation was not apparent in this 50-foot zone. Building setback zone on the east side of station 170-175 is 30 feet which encompasses minor tilting in older alluvium in T-1A (although similar deformation was not observed within T-1B). There is discontinuous setback as depicted on the fault map from trenches T-1A and T-1B as no evidence for faulting was observed north and south of trenches T-1A and T-1B, respectively. A north-northwest projection of the fault would have intersected trenches T-5, T-8, or T-9, however, no faulting was observed within trenches T-5, T-8, or T-9. Similarly, along a south-southeast projection, the fault would have intersected the eastern portion of trench T-7. Although the fault could be

located further east of trench T-7, geologic and geomorphic relations from trench T-7 did not support faulting. Southern setback from T-1B extended to 50-feet from T-7 and northern setback from T-1A extended north to T-9.

Trench T-2A – Plate T-2A, Trench length approximately 16 feet – **Assumed Recent faulting**

Trench T-2A was excavated to intercept a break in slope (as depicted on Plate 1A) at this location and to intercept published fault locations as depicted on Plate 4. There is assumed recent faulting at station 0-5 region where faulting appears to have thrust Franciscan Complex over older alluvium and possibly deformed the overlying colluvium. The strike of the fault is approximately N20W with a dip of 14W but varies with exact location. The fault within this trench is assumed to be a main trace of the Los Osos fault due to topographic expression (break in slope) and recent faulting characteristics.

Lettis Consultants International, Inc. (LCI) prepared a photo-mosaic and interpretation of trenches T-2A north wall, T-2A south wall, and T-2B north wall (See attachments within Appendix A). LCI trench T-2A south wall log shows faulting and a thickening of Holocene to modern slope colluvium (age of the soil developed in the colluvium is approximated to be 11.2 +/- 7.7 thousand years old {ka}). The colluvium is faulted against Pleistocene eolian silt (age of this soil developed in the silt is approximated to be 53 +/- 35 ka). LCI trench T-2A north wall log shows faulting of the Pleistocene eolian deposit and possibly extending upward into the overlying Holocene colluvium. Attitude of fault orientation as mapped by LCI varies with exact location as seen on the LCI log of this trench.

The recommended building setback is 50 feet on the west side (hanging wall) from the fault at station 0-5 and 30 feet east from station 0-5 in the trench. Although trench T-2A is only 15 feet long, the absence of faulting east of station 0-5 in the trench, coupled with the absence of faulting east of stations 75 to 95 in trench T-2B and stations 55 to 235 in T-7 supports a 30-foot wide setback east in the footwall in trench T-2A.

Trench T-2B – Plate T-2B, Trench length approximately 100 feet – **Assumed Recent faulting**

Trench T-2A was excavated to intercept a break in slope (as depicted on Plate 1A) at this location, to verify faulting in trench T-2A, and to intercept published fault locations as depicted on Plate 4. There is assumed recent faulting at station 70-75 of the trench where faulting appears to have thrust Franciscan Complex over older alluvium and possibly deformed Holocene colluvium. The fault within this trench is assumed to be a main trace of the Los Osos fault due to topographic expression (break in slope) and recent faulting characteristics

Lettis Consultants International, Inc. (LCI) prepared a photo-mosaic of this trench with interpretation of units and faulting (See attachments within Appendix A). LCI trench log for trench T-2B north wall shows faulting within Pleistocene eolian silt with possible extension of faulting of Holocene to modern slope colluvium. Fault has an attitude listed by LCI of N34-56W/36-41 SW and another fault with an attitude of N31W/08W. The undersigned also obtained a fault attitude of N24-42W/42 SW. A fault attitude of N34W/41W was used for this study as an average attitude for the trench. Variable fault orientations are likely due to "flowering" of fault as it reaches the surface.

Building setback is 50 feet on west side (hanging wall) from station 70-75 which is adequate due to no deformation observed within the Franciscan Complex/colluvium on this side of the fault. Building setback is 30 feet from station 70-75 on the east side from the fault as there is little indication of deformation east of the fault (longer trench to north (T-7) not showing faulting further to the east).

Trench T-3A – Plate T-3A, Trench length approximately 35 feet – **Assumed Recent faultiug**

Trench T-3A was excavated to intercept published fault locations as depicted on Plate 4. There is assumed recent faulting at station 25 of the trench where faulting appears to slightly displace Franciscan Complex and colluvium. Fault attitude is approximately N50W/40S but fault undulates. There is a highly sheared zone from the 10- to 25-foot region of the trench. This fault appears to be a main trace of the fault from the collective of information within trench T-3B also.

Building setback is 50 feet on the west side (hanging wall) from the fault and this setback includes the approximate 15-foot sheared zone west of the fault. Setback is 30 feet on the east side of the fault as there is little indication of deformation east of the fault (this fault trench intersects with Trench T-3C).

Trench T-3B – Plate T-3B, Trench length approximately 90 feet – **Assumed Recent faulting**

Trench T-3B was excavated to intercept published fault locations as depicted on Plate 4 and to verify information within trench T-3A. There is assumed recent faulting at station 65-70 of the trench where faulting appears to (very slightly) displace the base of the colluvium by thrusting from the underlying Franciscan Complex. The fault attitude appears as N60W/82N. This fault is coincident with inferred Holocene faulting in Trench T-3A. Shearing of the Franciscan Complex is evident in an approximate 5-foot wide zone. The fault is apparent in the Franciscan Complex at bottom of the trench as this is where the strike of the fault was observed. Displacement from faulting is small at this location. General geologic conditions in this trench exhibits colluvium overlying Franciscan Complex bedrock. This fault appears to be a main trace of the fault from the collective of information within trench T-3A also.

Building setback is 50 feet on the west side and appears adequate as there is little indication of deformation from folding and fracturing west of the fault. Setback is 30 feet on the east side from the fault as there is little indication of deformation east of the fault (as this fault trench intersects with Trench T-3C, see below).

Trench T-3C – Plate T-3C, Trench length approximately 122 feet – **no faulting observed.**

Trench T-3C was excavated to verify absence of faulting east of the fault observed within trench T-3A and to intercept published fault locations as depicted on Plate 4. This trench exhibited Franciscan Complex of mélange and greywacke at the base overlain by a thick section (approximately 5 feet) of colluvium that contained some caliche. Alluvium was observed in the eastern portion of the trench and consisted of cobbles and pebbles in a clayey-sandy matrix. No evidence of faulting was observed. No setback is recommended; however the western end of the trench lies within a recommended setback zone developed using trench T-3A.

Trench T-4 – Plate T-4, Trench length approximately 110 feet – **No Recent faulting observed.**

This trench was excavated to understand the fault geometry and relationship between trenches T-2A-B and trenches T-3A-B. There is assumed older faulting (not Recent) in the alluvium from station 65- to 70. Fault does not appear to displace colluvium. Attitude of fault is difficult to obtain due to fault not readily apparent on opposite wall. Dip varies due to sinuosity of fault.

Due to the complexity of the anomalous stratigraphic and structural relations from station 65-70, Holocene faulting in this trench is not precluded, therefore a building setback of 50 feet is established on the west side from the fault and 30 feet on the east side from the fault. Approximately horizontal "bedding" (pebbly layers) of Older Alluvium suggests this is the eastern extent of faulting as bedding is

not uplifted. Although no Recent faulting is observed within this trench, similar development setbacks of adjacent trenches has been applied to this trench.

Trench T-5 – Plate T-5, Trench length approximately 132 feet – **no faulting observed**

Trench T-5 was excavated to determine if faulting extended from trenches T-1A-B. The trench provided evidence for no recent faulting and no characteristics of faulting was observed within this trench. Older alluvium, colluvium, and recent stream deposits exposed and no observable offset.

Trench T-6 – Plate T-6, Trench length approximately 250 feet although only eastern 200 feet were logged and then trench was backfilled by mistake. **Faulting observed in portion not logged at very west termination of trench.**

Trench T-6 was excavated to locate faulting at the north portion of the property where fault locations are published as depicted on Plate 4. There is assumed faulting within a portion of trench not logged but observed by the undersigned. The location of this fault was demarcated in the field prior to (mistakenly) backfilling of trench (fault location mapped on Plate 1A). Faulting thrusts Franciscan Complex rock over older marine sand deposits (sand appears to be older than Older Alluvium, likely 100,000 years (?), interpreted as marine sand deposits). Fault attitude not collected due to backfilling of trench. Fault is similar to observed fault in trench T-10B.

Building setback is 25 feet on the west and east side of the fault as there is no evidence of recent faulting beyond deformation of Older Alluvium as observed in trench T-10B located south of T-6. There is a contact of Franciscan Complex metavolcanic rock thrust over older sand deposits in a cut-slope located approximately 100 feet north of trench T-6. The location of this contact, the observation of the fault at the west end of trench T-6, and the observation of the fault in trench T-10B constrain the fault in this area to the fault line depicted on Plate 1A.

Trench T-7 – Plate T-7, Trench length approximately 240 feet. **Recent faulting observed**

Trench T-7 was excavated to intercept faulting from trench T-1B and verify faulting observed in T-2A. There is assumed Recent faulting at station 45 to 55 in the trench where faulting appears to extend from Franciscan Complex into colluvium and thrusts Franciscan Complex over colluvium. Fault orientation in the trench is N27W/40W. This fault is coincident with topographic break in slope. No faulting further east within this trench.

Building setback is 50 feet from the western zone of faulting and 30 feet from the east side from the fault as there is little indication of Recent deformation east of the fault. Zone of faulting is approximately 10 feet wide. Setbacks are applied from either end of the zone of faulting.

Trench T-8 – Plate T-8, Trench length approximately 50 feet – **No faulting observed**

This trench was excavated to observe if faulting extended north from trench T-1A. No recent faulting or characteristics of faulting were observed within this trench. Older alluvium is exposed in the trench.

Trench T-9 – Plate T-9, Trench length approximately 61 feet – **No faulting observed**

This area was investigated due to topographic break in slope and to investigate extension of fault observed in Trench T-1A. No characteristics of faulting observed within this trench. Franciscan complex and Older alluvium exposed.

Trench T-10A – Plate T-10A, Trench length approximately 80 feet – **No faulting observed**

This trench was excavated to locate the fault observed within trench T-6. No recent faulting and no characteristics of faulting were observed within this trench. The trench exposed Older alluvium overlying alluvial sand deposits and Franciscan complex. Sand is interpreted as marine sand deposits.

Trench T-10B – Plate T-10B, Trench length approximately 90 feet. **Faulting observed in Older Alluvium, no Recent faulting observed.**

This trench was excavated to locate the fault observed within trench T-6. There is assumed faulting from station 53 to 64 in the trench although this faulting does not appear to be Holocene in age. Faulting thrusts Franciscan complex rock over older marine sand deposits but fault does not extend into colluvium. Fault attitude is N29W/50 W. Faulting within this trench is interpreted to be the main trace of the fault.

Building setback is 25 feet on either side of the fault as there is no indication of deformation east in the Older Alluvium or west in the Franciscan Complex. Setbacks are less due to no Recent faulting characteristics observed.

Table 1, is a summary of faulting characteristics within the trenches.

Table 1: Summary of Faulting Characteristics

FAULT TRENCH NUMBER	STRIKE AND DIP	COMMENT
T-1A	Attitude varies due to complex and irregular pattern in sidewall. Assumed Recent faulting	Faulting appears to have deformed older alluvium (Qal) and thrust a minor portion of Qal over colluvium with deformation in colluvium
T-1B	Strike N02W, dip varies from near vertical to 30 W. Assumed Recent faulting	Faulting appears to have deformed older alluvium (Qal) and offset a minor portion of Qal and colluvium
T-2A	N20W/14W although varies with location. Assumed Recent faulting.	Fault thrust Franciscan Complex over older alluvium and possibly deformed colluvium
T-2B	N34W/41W Assumed Recent faulting	Faulting appears to have thrust Franciscan Complex over older alluvium and possibly deformed colluvium
T-3A	N50W/40S (?) Assumed Recent faulting	Faulting appears to displace Franciscan Complex and colluvium
T-3B	Fault N60W/82N, assumed Recent faulting	Very slight displacement of the base of the colluvium by thrusting from the underlying Franciscan Complex
T-3C	No faulting observed	Franciscan Complex, Alluvium and Colluvium exposed
T-4	Faulting observed, no Recent faulting observed. Attitude not readily apparent.	Fault appears to offset Franciscan Complex and Older Alluvium but not displace Colluvium.
T-5	No faulting observed	Older Alluvium, colluvium, and Recent stream deposits exposed

FAULT TRENCH NUMBER	STRIKE AND DIP	COMMENT
T-6	Fault observed (no attitude collected due to backfilling of trench by mistake). No Recent faulting	Fault thrusts Franciscan Complex over marine sand deposits
T-7	Fault N27W/40W Recent faulting observed	Faulting appears thrusting Franciscan Complex over colluvium
T-8	No faulting observed	Older Alluvium and Colluvium exposed
T-9	No faulting observed	Franciscan Complex, Older Alluvium, and Colluvium exposed
T-10A	No faulting observed	Older Alluvium overlying marine sand deposits (beach sand)
T-10B	Fault N29W/50W Fault not considered Recent	Franciscan thrust over marine sand deposits (beach sand). Fault does not extend into colluvium

IX. DISCUSSION AND SETBACKS

It is understood that, although the subject property is not mapped as within an Earthquake Fault Zone (formerly Special Study Zone), there is an Earthquake Fault Zone map for an area of San Luis Obispo that is located approximately 8,000 feet northwest of the Madonna Froom Specific Plan Area (see Plate 2 and Plate 3A). This fault investigation was conducted as a due-diligence because of the near-by Earthquake Fault Zone map, the prominence of tectonic geomorphology, and prior published geologic mapping depicting potential faulting at the property.

Special Paper 42 (2007), states (p.27, section 3603): *No structure for human occupancy.... Shall be permitted to be placed across the trace of an active fault. Furthermore, as the area within fifty (50) feet of such active faults shall be presumed to be underlain by active branches of that fault unless proven otherwise by an appropriate geologic investigation....* The premise of this study was to locate the trace of the Los Osos fault through the site and provide adequate building setbacks based upon the appropriate geologic investigation and surveyed location of the fault and deformation characteristics of the subsurface geologic units.

Bray, 2009, states "Ground deformation is not uniformly distributed on each side of a dip-slip fault. Significantly more ground deformation occurs over the hanging wall... Thus, setback distance from the primary trace of a dip-slip fault should not be arbitrarily the same amount on each side of the fault. Ground warping and secondary ground ruptures are most significant over the hanging wall of dip-slip faults (i.e., over the upthrown block for reverse faults" (p.1273). Bray continues, "To provide some level of conservatism, the often misunderstood 50-foot setback criterion was also added. It required that an area within 50 feet of a trace of an active fault shall be presumed to be underlain by active branches of that fault unless proven otherwise.... If an appropriate geologic investigation demonstrates that the ground adjacent to an active trace does not contain active branches of that fault trace then a structure may be sited directly adjacent to the primary trace" (p.1276). Bray states "One of the primary deficiencies of the current version of the A-P Act is that it places all active faults in the same category. It is not reasonable to treat the primary trace of the San Andreas fault, which could have meters of movement across it, the same

as an unnamed minor bending moment fault that may have moved once in the last 11,000 years a few centimeters" (p.1276). Further, "Ground deformations associated with surface faulting are not equally distributed on each side of the fault. Hence, the engineering geologist should work toward interpreting the geologic information to establish non-arbitrary setbacks base on specific site, fault, and soil characteristics."

Setbacks are described in Earth Systems Pacific (February 28, 2000) for the Los Osos fault in the area located approximately 8,000 feet north of the Madonna Froom site (Earthquake Fault Zone) where faulting was observed within Pleistocene to late Pleistocene age units (which are not considered to be active). The potential for differential (horizontal and vertical) movement was stated and ground cracking could occur along these faults during strong ground shaking from an earthquake event. Building setbacks were a minimum of 25 feet from secondary antithetic thrust faults on the hanging wall block (up-thrown)..., and 10 feet on the foot wall. As faulting characteristics within the northern section of Madonna Froom (vicinity of Trench T10-B) do not appear to be Holocene active, the 25-foot setback on either side of the fault within this northern section at the Madonna Froom area appears adequate.

San Luis Obispo County Guidelines for Engineering Geology Reports (San Luis Obispo County, updated October, 2013) suggest a fault setback calculation where there are "wide discrepancies in fault setback recommendations". For comparative purposes for development setbacks at the Madonna Froom site, San Luis Obispo County suggests utilizing the setback calculations by Batatian and Nelson (1999). The Guidelines for Engineering Geology Reports states "the fault study report should use this method to establish the recommended fault setback for critical facilities and structures designed for human occupancy." Minimum setbacks are also provided and "the greater of the two (table listed setback or calculated setback) is the setback". The setback calculation method equation is $S = U(2D + F/\tan\Theta)$ where S=setback, U = critically factor (based on table information, 1.5 for single family residences, 2.0 for commercial structures), D = expected displacement of the fault, F = footing depth, Θ = dip of fault. Using the parameters of U = 1.5, D = 0.833 feet, Θ = (high = 82 degrees {trench T-3B}, low = 14 degrees {trench T-2A}), F = 3 feet, the equation yields a building set back of 3 feet in the high angle fault (T-3B), and a building set back of 21 feet in the low angle fault (T-2A). Minimum fault setback as listed in San Luis Obispo County (October, 2013) is 15 feet for a single family home.

Plates 1A, 1B, and 1C depict geologic conditions at the site, the location of exploratory trenches excavated during this fault investigation, and the Los Osos fault through the site. Reverse faults can be discontinuous (as observed within the Earthquake Fault Zone map located approximately 8,000 feet to the north of the site) and as such, this fault investigation has shown that the Los Osos fault through the site is discontinuous (active faulting, older (Quaternary) faulting, and location of faulting varies ie, T1-A, T-1B). Surface expression including topographic expression (scarps) were observed and investigated during this study.

Development setbacks are provided on Plates 1D, 1E, and 1F and are based upon age of offset (in relationship within the geologic unit), the characteristics of faulting (up-thrown block in relation to down-dropped block, dip angle), and displacement of geologic units in a discrete location or "zone" of faulting. Where characteristics of active faulting was observed, a 50-foot development setback was established on the hanging wall of the fault. The hanging wall is thrust over the footwall block and typically incurs a wider zone of deformation compared to the footwall due to compression. Development setbacks are reduced on the footwall side of the fault to 25- and 30-feet and are based upon little to no deformation on this side of the fault. It is noted that this setback assumes the lowest dip angle of the fault which is an additional conservative element (utilizing the San Luis Obispo County Guidelines for Engineering Geology Reports fault setback calculation) because the lowest angle is observed within one fault trench at

the site. Where fault deformation has been observed to be in a zone (fault trench T7), the setback parameters were established from the ends of the zone. As the location of the fault in trenches is accurately known and surveyed (not an "inferred" location), and deformation has been accurately mapped and assessed, the fault setbacks provided herein are appropriate for the development. The quantity and location of trenches excavated at the project are appropriate for the current proposed development as depicted on Plates 1A-1F. Local changes in fault orientation and dip should be expected but has been captured by the uncertainty limits in the fault setbacks. As a conservative element, fault traces observed to be older than Holocene age maintain a minimum 25-foot setback on each side of the fault as a factor of safety for the possibility of horizontal and/or vertical movement during coseismic rupture or strong ground shaking (a 25-foot setback is established in the north portion of the property in the vicinity of trenches T-6, T-10A, and T-10B). Intra-formational faults or shears observed within the Franciscan Complex rocks are considered inactive due to the late Jurassic-Cretaceous age of the rocks. It is assumed that where a fault is identified in a trench and offsets the surface soil or a near-surface soil, and is correlative with tectonic-related geomorphology (ie, break in slope), it is assumed to be Holocene active. Similarly, where the landscape has been modified through anthropogenic activity, and the surface soil is disturbed or missing, it is assumed that the fault encountered within the trench is potentially Holocene active. The resulting setback map supports the interpretation of Holocene activity at the site.

X. CONCLUSIONS and RECOMMENDATIONS

For this fault investigation, a series of 10 sets of fault trenches (15 individual trenches total) were excavated at the site to locate the Los Osos fault through the Site. The fault exhibited characteristics of active movement (movement within the last 11,000 years before present or Holocene in age, offset in colluvial sediments), Quaternary age (last 2 million years before present) movement, and pre-Quaternary movement (movement prior to 2 million years before present). An Engineering Geologic Map of the site is depicted on Plates 1A, 1B, and 1C (Plates 1B and 1C are enlargements of Plate 1A) while development setbacks from the Los Osos fault are provided on Plates 1D, 1E, 1F (where Plates 1E and 1F are enlargements of Plate 1D).

The Los Osos fault zone maintains a broad and discontinuous complex rupture pattern typically associated with reverse fault zones. From several existing trench exposures excavated at the site (Trenches T-2a and T-2b), it is interpreted that the late Pleistocene-Holocene surface soil (colluvium) has been displaced by faulting or anomalously thinned and thickened near the fault zone. It is assumed that where a fault is identified in a trench that offsets the surface soil or a near-surface soil, and is correlative with tectonic-related geomorphology (ie, break in slope), it is assumed to be Holocene active. Similarly, where the landscape has been modified through anthropogenic activity, and the surface soil is disturbed or missing, it is assumed that the fault encountered in the trench is potentially Holocene active. Faulting that does not affect surface soils appears to be non-Holocene in age. This Madonna Froom Specific Plan Area fault study has maintained a conservative approach utilizing development setbacks where faults are apparent in lower sediments and older alluvial sediments although these lower sediments and older alluvial sediments are non-Holocene. Development setbacks are also applied in areas where surface soils are interpreted to be disturbed from faulting.

The following are recommended at the Madonna Froom Specific Plan Area:

1. Development of habitable structures, residences (single and multifamily) and residence garages, critical structures (ie, cellular towers, utility buildings), care facilities, and buildings occupied more than 2,000 hours per year are recommended to be developed outside of the

fault development setbacks as presented on Plates 1D, 1E, and 1F. Fault setbacks vary depending upon location with development setbacks ranging from 25 feet to 50 feet.

2. It is recommended that the recommendations within GeoSolutions, Inc., April 14, 2017 Preliminary Engineering Geology Investigation for the project site be incorporated into design.

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PLATES

Plates 1A, 1B, 1C - Site Engineering Geologic Maps

Plates 1D, 1E, 1F – Site Engineering Geologic Maps with Fault Setbacks

Plate 1G – Site Cross Sections

Plate 2 – Earthquake Fault Zone Map (State of CA, 1990)

Plate 3A, 3B – Lettis and Hall, 1994

Plate 4 – Superimposed Fault Map

Plate 5A, 5B - Regional Geologic Map, Hall, 1973 and Geologic Explanations

Plate 6 - Regional Geologic Map, PG&E, 2014 and Geologic Explanations

Plate 7A, 7B – Regional Geologic Map, Weigers, 2011

Plate 7A, 7B – Lettis & Hall, 1994 and Geologic Explanations

Plate 8 – Google Image with USGS KMZ faulting – 2016

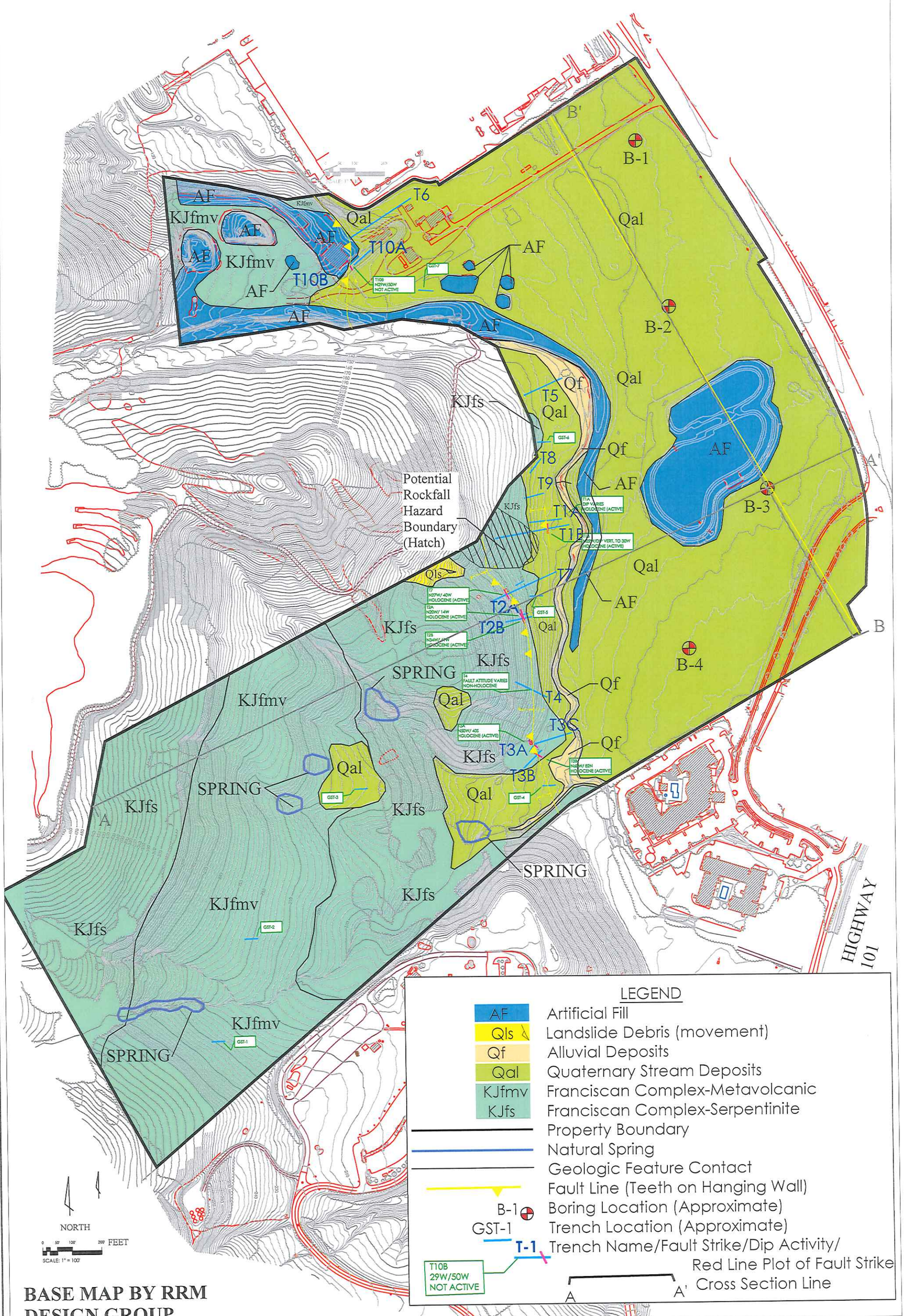
Plate 9 – Regional Fault Map, Jennings, 2010 and Explanations

Plate 10A, 10B - Regional Geologic Map, Dibblee, 2006 and Geologic Explanations

Plate 11 – LiDAR Image - 2011

Plate 12 – Lettis and Hall, 1994, Location of Los Osos Fault Segments

Plate 13 – USGS – KMZ faults in Earthquake Fault Zone Area



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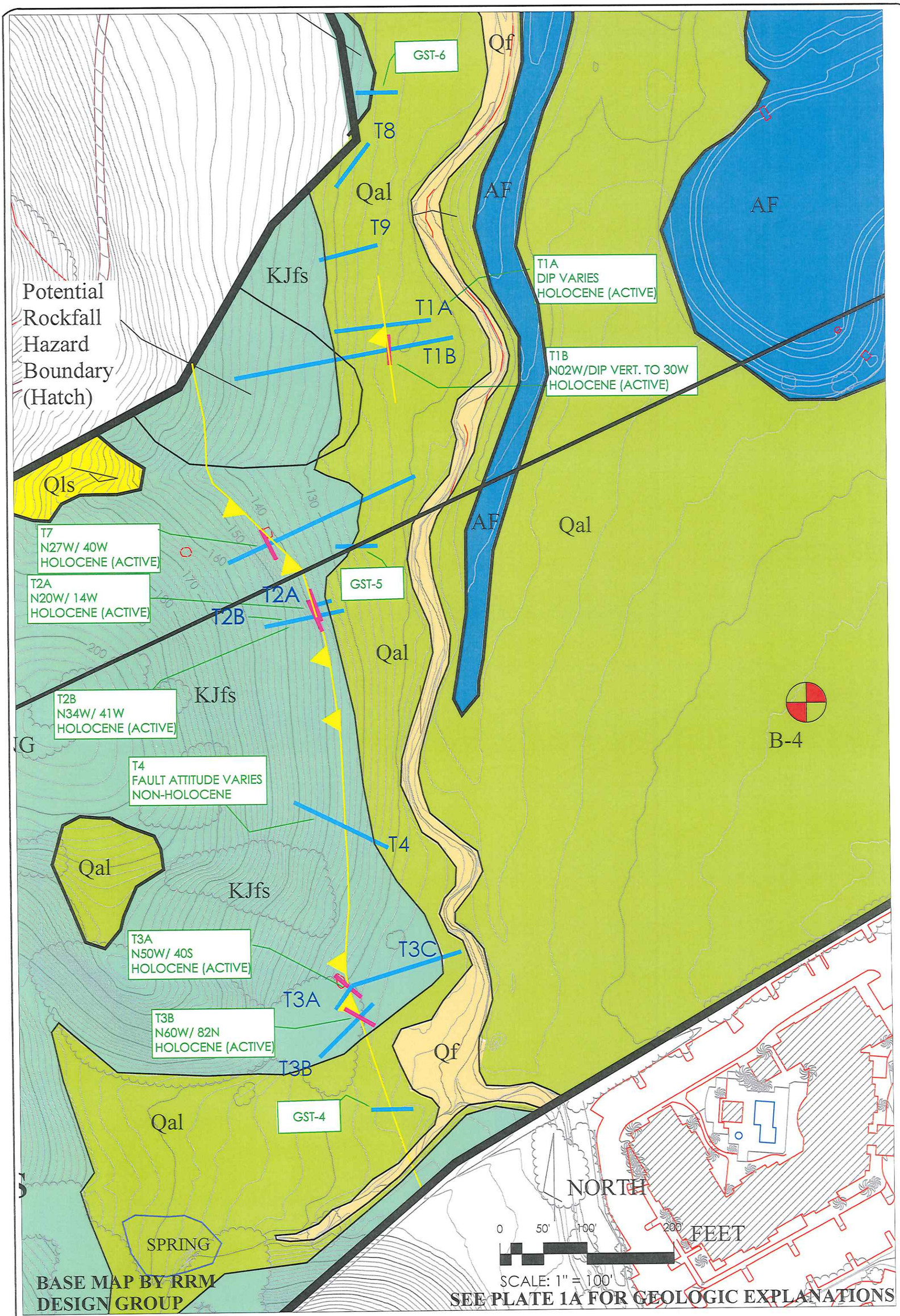
SITE ENGINEERING GEOLOGY MAP

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE
1A

PROJECT
SL09734-1



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SITE ENGINEERING GEOLOGY MAP

MADONNA FROOM RANCH
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PLATE
1B

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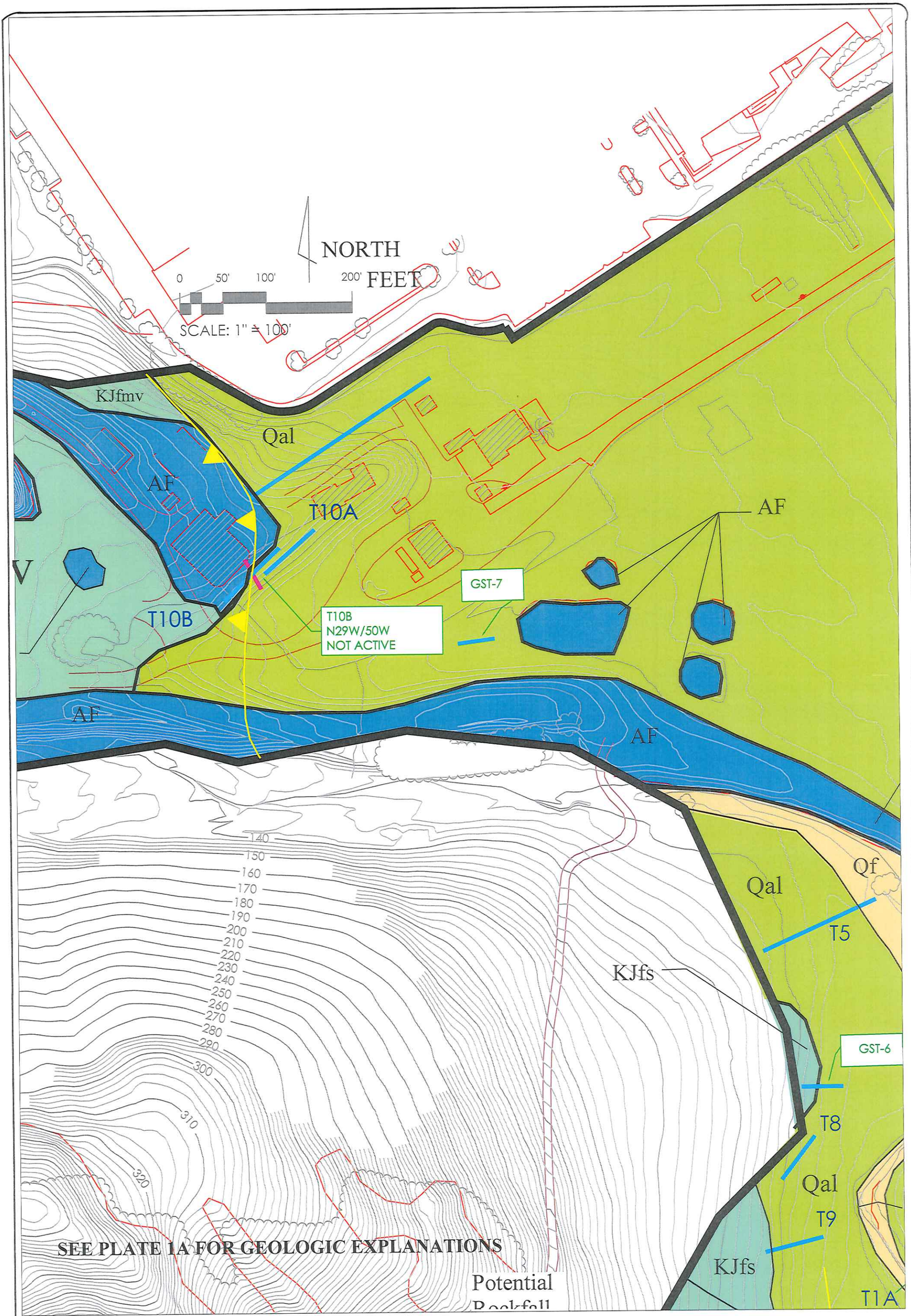

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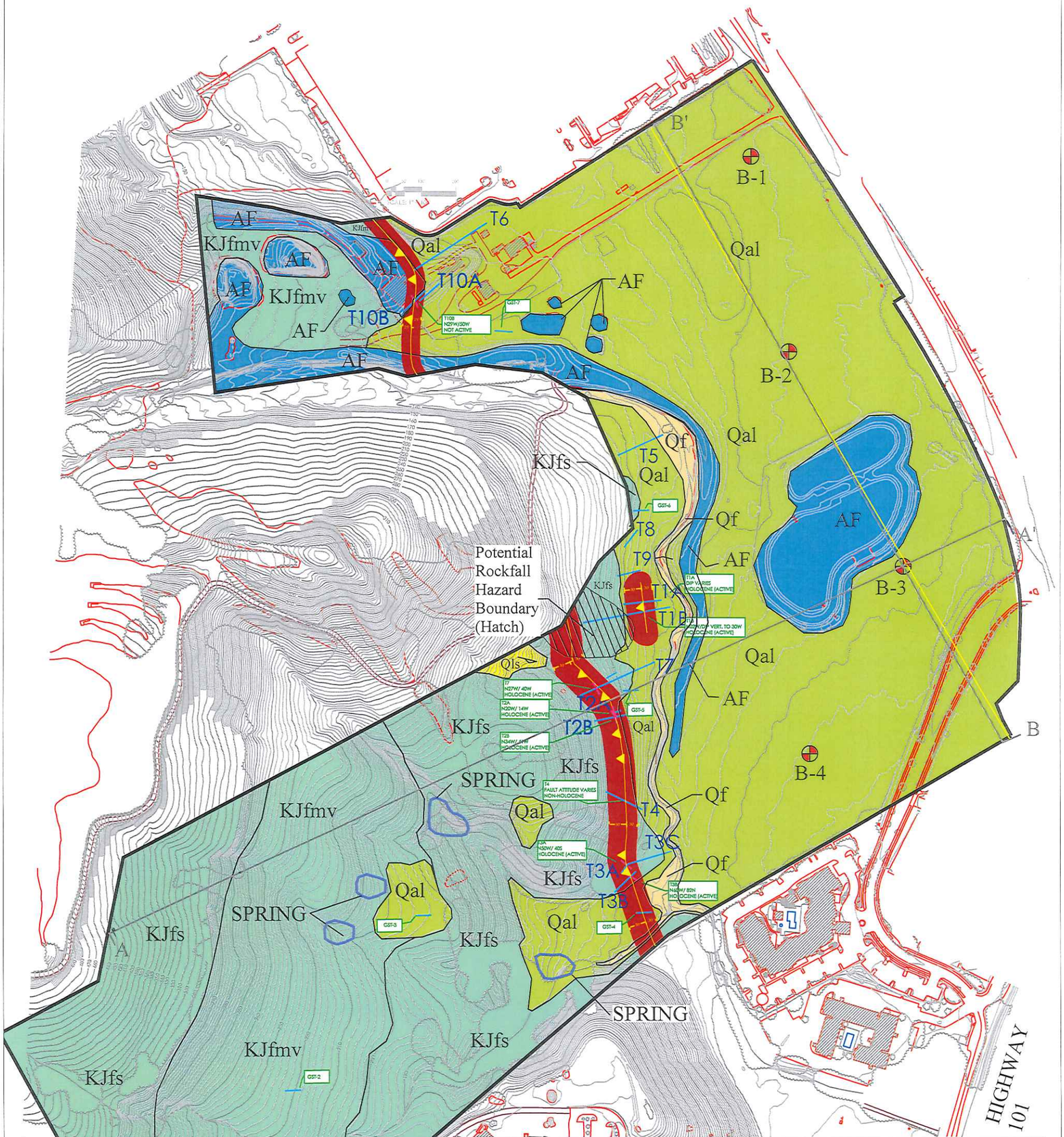
SITE ENGINEERING GEOLOGY MAP

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE
1C

PROJECT
SL09734-1



BASE MAP BY RRM DESIGN GROUP

LEGEND

AF	Artificial Fill
Qls	Landslide Debris (movement)
Qf	Alluvial Deposits
Qal	Quaternary Stream Deposits
KJfmv	Franciscan Complex-Metavolcanic
KJfs	Franciscan Complex-Serpentinite
	Property Boundary
	Natural Spring
	Geologic Feature Contact
	Fault Line/Setback
	(Teeth on Hanging Wall)
B-1	Boring Location (Approximate)
GST-1	Trench Location (Approximate)
T-1	Trench Name/Fault Strike/Dip Activity/
T10B 29W/50W NOT ACTIVE	Red Line Plot of Fault Strike
A — A'	Cross Section Line

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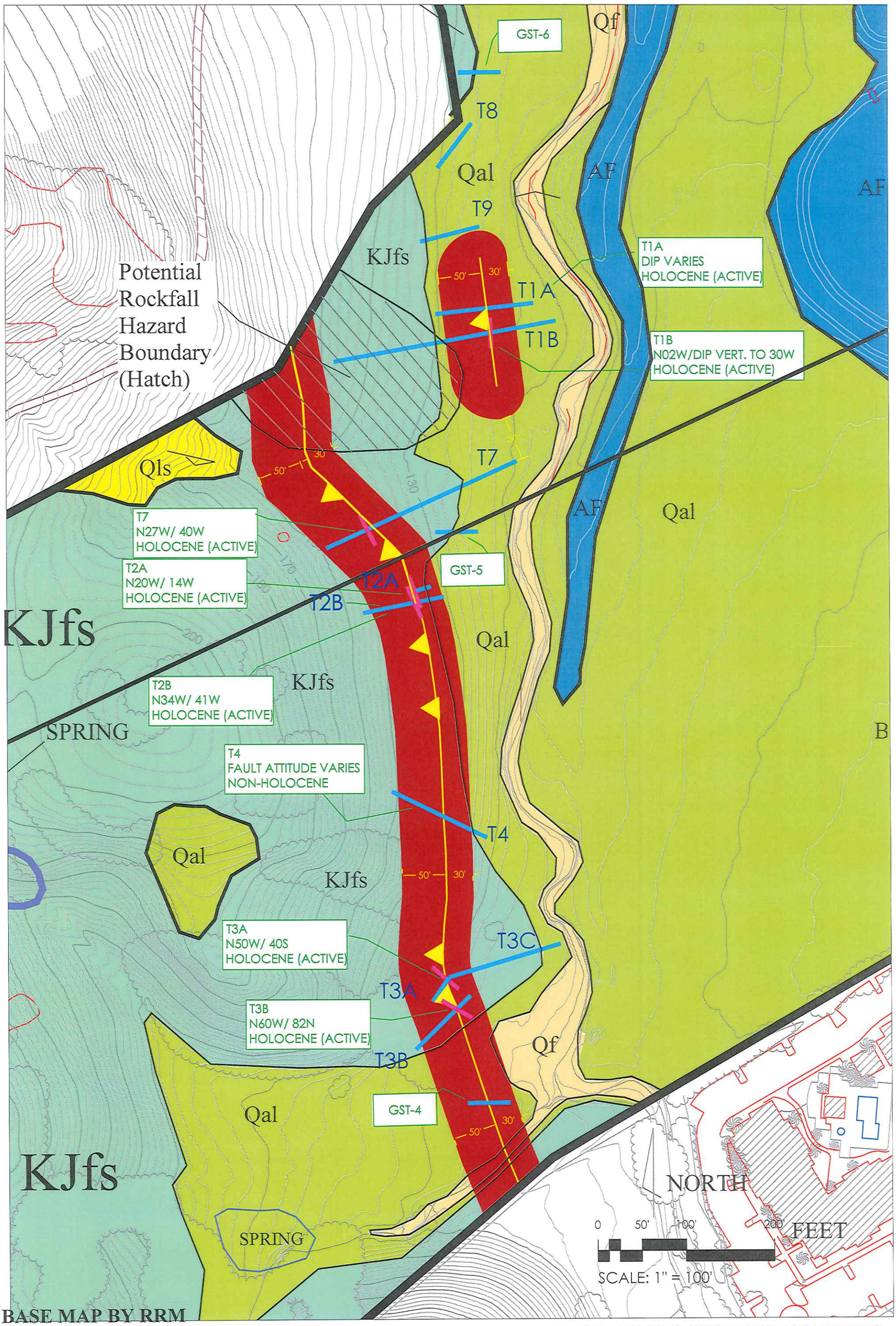
FAULT SETBACK MAP

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE 1D

PROJECT SL09734-1



BASE MAP BY RRM DESIGN GROUP

SEE PLATE 1D FOR GEOLOGIC EXPLANATIONS

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FAULT SETBACK MAP

MADONNA FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

PLATE
1E

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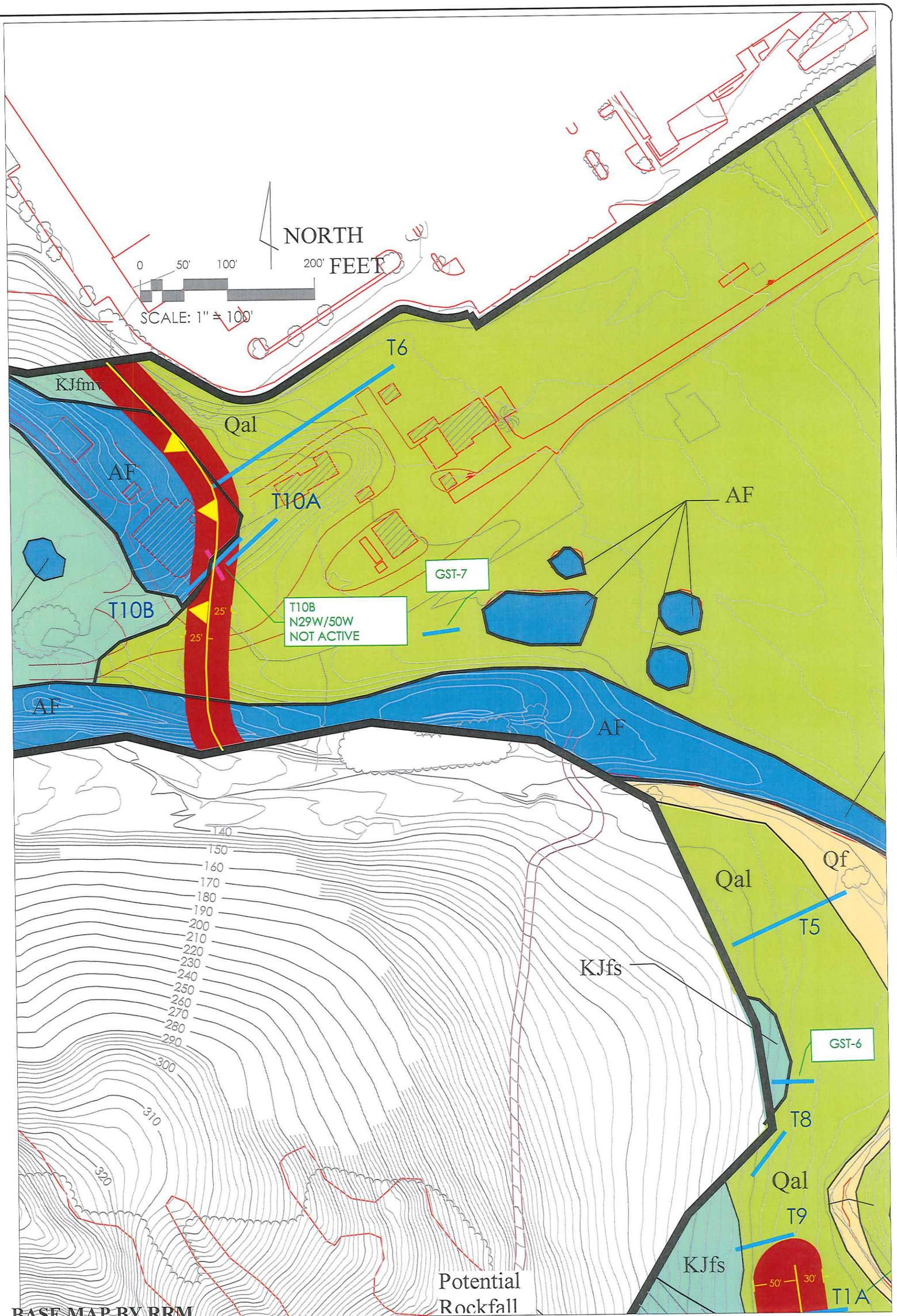

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FAULT SETBACK MAP

MADONNA FROOM RANCH
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PLATE
1F

PROJECT
SL09734-1

LEGEND

AF	Artifical Fill
Qal	Alluvial Material
KJfs, KJfmv	Franciscan Complex
—?—	Contact - ? where unknown
	Direction/Movement
	Horizontal scale exaggerated
45°	Dip Angle

PLATE 1G

PROJECT SL09734-1

ENGINEERING GEOLOGY CROSS SECTION

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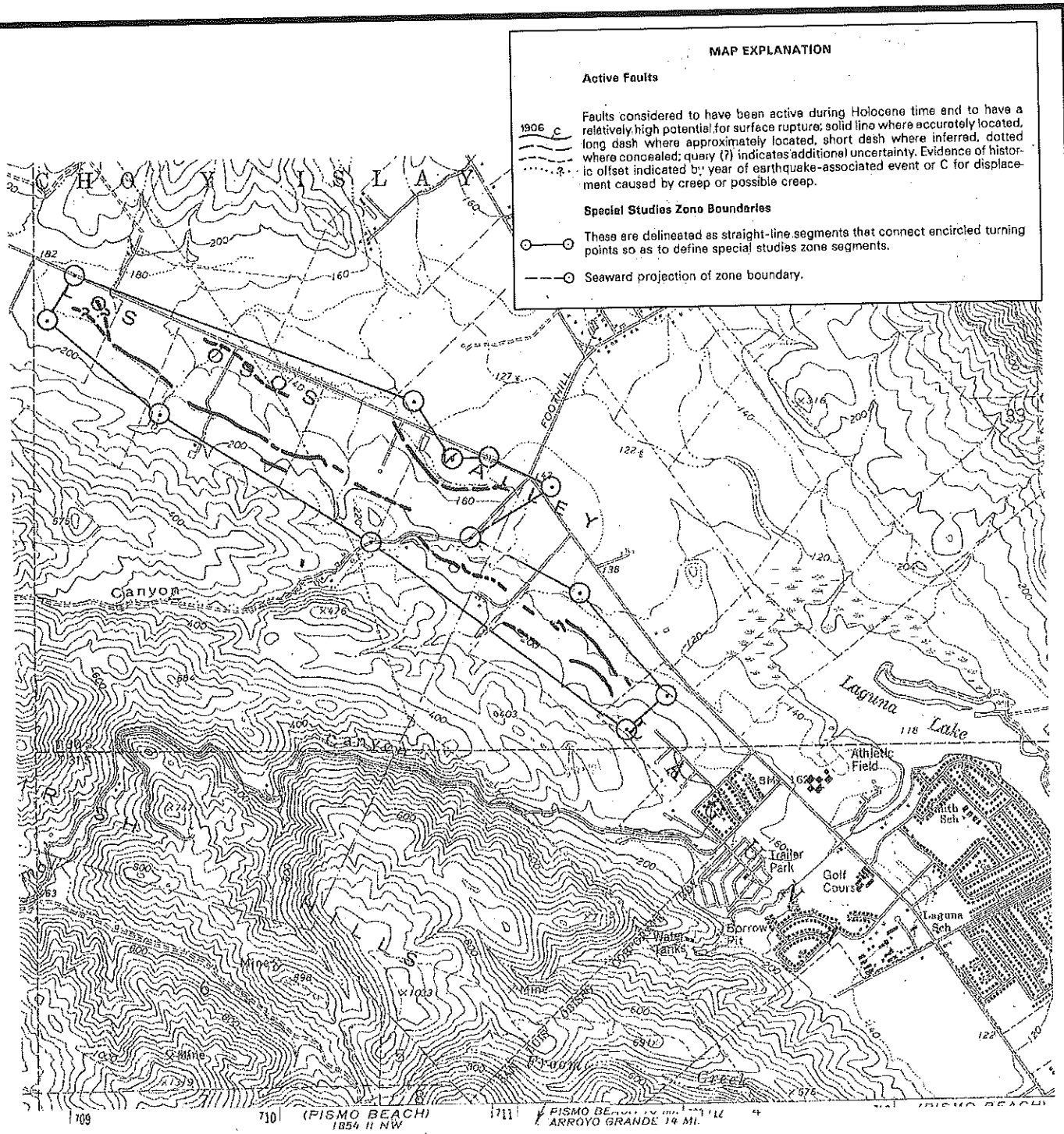

SCALE 1:24000

1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

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EARTHQUAKE FAULT ZONES MAP

(STATE OF CALIFORNIA, JANUARY 1, 1990)
FROOM/EI VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
2

PROJECT NO:
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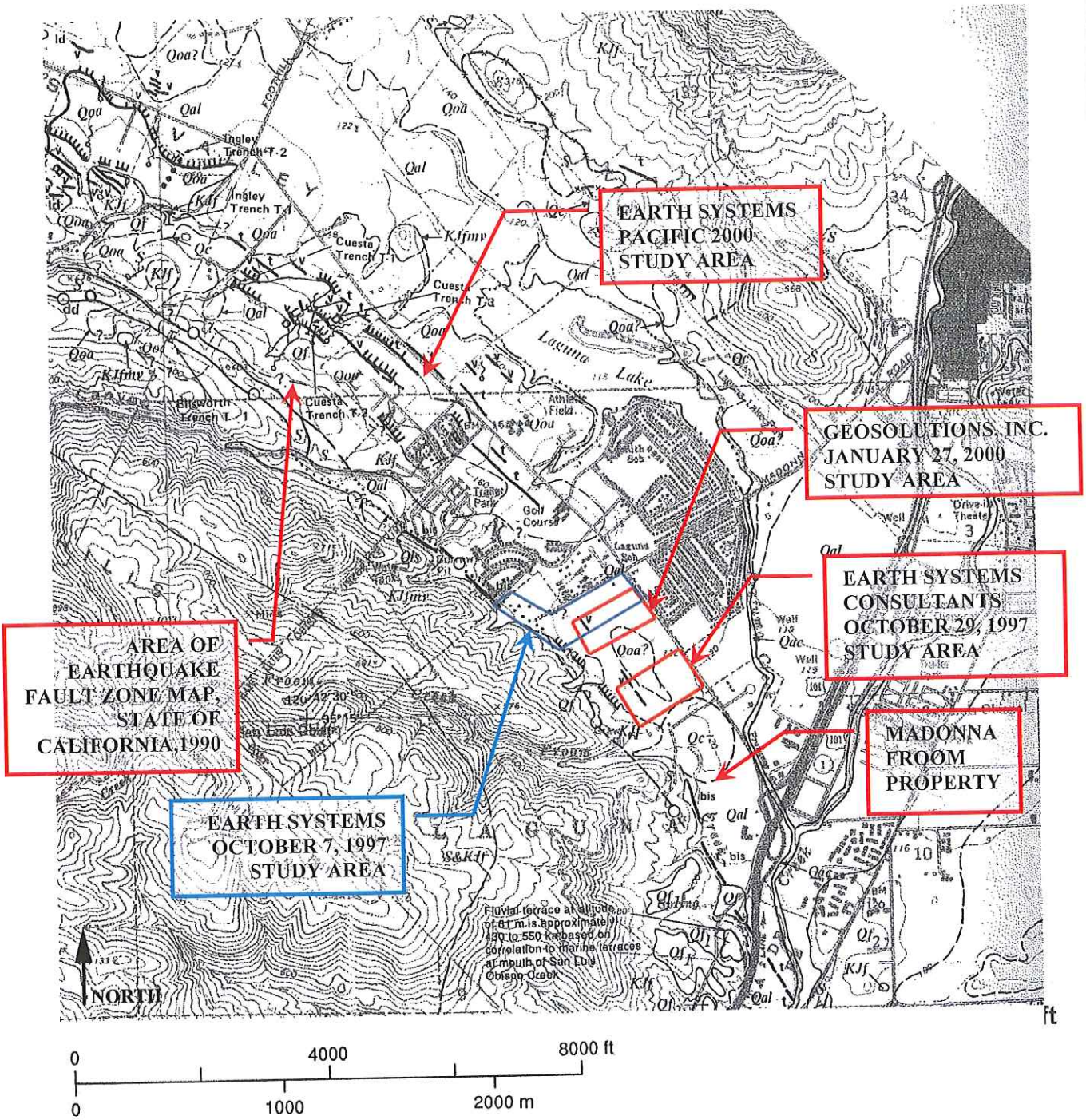

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REGIONAL GEOLOGIC MAP

(Lettis and Hall, 1994)
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
3A

PROJECT NO:
SL09734-2

EXPLANATION

MAP SYMBOLS

- Fault — Long dash where approximately located; short dash where concealed but location is well constrained; dotted where inferred; U = up/D = down and arrows indicate relative sense of displacement; small arrow and number indicate dip of fault plane exposed in outcrop
- Aerial photo lineament — Dashed where less distinct; probable fault; tc = tonal contrast, vl = vegetation lineament, ld = linear drainage, bls = break in slope, shb = side hill bench. Hachures on topographically downside of a scarp
- Shear zone in bedrock
- Strick and dip of bedding
- Marine terrace strandline — Solid where well constrained; double dot-dash where buried or less well constrained; dotted where eroded; queried where uncertain; altitude of shoreline angle in meters
- Contact — Dashed where approximately located, dotted where buried and inferred
- SR-8 — Seismic refraction survey line
- T-1 — Trench
- SP-T-5 — Soil pit
- EP-16 — Exploration pit
- Borehole — Completed as part of Long-Term Seismic Program (PG&E, 1988)
- Subsurface stratigraphy and altitude (meters) of the top of bedrock. See description of map units for explanation of Quaternary and bedrock symbols
- Landslide, arrow indicates direction of movement
- Spring
- Relict sea stack
- KH-42-A — Location of dated fossil sample
- 14C-KH-5C — Location of radiocarbon sample
- TL-1a — Location of sample for thermoluminescence analysis

DESCRIPTION OF MAP UNITS

- Q_b — Beach deposit — Modern beach sands, unconsolidated
- Q_e — Eolian deposit (Holocene and late Pleistocene) — Includes unconsolidated active sand dunes, and slightly to weakly cemented inactive dune sand on elevated marine terraces that has been stabilized by vegetation and soil development
- Q_c — Colluvium (Holocene and Pleistocene) — Unconsolidated, poorly sorted sand, gravel, silt, and clay deposited as a result of hillslope processes
- Q_f — Fluvial and alluvial deposits (Holocene and Pleistocene) undifferentiated — Unconsolidated cobble-pebble gravel, sand, silt, and clay
- Q_t — Stream terrace deposit (Holocene and late Pleistocene) — Undifferentiated

Oak Knoll Creek

Q_{t_1}	active	Q_{t_4}	2.5 - 3.8 ka
Q_{t_2}	historical	Q_{t_5}	5.5 to 7.9 ka
Q_{t_3}	2.25 ± 0.75 ka	Q_{t_6}	Late Pleistocene to early Holocene
$Q_{t_{4a}}$	2.25 ± 0.75 ka		

- Q_{es} — Estuarine deposit (Pleistocene)— Silty clay interbedded with thin layers of fine- to coarse-grained sand; dark gray; contains abundant charcoal, wood, and disseminated organic material
- Q_{oa} — Older alluvium (middle to late Pleistocene) — Unconsolidated, weakly to moderately stratified, moderately to poorly sorted gravel, sand, silt, and clay deposited in fluvial channels and alluvial fans overlying marine wave-cut platforms; presently undergoing dissection
- Q_{mt} — Marine deposit (middle to late Pleistocene) — Unconsolidated boulders, cobbles and sand, well- to moderately sorted clasts are typically subrounded to rounded and consist of Jurassic ophiolite, Franciscan Complex and Monterey lithologies

Bedrock outrops (Note: Bedrock geology is not mapped in detail)

- c — Careaga Sandstone (Pliocene and Pleistocene?) — Loosely consolidated to well-cemented, poorly bedded, medium- to coarse-grained sandstone and conglomerate; shell debris as much as 20% of rock (modified from Hall et al., 1979)
- m — Monterey Formation (middle and late Miocene) — Diatomaceous shale, porcelaneous shale, diatomite, silty sandstone, and opaline and cherty shale (modified from Hall et al., 1979)
- p_s — Point Sal Formation (middle Miocene) — Light brown siltsone, diatomaceous siltstone, and dolomite siltstone (modified from Hall et al., 1979)
- l — Lospe Formation (Oligocene) — Includes green and red conglomerate, sandstone, and silty claystone (modified from Hall et al., 1979)
- t — Tuff (age uncertain)

Franciscan Complex (Cretaceous or Jurassic) — Includes:

- f — Graywacke, shale, chert, and melange
- m_v — Metavolcanic rock
- b_s — Blueschist
- s — Serpentinite (Jurassic?)
- x — Undifferentiated bedrock
- x_p — Subscript p indicates presence of pholad borings on wave-cut platform

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GEOLOGIC EXPLANATIONS

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
3B

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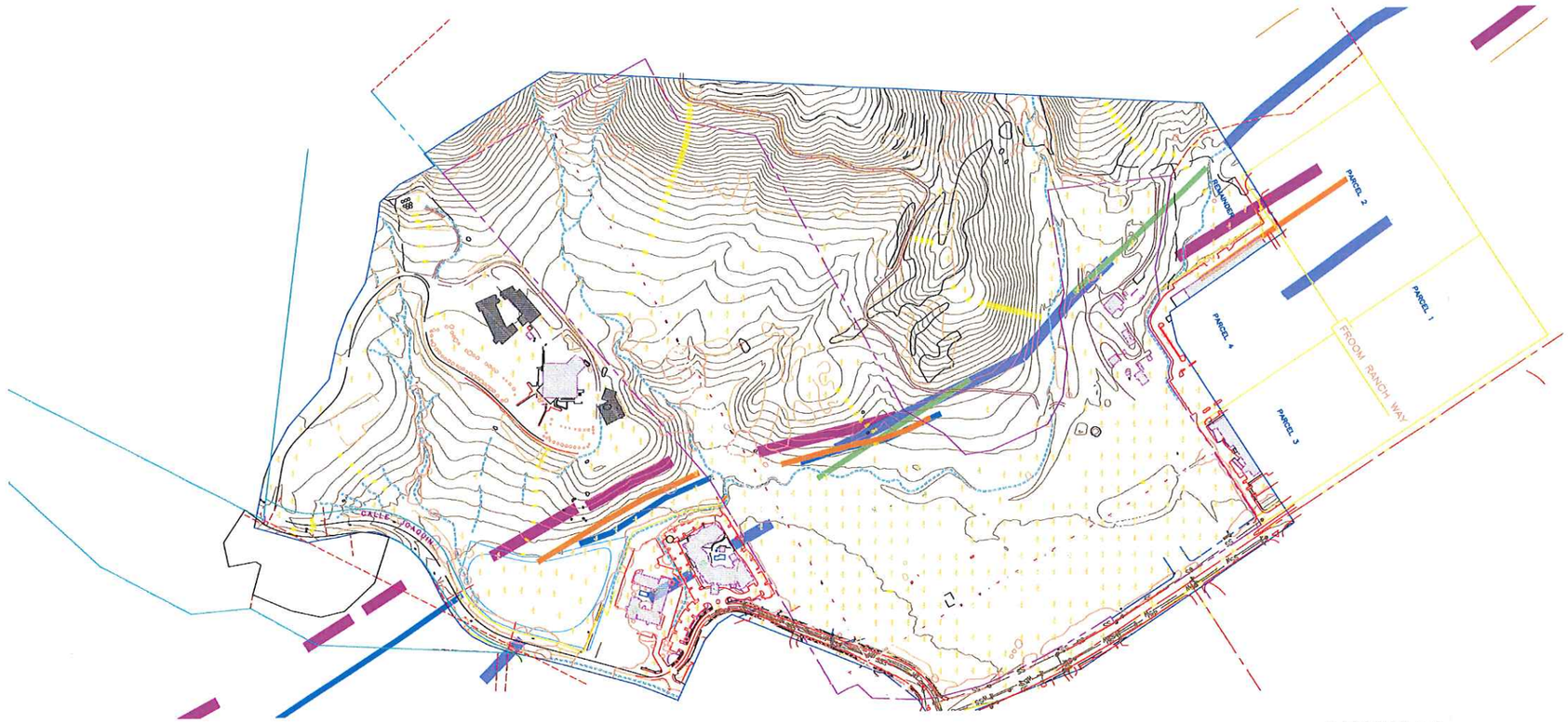

