QUESTA ENGINEERING CORP.

Peter's Creek Crossing and Trail Improvements Geotechnical Investigation

Prepared for:

Save the Redwoods League
111 Sutter Street
San Francisco, CA 94104

Submitted by:

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November 22, 2019

Civil,
Environmental
& Water
Resources

Peters Creek Crossing

Geotechnical Investigation Report

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Questa Project Number 1900028

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November 22, 2019

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INTRODUCTION

This report presents the results of the Geotechnical Investigation for the construction of new trail and two bridges for vehicle and pedestrian use along Peter's Creek on the Save the Redwoods League property near the Portola Redwoods State Park in San Mateo County, California. Due to access constraints, the Bridge #1 site was the only area to undergo subsurface exploration. Borehole locations were chosen for existing bridge reconstruction to allow for vehicle crossings. Soil testing was accomplished for planning the construction of a new pedestrian bridge upstream from this site, and for the construction of a new trail that will connect the new pedestrian bridge to an existing trail portion located upstream. This investigation included review of geologic, soils, and seismic maps of the region and site vicinity, a subsurface exploration including the drilling, logging, and sampling of two boreholes completed by using a Simco 2400 SK-1 portable drilling rig and an auxiliary mobile limited access unit, laboratory soils testing, engineering analysis and report preparation.

Boreholes B-1 and B-2, were drilled 10' east and west, respectively, of the existing bridge, as shown on **Figure 1**, and the **Pictures 1** and **2** displayed below. Due to limited accessibility, borehole B-1 was drilling with an A-frame portable drilling set-up, while Borehole B-1 was drilled with a Simco 2400 SK-1.

Photograph 1. B-1, east of bridge, drilled with a portable rig

Photograph 2. B-2, west of bridge, drilled with Simco 2400 SK-1

REGIONAL SEISMICITY

The Project site lies in the tectonically active Coast Ranges Geomorphic Province of Northern California. The geologic and geomorphic structure of the northwest trending ridges and valleys in the region, including the Santa Cruz Mountains, Marin Headlands, the Hamilton-Diablo Range, and San Francisco Bay, are controlled by active tectonism along the boundary between the North American and Pacific Tectonic Plates, defined by the San Andreas Fault System. Regional faults have predominantly right-lateral strike-slip (horizontal) movement, with lesser dip-slip (vertical) components of displacement. Horizontal and vertical movement is distributed on the various fault strands within a fault zone. Throughout geologic time the fault strands experiencing active deformation change in response to regional shifts in stress and strain from plate motions.

The nearest known active fault is the San Andreas fault, located approximately 3.4 miles to the northeast (**Figure 2**). Other nearby active faults include the San Gregorio fault located approximately 11 miles to the southwest, the Seal Cove fault located approximately 22 miles to the northwest, the Hayward fault approximately 25 miles east-northeast and the Calaveras fault located approximately 25 miles to the east-northeast (CDMG 1994)[1]. A listing of active earthquake faults located in the project vicinity is presented in **Table 1,** on the following page.

Table 1. Active Earthquake Faults in Project Vicinity

Fault Name	Distance from Project Site (mi.)	Direction	Last Surface Rupture	Status	Maximum Characteristic Moment Magnitude[2]
Butano	2.4	SW	Quaternary	Potentially Active	--
San Andreas	3.4	NE	Historic	Active	7.9
San Gregorio	11	SW	Holocene	Active	6.9
Monte Vista	12	SE	Holocene	Active	--
Seal Cove	22	NW	Holocene	Active	6.7
Hayward	25	E/NE	Historic	Active	6.9
Calaveras	25	E/NE	Historic	Active	6.9
Monterey Bay	36	S	Holocene	Active	--
Greenville	45	E	Holocene	Active	6.9

Seismicity of the project region has resulted in several major earthquakes during the historic period, including the 1868 Hayward Earthquake, the 1906 San Francisco Earthquake, and most recently, the 1989 Loma Prieta Earthquake. Given this history, it is likely that major earthquakes will occur in the region in the future.

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[1] California Division of Mines and Geology, 1996 and 2010, Fault Activity Map of California and Adjacent Areas, CDMG Geologic Data Map No. 6.

[2] 2007 Working Group on California Earthquake Probabilities (WGCEP). Uniform California Earthquake Rupture Forecast, Version 2. USGS Open File Report 2007-1437, CGS Special Report 20, 2008 and 2008 USGS National Seismic Hazards Maps – Source Parameters.

REGIONAL GEOLOGY

The project site lies in the tectonically active Santa Cruz Mountains within the Coast Ranges geomorphic province of Northern California. The northwest trending ridges and valleys of the Coast Ranges are characterized by northwest trending faults associated with and oriented sub-parallel to faults of the NW-SE trending San Andreas Fault System. This San Andreas fault is located ~4.5 miles northeast of the project location. In the San Francisco Bay area west of the San Andreas fault, regional geology is dominated by the Salinian Block granitic basement and overlying sedimentary rocks of Mesozoic and Cenozoic age.

Bedrock outcrops surrounding the site have been mapped as part of the Middle Miocene Monterey Formation, a medium to thick bedded laminated olive-gray bio-siliceous, organic rich mudstone and sandy siltstone deposit.[3] Bedrock is present in the creek channel in both of the proposed bridge locations as seen in Photographs 1 and 2 below.

Photograph 3. Bedrock exposed in channel bed near proposed Bridge Crossing 1.

Photograph 4. Bedrock exposed beneath existing bridge at proposed Bridge Crossing 2.

[3] California Geological Survey, 2017, Earthquake Zones of Required Investigation Mindego Hill Quadrangle, March, 2017.

SITE GEOLOGY

The geologic map of San Mateo County[4] (**Figure 3**) shows the site vicinity as underlain by the the Monterey Formation of middle Miocene age, consisting of grayish-brown, and brownish-black to very pale orange and white, porcelaneous shale with chert, porcelaneous mudstone, impure diatomite, calcareous claystone, and with small amounts of siltstone and sandstone near base. The Monterey is generally more silicious than the Santa Cruz Mudstone but closely resembles parts of the Purisima Formaition, especially the Pomponio Mudstone Member. Overlaying the site and bordering the entire east contacts with the Monterey Formation is what is known as the Lambert Shale (Oligocene and lower Miocene) which consists of a dark-gray to pinkish-brown, moderately well-cemented mudstone, siltstone, and claystone.

PRIMARY SEISMIC HAZARDS

Fault Rupture

Fault rupture is a seismic hazard that affects structures situated above an active fault. The hazard from fault rupture is the movement of the ground surface along a fault. Typically, this movement takes place during the short time of an earthquake, but can also occur slowly over many years in a process known as fault creep. As shown on the Earthquake Zones of Required Investigation (EZRI) map of the Mindego Hill Quadrangle[5] , the project site does not lie within an Alquist-Priolo Earthquake Fault Zone Boundary. The nearest Alquist-Priolo Earthquake Fault Zone Boundary to the site is for the San Andreas fault and is located approximately 3.4 miles northeast of the project site. Thus the potential for fault rupture at the site is considered very low.

SECONDARY SEISMIC HAZARDS

Ground Shaking

Strong ground, or seismic, shaking is a major hazard in the San Francisco Bay Region. The severity of ground shaking at any location depends on several variables such as earthquake magnitude, epicenter distance, local bedrock geology, thickness and seismic response of soil and sediment materials, ground water conditions, and topographic relief.

The active seismicity of the region also results in numerous earthquakes. Many of these earthquakes are too small to be felt by humans. The 1906 Great San Francisco Earthquake was a magnitude 7.9 earthquake which occurred along the San Andreas fault resulting in widespread damage in the San Mateo County area. The recent USGS Working Group on Earthquake Hazards (2014) indicates a greater than 70-percent chance of a M 7.0 or greater earthquake occurring in the San Francisco region (72%) and Northern California region (76%) between 2014 and 2043. For

[4] United States Geological Survey, 1996, Geology of the Onshore Parts of San Mateo County, California, USGS Open File Report 96-137.

[5] California Division of Mines and Geology, 2000, Digital Images of Alquist-Priolo Earthquake Fault Zone Map of the Richmond Quadrangle, California, 1982, 1:24,000.

the Northern San Andreas fault located east of the site, the probability for a M 6.7 or above earthquake occurring in the next 30 years (2014-2043) is 6.4 percent[6] (USGS, 2015).

The Peak Ground Accelaration (**PGA**) that is expected at the site was calculated using the USGS Seismic Design data and the SEA/OSHPD Seismic Design Calculator Program. The **PGA** with a 10 percent chance of exceedence in 50 years is 0.741 G, or 74.1% of the force of gravity. Violent ground shaking can be expected at the site if a major earthquake occurs on the San Andreas fault.

Seismically Induced Ground Failure

Seismically induced ground failure refers to a loss of ground strength and/or cohesion as a result of seismically induced ground shaking (generated by an earthquake). There are multiple types of ground failure hazards, including liquefaction, differential settlement, lurch cracking, lateral spreading and seismically induced landslides. Seismically induced ground failure could also result in landsliding on the adjacent steeply sloping areas. Large landslides could potentially cause changes to the drainage patterns within the creek as well as block access to the trail and proposed bridges. No active landslides were noted at either bridge site but there remains the possibility of larger deep seated or bedrock slides to impact the bridge sites as discussed below.

SLOPE INSTABILITY AND LANDSLIDES

The project site is a creek valley located adjacent to moderately to steeply sloping areas. The slopes in the area vary from 30 to 60 percent. Creek banks vary from 30 to 90 percent in steepness, with local instabilities caused by erosional forces in the stream and by the falling of trees in wind storms. These banks are subject to erosional and scour forces during storm events. Bank stability could also be affected by earthquake induced ground shaking resulting in bank failures. Based on potential for bank instability along Peters Creek, the abutments for the new bridges should be evaluated for active scour and shallow bank instabilities to impact the bridges. In addition, following removal of the existing bridge, the disturbed stream banks should be protected to prevent erosion and should be planted with appropriate native vegetation to provide long term stability and riparian habitat.

EXPANSIVE SOILS

Expansive soils are those that shrink and swell in response to changes in moisture content. Native soils on the site consist predominantly of clayey sand and sandy lean clay soils with a low to moderate expansion potential. The site is generally susceptible to low to moderate soil expansion due to soil moisture fluctuations. However, within a redwood forest environment moisture fluctuations seasonally are not as extreme as in open, non-coastal areas. Facility improvements at the site should be designed to resist the effects of soil heave and settlement in

[6] United States Geological Survey, 2015, UCERF3: A New Earthquake Forecast for California's Complex Fault System, USGS Fact Sheet 2015-3009

response to seasonal moisture fluctuations in underlying soils, in areas where moisture fluctuations are expected.