LEGEND

- Plate 5A: Hall 1973
- Plate 6: PG&E 2014
- Plate 7A: Wiegers, 2011
- Plate 3: Lettis & Hall, 1994
- Plate 8: KMZ-USGS 2016

FAULT LOCATIONS AS APPROXIMATELY MAPPED BY OTHERS

RRM DESIGN, 2016
FROOM/EI VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE 4

PROJECT NO: SL09734-2

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Froom Ranch

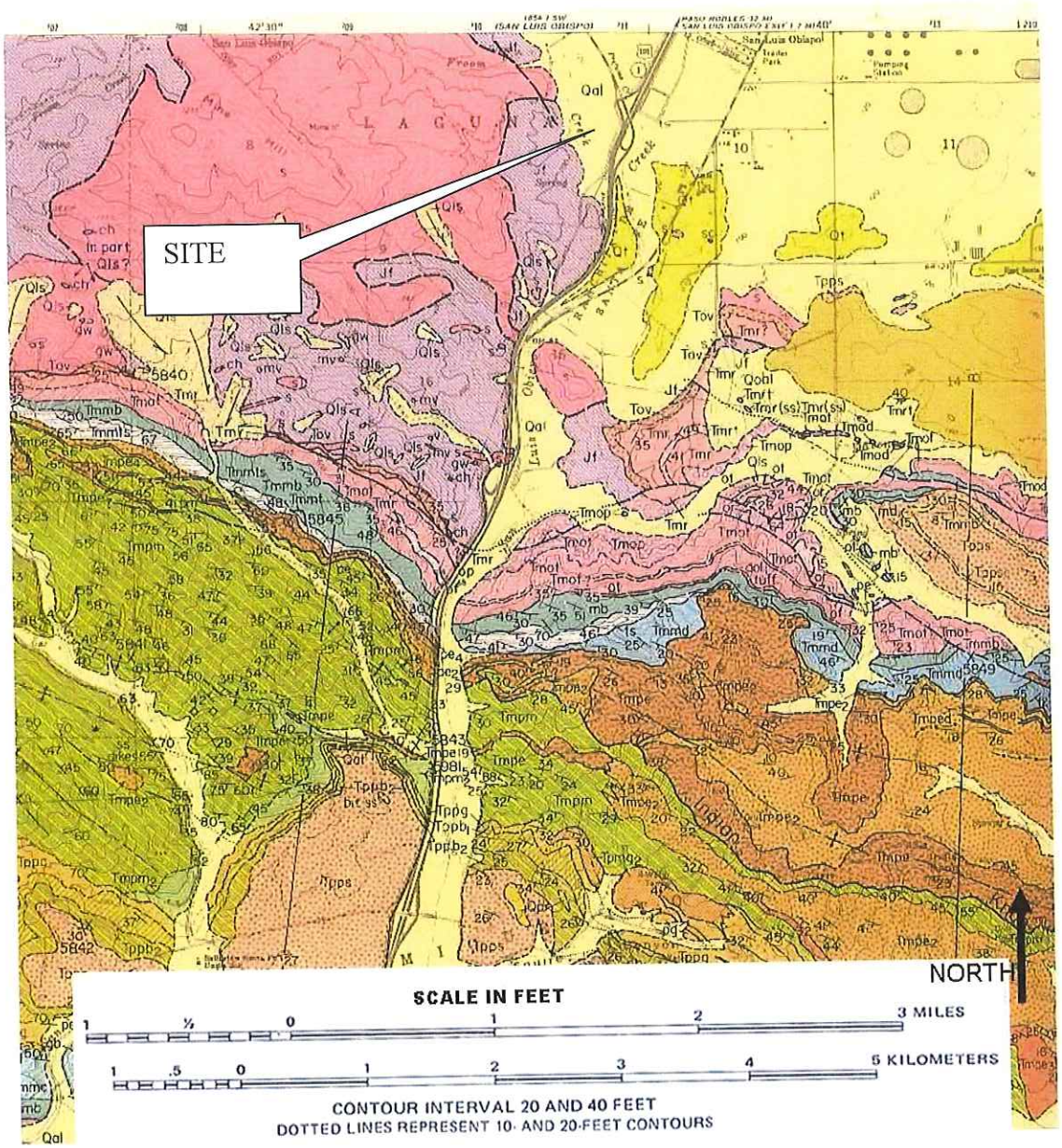
FROOM CREEK FAULT LINE EXHIBIT

0 125' 250' 500'
SCALE: 1" = 250'

Exhibit
June 23, 2016

rrm design group

\\Vboxsvr\Kelly\SLO\SHARED\SHARED\SL09734-1 - Madonna Froom Ranch\Graphics\drawings from rrm\Visual Line Creek\Froom_SLO734_Exhibit_Jul 01, 2016 9:05am_bwh



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Hall, 1973

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REGIONAL GEOLOGIC MAP

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
5A

PROJECT NO:
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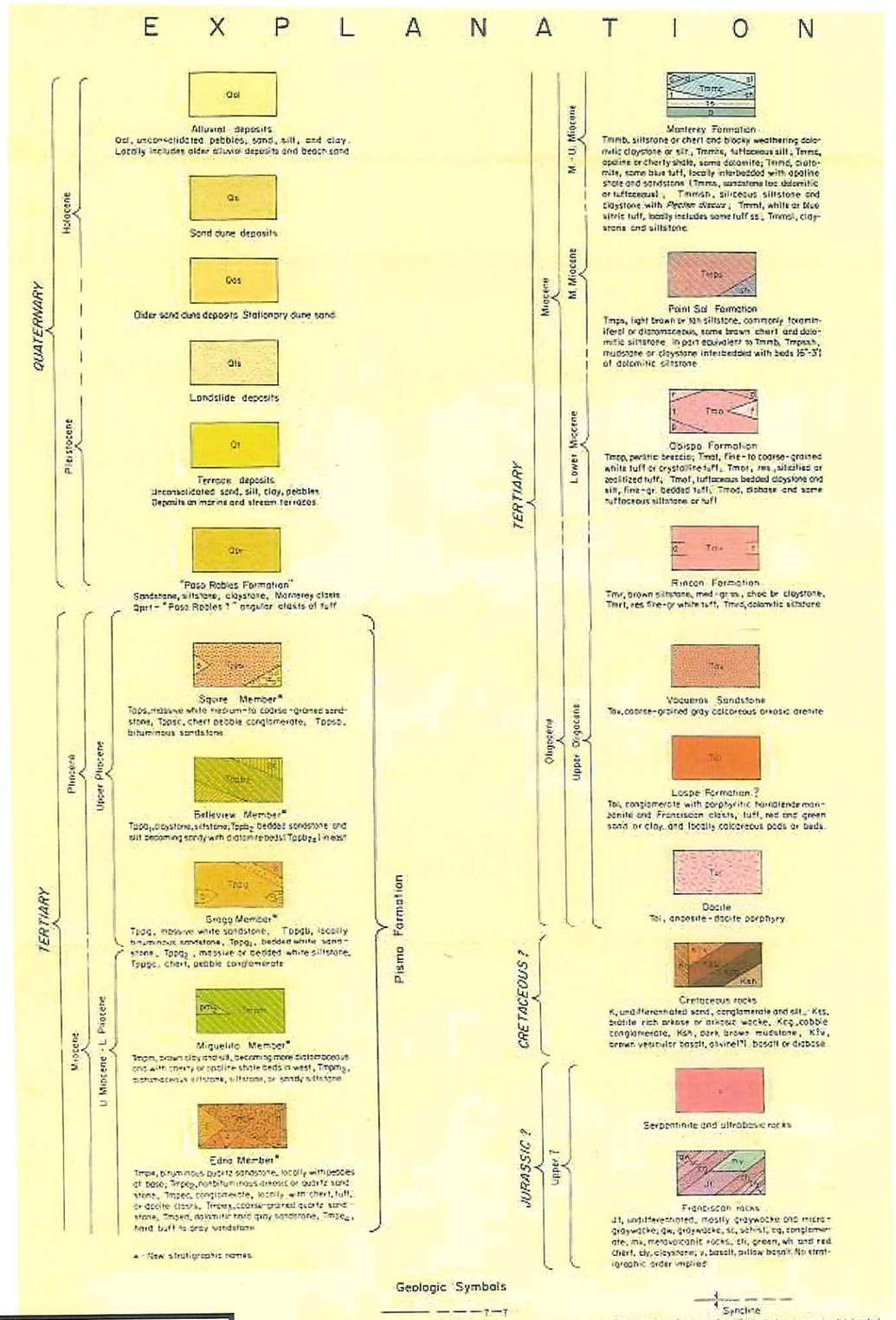
E X P L A N A T I O N





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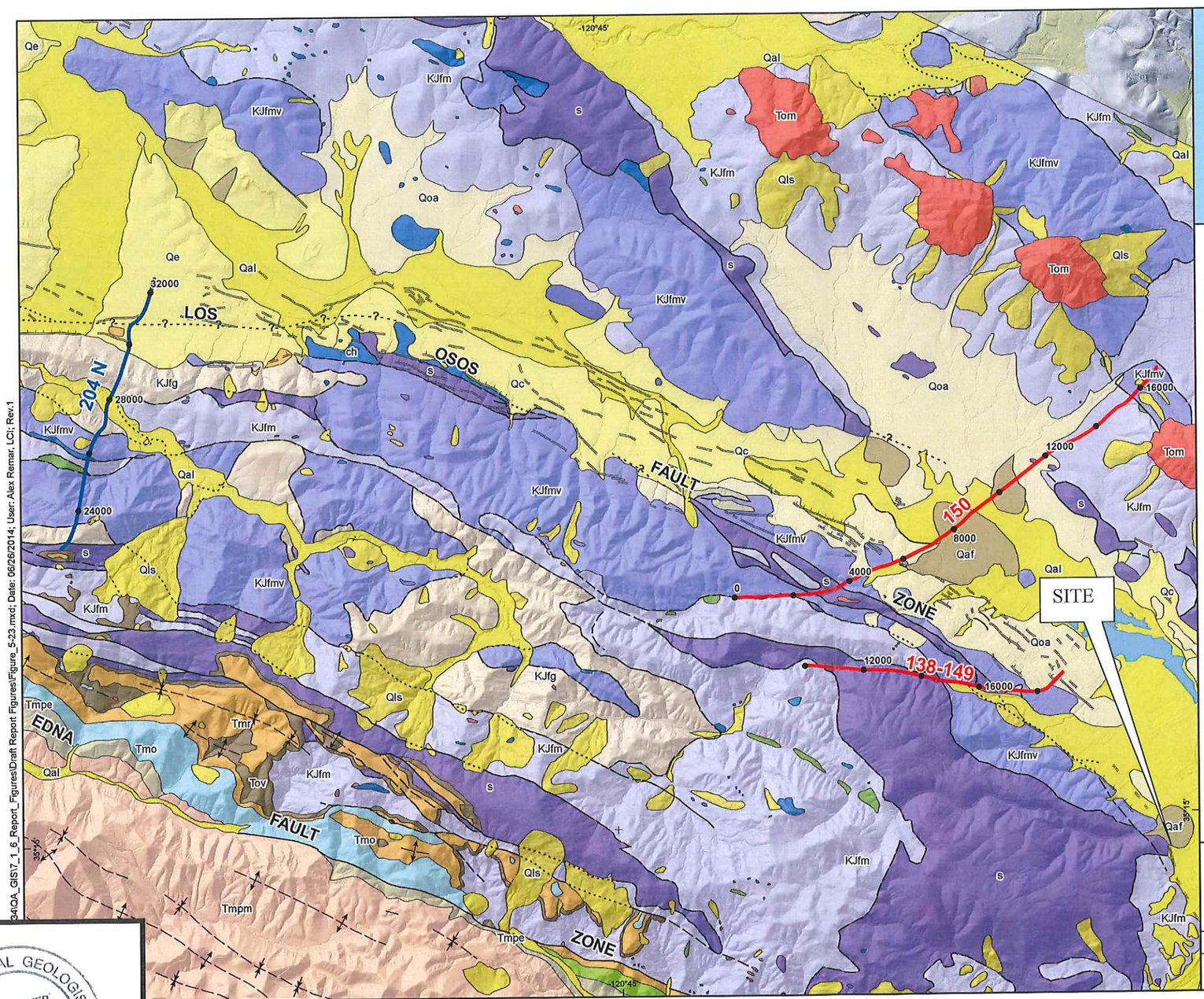
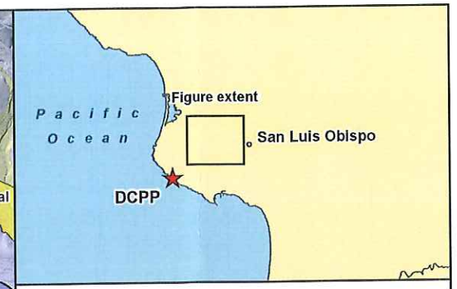
GEOLOGIC EXPLANATIONS

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
5B

PROJECT NO:
SL09734-2





EXPLANATION

- AWD seismic reflection line
- Vibroseis seismic reflection line
- Horizontal distance along seismic line, 2,000 ft. increments

Abbreviated List of Geologic Units

Quaternary continental deposits
- Qe Aeolian deposits
- Qal Alluvial deposits
- Qm Marine terrace deposits

Neogene marine deposits
- Tpps Pismo Formation, Squire Member
- Tmpm Pismo Formation, Miguelito Member
- Tmpe Pismo Formation, Edna Member
- Tmm Monterey Formation
- Tmod Obispo Formation, diabase
- Tmo Obispo Formation, undifferentiated

Continued
- Tmr Rincon Formation
- Tov Vaqueros Sandstone

Mesozoic basement
- Ks Cretaceous sandstone
- KJf Franciscan Complex, undifferentiated
- KJfm Franciscan Complex, melange
- s Franciscan Complex, serpentine
- KJg Franciscan Complex, graywacke sandstone
- KJfmv Franciscan Complex, metavolcanic rocks
- KJfo Franciscan Complex, ophiolite

Geologic Structures

Solid where known; dashed where approximate; dotted where concealed; queried where uncertain. Ticks on lineaments indicate facing direction of topographic scarps.

- Syncline
- Anticline
- Fault
- Lineament

Note: See Plate 1 for full list of geologic units and symbols.

N 0 0.5 1 mi. 0 1 2 km

Map projection and scale: WGS 84 / UTM Zone 10N, 1:40,061

Key Seismic Lines Imaging the Los Osos Fault

2011 ONSIP

Pacific Gas and Electric Company | Figure 5-23

Ch7.GEO.DCPP.TR.14.03 R0

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REGIONAL GEOLOGY MAP AND EXPLANATIONS

PG&E, 2014
FROOM/EI VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE 6

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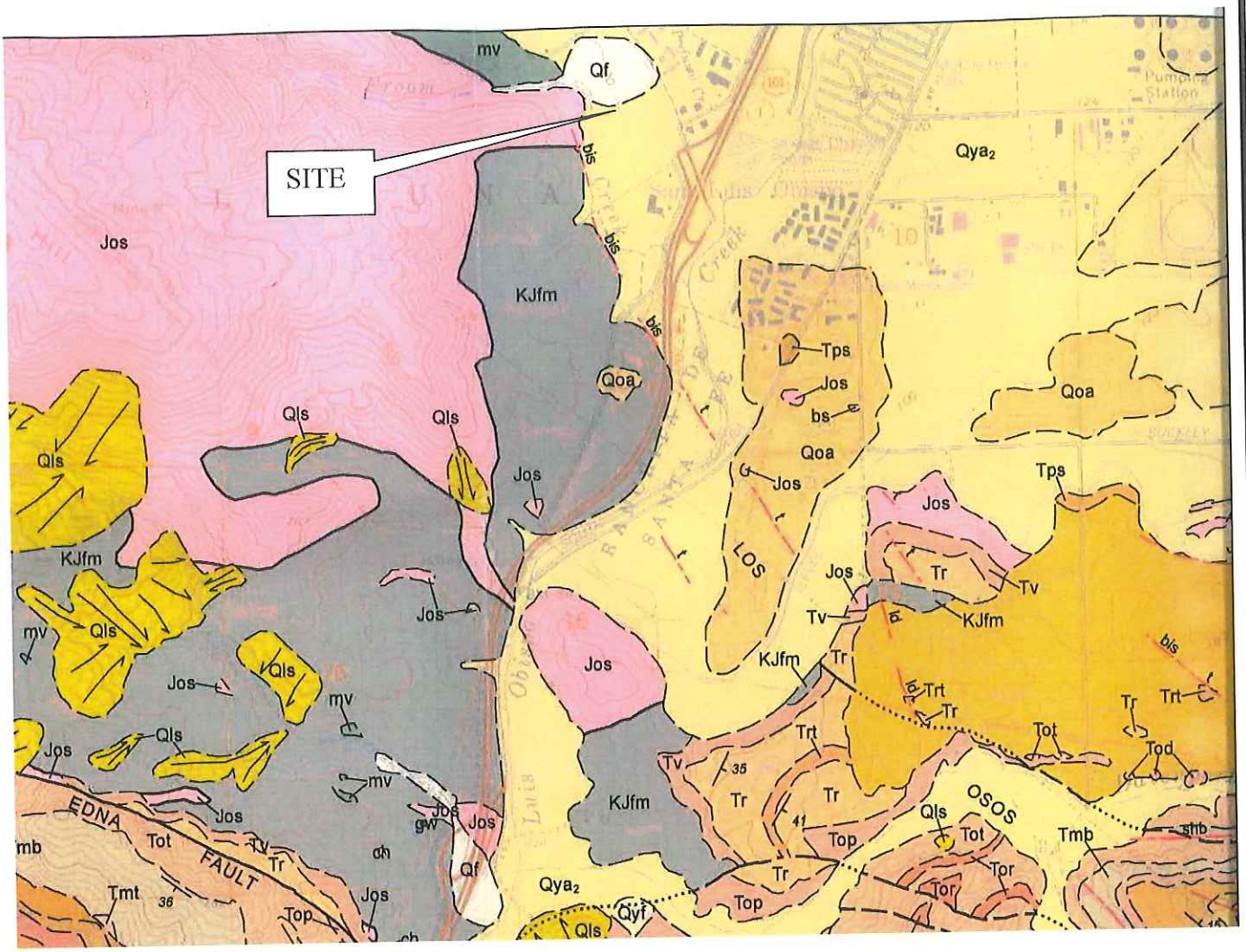

Contour Interval 40 feet
Supplementary Contour Interval 20 feet
National Geodetic Vertical Datum of 1929

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REGIONAL GEOLOGIC MAP

(Wiegers, 2011)
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
7A

PROJECT NO:
SL09734-2

DESCRIPTION OF MAP UNITS

QUATERNARY DEPOSITS

Very Young Surficial Deposits

Qa **Alluvial flood-plain deposits (late Holocene)** - Active and recently active flood-plain deposits. Consists of unconsolidated sandy, silty, and clay-bearing alluvium.

Qf **Alluvial fan deposits (late Holocene)** – Small active alluvial fans at the mouths of steep mountain streams. Consists of cobbles, gravel, sand, and silt.

Qb **Beach sand (late Holocene)** – Unconsolidated beach deposits consisting mostly of fine- to medium-grained well-sorted sand.

Qd **Dune sand (late Holocene)** – Unconsolidated, well-sorted white to brown windblown sand. Forms active dunes behind modern beaches.

Qls **Landslide deposits (Holocene)** – Highly fragmented to largely coherent landslide deposits.

Young Surficial Deposits

Qye **Young eolian deposits (Holocene to late Pleistocene)** – Stationary sand dune deposits. Well-sorted white to brown windblown sand.

Qya **Young alluvial valley deposits, undivided (Holocene to late Pleistocene)** – Unconsolidated sand, silt, and clay-bearing alluvium deposited on flood-plains and along valley floors. Locally divided by relative age (2 = youngest, 1 = oldest). Surfaces on young deposits are undissected and lack soil development. Surfaces on older deposits are slightly dissected and display weak soil development:

- Qya_2 **Young alluvial valley deposits, Unit 2**
- Qya_1 **Young alluvial valley deposits, Unit 1**

Old Surficial Deposits

Qoa **Old alluvial valley deposits (late to middle Pleistocene)** – Fluvial sediments preserved above active flood plains and channels. These deposits are moderately consolidated, slightly dissected and capped by moderate to well-developed pedogenic soils. Consists of relatively thin deposits of gravel, sand, silt and clay-bearing alluvium overlying eroded bedrock surfaces and older sediments. Forms low rounded topographic rises in San Luis Obispo Valley. Locally perched on isolated strath terraces.

Qop_{1-3} **Old paralic deposits (late to middle Pleistocene)** – Marine terrace deposits consisting of beach and nearshore sands and gravels covered by colluvium and alluvium. These deposits rest on emergent wave-cut platforms preserved by regional uplift. Marine deposits consist of well-sorted sand and gravel locally containing fossils and shell fragments. Overlying non-marine cover consists of poorly-sorted sand, silt, gravel and clay deposited by slope wash and alluvial processes. Divided by relative age (3 = youngest, 1 = oldest). Estimated ages of deposits are as follows (Hanson and others, 1994):

- Qop_3 **Old paralic deposits, Unit 3 – 80 ka**
- Qop_2 **Old paralic deposits, Unit 2 – 120 ka**
- Qop_1 **Old paralic deposits, Unit 1 – 210 ka - 430 ka**

Old Surficial Deposits

Qvoa **Very old alluvial valley and pediment deposits (middle to early Pleistocene)** – Tan silt and fine sand deposited on a gently sloping pediment surface extending down the northeast side of the San Luis Range into San Luis Obispo Valley. Mapped as Paso Robles Formation by Hall (1973). Lacks channel conglomerates. Much of the unit appears gradational with underlying sandstone of the Squire Member of the Pismo Formation (Tps) and may in part be residual soil developed on that unit (Nitchman, 1988).

Qvop **Very old paralic deposits (middle to early Pleistocene)** – Marine terrace deposits consisting of beach and near shore sands and gravels covered by colluvium and alluvium. These deposits rest on emergent wave-cut platforms preserved by regional uplift. Well preserved terraces are found about 400 feet above sea level on slopes north and northwest of Pismo Beach. These terraces are estimated to be older than 560 ka (Hanson and others, 1994).

TERTIARY AND OLDER ROCKS

Pismo Formation (lower Pliocene to upper Miocene)

Tps **Squire member** – Massive, white, calcareous, fine- to medium-grained, quartzose to arkosic, silty sandstone. Sand grains subrounded to subangular; 75-80% quartz, 15-20% feldspar, less than 15% mafic minerals (Hall, 1973). Contains lenses of white, well-rounded pebbles and cobbles of Monterey and Obispo Formation clasts north of Edna Fault. Basal conglomerate of rounded chert and basalt cobbles near mouth of San Luis Obispo Creek. Bioturbated with greenish glauconitic sand coatings and clay and silt interbeds in footwall of Wilmar Avenue Fault at Pismo Beach (Nitchman, 1988). **Tpsc** - Conglomerate of rounded chert pebbles near middle of unit on north side of Edna Fault.

Tpb **Belleview member** – Light-gray, bedded, resistant sandstone and interbedded siltstone. Sandstone medium-grained; 60% quartz, 30% feldspar, locally 15% rock fragments (Hall, 1973). **Tpbc** - Interbedded, buff claystone, siltstone and fine-grained sandstone. Claystone speroidally fractured. Sandstone beds locally fossiliferous. **Tpbd** - Well-bedded diatomaceous siltstone, claystone and silty diatomite.

Tpg **Gregg member** – Massive, white, buff-weathering sandstone, soft to resistant, medium-grained; 65% quartz, 30% feldspar, clay 4%, mafic minerals 1% (Hall, 1973). **Tpgs** – Well-bedded sandstone, beds 2 inches to 2 feet thick. **Tpgf** – Massive buff siltstone. **Tpgb** – Locally bituminous sandstone. **Tbgc** – Chert pebble conglomerate. **Tpgd** – Diatomaceous siltstone.

Tpm **Miguelito member** – Brown to buff interbedded siltstone and claystone, moderately resistant, well-bedded, beds generally 2 to 4 inches thick. Locally includes beds and lenses of siliceous and dolomitic siltstone and friable, locally bituminous sandstone (Hall, 1973). Opaline and porcelaneous shale is present in the western part of the map area. **Tpms** – Poorly bedded siltstone, diatomaceous siltstone and sandy siltstone. The Miguelito Member consists of basinal mudstones in the west and south parts of the map area that interfinger with coeval inner shelf sandstones of the Edna member to the east.

Tpe **Edna member** – Buff, massive arkosic to quartzose sandstone, fine- to coarse-grained; quartz 80-95%, feldspar less than 5-15% (Hall, 1973). **Tpeb** – Bituminous sandstone zones within Tpe. Oil can be seen leaking from exposures near Price Canyon Oil Field and oily sandstones are exposed on the ridge north of Shell Beach. **Tpec** – Basal conglomerate and/or breccia with clasts ¼-inch to several feet in diameter of Monterey chert, dacite and Franciscan debris. Clasts commonly angular and poorly sorted but locally rounded and well-sorted. Basal conglomerate overlying Monterey Formation well exposed at Shell Beach. **Tpes** – Massive medium- to coarse-grained pebbly sandstone, locally calcareous and fossiliferous. **Tpet** – Hard, buff to gray tuffaceous sandstone, locally siliceous and bituminous. **Tped** – Fine-grained dolomitic sandstone.

Tmt / Tmc / Tmd / Tmb **Monterey Formation (upper to middle Miocene)** – Bedded, resistant chert, color varies from white and gray to brown and reddish-brown, weathering to chalky white. Brittle, concholdal fracturing, commonly sheared, beds ½ to 6-inches thick, commonly laminated, locally interbedded with diatomite (Hall,1973). **Tmd** – White to buff diatomite with minor tuff, opaline chert and tuffaceous sandstone. **Tmts** – Tuffaceous siltstone, locally interbedded with dolomitic siltstone and opaline chert. **Tmt** – White to blue-gray tuff, very fine- to coarse-grained, locally includes virtic tuff and tuffaceous sandstone. **Tms** – Brown to white siltstone with some claystone. **Tmb** – Tan to yellowish-white siltstone and dolomitic claystone locally tuffaceous or interbedded with chert.

Tof / Tot **Obispo Formation (lower Miocene)** – Coarse-grained tuff with subangular clasts of pumice (5%-50%), perlite (5%-15%), white to dark-gray glass shards (20%) and feldspar (5%) in a vitric ashy matrix; commonly altered to montmorillonite (Hall, 1973). Type locality along San Luis Obispo Creek. Locally contains clasts of reddish- brown tuffaceous mudstone. **Top** – Perlite breccia. Patchy white and gray, weathering to dark-gray, contains subangular perlite and pumice clasts 2 to 8 inches in diameter in a tuffaceous matrix. **Tor** – Resistant, hard, fine-grained, zeolized tuff. Forms resistant cliffs at Fossil Point near Avila Beach and resistant outcrops and an ancient sea stack along State Route 1 at Pismo Beach. **Tof** – Yellow to brown tuffaceous siltstone and claystone. **Tod** – Diabase dikes and sills. Exposed locally in cliffs at Pismo Beach.

Tr **Rincon Shale (Oligocene and lower Miocene)** – Dark-brown to orange-brown siltstone and claystone, poorly to well-bedded, weathers white to light-brown. Locally contains yellowish, fine-grained quartzose sandstone. **Trt** – White to buff rhyolitic vitric tuff. Contains quartz and feldspar crystals in a fine-grained ash matrix (Hall, 1973).

Tv **Vaqueros Sandstone (Oligocene)** – Gray to brown, medium- to coarse-grained sandstone and conglomerate, poorly to well-indurated. Conglomerate clasts typically black and green chert. Sandstone grains well-rounded to subrounded with a typical composition of 40% to 60% quartz, 5% to 15% feldspar, 30% to 50% rock fragments (Hall, 1973). Contains fossiliferous zones with broken mollusk shells and large oysters.

KJfm **Franciscan Complex mélange (Cretaceous to Jurassic)** – Chaotic mixture of fragmented rock masses embedded in a penetratively sheared matrix of argillite and crushed metasandstone. Individual rock masses contained in the matrix range from less than a meter to kilometers in scale. Blocks large enough to be shown on map include high grade blueschist (**bs**), greenstone (**mv**), pillow basalt (**v**), graywacke (**gw**) and chert (**ch**). Penetrative deformation of matrix postdates metamorphism of enclosed rock masses.

Jos **Serpentinized ultramafic rocks** – Pervasively sheared serpentinite occurring as lenticular fault-bounded bodies in Franciscan mélange. Considered to be dismembered bodies of the Coast Range Ophiolite tectonically interleaved with mélange during subduction. Locally, hydrothermally altered to silica-carbonate rock.

SYMBOL EXPLANATION

Contact between map units - Solid where accurately located, dashed where approximately located, dotted where concealed.

Fault - Solid where accurately located, dashed where approximately located, dotted where concealed. U = upthrown block; D = downthrown block.

Thrust fault - Solid where accurately located, dashed where approximately located, dotted where concealed. Barbs on upper plate.

Synclinal axis - Solid where accurately located, dashed where approximately located, dotted where concealed. Arrow shows plunge direction.

Anticlinal axis - Solid where accurately located, dashed where approximately located, dotted where concealed. Arrow shows plunge direction.

t v ld — Aerial photo lineaments (Lettis and Hall, 1994). Dashed where less distinct, queried where questionable. Hachures indicate topographic scarp and direction of slope. t = tonal contrast; v = vegetative lineament; ld = linear drainage.

Strike and dip of bedding plane.

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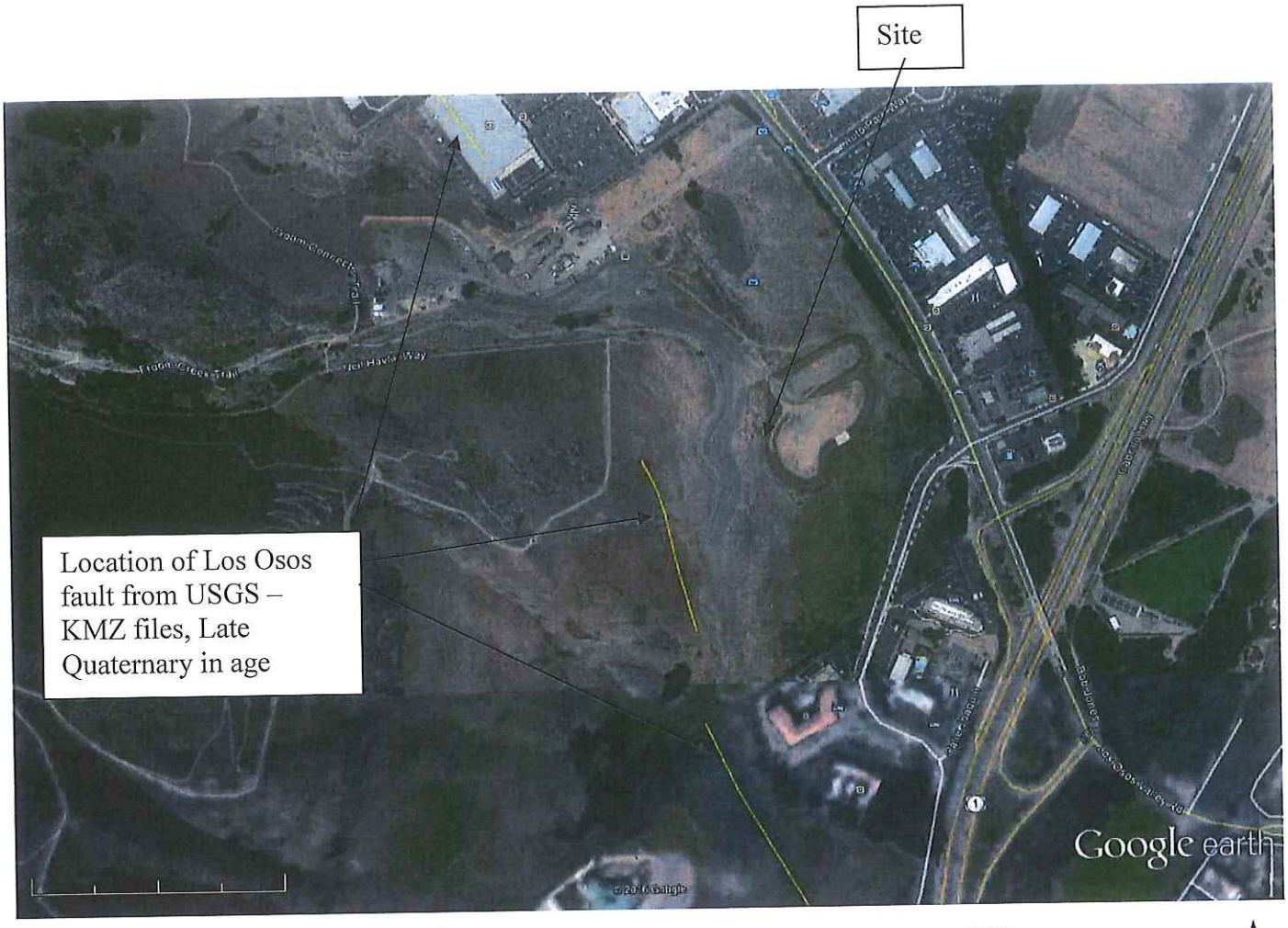
GEOLOGIC EXPLANATIONS

WIEGERS, 2011
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
7B

PROJECT NO:
SL09734-2



Google earth

feet 2000
meters 700

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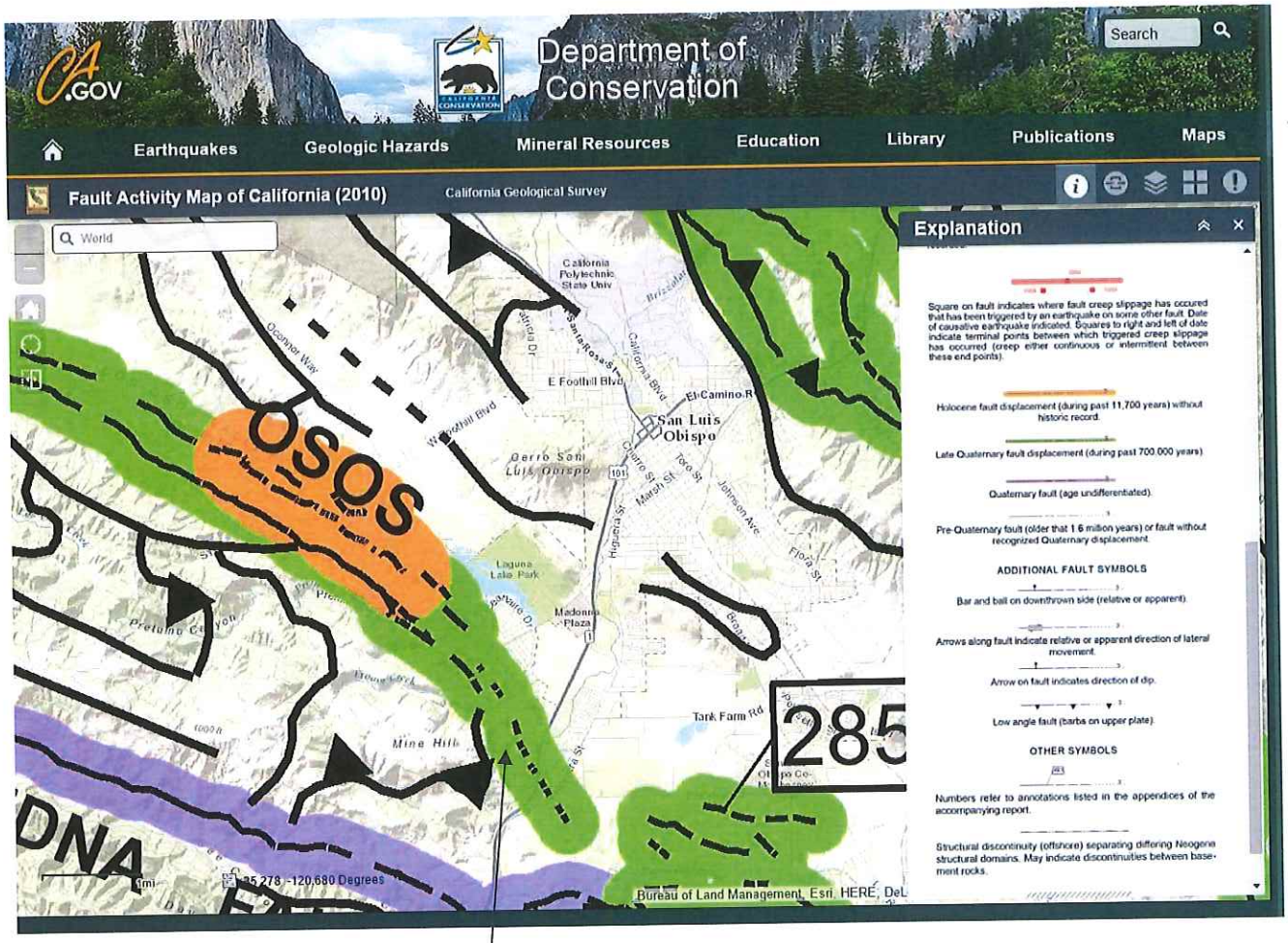
GOOGLE IMAGE WITH USGS KMZ FAULTING

Date: 2016
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
8

PROJECT NO:
SL09734-2



SITE

NORTH

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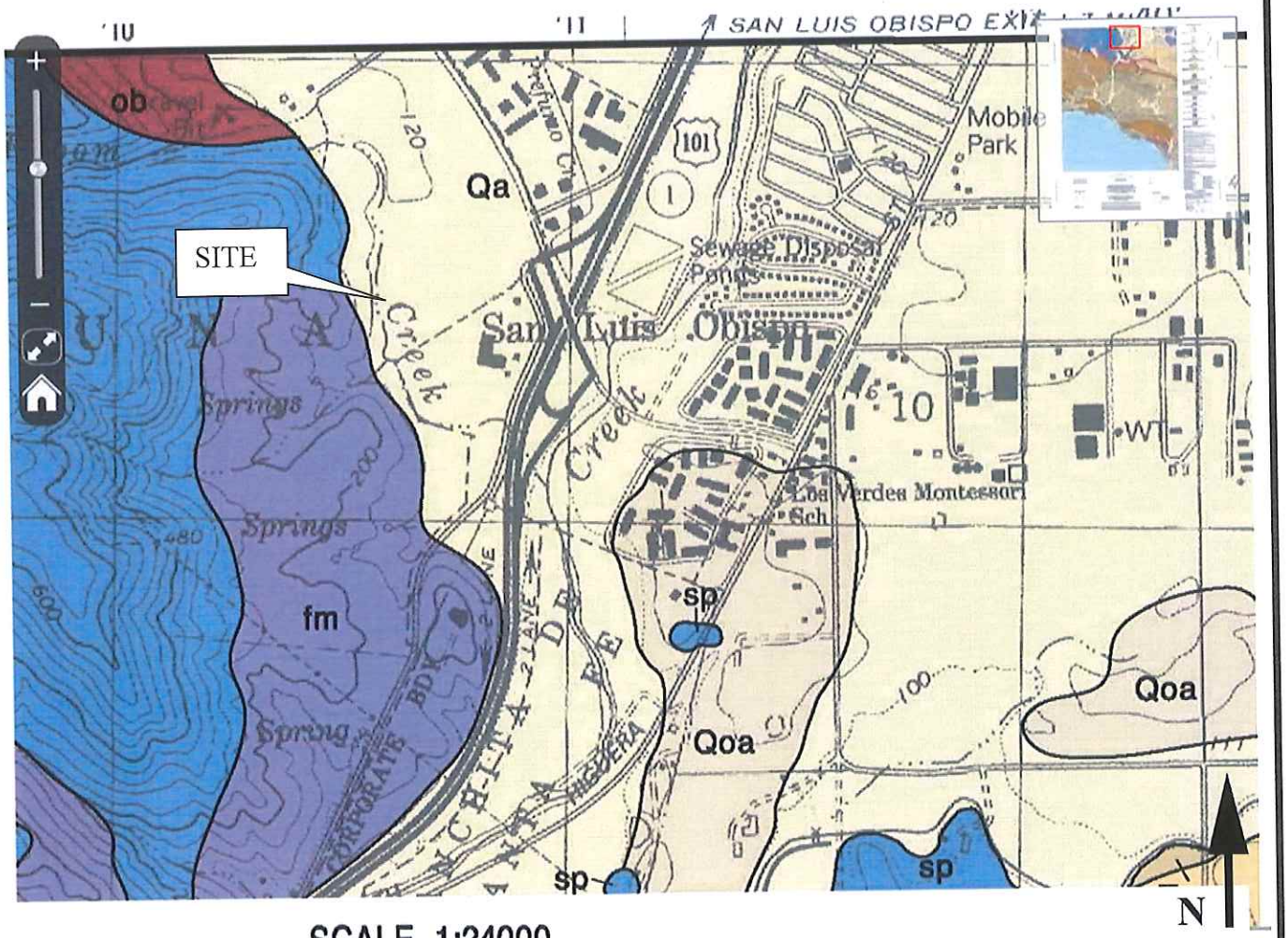
REGIONAL FAULT MAP AND EXPLANATIONS
Jennings, 2010
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
9

PROJECT NO:
SL09734-2

Dibblee, T.W., and Minch, J.A., 2006, Geologic map of the Pismo Beach quadrangle, San Luis Obispo County, California: Dibblee Geological Foundation, Dibblee Foundation Map DF-212, scale 1:24,000

View Product Description Page



SCALE 1:24000

1/2 0 1 MILE

1000 2000 3000 4000 5000 6000 7000 FEET

.5 0 1 KILOMETER

PISMO BEACH QUADRANGLE

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REGIONAL GEOLOGIC MAP

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
10A

PROJECT NO:
SL09734-2

PISMO BEACH MAP (DF-212)

LEGEND

Qa | Qbs

SURFICIAL SEDIMENTS
Qa *Alluvial gravel, sand and clay*
Qbs *Beach sand*

Qls

LANDSLIDE RUBBLE

Qos | Qoa

OLDER ALLUVIUM
Qos *Sand of older stabilized dunes, dissected*
Qoa *Dissected gravel and sand*

— *UNCONFORMITY* —

QTp

PASO ROBLES FORMATION
Of Hall, 1973; Valley sediments, weakly indurated, may be older alluvium (Qoa); age, Pliocene to Pleistocene
QTp *Older alluvial gravel sand and clay with siliceous shale pebbles, undeformed but dissected*

— *UNCONFORMITY* —

Tsw

SQUIRE SANDSTONE
Squire Member of Pismo Formation of Hall, 1973; designated herein as a formation because of major unconformity at base; age, Pliocene
Tsw *Sandstone, white to gray-white, fine to medium grained, arkosic, friable; equivalent to Careaga Sandstone of Santa Maria basin*

— *UNCONFORMITY* —

Tpsb | Tp | Tps

PISMO FORMATION
Marine; age, late Miocene, possibly early Pliocene, Mohnian and Delmontian Stages
Tps *Sandstone, light gray, friable, quartzose (Edna Member of Hall south of Morro Bay)*
Tpsb *Sandstone, similar to Tps, but bituminous*
Tp *Claystone to siltstone, gray, weathered tan, vaguely bedded, includes sandstone, similar to Tps, in north area*

— *UNCONFORMITY* —

Tmm | Tm | Tml

MONTEREY FORMATION
Marine biogenic; age, middle to late Miocene
Tmm *Siliceous shale, white-weathered, thin-bedded, platy, porcelaneous to cherty; age, upper Miocene, Mohnian Stage; assigned by Hall, 1973, to Pismo formation as part of Miguelito Member in west area*
Tm *Siliceous shale, thin-bedded, platy, white-weathered, porcelaneous to cherty in upper part; age, upper to middle Miocene, Mohnian Stage*
Tml *Lower part (Point Sal formation of Hall, 1973), shale, cream-white-weathered, thin-bedded, fissile; includes thin calcareous layers, mostly at base; age, middle Miocene, Luisian-Relizian Stages*

Tot | Top | Tov

OBISPO FORMATION
Pyroclastic-volcanic rocks, lithified; age, early middle Miocene, Saucesian-Relizian Stages
Tot *Tuff and tuff breccia, white to creamy-white, locally silicified or zeolitized to coherent rock*
Top *Perlitic glass and breccia*
Tov *Volcanic rocks, mostly basalt but includes some dark gray andesitic rock, mostly in upper part, not differentiated; basalt, black fine-grained, massive to vaguely bedded, somewhat incoherent where weathered, locally vesicular, composed of plagioclase feldspar and mafic minerals including olivine, locally incudes diabase sills and dikes*

Holocene / Pleistocene / ? / ? / Pliocene / Miocene — QUATERNARY / TERTIARY — CENOZOIC

Tr

RINCON SHALE
Marine clastic; age, Oligocene-early Miocene, Zemorrian-Saucesian Stages
Tr *Clay shale, gray, crumbly*

Tvq

VAQUEROS SANDSTONE
Marine clastic; age, early Miocene or late Oligocene, Zemorrian Stage
Tvq *Sandstone, light gray, locally calcareous*

sp

SERPENTINITE
sp *Bluish-green, severly fractured, with shiny slickensides, hydrothermally metamorphosed from intrusive rocks, such as ultramafic, peridotite*

ob

DIABASE
Assigned to Franciscan Rocks by Hall, 1973, 1975, but may be part of Coast Range Ophiolite Complex; associated with **sp**
ob *Diabase, black, fine-grained, massive, of calcic plagioclase and mafic minerals; includes basalt, minor chert; structurally overlies? Franciscan Assemblage*

fm | fg

FRANCISCAN ROCKS
Marine, eugeosynclinal sedimentary and volcanic rocks; age, Jurassic and Cretaceous
fm *Pervasively sheared melange, primarily dark claystone and graywacke sandstone, includes blocks of graywacke, chert, greenstone and glaucophane schist*
fg *Greenstone (meta-basalt)*

Jurassic & Cretaceous — MESOZOIC

GEOLOGIC SYMBOLS

not all symbols shown on each map

FORMATION CONTACT *dashed where inferred or indefinite, dotted where concealed*
MEMBER CONTACT *between units of a formation* ..... *Prominent bed*
CONTACT BETWEEN SURFICIAL SEDIMENTS *located only approximately in places*

FAULT: *Dashed where indefinite or inferred, dotted where concealed, queried where existence is doubtful. Parallel arrows indicate inferred relative lateral movement. Relative vertical movement is shown by U/D (U=upthrown side, D=downthrown side). Short arrow indicates dip of fault plane. Sawteeth are on upper plate of low angle thrust fault.* U / D, 25, ?

FOLDS: *overturned* — **ANTICLINE** — **SYNCLINE**
arrow on axial trace of fold indicates direction of plunge; dotted where concealed by surficial sediments

Strike and dip of sedimentary rocks: 18 *inclined*; 20 *inclined (approximate)*; 80 *overturned*; *horizontal*; *vertical*

Strike and dip of metamorphic or igneous rock foliation or flow banding or compositional layers: 75 *inclined*; *inclined (approximate)*; *vertical*; 80 *overturned*

OTHER SYMBOLS: *Direction of landslide movement*; *outline of water bodies shown on map*; *water well*; *oil well*; *springs*

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REGIONAL GEOLOGIC MAP

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
10B

PROJECT NO:
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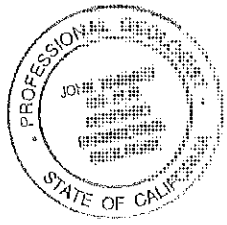
No scale

NORTH



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LiDAR Image 2011

FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
11

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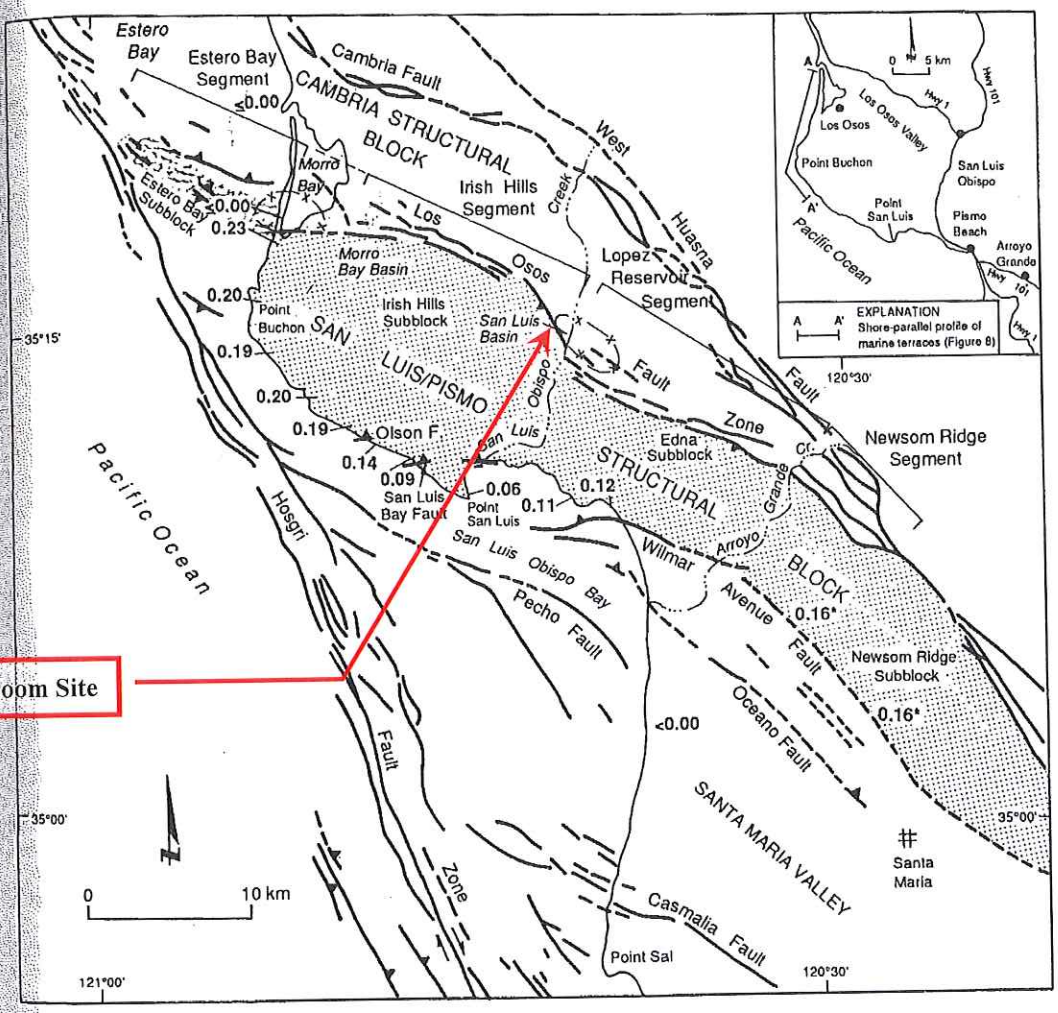

Madonna-Froom Site

EXPLANATION

Fault: dashed where approximately located, teeth indicate dip direction of reverse fault, arrows indicate relative sense of displacement

Structurally complex zone

0.23 Late Pleistocene (post-120 ka) uplift rate (m/kyr)

0.16* Uplift rate (m/kyr) based on the altitude estimated age (~560 ka) of the Q7 marine terrace (Hanson et al., this volume)

Inferred structural basin; may or may not be bounded by faults

Figure 2. Regional map showing segments of the Los Osos fault zone and late Quaternary uplift rates of the San Luis/Pismo structural block.

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REGIONAL GEOLOGIC MAP
Los Osos Fault Segments
(Lettis and Hall, 1994)
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
12

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North of Madonna Froom site – KMZ –USGS files in area of AP Zoning - note discontinuous locations of faulting – Google Earth Image

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LOCATION OF FAULTS ON EARTHQUAKE FAULT ZONE

USGS KMZ FILES
FROOM/El VILLAGGIO SPECIFIC PLAN
SAN LUIS OBISPO AREA, CALIFORNIA

PLATE
13

PROJECT NO:
SL09734-2

APPENDIX A

Trench Logs - T-1, T-2, T-3, T-4, T-5, T-6, T-7, T-8, T-9, T-10A, T-10B

GST Trench Logs – Sheet Logs 1

Boring Logs

North Wall of Trench T-2a – Lettis Consultants International, Inc.

Photo Log of Trench T-2B North Wall - Lettis Consultants International, Inc.

Photo Log of Trench T-2A South Wall - Lettis Consultants International, Inc.

Earth Consultants International – November 18, 2016 report

Earth Systems Pacific, February 28, 2000 – Portion of report

Earth Systems Consultants – October 29, 1997 – Portion of report

GeoSolutions, Inc., - January 27, 2000 – Portion of report

Earth Systems Consultants – October 7, 1997 – Portion of report

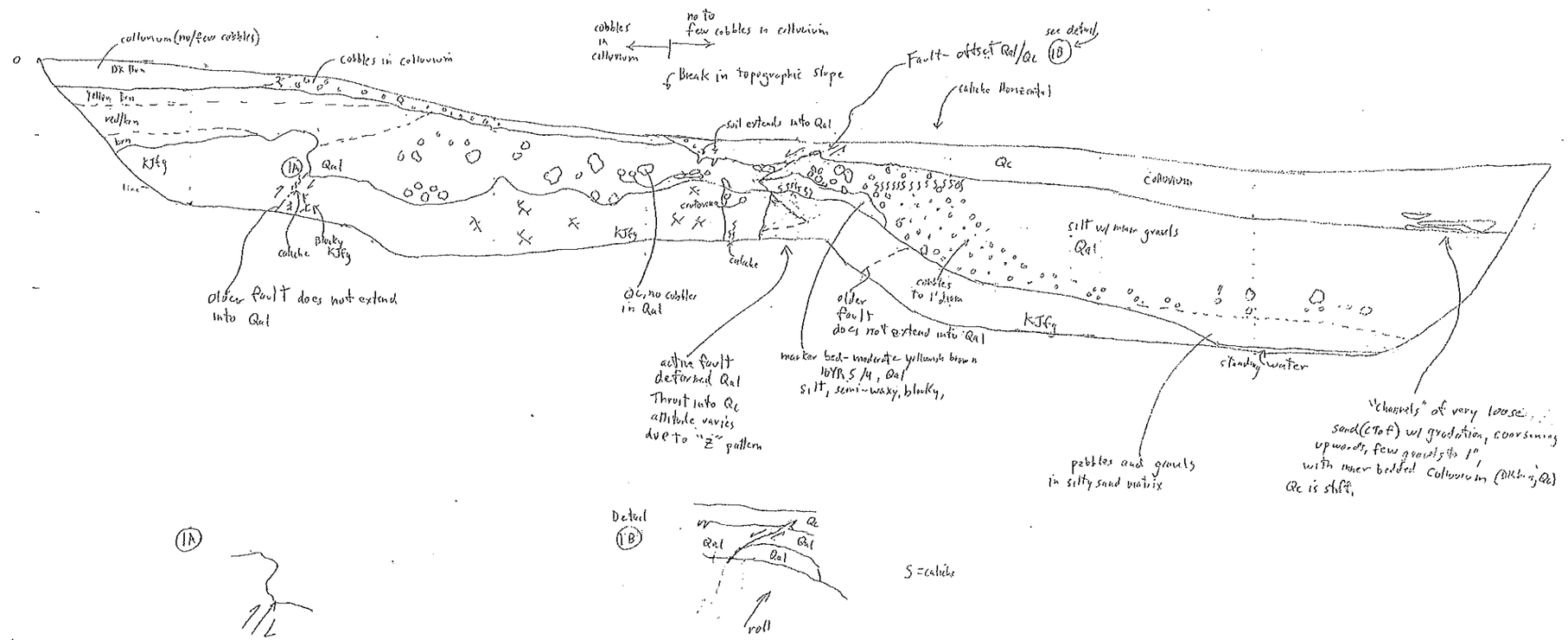
T1-A

→ N89E

View of North wall

SCALE IN FEET

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100



(1A)

Detail (1B)

S = caliche

TRENCH T1-A

Notes - Fault at 50-55' offset Qal and Qc

- on both sides of trench- offset Qal and Qc at this location

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction, dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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TRENCH LOG T1-A

Fault Trenching - FROOM RANCH

A

1"= 5'

T1-B

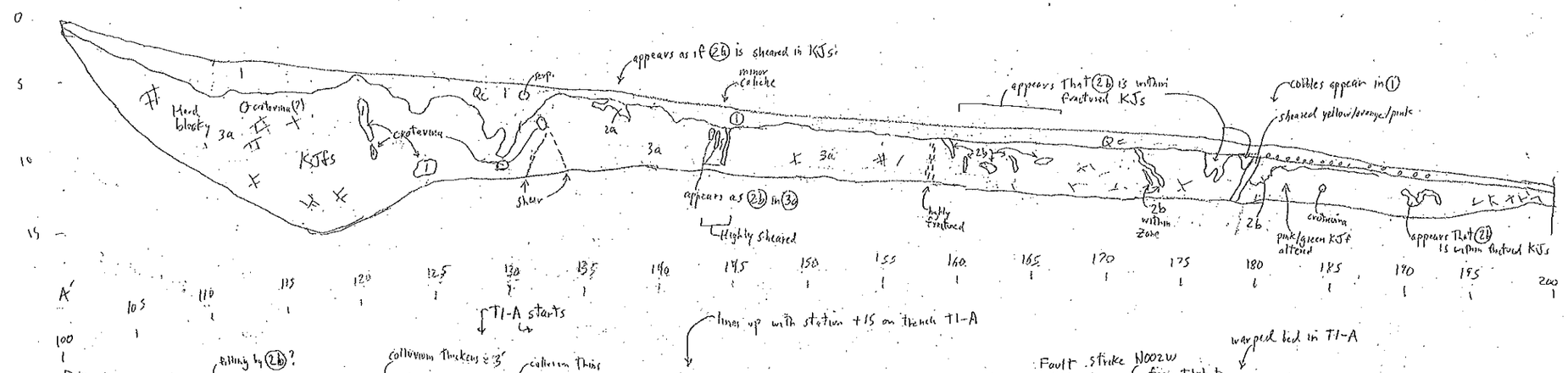
N75E

NW wall

A'

SCALE IN FEET

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

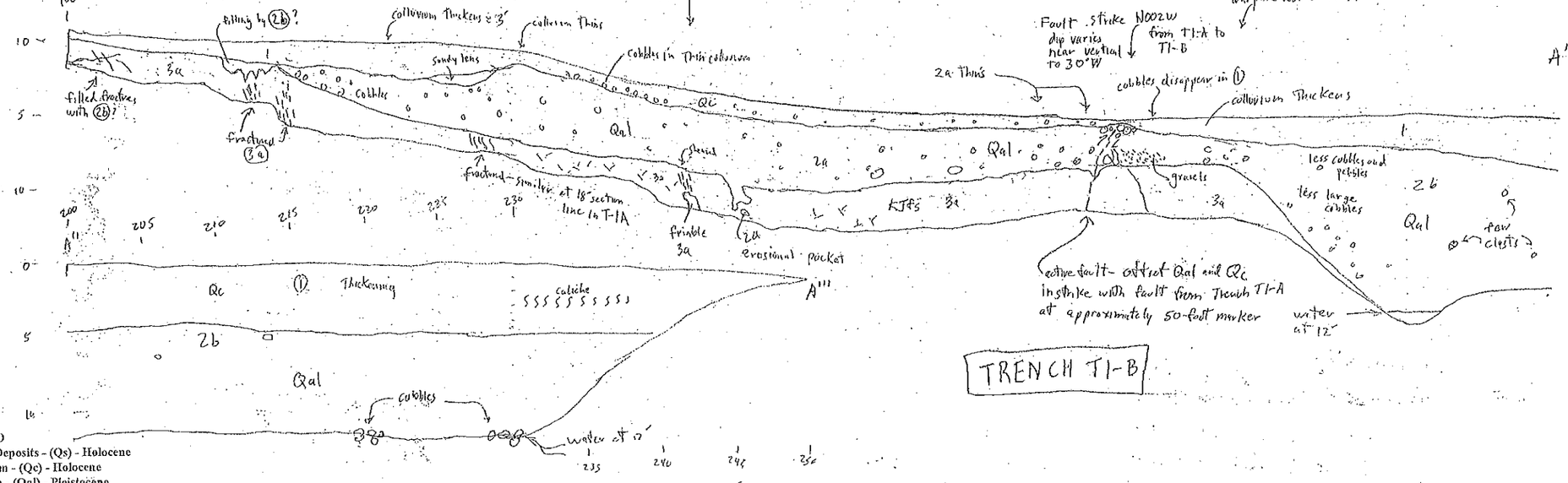


A' 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200

T1-A starts

lines up with station +15 on trench T1-A

warped bed in T1-A



TRENCH T1-B

LEGEND

Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic

- Contact between units
- Fault with arrows showing movement direction, dashed where sheared
- Cobbles
- Pebbles and gravel, coarse sand
- Fractures
- Caliche

(1) - colluvium - Dark brown, silty clay, few cobbles, Qc

(2a) - older Alluvium - silty sandy clay with pebbles, cobbles, boulders to 2' diam, rounded to subrounded, clasts are Franciscan Complex, Qal

(2b) - older Alluvium - silty clay with minor cobbles and pebbles, Qal

(3) - Franciscan complex, KJfmfs

- 3a - serpentinite
- 3b - metavolcanic
- 3c - greywacke/melange

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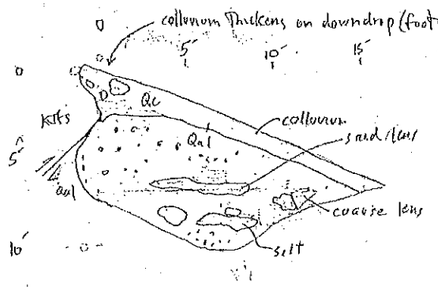
TRENCH LOG
T-1B

T-2A [illegible] logs

SCALE IN FEET



Fault here is N20W/14W

Active Faulting -

See LCI photo mosaic for detail

Trench T-2A

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic
melange, greywacke sandstone, serpentinite, metavolcanic
— Contact between units
Fault with arrows showing movement direction
dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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TRENCH LOG
T2-A