FIELD INVESTIGATION

Questa Engineering performed a subsurface investigation including the drilling, logging and sampling of four boreholes on September 9, 2019. Drilling was performed by Cenozoic Exploration of Aptos, California, using a Simco 2400 SK-1 drilling rig and an auxiliary mobile limited access unit powered with hydraulic hoses from the drilling rig. Hollow stem and solid stem continuous flight augers were used to drill the holes.

Two sampler types were employed, a California Modified Sampler (CA Mod.) with a 2.45-inch inside diameter (I.D.) and a Standard Penetration Test Sampler (SPT) with a 1.38-inch I.D. Blow counts were based on a 30-inch free fall with a 140-pound hammer driving the sampler into the ground. The blow count used to drive the SPT sampler one foot, also known as the N-value, is reported on the logs of boreholes. Blow counts from the California Modified Sampler were converted to the N-value by multiplying the number of blow counts taken to drive the bottom foot of the sampler by 0.67 (i.e., the ratio of the outside diameters of the SPT to the CA Mod. sampler). Boreholes were completed to depths of 7.5 feet to 20 feet BGS.

Locations of the boreholes are presented on **Figure 1.** The logs of boreholes are presented as **Figures 4** and **Figure 5.** Soils were logged in accordance with the Unified Soil Classification System (ASTM D 2487), which is summarized on **Figure 6**. Rocks were logged according to the Physical Properties Criteria for Description of Bedrock that is presented as **Figure 7**. Soil and rock colors were determined by use of a Munsell Soil Color Chart.

Borehole B-1 (**Figure 4**) penetrated medium dense clayey sand to a depth of 1.5 feet below ground surface (BGS), underlain by yellow brown siltstone from 1.5 feet BGS to 2.5 feet and dark yellow brown siliceous siltstone from 2.5 to 5 feet BGS. From 5 feet BGS to the bottom of the borehole at 7.5 feet BGS, yellowish brown siliceous mudstone with thin interbedded siltstone was encountered.

Borehole B-2 (**Figure 5**) penetrated dark brown clayey sand from the ground surface to a depth of 1.5 feet BGS. From 1.5 to 3.0 feet BGS, dark grayish brown clayey gravel with mudstone clasts was encountered. From 3.0 to 6.0 feet BGS, brown sandy, clayey gravel with pinkish white mudstone clasts was encountered. From 6.0 feet to 7.0 feet, fine-grained sandstone was found. From 7.0 feet BGS to 12.5 feet BGS very dark grayish-brown mudstone was penetrated. Black siliceous shale was found from 12 to 12.5 feet BGS and was underlain by very dark grayish brown mudstone to the bottom of the hole at 20 feet BGS.

No groundwater was present in either of the boreholes.

LABORATORY TESTING

Laboratory testing was performed on selected soil samples from the boreholes. Laboratory testing was performed in Questa's laboratory in general accordance with American Society for Testing and Materials (ASTM) standards for moisture content, dry density, particle size analysis, and liquid and plastic limits (including plasticity index), and compressive strength using the pocket penetrometer. Corrosion testing was performed in accordance with Caltrans standards by Cooper Testing of Palo Alto, California, with the testing report included as **Appendix A.** A brief explanation of testing performed follows.

Moisture-Density

Moisture content and dry density testing were performed on selected soil samples to characterize the moisture content and dry density of material throughout the soil column. Testing was performed in accordance with ASTM 2937. In this test, the dry density of the soil is determined by a mathematical relationship between moisture content and wet density of the soil sample. Results of moisture-density testing are summarized on the borehole logs (**Figures 4** and **5**).

Particle Size Analysis

Particle size analysis testing was performed in accordance with ASTM D 422. Samples were washed through the number 200 sieve to determine the percentage of silt plus clay. Following drying, samples were analyzed for particle size using the dry sieve method to determine various gravel and sand fraction percentages. Results are presented on **Figures 8** and **9**.

Liquid Limit, Plastic Limit and Plasticity Index

Testing of liquid limit, plastic limit and plasticity index were performed in accordance with ASTM D 4318. Results are presented on **Figures 10** and summarized on the borehole logs.

Corrosion Testing

Soil samples were obtained for corrosion analyses from borehole B-2 at 1.5 to 2.0 feet BGS. Based on the results of the corrosion analyses, the site soils are considered not corrosive to concrete by Caltrans standards (Caltrans Corrosion Guidelines version 2.0). The chloride concentration is less than 500 mg/kg (result is 7 mg/kg), and resistivity is greater than 1,000 Ohm-cm (result is 2,110 Ohm-cm), and pH was 6.5. Testing was also performed for sulfate concentration (53 mg/kg), redox (566 mv), and percent moisture (32.8 percent). The full laboratory test report by Cooper Testing Labs is presented in **Appendix A**.

GEOTECHNICAL RECOMMENDATIONS

Site Preparation and Grading

Areas to be graded for road and bridge construction should be cleared and grubbed to a minimum depth of 4 to 6 inches to remove vegetation and surface organic soils, or to the depth of subgrade soil preparation at the base of the structural section which includes aggregate base (AB) and trail or road surfacing. Subgrade soils should be scarified to a depth of six to ten inches, moisture conditioned (wetted or dried) to a moisture content of 2 to 4 percent above the optimum, and recompacted to a minimum of 95 percent of the maximum dry density. A woven geotextile segregation fabric could be placed at the top of the compacted subgrade soils where needed to provide subgrade stabilization and segregation from the overlying aggregate base and surface treatment. The woven geotextile fabric should consist of Mirafi HP 370 or approved equivalent.