T2-B

N70 E →

North wall

SCALE IN FEET

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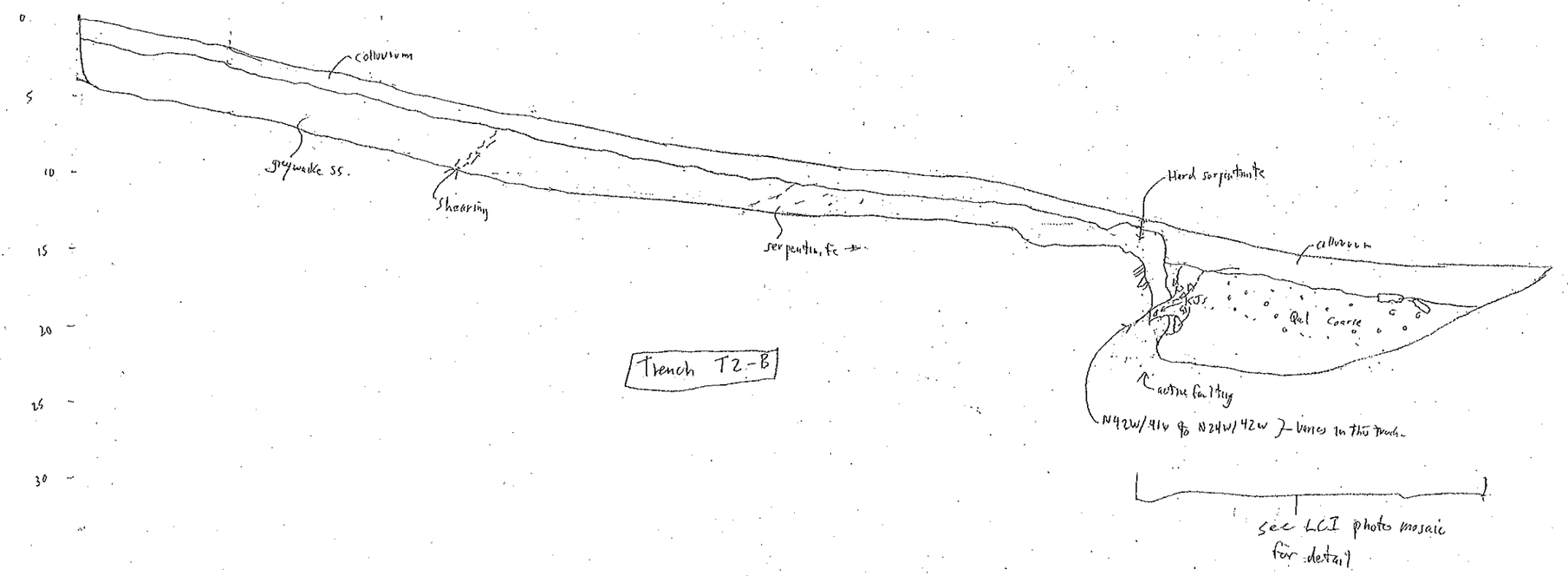

Trench T2-B

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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TRENCH LOG T2-B

Trench T-3A

N54E →

SCALE IN FEET

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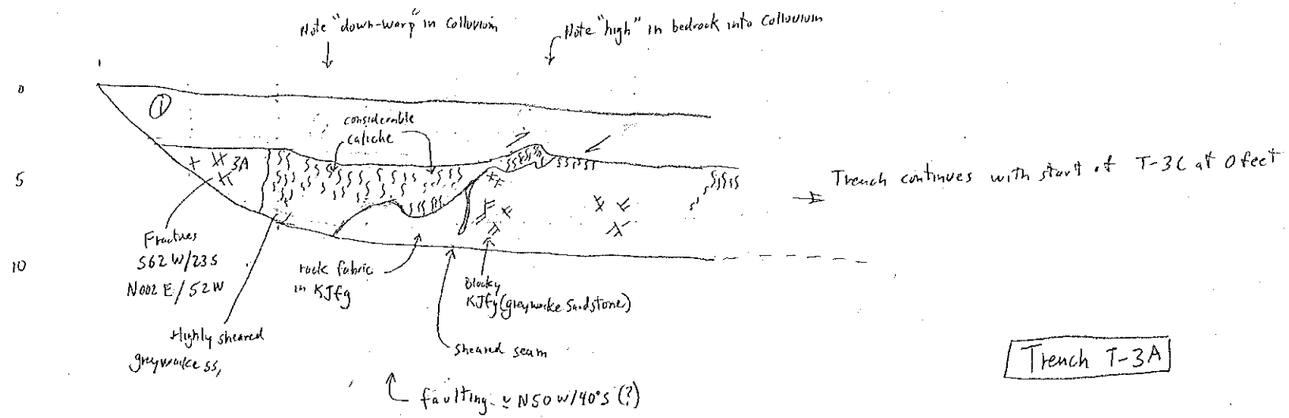

Trench T-3A

This area coincides with Fault in Trench T-3B

apparent

← Fault Zone →

Notes- Bedrock "High" suggests recent fault displaces Franciscan Complex and overlying Colluvium
- Bedrock underlying colluvium - no alluvium
- fault appears as Thrust (Reverse)

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, grewacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction
dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

S = caliche

① - Colluvium -

② - not in Trench - Older Alluvium

③ Franciscan Complex -
3A - Blocky
3B - Pale Olive 10Y 6/2

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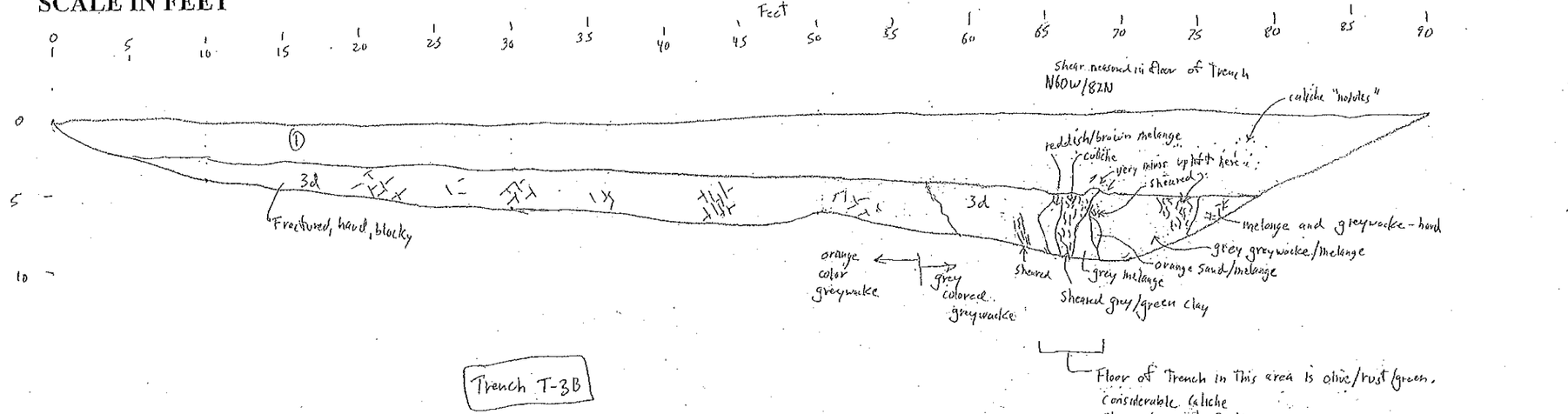
TRENCH LOG T3-A

T-3B N55E Trench

This mark lines up with the 10' line on T-3C

SCALE IN FEET



Trench T-3B

① - colluvium - Dark gray 10YR 4/1 - clay, v. stiff

② Franciscan Complex

3d - greywacky sandstone, blocky

Notes— 1) only Franciscan complex overlain by colluvium, No alluvium
2) Fault orientation in bottom of trench.
3) very minor uplift of KJfg within colluvium at station 68 feet
4) Fault is dying south of here compared to north into T-3A
5) bedrock dives deep south of here due to creek

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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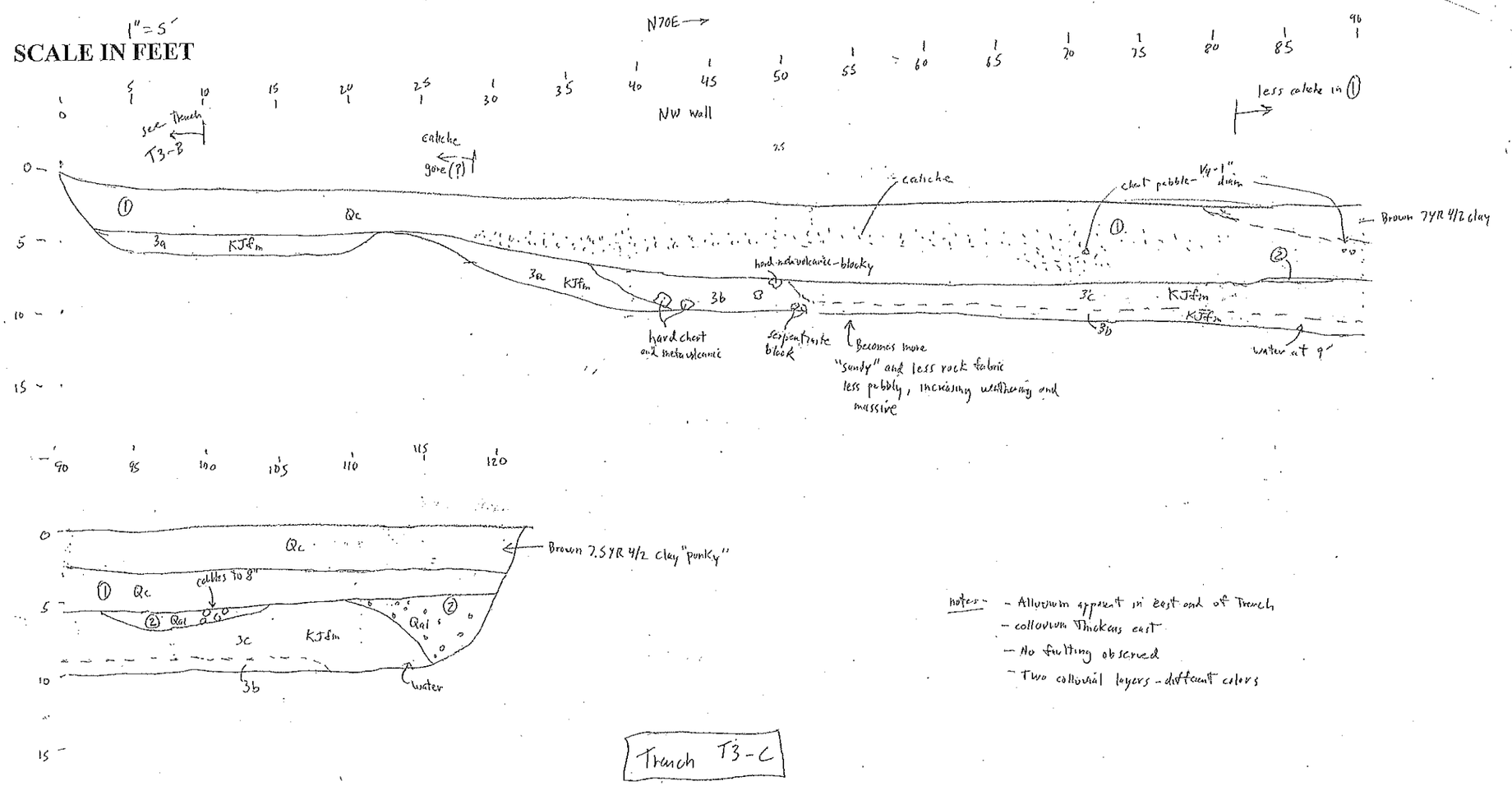
TRENCH LOG T3-B

Fault TRENCH T3-C

1"=5'

SCALE IN FEET



notes -
- Alluvium apparent in east end of Trench
- colluvium thickens east
- No faulting observed
- Two colluvial layers - different colors

Trench T3-C

(1) - Olive Black 5YR2.5/1 silty Clay - Colluvium - dry, deep dessication cracks to 3.5 feet, caliche "nodules", very stiff

(2) Older Alluvium - clay, sand, silt, pebbles, cobbles - Monterey Fm clasts, red sandstone, serpentinite, rounded to semi-rounded, altered basalt, matrix is Pale Yellow (5Y 7/3) to Brownish Yellow (10YR 6/6).

(3) Franciscan Complex -

(3a) Greywacke/melange - yellowish gray 5Y7/2 hard, rock fabric.

(3b) - melange/greywacke - yellowish gray 5Y 7/2 slight "pebbly" appearance, faint rock fabric, moderately hard.

(3c) Greywacke/melange - yellowish gray 5Y 7/2 heavily sheared, soft.

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, grewacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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TRENCH LOG T3-C

T-4 southwall
Trench N58W orientation

SCALE IN FEET

110 100 90 80 70 60 50 40 30 20 10 0

Fault does not appear to displace Qal (older fault) – alluvium appears depositional

Qal – Pebbly (rounded), sandy

Zone of caliche in clayey sand

colluvium increases in thickness

large angular rock ↓

depositional

colluvium Thins

cobbles in colluvium stints

colluvium Thins to N

caliche ends

Qc

Qc

Qc

silty

rocky Qal

Qal silty

Qal rocky

metavolcanic

graywacke

metavolcanic

emplacement fault does not cut Qc

older alluvium ② deposited on ①

Qal

KJfmv

KJfg/mv

Interpreted as geologic contact – no faulting on other side of trench

fault (?) does not cut Qc

sheared bedrock

KJfmv

Fault – does not truncate Qal – so older fault

water seep in bottom of trench only from ≈ 40' – 50'

Qal – boulders to 2-feet diam, rounded, sometimes clast supported

bedding of Qal is gross-horizontal – no faulting to east that uplifts bedding after deposition – only faulting of beds – no regional uplift – localized faulting – Tip of fault is here – not toward LOWR

TRENCH T-4

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, grewacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

Notes – 1 event of faulting – one older (does not cut Qal), ≈ 70°
– That main faulting is here in trench, not in flats of Trench (no tilting of Qal) – eastern limits found –
– mullions on bedrock, N33E ≈ 55° in trench

Bedding of older Qal seen Horizontal – no faulting east of here that would indicate more uplift east.

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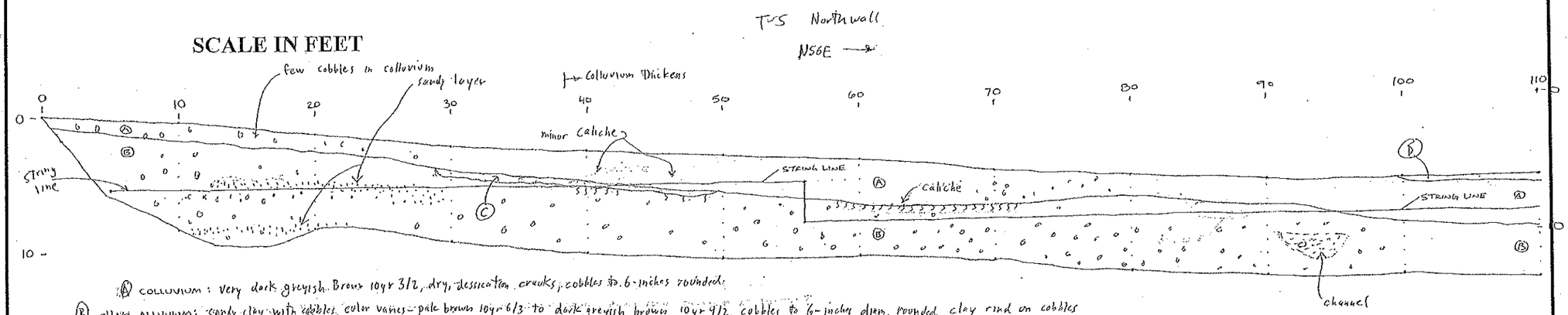
TRENCH LOG T-4

SCALE IN FEET

T-5 Northwall

N56E →

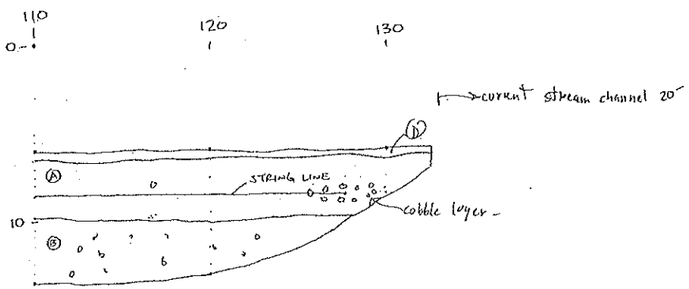


(A) colluvium: very dark greyish Brown 10yr 3/2, dry, dessication cracks, cobbles to 6-inches rounded

(B) older alluvium: sandy clay with cobbles, color varies - pale brown 10yr 6/3 to dark greyish brown 10yr 4/2, cobbles to 6-inches diam, rounded, clay rind on cobbles

(C) - silty clay - minor pebbles - Brown 7.5YR 4/4

(D) - recent stream - overbank deposits, gravel and cobbles in loose sand, light yellowish brown 10YR 6/4



Notes- No fault seen
- Horizontal units
- older alluvium - clay rinds on clasts, red soil in (C)

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction, dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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TRENCH LOG
T-5

T-6

South wall

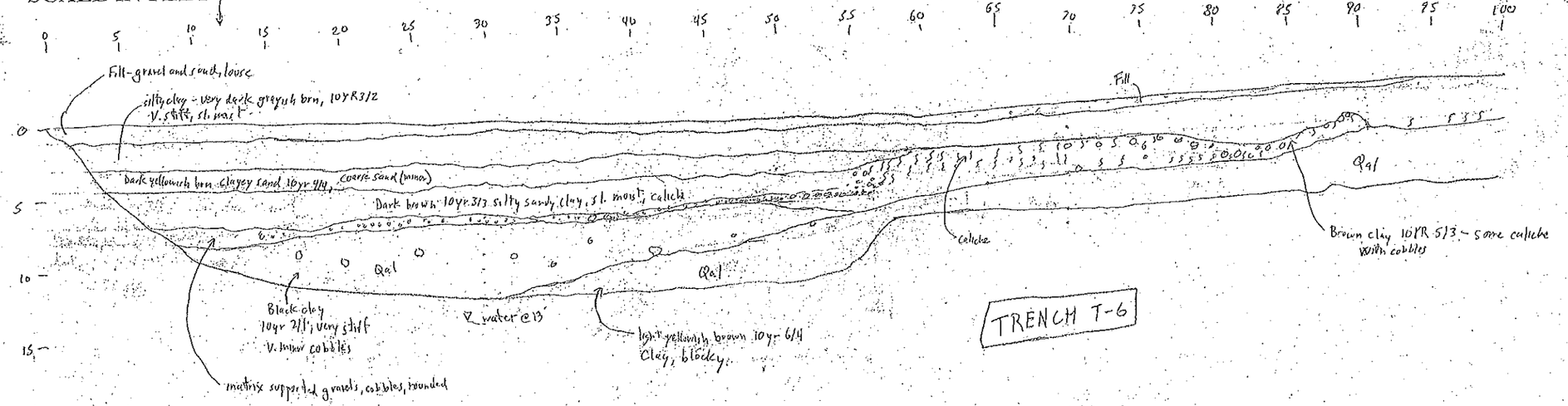
← N58°E

SCALE IN FEET

North corner of sheet.

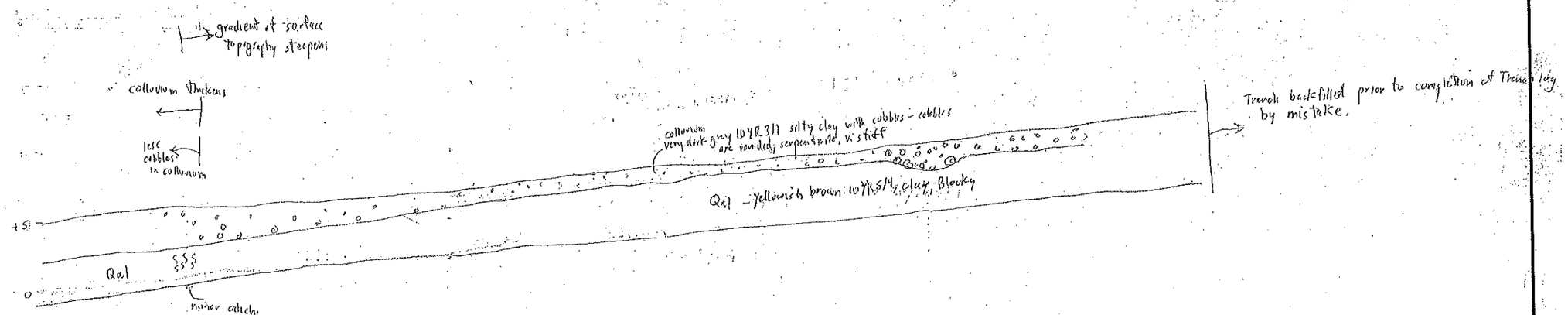
→ caliche

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100



100 105 110 115 120 130 140 150 155 160 115 170 175 180 185 190 195 200 205 210 215

0



LEGEND

Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic

—— Contact between units
Fault with arrows showing movement direction, dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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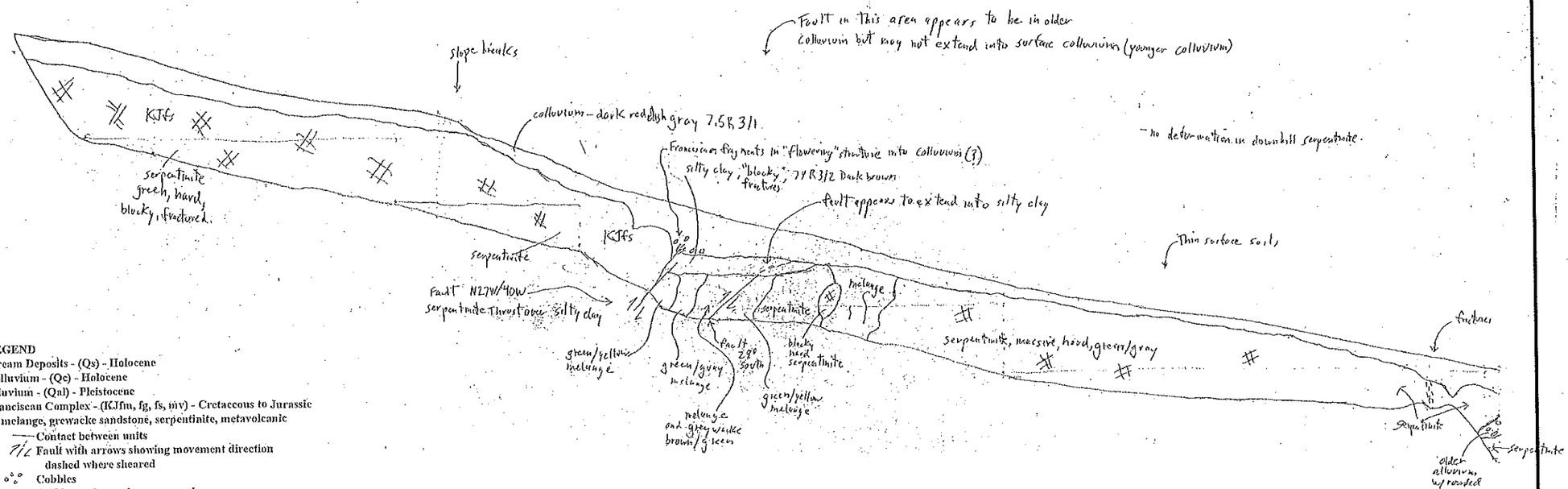
TRENCH LOG
T-6

North wall T-7 N63E→

SCALE IN FEET

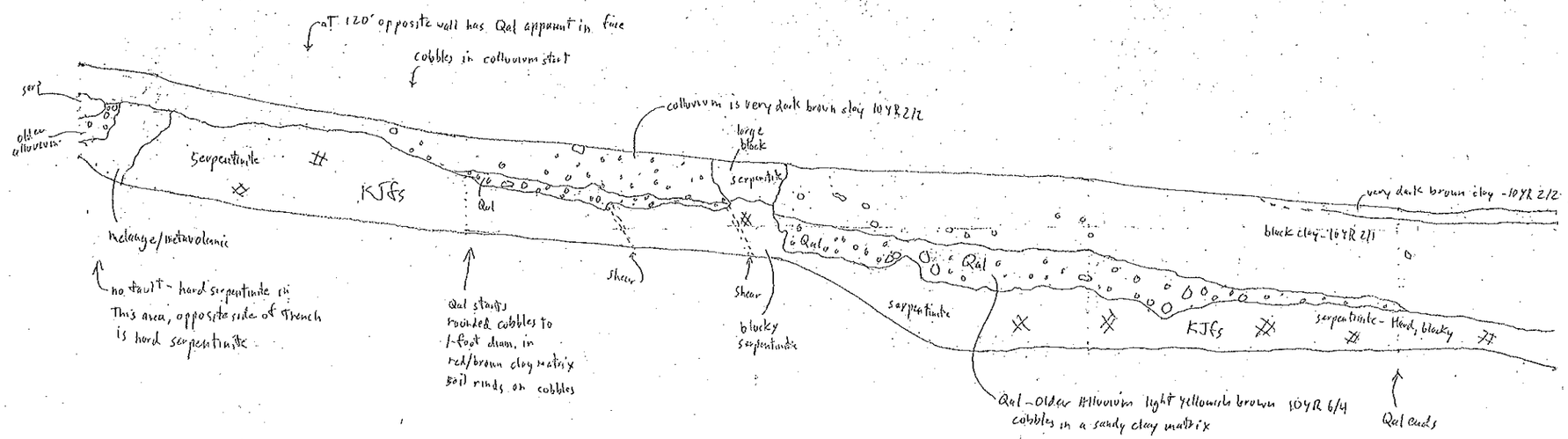
Feet 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105



LEGEND

- Stream Deposits - (Qs) - Holocene
- Colluvium - (Qc) - Holocene
- Alluvium - (Qal) - Pleistocene
- Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
- —— Contact between units
- Fault with arrows showing movement direction, dashed where sheared
- Cobbles
- Pebbles and gravel, coarse sand
- Fractures
- Caliche

105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200



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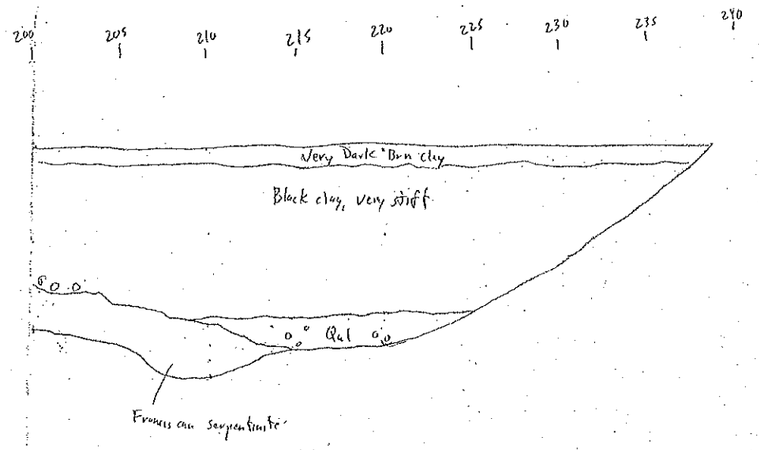
TRENCH LOG
T-7

T-7 (continued)

SCALE IN FEET



LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic
melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction
dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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TRENCH LOG
T-7

T-8 adjacent to property corner

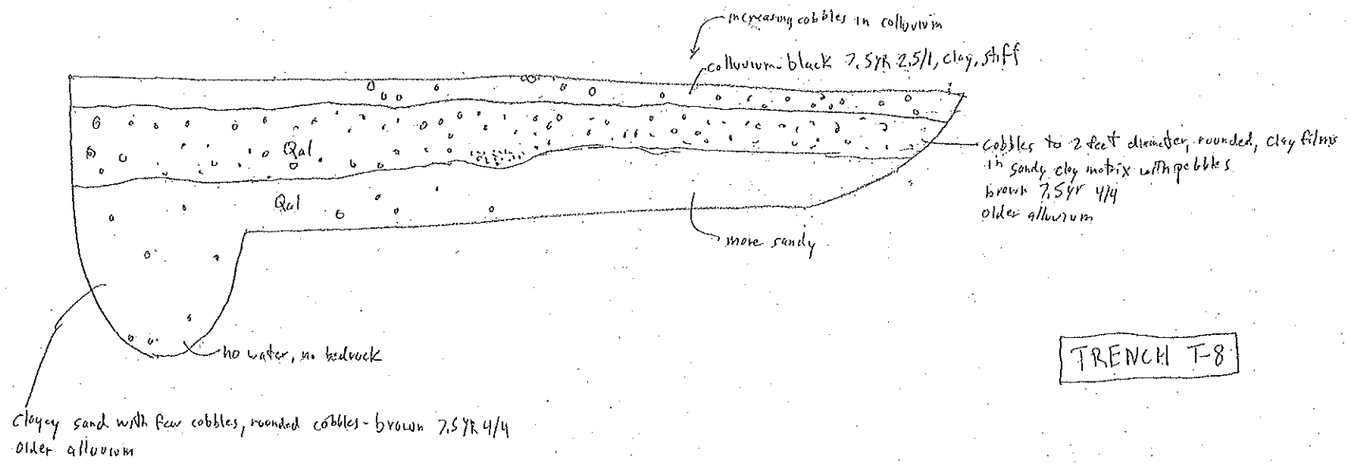
N39E →

1698

property corner

SCALE IN FEET

0 5 10 15 20 25 30 35 40 45 50



TRENCH T-8

Notes- No faulting characteristics
- excavated to clear homes to North/Northeast along property line

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic
melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction
dashed where sheared
Cobbles
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Fractures
Caliche

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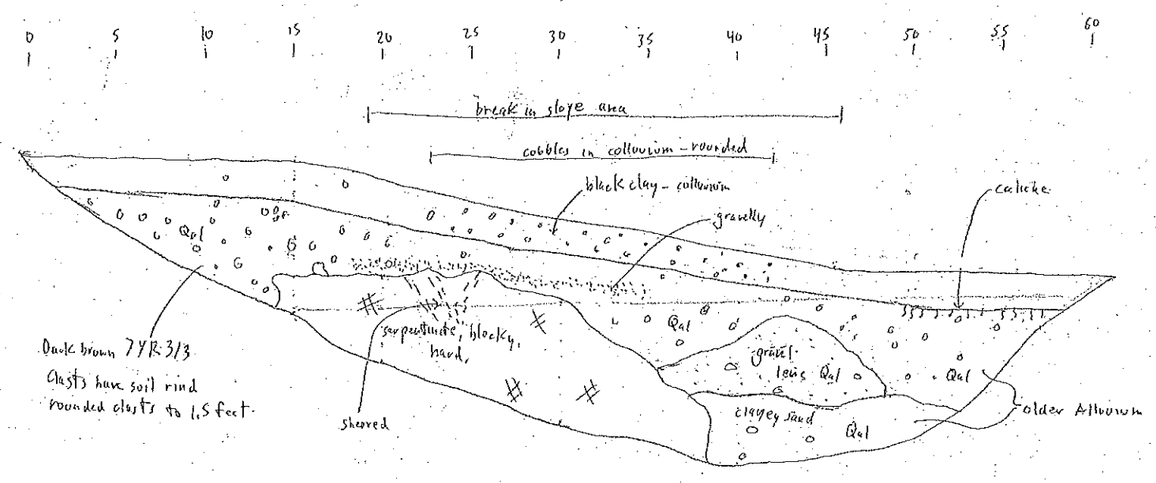
TRENCH LOG
T-8

T-9 between T1A + T-8

N75E →

SCALE IN FEET



TRENCH T-9

Notes:
- no faulting observed
- fault in T-1A does not extend here.

LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, greywacke sandstone, serpentinite, metavolcanic
—— Contact between units
Fault with arrows showing movement direction, dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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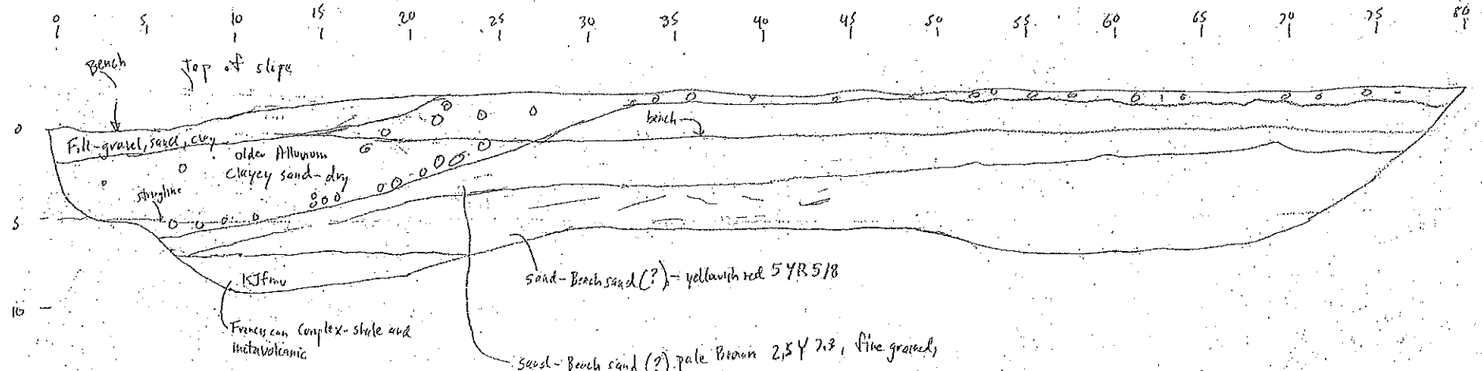
TRENCH LOG T-9

T-10A

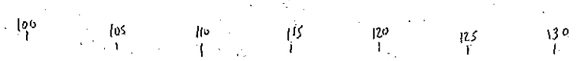
NW8E →

SCALE IN FEET

lower slope below bench



TRENCH T-10A



LEGEND

Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, grewacke sandstone, serpentinite, metavolcanic

- Contact between units
- Fault with arrows showing movement direction dashed where sheared
- Cobbles
- Pebbles and gravel, coarse sand
- Fractures
- Caliche

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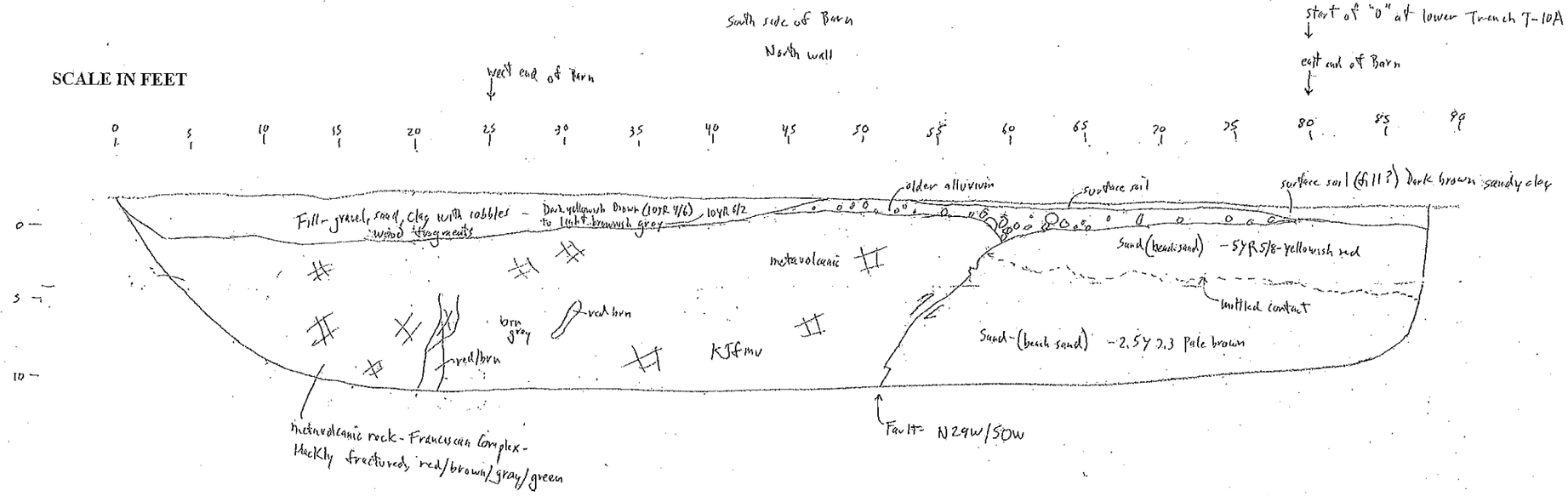
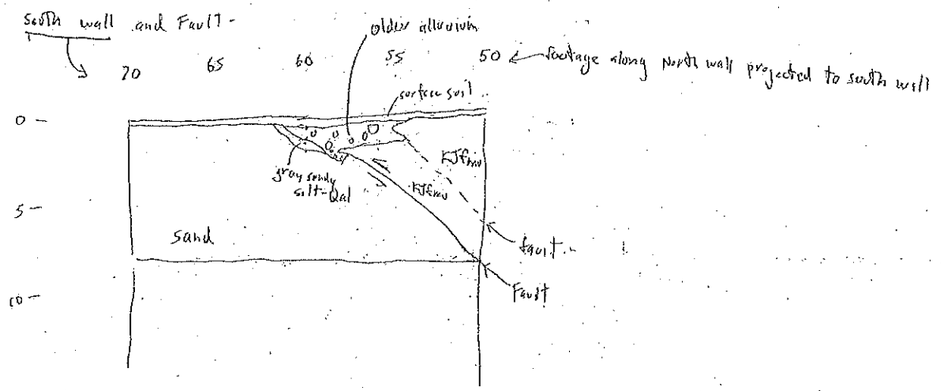
TRENCH LOG
T10-A

T-10B



TRENCH 10B

Sketch of South wall and Fault -



LEGEND
Stream Deposits - (Qs) - Holocene
Colluvium - (Qc) - Holocene
Alluvium - (Qal) - Pleistocene
Franciscan Complex - (KJfm, fg, fs, mv) - Cretaceous to Jurassic melange, grewacke sandstone, serpentinite, metavolcanic
Contact between units
Fault with arrows showing movement direction dashed where sheared
Cobbles
Pebbles and gravel, coarse sand
Fractures
Caliche

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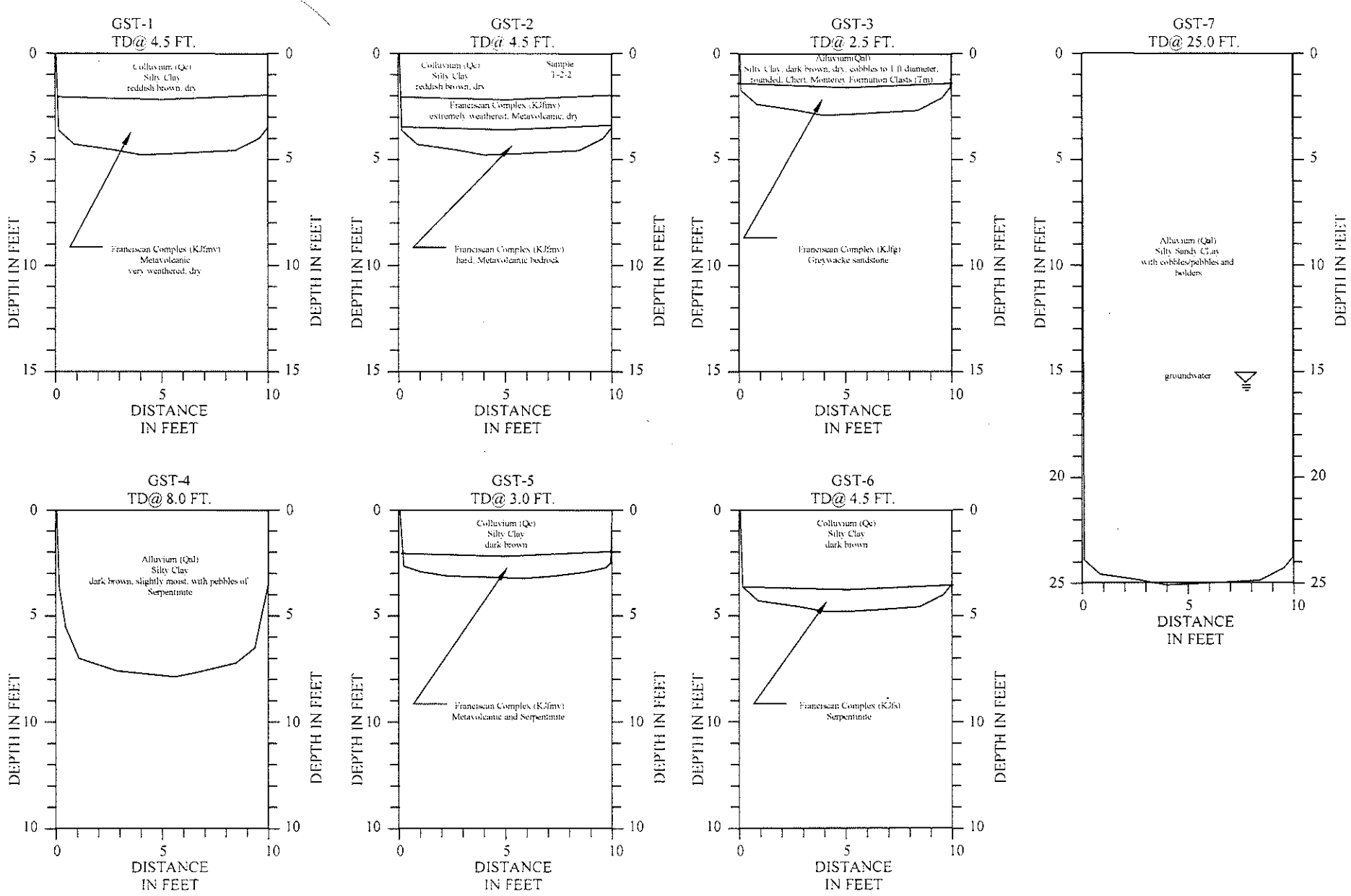
TRENCH LOG T0-B



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TRENCHING LOGS

MADONNA - FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

LOGS
1

PROJECT
SL09734-1

GeoSolutions, Inc.

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BORING LOG

BORING NO. **B-1**

JOB NO. **SL09734-1**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 18, 2016**	SAMPLING METHOD:	**SPT and CA**
LOGGED BY:	**GTV**	HOLE ELEVATION:	**Not Recorded**

▼ Depth of Groundwater: **Not Encountered** Boring Terminated At: **10.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	CLAYEY SAND: very dark grayish brown, dry	CH		A			28.7				107	79.6	31
-1													
-2	stiff			SPT	6	9							
-3	SANDY CLAY: dark brown, dry	CH											
-4													
-5	stiff			CA	8	8		110					
-6													
-7													
-8	stiff			SPT	9	9							
-9													
-10													
-11													
-12													
-13													
-14													
-15													
-16													
-17													
-18													
-19													
-20													

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BORING LOG

BORING NO. **B-2**

JOB NO. **SL09734-1**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 19, 2016**	SAMPLING METHOD:	**SPT**
LOGGED BY:	**GTV**	HOLE ELEVATION:	**Not Recorded**

▼ Depth of Groundwater: **4.0 Feet** Boring Terminated At: **46.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	CLAYEY SAND: very dark grayish brown, dry	CH											
-2	SANDY CLAY: dark brown, dry	CH											
-4	firm			SPT	5	7							
-6	SANDY CLAY: dark olive brown, very moist	CH											
-8	stiff			SPT	8	8							
-10	SANDY CLAY: black, very moist	CH											
-13	stiff			SPT	16	15							
-16	SANDY CLAY: dark olive brown, with gravel, coarse grained	CH											
-18	stiff			SPT	5	4							

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BORING LOG

BORING NO (cont). **B-2**

JOB NO. **SL09734-1**

▼ Depth of Groundwater: **4.0 Feet** Boring Terminated At: **46.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	(N) 60	FRICTION ANGLE (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINE CONTENTS	PLASTICITY INDEX (PI)
-24													
-25	SANDY CLAY: dark yellowish brown, saturated	CH											
-26													
-27	very stiff												
-28													
-29				SPT	21	16							
-30													
-31													
-32													
-33													
-34													
-35													
-36													
-37													
-38													
-39													
-40													
-41													
-42													
-43													
-44													
-45	very sticky												
-46	FRANCISCAN COMPLEX: serpentinite & melange, meta volcanic, very weathered			SPT	50/1"								
-47													
-48													
-49													
-50													

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BORING LOG

BORING NO (cont). **B-2**

JOB NO. **SL09734-1**

▼ Depth of Groundwater: **4.0 Feet** Boring Terminated At: **46.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	60 (N)	FRICTION ANGLE (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINE CONTENTS	PLASTICITY INDEX (PI)
-25	SANDY CLAY: dark yellowish brown, saturated very stiff	CH		SPT	21	16							
-45	very sticky												
-46	FRANCISCAN COMPLEX: serpentinite & melange, meta volcanic, very weathered			SPT	50/1"								

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BORING LOG

BORING NO. **B-3**

JOB NO. **SL09734-1**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 18, 2016**	SAMPLING METHOD:	**SPT and CA**
LOGGED BY:	**GTV**	HOLE ELEVATION:	**Not Recorded**

▼ Depth of Groundwater: **1.5 Feet** Boring Terminated At: **10.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	FAT CLAY: very dark grayish brown, dry	CH		B							186	94.7	48
-2	firm			SPT	4	6							
-3	SANDY CLAY: dark olive brown, very moist	CH											
-4													
-5	firm			CA	6	6							
-6													
-7	soft												
-8													
-9				SPT	2	2							
-10													
-11													
-12													
-13													
-14													
-15													
-16													
-17													
-18													
-19													
-20													

GeoSolutions, Inc.

220 High Street, San Luis Obispo, CA 93401
1021 West Tama Lane, Suite 105
Santa Maria, CA 93454

BORING LOG

BORING NO. **B-4**

JOB NO. **SL09734-1**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 18, 2016**	SAMPLING METHOD:	**CA and SPT**
LOGGED BY:	**GTV**	HOLE ELEVATION:	**Not Recorded**

▼ Depth of Groundwater: **2.5 Feet** Boring Terminated At: **10.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	CLAYEY SAND: very dark brown, very moist	CH											
-1	soft												
-2													
-3													
-4													
-5	SANDY CLAY: dark brown, very moist	CH		CA	3	3							
-6													
-7													
-8													
-9	firm			SPT	6	6							
-10													
-11													
-12													
-13													
-14													
-15													
-16													
-17													
-18													
-19													
-20													

GeoSolutions, Inc. | **SOILS REPORT** | **(805) 543-8539**

Project:	Madonna Froom Ranch			Date Tested:	June 3, 2016
Client:				Project #:	SL09734-1
Sample:	A	Depth:	1.0 Foot	Lab #:	16516
Location:	B-1			Sample Date:	May 18, 2016
				Sampled By:	GV/TG

Soil Classification
ASTM D2487, D2488

Result:	Very Dark Grayish Brown Sandy Fat CLAY
Specification:	CH

Sieve Analysis
ASTM D422

Sieve Size	Percent Passing	Project Specifications
3"		
2"		
1 1/2"		
1"		
3/4"		
No. 4	93	
No. 8	90	
No. 16	89	
No. 30	87	
No. 50	84	
No. 100	82	
No. 200	79.6	

Sand Equivalent Cal 217

1		SE
2		
3		
4		

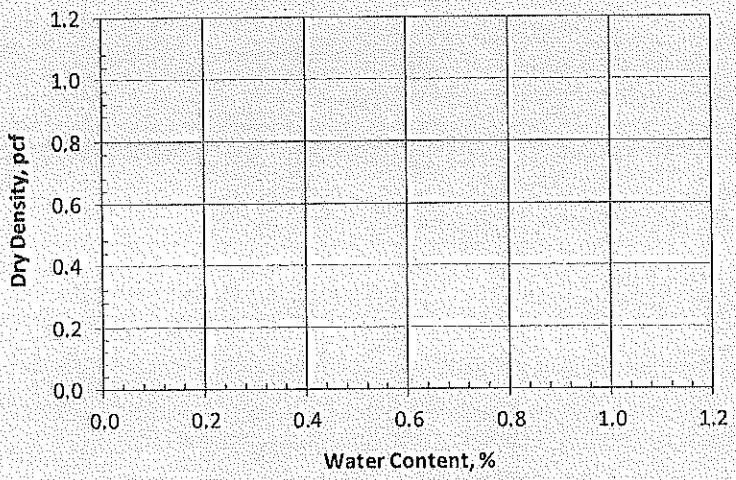
Plasticity Index
ASTM D4318

Liquid Limit:	54
Plastic Limit:	23
Plasticity Index:	31

Expansion Index
ASTM D4829

Expansion Index:	107
Expansion Potential:	High
Initial Saturation, %:	50

Laboratory Maximum Density
ASTM D1557



Mold ID	n/a	Mold Diameter, ins.	4.00
No. of Layers	5	Weight of Rammer, lbs.	10.00
No. of Blows	25		

Estimated Specific Gravity for 100% Saturation Curve =

Trial #	1	2	3	4
Water Content:				
Dry Density:				

Maximum Dry Density, pcf:	
Optimum Water Content, %:	

Moisture-Density ASTM D2937, **Moisture Content** ASTM D2216

Sample	Depth (ft)	Water Content (%)	Dry Density (pcf)	Relative Density	Sample Description
B-1	2.5	38.5			Dark Olive Gray Sandy CLAY
B-2	2.5	27.4			Dark Olive Gray Sandy CLAY

Report By: Aaron Eichman

GeoSolutions, Inc. **SOILS REPORT** **(805) 543-8539**

Project:	Madonna Froom Ranch			Date Tested:	June 8, 2016
Client:				Project #:	SL09734-1
Sample:	B	Depth:	1.0 Foot	Lab #:	16516
Location:	B-3			Sample Date:	May 18, 2016
				Sampled By:	GV/TG

Soil Classification
ASTM D2487, D2488

Result: Dark Gray Fat CLAY

Specification: CH

Sieve Analysis
ASTM D422

Sieve Size	Percent Passing	Project Specifications
3"		
2"		
1 1/2"		
1"		
3/4"		
No. 4	100	
No. 8	100	
No. 16	100	
No. 30	99	
No. 50	98	
No. 100	96	
No. 200	94.7	

Sand Equivalent Cal 217

1		SE
2		
3		
4		

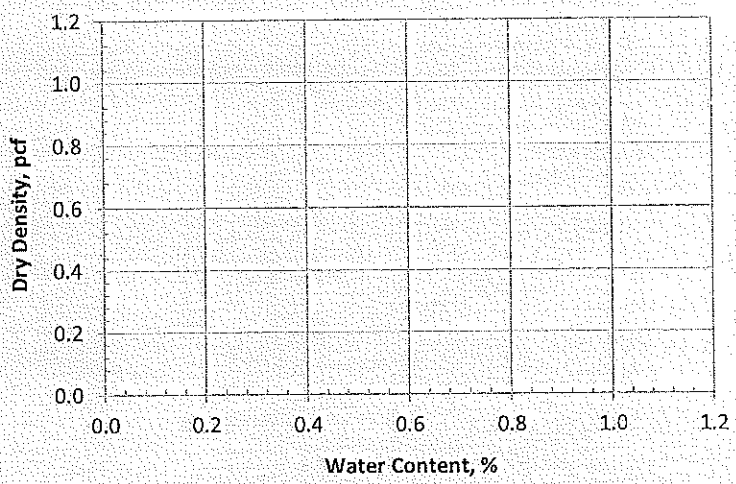
Plasticity Index
ASTM D4318

Liquid Limit:	84
Plastic Limit:	36
Plasticity Index:	48

Expansion Index
ASTM D4829

Expansion Index:	186
Expansion Potential:	Very High
Initial Saturation, %:	50

Laboratory Maximum Density
ASTM D1557



Mold ID	n/a	Mold Diameter, ins.	4.00
No. of Layers	5	Weight of Rammer, lbs.	10.00
No. of Blows	25		

Estimated Specific Gravity for 100% Saturation Curve =

Trial #	1	2	3	4
Water Content:				
Dry Density:				

Maximum Dry Density, pcf:	
Optimum Water Content, %:	

Moisture-Density ASTM D2937, **Moisture Content** ASTM D2216

Sample	Depth (ft)	Water Content (%)	Dry Density (pcf)	Relative Density	Sample Description

Report By: Aaron Eichman

GeoSolutions, Inc. **SOILS REPORT** **(805) 543-8539**

Project:	Madonna Froom Ranch			Date Tested:	June 9, 2016
Client:				Project #:	SL09734-1
Sample:	C	Depth:	2.0 Feet	Lab #:	16516
Location:	T-2			Sample Date:	May 18, 2016
				Sampled By:	GV/TG

Soil Classification
ASTM D2487, D2488

Result: Dark Reddish Brown Sandy Fat CLAY

Specification: CH

Sieve Analysis
ASTM D422

Sieve Size	Percent Passing	Project Specifications
3"		
2"		
1 1/2"		
1"		
3/4"		
No. 4		
No. 8		
No. 16		
No. 30		
No. 50		
No. 100		
No. 200		

Sand Equivalent Cal 217

1		SE
2		
3		
4		

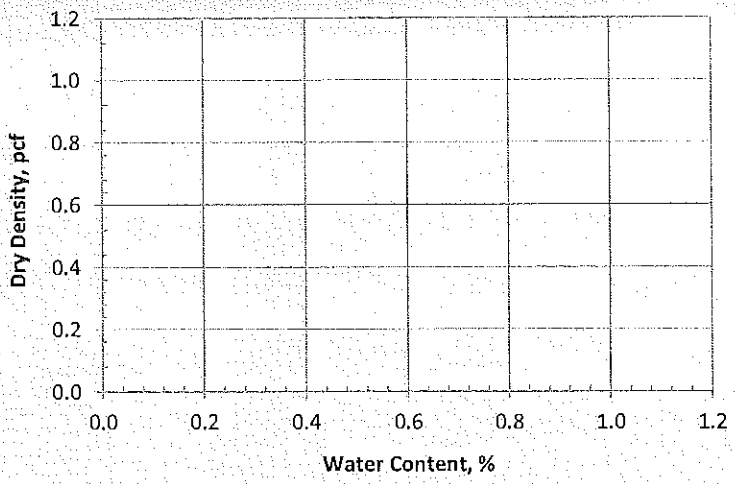
Plasticity Index
ASTM D4318

Liquid Limit:	65
Plastic Limit:	23
Plasticity Index:	42

Expansion Index
ASTM D4829

Expansion Index:	79
Expansion Potential:	Medium
Initial Saturation, %:	50

Laboratory Maximum Density
ASTM D1557



Mold ID	n/a	Mold Diameter, ins.	4.00
No. of Layers	5	Weight of Rammer, lbs.	10.00
No. of Blows	25		

Estimated Specific Gravity for 100% Saturation Curve =

Trial #	1	2	3	4
Water Content:				
Dry Density:				

Maximum Dry Density, pcf:	
Optimum Water Content, %:	

Moisture-Density ASTM D2937, **Moisture Content** ASTM D2216

Sample	Depth (ft)	Water Content (%)	Dry Density (pcf)	Relative Density	Sample Description

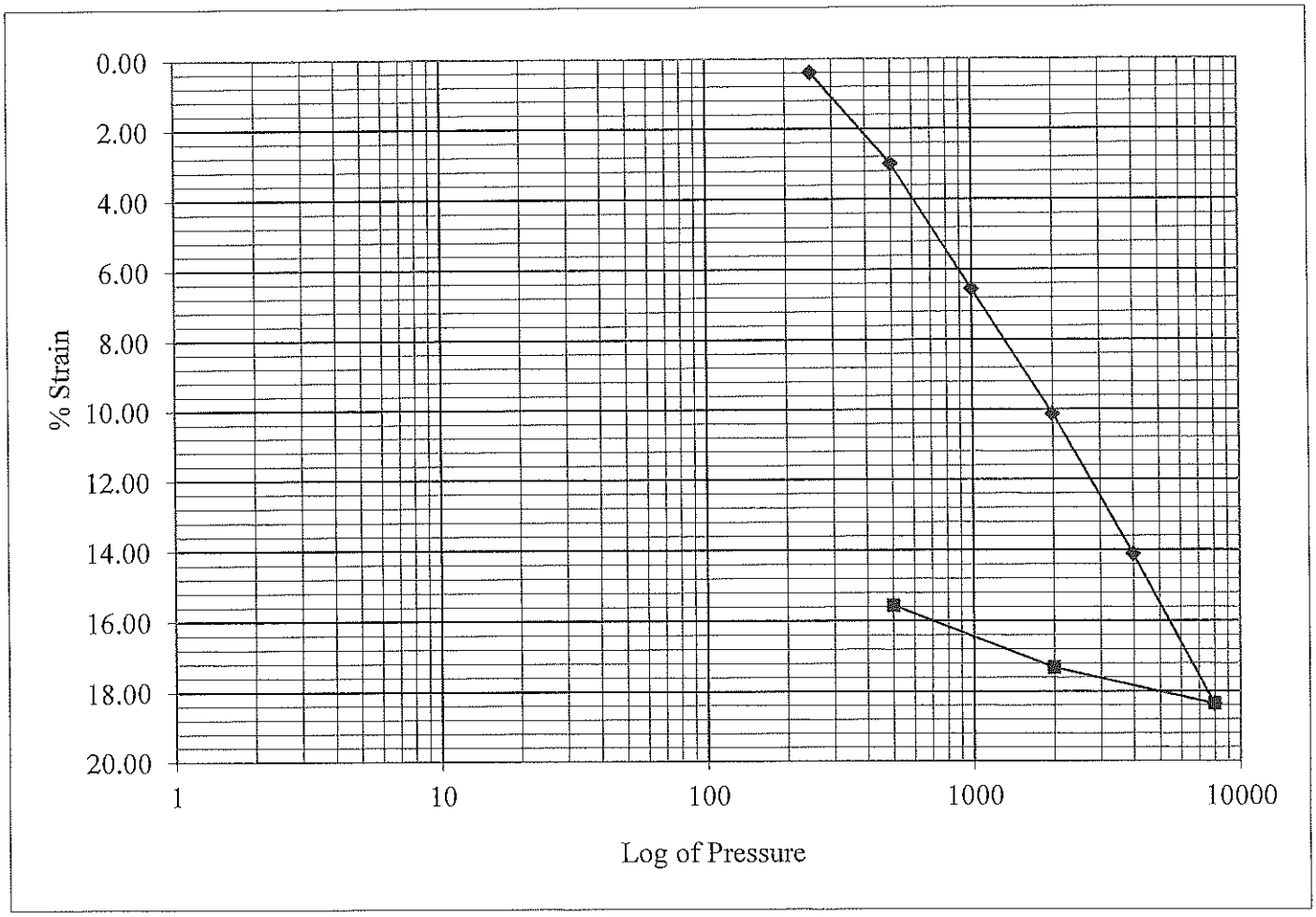
Report By: Aaron Eichman

GeoSolutions, Inc.