Bridge #1

Based on results of our preliminary geotechnical investigation, the soils and bedrock at the proposed Bridge #1 abutment locations have good supporting characteristics for the proposed bridge foundation at the location of borehole B-1 and moderately good characteristics at borehole B-2.

The pedestrian bridge can be founded on spread footings provided that the soils and bedrock underlying the proposed bridge abutments are excavated to a minimum depth of 3.0 feet below ground surface at B-1 and 7.0 feet at borehole B-2, and replaced with Controlled Low Strength Material (CLSM), a low strength Portland cement, sand and gravel mix, or with lean cement concrete. The CLSM or lean cement-concrete should have a minimum strength of 100 psi at 28 days.

Spread Footings

For spread footings founded on CLSM over bedrock, allowable bearing pressure of 3,000 pounds per square foot (psf) can be used for dead plus live loads, and can be increased by 33 percent for total loads, including wind or seismic forces. Resistance to lateral loads should be based on a passive pressure of 250 psf on the face of the footing in soil and bedrock. In addition, a friction coefficient of 0.23 can be used on the base of the footing on CLSM/lean cement concrete. If water is present in footings, it should be pumped out prior to placement of the concrete.

The footing steel rebar reinforcements should be placed with a minimum of 3 inches clearance from the bottom and sidewalls of the footings using dobees or other approved spacers. Concrete should be Type II/V, a corrosion resistant concrete.

Bridge #2

The soils and bedrock appear to be similar at Bridge #2 to those found at Bridge #1. Relatively shallow bedrock depths are anticipated at the Bridge #2 location based on the observed exposures of bedrock in the channel and locally along the creek banks. This site will be further evaluated and a subsurface investigation will be performed when access to the site is improved.

Retaining Wall Design Parameters

Retaining walls at the site must be designed to resist lateral earth pressures plus additional lateral pressures that may be caused by surcharge loads such as seismic forces. Walls that are free to rotate should be designed for active lateral earth pressures. If walls are restrained by rigid elements to prevent rotation, then they should be designed for at-rest earth pressures. Retaining walls backfilled with granular soils should be designed to resist lateral earth pressures due to an equivalent fluid having unit weight as shown in **Table 2**.

Table 2. Retaining Wall Design Parameters

	Active Pressure pounds per cubic foot (pcf)	At-Rest Earth Pressure (pcf)	Seismic Pressure (psf)
Level Backfill	45	65	20H

Retaining walls should be designed to be fully drained and include a backdrain can be designed for active pressures or at-rest earth pressure in accordance with the values given in **Table 2** for the above design groundwater condition. Retaining walls that are designed to be located below the design groundwater table or that do not include a backdrain should be designed to withstand the pressure of saturated soils as presented in **Table 2** for below design groundwater table elevation.

The seismic conditions should be determined by adding the pressures from earthquake loading to active pressure on the retaining walls. All walls greater than 6 feet in height should include seismic pressure. We recommend an incremental seismic pressure of 20H in pounds per square foot (psf), where H is the height of the retaining wall in feet. The pressure distribution may be considered to be an inverted triangle with the maximum pressure at the top and zero on the bottom. The resultant of this force may be assumed to be located at 1/3 the height of the wall below the top of the wall.

Unit weight (total) of the existing soils and weathered rock is approximately 110 pcf. Unit weight (total) of aggregate base granular backfill is approximately 135 pcf for recycled and 145 pcf for quarried material. The effective internal angle of friction of the existing soils can be assumed to be 25 degrees and the aggregate base or gravel backfill 40 degrees for design purposes.

Seismic Design Criteria

The project seismic design criteria were calculated in accordance with provisions of 2010 ASCE 7-10 (with 2013 errata) in accordance with the 2016 California Building Code, using the OSHPD Seismic Design Maps calculator on 10/30/2019. This is based on United States Geological Survey data. The project site was assigned to Site Class C, very dense soil and soft rock conditions based on results of our Geotechnical Investigation. This information is summarized in **Table 3**, along with seismic design criteria for design of project elements required to be designed in accordance with the 2016 California Building Code seismic design criteria and 2010 ASCE 7-10 (with 2013 errata).

Table 3. Seismic Design Criteria in accordance with ASCE 7-10 and 2016 CBC

Site Class	C
Soil Profile Name	Very Dense soil and soft rock
Seismic Design Category	E
Mapped Spectral Response for Short Periods- 0.2 Sec (S_s)	1.882 g
Mapped Spectral Response for Long Periods- 1 Sec (S_1)	0.878 g
Adjusted Maximum Considered EQ Spectral Response for Short Periods (S_{MS})	1.882
Adjusted Maximum Considered EQ Spectral Response for Long Periods (S_{M1})	1.141
Design (5-percent damped) Spectral Acceleration Parameters at short periods (S_{DS})	1.254
Design (5-percent damped) Spectral Acceleration Parameters at long periods (S_{D1})	0.761
F_a Site amplification factor at 0.2 second	1.0
F_v Site amplification factor at 1.0 second	1.3
T_L Long-period Transition period in seconds	12 seconds
PGA MCE_G Peak Ground Acceleration	0.741
F_{PGA} Site Amplification factor at PGA	1.0
PGA_M Site-modified Peak Ground Acceleration	0.741
C_{RS} Mapped value of the risk coefficient at short periods	0.956
C_{R1} Mapped value of the risk coefficient at a period of 1 second	0.908

CONCLUSIONS

The project is feasible from a Geotechnical standpoint, provided that our recommendations are followed during design and construction of the project. Provided that the site is properly prepared and the structures and foundations are designed and constructed as recommended, we estimate that normal post-construction settlement for the bridge #1 will be relatively small, less than 1.5 inches. Differential settlements from the west abutment to the east abutment could be as much as 1.0 inches.