CONSOLIDATION REPORT
D2435-11

(805) 543-8539

Project:	Madonna Froom Ranch			Date Tested:	6/7/2016
Client:				Project #:	SL09734-1
Sample:	B-1 @ 5'	Depth:	5.0 Feet	Lab #:	16516
Location:	B-1			Sample Date:	5/18/2016
Material:	Very Dark Grayish Brown Sandy CLAY			Sampled By:	GV/TG



Applied Pressure (psf)	% Strain
250	0.38
500	2.99
1000	6.55
2000	10.12
4000	14.11
8000	18.35
2000	17.32
500	15.56

Compression Index, Cc
0.165
Recompression Index, Cr
0.017

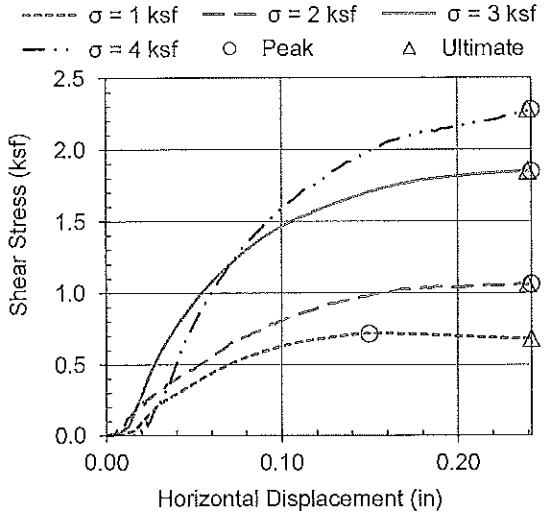
Report By: Aaron Eichman

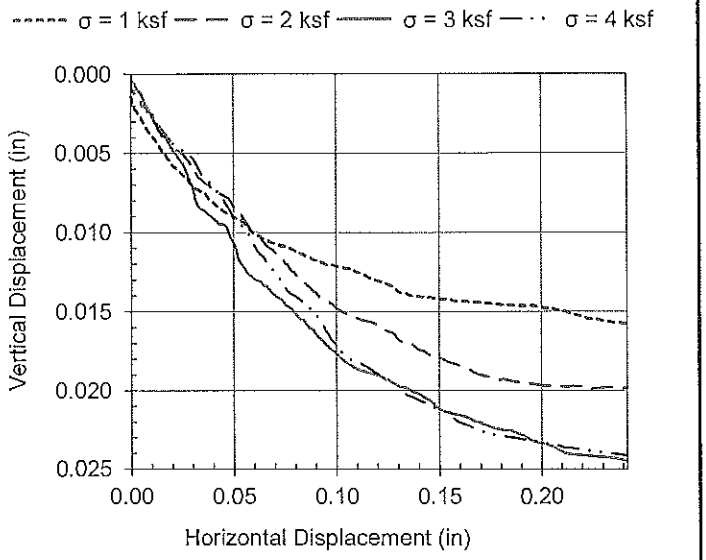
GeoSolutions, Inc. | **DIRECT SHEAR TEST SUMMARY REPORT (ASTM D3080)** | **(805) 543-8539**

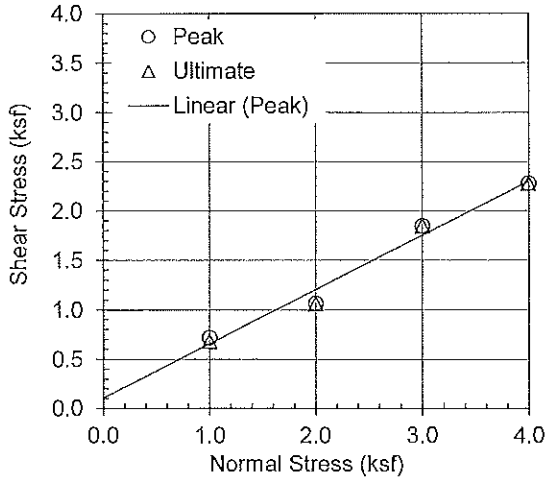
Project:	Madonna Froom Ranch			Project No.:	SL09734-1
Client:				Date Tested:	6/9/2016
Sample No.:	B-1 @ 5'	Depth:	5.0 Feet	Lab No.:	16516
Location:	B-1			Checked By:	AE

MATERIAL DESCRIPTION	LL	PL	PI	% passing No. 200	Gs *	Sample Type
Very Dark Grayish Brown Sandy CLAY	nm	nm	nm	nm	2.4	in-situ (rings)

* Gs = assumed; nm = not measured







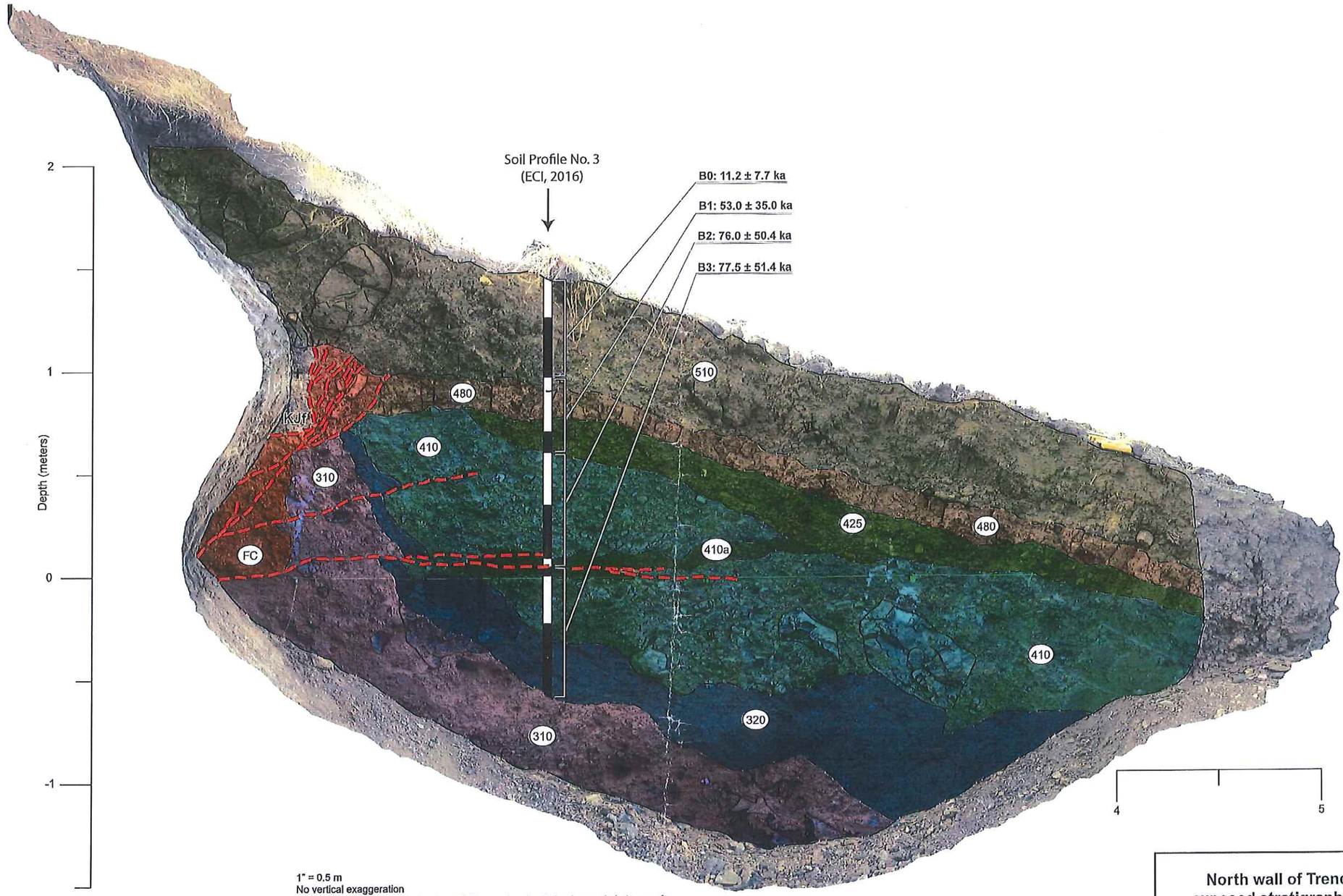
Angle of Internal Friction, ϕ_{peak} (degrees):	28.7
Cohesion, C_{peak} (psf)	110

Initial Conditions	Specimen No. 1	2	3	4
Dry Density	92.3	90.3	87.4	95.7
Water Content (%)	25.8	25.8	25.8	25.8
Diameter (in)	2.42	2.42	2.42	2.42
Sample Height (in)	1.00	1.00	1.00	1.00

Test Data	Specimen No. 1	2	3	4
Normal Stress (ksf)	1.00	2.00	3.00	4.00
Peak Shear Stress (ksf)	0.72	1.06	1.85	2.28
Horiz. Displacement at Peak Shear (in)	0.15	0.24	0.24	0.24
Ultimate Shear Stress (ksf)	0.68	1.06	1.85	2.28
Horiz. Displ. at Ult. Shear (in)	0.24	0.24	0.24	0.24
Rate of Deformation (in/min)	0.002	0.002	0.002	0.002

Remarks:

Samples were not saturated prior to shearing



North wall of Trench T-2a detailing exposed stratigraphy and locations of pedologic study of ECI (2016)

PG&E Los Osos Fault Trench Evaluation

LCI Lettis Consultants International, Inc. | Figure 2

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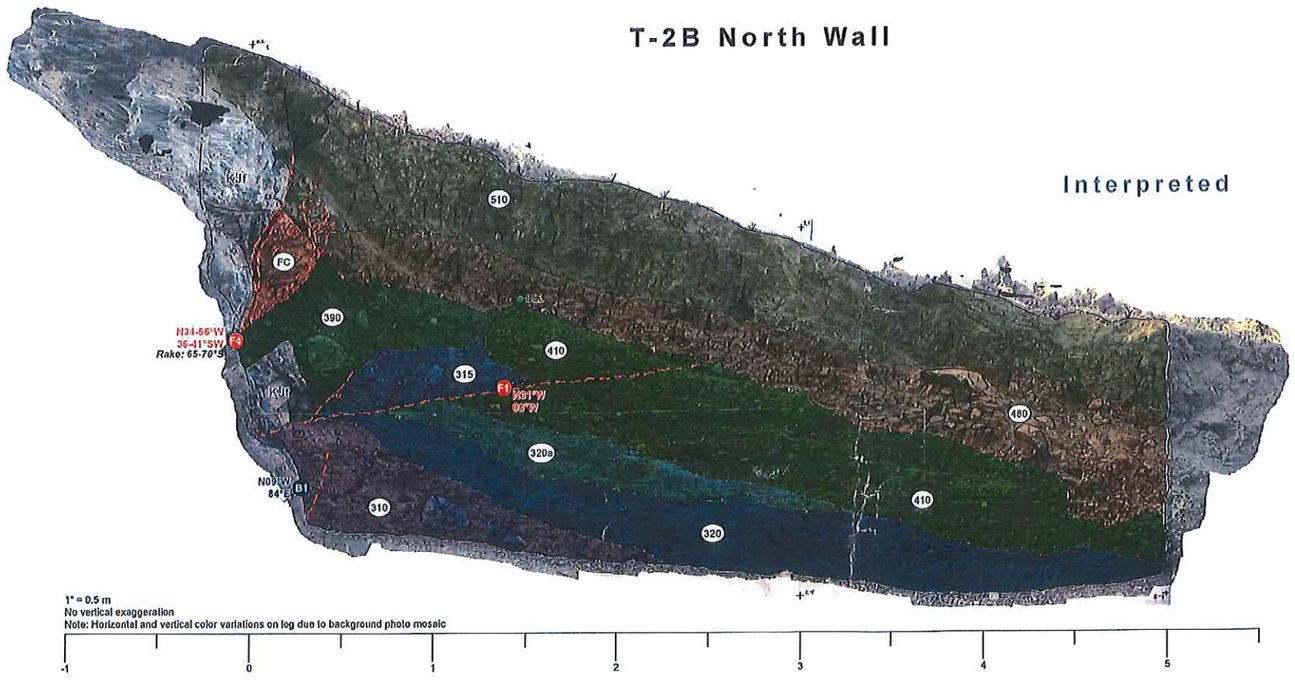
North wall of Trench T-2a detailing exposed stratigraphy and locations of pedologic study of ECI (2016)



EXPLANATION:

510 - **Unit 510 - Silt with occasional pebble to medium cobbles. Brown (10YR 4/3); clasts are dominantly Franciscan, increasing in size to small boulders to west, angular, fractured, slightly weathered; matrix is eolian silt, with some clay and sparse fine sand; loose, moist, slightly to moderately cohesive; a surface soil sequence is developing in unit: upper 5-15 cm is an Ap/AB horizon with weak granular structure, middle 10-20 cm is an A/Btj with weak angular blocky to prismatic structure, and the basal 20 cm is a Btss, similar to Unit 480, with a weak small angular blocky structure; basal contact is clear and smooth. Holocene to modern slope colluvium with stable soil.**

480 - **Unit 480 - Massive clayey silt with sparse small pebbles. Very dark brown to dark grayish brown (10YR 4/2 to 3/2); matrix is completely eolian silt and clay, prominently desiccated; tough, dry to slightly moist, indurated; deep clay soil development of a strong medium to large prismatic to angular blocky structure, discontinuous clay coatings on peds exhibit soil slickensides, soil is a Btss, structural soil fractures are normal to upper and lower contact orientations which suggests unit was not eroded after soil formation; common root filaments, occasional small krotovina, few small pores; basal contact is wavy and clear. Pleistocene eolian silt with strong argillaceous soil.**

410 - **Unit 410 - Sandy gravel with clay. Dark reddish brown (5YR 3/3); clasts are angular to sub-angular, up to 20% chert, unweathered, rest serpentine and other Franciscan ultramafics, appear weathered in situ; fine silt matrix has been pedogenically altered with addition of clay; as in T-2a, fine lens of fine material is less obvious at station 2.5, this lens has well developed Bt, with strong small angular blocky structure; bedding is diffuse, weakly stratified; basal contact is sharp, clear. Pleistocene alluvium of Froom Creek.**

390 - **Unit 390 - Sandy clay with gravel and cobbles. Dark brown (7.5YR 3/2); clasts are angular to sub-angular, all Franciscan serpentine, clasts are slightly weathered, fractured, along fracture faces, appear not weathered; very dense, cohesive, moist; well-developed Bt throughout, strong small to medium angular blocky soil structure is formed in matrix; basal contact is wavy and diffuse, unclear locally, possibly due to soil overprinting; unit bounded by faults on east and west, contacts to west, upper contact dips east imparting wedge morphology to unit. Pleistocene scarp-derived colluvium.**

320a - **Unit 320a - Silty sand with gravel. Strong brown (7.5YR 5/6 to 4/6); sand is fine to coarse, gravel composed of small to medium pebbles, angular to sub-rounded, 5-10% chert, trace meta-volcanic clasts which appear completely rusted, rest serpentine; basal contact is wavy and clear over 1-2 cm. Pleistocene alluvium.**

320 - **Unit 320- Sandy silt with gravel. Dark yellowish brown (10YR 4/6) to pale yellow (2.5Y 7/4); Matrix similar to Unit 310, fewer large clasts, gravel content down to less than 5%; basal contact is clear, smooth to wavy over 2 to 3 cm. Pleistocene colluvium.**

315 - **Unit 315 - Sandy silt with abundant gravel and sparse cobbles. Strong brown (7.5YR 4/6); similar to Unit 1; clasts all serpentine, angular; prominent soil structure from above unit developed throughout, weak to moderate sub-angular blocky structure localized to upper 20 cm; basal contact is low angle fault, unit bounded by faulting west. Pleistocene pedogenically altered colluvium.**

310 - **Unit 310 - Sandy silt with gravel and few cobbles to boulders. Dark yellowish brown (10YR 4/6) to pale yellow (2.5Y 7/4); sand is fine to medium, moderately sorting, massive, gravel is angular to sub-angular, cobbles to boulders are slightly to moderately weathered, fractured, clasts are all serpentine; basal contact is buried. Pleistocene colluvium**

FC - **Unit FC - Silty gravel with pedogenic clay. Brown (10YR 4/3); clasts are all Franciscan, deeply to slightly weathered depending on Franciscan rock type; clasts are angular, highly fractured; where fractured rock appear unweathered; moist, cohesive, slightly tough, slightly hard; weak medium sub-angular blocky structure throughout, very weakly expressed Bt, yet clay development is extensive, may reflect post-depositional movement of unit; basal contact is buried, western contact is moderately west dipping fault. Colluvial wedge material.**

KJf - **Franciscan melange and serpentinite (Cretaceous/Jurassic)**

Contact
Dashed where approximate;
Queried where uncertain

Bedding
Dashed where approximate;
Queried where uncertain

Trench base and corners

Fault (Active)
Dashed where approximate;
Queried where uncertain

N31°W 08°W — Fault Attitude

N09°W 84°E — Bedrock ?

B52 — Bag Sample

DRAFT

Photo Log of Trench T-2B North Wall	
PG&E Los Osos Fault Trench Evaluation	
LCI Lettis Consultants International, Inc.	Plate 3

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T-2A South Wall

N75°E

Uninterpreted

Interpreted

Horizontal Distance (meters)

Depth (meters)

1" = 0.5 m
No vertical exaggeration
Note: Horizontal and vertical color variations on log due to background photo mosaic

EXPLANATION:

510 — Unit 510- Silt with occasional pebbles to medium cobbles. Brown (10YR 4/3); clasts are dominantly Franciscan, increasing in size to small boulders to west, angular, fractured, slightly weathered; matrix is eolian silt, with some clay and sparse fine sand; loose, moist, slightly to moderately cohesive; a surface soil sequence is developing in unit: upper 5 to 15 cm is an Ap/AB horizon with weak granular structure, middle 10 to 20 cm is an A/Btj with weak angular blocky to prismatic structure, and the basal 20 cm is a Btss, similar to Unit 480, with a weak small angular blocky structure; basal contact is clear and smooth. Holocene to modern slope colluvium with stable soil.

480 — Unit 480 - Massive clayey silt with sparse small pebbles. Very dark brown to dark grayish brown (10YR 4/2 to 3/2); matrix is completely eolian silt and pedogenic clay, prominently desiccated; tough, dry to slightly moist, indurated; deep clay soil development of a strong medium to large prismatic to angular blocky structure, discontinuous clay coatings on peds exhibit soil slickensides, soil is a Btss, structural soil fractures are normal to upper and lower contact orientations which suggests unit was not eroded after soil formation; common root filaments, occasional small krotovina, few small pores; basal contact is wavy and clear. Pleistocene eolian silt with strong argillaceous soil.

425 — Unit 425 - Poorly sorted gravel. Unit is of similar composition to subjacent Unit 410 yet displays different internal bedding; darker than Unit 410, brown to dark brown (10YR 4/3 to 3/3); unit is more cohesive, with more matrix than below, and increased soil development, moderate Bt, moderate small angular blocky soil structure throughout; diffuse beds match slope angle, dip east, contrary to Unit 410; basal contact is sharp, smooth. Slope Pleistocene Qe locally sourced from Unit 410.

410a — Unit 410a - Silty sand. Brown (10YR 4/3); massive, coarse to medium sand, well sorted, some silt imparts a "dirty" appearance to otherwise clean quartz sand; no bedding, loose, slightly cohesive; fines upward and laterally to east into silty clay, may reflect ponding of previously moving water; single grained structure to very weak sub-angular blocky structure, some desiccation cracking indicative of clay content, may contain weakly developed Bt; basal contact is concave, may be channelized, clear, smooth; a single low angle fault continues through unit from Unit 410, coarser sand is concentrated at fault. Pleistocene fluvial deposit.

410 — Unit 410 - Poorly sorted gravel of diverse provenance. Clasts are composed of reddish brown chert (2.5YR 4/3), pale yellow greenstone (5Y 7/4), completely weathered yellowish brown volcanic rocks (10YR 5/6), matrix is brown (10YR 4/3); clasts are angular to sub angular, with >50% spit; matrix is loose, slightly moist, friable, increased clay content may indicate moderately developed Bt horizon in upper 30 cm, clay films discontinuous over clasts, weak to moderate small sub-angular blocky soil structure in matrix; no roots, few to common small pores; diffuse beds are defined by slight changes in clast size, from coarse sand matrix dominated areas to small cobble clast supported areas, beds dip to west; basal contact dips to east, flattens to east, may be warped, contact is clear, wavy to smooth; Unit is faulted at least once, possibly twice, from faults extending from Unit 320. Pleistocene bedded alluvium.

320 — Unit 320 - Bedded silts and moderate to fine sand. Silt beds are pale yellow (2.5Y 7/3), coarser layers are very pale yellow (10YR 7/4); bedding is defined by coarsening of matrix with discontinuous layers of coarse sand to granules of Franciscan ultramafic rocks, silt is massive; bedding is diffuse, wavy, 5 to 20 cm wide, and appears synformally warped near west end of trench; beds appear to fine upward, with sand concentrated at the base; silt layers are moderately cohesive, friable, slightly hard, sporadic desiccation cracking indicates slight clay content; coarser layers are looser, single grain structure, with discontinuous layers of granules; sporadic sub-vertical white filaments are formed in desiccation cracks, not carbonate, may reflect translocated light colored clay from KJfm uphill; no roots, few small pores; basal contact is very diffuse, defined by change in color and texture over 5 to 10 cm; Unit is faulted at least once, possibly twice between stations 0 and 1. Pleistocene slope colluvium.

310 — Unit 310 - Coarse sandy silt with sparse medium cobbles. Light yellow brown (10YR 6/4 to 2.5Y 6/3); Clasts are angular to sub angular, fractured, slightly weathered, all ultramafic Franciscan rock, well sorted throughout; loose, dry, friable; slight granular soil structure, Bw/C soil; very weakly discontinuously bedded, few small pores, no roots. Pleistocene single source colluvium.

FC — Unit FC - Silty gravel with pedogenic clay. Brown (10YR 4/3); clasts are all Franciscan, deeply to slightly weathered depending on Franciscan rock type; clasts are angular, highly fractured; where fractured rock appear unweathered; moist, cohesive, slightly tough, slightly hard; weak medium sub-angular blocky structure throughout, very weakly expressed Bt, yet clay development is extensive, may reflect post-depositional movement of unit; basal contact is buried, western contact is moderately west dipping fault. Colluvial wedge material.

KJf — Franciscan melange and serpentinite (Cretaceous/Jurassic)

Contact
Dashed where approximate;
Queried where uncertain

Bedding
Dashed where approximate;
Queried where uncertain

Trench base and corners

Fault (Active)
Dashed where approximate;
Queried where uncertain

F1 N10°W 0.5°SW — Fault Attitude

F4 N37°E 10°S — Foliation Attitude

DRAFT

Photo Log of Trench T-2A South Wall

PG&E Los Osos Fault Trench Evaluation

LCI Leitis Consultants International, Inc. | Plate 2

File path: S:\1\005_076\Adjacent\Illustrator_Production\T2a_SouthWall.ai; Date: 12/01/2016; User: Ace Mitchell, LCI; Rev:1

November 18, 2016
ECI Project No. 3613

Earth Consultants International

To: **Pacific Gas & Electric Company**
Geosciences Department
245 Market Street, MC N4C
San Francisco, California 94105

Attention: **Dr. Chris Madugo, Senior Geologist**

Subject: **Report - Soil Stratigraphic Assessments in Support of a Study to Characterize the Activity of Strands of the Los Osos Fault Exposed in Trenches Along the Los Osos Valley Road, in San Luis Obispo, California**

1.0 INTRODUCTION

We are pleased to present this report describing our findings of a soil stratigraphic study that we conducted at your request for a site along Los Osos Valley Road, in San Luis Obispo, California. The purpose of our study was to estimate the age of the soils observed in trenches excavated by others. These trenches exposed strands of the Los Osos fault, and we were asked to provide assistance in characterizing the age of the soils involved in the faulting to better understand the recency of activity of the faults exposed, and if possible, their earthquake recurrence. Determination of the age of the faults exposed will be conducted by others using our soils data and observations regarding how the faults interact with various surface and buried soils that we identified in two trenches.

1.1 SCOPE OF WORK

The specific tasks that we conducted as part of this study are described below. More detailed information regarding the methodology we used to describe the soils, calculate the soil indices, and estimate the ages of the soils is provided in the following sections.

- We reviewed photos and photomosaics of the trench exposures and discussed our preliminary impressions with you and the project team via telephone and video conferencing.
- We compiled, reviewed and analyzed several soil chronosequences and soil profiles developed in coastal areas of central and southern California and the Baja Peninsula, Mexico, that were described and dated by others. If soil descriptions were provided in the sources used, we calculated their Soil Development Indices (SDI) and Mean Horizon Indices (MHI) in an effort to develop soil chronofunctions appropriate for the San Luis Obispo location. The references used are listed in Appendix A.
- We traveled to/from the Los Osos Valley trenching site in San Luis Obispo, where we reviewed the trench exposures still open, discussed with you the stratigraphy observed

in the trenches, and photographed and collected soil samples from four separate soil profiles. We also collected samples of unaltered or slightly altered alluvium from the walls of the active wash near the east side of the property to use as proxies for the soils' parent materials.

- Back in our office, we completed the soil profile descriptions. These are presented in Appendix B.
- We calculated the SDIs and MHIs for the profiles that we described in the field and compared them to the indices of the soils described and dated by others that we had analyzed and compiled as part of our desktop study. Using the chronofunctions developed from the soils data analyzed, we estimated a range of ages for the soils at the site. The soil age estimates computed were then vetted for reasonableness based on topographic and geomorphic position, and geological context.
- We prepared this report summarizing the work completed.

2.0 METHODOLOGY USED FOR SOIL-STRATIGRAPHIC ANALYSES

2.1 BACKGROUND

The term soil as used herein refers to a natural body of mineral and/or organic material consisting of layers (or horizons) that are different from the underlying or original geologic (parent) material in their "morphological, physical, chemical and mineralogical properties and their biological characteristics" (Birkeland, 1984). These differences are the result of weathering and the effects of five main soil-forming factors: parent material, climate, slope or topography, organisms, and time (Jenny, 1941). Time is an important factor because the longer a geologic deposit is exposed to the effects of weathering and soil formation, the better developed the soil characteristics generally become. We take advantage of this when using soils to estimate the age of the deposits.

Soil development occurs on stable geomorphic surfaces (a stable surface is one that is not being significantly impacted by deposition or erosion). Soil development typically starts to occur as soon as a surface stops being eroded or deposited on. Therefore, in some environments, such as an alluvial plain or alluvial fan, it is common to find several weakly to moderately developed buried soils that rest one upon the other, sometimes separated by unaltered or only slightly altered sediments (the parent material). The soils represent periods of sub-aerial weathering and soil formation that occurred in between periods of alluvial erosion and deposition.

In these environments, the age of the primary, unaltered deposits is estimated by summing the age of the individual soils, including the surface soil and the buried soils that overlie the section of interest. It is important to recognize, however, that the soil-age estimates will provide a minimum age for the parent material, as the estimated ages do not account for the length of time it took for the sediments to be deposited. Furthermore, if portions of soil horizons, or even entire soil horizons, have been removed (truncated) from the area by erosion, the age estimates will not capture that erosional period of time. Nevertheless, if these limitations are recognized, soils can provide useful information on the age and geological history of a constructional surface, such as an alluvial or marine terrace or alluvial fan. This is especially true for sediments that 1) do not contain suitable datable materials such charcoal, 2) whose age extends beyond the useful range of radiocarbon

dating, 3) that are too coarse-grained or too clayey to date using Optically Stimulated Luminescence, and 4) cannot be dated by some other absolute dating method. In these cases, soil-age estimations are particularly useful.

2.2 SOIL DESCRIPTIONS

For this project we described four soil profiles; three in trench T-1A and one in trench T-2A. Three of these profiles include a surface soil and two underlying buried soils. The last profile we described is a soil developed in a fining-upward section of fine-grained sediments that were deposited in a low spot that appears to have formed as a result of movement on the adjacent fault. These sediments are referred to here as "ponded deposits." Lastly, we also collected and described samples of unweathered to slightly weathered alluvium from the active channel near the eastern portion of the site. These alluvial deposits are considered representative of the parent materials for the soils described in the trenches.

The descriptions were made using a combination of the characteristics and nomenclature established by the Soil Survey Staff (1975, 1992), the National Soil Survey Center (2012), and Birkeland (1984, 1999). Colors of the soil horizons were recorded by comparing the color of the matrix and clay films, both in the dry and wet states, to color chips in a Munsell Soil Color Chart.

Other characteristics that we recorded include: 1) texture or grain-size distribution, 2) structure (whether the soil mass breaks into distinctive peds, or is single-grained), 3) the amount, distribution and thickness of translocated clay forming films or stains on the soil ped faces and clasts, in pores, between sand grains (called bridges), around clasts, and in clast pockets, 4) the looseness or induration of the soil peds when dry and moist, and 5) the stickiness and plasticity of the wet soil. The sharpness and relief characteristics of the contact (or boundary) between horizons were also noted.

Finally, we also noted and qualitatively described the content, size, angularity or roundness, predominant composition and degree of weathering of the clasts found mixed with the finer-grained soil matrix. The clast weathering stages used follow the nomenclature defined by Tinsley and others (1982)[1], who found a positive correlation between the age of a deposit and the degree of weathering of the clasts therein. The complete soil descriptions for all profiles are provided in Appendix B.

2.3 SOIL INDICES AND DEVELOPMENT COMPARISONS

To estimate the age of geologic deposits using soil-stratigraphic techniques we rely on a comparison of the characteristics of the soils in question with those of other soils

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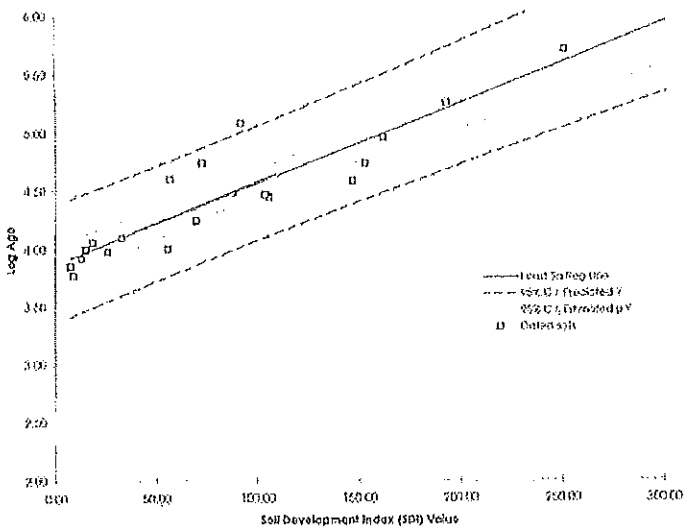
[1] Stage 1: Unweathered bedrock, rings sharply to blow of hammer.
Stage 2: Slightly weathered bedrock, incipient to moderate surface pitting, fractured, with oxidation rinds greater than 1-2 mm in thickness, yields moderate ring to blow of hammer.
Stage 3:Substantially weathered bedrock, surface highly pitted, strongly fractured, mafic minerals and feldspars may be strongly altered, clasts can be broken with difficulty by hand, dull sound to blow of hammer.
Stage 4: Very strongly weathered bedrock, easily disaggregated by hand into grus; very dull sound when struck with hammer.

developed in similar parent materials and climate conditions that have been dated using both absolute and relative dating methods. For this quantitative comparison, the characteristics of the soils are assigned numerical values that are then used to calculate the soils' degree of development. We used two of these quantitative methods for this study: Harden's (1982) Soil Development Index (SDI), and Ponti's (1985) Maximum Horizon Index (MHI). Both SDI and MHI values have been shown to be useful relative indicators of soil age, with older, better developed soils typically having higher SDI and MHI values (Harden, 1982; Harden and Taylor, 1983; Rockwell et al., 1984; Rockwell et al., 1990; Bornyasz and Rockwell, 1997).

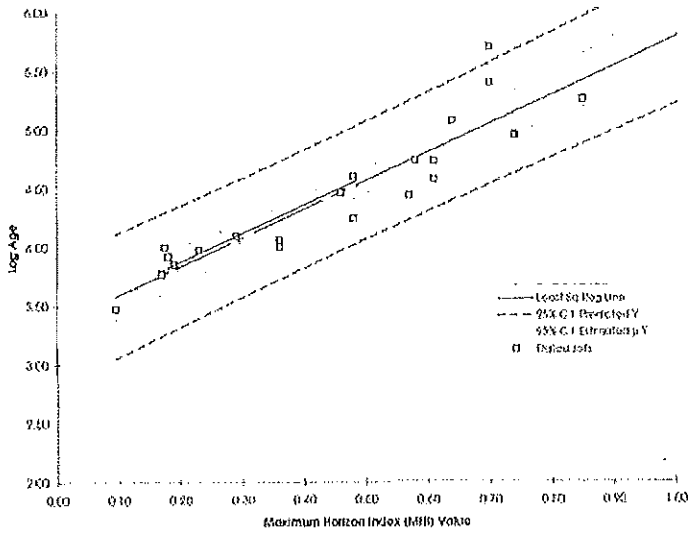
In these quantitative assessments, the characteristics of the soil are "subtracted" from the characteristics of the parent material to develop an empirical estimate of the length of time that a geologic deposit has been subjected to the effects of weathering and soil formation. Field studies have shown that all other conditions being equal, a soil developed in fine-grained sediments appears better developed, with increased horizonation and illuviation, than a coarse-grained soil of similar age (Rockwell et al., 1985). We accounted for these differences when estimating the age of these soils as follows: For the coarse-grained buried soils we used the gravelly loamy sand alluvium that we collected from the active channel as parent material. For the fine-grained surface soils and the ponded deposits, we used sandy loam alluvium as the parent material. The descriptions of these alluvial parent materials are included in Appendix B, at the end.

To obtain minimum age estimates for the soils in the profiles described, we compared the soils' SDI and MHI values with the chronofunctions presented in Dolan et al. (1997; see Graphs 1 and 2 below), which are based on the chronosequences of the Ventura Basin by Rockwell (1983) and Rockwell et al. (1985), the Merced Valley by Harden (1982), and Cajon Pass by McFadden and Weldon (1987). Since two of these chronosequences (Merced Valley and Cajon Pass) developed in inland areas of southern California not exposed to coastal fog, and are thus unlike the coastal area of San Luis Obispo where the site is located, we also compiled, reviewed and analyzed four additional soil chronosequences developed in coastal areas of central and southern California (Rockwell et al., 1994; Muhs, 1982), and in the Baja Peninsula in Mexico (Rockwell et al., 1993). Coastal soils typically develop faster than inland soils because sodium input from sea spray and coastal fog helps to deflocculate (disperse) the clay minerals (Shlemon, 1978; Shlemon and Hamilton, 1979; Birkeland, 1984), and the moisture provided by the fog helps to translocate (mobilize) the clay fraction down the sediment section. As a result, argillic (Bt) soil horizons tend to form faster in this environment than in more inland areas not subject to these fluxes. The properties of these soils were quantified using both the Harden (1982) and Ponti (1985) methods to develop soil indices that we then plotted as a function of time to develop chronofunctions that would theoretically be more representative of the site than some of the chronosequences used for the soil age regressions used by Dolan et al. (1987).

Graph 1: Soil Development Index vs Log Age Regression published by Dolan et al. (1997) and used in this study to estimate the age of the Los Osos Valley Soils



Graph 2: Maximum Horizon Index vs Log Age Regression published by Dolan et al (1997) and used in this study to estimate the age of the Los Osos Valley Soils



The age estimates calculated using soil-stratigraphic methods provide the approximate minimum length of time that a soil was exposed to soil-forming processes when at the ground surface. In areas where the surface soil is underlain by one or more buried soils,

the age of the buried soils and the underlying sediments is best estimated by adding the age of the overlying, surface soil to the amount of time that each of the now-buried soils was exposed to soil-forming processes prior to burial. This method is considered to provide a minimum age for the sediments that the soils developed in because the age estimates do not account for the length of time it took for the sediments to be deposited, nor do they include any soils (or portions of soil horizons) since removed by erosion that are no longer present in the record.

Finally, and of significant note, the age estimates obtained by applying these chronofunctions need to be evaluated and reconciled with other criteria that also provide general information on the possible age of the sediments. These criteria include but are not limited to geomorphic position and the region's Quaternary history, including glacial and interglacial events that defined whether the processes of incision, backfill, or soil formation predominated.

3.0 FINDINGS

3.1 SUMMARIZED SOIL PROFILE DESCRIPTIONS

Three of the soil profiles that we described in trenches T-1a and T-2a are relatively similar in appearance and stratigraphic position. All three of these profiles have a surface soil and two buried soils (Soil Profile 3 in Trench T-2a has an additional truncated soil that is buried under a low-angle fault). Characteristics of each of these soils are summarized below. For the complete soil descriptions, refer to Appendix B.

Surface Soil: ABt1/ABt2 in Profile 1; A1/A2/Bt in Profile 2; A1/A2/Btj in Profile 3
The surface soil consists of organic-rich silty clay to silty clay loam that is very dark gray and dark brown when dry, and black, very dark brown and very dark grayish brown when moist (10YR to 7.5YR hues). The section is between 43 and 58 cm thick, and has characteristics of both A and Bt horizons, with structure that ranges from granular within the root zone to strong subangular blocky below. Clay films in the argillic section vary from few to common thin to continuous thick on ped faces, coating clasts and lining clast pockets. Sand grains are common, but fine gravel-sized clasts are few and scattered throughout.

This deposit is distinctly finer-grained than the underlying buried soils, with only a few scattered gravel-sized clasts, and a high concentration of silt. We suggest that it was deposited primarily by eolian processes, either as coastal fog fallout over a long period of time (Keller et al., 1981), or as a paleodune emplaced during a marine regression, typically during and after a falling sea level (Orme, 1990). Orme (1990) mapped several paleodune deposits in the study area and to the south, including several that "feather out at 300 m against the San Luis Range (Irish Hills)." Although Orme (1990) did not map dune deposits in the immediate site vicinity, he indicated that Pleistocene eolian deposits in the region are buried under predominantly fluvial sequences, resulting in complex stratigraphic sections that require additional research. In the Santa Maria and Santa Ynez valley south of Pismo Beach, Orme (1990) mapped several late Quaternary dune deposits more than 30 km inland, including paleodune sediments that nearly wrap around the Casmalia Hills. These observations indicate that it is plausible for similar paleodune sediments to occur in the site vicinity. Burke et al. (2016) have studied sediments with similar characteristics in

coastal northern California, and suggest that these eolian sediments were deposited during the last glacial maximum, 20-30ka.

First Buried Soil: 2Btkb/3Btb/4BCb in Profile 1; 2Btkb in Profile 2; 2Btb1/2Btb2 in Profile 3
In two of the profiles described, the first buried soil is defined by, or includes a calcium carbonate-rich argillic horizon (Btk) with Stage I to II calcium carbonate as coatings on ped faces, lining pores, in veins, and as nodules (Machette, 1985). San Luis Obispo's current climatic environment (annual average precipitation of 48.3 cm and temperature of 15.2°C) is not conducive to the formation of Stage I-II calcium carbonate morphology. These calcic horizons therefore most likely formed when this area was drier and warmer than today, sometime during the Pleistocene.

This buried soil is a relatively thin, partly truncated soil that varies in thickness between 39 and 64 cm. Although these are minimum thicknesses, as the A horizons are not preserved, and the argillic horizons appear to be truncated, the better-preserved section in Profile 1 is still thin, suggesting that this buried soil was formed during a dry period, limiting the effective depth of translocated clay. The horizons observed have a silty clay to silty clay loam texture, with visibly more gravel than the surface soil described above, and moderate to strong subangular blocky to prismatic structure. Color hues are generally in the 7.5YR to 10YR range, with low chromas that are the result of overprinting by (leaching from) the overlying organic-rich surface soil. The clay films are well developed, described as moderately thick to thick and common to continuous on ped faces, coating clasts and on clast pockets. All of these characteristics indicate a relatively long period of exposure to soil-forming processes. In the trench walls that we reviewed, the contact between this first buried soil and the underlying buried soil is locally defined by a stoneline consisting of rounded to subrounded pebbles and cobbles, suggesting a hiatus of deposition between the deeper buried soil and the overlying deposit.

Second Buried Soil: 5Btb2/5Btb3/5Btb4/6Btb5/6btb6 in Profile 1; 3Btb1/4Btb2/5Btlam1b/5Btlam2b in Profile 2; 3Btb3/4Btb4 in Profile 3
In Profiles 1 and 2, this second buried soil ranges in thickness from 133 to 151 cm. These are minimum thicknesses as the A horizons for these soils are not preserved, and the overlying argillic horizons are most likely truncated.

The thickness of the second buried soil in Profile 3 is unknown, as the bottom of the soil is truncated by a low-angle fault, although its original thickness could be reconstructed if we are correct in our assessment that the buried soil below is part of a repeated section. In the area where we described our soil profile, the fault zone appears to be enhanced by translocated clay, whereas farther east, closer to what was the slope face prior to burial, the fault tip is obscured by soil development. This suggests that the faulting event represented by this low-angle fault occurred when the deposit was still being exposed to pedogenesis, prior to burial by the overlying alluvial fan deposits. However, at Station 1.2 the fault plane removed the bottom section from the zone of pedogenic influence.

These now-buried soils developed in coarse-grained parent materials that include many scattered clasts several inches in diameter, yet the texture of the soils ranges from silty clay to sandy clay, indicating significant chemical weathering of the original parent material and/or accumulation and translocation of wind-transported silt over a lengthy period of

time. The thickness and distribution of pedogenic clay down the entire profile also indicates that these soils formed during a former wetter climate, most likely during a major interglacial. Color hues are in the 7.5YR range, with 7.5YR clay films. Clay films on ped faces are found preferentially in the upper argillic horizon; the lower argillic horizons have clay films on clast pockets and coating clasts. These clay films vary from common and thin to continuous and thick.

Soil buried under fault in Profile 3: 5Btb5/5Btb6/6Btb7/7BCb
This is a coarsening-downward soil profile that ranges from sandy clay at the top to loam at the bottom. The profile is at a minimum 67 cm thick at Station 1.2, where we described it, but thickens eastward, away from the low-angle fault described above (at Station 3, the profile was at least 119 cm thick). The bottom of this soil profile extends below the depth of the trench, so these thicknesses are minimum values.

Colors also vary with depth from brown to dark brown (7.5YR 5/3 to 3/3) at the top, to light yellowish brown to brown (10YR 6/4 to 4/4) at the bottom. Clay films in the upper sandy clay and sandy clay loam sections include many moderately thick on ped faces, and many to continuous moderately thick to thick coating clasts and lining clast pockets. The soil formed in an originally coarse-grained deposit that includes many subrounded to subangular Franciscan Formation-type clasts up to 3 inches (7.5 cm) in diameter weathered to Stages 2 to 4.

This soil appears to represent a repeated section of the overlying second buried soil described above. As we suggested above, this lower buried soil appears to have been removed from the effective depth of pedogenic influence by the faulting event, with continued accumulation of translocated clay after the faulting occurring predominantly in the overlying soil and along the fault plane itself. To the east, closer to the slope face, continued soil development, possibly enhanced by bioturbation, obscured the fault plane so that it is no longer visible in that area. In the area where we described the soil, the deposit below the fault was removed from the effective depth of soil formation such that physical and chemical weathering of the sand fraction and/or influx of eolian silt ceased. This explains why this profile is sandier than the soil above. If this argument is correct, the estimated age of the entire section in this area is not represented by the sum of the time it took for the surface soil and each of the underlying three buried soils to form. Instead, the age of the entire section is best represented by the sum of the time it took for the surface soil and each of the first two buried soils to form, plus the difference in age between the second and third buried soils.

Soil developed in the Ponded Deposits west of the fault in Trench T-1a: Btb1/Btb2/Btb3/2Bt4b
This soil developed in what is interpreted to have been a fining-upward sequence of clean, well-sorted sand deposited in a topographic low-spot that developed uphill from the fault exposed in the trench, presumably as a result of the most recent earthquake event on the fault. If this is the case, then estimating the age of this soil would help establish the timing of when this fault trace last moved. This soil is overlain by a 51-cm thick surface soil comparable to that described in Profile 1.
The entire profile is 61 cm thick and includes four argillic soil horizons that vary in texture from clay at the top, to silty clay to sandy clay in the middle, and sandy loam to sandy clay

loam at the bottom. The upper horizons have 7.5YR hues and low chromas, whereas the lower horizons have 10-7.5YR hues. Clay films are common in the upper three horizons, with few thick and common to many thin to moderately thick on ped faces, common thin to moderately thick coating clasts, and common moderately thick lining clast pockets.

3.2 REGIONAL SOIL INDICES USED FOR COMPARISON PURPOSES

As discussed above, we compiled, reviewed and analyzed several soil chronosequences that have been described by others. In particular, we looked for soils developed in coastal areas of California and the Baja Peninsula that are exposed to marine fog and thus sodium influx, on the premise that the soils at the site have been similarly exposed to these conditions, and as a result have developed more quickly than other soils from more inland areas that formed in similar parent materials.

To that end we found and analyzed data for four coastal soil chronosequences. These include 1) soils formed on marine terraces in the nearby San Simeon area described by Rockwell et al. (1994), 2) soils that formed on marine terraces on San Clemente Island described by Muhs (1982), 3) soils that formed on marine terraces in the Punta Banda area of the Baja Peninsula (Rockwell et al., 1987 and 1989, based on the summary by Rockwell et al., 1993), and 4) soils developed on alluvial terraces in the Valle Agua Blanca area, also in the Baja Peninsula, Mexico (Rockwell et al., 1993).

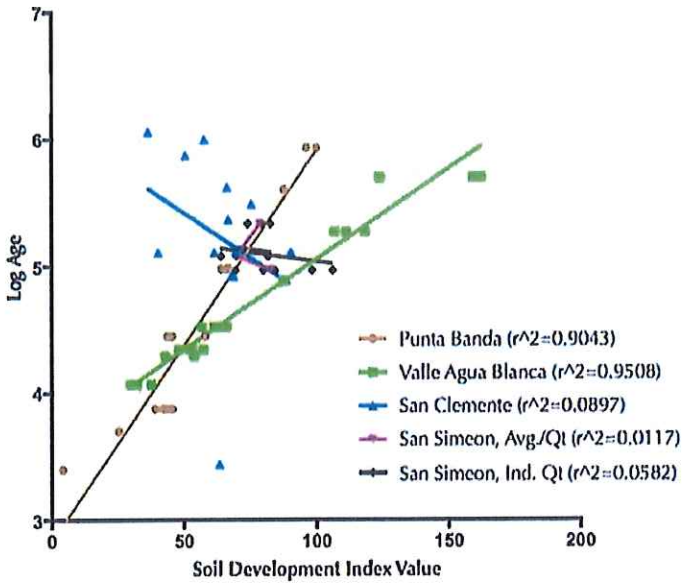
For the San Simeon and San Clemente soils, we took the soil descriptions provided in those sources and calculated their soil indices (SDI and MHI) normalized to a total depth of 200 cm. The Rockwell et al. (1993) publication covering the Punta Banda and Valley Agua Blanca soils did not include individual soil descriptions, but they did provide the SDI and MHI values and age estimates for the various profiles that they described. It is important to note, however, that the soil indices that Rockwell et al. (1993) calculated and published for the Valle Agua Blanca profiles were normalized to a depth of 250 cm, and we have assumed that the same is true for the Punta Banda soils, although Rockwell et al. (1993) do not say so. This is not expected to have an impact on the MHI vs soil age regression curves, as the diagnostic, better developed horizon that provides the MHI value is typically going to be found in the upper 200 cm, and MHI values are independent of overall profile thickness, but the published SDIs for these soils will be higher than the SDIs normalized to a depth of 200 cm. As a result, theoretically, a soil age regression plot generated with SDIs normalized to 250 cm will yield lower age estimates than a regression generated with the same soil data but normalized to 200 cm.

Our analysis shows that there are significant differences among the soil indices developed for these four soil chronosequences. These differences are illustrated in Graphs 3 and 4 below. Graph 3 shows the Soil Development Index (SDI) versus Log Age for the four individual soil chronosequences analyzed for this study, and Graph 4 shows the Mean Horizon Index (MHI) versus Log Age for the same set of soil profiles. The Punta Banda, Valle Agua Blanca, San Clemente, and San Simeon soils data are included in both graphs, with each dataset shown in a different color.

The San Simeon data we analyzed includes twelve soil profiles described from what Rockwell et al. (1994) interpreted as three separate marine terraces (Qt5a, Qt5e, and Qt7). Although the number of profiles is relatively large, the ages of these samples are limited to

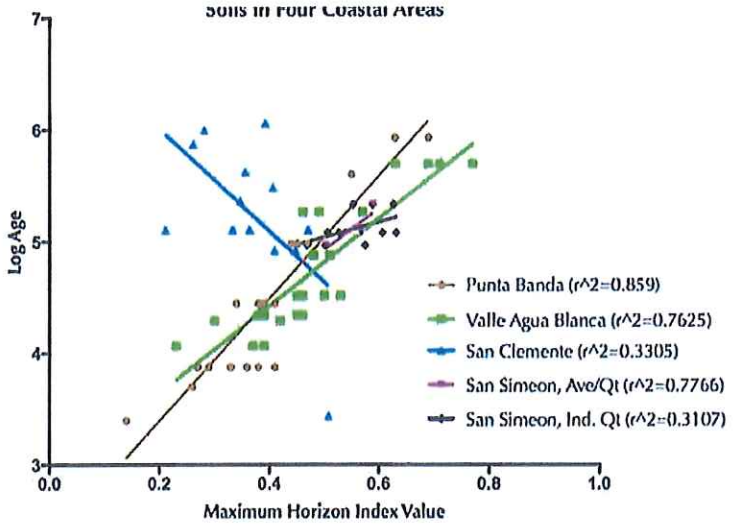
three values, resulting in a fairly limited data set on the graphs used for our analyses. We opted to show and analyze the San Simeon soils data in two different ways: 1) as an average of the SDI and MHI values for each terrace (pink dataset on Graphs 3 and 4), and 2) as individual SDI and MHI values (black dataset).

Graph 3: Soil Development Index (SDI) vs Log Age for Soils in Four Coastal Areas in California and Baja California

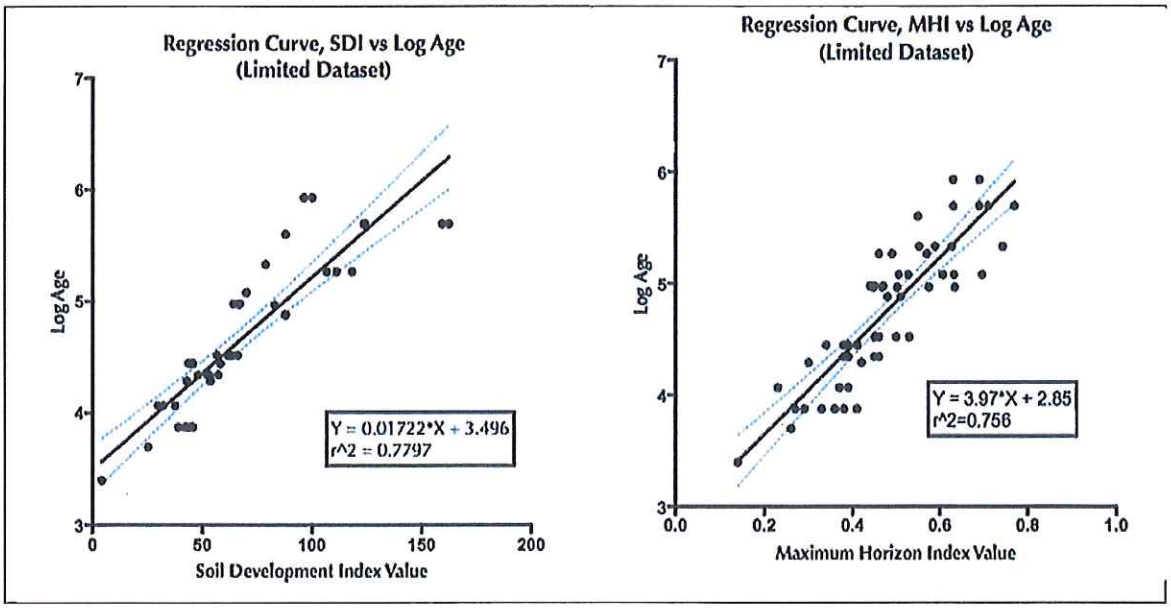


The curves show that the San Clemente soils yield a linear regression solution with a negative slope, meaning that the youngest soils display the strongest soil characteristics. Because this result is contrary to most observations that show an increase in soil indices with increasing age, we chose to not use the San Clemente data to generate the chronofunctions shown in Graphs 5 and 6. Although not as obvious, the Soil Development Indices (SDI) calculated for the San Simeon soils also yield negative slopes (see Graph 3). This may be a function of the relatively small age data set; it is possible that if a larger spread of soils of different ages were available in the region, and these were described and analyzed, the combined results would result in a direct correlation between SDI and log soil age (meaning a positive slope for the linear regression equation). For the purposes of this project, however, we chose to not use the individual San Simeon SDI values to generate the chronofunction shown on Graph 5. Interestingly, the averaged MHI values for each terrace in the San Simeon area plot as expected, with a positive slope (see pink line in Graph 4). As a result, we kept and used the San Simeon average MHI values in generating the combined MHI vs Log Age chronofunction shown in Graph 6.

Graph 4: Maximum Horizon Index (MHI) vs Log Age for Soils in Four Coastal Areas in California and Baja California



Graphs 5 (left) and 6 (right): Chronofunctions Developed for this Study
Using the Punta Banda, Valle Agua Blanca and Average San Simeon Soils Data (MHI only)
Graph 5 shows the Soil Development Index vs Log Age, and
Graph 6 shows the Mean Horizon Index vs Log Age
These functions were used to calculate estimated ages for the soils in this study, with the results presented under the column "Combined PB, VAB and SSavg" in Table 1



3.3 ESTIMATED SOIL AGES BASED ON SOIL INDICES

For our final analysis we used four separate soil chronofunctions to estimate the ages of the soils described for this study. These chronofunctions include the Dolan et al. (1997) SDI

and MHI vs Log Age regressions shown on Graphs 1 and 2, and the limited combined data from the coastal soils shown on Graphs 5 and 6. We also used the chronofunctions calculated for the Punta Banda and Valle Agua Blanca soil indices, since these soil chronosequences generated fairly robust linear regressions (see Graphs 3 and 4).

The results of these analyses are summarized in Table 1. The values presented in Table 1 represent the length of time that each of the soils in a given profile was exposed to soil forming processes when that soil was at the ground surface. As discussed previously, all other conditions being equal, coastal soils are expected to develop faster than inland soils. Thus, we expected that the chronofunctions developed for the Punta Banda, Valle Agua Blanca and the combined coastal soils data would yield younger ages for the Los Osos Valley soils than the values obtained using the Dolan et al. (1997) regressions. However, as Table 1 shows, this is not the case. With the exception of the surface soil from Profile 3, the Dolan et al. (1997) regressions generally returned significantly younger ages than the other chronofunctions.

Table 1: Soil Development Age Estimates Calculated for the Soil Profiles Described for This Study

Soil	MHI	SDI (n=200cm)	Mean Length of Time Soil Was Exposed to at the Surface, based on the Following Soil Chronofunctions:			
			Dolan et al. (1997) (Avg / Min)	Combined PB, VAB, SSavg* (this study)	Punta Banda (this study)	Agua Blanca (this study)
Soil Profile 1, Surface Soil	0.5164		40,793 / 14,014	79,440	135,019	76,116
		93.52	32,857 / 10,658	127,766	515,799	91,326
Soil Profile 1, Buried Soil 1	0.4814		33,513 / 11,376	57,698	86,784	55,573
		93.63	32,916 / 10,677	128,324	519,838	91,657
Soil Profile 1 Buried Soil 2	0.4093		22,348 / 7,402	29,848	34,900	29,061
		72.67	23,524 / 7,576	55,894	117,623	46,054
Soil Profile 2, Surface Soil	0.3591		16,851 / 5,488	18,863	18,508	18,504
		71.18	22,970 / 7,393	52,689	105,836	43,856
Soil Profile 2, Buried Soil 1	0.4505		28,163 / 9,462	43,488	58,713	42,081
		90.09	31,099 / 10,076	111,519	404,456	81,599
Soil Profile 2, Buried Soil 2	0.4409		26,683 / 8,936	39,833	52,004	38,600
		57.4	18,418 / 5,900	30,508	39,840	27,894
Soil Profile 3, Surface Soil	0.2866		11,212 / 3,563	9,724	7,407	9,643
		56.7	18,214 / 5,833	29,674	37,913	27,261
Soil Profile 3, Buried Soil 1	0.5206		41,767 / 14,369	82,550	142,379	79,046
		75.11	24,462 / 7,884	61,574	139,842	49,896
Soil Profile 3, Buried Soil 2	0.4146		23,017 / 7,639	31,322	37,305	30,472
		59.07	18,918 / 6,063	32,598	44,852	29,468
Soil Profile 3, Buried Soil 3	0.4260		24,550 / 8,177	34,785	43,122	33,783
		41.41	14,255 / 4,541	16,183	12,822	16,500
Ponded Deposits	0.4255		24,482 / 8,153	34,628	42,853	33,633
		58.5	18,746 / 6,007	31,868	43,070	28,920

Abbreviations: MHI = Maximum Horizon Index; SDI = Soil Development Index; PB = Punta Banda; VAB = Valley Agua Blanca; SSavg = San Simeon, terrace average

The Dolan et al. (1997) soil age regressions include curves that capture 95% of the data used to generate the chronofunction. We typically use these curves to calculate the minimum and maximum age values for a given soil index, and on Table 1 we present both the median and minimum age values calculated using the Dolan et al. (1997) regressions. The chronofunctions that we generated for this study, such as those shown on Graphs 5 and 6, include 95% confidence interval (CI) envelopes around the median that delineate the area where the linear regression equation that best fits the data is likely to be located. These 95% CI envelopes, however, do not capture 95% of the data used, and are thus not comparable to the envelopes shown on the Dolan et al. (1997) graphs. Because we did not develop similar envelopes to capture 95% of the data used, all other values on Table 1 represent median age estimates. Given that the Dolan et al. (1997) regressions generally returned the youngest ages for the soils described for this study, it is our opinion that the minimum soil development age estimates we calculated with these chronofunctions represent the absolute minimum ages possible for these deposits.

4.0 DISCUSSION and SUMMARY OF RESULTS

Given that the surface soil described in Profiles 1, 2 and 3 is thought to have developed on eolian sediments that were most likely deposited during the last glacial maximum, approximately 20-30ka, the soil development age estimates calculated using the Dolan et al. (1997) regressions appear provide the best age estimates for these surface soils. Furthermore, and as discussed extensively above, the soil age regressions in Dolan et al. (1997) return the youngest age estimates for the soils we described in the trenches. Since these soils are thought to be exposed to coastal fog, and are thus likely to have formed faster than inland soils, the youngest ages seem to be most appropriate for this site.

Table 2 summarizes our preferred ages for the soils described for this study. Our preferred age for the surface soil is constrained between the minimum age returned by the Dolan et al. (1997) regressions, and the age of the eolian sediments that this soil formed. Assuming that these eolian sediments began to be deposited when sea level fell during the last glacial maximum, the soil cannot be more than about 18,000 years old. Thus, even though the soil regressions returned ages significantly older than 18,000 years, we opted to cap the age of the surface soil in all exposures to 18,000 years.

For the buried soils, we chose to give a range of possible development ages that stretch from the lowest average age returned by the regressions to the "middle of the road" values that do not extend into the 100,000s. In particular, we chose to ignore the high age estimates returned by the Punta Banda SDI regressions.

To obtain the total minimum age for a given profile, the development age estimates for all of the soils in that profile were added together, except for Profile 3, where the second buried soil was truncated by faulting, and the third buried soil likely represents a repeated section of the second buried soil. In this case, we suggest that the age of the entire profile is best represented by the sum of the estimated time the surface soil and each of the first two buried soils were exposed to pedogenic processes, plus the difference in soil-development age between the second and third buried soils. Finally, the age of the ponded deposits is determined by adding the length of time that these sediments are thought to have been exposed to soil-forming processes before burial,

plus the age of the overlying surface soil developed in eolian deposits. We used our preferred age of the surface soil from Profile 1, for this calculation. Additional discussion regarding the age of these soils based on their geologic history is provided in the paragraphs below.

Table 2: Preferred Age Estimates for the Soils and Soil Profiles Described for this Study

Soil	Preferred Development Age of Individual Soil	Preferred Age of Profile
Soil Profile 1, Surface Soil	11,000 - 18,000	
Soil Profile 1, Buried Soil 1	33,000 - 87,000	
Soil Profile 1, Buried Soil 2	22,000 – 35,000	66,000 – 140,000
Soil Profile 2, Surface Soil	16,000 – 18,000	
Soil Profile 2, Buried Soil 1	28,000 – 59,000	
Soil Profile 2, Buried Soil 2	18,000 – 40,000	62,000 – 117,000
Soil Profile 3, Surface Soil	7,000 – 18,000	
Soil Profile 3, Buried Soil 1	25,000 – 83,000	
Soil Profile 3, Buried Soil 2	19,000 – 45,000	
Soil Profile 3, Buried Soil 3	13,000 – 43,000	57,000 – 148,000
Ponded Deposits	19,000 – 43,000	30,000 – 61,000

The first buried soil represents the stable ground surface before the last glacial maxima exposed the continental shelf, facilitating burial by the eolian sediments in which the surface soil formed. This paleo surface was composed of alluvial and alluvial fan deposits that were graded to a more distant coastline than today's, probably the MIS 3 coastline of 30-60 ka, but not impossibly the MIS 5a at 75-85 ka (especially considering that this soil appears to have formed during a dry and warm climate, such as MIS 5a).

The second buried soil is locally separated from the overlying soil by a stoneline, implying at least some erosional lowering of the second soil's ground surface before and while undergoing pedogenic weathering. These deposits could be MIS 5e, with surface stabilization occurring during MIS 5c, or they could be as old as MIS 7 with the surface lowering during MIS 6 and pedogenic development occurring during the MIS 5 intervals.

To conclude, therefore, the surface soil is a latest Pleistocene to early Holocene soil developed on late Pleistocene (MIS 2 - 20-30 ka) eolian sands. Those sands blanket a paleosurface that formed during MIS 3 (30-50 ka) that is most likely composed of MIS 4 (60-80 ka) sediments, which in turn overlie an MIS 5 (80-120 ka) paleosol developed upon older alluvial sediments. This would be the youngest age interpretation for all the units.

We hope that the information provided above helps you and team in further characterizing the earthquake history of this segment of the Los Osos fault. Thank you for the opportunity to assist you on this project. Should you have any questions regarding the above, please do not hesitate to contact the undersigned at (714) 412-2654.

Respectfully submitted,
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APPENDIX B: SOIL DESCRIPTIONS

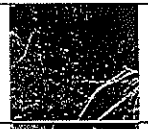
Profile No. 1: Trench T-1A, at about Station 66, on the North Wall

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
0 - 0.75 (0 - 23)	23		ABt1	Surface Soil	SILTY CLAY; very dark gray (10YR 3/1) with very dark grayish brown (10YR 3/2) clay films when dry, black (10YR 2/1) with black (10YR 2/1) clay films when moist; strong medium angular blocky soil structure; extremely hard when dry, very firm when moist, very sticky and very plastic when wet; continuous thick clay films on ped faces, common to many moderately thick clay films coating clasts, many thick clay films lining clast pockets; many fine and common medium roots; scattered fine gravel; clear wavy lower boundary.
0.75 - 1.41 (23 - 43)	20		ABt2		SILTY CLAY; very dark gray and dark brown (10YR3/1 and 10YR 3/3) when dry, black and very dark brown (10YR 2/1 and 7.5YR 2.5/3) when moist; strong medium angular blocky soil structure; extremely hard when dry, firm when moist, very sticky and very plastic when wet; continuous thick clay films on ped faces, many moderately thick and common thick clay films coating clasts, continuous thick clay films lining clast pockets; common fine roots; mix of A and Bt material; scattered fine gravel; clear wavy lower boundary.
1.41 - 1.97 (43 - 60)	17		2Btkb	Buried Soil 1	SILTY CLAY LOAM; dark brown (7.5YR 3/3) when dry, dark brown (7.5YR 3/2) when moist; moderate fine subangular blocky to granular soil structure; hard to very hard when dry, very firm when moist, sticky and plastic when wet; few thick and many to continuous moderately thick clay films on ped faces, common moderately thick clay films coating clasts, few moderately thick clay films lining clast pockets; few to common fine roots; moderately thick calcium carbonate coatings on ped faces and as veins; clear irregular lower boundary.
1.97 - 2.72 (60 - 83)	23		3Btb		SILTY CLAY; brown (7.5YR 4/4) with dark brown (7.5YR 3/2) clay films when dry, dark brown (7.5YR 3/3) with very dark brown (7.5YR 2.5/2) clay films when moist; moderate fine to coarse angular blocky soil structure; extremely hard when dry, firm when moist, very sticky and very plastic when wet; few thick and many moderately thick clay films on ped faces, common moderately thick clay films coating clasts, many moderately thick clay films lining clast pockets, few thin clay films lining pores; common fine gravel; common medium pores; abrupt smooth to wavy lower boundary.

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
2.72 - 3.51 (83 - 107)	24		4BCb		SILTY CLAY; brown (7.5YR 4/4) with dark brown (7.5YR 3/2) clay films when dry, dark brown (7.5 3/3) with dark brown (7.5YR 3/2) clay films when moist; moderate fine to medium subangular blocky soil structure breaking to moderate fine granular and single-grained; hard when dry, firm when moist, sticky and plastic when wet; few moderately thick and common thin clay films on ped faces, common moderately thick and many thin clay films coating clasts, common moderately thick clay films lining clast pockets; with pockets of clay; developed on a different sedimentary unit with scattered subangular and angular cobbles, common subangular coarse gravel, and more fine to medium sand than units above; abrupt wavy lower boundary.
3.51 - 4.04 (107 - 123)	16		5Btb2	Buried Soil 2	SILTY CLAY; brown (7.5YR 4/4) with dark brown ((7.5YR 3/3 clay films when dry, brown (7.5YR 4/3) with dark brown (7.5YR 3/2) clay films when moist; strong medium to coarse subangular blocky breaking to strong fine prismatic soil structure; very hard when dry, firm when moist, very sticky and very plastic when wet; common thin and few moderately thick clay films on ped faces, many moderately thick clay films coating clasts, common moderately thick clay films lining clast pockets, common thin clay films lining pores; scattered subangular pebbles; few to common fine gravel; clear wavy lower boundary.
4.04 - 4.76 (123 - 145)	22		5Btb3		SILTY CLAY; brown (7.5YR 5/4) with brown (7.5YR 4/3) clay films when dry, brown (7.5YR 4/4) when moist; moderate fine subangular blocky soil structure breaking to single-grained; hard when dry, firm when moist, sticky and very plastic when wet; common to continuous thick clay films coating clast pockets, continuous thin and common moderately thick clay films lining clast pockets; soil developed on a matrix-supported fine-grained mudflow deposit with scattered clasts up to 10 cm in diameter, common subangular pebbles and gravel; clear irregular lower boundary.
4.76 - 6.07 (145 - 185)	40		5Btb4		SILTY CLAY to SANDY CLAY; brown (7.5YR 5/4) when dry, brown (7.5YR 4/4) when moist; moderate fine to medium subangular blocky soil structure breaking to granular and single-grained; very hard when dry, firm when moist, very sticky and very plastic when wet; common to many moderately thick clay films coating clasts, continuous thick clay films lining clast pockets; common clasts greater than 10 cm at Stage 2 clast-weathering; common fine gravel and common angular to subrounded pebbles; localized iron oxide staining; clear irregular lower boundary.

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
6.07 - 7.19 (185 - 219)	34		6Btb5		SANDY CLAY; brown (7.5YR 4/4) when dry, brown (7.5YR 4/3) when moist; weak medium subangular blocky soil structure breaking to single-grained; hard when dry, firm when moist, sticky and very plastic when wet; continuous moderately thick clay films on clast pockets, many thin and common moderately thick clay films coating clasts, clay films on rock fractures; soil developed on a clast-supported, coarser-grained mudflow deposit with clasts 10 -25 cm in diameter, common subangular to subrounded cobbles and common fine gravel; most clasts at Stage 2 clast weathering, a few at Stage 3; gradual irregular lower boundary.
7.19 - 8.46 (219 - 258)	39		6Btb6		SANDY CLAY; brown (7.5YR 5/4) when dry, brown (7.5YR 4/4) when moist; moderate fine to medium subangular blocky soil structure; slightly hard to hard and fragic when dry, firm when moist, sticky and very plastic when wet; common thin clay films on ped faces, common moderately thick clay films coating clasts, common thin clay films lining clast pockets, continuous thick clay films on clast pockets; common angular to subangular pebbles, common fine gravel; abrupt smooth to wavy lower boundary to serpentinite bedrock of the Franciscan Formation below, to the bottom of the trench at a depth of 302 cm.

Profile No. 2: Trench T-1A, at about Station 3, on the South Wall

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
0 - 0.72 (0 - 22)	22		A1	Surface Soil	SILTY CLAY; dark brown (7.5YR 3/2) when dry, black (7.5YR 2.5/1) when moist; moderate fine to coarse granular soil structure; extremely hard when dry, extremely firm when moist, sticky and plastic when wet; many roots and rootlets; clear wavy lower boundary.
0.72 - 1.38 (22 - 42)	20		A2		SILTY CLAY; very dark gray (7.5YR 3/1) when dry, black (7.5YR 2.5/1) when moist; moderate fine to medium subangular blocky to granular soil structure; extremely hard when dry, firm when moist, very sticky and very plastic when wet; many roots; common to many medium sand grains and fine gravels; clear to gradual and wavy lower boundary.
1.38 - 1.90 (42 - 58)	16		Bt		SILTY CLAY; very dark gray (7.5YR 3/1) when dry, black (7.5YR 2.5/1) when moist; moderate fine to medium subangular blocky to granular soil structure; very hard when dry, firm when moist, very sticky and very plastic when wet; common thin clay films on ped faces, few thin clay films coating clasts; common fine roots; many visible sand grains and fine gravels; clear to gradual wavy lower boundary.
1.90 - 3.08 (58 - 94)	36		2Btkb	Buried Soil 1	SILTY CLAY; very dark gray (7.5YR 3/1) with brown (7.5YR 4/3) clay films when dry, black (7.5YR 2.5/1) with brown (7.5YR 4/3) clay films when moist; strong medium to coarse prismatic breaking to strong medium subangular blocky soil structure; very hard to extremely hard when dry, very firm when moist, very sticky and very plastic when wet; common to many moderately thick and few thin clay films on ped faces, many thin and few moderately thick clay films coating clasts, common thin clay films lining clast pockets; many rootlets; Stage I to II calcium carbonate lining pores and as nodules; common visible sand grains and small pebbles; abrupt wavy lower boundary on a stoneline of rounded to subrounded pebbles to cobbles.

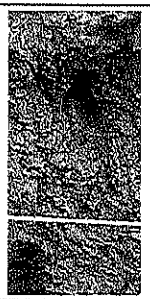
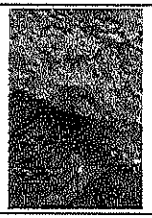
Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
3.08 - 4.30 (94 - 131)	37		3Btb1	Buried Soil 2	SANDY CLAY; brown (7.5YR 4/4) with dark brown (7.5YR 3/4) clay films when dry, brown (7.5YR 4/3) with dark brown (7.5YR 3/3) clay films when moist; weak fine to medium subangular blocky soil structure breaking to single-grained; slightly hard and fragic when dry, friable when moist, slightly sticky and slightly plastic when wet; few thin clay films on ped faces, common to many moderately thick clay films coating clasts, many thin clay films lining clast pockets; sand fraction is predominantly medium- to coarse-grained; many fine gravels and common pebbles weathered to clast-weathering Stages 2 to 3; zones of increased clay content; gradual wavy lower boundary.
4.30 - 5.09 (131 - 155)	24		4Btb2		Clast-supported cobbly SANDY CLAY; brown (7.5YR 4/4) with dark brown (7.5YR 3/4) clay films when dry, dark brown (7.5YR 3/3) with dark brown (7.5YR ¾) clay films when moist; weak fine subangular blocky soil structure breaking to single-grained; slightly hard when dry, friable when moist, non-sticky to slightly sticky and plastic when wet; many to continuous moderately thick clay films coating clasts, many to continuous moderately thick clay films lining clast pockets; with fine gravel and pebbles up to 2.5-inches (5 cm) in diameter, felsic, subrounded to subangular, weathered to clast-weathering Stages 2 to 3; sand fraction is predominantly medium to coarse grained; clear wavy lower boundary on a stoneline.
5.09 - 6.27 (155 - 191)	36		5Bt_{lam}1b		SANDY CLAY; dark brown (7.5YR 3/4) with dark brown (7.5YR 3/3 clay films and Bt lamellae when dry, dark brown (7.5YR 3/4) with dark brown (7.5YR 3/3) clay films and Bt lamellae when moist; single-grained; slightly hard and fragic when dry, friable when moist, non-sticky and slightly plastic when wet (Bt lam material); many to continuous moderately thick to thick clay films coating clasts, many moderately thick clay films lining clast pockets; the gravel and pebbles are finer grained than above, subangular to subrounded, weathered to clast weathering Stages 2 to 3; Bt lamellae and zones of increased clay are redder in color but still single-grained; gradual wavy lower boundary.

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designations		Description
6.27 - 7.45 (191 - 227)	36		$5Bt_{lam}2b$		SANDY CLAY LOAM; dark brown (7.5YR 3/4) with dark brown (7.5YR 3/3) clay films and Bt lamellae when dry, very dark brown (7.5YR 2.5/3) with dark brown (7.5YR 3/3) clay films and Bt lamellae when moist; single-grained; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many moderately thick clay films coating clasts, many to continuous moderately thick clay films lining clast pockets; sand fraction is medium- to coarse-grained; fine gravel and pebbles to 1-inch (2.5 cm) in diameter, rounded to subangular, weathered to clast-weathering Stages 2 to 3; clear wavy lower boundary with another clast-supported mudflow unit with little soil development. This lower mudflow deposit was not described. Below the mudflow deposit was bedrock of the Franciscan Formation.

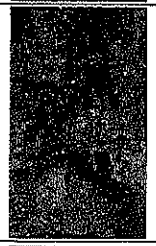
Profile No. 3: Trench T-2A, at about Station 1.2, on the North Wall

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designation		LCI's Geologic Unit Name	Description
0 - 0.59 (0 - 18)	18		A1	Surface Soil	Unit 7	SILTY CLAY LOAM; dark grayish brown (10YR 4/2) when dry, very dark grayish brown (10YR 3/2) when moist; moderate to strong coarse subangular blocky breaking to strong fine to medium granular soil structure; hard when dry, firm when moist, non-sticky to slightly sticky and slightly plastic when wet; common fine roots; scattered coarse sand to fine gravel; common fine to coarse pores; gradual wavy lower boundary.
0.59 - 1.64 (18 - 50)	32		A2/Btj			SILTY CLAY LOAM; dark grayish brown (10YR 4/2) with brown (10YR 4/3) clay films when dry, very dark brown (10YR 2/2) when moist; strong coarse subangular blocky breaking to moderate fine granular soil structure and single-grained; slightly hard to hard when dry, firm when moist, sticky and plastic when wet; few thin clay films on ped faces; many roots; scattered coarse sand to fine gravel; common fine to coarse pores; clear smooth lower boundary.
1.64 - 2.46 (50 - 75)	25		2Btb1	Buried Soil 1	Unit 5	SILTY CLAY; dark grayish brown (10YR4/2) with brown (10YR 4/3) clay films when dry, very dark grayish brown (10YR 3/2) when moist; moderate coarse subangular blocky soil structure; hard when dry, firm when moist, very sticky and plastic when wet; few thin clay films in pores, many thick clay films coating clasts, many moderately thick clay films lining clast pockets; few fine roots; scattered coarse sand to fine gravel; clasts are weathered to weathering Stages 3 to 4; clear wavy lower boundary.
2.46 - 2.92 (75 - 89)	14		2Btb2		Unit 3	SILTY CLAY; dark grayish brown (10YR 4/2) when dry, dark brown (10YR 3/3) with very dark grayish brown (10YR 3/2) clay films when moist; strong medium prismatic soil structure; very hard when dry, very firm when moist, very sticky and very plastic when wet; continuous thick clay films on ped faces, many moderately thick clay films coating clasts; common coarse sand and fine gravel, clasts are weathered to Stage 3 to 4; few fine roots; clear wavy to irregular lower boundary defined by a stoneline.

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designation		LCI's Geologic Unit Name	Description
2.92 - 3.64 (89 - 111)	22		3Btb3	Buried Soil 2		Gravelly SILTY CLAY; brown (7.5YR 4/3) with brown (7.5YR 4/2) clay films when dry, brown (10YR 4/3) with very dark grayish brown (10YR 3/2) clay films when moist; strong coarse angular blocky breaking to strong fine to medium angular blocky soil structure at the top and strong fine angular blocky soil structure at the bottom; very hard when dry, extremely firm when moist, very sticky and very plastic when wet; common moderately thick clay films on ped faces; many moderately thick clay films coating clasts, continuous moderately thick clay films lining clast pockets; many scattered fine-gravel-sized angular to subangular clasts of Franciscan Formation bedrock weathered to Stage2 to 3; abrupt to clear wavy lower boundary.
3.64 - 4.53 (111 - 138)	27		4Btb4			SILTY CLAY LOAM; brown to yellowish brown (7.5-10YR 5/4) with brown (7.5YR 5/4) clay films when dry, dark yellowish brown (10YR 4/4) when moist; moderate fine to medium subangular blocky soil structure breaking to single-grained; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; common moderately thick clay films on ped faces, continuous moderately thick clay films coating clasts, continuous moderately thick to thick clay films lining clast pockets; scattered clasts weathering to Stage3 to 4; abrupt smooth lower boundary defined by a **fault.**
4.53 – 4.79 (138 – 146)	30 cm thick at Station 3+00, where sample was collected		5Btb5	Buried Soil 3	**Unit 3**	SANDY CLAY; brown (7.5YR 5/3) with brown (7.5YR 4/3) clay films when dry, dark brown (7.5YR 3/3) with dark brown (7.5YR 3/3) clay films when moist; weak fine subangular blocky soil structure breaking to single-grained; hard to very hard when dry, very firm when moist, sticky and plastic when wet; many moderately thick clay films on ped faces, many moderately thick clay films coating clasts, continuous moderately thick to thick clay films coating clast pockets; many scattered subrounded to subangular clasts up to 3 inches (7.5 cm) in diameter consisting predominantly of Franciscan Formation bedrock weathered to Stage 3 to 4, chert clasts weathered to Stage 1; gradual wavy lower boundary.

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon and Soil Designation	LCI's Geologic Unit Name	Description
	30 cm thick at Station 3+00, where sample was collected		5Btb6		SANDY CLAY LOAM; brown (10YR 4/3) when dry and crushed, dark brown (7.5YR 4/3) when moist; weak fine subangular blocky soil structure breaking to single-grained; slightly hard when dry, very friable to friable when moist, sticky and plastic when wet; many moderately thick clay films on ped faces, continuous moderately thick and common thick clay films coating clasts, common thick clay films lining clast pockets; scattered clasts predominantly of Franciscan Formation bedrock that range from fine gravel to 3 inches (7.5 cm) in diameter, subrounded to subangular and broken, weathered to Stages 2 to 4; abrupt wavy lower boundary.
4.79-5.54 (146-169)	23		6Btb7	**Unit 2**	SANDY LOAM; yellowish brown (10YR 5/4) with (7.5YR 5/4) clay films when dry, brown (7.5YR 4/3) when moist; massive breaking to weak to moderate fine subangular blocky soil structure; slightly hard when dry, friable when moist, non-sticky and slightly plastic when wet; few to common thin clay films on ped faces, common moderately thick and many thin clay films coating clasts, many moderately thick clay films lining clast pockets; indurated; common fine to medium gravel, common matrix-supported, subangular to subrounded gravel and pebbles predominantly of Franciscan Formation bedrock, weathered to Stages 2 - 4, less Stage 4 weathered clasts than horizon above; clear wavy lower boundary.
5.54 - 6.73 (169 - 205)	36		7BCb	**Unit 1**	LOAM; light yellowish brown (10YR 6/4 when dry, brown (10YR 4/4) when moist; massive breaking to moderate fine subangular blocky soil structure; hard when dry, friable when moist, non-sticky and slightly plastic when wet; indurated; few scattered fine gravel up to 2 inches (5 cm) in diameter consisting predominantly of Franciscan Formation bedrock weathered to Stage 3; many manganese oxide stains on parting surfaces; fractured; lower boundary not observed.

Ponded Deposit Profile West of Profile 2 in Trench T-1A

Depth below the surface (ft; cm)	Thickness (cm)	Photo (not to scale)	Horizon Designation	Description
1.67- 2.30 (51-70)	19		Btb1	CLAY; dark brown (7.5YR 3/2) with very dark brown (7.5YR 2.5/2) and very dark gray (7.5YR 3/1) clay films when dry, dark brown (7.5YR 3/2) with dark brown (7.5YR 3/3) and black (7.5YR 2.5/1) clay films when moist; strong coarse angular blocky soil structure; very hard when dry, very firm to extremely firm when moist, very sticky and very plastic when wet; many thin and common moderately thick to thick clay films on ped faces, common moderately thick clay films coating clasts, many moderately thick clay films lining clast pockets; many fine rootlets; scattered visible coarse sand grains; clear irregular lower boundary.
2.30 - 2.99 (70 - 91)	21		Btb2	SILTY CLAY to CLAY; dark brown (7.5YR 3/2) and very dark gray (7.5YR 3/1) when dry, dark brown (7.5YR 3/3) and black (7.5YR 2.5/1) when moist; strong very coarse prismatic breaking to strong coarse angular blocky soil structure; extremely hard when dry, firm to very firm when moist, very sticky and very plastic when wet; common to many moderately thick and few thick clay films on ped faces, common thin to moderately thick clay films coating clasts, common moderately thick clay films lining clast pockets; common fine rootlets; scattered visible medium to coarse sand grains; clear irregular lower boundary.
2.99 - 3.31 (91 - 101)	10		Btb3	SILTY CLAY to SANDY CLAY; dark brown (10YR 3/3) and black (10YR 2/1) with dark brown (7.5YR 3/2) clay films when dry, dark brown (10YR 3/3) and black (10YR 2/1) with dark brown (7.5YR 3/3) clay films when moist; moderate medium subangular blocky soil structure; very hard to extremely hard when dry, extremely firm when moist, sticky and very plastic when wet; many thin to moderately thick clay films on ped faces, common thin clay films bridging grains, common thin clay films in pores; few fine rootlets; some fine pores; clear wavy lower boundary.
3.31 - 3.67 (101 - 112)	11		2Btb4	SANDY LOAM to SANDY CLAY LOAM; dark yellowish brown (10YR 3/6) with dark yellowish brown to dark reddish brown (10-7.5YR 3/4) clay films when dry, dark brown (10YR 3/3) with dark brown (10YR 3/3) clay films when moist; few peds with increased clay have very weak fine subangular blocky soil structure breaking to single-grained, most section is single-grained; slightly hard when dry, friable when moist, non-sticky and slightly plastic when wet; common thin and few moderately thick clay films coating clasts; few scattered subangular gravel to small pebbles; abrupt wavy lower boundary to a cobbly gravel unit below.

Samples of Alluvium Collected from Wall of the Modern-Day Incised Channel (Parent Material)

Designation	Photo (not to scale)	Description
Sandy Channel section		LOAM; brown (10YR 5/3) when dry, dark brown (10YR 3/3) when moist; moderate fine subangular blocky soil structure; slightly hard when dry, friable to firm when moist, non-sticky and slightly plastic when wet; common fine pores; common fine rootlets; visible medium to coarse sand grains.
Gravelly Channel section		Gravelly to Stony LOAMY SAND; brown (10YR 4/3) when dry, dark brown (10YR 3/3) when moist; single-grained; loose when dry and moist, non-sticky and non-plastic when wet; many subangular fine gravel, pebbles and cobbles up to 4 inches (10 cm) in diameter; predominantly mafic; sand fraction is fine- to coarse-grained.

SUPPLEMENTAL FAULT INVESTIGATION REPORT IRISH HILLS ESTATE TENTATIVE TRACT 2270 SAN LUIS OBISPO, CALIFORNIA

February 28, 2000

Prepared for

Oasis Landscape Architecture and Planning

Prepared by

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reverse faults and a low-angle thrust fault in the southern end of the trench were not active. However, in the low-angle thrust fault near the northern end (Station 2+95) of Cuesta Trench T-3, PG&E (1988) noted that the thrust fault appeared to extend into the colluvium soil, suggesting Holocene activity. A fault investigation performed by Earth Systems Consultants Northern California (ESCNC) (1998) excavated Trench 1, which consisted of 1,325-foot long trench. This trench shadowed Cuesta Trench T-3 and was approximately 735 feet northwest of Cuest Trench T-3 (see Geologic Map in Appendix A). No evidence of the low-angle thrust faults in Cuesta Trench T-3 was observed in ESCNC's Trench 1. William Lettis and Associates, Inc. (WLA) (1999), under contract with the County of San Luis Obispo reviewed ESCNC's fault investigation report. The WLA report review letter states that the questionable Holocene low-angle thrust fault in the northern end of Cuesta Trench T-3 may have been the result of shrink-swell cracking within the highly expansive clay rich soil, rather than tectonic faulting. However, to evaluate whether the thrust fault extended to the north or was discontinuous, ESCNC recommended excavating a trench between Trench 1 and Cuesta Trench T-3. The ESCNC fault investigation report indicated that if the low-angle thrust fault was found, it could be more accurately projected across the site. ESCNC also recommended excavating two trenches in the southern part of the property (in the vicinity of Lots 31 and 34) to evaluate whether the two secondary fault splays are present in these locations.

Purpose and Scope of Work

The purpose of this supplemental fault investigation was to excavate a trench to locate the low-angle thrust fault identified in the northern end of Cuesta Trench T-3 (PG&E 1988) and to excavate two trenches in the southern part of the site to locate the two secondary fault splays, pursuant to the conditions of approval for the tentative tract map 2270.

Our scope of services consisted of the excavation of 5 trenches totaling approximately 640 lineal feet of trench, interpretation and evaluation of the exposed subsurface conditions, and

the preparation of this report. This report is intended to provide supplemental geologic information to the ESCNC "Fault Investigation Report" dated March 11, 1998.

2.0 FIELD INVESTIGATION

The trench exploration began on November 15, 1999 and was completed on November 18, 1999. Trench 2 was sited approximately 440 feet southeast of ESCNC Trench 1 and 290 feet northeast of Cuesta Trench T-3 (see Appendix A, Geologic Site Map). Trench 3 was located at the boundary to Lots 31 and 32. Trenches 4 and 5 were located near the southeastern boundary of Lot 32 (see Geologic Map). The trenches were excavated with a backhoe using a 36-inch wide bucket. The depth of the trenches varied from 6 to 11 feet. Shoring was used to support the trench side walls during logging and mapping. After the logging of the side walls was completed, the trench was backfilled with on-site soils. The soils were backfilled with little or no compactive effort.

3.0 GEOLOGIC UNITS

Colluvium (Holocene)

The colluvium soil unit (Unit 1) was encountered at or near the ground surface. Geomorphically, with respect to the southern edge of Los Osos Valley and the general site vicinity, this soil unit is similar, particularly in age, to the colluvium soil unit in PG&E Cuesta Trench T-3. Unit 1 is a dark gray to black sandy fat clay that varied in thickness from 2 to 5 feet. It was stiff, dry to moist, exhibited numerous expansion cracks that varied from 1/8-inch wide to 1/2-inch wide. The colluvium was the youngest soil unit encountered at the site. PG&E dated a charcoal sample found in this soil, with age dates ranging from 1,840 to 2,516 years old. The sample was taken from the Cuesta Trench T-3 at a depth of 2 feet, near Station 8+90 feet.

6.0 CONCLUSIONS

There was no evidence in Trench 2 that would suggest the presence of active faulting within the proposed building areas in the northern part of the site. The colluvium soil (Unit 1) was generally horizontal, continuous, and unbroken. This soil is similar in age and stratigraphically to the soil unit on which PG&E based their findings for Holocene fault activity in Ingley Trench T-2 (see Appendix B, Ingley Trench T-2). The low-angle thrust fault near the northern end (Station 2+95) of Cuesta Trench T-3 was found in our Trench 2 at Station 2+25. As the fault in each of the trenches were found to be at an equal elevation (elevation 163 feet), the strike the fault was determined by connecting ground surface point of each fault (Dennison, 1966). The outcrop pattern of the fault was then plotted graphically across the site (see Geologic Site Map). The outcrop pattern of the fault crosses ESCNC Trench 1 at Station 10+10, where younger alluvium is present. The age of the younger alluvium was dated (ESCNC, 1998) to be approximately 11,650 years old. No evidence of faulting was observed in this part of Trench 1, therefore, it is concluded that the low-angle thrust fault near the northern end (Station 2+95) of Cuesta Trench T-3 is not an active fault and that the fault predates the younger alluvium. The gravelly colluvium zone that was observed on the hanging wall of the fault in Trench 2 probably developed post-faulting. The fault scarp may have caused differential erosion, consisting of scouring of the older alluvium and mixing with slope wash soils. The gravelly colluvium zone may also have been the results of soil over-turning due to seasonal expansion and contraction of the clay-rich colluvium.

The secondary low-angle thrust fault trace at Station 1+60 in Cuesta Trench T-3 was also observed in Trench 2 at Station 1+05. The strike and outcrop pattern of this fault were graphically plotted on the Geologic Site Map (see Appendix B). The plotted trace of the fault crosses Trench 1 at Station 9+00 where younger alluvium is present. No evidence of

faulting was observed in this part of Trench 1, indicating that the fault movement pre-dates the younger alluvium.

The high-angle fault PG&E mapped in Cuesta Trench T-3 appears to trend south of our Trench 2, as no evidence of this fault was observed. This fault is also plotted on the Geologic Site Map; however, the presence of this fault west of Trench 2 is queried. No evidence of this fault was observed in Trench 1. The projected trace of this fault intercepts Trench 1 at Station 7+70. At Station 7+70, a clay-filled shear is present. The shear offsets Franciscan metavolcanic rock to the south against Franciscan claystone to the north and is an intra-formational fault, unrelated to the high-angle fault in Cuesta Trench T-3.

The two faults in the southern part of the site that cross Lots 31, 32, and 33 are not active faults. However, the trend of the these faults were found to be slightly different than the fault trends mapped by Hall and Prior (1975). The faults are spaced more closely together and appear to trend more parallel to each other (see Geologic Site Map).

7.0 RECOMMENDATIONS

The faults encountered on the subject site were determined to be Pleistocene to late Pleistocene age, which are not considered to be active, as defined by the State. Although these faults are not active, there is a potential for differential (horizontal and vertical) movement and ground cracking to occur along these faults during strong ground shaking from and earthquake event. Therefore, it is recommended that the building foundations be set back from each fault. The intra-formational faults or shear features observed within the Franciscan rock complex are considered to be inactive due to the late Jurassic-Cretaceous age of the rocks and the absence of broken or disturbed colluvium soil overlying these rocks. Therefore, no building setback is recommended for these faults. Because these are probably

non-tectonic fault features, proposed buildings may straddle these faults, as differential movements along these faults will be negligible.

The building setback distance was determined using the following criteria described below.

Dip Angle of the Fault

Compared to a vertical or high-angle fault, faults with low dip angles, such as thrust faults, have a wider zone of deformation due to the potential for compressional shears to develop in the hanging wall block. These compressional shears can occur several feet or more away from the secondary antithetic fault zone. If these shears are present they are considered to be part of the fault zone and buildings are set back from the most distal shear. The secondary antithetic thrust faults observed on the subject site appear to have relatively narrow zones of deformation, with some minor flowering of the fault just below the colluvium soil. No compressional shears were observed adjacent to the fault zones during the field investigation.

Activity of the Los Osos Fault

The level of activity on the Los Osos Fault is significantly lower compared to the activity level on the active San Andreas Fault, located 43 miles northeast of the site, and the Hosgri Fault, located 12 miles west. A 6.8 maximum moment magnitude occurring on the Los Osos Fault has a recurrence interval of about 1,925 years, while the recurrence interval for a 7.3 moment magnitude earthquake on the Hosgri Fault is 646 years and 206 years for a 7.8 moment magnitude earthquake occurring on the 1857 rupture zone of the San Andreas Fault (CDMG Open File Report 96-08). The recurrence interval for the secondary antithetic thrust faults on site is much longer because they may not move during every earthquake event that occurs on the main trace of the Los Osos Fault. This was evident in Trench 1 where the two thrust faults observed in our Trench 2 and Cuesta Trench T-3 did not break (11,000+years old) younger alluvium in Trench 1. Based on this information, the recurrence interval for these faults would be more than 11,000 years.

Level of Risk

If one of these secondary antithetic thrust faults did move, it is estimated that horizontal and vertical displacements would be minor (<12 inches) compared to displacement along the main trace of the Los Osos fault. Building foundations may experience minor damage if ground displacement occurs, but loss of life would be unlikely. Also, due to the long recurrence interval of these secondary faults, there is a very low potential for ground surface fault rupture to occur during the 75-year design life of the proposed development.

Recommended Setbacks for Habitable Structure

Based on the above criteria, it is recommended that buildings be set back a minimum of 25 feet from secondary antithetic thrust fault on the hanging wall block (up-thrown), which would be the downslope or north side of the fault, and 10 feet on the foot wall (down-thrown) (see Geologic Site Map). As a comparison to the above recommended building setbacks, Salt Lake County in Utah has implemented a standardized method for calculating building setbacks for thrust and reverse faults (Balatian and Nelson, 1999). The method consists of the equation $S = U(2D+F/\tan q)$ that is used to determine the required setback (S) on both the hanging wall and footwall of the fault, where U = criticality factor (1.5 for single family residences and 2.0 for commercial buildings), D = expected displacement on the fault, F = footing depth, and q = dip of the fault. Using the following estimated site parameters of U = 1.5, D = 0.833 feet, q = 47 degrees, F = 3 feet, the equation yielded a building setback of 6.7 feet.

For the high-angle fault that crosses Lots 31, 32, and 33, and the queried high-angle fault observed in the southern end of Cuesta Trench T-3 buildings should have a minimum setback of 10 feet on each side of the fault (see Geologic Site Map). It also recommended that an engineering geologist observe footing excavations in the vicinity of the mapped faults to confirm their location.

GEOLOGIC AND SOILS STUDY
DE VAUL RANCH
MADONNA AND LOS OSOS VALLEY ROADS
SAN LUIS OBISPO, CALIFORNIA

October 7, 1997

1.0 INTRODUCTION

The De Vaul Ranch property is the proposed site of a residential subdivision, apartment complexes, and a public park. One-hundred sixty-two single family residential lots will be created, along with 16 zero-lot-line residential lots (patio homes), large parcels for apartment complexes, and a public park. The property encompasses a total of about 112 acres; 56 of these acres will be developed and the remainder will be dedicated to the City of San Luis Obispo following annexation.

Approximately 8.8 acres at the corner of Madonna and Los Osos Valley Roads will be the site of the proposed apartment complexes. The zero-lot-line patio homes will be located immediately to the south of the apartment complexes. The remaining lots will be designated as custom single-family residential homesites. These lots extend to the south from the patio homes, and to the west across the proposed extension of Madonna Road. For the purpose of this report, it is assumed that all of the structures will be one to three stories, of wood-frame construction and will utilize slabs-on-grade and/or suspended wood floors. Maximum loads on continuous foundations of 2 kips per foot and maximum loads on spread footings of 10 kips were assumed.

Additional improvements planned as part of the project include the construction of several interior roads providing access from Los Osos Valley and Madonna Roads, two drainage basins, and a neighborhood park.

2.0 SCOPE OF SERVICES

As annexation into the City of San Luis Obispo is proposed, an Environmental Impact Report (EIR) is required by the City. According to the City's Request for Proposals (RFP) for the EIR, as amended by subsequent discussions and correspondence, the following scope of work for the geologic engineering study was determined:

a. Identification of the likelihood of a fault at the base of the Irish Hills and identification of all active faults in the area and the potential magnitude of seismic events on each of the identified faults. Discussion of the impacts of geologic conditions on the proposed development.

TABLE 1
ACTIVE FAULTS

Fault Name	Distance to Nearest Point of Fault (miles)	Maximum Magnitude (Mw)	Esitmated Peak Ground Acceleration (g)	
			Mean	84th Percentile
Hosgri	13	7.30	0.28	0.47
Los Alamos	38	6.80	0.10	0.17
Los Osos	0	6.8	0.63	1.07
San Andreas (Parkfield)	40	6.7	0.09	0.15
San Andreas (Carrizo Plains)	38	7.2	0.12	0.20

7.0 SUBSURFACE EXPLORATION

Two programs of subsurface exploration were undertaken as part of this study. The first was a series of trenches that were excavated in the proposed development areas. The purpose of the trenches was to determine if any potentially fault-related features could be discerned in the areas slated for development. The second type of exploration conducted consisted of soil borings. The purpose of the borings was to further define subsurface soil conditions with respect to geotechnical engineering properties, and to acquire samples for laboratory analysis. The results of the subsurface exploration and laboratory analysis formed the basis of conclusions with respect to the soil and geologic impacts that are expected to be associated with the project.

Trench Exploration

On July 16, 1997 through July 19, 1997, Trenches 1 through 6 were excavated within the proposed development areas. The trenches were excavated with a backhoe equipped with a 24 inch wide bucket to an average depth of 10 feet. The lengths of the trenches varied from 30 feet to

200 feet. The trend of the trenches was approximately north 57 degrees east, which is roughly perpendicular to the mapped trend of the Los Osos fault. The profiles of the exploratory trenches can be found in Appendix B; their approximate locations are shown on the Boring and Trench Location Map, also in Appendix B.

The trench locations were selected to determine if the known or suspected fault-related features described earlier extend into the planned development areas. Trenches 1 through 4 were excavated in the southwestern part of the site to assess whether a secondary fault trace off the main branch of the Los Osos fault, as mapped above elevation 150 MSL by Hall and Prior (1975), extends into the planned development area.

Trench 5 was excavated to explore a tonal/topographic lineament that was observed in the field during our site reconnaissance. Trench 6 was excavated to determine if a vegetation lineament mapped by PG&E (1988) near the center of the proposed development was a fault-related feature.

All of the six trenches excavated on the valley floor generally revealed a sequence of stratified soil units. The upper soil consisted of a dark gray silty clay topsoil that was underlain by mottled yellow brown and olive brown silty fine sand with clay (alluvial deposits) or a dark reddish brown, organic rich, silty clay (buried topsoil). The contact between the alluvial deposits and the surface or buried topsoil units was generally gradational. The buried topsoil unit and the underlying alluvial deposit sequence was repeated at least twice in Trenches 1, 2, 3, 5 and 6. The soil layers ranged in thickness from 6 inches to 2 feet and were, for the most part, continuous, unbroken and horizontal.

It should be noted that while the soil units varied only slightly in color and texture, twelve soil units were logged to document the minor soil differences observed in the alluvium. Detailed descriptions of the soil units encountered are presented in the Trench Profiles in Appendix B.

The soil units exhibit structures and contact relationships which suggest that they were deposited as alluvial "overbank" flood plain deposits by low energy currents of the ancestral Prefumo Creek. Occasional buried channels were observed which consisted of unconsolidated, light brown sandy gravel. These channels were often discontinuous and irregularly shaped.

The sidewalls of Trench 4, which was excavated near the southern margin of the valley floor, exposed a dark gray silty clay topsoil underlain by a dark reddish brown sandy clay residual soil that is believed to be remnants of decomposed metavolcanic rock. Near station 40+00, the residual soil transitions to a dark reddish brown silty clay soil. It is believed that this localized soil transition is the result of the two soils mixing due to the past erosion and deposition that occurred in this area.

Recent channel deposits consisting of sandy clay with gravel were encountered at the ground surface of Trench 5. These deposits extended from Station 0+00 to Station 23+00, where they pinched out laterally.

A one foot thick layer of sandy clay fill was encountered at the surface of Trench 3. The fill continued across the entire length of the trench. Also in Trench 3, the silty sand with clay graded out laterally and was not discernible beyond Station 21+00.

Trench 6 consisted of a uniform, horizontal sequence of topsoil underlain by clayey fine sand. This soil profile was repeated twice in the trench. A charcoal sample was collected at a depth of 7.5 feet in the dark reddish brown silty clay soil. The sample was age-dated using the accelerated mass spectrometry (AMS) method. The results of the AMS dating indicated the soil at 7.5 feet originated approximately 2,290 years (± 40 years) before present (Holocene age). This soil date generally correlates with a soil date of 2,516 before present (Holocene age) from the PG&E Cuesta Trench T-3. The PG&E trench was located south of Los Osos Valley Road approximately 1 mile west of the site, in the same alluvial valley. The PG&E soil sample was taken at an approximate depth of 6 feet where distinct fault traces of the Los Osos fault were observed and mapped.

In a further effort to locate and define the trace of the fault as mapped in the hills above the site by Hall and Prior (1975) additional exploratory trenches were excavated on August 5, 1997. These trenches were designated as Trenches 7 and 8.

No evidence of faulting was observed in Trench 7. The sidewalls of Trench 7 exposed approximately 18 inches of a dark gray silty clay topsoil underlain by a dark reddish brown

fractured, moderately hard metavolcanic rock. At Station 32+00 a 1/4" thick clay filled fracture was observed. The fracture is not fault related but may have been caused by stress from the Los Osos fault or was formed during intraformational processes.

Fault related features were observed in several areas within the 200-foot length of Trench 8. Two distinct northwest trending fault planes were observed; one at Station 0+13 and the other at Station 0+20. The fault planes were approximately 1 to 2 inches wide and consisted a dark reddish brown sandy clay. The clay is decomposed metavolcanic rock that has been altered as result of the fault movement. The fault planes did not extend up into the overlying topsoil layer. They are related to strike-slip and/or reverse movement; no evidence of the underlying thrust fault was found. On the north side of the fault plane at Station 0+20, the bedrock was distinctly harder, more competent and had a blocky structure. Similar fault planes were observed at Stations 0+85 and 1+82. Highly sheared zones were observed at Stations 0+70 and 1+10.

Soil Borings

On July 24, 1997, five borings were drilled at the site using a Mobile Drill rig, model B-53, equipped with an 8-inch outside diameter hollow stem auger. The approximate locations of the borings are shown on the Boring and Trench Location map in Appendix B.

Soils encountered in the borings were categorized and logged in general accordance with the Unified Soil Classification System (ASTM D 2488-93). Logs of the borings are presented in Appendix B. As the borings were drilled, soil samples were obtained using a ring-lined barrel sampler (ASTM D 3550-84, with shoe similar to D 2937-94). Also, as the borings were drilled, standard penetration tests were performed (ASTM D 1586-84/92). Bulk soil samples were obtained from the auger cuttings.

The borings revealed profiles consisting predominantly of sandy lean clay and sandy fat clay. The clay was in a stiff to very stiff condition, and contained occasional gravels. In Boring 3, a layer of clayey sand with abundant gravel was encountered between the depths of 4 and 8 feet. In Boring 5, a layer of loose, well-graded sand was found at a depth of 18 feet, between layers of sandy lean clay. The well-graded sand extended to a depth of 21 feet.

Primary Earthquake Effects

At this time, the site is not located within an Earthquake Fault Zone. There was no physical evidence in any of the trenches that would suggest the presence of faulting within the proposed development area. Soil layers were generally horizontal, continuous and unbroken except in Trench 8 (outside the proposed development area), where evidence of strike-slip and/or reverse faulting was observed. No evidence of the underlying thrust fault was encountered in any of the trenches.

The vegetative lineament that was mapped on site by PG&E (1988), the secondary fault trace mapped by Hall & Prior (1975), and the tonal/topographic lineament observed during our site reconnaissance were found to be unrelated to faulting. These features were due to surficial differential erosion, which caused different soil types to be deposited against each other.

The fault features observed and mapped by PG&E in the Cuesta Trench T-3 displaced sediments believed to be approximately 2,500 years old. Based upon the soil age date of approximately 2,300 years collected at 7.5 feet in Trench 6 on the subject site, it is estimated that the soils at the bottom of the trenches excavated on the subject site in the alluvial valley are at least 3,000 years old. In view of the continuous and unbroken condition of these soils, and that the age of the soils encountered on the subject site pre-date the soils encountered by PG&E, it is concluded that the fault features mapped by PG&E do not extend into this area.

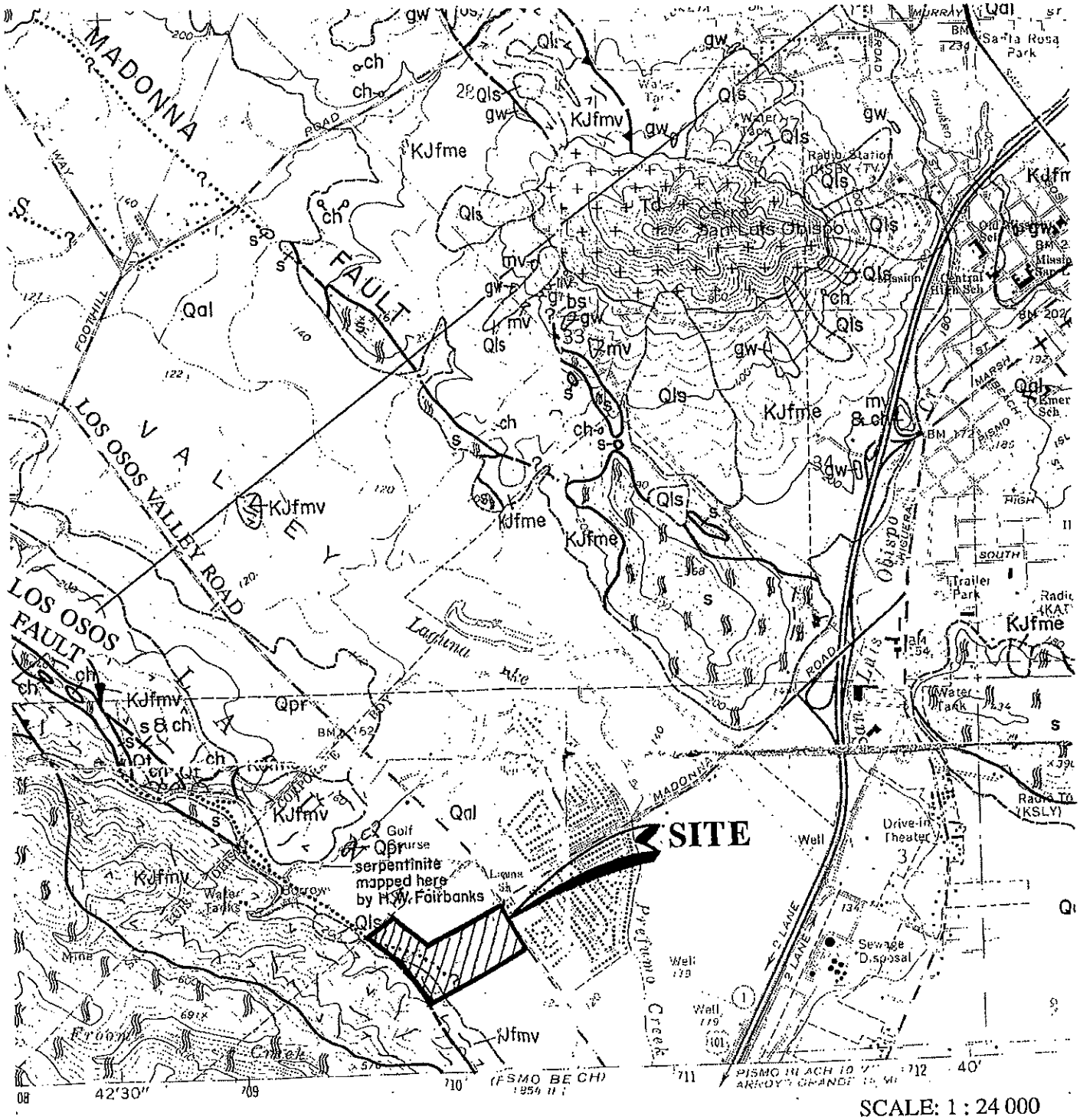
Fault-Related Ground Rupture. Based upon the above, no active faults are known to cross or be immediately adjacent to the proposed development area; however, a thrust fault could underlie the site. If one does, it probably would daylight (or come very near the surface) near Los Osos Valley Road, or off-site to the north. No visual evidence of a thrust fault daylight line was observed anywhere on the site. Therefore, based upon the current level of knowledge, the potential for fault-related ground rupture in the proposed building areas is considered to be low.

Ground Shaking. Ground shaking from a seismic event is the primary seismic hazard that will have the greatest impact on proposed structures within their designed life span.

GEOLOGIC MAP

DeVAUL RANCH

Los Osos Valley Road and Madonna Road
San Luis Obispo County, California



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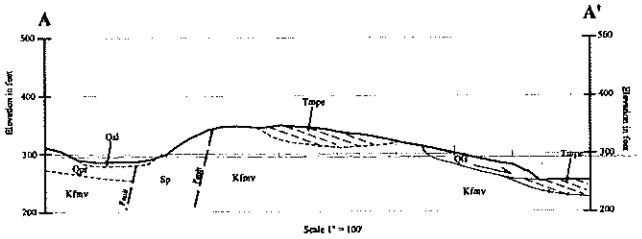
Earth Systems Consultants
Northern California

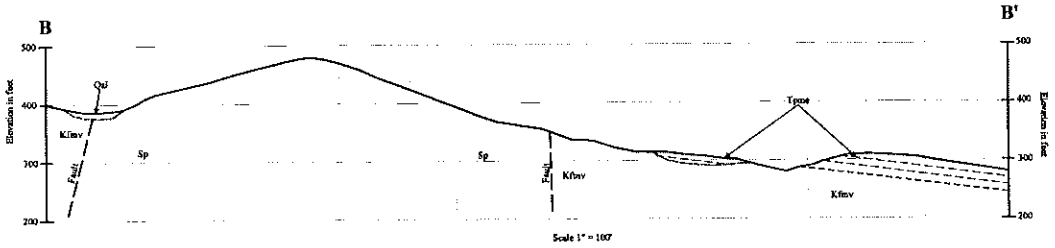
4378 Sant Fe Road, San Luis Obispo, CA 93401
(805) 544-3276 (805) 5441786 FAX

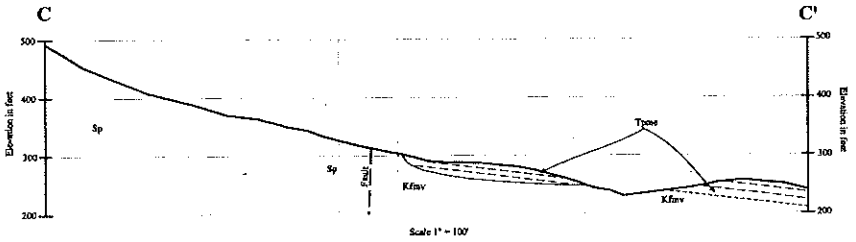
August 12, 1997 EC NGS10623-01

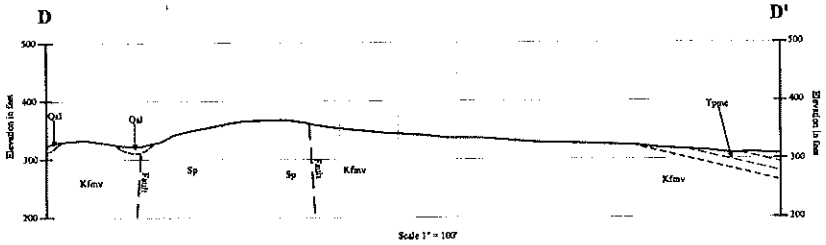
GEOLOGIC CROSS SECTIONS A THROUGH E

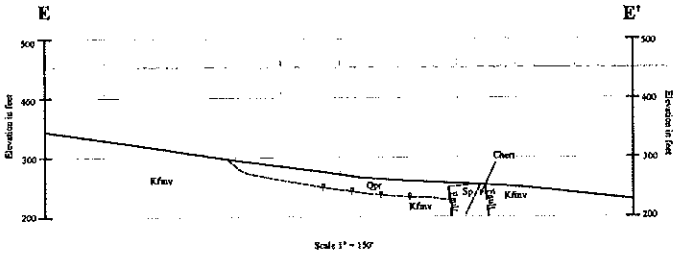
HIGHLAND RANCH
7515 LOS OSOS ROAD
SAN LUIS OBISPO, CALIFORNIA











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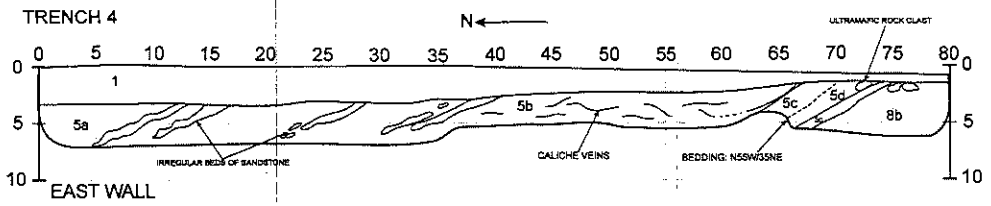
SL - 15624-GA

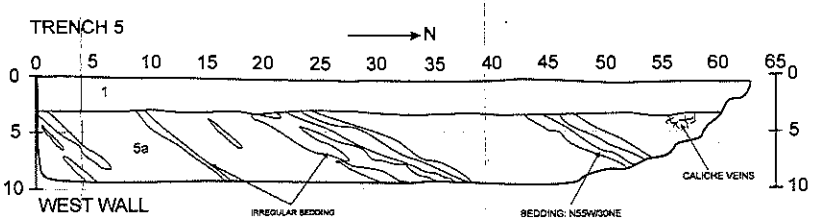
September 2008

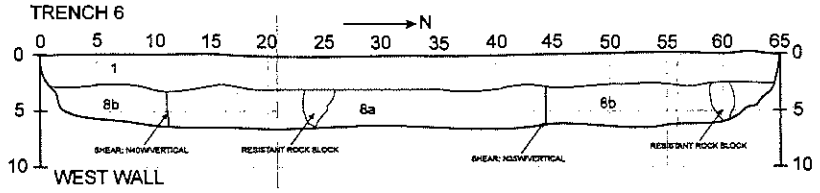
TRENCH LOG

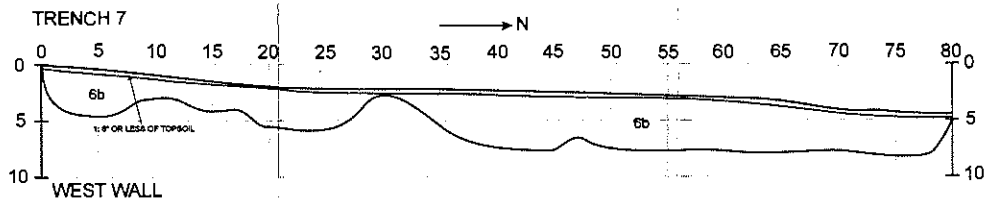
HIGHLAND RANCH FAULT INVESTIGATION

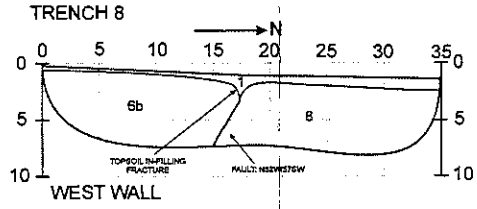
7515 Los Osos Valley Road
San Luis Obispo County, California

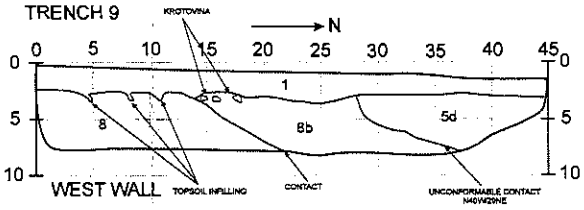












EXPLANATION

1) Topsoil: SANDY FAT CLAY, dark brown to black, stiff, moist, trace gravel to 1.0" diameter

5) Pismo formation, Edna member: SANDSTONE, olive gray, soft, moist, very poorly indurated
- 5a) SANDSTONE, reddish brown, very soft, moist, fine to medium grained, weathered, very poorly to moderately indurated, massive
- 5b) SANDSTONE, tan, soft, moist, irregular bedding, chaotic, some caliche veins and nodules, gravel and cobble size clasts
- 5c) CONGLOMERITIC SANDSTONE, buff to white, moderately hard, moist, moderately to well indurated, fine to coarse grained
- 5d) CONGLOMERITIC SANDSTONE, light brown, moderately hard, moist, poorly indurated

6) SERPENTINITE, brown/green/black/yellow mottled, soft, moist, severely fractured and weathered, sheared
- 6a) SERPENTINITE, olive green/ gray mottled, moderately hard, fractured, sheared
- 8b) SERPENTINITE, blue gray, hard, slightly moist, fractured and weathered

8) Franciscan melange: METAVOLCANIC ROCK, reddish brown, moderately hard, mosit, severely weathered and fractured
- 8a) METAVOLCANIC ROCK, light brown, moderately hard, slightly moist, severely fractured
- 8b) METAVOLCANIC ROCK, olive brown, soft, moist, severely sheared, weathered, slickened sides

0 5 10 15 20

SCALE: 1" = 5'

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August 2008

SL-15624-GA

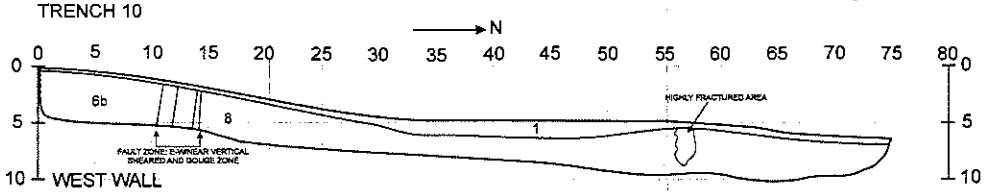
TRENCH LOG

HIGHLAND RANCH FAULT INVESTIGATION

7515 Los Osos Valley Road

San Luis Obispo County, California

TRENCH 10



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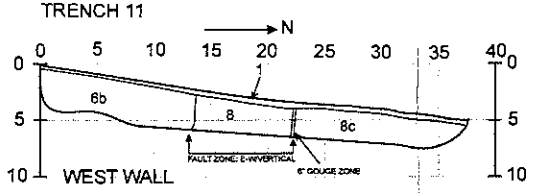

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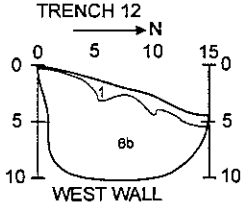

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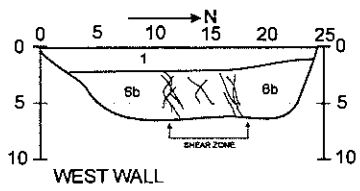

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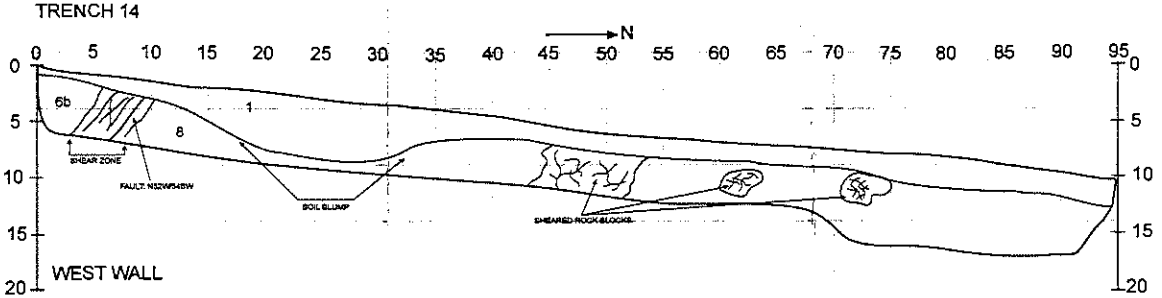

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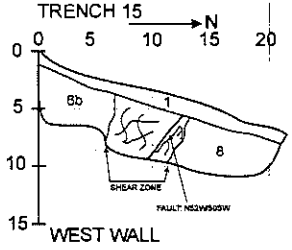

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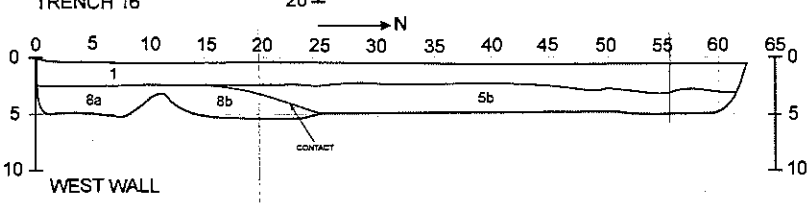

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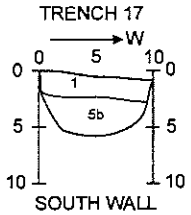

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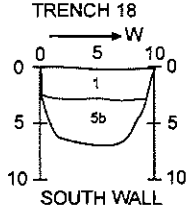

EXPLANATION

1) Topsoil: SANDY FAT CLAY, dark brown to black, stiff, moist, trace gravel to 1.0" diameter

5) Pismo formation, Edna member: SANDSTONE, olive gray, soft, moist, very poorly indurated
   5b) SANDSTONE, tan, soft, moist, irregular bedding, chaotic, some caliche veins and nodules, gravel and cobble size clasts

6) SERPENTINITE, brown/green/black/yellow mottled, soft, moist, severely fractured and weathered, sheared
   6a) SERPENTINITE, olive green/ gray mottled, moderately hard, fractured, sheared
   6b) SERPENTINITE, blue gray, hard, slightly moist, fractured and weathered

8) Franciscan melange: METAVOLCANIC ROCK, reddish brown, moderately hard, mosit, severely weathered and fractured
   8a) METAVOLCANIC ROCK, light brown, moderately hard, slightly moist, severely fractured
   8b) METAVOLCANIC ROCK, olive brown, soft, moist, severely sheared, weathered, slickened sides
   8c) METAVOLCANIC ROCK, olive to reddish brown, soft, moist, severely sheared and weathered

0 5 10 15 20

SCALE: 1" = 5'

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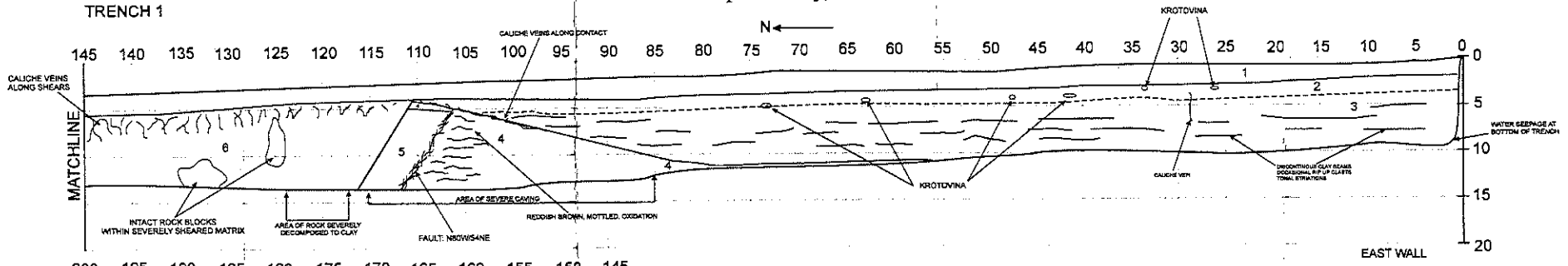
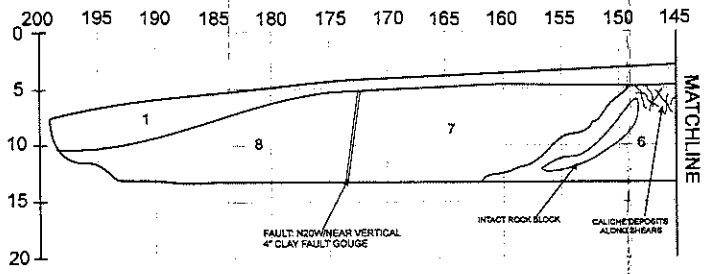
TRENCH LOG

HIGHLAND RANCH FAULT INVESTIGATION

7515 Los Osos Valley Road
San Luis Obispo County, California

TRENCH 1





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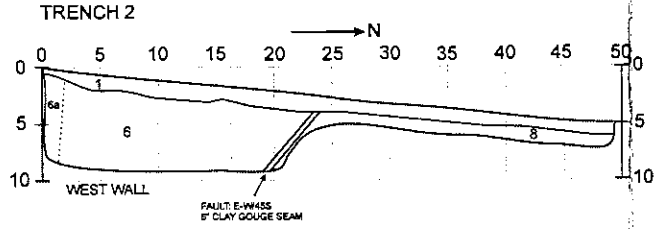

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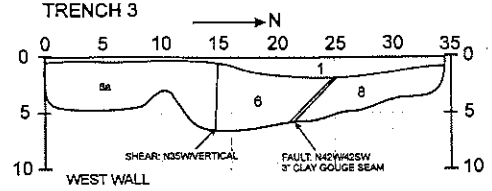

EXPLANATION

1) Topsoil: SANDY FAT CLAY, dark brown to black, stiff, moist, trace gravel to 1.0" diameter

2) Paso Robles formation: SANDY CLAYSTONE, brown, stiff, moist, trace gravel to 1.0" diameter, abundant claiche deposits, veins, streaks, and nodules

3) Paso Robles formation: CLAYEY SANDSTONE WITH GRAVEL, orange brown/gray brown mottled, dense, moist, gravel to 1.0" diameter

4) Paso Robles formation: CLAYSTONE: olive gray, soft, moist, sheared, slickened sides

5) Pismo formation, Miguelito member: SANDSTONE, olive gray, soft, moist, very poorly indurated

6) SERPENTINITE, brown/green/black/yellow mottled, soft, moist, severely fractured and weathered, sheared
6a) SERPENTINITE, olive green/ gray mottled, moderately hard, fractured, sheared

7) SILICA-CARBONATE ROCK, olive green, moderately hard, moist, fractured

8) Franciscan melange: META-VOLCANIC ROCK, reddish brown, moderately hard, mosit, severely weathered and fractured

0 5 10 15 20
SCALE: 1" = 5'

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SL-15624-GA

GeoSolutions, INC.

220 High Street, San Luis Obispo, CA 93401
(805) 543-8539, 543-2171 fax
info@GeoSolutions.net

January 27, 2000
Project No. SL01321-2

Mr. Richard Komorowski
H.M. WEST BUILDERS
484 Mobil Avenue, Suite 19
Camarillo, CA 93010

SUBJECT: **Geologic Fault Investigation**
Irish Hills Development
Los Osos Valley Road and Madonna Road
San Luis Obispo Area of San Luis Obispo County, California

Dear Mr. Komorowski:

INTRODUCTION

In accordance with our proposal dated December 10, 1999 we have conducted a subsurface fault investigation of the approximate 13 acre parcel located approximately 500 feet southeast of the intersection of Los Osos Valley Road and Madonna Road in the San Luis Obispo Area of the County of San Luis Obispo, California. Figure 1 is a Site Location Map that identifies the location of the property. Figure 2 is a map indicating preliminary building lots and the location of fault trench excavated for this study. It is our understanding that the property is to be developed with single-family homes and condominiums.

The purpose of the investigation was to determine if the Los Osos fault or a splay of the Los Osos fault is present within the southern half of the development area. During reference review of a professional paper by Lettis and Hall, 1994, a vegetation lineament (possible fault splay) of the Los Osos fault is suggested in the southern half of the proposed development, see Figure 3, Geologic Map. Due to the inference of this lineament, a fault trench was excavated to confirm the absence or presence of the Los Osos fault at the inferred location postulated by Lettis and Hall.

Our scope of services consisted of managing excavation activities and graphically logging one, 505-foot long trench and preparing a description of the geologic units and geologic features observed within the fault trench. The trench was oriented in southwest-northeast direction (N60E), perpendicular to the general east-west trend of the Los Osos fault. The trench was excavated during the period from January 10, 2000 through January 14, 2000 by a tracked excavator to an average depth of 15 feet below ground surface.