CONSTRUCTION OBSERVATIONS AND TESTING

We should review the project plans and specifications for conformance with the intent of our recommendations. During construction we should observe and test all site preparation and grading to check the results of work by your contractor. This will allow us to observe that subsurface conditions are as anticipated and to make supplemental recommendations when needed. These services during construction should include:

X Site preparation and fill placement should be observed and tested.

X Subgrade for all fill and concrete should be tested and approved before placing fill or rock.

- X The excavation of footings should be observed on a continuous basis to confirm that firm supporting material is encountered and to develop/verify depth criteria in accordance with building code requirements.

- X Cylinders of CLSM or lean cement concrete should be collected at the time of pouring and should be tested at 7 and 28 days.

- X We should be present during concrete pouring to verify that the water is pumped and concrete is placed correctly in footings.

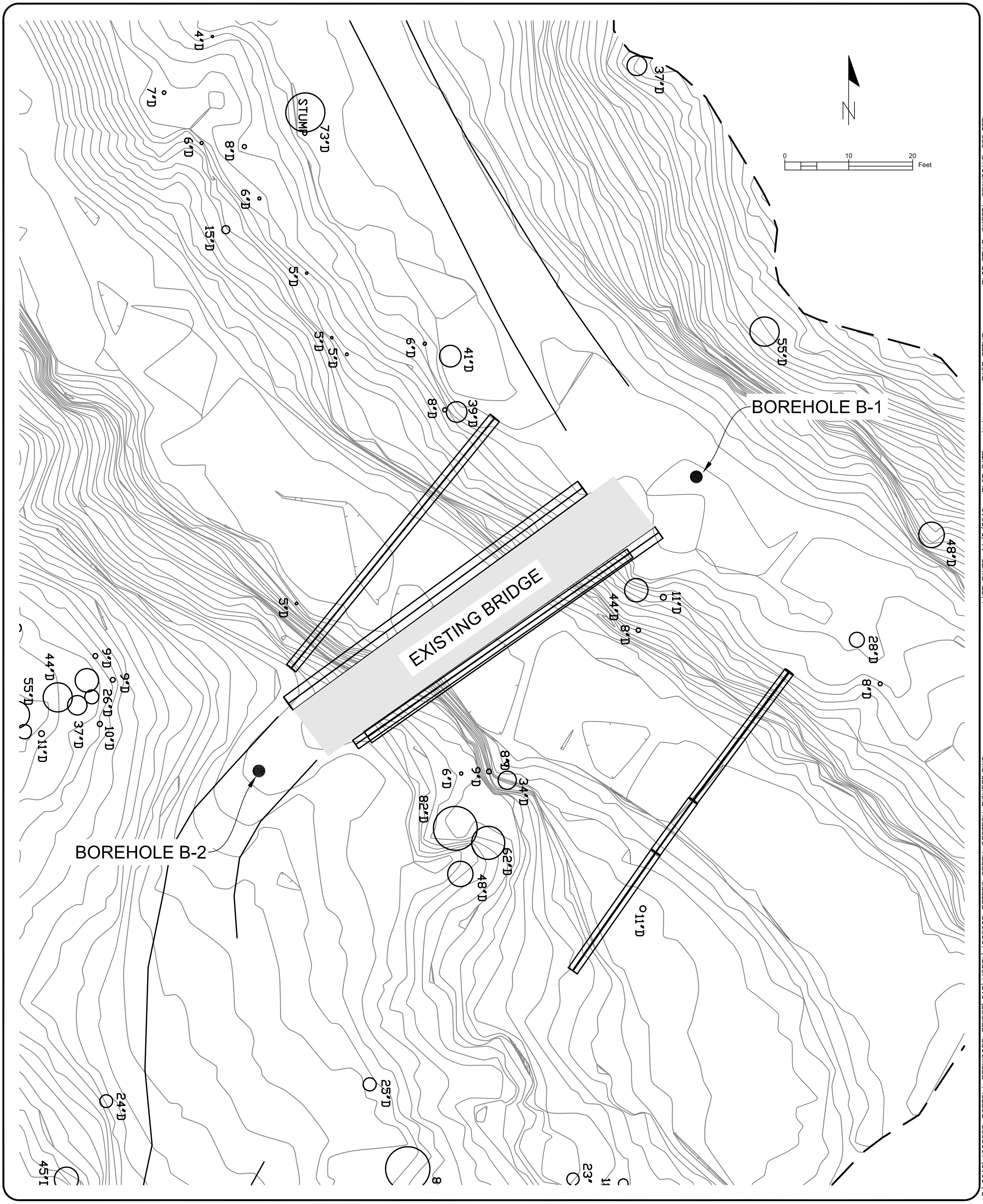
LIMITATIONS

This investigation was performed in accordance with present geotechnical and engineering geologic standards applicable to this project. In our opinion, the scope of services adequately supports the conclusions and recommendations presented. The findings are valid now, but should not be relied upon after two years without our review.

The recommendations of this report are based upon the assumption that the conditions do not deviate from those interpreted from the surface observations of this investigation and review of available subsurface information developed by others. If any variation or undesirable conditions are encountered during construction, or if the proposed construction differs from that planned at the present time, we should be notified so that supplemental recommendations can be given. The recommendations of this report are intended for the site described only, and must not be extended to adjacent areas.

This report is issued with the understanding that it is the responsibility of the owner to ensure that contractors and subcontractors carry out the recommendations presented.

Figures



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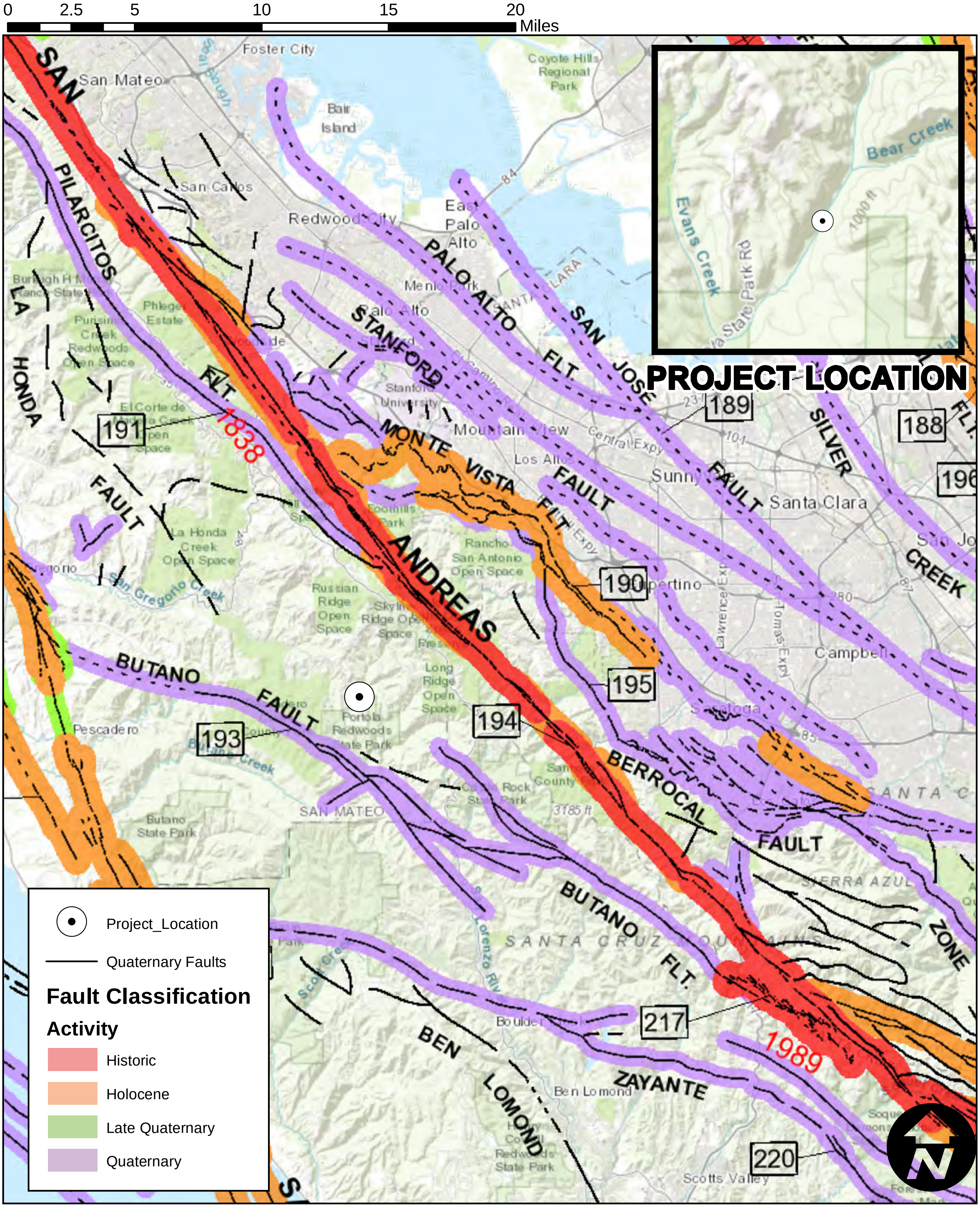
Drawn: AM
Checked: ST
Appr'd: ST