FAULTING

Studies performed by P.G. & E. (1988) and Lettis and Hall (1994) indicate that the Los Osos Fault Zone is a northwest trending zone of high and low angle faults that exhibit a complex history of both strike slip and reverse displacement. The Los Osos Fault Zone is divided into four distinct segments. From the northwest to the southwest they are the Estero Bay, Irish Hills, Lopez Reservoir, and Newsom Ridge segments. The Site is located near the Irish Hills segment. P.G. & E. suggests that the Irish Hills segment displays the most well expressed geomorphic features displacing late Pleistocene and Holocene deposits. A portion of the Irish Hills segment, located approximately 6,000 feet northwest of the Site, is considered "active" and has been included as an Alquist-Priolo Earthquake Fault Zone by the State of California. Figure 4, Earthquake Fault Zone Map, depicts the location of the active Los Osos Fault Zone documented by the State of California. A Maximum Credible Earthquake of 7.0 magnitude and a Maximum Probable Earthquake of 5.3 magnitude is associated with the fault.

At the base of Irish Hills, approximately 450 feet south of the southern property boundary, Lettis and Hall mapped a topographic scarp associated with the Los Osos fault. This topographic scarp and the vegetation lineament at the Site are depicted on Figure 3.

GEOLOGIC UNITS

The subsurface trenching investigation was completed into Holocene age (last 10,000 years before present) alluvium deposits. Dibblee, 1974 and Hall and others, 1979 classify these alluvial deposits as consisting of cobbles, pebbles, gravel, sand, silt, and clay. Thickness of this unit at the Site is unknown but Hall, 1973 depicts a 90-foot thickness on a stratigraphic column on his geologic map. The trenching investigation exposed only alluvial deposits. Stratigraphically underlying the alluvial deposits are Franciscan rocks consisting of greywacke sandstone, sheared shale, blueshist, and metavolcanic rocks. Franciscan rocks are Cretaceous to Jurassic age (63 million to 205 million years before present) and are estimated to be thousands of feet thick. Groundwater was measured at a depth of 25.2 below ground surface within a water well located on Site.

Subunits within the alluvial deposit were mapped and are depicted on a series of trench logs, Figure 5A through 5G. The upper one to three feet of surface soil consisted of dark brown, dry, silt and dark brown silty clay. Below the surface soil, a three- to four-foot thick, brown sandy silt was encountered in a moist condition. Below this, a 1.5-foot thick, dark brown clay was used as a "marker" or locator bed throughout most of the trench length. Except for one location (to be discussed below), this unit was consistent in thickness and lithology. Below the marker bed, a three- to five-foot thick brown, moist, clayey silt was encountered. Conspicuous within this unit, were lenses of cobbles, gravel, and sand most likely deposited as fluvial channel deposits. An approximate one-foot thick, dark brown clay and a thicker, brown silt comprised the bottom of the trench.

A fluvial channel feature was mapped in the vicinity of the 253 foot to 300 foot interval within the trench. The channel was approximately 50 feet wide at the top and tapered with depth to approximately 5 feet wide. This deposit was loose and was comprised of gravels, sand, cobbles, and minor silts. The dark brown clay marker bed was observed draped within one side of this channel indicating fast deposition of the coarse deposits. The bottom of the channel was located to verify depth.



DISCUSSION

Prior to excavation activities at the Site, surface topography exhibited a very slight depression in the middle section of the (then) proposed fault trench. It was postulated that this surface depression correspond to the vegetation lineament published on the Lettis and Hall, 1994 geologic map. Subsequent to trench excavation, the surface depression was found to correlate with the fluvial channel feature observed in the vicinity of the 253- to 300-foot trench interval. Loose, subsurface channel deposits at this location may have consolidated through time causing a slight surface depression. In addition, the coarse channel material may have allowed increased groundwater movement in this area creating increased vegetation growth or a "vegetation lineament" as observed on the Lettis and Hall's 1994 geologic map.

Within the fault trench, no faulting characteristics were observed. There was no offset bedding and no folding indicating subsurface stress from below. No caliche (calcium carbonate deposited by groundwater) was associated with the trench. Caliche is sometimes fills voids within fault-disturbed sediments or rocks.

GeoSolutions, Inc. is in the process of completing an Engineering Geology Investigation and Soil Engineering Investigation at the Site. These studies will include subsurface drilling results to depths of 50 feet below ground surface and will allow for quantification of subsurface conditions. GeoSolutions, Inc. will monitor drilling operations for indications of changing subsurface conditions other than those found within the fault trench.

CONCLUSIONS

A 505-foot long trench was excavated within Holocene (last 10,000 years) alluvial deposits at the south end of the proposed Irish Hills Development. The Development consists of approximately 3.8 acres of vacant land located approximately 500 feet southeast of the intersection of Los Osos Valley Road and Madonna Road in the County of San Luis Obispo, California. The purpose of this investigation was to verify the absence or presence of the Los Osos fault in the southerly portion of the Site. A geologic map published by Lettis and Hall, 1994 depicts a vegetation lineament through the southwest portion of the Site. The Lettis and Hall publication suggests the vegetation lineament could be a splay of the active Los Osos fault.

No evidence of faulting was identified within a 505-foot long fault trench excavated at the Site. The length of the fault trench more than adequately investigated any possibility of the presence of a fault at the Site suggested by Lettis and Hall, 1994. The vegetation lineament published on the Lettis and Hall, 1994 map coincides with a subsurface, sedimentary channel feature in the vicinity of the 253- to 300- foot trench markers. It is our opinion that the vegetation lineament from the Lettis and Hall, 1994 geologic map indicates a subsurface sedimentary channel feature and not a splay of the Los Osos fault.

It is recommended that an Engineering Geologist periodically review grading operations to observe subsurface conditions at the Site.

Thank you for this opportunity to have been of service. If you have any questions regarding content of this letter, please contact this office at your convenience.

Sincerely,
GeoSolutions, Inc.

John M.D. Kammer
Project Engineering Geologist

REGISTERED GEOLOGIST
JOHN M.D. KAMMER
NO. 2118
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

Richard A. Pfost
Senior Engineering Geologist

REGISTERED GEOLOGIST
RICHARD A. PFOST
No. CEG1281
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

REFERENCES

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Lettis, William R., and Hall, N. Timothy, 1994, Los Osos fault zone, San Luis Obispo, California, in Seismotectonics of the Central California Coast Ranges, Geological Society of America Special Paper 292, 1994

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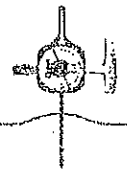

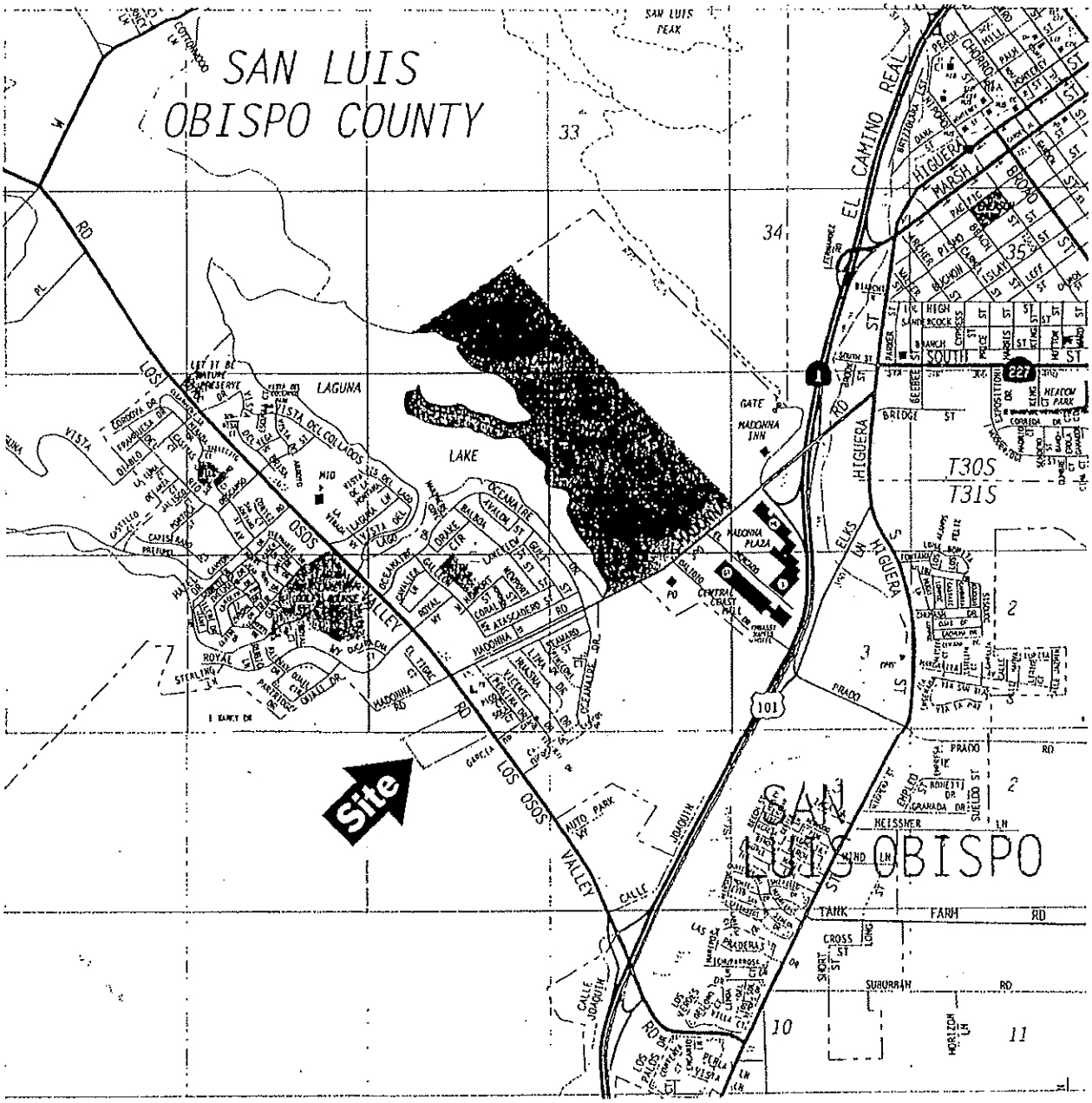

1999 Thomas Bros. Maps Guide

GEOSOLUTIONS, INC.
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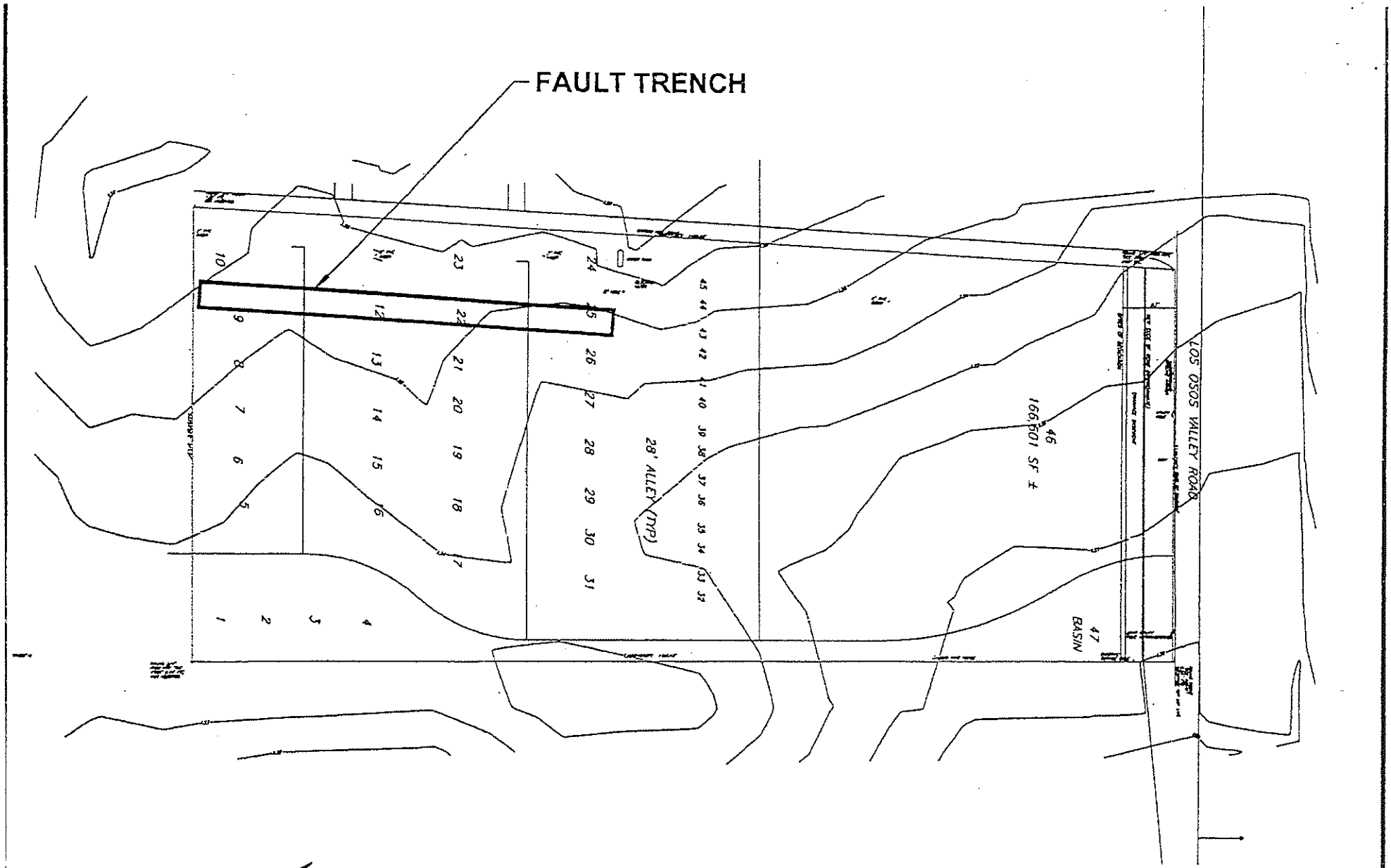
(805) 543-8539 FAX: (805) 543-2171

AREA LOCATION MAP

IRISH HILLS DEVELOPMENT
SAN LUIS OBISPO, CALIFORNIA

FIGURE:
1

PROJECT:
SL01321-2



SCALE: 1" = 160'

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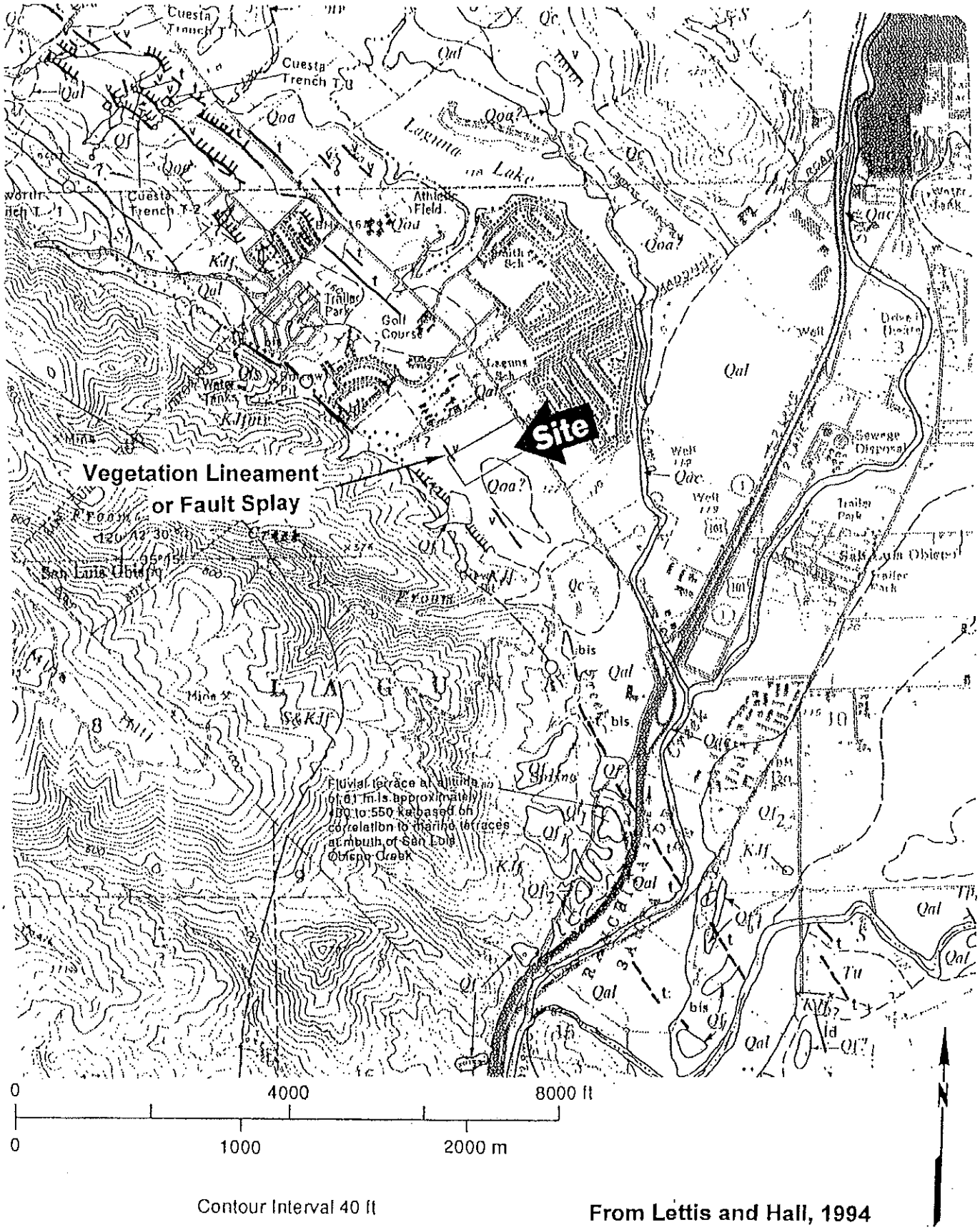
SITE MAP

IRISH HILLS DEVELOPMENT
SAN LUIS OBISPO, CALIFORNIA

FIGURE: 2

PROJECT: SL01321-2



Contour Interval 40 ft

From Lettis and Hall, 1994

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GEOLOGIC MAP

IRISH HILLS DEVELOPMENT
SAN LUIS OBISPO, CALIFORNIA

FIGURE:
3A

PROJECT:
SL01321-2

MAP SYMBOLS

Fault — Dashed where approximately located; dotted where concealed; U = up/D = down indicates relative sense of displacement; small arrow and number indicate strike and dip of fault exposed in outcrop

Aerial photo lineament — Or fault-related feature; dashed where less distinct; queried where uncertain; hachures indicate topographic scarp and show slope direction; ld = linear drainage, tc = tonal contrast, v = vegetation lineament, dd = deflected drainage, bls = break in slope, s = saddle, shb = side hill bench

Los Osos fault of Hall (1973) — Dashed where approximately located; dotted where concealed

Hall and others (1979) — Dashed where approximately located; dotted where concealed

Edna fault

Indian Knob fault

Other faults

Shoreline angle — Solid where well constrained; double dot dash where concealed; dotted where eroded; altitude shown in meters

Contact — Dashed where approximately located or inferred; queried where uncertain

Strike and dip of bedding

Syncline — Showing trace of axial surfaces and direction of plunge

Anticline — Showing trace of axial surface and direction of plunge

Borehole — GS-1 - U.S. Geological Survey (unpublished data, G. Yates, Water Resource Division); MBO-2 - California Department of Water Resources (1972); altitude of subsurface of formations shown in meters

Borehole — Completed during this study

Exploratory oil well — Producer, name of well, and total depth (meters) are indicated

Closed depression

Spring

Trench location

Bedrock exposure

Limit of mapping

Base map from U.S. Geological Survey 7.5-minute Topographic series, Morro Bay South, San Luis Obispo and Arroyo Grande, NE quadrangles

DESCRIPTION OF MAP UNITS

Qal — Stream deposit (Holocene) — Unconsolidated cobbles, pebbles, sand, and silt in active floodplains and channels

Qac — Active stream channel (Holocene)

Qe 2/1 — Eolian deposit (Holocene-upper Pleistocene) — Unconsolidated to moderately consolidated windblown sand (2 = youngest, 1 = oldest)

Qf 2/1 — Fluvial and alluvial deposits (Holocene-upper Pleistocene) — Unconsolidated cobbles, pebbles, sand, silt, and clay in active stream channels and floodplains, and in fluvial terraces inset within the margins of valleys (2 = youngest, 1 = oldest)

Qc — Colluvial deposit (Holocene-Pleistocene) — Unconsolidated, poorly sorted boulders, cobbles, pebbles, sand, silt, and clay deposited as a result of hillslope and alluvial processes; includes colluvial fan deposits

Qls — Landslide deposit (Holocene-Pleistocene) — Unconsolidated, poorly sorted boulders, cobbles, pebbles, sand, silt, and clay derived from rock units upslope. Not all mapped landslides are shown; arrows indicate downslope movement direction

Qm — Marine terrace deposit (Pleistocene) — Unconsolidated, well- to poorly sorted cobbles, pebbles, and sand; clasts are typically subrounded to rounded; marine fossils and shell fragments are locally present

Qoa — Older alluvial deposit (Pleistocene) — Unconsolidated to well-consolidated cobbles, pebbles, sand, silt and clay deposited in fluvial channels, floodplains, and alluvial fans; includes deposits of several ages and deposits mapped as Paso Robles Formation by Hall et al., (1979)

Tu — Tertiary bedrock undifferentiated

Tpps — Squire Member of Pismo Formation (upper Pliocene) — Massive, white to green medium- to coarse-grained sandstone (modified from Hall et al., 1979)

Tmpm — Miguelito Member of Pismo Formation (lower Pliocene and Miocene) — Brown claystone and siltstone with minor amounts of shale, chert, and sandstone (modified from Hall et al., 1979)

Tmpe — Edna Member of Pismo Formation (lower Pliocene and upper Miocene) — Poorly to moderately well-indurated, orange, brown, and gray fine- to medium-grained arkosic sandstone with minor yellow claystone (modified from Hall et al., 1979)

Tmm — Monterey Formation (Miocene) — Siltstone or chert, dolomitic claystone or silt, some tuff and opaline or cherty shale and sandstone (modified from Hall, et al., 1973)

Tp — Obispo Formation (lower Miocene) — Fine- to coarse-grained white tuff or crystalline tuff and resistant, silicified, or zeolitized tuff, metavolcanics, red, white, or green cherts, graywacke (modified from Hall, 1973)

Tol — Lospe Formation? (Oligocene) — Green and red conglomerate, sandstone and silty claystone (modified from Hall et al., 1979)

Td — Dacite (Oligocene) — Porphyritic-aphanitic dacite (modified from Hall et al., 1979)

KJf — Franciscan Complex (Cretaceous to Jurassic) — Undifferentiated graywacke, schist, conglomerate, and metavolcanic rocks

- *KJfmv* — Metavolcanics
- *KJfch* — Red, white or green cherts
- *KJfg* — Graywacke

S — Serpentinite (Jurassic)

Note: Bedrock geology simplified from Hall (1973) and Hall et al. (1979).

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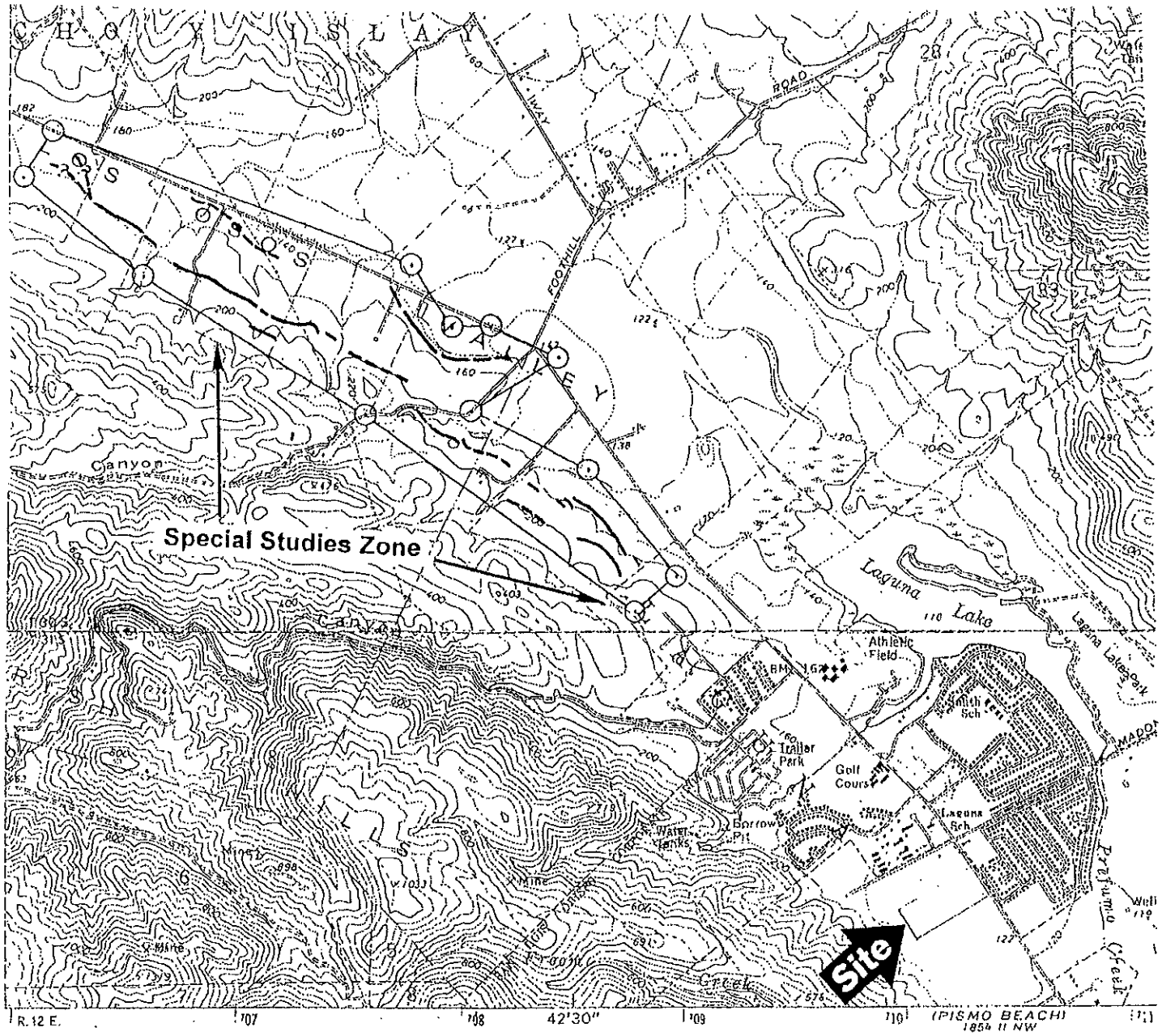
GEOLOGIC MAP EXPLANATIONS

IRISH HILLS DEVELOPMENT
SAN LUIS OBISPO, CALIFORNIA

FIGURE: 3B

PROJECT: SL01321-2



SCALE

1 0

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

N

From State of California Special Studies Zone Map, 1990

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EARTHQUAKE FAULT ZONE MAP

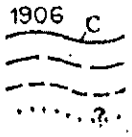
IRISH HILLS DEVELOPMENT
SAN LUIS OBISPO, CALIFORNIA

FIGURE:
4A

PROJECT:
SL01321-2

MAP EXPLANATION

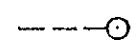
Active Faults



Faults considered to have been active during Holocene time and to have a relatively high potential for surface rupture; solid line where accurately located, long dash where approximately located, short dash where inferred, dotted where concealed; query (?) indicates additional uncertainty. Evidence of historic offset indicated by year of earthquake-associated event or C for displacement caused by creep or possible creep.

Special Studies Zone Boundaries

These are delineated as straight-line segments that connect encircled turning points so as to define special studies zone segments.



Seaward projection of zone boundary.

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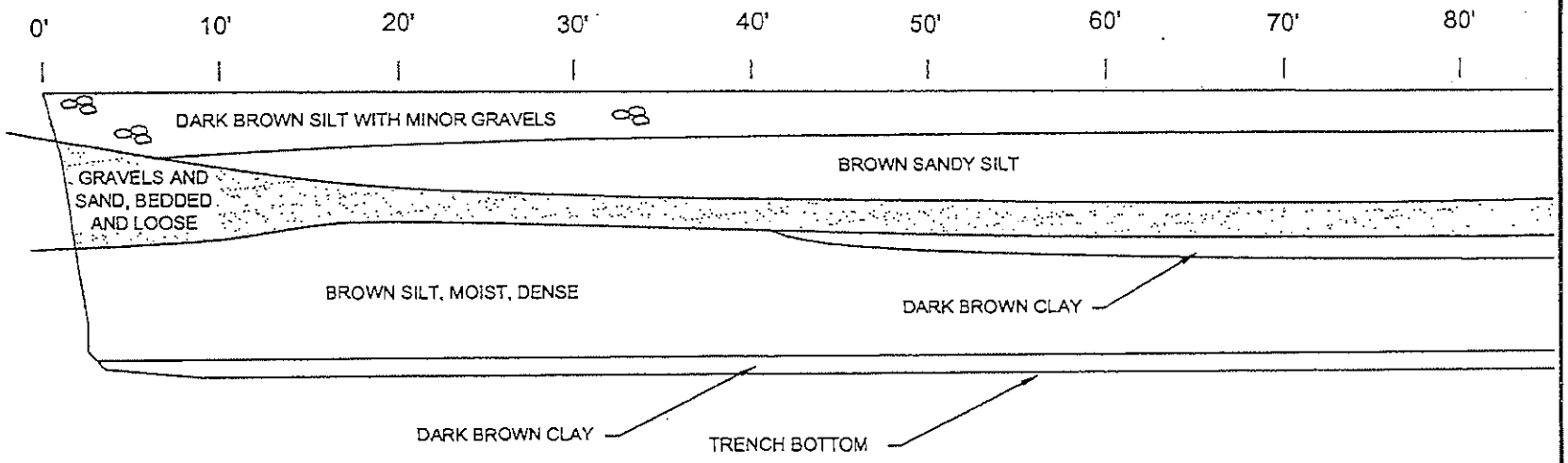
EARTHQUAKE FAULT ZONE MAP
EXPLANATIONS

IRISH HILLS DEVELOPMENT
SAN LUIS OBISPO, CALIFORNIA

FIGURE:
4B

PROJECT:
SL01321-2

SW NE



NO FAULTING-NO CALICHE, NO DISTURBED BEDS

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IRISH HILLS FAULT TRENCH
SAN LUIS OBISPO, CALIFORNIA

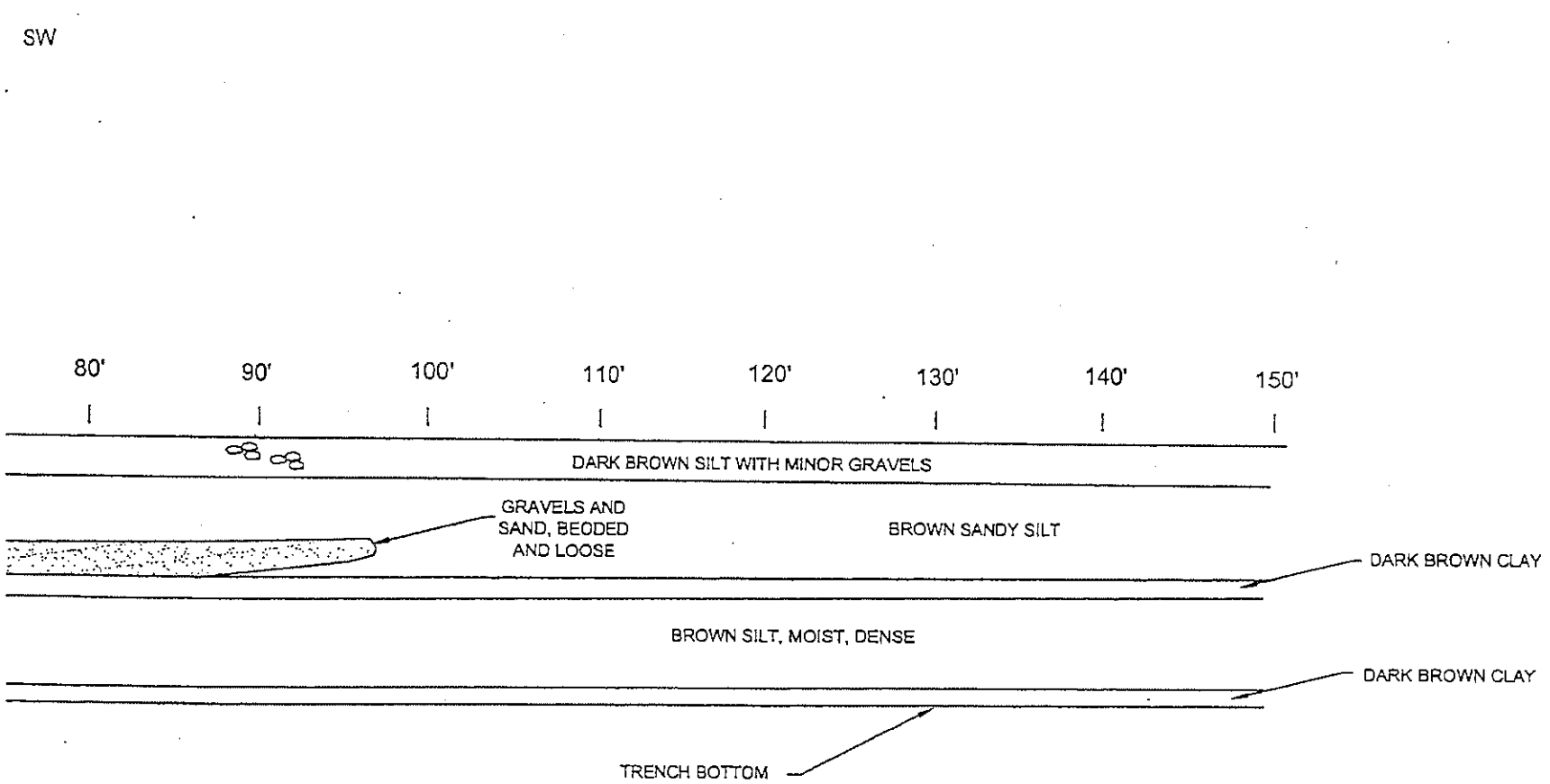
ORIENTED N60E
510' LONG, APPROXIMATELY 5' WIDE AND BASE

FIGURE: 5A

JANUARY 11, 2000

SCALE=1:10

SL01321-2



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IRISH HILLS FAULT TRENCH
SAN LUIS OBISPO, CALIFORNIA

ORIENTED N60E
510' LONG, APPROXIMATELY 5' WIDE AND BASE

FIGURE: 5B

JANUARY 11, 2000

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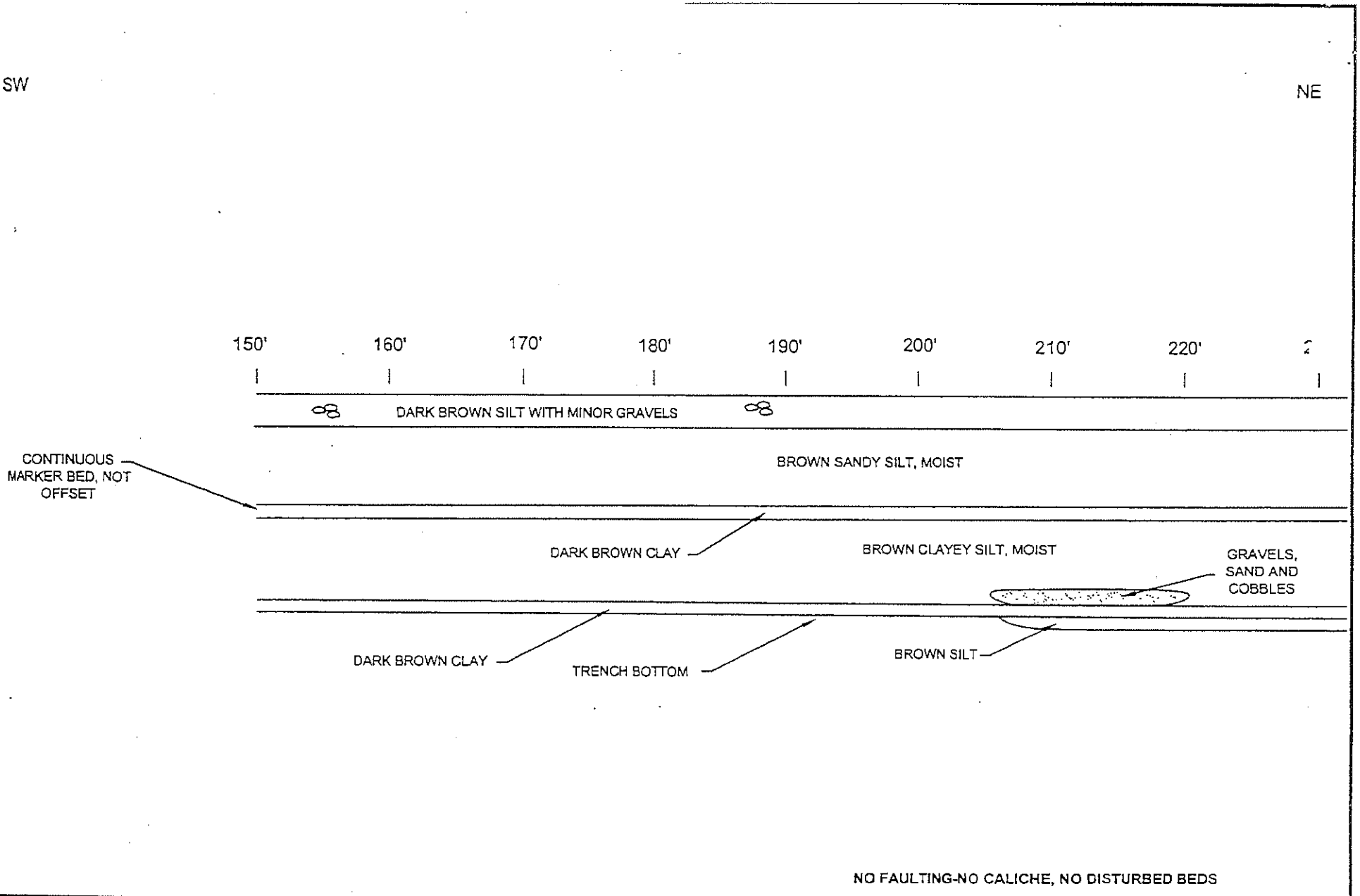

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IRISH HILLS FAULT TRENCH
SAN LUIS OBISPO, CALIFORNIA

ORIENTED N60E
510' LONG, APPROXIMATELY 5' WIDE AND BASE

FIGURE: 5C

JANUARY 11, 2000

SCALE=1:10

SL01321-2

F220

Earth Systems Consultants
Northern California

4378 Santa Fe Road
San Luis Obispo, CA 93401
(805) 544-3276
FAX (805) 544-1786

October 29, 1997

FILE NO.: NGS 10709-01

Mr. Tom Sconzo
Sconzo Hallstrom
919 124th Avenue N.E., Suite 101
Bellevue, WA 98055

PROJECT: EAGLE HARDWARE AND GARDEN
PORTION OF LOT 68
RANCHO CANADA DE LOS OSOS
COUNTY OF SAN LUIS OBISPO, CALIFORNIA

SUBJECT: Fault Study

REF:
1) Proposal for Fault Study, Soils Engineering Investigation, and Percolation Tests, Eagle Hardware and Garden, by Earth Systems Consultants Northern California, dated August 28, 1997.
2) Pacific Gas and Electric, Diablo Canyon Power Plant Long Term Seismic Program, Pacific Gas & Electric Company (U.S. Government Document), 1988.

Dear Mr. Sconzo:

In accordance with your authorization of the above-referenced proposal, this fault study has been prepared for use in the development of plans and specifications for the Eagle Hardware and Garden project. The purpose of the fault study was to explore the proposed building area and 50 feet beyond the east and west building boundaries for the presence of faulting. The scope of our services included excavating a 473-foot long by trench 3-foot wide trench to a maximum depth of 14 feet. The trench was excavated with a rubber tired backhoe. The trench was backfilled with on-site soils. The trench backfill soils were not compacted.

The trench exploration began on September 10, 1997 and was completed on September 12, 1997. The trend of the trench was approximately north 57 degrees east, which is roughly perpendicular to the mapped trend of the Los Osos fault. A detailed description of the soils encountered is presented in the Trench Profile attached with this report. The approximate location of the trench is presented on the Trench Location Map, also attached.

The trench generally revealed a sequence of stratified soil units. The upper soil consisted of a reddish gray to black silty clay topsoil that was underlain by mottled dark yellowish brown clayey sand with gravel. These units were underlain by a reddish brown silty fine sand (alluvial deposits). A black, organic rich, silty clay (buried topsoil) soil underlies the reddish brown silty fine sand. The contact between the alluvial deposits and the buried topsoil units was generally gradational. The interlayered sandy alluvial deposits and the clayey buried topsoil unit sequence was repeated at least twice in the trench. The soil layers ranged in thickness from 6 inches to 2 feet and were, for the most part, continuous, unbroken and horizontal.

The soil units exhibit structures and contact relationships which suggest that they were deposited as alluvial "overbank" flood plain deposits by low energy currents of the ancestral Prefumo Creek. Occasional buried channels were observed which consisted of unconsolidated, light brown sandy gravel. These channels were often discontinuous and irregularly shaped.

A charcoal sample was collected at a depth of 9.0 feet in the black silty clay soil, approximately 3 inches below the contact between the reddish brown silty fine sand and the black silty clay. The sample was age-dated using the accelerated mass spectrometry (AMS) method to measure the Carbon 14 content. The results of the AMS dating indicated the soil originated approximately 2,650 years (± 50 years) before present (Holocene age). This soil date generally correlates with a soil date of 2,516 before present (Holocene age) from the PG&E Cuesta Trench T-3 (PG&E, 1988). The PG&E trench was located south of Los Osos Valley Road approximately 1.25 miles west of the site, in the same alluvial valley. The PG&E soil sample was taken at an approximate depth of 6 feet where distinct fault traces of the Los Osos fault were observed and mapped.

Conclusions

There was no physical evidence in the subject trench that would suggest the presence of faulting within the proposed Building area. Soil layers were generally horizontal, continuous and unbroken.

The fault features observed and mapped by PG&E in the Cuesta Trench T-3 displaced sediments believed to be approximately 2,500 years old. Based upon the soil age date of approximately 2,650 years collected at 9.0 feet in the trench on the subject site, it is estimated that the soils at the bottom of the trenches excavated on the subject site in the alluvial valley are over 3,000 years old. In view of the continuous and unbroken condition of these soils, and that the age of the soils encountered on the subject site pre-date the soils encountered by PG&E, it is concluded that the fault features mapped by PG&E do not extend into the zone investigated.

Based upon the above, we are of the opinion that no active faults cross or are within 50 feet of the proposed building area. Therefore, based upon the current level of knowledge, the potential for fault-related ground rupture to occur in the proposed building areas is considered to be low.

We appreciate the opportunity to have provided services for this project and look forward to working with you again in the future. If there are any questions concerning this report, please do not hesitate to contact the undersigned.

Sincerely,

Earth Systems Consultants Northern California

Richard T. Gorman, C.E.G

REGISTERED GEOLOGIST
RICHARD T. GORMAN
No. CEG 1325
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

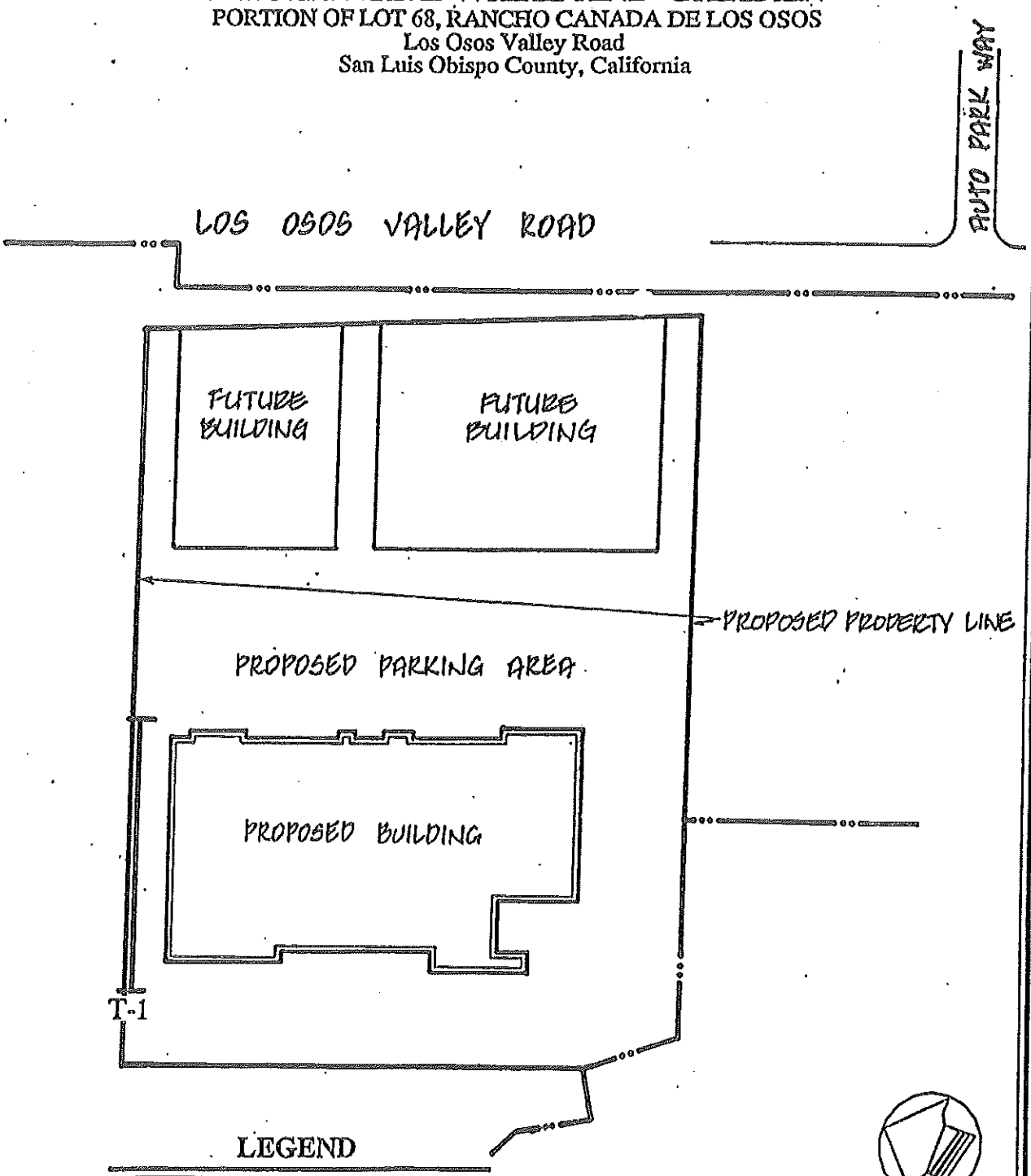
Copy to: Central Coast Engineering, Attention: Ben Maddalena

Doc. No.: 9710-228.LTR/dm

TRENCH LOCATION MAP

EAGLE HARDWARE AND GARDEN

PORTION OF LOT 68, RANCHO CANADA DE LOS OSOS
Los Osos Valley Road
San Luis Obispo County, California



LEGEND

T-1 Location of Trench

NOT TO SCALE

Earth Systems Consultants
Northern California
4378 Santa Fe Road, San Luis Oblspo, CA 93401
(805) 544-3276 (805) 5441786 FAX

October 28, 1997 EC NGS10709-01

APPENDIX G.3

Preliminary Soils Engineering Report

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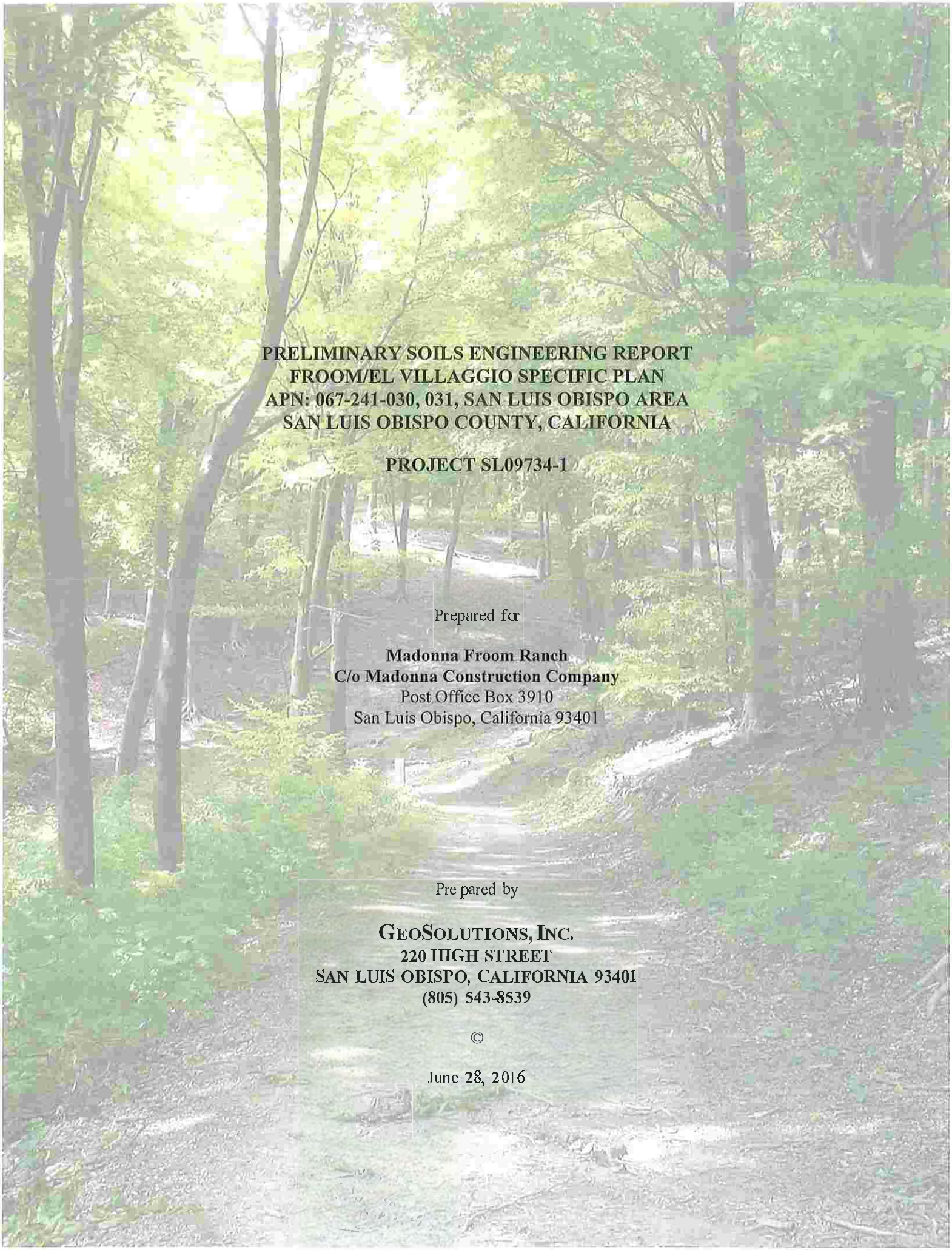

PRELIMINARY SOILS ENGINEERING REPORT
FROOM/EL VILLAGGIO SPECIFIC PLAN
APN: 067-241-030, 031, SAN LUIS OBISPO AREA
SAN LUIS OBISPO COUNTY, CALIFORNIA

PROJECT SL09734-1

Prepared for

Madonna Froom Ranch
C/o Madonna Construction Company
Post Office Box 3910
San Luis Obispo, California 93401

Prepared by

GEOSOLUTIONS, INC.
220 HIGH STREET
SAN LUIS OBISPO, CALIFORNIA 93401
(805) 543-8539

©

June 28, 2016

GeoSolutions, INC.

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SBinfo@geosolutions.net

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info@geosolutions.net

June 28, 2016
Project No. SL09734-1

Madonna Froom Ranch
c/o Madonna Construction Company
Post Office Box 3910
San Luis Obispo, California 93401

Subject: **Preliminary Soils Engineering Report**
Froom/ El Villaggio Specific Plan, APNs: 067-241-030 and -031
San Luis Obispo area, San Luis Obispo County, California

Dear Mr. Madonna:

This preliminary Soils Engineering Report has been prepared for the proposed development to be referred to as the Froom/ El Villaggio Specific Plan, located on APN Parcels 067-241-030 and -031, in the San Luis Obispo area, San Luis Obispo County, California. Geotechnically, the site is suitable for the proposed development provided the recommendations in this report are incorporated into the design.

It is anticipated that graded pads will be constructed for a majority of the proposed development and that foundations will be supported by engineered fill. Based on the sub-surface investigation in the upper sloping portions of the Site it is anticipated that the foundations for structures in this area will be excavated into competent formational material. Deepened footings may be required in some areas to maintain the minimum embedment into competent formational material.

All foundations are to be excavated into uniform material to limit the potential for distress of the foundation systems due to differential settlement. If cuts steeper than allowed by State of California Construction Safety Orders for "Excavations, Trenches, Earthwork" are proposed, a numerical slope stability analysis may be necessary for temporary construction slopes.

Thank you for the opportunity to have been of service in preparing this report. If you have any questions or require additional assistance, please feel free to contact the undersigned at (805) 543-8539.

Sincerely,
GeoSolutions, Inc.



Kraig R. Crozier, PE
Principal, C61361

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1.2 Project Description 1
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PRELIMINARY SOILS ENGINEERING REPORT
FROOM/EL VILLAGGIO SPECIFIC PLAN
APN: 067-241-030, 031, SAN LUIS OBISPO AREA
SAN LUIS OBISPO COUNTY, CALIFORNIA

PROJECT SL09734-1

1.0 INTRODUCTION

This preliminary report presents the results of the geotechnical investigation for the proposed development to be located on the property referred to as Froom/El Villaggio Specific Plan located on APN Parcels 067-241-030 and -031, in the San Luis Obispo area, San Luis Obispo County, California. See Figure 1: Site Location Map for the general location of the project area. Figure 1: Site Location Map was obtained from the computer program *Topo USA 8.0* (DeLorme, 2009).

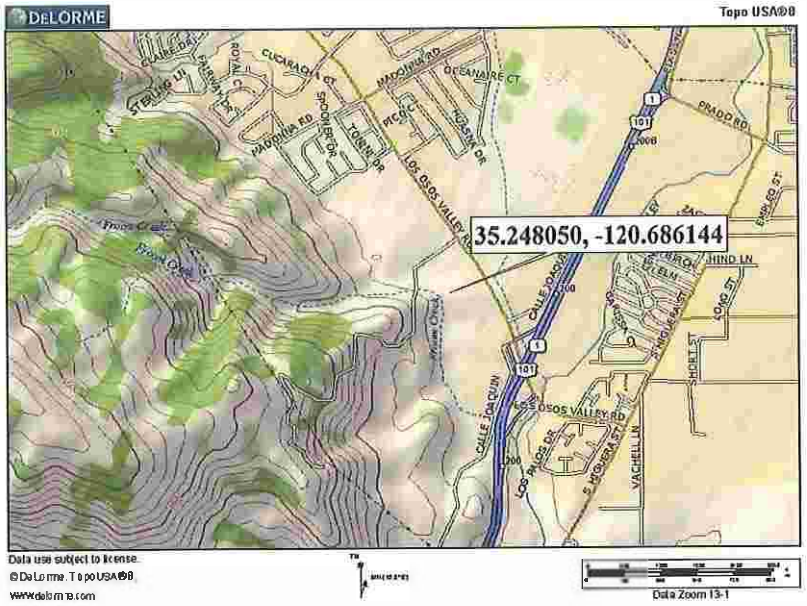


Figure 1: Site Location Map

1.1 Site Description

Froom/El Villaggio Specific Plan is located in the general vicinity of 35.248050 degrees north latitude and 120.686144 degrees west longitude at an approximate general elevation between 110 to 200 feet above mean sea level. The property is irregular in shape and 111.39 acres in size. The site is bounded by Los Osos Valley Road to the north-east, the Home Depot / T.J Maxx development to the north-west, a combination of development and open space to the south, and the Irish Hills Natural Reserve open space to the west. The nearest major intersection is where Los Osos Valley Road intersects Highway 101 approximately 500 feet south from the most easterly portion of the property.

The Site is characterized by flat to rolling grassland with an existing irrigation basin which rises to a steep, rocky hill at the westerly edge of the property, known as the Irish Hills Natural Reserve. The Site is currently developed with few farm/ranch buildings and undeveloped amongst most of the southern portion of the site utilized for animal grazing. Annual grasses, shrubs and a few trees currently vegetate the Site. Surface drainage generally follows the topography toward the east.

1.2 Project Description

The proposed development is to include the construction of mixed residential and commercial development. The proposed structures are anticipated to be constructed using light wood framing and/or light gauge steel/structural steel. The project property will hereafter be referred to as the "Site." See Figure 2: Site Plan for the general layout of the Site.

It is anticipated that the proposed structures will utilize slab-on-grade lower floor systems. Dead and sustained live loads are currently unknown, but they are anticipated to be moderate with maximum

continuous footing and column loads estimated to be approximately 2.5 kips per linear foot and 25 kips, respectively.

2.0 PURPOSE AND SCOPE

The purpose of this study was to explore and evaluate the surface and sub-surface soil conditions at the Site and to develop geotechnical information and design criteria. The scope of this study includes the following items:

1. A literature review of available published and unpublished geotechnical data pertinent to the project site including geologic maps, and available on-line or in-house aerial photographs.

2. A field study consisting of site reconnaissance and subsurface exploration including exploratory borings in order to formulate a description of the sub-surface conditions at the Site.

3. Laboratory testing performed on representative soil samples that were collected during our field study.

4. Engineering analysis of the data gathered during our literature review, field study, and laboratory testing.

5. Development of recommendations for site preparation and grading as well as preliminary geotechnical design criteria for building foundations, retaining walls, pavement sections, underground utilities, and drainage facilities.

3.0 FIELD AND LABORATORY INVESTIGATION

The field investigation was conducted on May 18 & 19, 2016 using a Mobile B-24 drill rig. Three six-inch diameter exploratory borings were advanced to a maximum depth of 10 feet below ground surface (bgs) and one six-inch diameter exploratory boring was advanced to a maximum depth of 46 feet below ground surface (bgs) at the approximate locations indicated on Figure 2: Site Plan. Sampling methods included the Standard Penetration Test utilizing a standard split-spoon sampler (SPT) without liners and a Modified California sampler (CA) with liners. The Mobile B-24 drill rig was equipped with a safety hammer, which has an efficiency of approximately 60 percent and was used to obtain test blow counts in the form of N-values.

An additional investigation was conducted on June 7, 2016 using a backhoe and excavator. Seven exploratory trenches were advanced to a maximum depth of 25 feet below ground surface (bgs) at the approximate locations indicated on Figure 2: Site Plan. Sampling methods included bulk bags.

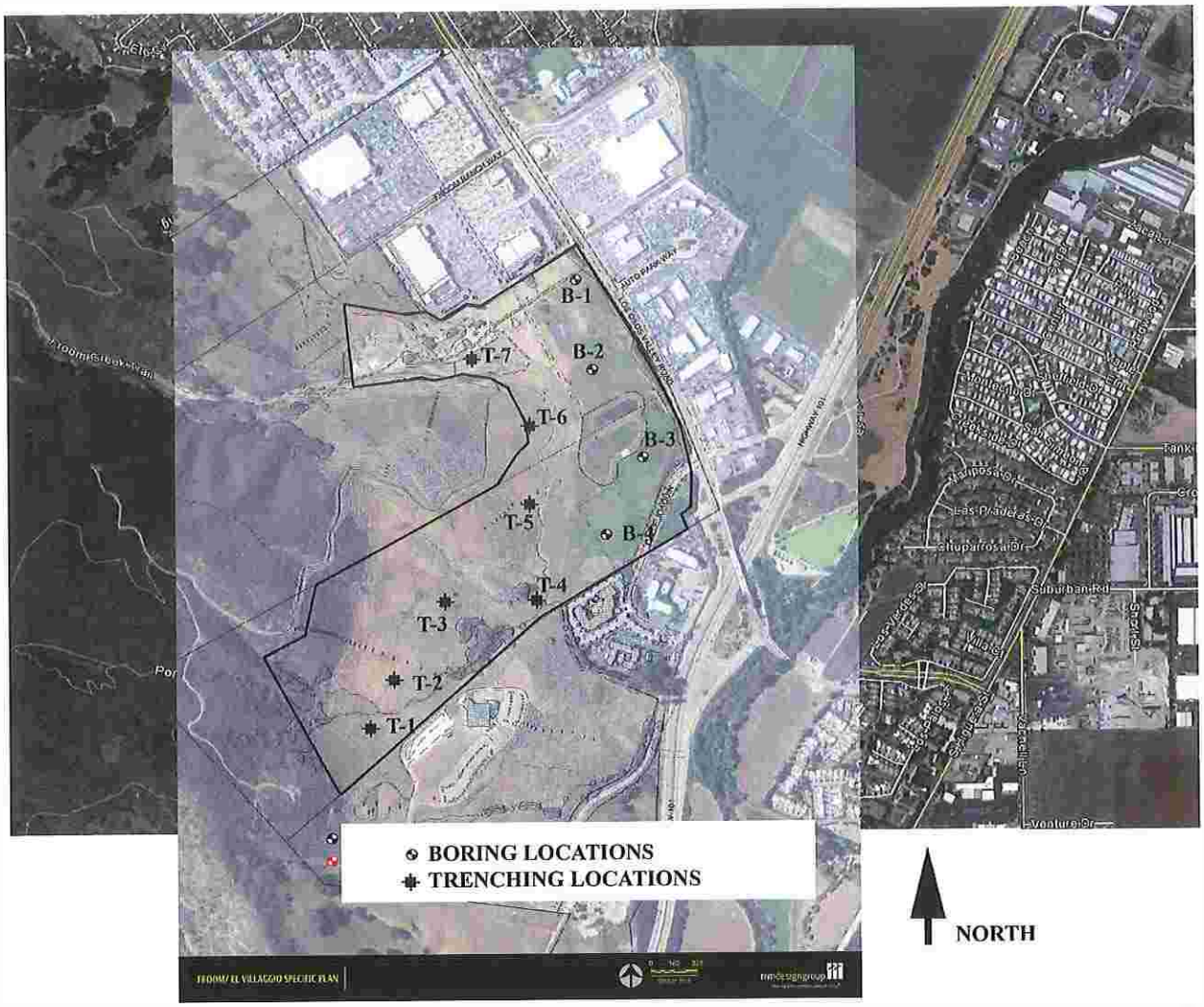


Figure 2: Site Plan

Data gathered during the field investigation suggest that the soil materials at the Site consist of alluvial soil overlying competent formational material. The depth to competent formational material varies across the site, increasing in depth towards Los Osos Valley Road to a maximum depth of approximately 50 feet bgs. The surface material at the Site generally consisted of dark gray to dark grayish brown sandy FAT CLAY (CH) encountered in a soft to stiff and moist to wet condition to termination depth of borings B1-B4, and dark reddish brown sandy CLAY (CL) encountered in a dry to moist condition to an approximate depth of 2.0 to 8.0 feet bgs, underlain by competent formational material in trenches T1-T7.

Regional site geology was obtained by using the *Geologic Map of the Pismo Beach Quadrangle* (Dibblee, 2006) and the MapView internet application (USGS, 2013); the later application is available from the United States Geological Survey website (USGS, 2013) and compiles existing geologic maps. The majority of all underlying material at the Site was interpreted as Surficial Alluvial Sediments alongside/overlying Franciscan Formation and Serpentinite, which will hereafter be referred to as competent formational material. **Shallow ground water was encountered between the depths of 1.5 to 4.0 feet**, although it should be expected that groundwater elevations may vary seasonally and with irrigation practices. See Figure 3: Regional Geologic Map.

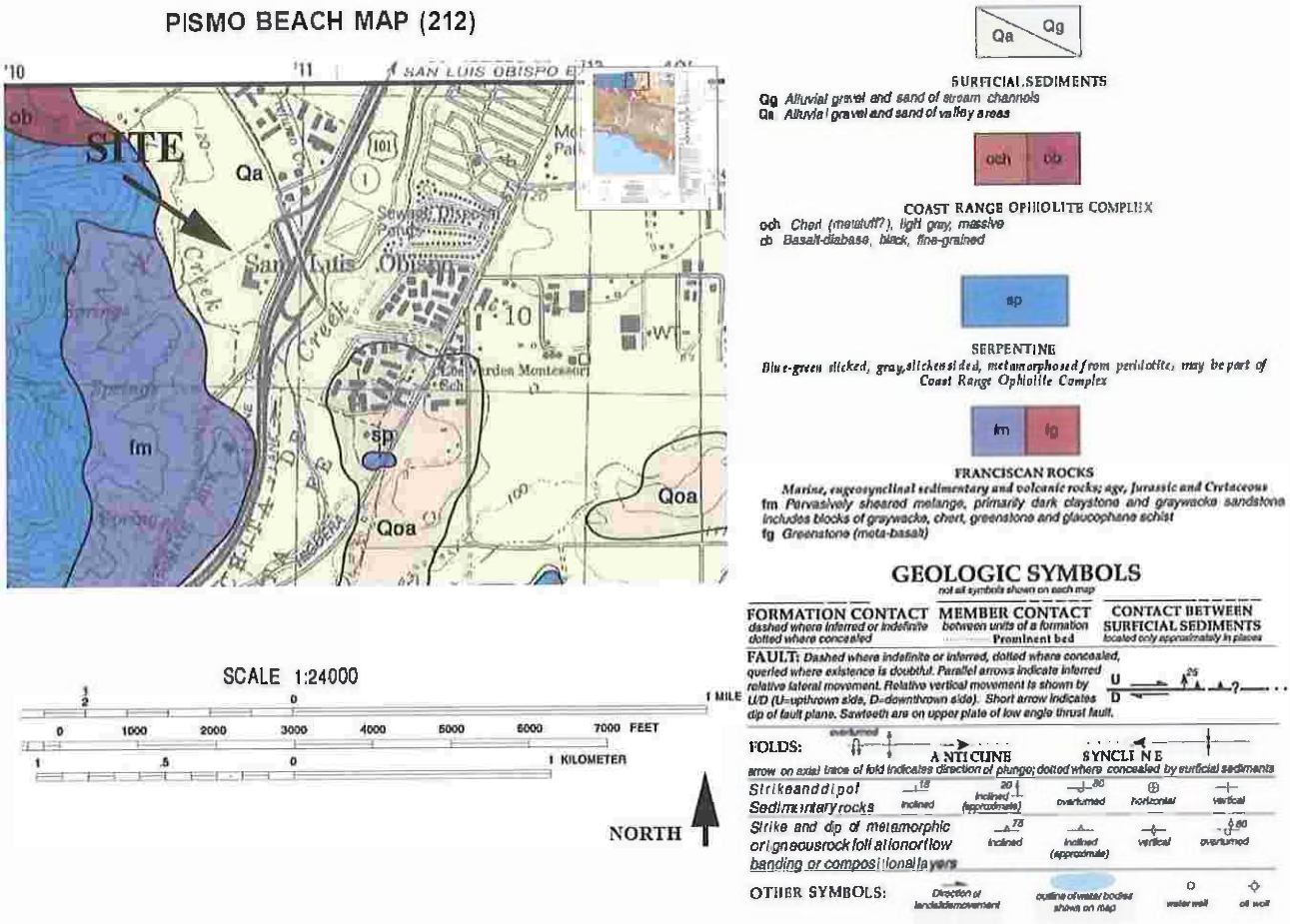


Figure 3: Regional Geologic Map

During the boring operations the soils encountered were continuously examined, visually classified, and sampled for general laboratory testing. A project engineer has reviewed a continuous log of the soils encountered at the time of field investigation. See **Appendix** A for the Boring Logs from the field investigation.

Laboratory tests were performed on soil samples that were obtained from the Site during the field investigation. The results of these tests are listed below in Table 1: Engineering Properties. Laboratory data reports and detailed explanations of the laboratory tests performed during this investigation are provided in **Appendix B**.

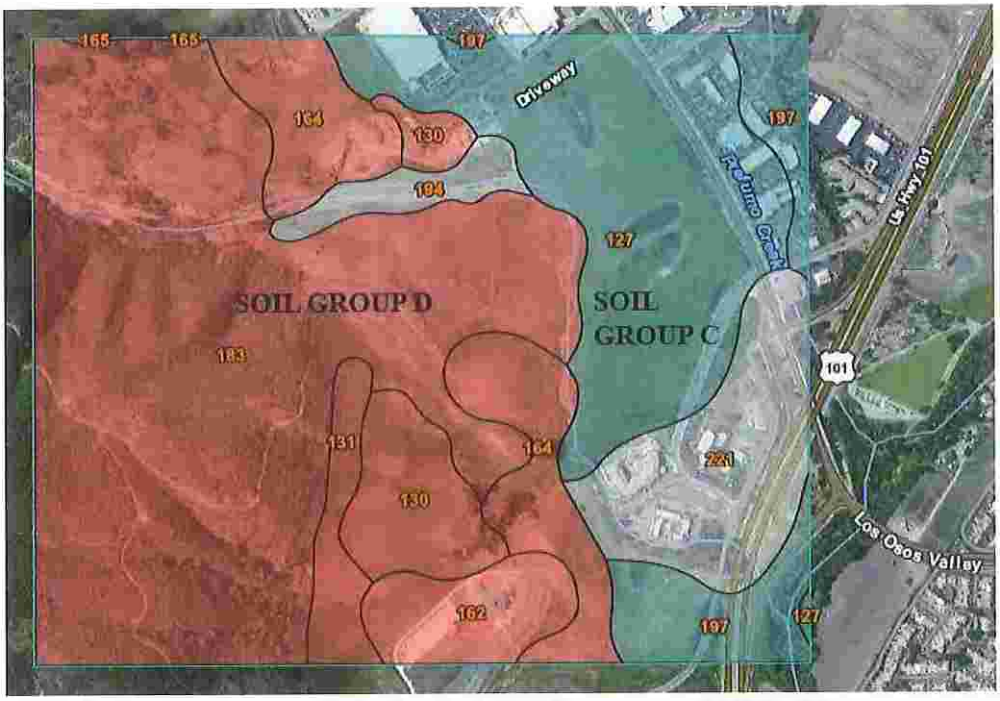
Table 1: Engineering Properties

Sample Name	Sample Description	USCS Specification	Expansion Index	Expansion Potential	Angle of Internal Friction, ϕ (deg.)	Cohesion, c (psf)	Plasticity Index	Fines Content (%)	Compression Index, C_C	Recompression Index, C_r
A B-1@ 1.0'	Very Dark Grayish Brown Sandy FAT CLAY	CH	107	High	-	-	31	79.6	-	-
B B-3 @1.0'	Dark Gray FAT CLAY	CH	186	Very High	-	-	48	94.7	-	-
C T-2@2.0'	Dark Reddish Brown Sandy CLAY	CL	79	Medium	-	-	-	-	-	-
B-1@5.0'	Very Dark Grayish Brown Sandy CLAY	CL	-	-	28.7	110	-	-	0.165	0.017

4.0 HYDROLOGIC SOIL GROUP

Based on the Web Soil Survey provided by the Natural Resources Conservation Service, the Site was initially designated as containing Hydrologic Soil Groups C and D. Groups C and D are similar in that they are both comprised of fine-grained and/or nearly impervious material with slow to very slow infiltration rates. The main distinction between the two groups is that Group D soil conditions are less favorable for infiltration of storm water and runoff due to; very slow infiltration rate (high runoff potential), clays with high shrink-swell potential, soils with high water table, and soils that are shallow over nearly impervious material. Based on the sub-surface data obtained during the field investigation and the results of the laboratory testing, it is our opinion that the entire Site is best defined as **Hydrologic Soil Group D**. See Figure 4: Hydrologic Soil Group.

Due to shallow groundwater encountered at an approximate depth of 1.5 to 4.0 bgs during the field investigation, field infiltration testing was not performed. Observed shallow ground water and soil characteristics, including competent formational material encountered at shallow depths, are indicative of slow to very slow infiltration rate and are in support of the prescribed hydrologic soil group.



Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Figure 4: Hydrologic Soil Group

5.0 SEISMIC DESIGN CONSIDERATIONS

4.1 Seismic Hazard Analysis

1. According to section 1613 of the 2013 CBC (CBSC, 2013), all structures and portions of structures should be designed to resist the effects of seismic loadings caused by earthquake ground motions in accordance with the *Minimum Design Loads for Buildings and Other Structures* (ASCE7) (ASCE, 2010). ASCE7 considers the most severe earthquake ground motion to be the ground motion caused by the Maximum Considered Earthquake (MCE) (ASCE, 2010), which is defined in Section 1613 of the 2013 CBC to be short period S_{MS} and 1-second period S_{M1}, spectral response accelerations.

2. The a_{max} of the Site depends on several factors, which include the distance of the Site from known active faults, the expected magnitude of the MCE, and the Site soil profile characteristics.

3. As per section 1613.3.2 of the 2013 CBC (CBSC, 2013), the Site soil profile classification is determined by the average soil properties in the upper 100 feet of the Site profile

(ASCE 7). Based on the $(N_1)_{60}$ values calculated for the in-situ tests performed during the field investigation, and the results of the laboratory analysis of the in-situ soils the Site was defined as **Site Class E, Soft Soil** profile for the lower portion of the Site and **Site Class C, Very Dense Soil and Soft Rock profile** for the upper portion of the Site where shallow formational material was encountered, per ASCE 7 Chapter 20.

4. According to section 11.2 of ASCE7 and section 1613 of the 2013 CBC (CBSC, 2013), buildings and structures should be specifically proportioned to resist Design Earthquake Ground Motions (Design a_{max}). ASCE7 defines the Design a_{max} as "the earthquake ground motions that are two-thirds of the corresponding MCE ground motions" (ASCE, 2006, p. 109). Therefore, the **Design a_{max} for the Site is equal to S_{D1}=0.425 g and S_{DS}=0.854 g, for the upper portion of the Site (Site Class C) and S_{D1}=0.774g and S_{DS}=0.769 g for the lower portion of the Site (Site Class E)**, which are 1-second period and short period design spectral response accelerations that are equal to two-thirds of the a_{max} or MCE for the Site.

5. Site coordinates of 35.24805 degrees north latitude and -120.686144 degrees west longitude and a search radius of 100 miles were used in the probabilistic seismic hazard analysis.

4.2 Structural Building Design Parameters

1. Structural building design parameters within chapter 16 of the 2013 CBC (CBSC, 2013) and sections 11.4.3 and 11.4.4 of ASCE7 are dependent upon several factors, which include site soil profile characteristics and the locations and characteristics of faults near the Site. As described in section 4.1 of this report, the Site soil profile classification was determined to be **Site Class C and Site Class E**. This Site soil profile classification and the latitude and longitude coordinates for the Site were used to determine the structural building design parameters.

2. Spectral Response Accelerations and Site Coefficients were obtained from the Seismic Hazard Curves and Uniform Hazard Response Spectra, U.S. Seismic Design Map computer application (USGS, 2013); this program is available from the United States Geological Survey website (USGS, 2013). This computer program utilizes the methods developed in the 1997, 2000, 2003, 2008 and 2013 errata editions of the NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures and user-inputted Site latitude and longitude coordinates to calculate seismic design parameters and response spectra (both for period and displacement), for Site Classifications A through E. Analysis of the Design Spectral Response Acceleration Parameters for the Site and of the Occupancy Category for the proposed structure assign to this project a **Seismic Design Category of D** per Tables 1613.3.5(1) and 1613.3.5(2) of the 2013 CBC (CBSC, 2013).

3. The site specific MCE peak ground acceleration (**PGA_M**) as determined by the USGS computer program (Web based) **PGA_M = 0.541 g** for the upper portion of the Site (Site Class C) and **PGA_M = 0.487g** for the lower portion of the Site (Site Class E) which is present on Sheet 5 of 6 of the USGS Design Maps Detailed Reports (ASCE 7-10 Standard). See **Appendix C**: USGS Design Maps Summary and Detailed Reports.

4.3 Liquefaction Potential

1. In the context of soil mechanics, liquefaction is the process that occurs when the dynamic loading of a soil mass causes the shear strength of the soil mass to rapidly decrease. Liquefaction can occur in saturated cohesionless soils.

2. The most typical liquefaction-induced failures include consolidation of liquefied soils, surface sand boils, lateral spreading of the ground surface, bearing capacity failures of structural foundations, flotation of buried structures, and differential settlement of above-ground structures.

3. Liquefiable soils must undergo dynamic loading before liquefaction occurs. Ground motion from an earthquake may induce large-amplitude cyclic reversals of shear stresses within a soil mass. Repetitive lateral and vertical loading and unloading usually results from this process. This process is considered to be dynamic loading. In a liquefiable soil mass, liquefaction may occur as a result of the dynamic loading caused by ground motion produced by an earthquake.

4. The presence of loose, poorly graded, fine sand material that is saturated by groundwater within an area that is known to be subjected to high intensity earthquakes and long-duration ground motion are the key factors that indicate potentially liquefiable areas and conditions that lead to liquefaction.

5. Based on the consistency and relative density of the in-situ soils the potential for seismic liquefaction of soils at the Site is low. Assuming that the recommendations of the Soils Engineering Report are implemented, the potential for seismically induced settlement and differential settlement at the Site is considered to be low.

6.0 GENERAL SOIL-FOUNDATION DISCUSSION

It is anticipated that graded pads will be constructed for a majority of the proposed development and that foundations will be supported by engineered fill. Based on the sub-surface investigation in the upper sloping portions of the Site it is anticipated that the foundations for structures in this area will be excavated into competent formational material. Deepened footings may be required in some areas to maintain the minimum embedment into competent formational material.

Soil conditions encountered during the field investigation varied, including soft, highly compressible and expansive soils, and shallow competent formational material. Due to the presence of highly expansive surface soils and shallow groundwater within the lower development areas, it is recommended that as a minimum, the upper 36 inches (3 feet) of the development area should consist of a select import material on top of existing grade or in replacement of the existing surficial soils. This is intended to act as a ballast or cap, providing isolation and increased stability above areas of underlying soft, highly compressible and expansive soils. An increase in depth of select import material to a minimum of 5.0 feet will allow for a reduction in foundation requirements. This report discusses both options.

Due the presence of shallow weathered bedrock materials encountered during the field investigation, hard rock excavation conditions are expected during development of building pad areas and underground utility construction in the upper portion of the Site.

All foundations are to be excavated into uniform material to limit the potential for distress of the foundation systems due to differential settlement. If cuts steeper than allowed by State of California

Construction Safety Orders for "Excavations, Trenches, Earthwork" are proposed, a numerical slope stability analysis may be necessary for temporary construction slopes.

Natural seepage at the interface of two materials with different densities, such as native soil and engineered fill/competent formational material, is very common. This interface occurs at the Site and is likely to require sub-surface drains. Sub-drains should be placed in established drainage courses, potential seepage areas, and during the development of all key and bench grading operations.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The Site is suitable for the proposed development provided the recommendations presented in this report are incorporated into the project plans and specifications.

The primary geotechnical concerns at the Site are:

1. The potential of groundwater seepage, encountered between 1.5 to 4.0 feet bgs in the shallow subsurface.

2. The presence of highly expansive surface soils. Expansive soils tend to swell when exposed to excess moisture and shrink when allowed to dry. The soil zone within the upper 2 to 3 feet of the Site is most affected by these seasonal changes in moisture content. The volume change associated with this soil movement can stress and damage foundations, concrete flatwork, interior slabs-on-grade, and roadway pavements. Foundations supported by expansive soils should be designed by a Structural Engineer in accordance with the 2013 California Building Code.

3. The potential for loose soil materials generated from removal of existing trees and root systems within the proposed building pad areas.

4. The presence of shallow, hard bedrock materials within the upper portion of the development. Hard digging/excavation conditions are anticipated in some areas during building pad preparation and underground utility construction.

5. The potential for differential settlement occurring between foundations supported on two soil materials having different settlement characteristics, such as native soil and engineered fill/competent formational material. Therefore, it is important that all of the foundations are founded in equally competent uniform material in accordance with this report.

7.1 Site Preparation of Building Pad Areas

1. It is anticipated that graded pads will be constructed for a majority of the proposed development and that foundations will be supported by engineered fill. Based on the sub-surface investigation in the upper sloping portions of the Site it is anticipated that the foundations for structures in this area will be excavated into competent formational material. Deepened footings may be required in some areas to maintain the minimum embedment into competent formational material.

2. Due to the presence of highly expansive surface soils and shallow groundwater within the lower development areas, it is recommended that as a minimum, the upper 36 inches (3 feet) of the development area should consist of a select import material on top of existing grade or in replacement of the existing surficial soils. This will allow for support of mat foundations for the proposed structures. An increase in thickness of the select import

material to a minimum of 5.0 feet will allow for the use of conventional foundation systems.

3. For the development of an engineered fill pad with a **36 inch (3 feet) select import pad cap to receive a mat foundation**, the native material should be over-excavated at least 36 inches below slab sub-grade elevation, to competent material, or to one-half the depth of the deepest fill (measured from the bottom of the deepest footing); whichever is greatest. The exposed surface should be scarified to a depth of 6 inches; moisture conditioned to 3% over optimum moisture content, and compacted to a minimum relative density of 90 percent (ASTM D1557-07). **The upper 36 inches of building pad areas should consist of an approved select import material processed as engineered fill.** All material to be used as select import fill should be granular soil with a very low to low expansion potential (i.e., expansion index of 50 or less) and must be observed and approved by a representative of GeoSolutions, Inc. prior to its delivery to the Site. Refer to Figure 5: Sub-Slab Detail for under-slab drainage material and **Appendix D** for more details on fill placement.

4. For the development of an engineered fill pad with a **60 inch (5 feet) select import pad cap to receive conventional foundations**, the native material should be over-excavated at least 60 inches (5 feet) below existing grade, 36 inches (3 feet) below the bottom of the footings, to competent material, or to one-half the depth of the deepest fill (measured from the bottom of the deepest footing); whichever is greatest. The limits of over-excavation should extend a minimum of 5 feet beyond the perimeter foundation, to property lines, or existing improvements, whichever is least. The exposed surface should be scarified to a depth of 6 inches; moisture conditioned to 3% over optimum moisture content, and compacted to a minimum relative density of 90 percent (ASTM D1557-07). The over-excavated material, cleared of oversized aggregates and debris, should then be processed as engineered fill up to within 60 inches of the surface of the building pad. **The upper 60 inches (5 feet) of building pad areas should consist of an approved select import material processed as engineered fill.** All material to be used as select import fill should be granular soil with a very low to low expansion potential (i.e., expansion index of 50 or less) and must be observed and approved by a representative of GeoSolutions, Inc. prior to its delivery to the Site. Refer to Figure 5: Sub-Slab Detail for under-slab drainage material and **Appendix D** for more details on fill placement.

5. For slab-on-grade construction with footings founded a **minimum of 12 inches into uniform competent formational material**, the pad area to receive slab-on-grade construction should be graded such that all slabs are supported on uniform competent material. The native material should be excavated beneath the slab at least 12 inches below existing grade and finished slab elevation, to competent material, or to one-half the depth of the deepest fill; whichever is greatest. The exposed surface should be scarified to a depth of 6 inches, moisture conditioned to 3% over optimum moisture content, and compacted to a minimum relative density of 90 percent (ASTM D1557-07). The over-excavated material may then be processed as engineered fill. Figure 5: Sub-Slab Detail for under-slab drainage material and **Appendix D** for more details on fill placement.

6. There is potential that soils encountered at the required foundation excavation depth may exhibit soft, compressible conditions. If pumping soils are encountered at the bottom of the excavation, stabilization will be necessary and may require the installation of a woven geotextile fabric, such as Mirafi 600x or equivalent, on the prepared bottom of the excavation. If the soil within the excavation is not stable enough for proper installation of the geotextile fabric, rock stabilization of the exposed sub-grade may be required, with the placement and compaction of 3-inch to 8-inch diameter (gabion) crushed stone into the soft sub-grade, until stability is achieved, as observed and approved by a representative of this firm. Alternative recommendations may be prepared based on the conditions encountered.

7. If fill areas are constructed on slopes greater than 10-to-1 (horizontal-to-vertical), we recommend that benches be cut every four feet as fill is placed. Each bench shall be a minimum of 10 feet wide with a minimum of two percent gradient into the slope. If fill areas are constructed on slopes greater than 5-to-1, we recommend that the toe of all areas to receive fill be keyed a minimum of 24 inches into underlying dense material. Sub-drains shall be placed in the keyway and benches as required. See **Appendix D**, Detail A, Key and Bench with Backdrain for details on key and bench construction.

8. The recommended soil moisture content should be maintained during construction and following construction of the proposed development. Where soil moisture content is not maintained, desiccation cracks may develop which indicate a loss of soil compaction, leading to the potential for damage to foundations, flatwork, pavements, and other improvements. Soils that have become cracked due to moisture loss should be removed sufficient depth to repair the cracked soil as observed by the soils engineer, and the removed materials shonld then be moisture conditioned to approximately 3 percent over optimum value, and compacted.

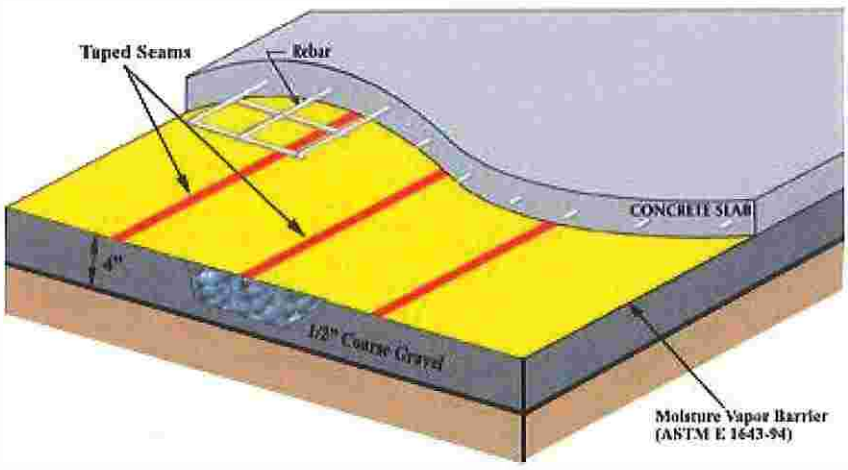


Figure 5: Sub-Slab Detail

7.2 Preparation of Paved Areas

1. Pavement areas should be excavated to approximate sub-grade elevation or to competent material; whichever is deeper. The exposed surface should be scarified an additional depth

of 12 inches, moisture conditioned to 3% over optimum moisture content, and compacted to a minimum relative density of 95 percent (ASTM D1557-07 test method). The top 12 inches of sub-grade soil under all pavement sections should be compacted to a minimum relative density of 95 percent based on the ASTM D1557-07 test method at slightly above optimum.

2. Sub-grade soils should not be allowed to dry out or have excessive construction traffic between moisture conditioning and compaction, and placement of the pavement structural section.

3. There is potential that soils encountered at the required foundation excavation depth may exhibit soft, compressible conditions. If pumping soils are encountered at the bottom of the excavation, stabilization will be necessary and may require the installation of a woven geotextile fabric, such as Mirafi 600x or equivalent, on the prepared bottom of the excavation. If the soil within the excavation is not stable enough for proper installation of the geotextile fabric, rock stabilization of the exposed sub-grade may be required, with the placement and compaction of 3-inch to 8-inch diameter (gabion) crushed stone into the soft sub-grade, until stability is achieved, as observed and approved by a representative of this firm. Alternative recommendations may be prepared based on the conditions encountered.

4. Due to the expansive potential of the soils at the Site, the base courses beneath un-reinforced pavement sections may fail, causing cracking of the pavement surfaces, as the sub-grade materials move laterally during expansive shrink-swell cycles.

5. Therefore, in order to minimize the potential for the failure of pavement sections at the Site, GeoSolutions, Inc. recommends that a laterally-reinforcing geotextile grid, such as Tensar BX1100, Syntec SBX11, ADS BX114GG, or equivalent, be installed to reinforce the base courses under paved areas at the Site.

6. GeoSolutions, Inc. should be contacted prior to the design and construction of pavement sections at the Site in order to assist in the selection of an appropriate laterally-reinforcing biaxial geogrid product and to provide recommendations regarding the procedures for the installation of geogrid products at the Site.

7.3 Pavement Design

1. All pavement construction and materials used should conform to Sections 25, 26 and 39 of the latest edition of the State of California Department of Transportation Standard Specifications (State of California, 1999).

2. As indicated previously in Section 7.2, the top 12 inches of sub-grade soil under pavement sections should be compacted to a minimum relative density of 95 percent based on the ASTM D1557-07 test method at slightly above optimum moisture content. Aggregate bases and sub-bases should also be compacted to a minimum relative density of 95 percent based on the aforementioned test method.

3. Based on the soil conditions observed and the results of the laboratory testing performed on surface soils within the Site, an **R-Value of 5** is estimated for preliminary pavement design purposes. A minimum of **10 Inches** of Class II Aggregate Base is recommended for all pavement sections. Following Site improvement with select import in proposed

development areas, additional R-Value testing may be performed to determine the appropriate pavement structural section. All pavement sections should be crowned for good drainage.

4. In order to minimize the potential for cracking of the pavement surfaces at the Site due to lateral movement of the base courses during expansive shrink-swell cycles of the sub-grade materials, GeoSolutions, Inc. recommends that a laterally-reinforcing geotextile grid, such as Tensar BX1100, Syntec SBX11, ADS BX114GG, or equivalent, be installed between the prepared sub-grade and base materials at the Site.

5. GeoSolutions, Inc. should be contacted prior to the design and construction of the pavement sections to provide recommendations regarding the selection of and installation of an appropriate laterally-reinforcing biaxial geogrid product.

7.4 Conventional Foundations

1. Conventional continuous and spread footings with grade beams may be used for support of the proposed structures. Isolated pad footings are not allowed. Foundations must be designed in accordance to section 1808.6, 2013 CBC, Foundations on Expansive Soils.

2. Minimum footing and grade beam sizes and depths in engineered fill or uniform competent formational material should conform to the following table, as observed and approved by a representative of GeoSolutions, Inc.

Table 2: Minimum Footing and Grade Beam Dimensions

	Perimeter Footings	Grade Beams
Minimum Width	12 inches (one story) 15 inches (two story)	12 inches
Minimum Depth	24 inches	18 inches
Minimum Embedment in Competent Formational Material	12 inches	-
Minimum Reinforcing*	4 #5 bars (2 top / 2 bottom)	4 #4 bars (2 top / 2 bottom)
Spacing	-	19 feet on-center each way
* Steel should be held in place by stirrups at appropriate spacing to ensure proper positioning of the steel (see WRI Design of Slab-on-Ground Foundations and ACI 318, Section 7.5 – Placing Reinforcement).		

3. Minimum reinforcing for footings should conform to the recommendations provided in Table 2: Minimum Footing and Grade Beam Dimensions which meets the specifications of Section 1808.6 of the 2013 California Building Code for the soil conditions at the Site. Reinforcing steel should be held in place by stirrups at appropriate spacing to ensure proper positioning of the steel in accordance with WRI Design of Slab-on-Ground Foundations, and ACI 318, Section 7.5 – Placing Reinforcement.

4. A representative of this firm should observe and approve all foundation excavations for required embedment depth prior to the placement of reinforcing steel and/or concrete. Concrete should be placed only in excavations that are free of loose, soft soil and debris and that have been maintained in a moist condition with no desiccation cracks present.

5. An allowable dead plus live load bearing pressure of **2,000 psf** may be used for the design of footings founded in **60 inches of select import fill** in accordance with the recommendations presented in **Section 7.1 Site Preparation of Building Pad Areas, paragraph 4 (7.1.4)**, and an allowable dead plus live load bearing pressure of **2,500 psf** may be used for the design of footings founded in **uniform competent formational material** in accordance with the recommendations presented in **Section 7.1 Site Preparation of Building Pad Areas, paragraph 5 (7.1.5)**.

6. Allowable bearing capacities may be increased by one-third when transient loads such as wind and/or seismicity are included.

7. A total settlement of less than 1 inch and a differential settlement of less than 1 inch in 30 feet are anticipated.

8. Lateral forces on structures may be resisted by passive pressure acting against the sides of shallow footings and/or friction between the engineered fill or uniform competent formational material and the bottom of the footings. Values from Table 3: Foundation Lateral Resistance Parameters can be used to design for resistance to lateral loads. If friction and passive pressures are combined to resist lateral forces acting on shallow footings, the lesser value should be reduced by 50 percent.

Table 3: Foundation Lateral Resistance Parameters

Foundation Embedment Material	Lateral Passive Pressure, pcf	Friction Factor
Uniform Competent Formational Material	400	0.45
Select Import Material	300	0.35

9. Foundation excavations should be observed and approved by a representative of this firm prior to the placement of reinforcing steel and/or concrete.

10. Foundation design should conform to the requirements of Chapter 18 of the latest edition of the CBC (CBSC, 2013).

11. The base of all grade beams and footings should be level and stepped as required to accommodate any change in grade while still maintaining the minimum required footing embedment and slope setback distance.

12. The minimum footing setback distance from ascending or descending steeper than 3-to-1 (horizontal-to-vertical) but less than 1-to-1 must be maintained. See Figure 6: Setback Dimensions – Slope Gradients Between 3-to-1 and 1-to-1 Setback Dimensions – Slope Gradients Between 3-to-1 and 1-to-1 for the minimum horizontal setback distances from ascending and descending slopes steeper than 3-to-1 but not steeper than 1-to-1.

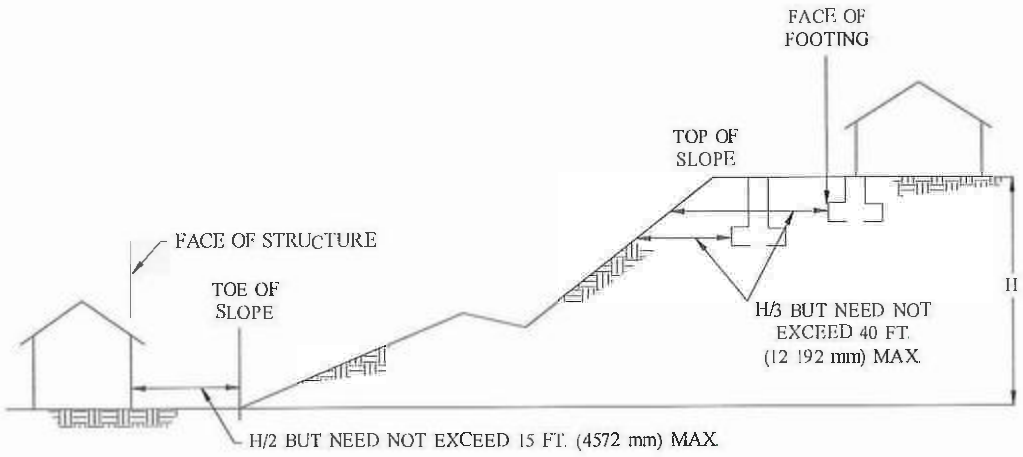


Figure 6: Setback Dimensions–Slope Gradients Between 3-to-1 and 1-to-1

7.5 Mat Foundations

1. A conventionally reinforced structural mat slab foundation system could be utilized to support the proposed structures as part of the development. The mat may be of a uniform thickness design, or may consist of shear and moment-resisting grade beams with structural slab elements connecting the grade beams. The mat may be constructed directly on the 36 inch layer of select import material, per section **7.1.3**.

2. Based on our experience, a mat slab approximately **10 to 15 inches thick** could be anticipated. A modulus of sub-grade reaction (k_s) of **50 pci** may be used in design.

3. An allowable dead plus live load bearing pressure of **1,000 psf** may be used for design of mat foundations in accordance with the recommendations presented in **Section 7.1 Site Preparation of Building Pad Areas, paragraph 3 (7.1.3).** Minimum reinforcing should be as directed by the project Structural Engineer.

4. Foundation excavations should be observed and approved by a representative of this firm prior to the placement of reinforcing steel and/or concrete. Concrete should be placed only in excavations that have been kept moist and are free of loose, soft soil or debris.

5. Lateral forces on structures may be resisted by passive pressure acting against the sides of shallow footings and/or friction between the native material and the bottom of the footings. For resistance to lateral loads, a friction factor of **0.35** may be utilized for sliding resistance at the base of footings.

6. Foundation excavations should be observed and approved by a representative of this firm prior to the placement of reinforcing steel and/or concrete.

7. Foundation design should conform to the requirements of Chapter 18 of the latest edition of the California Building Code.

7.6 Slab-On-Grade Construction

1. Concrete slabs-on-grade and flatwork should not be placed directly on unprepared native materials. Preparation of sub-grade to receive concrete slabs-on-grade and flatwork should

be processed as discussed in the preceding sections of this report. Concrete slabs should be placed only over sub-grade that is free of loose, soft soil and debris and that has been maintained in a moist condition with no desiccation cracks present.

2. Concrete slabs-on-grade should be in conformance with the recommendations provided in Table 4: Minimum Slab Recommendations. Reinforcing should be placed on-center both ways at or slightly above the center of the structural section. Reinforcing bars should have a minimum clear cover of 1.5 inches. Where lapping of the slab steel is required, laps in adjacent bars should be staggered a minimum of every five feet (see WRI Design of Slab-on-Ground Foundations, Steel Placement). The recommended reinforcement may be used for anticipated uniform floor loads not exceeding 200 psf. If floor loads greater than 200 psf are anticipated, a Structural Engineer should evaluate the slab design.

Table 4: Minimum Slab Recommendations

Minimum Thickness	5 inches
Reinforcing*	#4 bars at 16 inches on-center each way
* Where lapping of the slab steel is required, laps in adjacent bars should be staggered a minimum of every five feet (see WRI/CSRI-81 recommendations for Steel Placement, Section 2).	

3. Concrete for all slabs should be placed at a maximum slump of less than 5 inches. Excessive water content is the major cause of concrete cracking. If fibers are used to aid in the control of cracking, a water-reducing admixture may be added to the concrete to increase slump while maintaining a water/cement ratio, which will limit excessive shrinkage. Control joints should be constructed as required to control cracking.

4. Where concrete slabs-on-grade are to be constructed for interior conditioned spaces, the slabs should be underlain by a minimum of four inches of clean free-draining material, such as a ½ inch coarse aggregate mix, to serve as a cushion and a capillary break. Where moisture susceptible storage or floor coverings are anticipated, a 15-mil Stego Wrap membrane (or equivalent installed per manufacturer's specifications) should be placed between the free-draining material and the slab to minimize moisture condensation under the floor covering. See Figure 5: Sub-Slab Detail for the placement of under-slab drainage material. It is suggested, but not required, that a two-inch thick sand layer be placed on top of the membrane to assist in the curing of the concrete, increasing the depth of the under-slab material to a total of six inches. The sand should be lightly moistened prior to placing concrete.

5. It should be noted that for a vapor barrier installation to conform to manufacturer's specifications, sealing of penetrations, joints and edges of the vapor barrier membrane are typically required. As required by the California Building Code, joints in the vapor barrier should be lapped a minimum of 6 inches. If the installation is not performed in accordance with the manufacturer's specifications, there is an increased potential for water vapor to affect the concrete slabs and floor coverings.

6. The most effective method of reducing the potential for moisture vapor transmission through concrete slabs-on-grade would be to place the concrete directly on the surface of the vapor barrier membrane. However, this method requires a concrete mix design specific to this application with low water-cement ratio in addition to special concrete finishing and curing practices, to minimize the potential for concrete cracks and surface defects.

The contractor should be familiar with current techniques to finish slabs poured directly onto the vapor barrier membrane.

7. Moisture condensation under floor coverings has become critical due to the use of water-soluble adhesives. Therefore, it is suggested that moisture sensitive slabs not be constructed during inclement weather conditions.

7.7 Exterior Concrete Flatwork

1. Due the presence of highly expansive surface soils within the proposed development areas, there is a high potential for considerable soil movement and flatwork if conventional measures are used, such as the placement of 4 to 6 inches of imported sand materials placed beneath concrete flatwork. Heaving and cracking are anticipated to occur. To reduce the potential for movement associated with expansive soils, we recommend the placement of a minimum of **36 inches of approved select import material placed as engineered fill beneath the flatwork**.

2. Minimum flatwork reinforcement for conventional pedestrian areas should consist of No. 3 (#3) rebar spaced at 24 inches on-center each-way at or slightly above the center of the structural section. The flatwork should be a minimum of 4 inches thick.

3. Flatwork should be constructed with frequent joints to allow for movement due to fluctuations in temperature and moisture content in the adjacent soils. Flatwork at doorways, driveways, curbs and other areas where restraining the elevation of the flatwork is desired, should be doweled to the perimeter foundation by a minimum of No. 3 reinforcing steel dowels, spaced at a maximum distance of 24 inches on-center.

7.8 Retaining Walls

1. Retaining walls should be designed to resist lateral pressures from adjacent soils and surcharge loads applied behind the walls. We recommend using the lateral pressures presented in Table 5: Retaining Wall Design Parameters and Figure 7: Retaining Wall Detail for the design of retaining walls at the Site. The Active Case may be used for the design of unrestrained retaining walls, and the At-Rest Case may be used for the design of restrained retaining walls.

Table 5: Retaining Wall Design Parameters

Lateral Pressure and Condition	Equivalent Fluid Pressure, pcf
Static, Active Case, ($\gamma' K_A$)	
Select Import Material	40
Static, At-Rest Case, ($\gamma' K_O$)	
Select Import Material	60
Static, Passive Case, ($\gamma' K_P$)	
Select Import Material	300
Competent Formational Material	400

2. The above values for equivalent fluid pressure are based on retaining walls having level retained surfaces, having an approximately vertical surface against the retained material, and retaining granular backfill material or engineered fill composed of native soil within the active wedge. See Figure 7: Retaining Wall Detail and Figure 8: Retaining Wall Active and Passive Wedges for a description of the location of the active wedge behind a retaining wall.

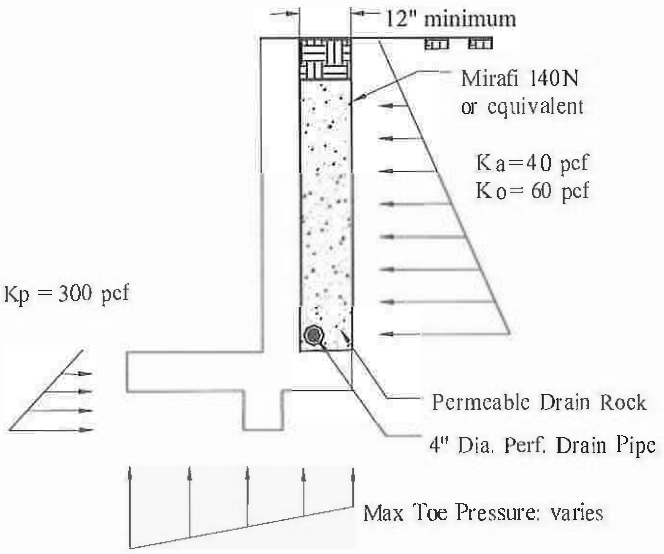


Figure 7: Retaining Wall Detail

3. Proposed retaining walls having a retained surface that slopes upward from the top of the wall should be designed for an additional equivalent fluid pressure of 1 pcf for the active case and 1.5 pcf for the at-rest case, for every degree of slope inclination.

4. We recommend that the proposed retaining walls at the Site have an approximately vertical surface against the retained material. If the proposed retaining walls are to have sloped surfaces against the retained material, the project designers should contact the Soils Engineer to determine the appropriate lateral earth pressure values for retaining walls located at the Site.

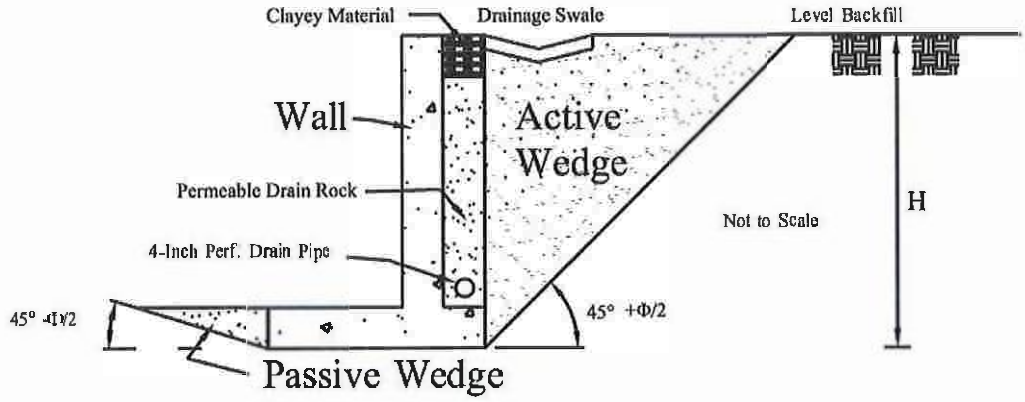


Figure 8: Retaining Wall Active and Passive Wedges

5. Retaining wall foundations should be founded a minimum of 24 inches below lowest adjacent grade in **select import fill** or founded a minimum of 24 inches below lowest adjacent grade with a minimum embedment of 12 inches in uniform **competent formational material** as observed and approved by a representative of GeoSolutions, Inc.

A coefficient of friction of **0.35** may be used between **select import fill** and concrete footings or **0.45** may be used between uniform **competent formational material** and concrete footings. Project designers may use a maximum toe pressure of **2,400 psf** for the design of retaining wall footings founded in **select import fill** and **3,000 psf** for footings founded in uniform **competent formational material**.

6. For earthquake conditions, retaining walls greater than 6 feet in height should be designed to resist an additional seismic lateral soil pressure of **25 pcf** equivalent fluid pressure for unrestrained walls (active condition). The pressure resultant force from earthquake loading should be assumed to act a distance of $^1/_3H$ above the base of the retaining wall, where H is the height of the retaining wall. Seismic active lateral earth pressure values were determined using the simplified dynamic lateral force component (SEAOC 2010) utilizing the design peak ground acceleration, PGA_M, discussed in Section 5.0 (**PGA_M = 0.541g (Site Class C) or PGA_M = 0.487g (Site Class E)**). The dynamic increment in lateral earth pressure due to earthquakes should be considered during the design of retaining walls at the Site. Based on research presented by Dr. Marshall Lew (Lew et al., 2010), lateral pressures associated with seismic forces should not be applied to restrained walls (at-rest condition).

7. Seismically induced forces on retaining walls are considered to be short-term loadings. Therefore, when performing seismic analyses for the design of retaining wall footings, we recommend that the allowable bearing pressure and the passive pressure acting against the sides of retaining wall footings be increased by a factor of one-third.

8. In addition to the static lateral soil pressure values reported in Table 5: Retaining Wall Design Parameters, the retaining walls at the Site should be designed to support any design live load, such as from vehicle and construction surcharges, etc., to be supported by the wall backfill. If construction vehicles are required to operate within 10 feet of a retaining wall, supplemental pressures will be induced and should be taken into account in the design of the retaining wall.

9. The recommended lateral earth pressure values are based on the assumption that sufficient sub-surface drainage will be provided behind the walls to prevent the build-up of hydrostatic pressure. To achieve this we recommend that a granular filter material be placed behind all proposed walls. The blanket of granular filter material should be a minimum of 12 inches thick and should extend from the bottom of the wall to 12 inches from the ground surface. The top 12 inches should consist of moisture conditioned, compacted, clayey soil. Neither spread nor wall footings should be founded in the granular filter material used as backfill.

10. A 4-inch diameter perforated or slotted drainpipe (ASTM DI 785 PVC) should be installed near the bottom of the filter blanket with perforations facing down. The drainpipe should be underlain by at least 4 inches of filter type material and should daylight to discharge in suitably projected outlets with adequate gradients. The filter material should consist of a clean free-draining aggregate, such as a coarse aggregate mix. If the retaining wall is part of a structural foundation, the drainpipe must be placed below finished slab sub-grade elevation.

11. The filter material should be encapsulated in a permeable geotextile fabric. A suitable permeable geotextile fabric, such as non-woven needle-punched Mirafi 140N or equal, may be utilized to encapsulate the retaining wall drain material and should conform to Caltrans Standard Specification 88-1.03 for underdrains.

12. For hydrostatic loading conditions (i.e. no free drainage behind retaining wall), an additional loading of 45-pcf equivalent fluid weight should be added to the active and at-rest lateral earth pressures. If it is necessary to design retaining structures for submerged conditions, the allowed bearing and passive pressures should be reduced by 50 percent. In addition, soil friction beneath the base of the foundations should be neglected.

13. Precautions should be taken to ensure that heavy compaction equipment is not used adjacent to walls, so as to prevent undue pressure against, and movement of the walls.

14. The use of water-stops/impermeable barriers should be used for any basement construction, and for building walls that retain earth.

8.0 ADDITIONAL GEOTECHNICAL SERVICES

The recommendations contained in this report are based on a limited number of borings and trenches, and on the continuity of the sub-surface conditions encountered. GeoSolutions, Inc. assumes that it will be retained to provide additional services during future phases of the proposed project. These services would be provided by GeoSolutions, Inc. as required by County of San Luis Obispo, the 2013 CBC, and/or industry standard practices. These services would be in addition to those included in this report and would include, but are not limited to, the following services:

1. Consultation during plan development.

2. Plan review of grading and foundation documents prior to construction and a report certifying that the reviewed plans are in conformance with our geotechnical recommendations.

3. Consultation during selection and placement of a laterally-reinforcing biaxial geogrid product.

4. Construction inspections and testing, as required, during all grading and excavating operations beginning with the stripping of vegetation at the Site, at which time a site meeting or pre-job meeting would be appropriate.

5. Special inspection services during construction of reinforced concrete, structural masonry, high strength bolting, epoxy embedment of threaded rods and reinforcing steel, and welding of structural steel.

6. Preparation of construction reports certifying that building pad preparation and foundation excavations are in conformance with our geotechnical recommendations.

7. Preparation of special inspection reports as required during construction.

8. In addition to the construction inspections listed above, section 1705.6 of the 2013 CBC (CBSC, 2013) requires the following inspections by the Soils Engineer for controlled fill thicknesses greater than 12 inches as shown in Table 6: Required Verification and Inspections of Soils:

Table 6: Required Verification and Inspections of Soils

Verification and Inspection Task	Continuous During Task Listed	Periodically During Task Listed
1. Verify materials below footings are adequate to achieve the design bearing capacity.	-	X
2. Verify excavations are extended to proper depth and have reached proper material.	-	X
3. Perform classification and testing of controlled fill materials.	-	X
4. Verify use of proper materials, densities and lift thicknesses during placement and compaction of controlled fill.	X	-
5. Prior to placement of controlled fill, observe sub-grade and verify that site has been prepared properly.	-	X

9.0 LIMITATIONS AND UNIFORMITY OF CONDITIONS

1. The recommendations of this report are based upon the assumption that the soil conditions do not deviate from those disclosed during our study. Should any variations or undesirable conditions be encountered during the development of the Site, GeoSolutions, Inc. should be notified immediately and GeoSolutions, Inc. will provide supplemental recommendations as dictated by the field conditions.

2. This report is issued with the understanding that it is the responsibility of the owner or his/her representative to ensure that the information and recommendations contained herein are brought to the attention of the architect and engineer for the project, and incorporated into the project plans and specifications. The owner or his/her representative is responsible to ensure that the necessary steps are taken to see that the contractor and subcontractors carry out such recommendations in the field.

3. As of the present date, the findings of this report are valid for the property studied. With the passage of time, changes in the conditions of a property can occur whether they are due to natural processes or to the works of man on this or adjacent properties. Therefore, this report should not be relied upon after a period of 3 years without our review nor should it be used or is it applicable for any properties other than those studied. However many events such as floods, earthquakes, grading of the adjacent properties and building and municipal code changes could render sections of this report invalid in less than 3 years.

REFERENCES

REFERENCES

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APPENDIX A

Field Investigation

Soil Classification Chart

Boring Logs

Trench Logs

FIELD INVESTIGATION

The field investigation was conducted May 18-19 & June 7, 2016 using a Mobile B-24 drill rig and extendahoe equipment. The surface and sub-surface conditions were studied by advancing four exploratory borings and seven exploratory trenches. This exploration was conducted in accordance with presently accepted geotechnical engineering procedures consistent with the scope of the services authorized to GeoSolutions, Inc.

The Mobile B-24 drill rig with a six-inch diameter solid-stem continuous flight auger bored four exploratory borings and the extendahoe advanced seven exploratory trenches near the approximate locations indicated on Figure 2: Site Plan. The drilling and field observation was performed under the direction of the project engineer. A representative of GeoSolutions, Inc. maintained a log of the soil conditions and obtained soil samples suitable for laboratory testing. The soils were classified in accordance with the Unified Soil Classification System. See the Soil Classification Chart in this appendix.

Standard Penetration Tests with a two-inch outside diameter standard split tube sampler (SPT) without liners (ASTM D1586-99) and a three-inch outside diameter Modified California (CA) split tube sampler with liners (ASTM D3550-01) were performed to obtain field indication of the in-situ density of the soil and to allow visual observation of at least a portion of the soil column. Soil samples obtained with the split spoon sampler are retained for further observation and testing. The split spoon samples are driven by a 140-pound hammer free falling 30 inches. The sampler is initially seated six inches to penetrate any loose cuttings and is then driven an additional 12 inches with the results recorded in the boring logs as N-values, which area the number of blows per foot required to advance the sample the final 12 inches.

The CA sampler is a larger diameter sampler than the standard (SPT) sampler with a two-inch outside diameter and provides additional material for normal geotechnical testing such as in-situ shear and consolidation testing. Either sampler may be used in the field investigation, but the N-values obtained from using the CA sampler will be greater than that of the SPT. The N-values for samples collected using the CA can be roughly correlated to SPT N-values using a conversion factor that may vary from about 0.5 to 0.7. A commonly used conversion factor is 0.67 ($^{2}/_{3}$). More information about standardized samplers can be found in ASTM D1586-99 and ASTM D3550-01.

Disturbed bulk samples are obtained from cuttings developed during boring operations. The bulk samples are selected for classification and testing purposes and may represent a mixture of soils within the noted depths. Recovered samples are placed in transport containers and returned to the laboratory for further classification and testing.

Logs of the borings showing the approximate depths and descriptions of the encountered soils, applicable geologic structures, recorded N-values, and the results of laboratory tests are presented in this appendix. The logs represent the interpretation of field logs and field tests as well as the interpolation of soil conditions between samples. The results of laboratory observations and tests are also included in the boring logs. The stratification lines recorded in the boring logs represent the approximate boundaries between the surface soil types. However, the actual transition between soil types may be gradual or varied.

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS		LABORATORY CLASSIFICATION CRITERIA		GROUP SYMBOLS	PRIMARY DIVISIONS
COARSE GRAINED SOILS More than 50% retained on No. 200 sieve	GRAVELS More than 50% of coarse fraction retainined on No. 4 (4.75mm) sieve	Clean gravels (less than 5% fines*)	C_u greater than 4 and C_z between 1 and 3	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			Not meeting both criteria for GW	GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		Gravel with fines (more than 12% fines*)	Atterberg limits plot below "A" line or plasticity index less than 4	GM	Silty gravels, gravel-sand-silt mixtures
			Atterberg limits plot below "A" line and plasticity index greater than 7	GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS More than 50% of coarse fraction passes No. 4 (4.75mm) sieve	Clean sand (less than 5% fines*)	C_u greater than 6 and C_z between 1 and 3	SW	Well graded sands, gravely sands, little or no fines
			Not meeting both criteria for SW	SP	Poorly graded sands and gravelly and sands, little or no fines
		Sand with fines (more than 12% fines*)	Atterberg limits plot below "A" line or plasticity index less than 4	SM	Silty sands, sand-silt mixtures
			Atterberg limits plot above "A" line and plasticity index greater than 7	SC	Clayey sands, sand-clay mixtures
FINE GRAINED SOILS 50% or more passes No. 200 sieve	SILTS AND CLAYS (liquid limit less than 50)	Inorganic soil	PI < 4 or plots below "A"-line	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
		Inorganic soil	PI > 7 and plots on or above "A" line**	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		Organic Soil	LL (oven dried)/LL (not dried) < 0.75	OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS (liquid limit 50 or more)	Inorganic soil	Plots below "A" line	MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
		Inorganic soil	Plots on or above "A" line	CH	Inorganic clays of high plasticity, fat clays
		Organic Soil	LL (oven dried)/LL (not dried) < 0.75	OH	Organic silts and organic clays of high plasticity
Peat	Highly Organic	Primarily organic matter, dark in color, and organic odor		PT	Peat, muck and other highly organic soils

*Fines are those soil particles that pass the No. 200 sieve. For gravels and sands with between 5 and 12% fines, use of dual symbols is required (i.e. GW-GM, GW-GC, GP-GM, or GP-GC)

**If the plasticity index is between 4 and 7 and it plots above the "A" line, then dual symbols (i.e. CL-ML) are required.

the "A" line, then dual symbols (i.e. CL-ML) are required.

CONSISTENCY

CLAYS AND PLASTIC SILTS	STRENGTH TON/SQ. FT ++	BLOWS/ FOOT+
VERY SOFT	0- 1/4	0-2
SOFT	1/4- 1/2	2-4
FIRM	1/2-1	4-8
STIFF	1-2	8-16
VERY STIFF	2-4	16-32
HARD	Over 4	Over 32

RELATIVE DENSITY

SANDS, GRAVELS AND NON-PLASTIC SILTS	BLOWS/ FOOT+
VERY LOOSE	0-4
LOOSE	4-10
MEDIUM DENSE	10-30
DENSE	30-50
VERY DENSE	Over 50

+ Number of blows of a 140-pound hammer falling 30-inches to drive a 2-inch O.D. (1-3/8-inch I.D.) split spoon (ASTM D1586).

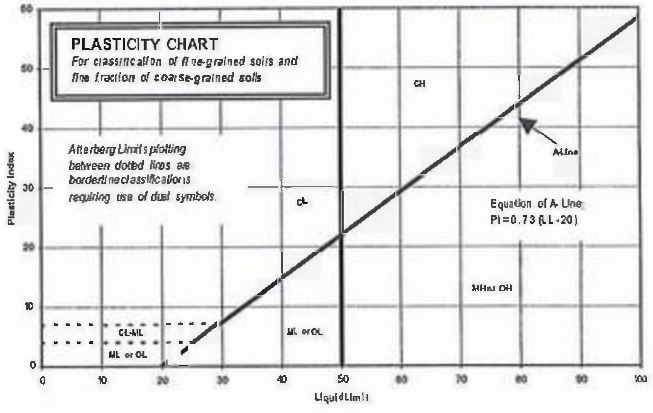
++ Unconfined compressive strength in tons/sq.ft. as determined by laboratory testing or approximated by the standard penetration test (ASTM D1586), pocket penetrometer, torvane, or visual observation.

CLASSIFICATIONS BASED ON PERCENTAGE OF FINES

Less than 5%, Pass No. 200 (75mm) sieve — GW, GP, SW, SP

More than 12% Pass N. 200 (75 mm) sieve — GM, GC, SM, SC

5%-12% Pass No. 200 (75 mm) sieve — Borderlife Classification requiring use of dual symbols



Drilling Notes:

1. Sampling and blow counts
   a. California Modified – number of blows per foot of a 140 pound hammer falling 30 inches
   b. Standard Penetration Test – number of blows per 12 inches of a 140 pound hammer falling 30 inches

Types of Samples:
X–Sample
SPT - Standard Penetration
CA - California Modified
N - Nuclear Gauge
PO– Pocket Penetrometer (tons/sq.ft.)

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BORING LOG

BORING NO. **B-1**

JOB NO. **SL09734-1**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 18, 2016**	SAMPLING METHOD:	**SPT and CA**
LOGGED BY:	GTV	HOLE ELEVATION:	**Not Recorded**

▼ Depth of Groundwater: **Not Encountered** Boring Terminated At: **10.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	CLAYEY SAND: very dark grayish brown, dry	CH											
-1				A			287				107	79.6	31
-2	stiff			SPT	6	9							
-3	SANDY CLAY: dark brown, dry	CH											
-4													
-5	stiff			CA	8	8		110					
-6													
-7													
-8	stiff												
-9				SPT	9	9							
-10													
-11													
-12													
-13													
-14													
-15													
-16													
-17													
-18													
-19													
-20													

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BORING LOG

BORING NO. **B-2**

JOB NO. **SL09734-1**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	Madonna - Froom Ranch	DRILLRIG:	Mobile B-24
DRILLING LOCATION:	See Figure 2, Site Plan	HOLE DIAMETER:	6 Inches
DATE DRILLED:	May 19, 2016	SAMPLING METHOD:	SPT
LOGGED BY:	GTV	HOLE ELEVATION:	Not Recorded

▼ Depth of Groundwater: **4.0 Feet** Boring Terminated At: **46.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	CLAYEY SAND: very dark grayish brown, dry	CH											
-2	SANDY CLAY: dark brown, dry	CH											
-4	▼ firm			SPT	5	7							
-6	SANDY CLAY: dark olive brown, very moist	CH											
-8	stiff			SPT	8	8							
-10	SANDY CLAY: black, very moist	CH											
-12	stiff			SPT	16	15							
-16	SANDY CLAY: dark olive brown, with gravel, coarse grained	CH											
-18	stiff			SPT	5	4							
-20													
-22													

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BORING LOG

BORING NO (cont). **B-2**

JOB NO. **SL09734-1**

▼ Depth of Groundwater: **4.0 Feet** Boring Terminated At: **46.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	(N1)60	FRICTION ANGLE (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINE CONTENTS	PLASTICITY INDEX (PI)
-25	SANDY CLAY: dark yellowish brown, saturated	CH											
-26	very stiff												
-27													
-28													
-29				SPT	21	16							
-30													
-31													
-32													
-33													
-34													
-35													
-36													
-37													
-38													
-39													
-40													
-41													
-42													
-43													
-44													
-45	very sticky												
-46	FRANCISCAN COMPLEX: serpentinite & melange, meta volcanic, very weathered			SPT	50/1"								
-47													
-48													
-49													
-50													

GeoSolutions, Inc.