PETERS CREEK CROSSING

LOCATION MAP

LA HONDA, CALIFORNIA

FIGURE
1



PROJECT NO. 1900028

DRAWN BY TJC 9-30-2019

FAULT ZONE MAP

PORTOLA REDWOODS STATE PARK
SAN MATEO, CALIFORNIA

SOURCE: CALIFORNIA GEOLOGICAL SURVEY (2010), MAPS OF THE ALIQUIST PRIOLO FAULT ZONES

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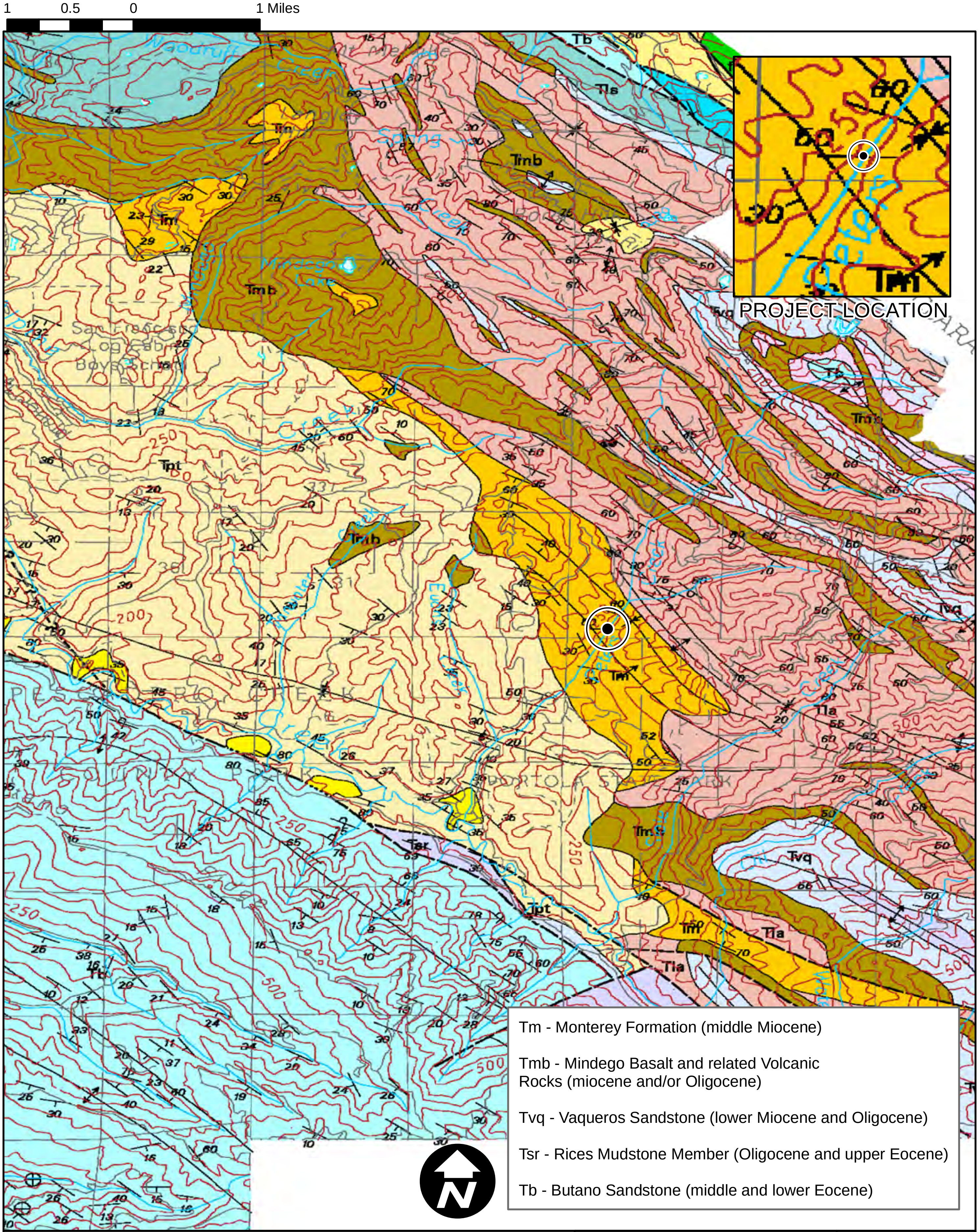
FIGURE 2



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DRAWN BY TJC ON 9/16/2019

GEOLOGIC MAP

PORTOLA REDWOODS STATE PARK

SAN MATEO, CALIFORNIA

SOURCE: GEOLOGY OF THE ONSHORE PART OF SAN MATEO COUNTY, CALIFORNIA
OPEN FILE REPORT 98-137

FIGURE
3

Lab Tests	Torvane, tsf	Sampler Type	% Passing #200 Sieve	Dry Density, pcf	Moisture %	Penetrometer, tsf	Blows/Foot * (Converted to SPT N-value)	Depth	USCS Symbol	Lithologic Description
								0	SC	SC: Clayey Silt: Pale brown 10YR 7/3 Clayey-Silt soil.
		CAM						-1		
							35*			Siltstone: Siltstone: Yellow Brown 10YR 7/6, Silica-rich Siltstone that is hard, moderately indurated and highly weathered, altering the color to pale brown and yellow, Monterey Formation(MF)
			26.8	54	52.6			-2		
		SPT								Siltstone: Siltstone (MF): Dark Yellowish Brown, 10YR 4/4, Siltstone interbedded with Silicious Mudstone and Shale lenses in places, friable, weak and highly weathered with moderate induration.
							48	-3		
								-4		
								-5		Mudstone: Mudstone (MF): Yellowish Brown, 10YR 5/4, Mudstone with thin interbeds and micro-clasts of Siltstone, Weak, Moderately indurated, deeply weathered and breaks easily along bedding planes.
		CAM						-6		
			55.4	59	47.3		44*			End at 7.5' BGS on 9/9/2019. No groundwater encountered.
		SPT					90	-7		

*Sampling was performed by Denovo Drilling using a hydraulic portable drill rig equipped with solid flight augers.