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BORING LOG

BORING NO. **B-3**

JOB NO. **SL09734-1**

PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 18, 2016**	SAMPLING METHOD:	**SPT and CA**
LOGGED BY:	**GTV**	HOLE ELEVATION:	**Not Recorded**

▼ Depth of Groundwater: **1.5 Feet** Boring Terminated At: **10.0 Feet**

DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	FAT CLAY: very dark grayish brown, dry	CH		B							186	94.7	48
-1													
-2	firm			SPT	4	6							
-3	SANDY CLAY: dark olive brown, very moist	CH											
-4													
-5	firm			CA	6	6							
-6													
-7	soft												
-8													
-9				SPT	2	2							
-10													
-11													
-12													
-13													
-14													
-15													
-16													
-17													
-18													
-19													
-20													

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BORING LOG

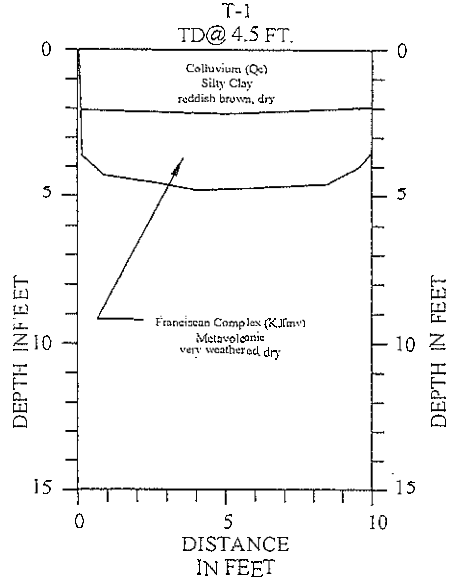
BORING NO. **B-4**

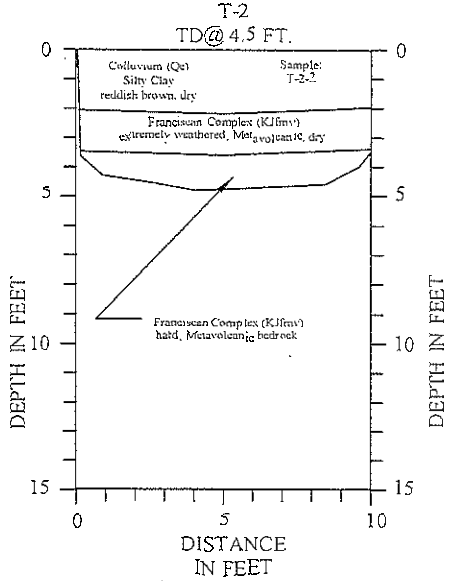
JOB NO. **SL09734-1**

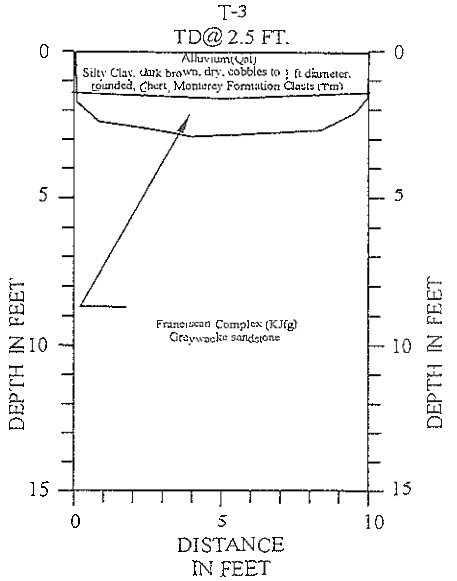
PROJECT INFORMATION		DRILLING INFORMATION	
PROJECT:	**Madonna - Froom Ranch**	DRILL RIG:	**Mobile B-24**
DRILLING LOCATION:	**See Figure 2, Site Plan**	HOLE DIAMETER:	**6 Inches**
DATE DRILLED:	**May 18, 2016**	SAMPLING METHOD:	**CA and SPT**
LOGGED BY:	**GTV**	HOLE ELEVATION:	**Not Recorded**

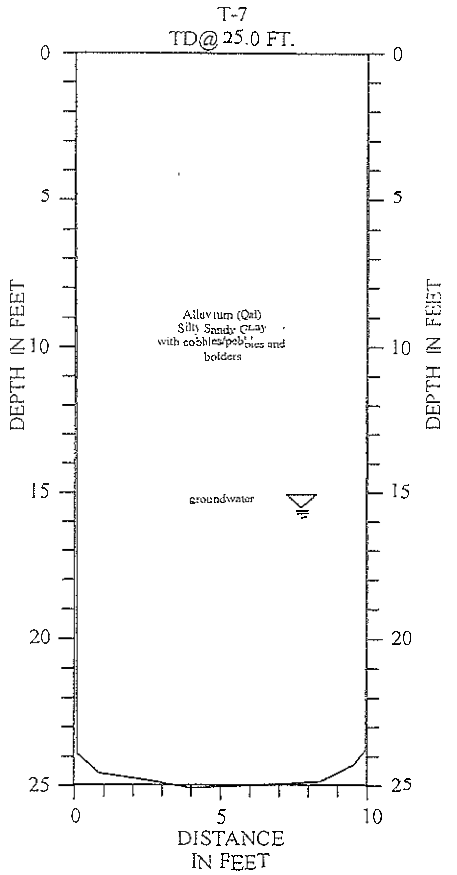
▼ Depth of Groundwater: **2.5 Feet** Boring Terminated At: **10.0 Feet**

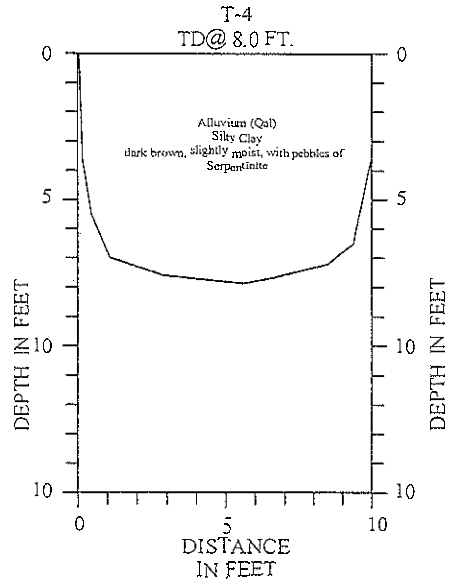
DEPTH	SOIL DESCRIPTION	USCS	LITHOLOGY	SAMPLE	BLOWS/ 12 IN	$(N_1)_{60}$	FRICTION ANGLE, (degrees)	COHESION, C (psf)	OPTIMUM WATER CONTENT (%)	MAXIMUM DRY DENSITY (pcf)	EXPANSION INDEX (EI)	FINES CONTENT (%)	PLASTICITY INDEX (PI)
0	CLAYEY SAND: very dark brown, very moist	CH											
-1	soft												
-2													
-3													
-4													
-5	SANDY CLAY: dark brown, very moist	CH		CA	3	3							
-6													
-7													
-8													
-9	firm			SPT	6	6							
-10													
-11													
-12													
-13													
-14													
-15													
-16													
-17													
-18													
-19													
-20													

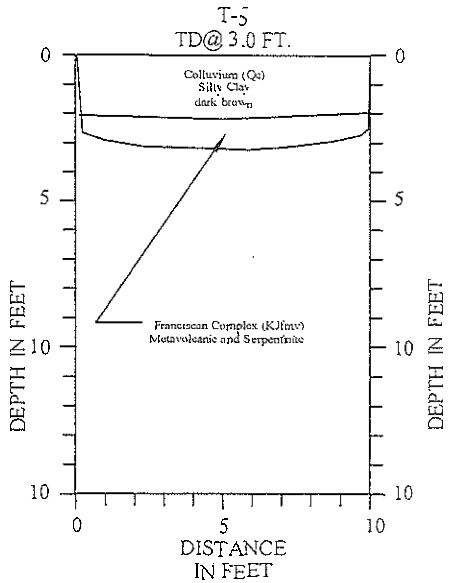


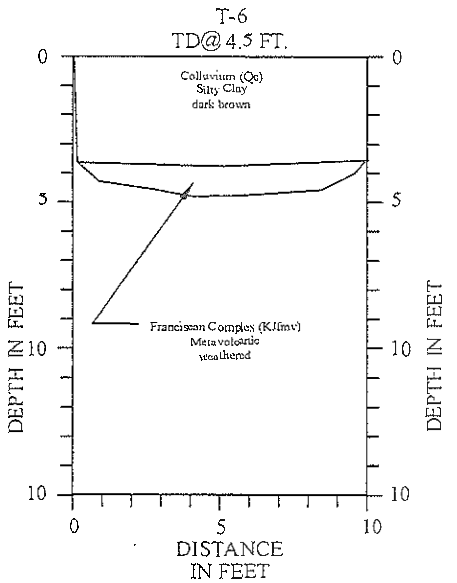












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STATE OF CALIFORNIA

TRENCHING LOGS

MADONNA - FROOM RANCH
SAN LUIS OBISPO, CALIFORNIA

LOGS
1

PROJECT
SL09734-1

APPENDIXB

Laboratory Testing

Soil Test Reports

LABORATORY TESTING

This appendix includes a discussion of the test procedures and the laboratory test results performed as part of this investigation. The purpose of the laboratory testing is to assess the engineering properties of the soil materials at the Site. The laboratory tests are performed using the currently accepted test methods, when applicable, of the American Society for Testing and Materials (ASTM).

Undisturbed and disturbed bulk samples used in the laboratory tests are obtained from various locations during the course of the field exploration, as discussed in **Appendix A** of this report. Each sample is identified by sample letter and depth. The Unified Soils Classification System is used to classify soils according to their engineering properties. The various laboratory tests performed are described below:

Expansion Index of Soils (ASTM D4829-08) is conducted in accordance with the ASTM test method and the California Building Code Standard, and are performed on representative bulk and undisturbed soil samples. The purpose of this test is to evaluate expansion potential of the site soils due to fluctuations in moisture content. The sample specimens are placed in a consolidometer, surcharged under a 144-psf vertical confining pressure, and then inundated with water. The amount of expansion is recorded over a 24-hour period with a dial indicator. The expansion index is calculated by determining the difference between final and initial height of the specimen divided by the initial height.

Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D4318-05) are the water contents at certain limiting or critical stages in cohesive soil behavior. The liquid limit (LL or W_L) is the lower limit of viscous flow, the plastic limit (PL or W_P) is the lower limit of the plastic stage of clay and plastic index (PI or I_P) is a range of water content where the soil is plastic. The Atterberg Limits are performed on samples that have been screened to remove any material retained on a No. 40 sieve. The liquid limit is determined by performing trials in which a portion of the sample is spread in a brass cup, divided in two by a grooving tool, and then allowed to flow together from the shocks caused by repeatedly dropping the cup in a standard mechanical device. To determine the Plastic Limit a small portion of plastic soil is alternately pressed together and rolled into a 1/8-inch diameter thread. This process is continued until the water content of the sample is reduced to a point at which the thread crumbles and can no longer be pressed together and re-rolled. The water content of the soil at this point is reported as the plastic limit. The plasticity index is calculated as the difference between the liquid limit and the plastic limit.

Direct Shear Tests of Soils Under Consolidated Drained Conditions (ASTM D3080-04) is performed on undisturbed and remolded samples representative of the foundation material. The samples are loaded with a predetermined normal stress and submerged in water until saturation is achieved. The samples are then sheared horizontally at a controlled strain rate allowing partial drainage. The shear stress on the sample is recorded at regular strain intervals. This test determines the resistance to deformation, which is shear strength, inter-particle attraction or cohesion c, and resistance to interparticle slip called the angle of internal friction ϕ.

Particle Size Analysis of Soils (ASTM D422-63R02) is used to determine the particle-size distribution of fine and coarse aggregates. In the test method the sample is separated through a series of sieves of progressively smaller openings for determination of particle size distribution. The total percentage passing each sieve is reported and used to determine the distribution of fine and coarse aggregates in the sample.

Density of Soil in Place by the Drive-Cylinder Method (ASTM D2937-04) and **Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass** (ASTM D2216-05) are used to obtain values of in-place water content and in-place density. Undisturbed samples, brought from the field to the laboratory, are weighed, the volume is calculated, and they are placed in the oven to dry. Once the samples have been dried, they are weighed again to determine the water content, and the in-place density is then calculated. The moisture density tests allow the water content and in-place densities to be obtained at required depths.

One-Dimensional Consolidation Properties of Soils Using Incremental Loading (ASTM D2435-11) is used to determine the magnitude and rate of consolidation of a soil by applying a series of load increments to an undisturbed soil sample and recording sample deformation at selected time intervals. In this test method, a soil specimen is restrained laterally and drained axially while subjected to incrementally applied controlled-stress loading. Each stress increment is maintained until excess pore water pressures are completely dissipated. During the consolidation process, measurements are made of the change in the specimen height and this data is used to determine the relationship between the effective stress and void-ratio or strain, and the rate at which consolidation can occur by evaluating the coefficient of consolidation. The data from the consolidation test is used to estimate the magnitude and rate of both differential and total settlement of a structure or earth-fill.

GeoSolutions, Inc. | **SOILS REPORT** | **(805) 543-8539**

Project:	Madonna Froom Ranch			Date Tested:	June 3, 2016
Client:				Project#:	SL09734-1
Sample:	A	Depth:	1.0 Foot	Lab#:	16516
Location:	B-1			Sample Date:	May 18, 2016
				Sampled By:	GV/TG

Soil Classification
ASTM D2487, D2488

Result:	Very Dark Grayish Brown Sandy Fat CLAY
Specification:	CH

Sieve Analysis
ASTMD422

Sieve Size	Percent Passing	Project Specifications
3"		
2"		
1 1/2"		
1"		
3/4"		
No. 4	93	
No. 8	90	
No. 16	89	
No. 30	87	
No. 50	84	
No. 100	82	
No. 200	79.6	

Sand Equivalent Cal 217

1		SE
2		
3		
4		

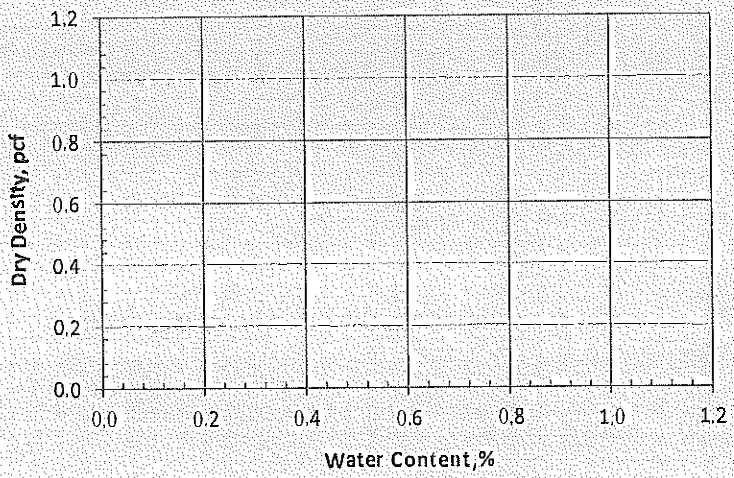
Plasticity Index
ASTM D4318

Liquid Limit:	54
Plastic Limit:	23
Plasticity Index:	**31**

Expansion Index
ASTMD4829

Expansion Index:	**107**
Expansion Potential:	High
Initial Saturation, %	50

Laboratory Maximum Density
ASTMD1557



Mold ID	n/a	Mold Diameter, ins.	4.00
No. of Layers	5	Weight of Rammer, lbs.	10.00
No. of Blows	25		

Estimated Specific Gravity for 100% Saturation Curve=

Trial#	1	2	3	4
Water Content:				
Dry Density:				

Maximum Dry Density, pcf:	
Optimum Water Content, %	

Moisture-Density ASTM D2937, **Moisture Content** ASTM D2216

Sample	Depth (ft)	Water Content(%)	Dry Density (pcf)	Relative Density	Sample Description
B-1	2.5	38.5			Dark Olive Gray Sandy CLAY
B-2	2.5	27.4			Dark Olive Gray Sandy CLAY

Report By: Aaron Eichman

GeoSolutions, Inc. | **SOILS REPORT** | **(805) 543-8539**

Project:	Madonna Froom Ranch			Date Tested:	June 8, 2016
Client:				Project#:	SL09734-1
Sample:	B	Depth:	1.0 Foot	Lab#:	16516
Location:	B-3			Sample Date:	May 18, 2016
				Sampled By:	GV/TG

Soil Classification
ASTM D2487, D2488

Result:	Dark Gray Fat CLAY
Specification:	CH

Sieve Analysis
ASTMD422

Sieve Size	Percent Passing	Project Specifications
3"		
2"		
1 1/2"		
1"		
3/4"		
No.4	100	
No. 8	100	
No. 16	100	
No. 30	99	
No. 50	98	
No. 100	96	
No. 200	94.7	

Sand Equivalent CA217

1		SE
2		
3		
4		

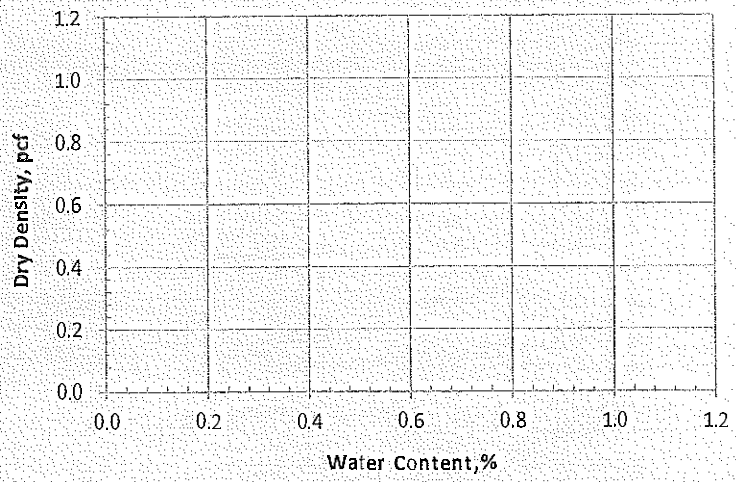
Plasticity Index
ASTMD4318

Liquid Limit:	84
Plastic Limit:	36
Plasticity Index:	48

Expansion Index
ASTM D 4829

Expansion Index:	186
Expansion Potential:	Very High
Initial Saturation, %:	50

Laboratory Maximum Density
ASTMD1557



Mold ID	n/a	Mold Diameter, ins.	4.00
No. of Layers	5	Weight of Rammer, lbs.	10.00
No. of Blows	25		

Estimated Specific Gravity for 100% Saturation Curve=

Trial#	1	2	3	4
Water Content:				
Dry Density:				

Maximum Dry Density, pcf:	
Optimum Water Content, %	

Moisture-Density ASTM D2937, **Moisture Content** ASTM D2216

Sample	Depth (ft)	Water Content(%)	Dry Density (pcf)	Relative Density	Sample Description

Report By: Aaron Eichman

GeoSolutions, Inc. **SOILS REPORT** **(805) 543-8539**

Project:	Madonna Froom Ranch			Date Tested:	June 9, 2016
Client:				Project#:	SL09734-1
Sample:	C	Depth:	2.0 Feet	Lab#:	16516
Location:	T-2			Sample Date:	May 18, 2016
				Sampled By:	GV/TG

Soil Classification
ASTM D2487, D2488

Result:	Dark Reddish Brown Sandy Fat CLAY
Specification:	CH

Sieve Analysis
ASTMD422

Sieve Size	Percent Passing	Project Specifications
3"		
2"		
1 1/2"		
1"		
3/4"		
No.4		
No.8		
No. 16		
No.30		
No. 50		
No. 100		
No.200		

Sand Equivalent Ca 217

		SE
1		
2		
3		
4		

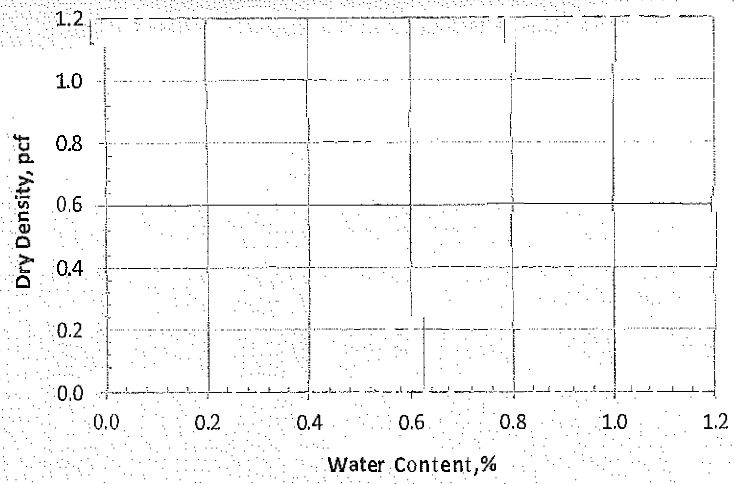
Plasticity Index
ASTMD4318

Liquid Limit:	65
Plastic Limit:	23
Plasticity Index:	42

Expansion Index
ASTM D4829

Expansion Index:	79
Expansion Potential:	Medium
Initial Saturation, %	50

Laboratory Maximum Density
ASTMD1557



Mold ID	n/a	Mold Diameter, ins.	4.00
No. ofLayers	5	Weight ofRammer, lbs.	10.00
No. of Blows	25		

Estimated Specific Gravity for 100% Saturation Curve=

Trial#	1	2	3	4
Water Content:				
Dry Density:				

Maximum Dry Density, pcf:	
Optimum Water Content,%:	

Moisture-Density ASTM D2937, **Moisture Content** ASTM D2216

Sample	Depth (ft)	Water Content(%)	Dry Density (pcf)	Relative Density	Sample Description

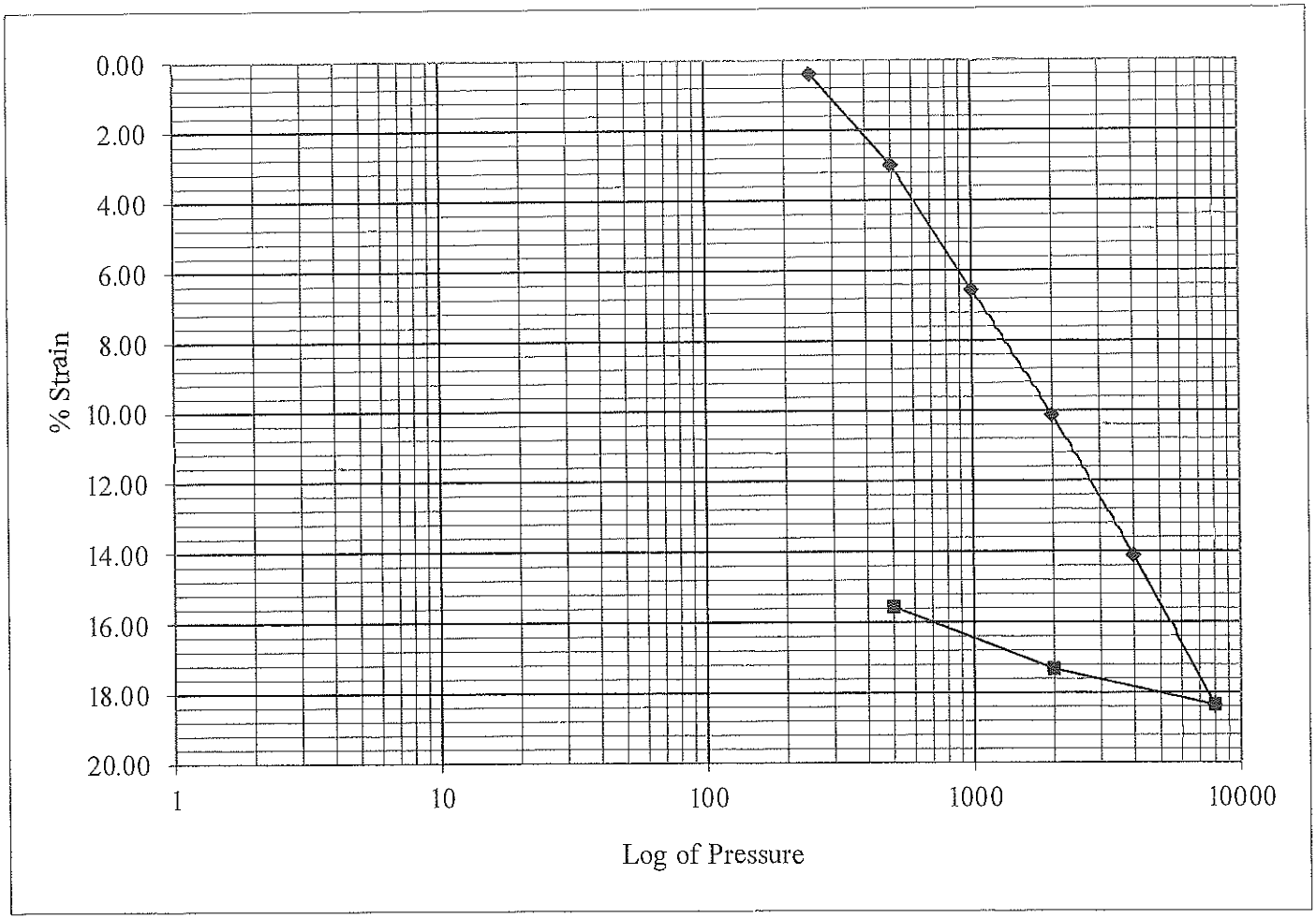
Report By: Aaron Eichman

GeoSolutions, Inc.

CONSOLIDATION REPORT
D2435-11

(805) 543-8539

Project:	Madonna Froom Ranch			Date Tested:	6/7/2016
Client:				Project #:	SL09734-1
Sample:	B-1 @ 5'	Depth:	5.0 Feet	Lab#:	16516
Location:	B-1			Sample Date:	5/18/2016
Material:	Very Dark Grayish Brown Sandy CLAY			Sampled By:	GV/TG



Applied Pressure (psf)	% Strain
250	0.38
500	2.99
1000	6.55
2000	10.12
4000	14.11
8000	18.35
2000	17.32
500	15.56

Compression Index, Cc
0.165
Recompression Index, Cr
0.017

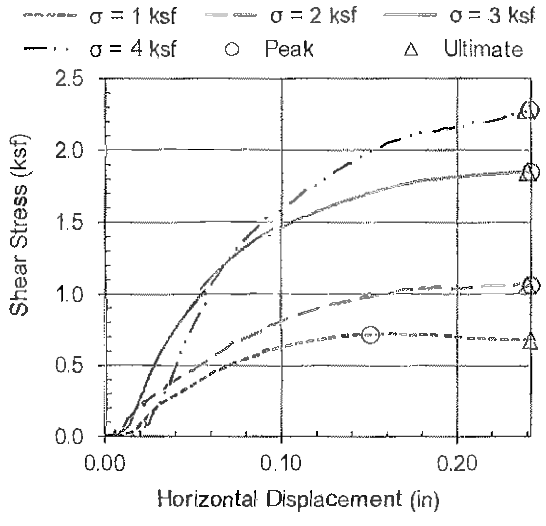
Report By: Aaron Eichman

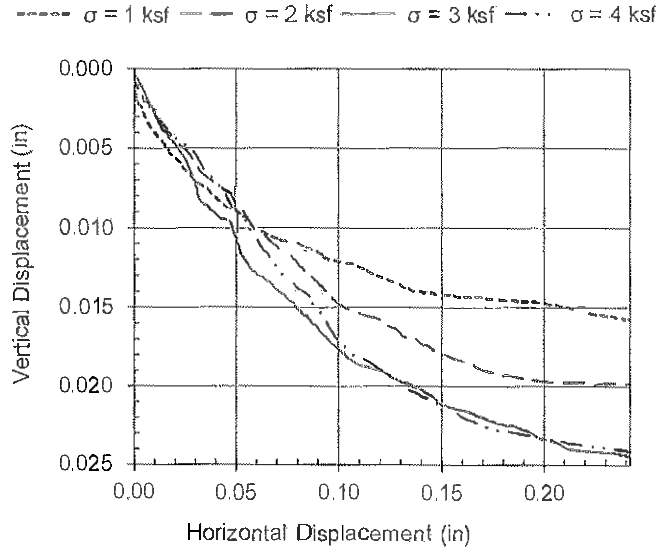
Geo Solutions, Inc. | **DIRECT SHEAR TEST SUMMARY REPORT (ASTM D3080)** | (805) 543-8539

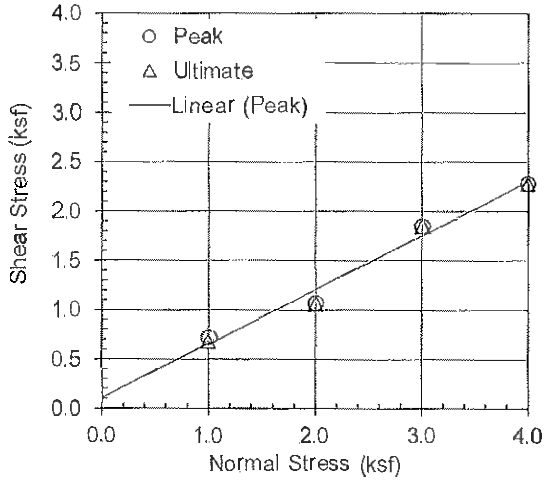
Project:	Madonna Froom Ranch			Project No:	SL09734-1
Client:				Date Tested:	6/9/2016
Sample No.:	B-1 @5'	Depth:	5.0 Feet	Lab No.:	16516
Location:	B-1			Checked By:	AE

MATERIAL DESCRIPTION	LL	PL	PI	% passing No.200	Gs*	Sample Type
Very Dark Grayish Brown Sandy CLAY	nm	nm	nm	nm	2.4	in-situ (rings)

*Gs = assumed; nm = not measured







Angle of Internal Friction, ϕ_{peak} (degrees):	28.7
Cohesion, C_{peak} (psf)	110

Initial Conditions	Specimen No. 1	2	3	4
Dry Density	92.3	90.3	87.4	95.7
Water Content (%)	25.8	25.8	25.8	25.8
Diameter (in)	2.42	2.42	2.42	2.42
Sample Height (in)	1.00	1.00	1.00	1.00

Test Data	Specimen No. 1	2	3	4
Normal Stress (ksf)	1.00	2.00	3.00	4.00
Peak Shear Stress (ksf)	0.72	1.06	1.85	2.28
Horiz. Displacement at Peak Shear (in)	0.15	0.24	0.24	0.24
Ultimate Shear Stress (ksf)	0.68	1.06	1.85	2.28
Horiz. Displ. at Ult. Shear (in)	0.24	0.24	0.24	0.24
Rate of Deformation (in/min)	0.002	0.002	0.002	0.002

Remarks:

Samples were not saturated prior to shearing

APPENDIX C

USGS Design Map Summary Report

USGS Design Map Detailed Report

USGS Design Maps Summary Report

User-Specified Input

Report Title	Froom Ranch - Upper Site Tue June 21, 2016 23:46:53 UTC
Building Code Reference Document	ASCE 7-10 Standard (which utilizes USGS hazard data available in 2008)
Site Coordinates	35.24805°N, 120.68614°W
Site Soil Classification	Site Class C – "Very Dense Soil and Soft Rock"
Risk Category	I/II/III

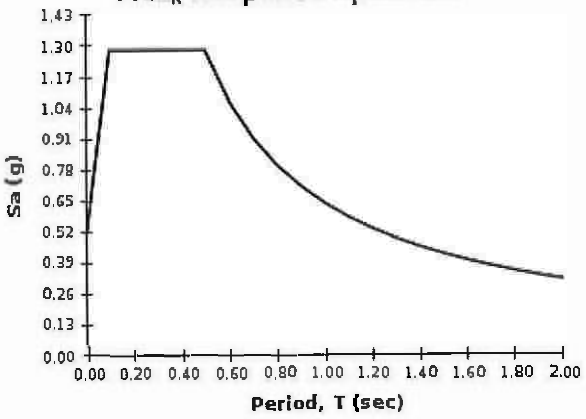


USGS-Provided Output

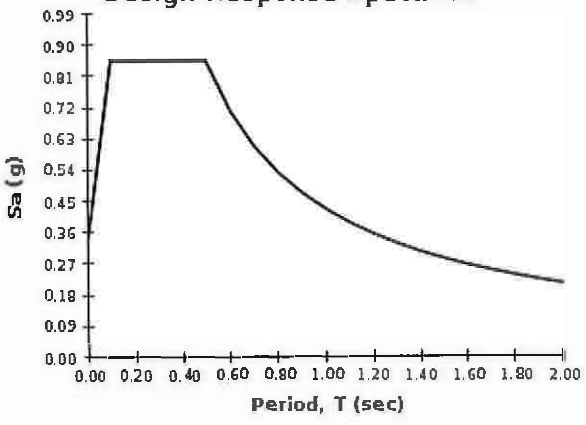
S_S =	1.281 g	S_{MS} =	1.281 g	S_{DS} =	0.854 g
S_1 =	0.484 g	S_{M1} =	0.637 g	S_{D1} =	0.425 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.

MCE_R Response Spectrum



Design Response Spectrum



For PGA_M, T_L, C_{RS}, and C_{R1} values, please view the detailed report.

Although this information is a product of the U.S. Geological Survey, we provide no warranty, expressed or implied, as to the accuracy of the data contained therein. This tool is not a substitute for technical subject-matter knowledge.

USGS Design Maps Detailed Report

ASCE 7-10 Standard (35.24805°N, 120.68614°W)

Site Class C – "Very Dense Soil and Soft Rock", Risk Category I/II/III

Section 11.4.1 — Mapped Acceleration Parameters

Note: Ground motion values provided below are for the direction of maximum horizontal spectral response acceleration. They have been converted from corresponding geometric mean ground motions computed by the USGS by applying factors of 1.1 (to obtain S_S) and 1.3 (to obtain S_1). Maps in the 2010 ASCE-7 Standard are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 11.4.3.

From Figure 22-1 [1] $S_S = 1.281$ g

From Figure 22-2 [2] $S_1 = 0.484$ g

Section 11.4.2 — Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class C, based on the site soil properties in accordance with Chapter 20.

Table 20.3-1 Site Classification

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard Rock	>5,000 ft/s	N/A	N/A
B. Rock	2,500 to 5,000 ft/s	N/A	N/A
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff Soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the characteristics: • Plasticity index PI > 20, • Moisture content $w \geq 40\%$, and • Undrained shear strength $\bar{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1ft/s = 0.3048 m/s 1lb/ft^2= 0.0479 kN/m^2

Section 11.4.3 — Site Coefficients and Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameters

Table 11.4-1: Site Coefficient F_a

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at Short Period				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_S

For Site Class= C and S_S = 1.281 g, F_a = 1.000

Table 11.4-2: Site Coefficient F_v

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at 1-s Period				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_1

For Site Class= C and S_1 = 0.484 g, F_v = 1.316

Equation (11.4–1): $S_{MS} = F_a S_S = 1.000 \times 1.281 = 1.281$ g

Equation (11.4–2): $S_{M1} = F_v S_1 = 1.316 \times 0.484 = 0.637$ g

Section 11.4.4 — Design Spectral Acceleration Parameters

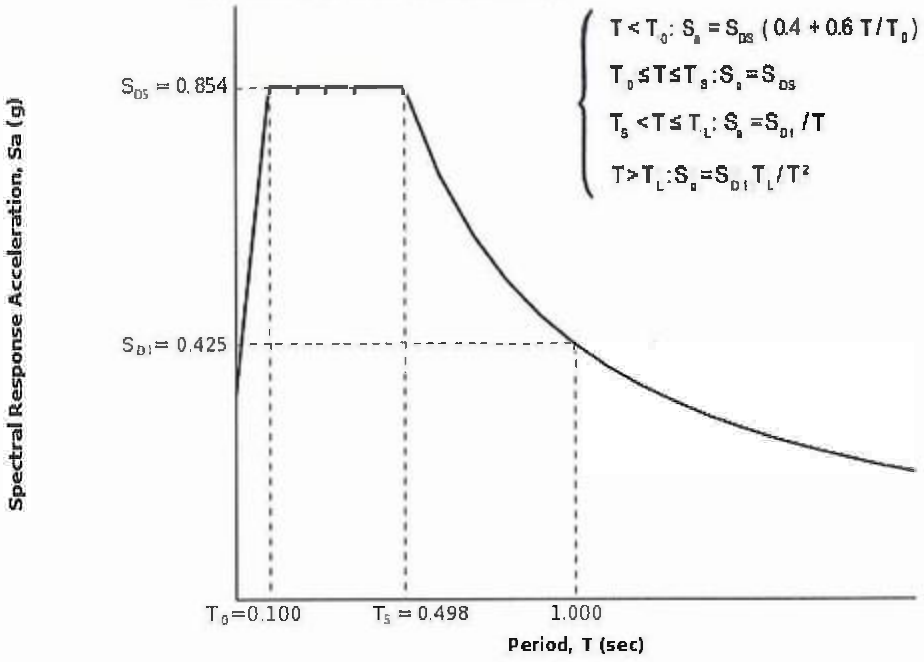
Equation (11.4–3): $S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3} \times 1.281 = 0.854$ g

Equation (11.4–4): $S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3} \times 0.637 = 0.425$ g

Section 11.4.5 — Design Response Spectrum

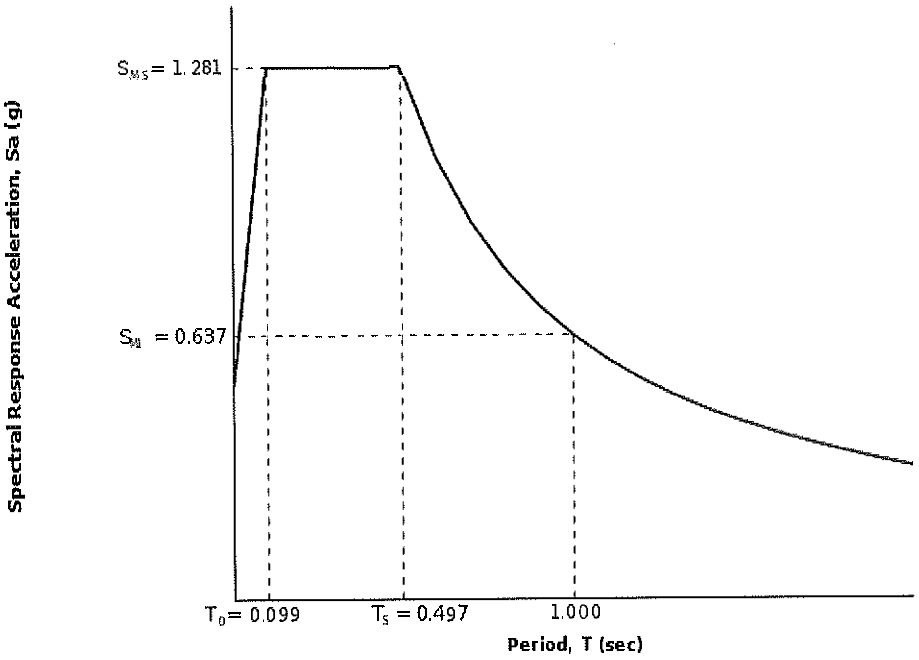
From Figure 22-12 [3] $T_L = 8$ seconds

Figure 11.4–1: Design Response Spectrum



Section 11.4.6 — Risk-Targeted Maximum Considered Earthquake (MCE_R) Response Spectrum

The MCE_R Response Spectrum is determined by multiplying the design response spectrum above by 1.5.



Section 11.8.3 — Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

From Figure 22-7 [4] PGA = 0.541

Equation (11.8-1): $PGA_M = F_{PGA}PGA = 1.000 \times 0.541 = 0.541$ g

Table 11.8-1: Site Coefficient F_{PGA}

Site Class	Mapped MCE Geometric Mean Peak Ground Acceleration, PGA				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of PGA

For Site Class= C and PGA = 0.541 g, F_{PGA} = 1.000

Section 21.2.1.1 — Method 1 (from Chapter 21 - Site-Specific Ground Motion Procedures for Seismic Design)

From Figure 22-17 [5] C_{RS} = 0.902

From Figure 22-18 [6] C_{R1} = 0.939

Section 11.6 — Seismic Design Category

Table 11.6-1 Seismic Design Category Based on Short Period Response Acceleration Parameter

VALUE OF S_{DS}	RISK CATEGORY		
	I or II	III	IV
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D	D	D

For Risk Category = I and S_{DS} = 0.854 g, Seismic Design Category = D

Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

VALUE OF S_{D1}	RISK CATEGORY		
	I or II	III	IV
$S_{D1} < 0.067g$	A	A	A
$0.067g \le S_{D1} < 0.133g$	B	B	C
$0.133g \le S_{D1} < 0.20g$	C	C	D
$0.20g \le S_{D1}$	D	D	D

For Risk Category = I and S_{D1} = 0.425 g, Seismic Design Category = D

Note: When S_1 is greater than or equal to 0.75g, the Seismic Design Category is **E** for buildings in Risk Categories I, II, and III, and **F** for those in Risk Category IV, irrespective of the above.

Seismic Design Category ≡ "the more severe design category in accordance with Table 11.6-1 or 11.6-2" = D

Note: See Section 11.6 for alternative approaches to calculating Seismic Design Category.

References

1. *Figure 22-1*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-1.pdf
2. *Figure 22-2*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-2.pdf
3. *Figure 22-12*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-12.pdf
4. *Figure 22-7*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-7.pdf
5. *Figure 22-17*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-17.pdf
6. *Figure 22-18*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-18.pdf

USGS Design Maps Summary Report

User-Specified Input

Report Title	Froom Ranch - Lower Site Tue June 21, 2016 23:48:46 UTC
Building Code Reference Document	ASCE 7-10 Standard (which utilizes USGS hazard data available in 2008)
Site Coordinates	35.24805°N, 120.68614°W
Site Soil Classification	Site Class E – "Soft Clay Soil"
Risk Category	I/II/III

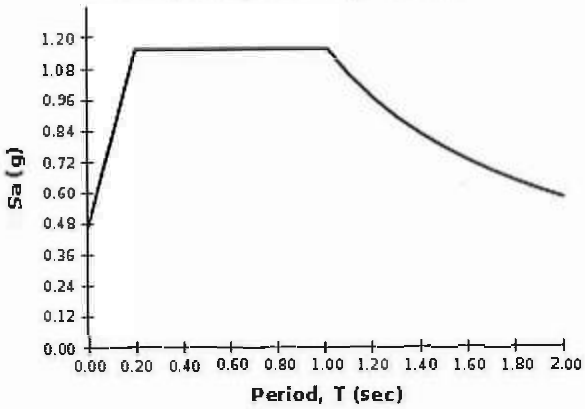


USGS-Provided Output

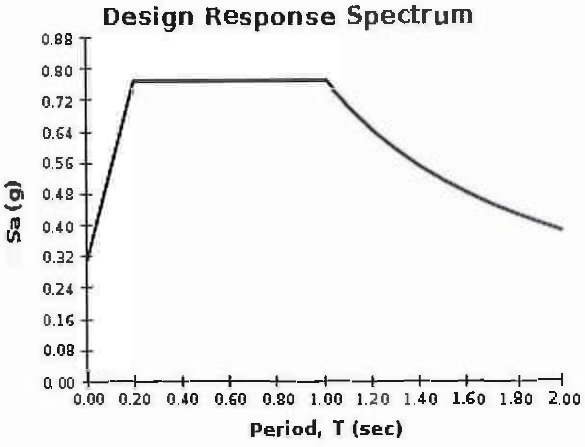
S_S =	1.281 g	S_{MS} =	1.153 g	S_{DS} =	0.769 g
S_1 =	0.484 g	S_{M1} =	1.162 g	S_{D1} =	0.774 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.

MCE_R Response Spectrum



Design Response Spectrum



For PGA_M, T_L, C_RS, and C_R1 values, please view the detailed report.

Although this information is a product of the U.S. Geological Survey, we provide no warranty, expressed or implied, as to the accuracy of the data contained therein. This tool is not a substitute for technical subject-matter knowledge.

USGS Design Maps Detailed Report

ASCE 7-10 Standard (35.24805°N, 120.68614°W)

Site Class E – "Soft Clay Soil", Risk Category I/II/III

Section 11.4.1 — Mapped Acceleration Parameters

Note: Ground motion values provided below are for the direction of maximum horizontal spectral response acceleration. They have been converted from corresponding geometric mean ground motions computed by the USGS by applying factors of 1.1 (to obtain S_S) and 1.3 (to obtain S_1). Maps in the 2010 ASCE-7 Standard are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 11.4.3.

From Figure 22-1 [1] $S_S = 1.281$ g

From Figure 22-2 [2] $S_1 = 0.484$ g

Section 11.4.2 — Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class E, based on the site soil properties in accordance with Chapter 20.

Table 20.3–1 Site Classification

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard Rock	>5,000 ft/s	N/A	N/A
B. Rock	2,500 to 5,000 ft/s	N/A	N/A
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff Soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the characteristics: • Plasticity index PI > 20, • Moisture content $w \geq 40\%$, and • Undrained shear strength $\bar{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Section 11.4.3 — Site Coefficients and Risk-Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameters

Table 11.4-1: Site Coefficient F_a

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at Short Period				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_S

For Site Class= E and S_S = 1.281 g, F_a = 0.900

Table 11.4-2: Site Coefficient F_v

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at 1-s Period				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_1

For Site Class= E and S_1 = 0.484 g, F_v = 2.400

Equation (11.4–1): $S_{M1S} = F_a S_S = 0.900 \times 1.281 = 1.153$ g

Equation (11.4–2): $S_{M1} = F_v S_1 = 2.400 \times 0.484 = 1.162$ g

Section 11.4.4 — Design Spectral Acceleration Parameters

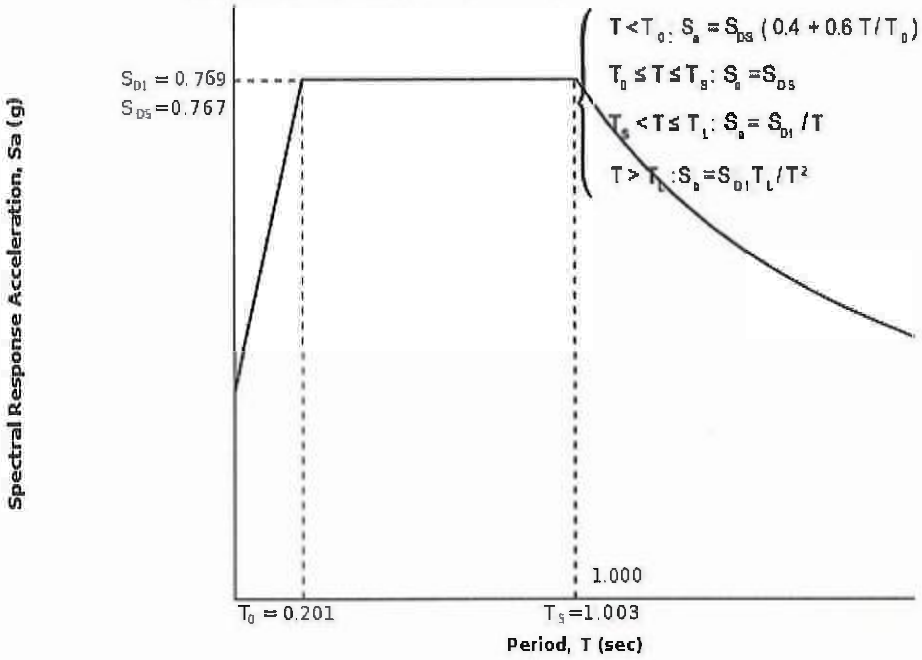
Equation (11.4–3): $S_{DS} = ⅔\ S_{MS} = ⅔ \times 1.153 = 0.769$ g

Equation (11.4–4): $S_{D1} = ⅔\ S_{M1} = ⅔ \times 1.162 = 0.774$ g

Section 11.4.S — Design Response Spectrum

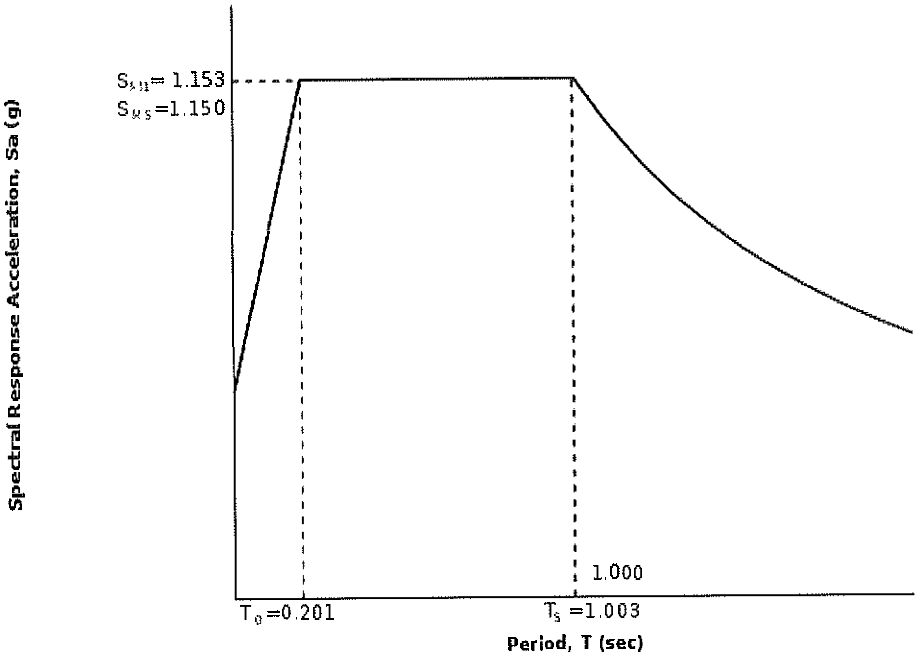
From Figure 22-12 [3] $T_L = 8$ seconds

Figure 11.4-1: Design Response Spectrum



Section 11.4.6 — Risk-Targeted Maximum Considered Earthquake (MCE_R) Response Spectrum

The MCE_R Response Spectrum is determined by multiplying the design response spectrum above by 1.5.



Section 11.8.3 — Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

From Figure 22-7 [4] PGA = 0.541

Equation (11.8-1): $PGA_M = F_{PGA}PGA = 0.900 \times 0.541 = 0.487$ g

Table 11.8-1: Site Coefficient F_{PGA}

Site Class	Mapped MCE Geometric Mean Peak Ground Acceleration, PGA				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of PGA

For Site Class= E and PGA = 0.541 g, F_{PGA} = 0.900

Section 21.2.1.1 — Method 1 (from Chapter 21 - Site-Specific Ground Motion Procedures for Seismic Design)

From Figure 22-17 [5] C_{RS} = 0.902

From Figure 22-18 [6] C_{R1} = 0.939

Section 11.6 — Seismic Design Category

Table 11.6-1 Seismic Design Category Based on Short Period Response Acceleration Parameter

VALUE OF S_{DS}	RISK CATEGORY		
	I or II	III	IV
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D	D	D

For Risk Category = I and S_{DS} = 0.769 g, Seismic Design Category= D

Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

VALUE OF S_{D1}	RISK CATEGORY		
	I or II	III	IV
$S_{D_1} < 0.067g$	A	A	A
$0.067g \le S_{D_1} < 0.133g$	B	B	C
$0.133g \le S_{D_1} < 0.20g$	C	C	D
$0.20g \le S_{D1}$	D	D	D

For Risk Category = I and S_{D1} = 0.774 g, Seismic Design Category= D

Note: When S_1 is greater than or equal to 0.75g, the Seismic Design Category is **E** for buildings in Risk Categories I, II, and III, and **F** for those in Risk Category IV, irrespective of the above.

Seismic Design Category ≡ "the more severe design category in accordance with Table 11.6-1 or 11.6-2" = D

Note: See Section 11.6 for alternative approaches to calculating Seismic Design Category.

References

1. *Figure 22-1*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-1.pdf
2. *Figure 22-2*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-2.pdf
3. *Figure 22-12*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-12.pdf
4. *Figure 22-7*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-7.pdf
5. *Figure 22-17*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-17.pdf
6. *Figure 22-18*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-18.pdf

APPENDIX D

Preliminary Grading Specifications

Key and Bench with Backdrain

PRELIMINARY GRADING SPECIFICATIONS

A. General

1. These preliminary specifications have been prepared for the subject site; GeoSolutions, Inc. should be consulted prior to the commencement of site work associated with site development to ensure compliance with these specifications.

2. GeoSolutions, Inc. should be notified at least 72 hours prior to site clearing or grading operations on the property in order to observe the stripping of surface materials and to coordinate the work with the grading contractor in the field.

3. These grading specifications may be modified and/or superseded by recommendations contained in the text of this report and/or subsequent reports.

4. If disputes arise out of the interpretation of these grading specifications, the Soils Engineer shall provide the governing interpretation.

B. Obligation of Parties

1. The Soils Engineer should provide observation and testing services and should make evaluations to advise the client on geotechnical matters. The Soils Engineer should report the findings and recommendations to the client or the authorized representative.

2. The client should be chiefly responsible for all aspects of the project. The client or authorized representative has the responsibility of reviewing the findings and recommendations of the Soils Engineer. During grading the client or the authorized representative should remain on-site or should remain reasonably accessible to all concerned parties in order to make decisions necessary to maintain the flow of the project.

3. The contractor is responsible for the safety of the project and satisfactory completion of all grading and other operations on construction projects, including, but not limited to, earthwork in accordance with project plans, specifications, and controlling agency requirements.

C. Site Preparation

1. The client, prior to any site preparation or grading, should arrange and attend a meeting which includes the grading contractor, the design Structural Engineer, the Soils Engineer, representatives of the local building department, as well as any other concerned parties. All parties should be given at least 72 hours notice.

2. All surface and sub-surface deleterious materials should be removed from the proposed building and pavement areas and disposed of off-site or as approved by the Soils Engineer. This includes, but is not limited to, any debris, organic materials, construction spoils, buried utility line, septic systems, building materials, and any other surface and subsurface structures within the proposed building areas. Trees designated for removal on the construction plans should be removed and their primary root systems grubbed under the observations of a representative of GeoSolutions, Inc. Voids left from site clearing should be cleaned and backfilled as recommended for structural fill.

3. Once the Site has been cleared, the exposed ground surface should be stripped to remove surface vegetation and organic soil. A representative of GeoSolutions, Inc. should determine the required depth of stripping at the time of work being completed. Strippings may either be disposed of off-site or stockpiled for future use in landscape areas, if approved by the landscape architect.

D. Site Protection

1. Protection of the Site during the period of grading and construction should be the responsibility of the contractor.

2. The contractor should be responsible for the stability of all temporary excavations.

3. During periods of rainfall, plastic sheeting should be kept reasonably accessible to prevent unprotected slopes from becoming saturated. Where necessary during periods of rainfall, the contractor should install check-dams, de-silting basins, sand bags, or other devices or methods necessary to control erosion and provide safe conditions.

E. Excavations

1. Materials that are unsuitable should be excavated under the observation and recommendations of the Soils Engineer. Unsuitable materials include, but may not be limited to: 1) dry, loose, soft, wet, organic, or compressible natural soils; 2) fractured, weathered, or soft bedrock; 3) non-engineered fill; 4) other deleterious materials; and 5) materials identified by the Soils Engineer or Engineering Geologist.

2. Unless otherwise recommended by the Soils Engineer and approved by the local building official, permanent cut slopes should not be steeper than 2:1 (horizontal to vertical). Final slope configurations should conform to section 1804 of the 2013 California Building Code unless specifically modified by the Soil Engineer/Engineering Geologist.

3. The Soil Engineer/Engineer Geologist should review cut slopes during excavations. The contractor should notify the Soils Engineer/Engineer Geologist prior to beginning slope excavations.

F. Structural Fill

1. Structural fill should not contain rocks larger than 3 inches in greatest dimension, and should have no more than 15 percent larger than 2.5 inches in greatest dimension.

2. Imported fill should be free of organic and other deleterious material and should have very low expansion potential, with a plasticity index of 12 or less. Before delivery to the Site, a sample of the proposed import should be tested in our laboratory to determine its suitability for use as structural fill.

G. Compacted Fill

1. Structural fill using approved import or native should be placed in horizontal layers, each approximately 8 inches in thickness before compaction. On-site inorganic soil or approved imported fill should be conditioned with water to produce a soil water content near optimum moisture and compacted to a minimum relative density of 90 percent based on ASTM D1557-07.

2. Fill slopes should not be constructed at gradients greater than 2-to-1 (horizontal to vertical). The contractor should notify the Soils Engineer/Engineer Geologist prior to beginning slope excavations.

3. If fill areas are constructed on slopes greater than 10-to-1 (horizontal to vertical), we recommend that benches be cut every 4 feet as fill is placed. Each bench shall be a minimum of 10 feet wide with a minimum of 2 percent gradient into the slope.

4. If fill areas are constructed on slopes greater than 5-to-1, we recommend that the toe of all areas to receive fill be keyed a minimum of 24 inches into underlying dense material. Key depths are to be observed and approved by a representative of GeoSolutions, Inc. Sub-drains shall be placed in the keyway and benches as required.

H. Drainage

1. During grading, a representative of GeoSolutions, Inc. should evaluate the need for a sub-drain or back-drain system. Areas of observed seepage should be provided with sub-surface drains to release the hydrostatic pressures. Sub-surface drainage facilities may include gravel blankets, rock filled trenches or Multi-Flow systems or equal. The drain system should discharge in a non-erosive manner into an approved drainage area.

2. All final grades should be provided with a positive drainage gradient away from foundations. Final grades should provide for rapid removal of surface water runoff. Ponding of water should not be allowed on building pads or adjacent to foundations. Final grading should be the responsibility of the contractor, general Civil Engineer, or architect.

3. Concentrated surface water runoff within or immediately adjacent to the Site should be conveyed in pipes or in lined channels to discharge areas that are relatively level or that are adequately protected against erosion.

4. Water from roof downspouts should be conveyed in solid pipes that discharge in controlled drainage localities. Surface drainage gradients should be planned to prevent ponding and promote drainage of surface water away from building foundations, edges of pavements and sidewalks. For soil areas we recommend that a minimum of 2 percent gradient be maintained.

5. Attention should be paid by the contractor to erosion protection of soil surfaces adjacent to the edges of roads, curbs and sidewalks, and in other areas where hard edges of structures may cause concentrated flow of surface water runoff. Erosion resistant matting such as Miramat, or other similar products, may be considered for lining drainage channels.

6. Sub-drains should be placed in established drainage courses and potential seepage areas. The location of sub-drains should be determined after a review of the grading plan. The sub-drain outlets should extend into suitable facilities or connect to the proposed storm drain system or existing drainage control facilities. The outlet pipe should consist of a non-perforated pipe the same diameter as the perforated pipe.

I. Maintenance

1. Maintenance of slopes is important to their long-term performance. Precautions that can be taken include planting with appropriate drought-resistant vegetation as recommended by a landscape architect, and not over-irrigating, a primary source of surficial failures.

2. Property owners should be made aware that over-watering of slopes is detrimental to long term stability of slopes.

J. Underground Facilities Construction

1. The attention of contractors, particularly the underground contractors, should be drawn to the State of California Construction Safety Orders for "Excavations, Trenches, Earthwork." Trenches or excavations greater than 5 feet in depth should be shored or sloped back in accordance with OSHA Regulations prior to entry.

2. Bedding is defined as material placed in a trench up to 1 foot above a utility pipe and backfill is all material placed in the trench above the bedding. Unless concrete bedding is required around utility pipes, free-draining sand should be used as bedding. Sand to be used as bedding should be tested in our laboratory to verify its suitability and to measure its compaction characteristics. Sand bedding should be compacted by mechanical means to achieve at least 90 percent relative density based on ASTM D1557-07.

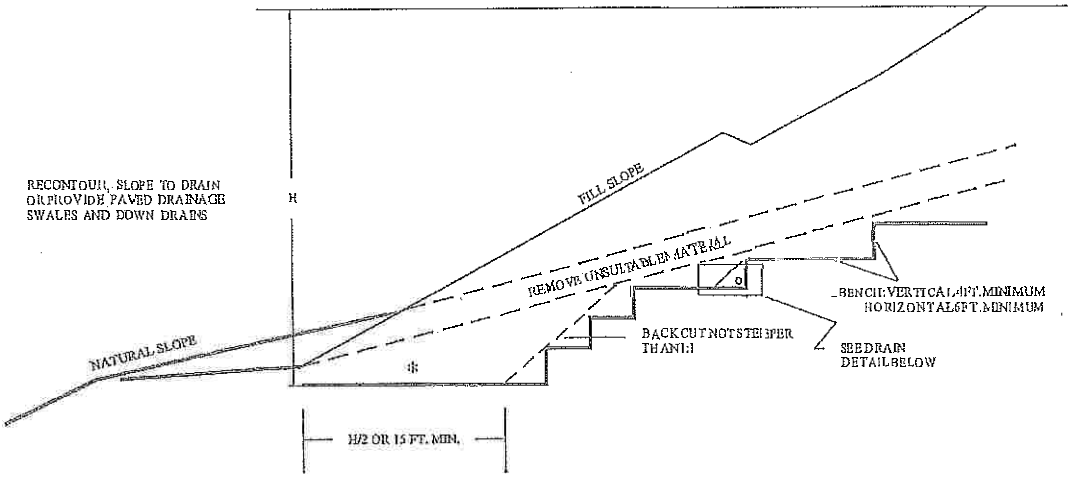
3. On-site inorganic soils, or approved import, may be used as utility trench backfill. Proper compaction of trench backfill will be necessary under and adjacent to structural fill, building foundations, concrete slabs, and vehicle pavements. In these areas, backfill should be conditioned with water (or allowed to dry), to produce a soil water content of about 2 to 3 percent above the optimum value and placed in horizontal layers, each not exceeding 8 inches in thickness before compaction. Each layer should be compacted to at least 90 percent relative density based on ASTM D1557-07. The top lift of trench backfill under vehicle pavements should be compacted to the requirements given in report under Preparation of Paved Areas for vehicle pavement sub-grades. Trench walls must be kept moist prior to and during backfill placement.

K. Completion of Work

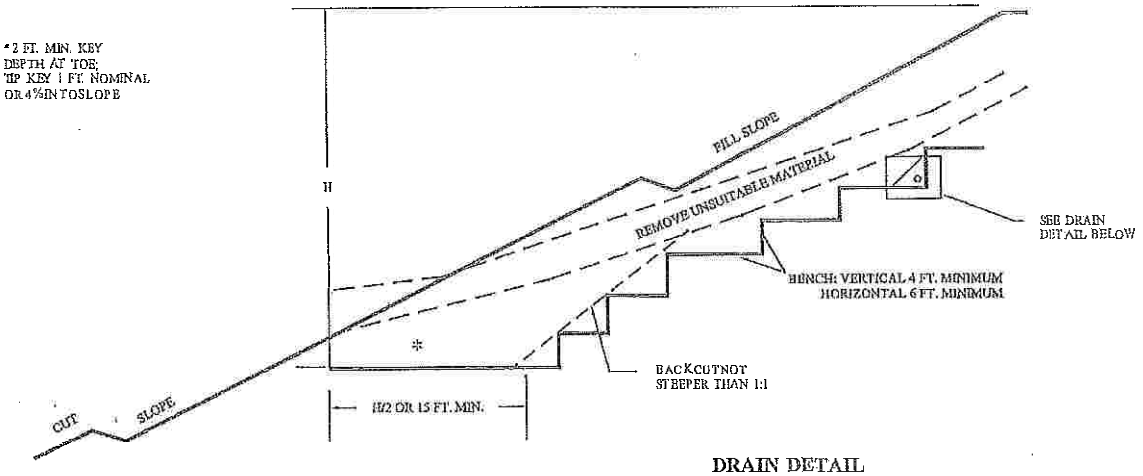
1. After the completion of work, a report should be prepared by the Soils Engineer retained to provide such services. The report should including locations and elevations of field density tests, summaries of field and laboratory tests, other substantiating data, and comments on any changes made during grading and their effect on the recommendations made in the approved Soils Engineering Report.

2. Soils Engineers shall submit a statement that, to the best of their knowledge, the work within their area of responsibilities is in accordance with the approved soils engineering report and applicable provisions within Chapter 18 of the 2013 CBC.

FILL OVER NATURAL SLOPE



FILL OVER CUT SLOPE

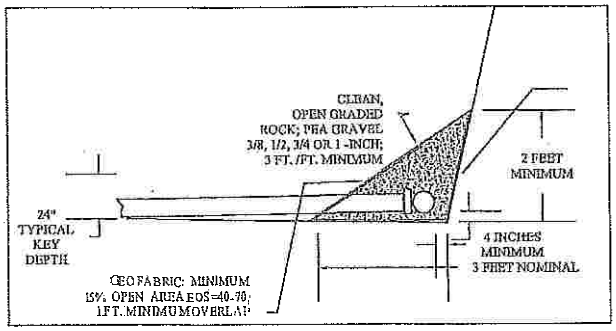


NOTES

1 - IF OVERFILLING AND CUTTING BACK TO GRADE IS ADOPTED, 15 FT. MIN. FILL WIDTH MAY BE REDUCED TO 12 FT. MIN IN NO CASE SHOULD THE FILL WIDTH BE LESS THAN 1/2 THE HEIGHT OF FILL REMAINING.

1 - BACKDRAIN AS RECOMMENDED BY GEOTECHNICAL CONSULTANT PER BUTTRESS BACKDRAIN DETAIL.

DRAIN DETAIL



GeoSolutions, Inc.
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San Luis Obispo, CA 93401
(805) 543-8539 Fax: (805) 543-2171

KEY AND BENCH WITH BACKDRAIN

DETAIL A