QUESTA ENGINEERING CORP. Civil Environmental & Water Resources (510) 236-6114 FAX (510) 236-2423 questa@questaec.com P.O. Box 70356 1220 Brickyard Cove Road Point Richmond, CA 94807	**LOG OF BOREHOLEB-1** Portola Redwoods Bridge La Honda, CA	**Figure** 4

Lab Tests	Torvane, tsf	Sampler Type	% Passing #200 Sieve	Dry Density, pcf	Moisture %	Penetrometer, tsf	Blows/Foot * (Converted to SPT N-value)	Depth	USCS Symbol	Lithologic Description
								0	SC	SC: Dark Brown 7.5YR 5/2 Clayey Sand, Moist, Medium Dense
								-1		
		CAM								
									GC	GC: Dark Grayish Brown 10YR 4/2 Clayey gravel with Mudstone clasts from the Monterey Formation (MF), Friable to Weak, Moderately Hard, Deeply Weathered
							10*			
								-2		
		SPT	38.8	70	35.6					
								-3	GC	GC: Brown 7.5YR 4/4 Sandy, Clayey Gravel, Moist, Dense with Pinkish White 7.5YR 8/2 Mudstone clasts
							19			
								-4		
								-5		
								-6		Sandstone: Yellow-brown and Gray-Brown Silty interbeds of Fine-grained Sandstone, Low to Moderate Hardness, Friable, Deep Weathering, Decomposed. Monterey Formation.
		CAM								
							16*			
								-7		Mudstone: Very Dark Grayish-Brown 10YR 3.2 Mudstone, with Discontinuous Microlaminations of Light-Brown Silt, Well-Indurated, Breaks Along Bedding Planes, inch-sized Embedded Clasts of Siltstone In Places.
		SPT								
				85	28.2					
			27.2				31	-8		
								-9		
								-10		

*Sampling was performed by Denovo Drilling using a hydraulic portable drill rig equipped with solid flight augers.

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LOG OF BOREHOLEB-2

Portola Redwoods Bridge

La Honda, CA

Figure 5

Lab Tests	Torvane, tsf	Sampler Type	% Passing #200 Sieve	Dry Density, pcf	Moisture %	Penetrometer, tsf	Blows/Foot * (Converted to SPT N-value)	Depth	Sample Location	Graphical Symbol	Groundwater Depth	USCS Symbol	Lithologic Description
								10					Mudstone: Very Dark Grayish-Brown 10YR 3.2 Mudstone, with Discontinuous Microlaminations of Light-Brown Silt, Well-Indurated, Breaks Along Bedding Planes, inch-sized Embedded Clasts of Siltstone In Places.
								11					
								12					
				62	25.8		50/ 5"						Shale: Black Silicious Shale (MF), High Organic Content. Silty Clasts and Lenses Interbeds between thcker shale layers, Friable, Poorly to Moderately Indurated
								13					
							69						
								14					Mudstone: Very Dark Grayish Brown Mudstone 2.5 YR 3/2, Well Indurated, Uniform Grain Size, with Thin Light Brown Silt Laminations in Places
								15					
								16					
				66	34.9		50/ 2"						Mudstone: Very Dark Grayish Brown Mudstone 2.5 YR 3/2, Well Indurated, Uniform Grain Size, with Thin Light Brown Silt Laminations in Places
								17					
			18.6										
								18					
							112						
								19					
							50/ 2"						End at 20' BGS on 9/9/2019. No groundwater encountered.
								20					

*Sampling was performed by Denovo Drilling using a hydraulic portable drill rig equipped with solid flight augers.

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LOG OF BOREHOLEB-2

Portola Redwoods Bridge

La Honda, CA

Figure 5

SOIL CLASS KEY.CDR

MAJOR DIVISION				TYPICAL NAMES
COARSE GRAINED SOILS MORE THAN HALF IS LARGER THAN #200 SIEVE	GRAVELS MORE THAN HALF COARSE FRACTION IS LARGER THAN #4 SIEVE SIZE	CLEAN GRAVELS WITH LITTLE OR NO FINES	GW	Well graded Gravels, Gravel-Sand mixtures
			GP	Poorly graded Gravels, Gravel-Sand mixtures
		GRAVELS WITH OVER 12% FINES	GM	Silty Gravels, poorly graded, Gravel-Sand-Silt mixtures
			GC	Clayey Gravels, poorly graded Gravel-Sand-Clay mixtures
	SANDS MORE THAN HALF COARSE FRACTION IS LARGER THAN #4 SIEVE SIZE	CLEAN SANDS WITH LITTLE OR NO FINES	SW	Well graded Sands, Gravelly-Sands
			SP	Poorly graded Sands, Gravelly-Sands
		SANDS WITH OVER 12% FINES	SM	Silty Sands, poorly graded, Sand-Silt mixtures
			SC	Clayey Sands, poorly graded, Sand-Clay mixtures
FINE GRAINED SOILS MORE THAN HALF IS SMALLER THAN #200 SIEVE	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50		ML	Inorganic Silts and very fine Sands, rock flour, Silty or Clayey fine Sands, or Clayey-Silts with slight plasticity
			CL	Inorganic Clays of low to medium plasticity, Gravelly Clays, Sandy Clays, Silty Clays, lean Clays
			OL	Organic Clays and Organic Silty Clays of low plasticity
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50		MH	Inorganic Silts, micaceous or diatomaceous fine Sandy or Silty Soils,elastic Silts
			CH	Inorganic Clays of high plasticity, fat Clays
			OH	Organic Clays of medium to high plasticity, organic Silts
HIGHLY ORGANIC SOILS			Pt	Peat and other highly organic soils

BOH	Bottom of hole	140 #	140 pound hammer dropped 30“
SPT	Standard Penetration Test Sampler (1.0“ inside diameter)	70 #	70 pound hammer dropped 30“
CAM	California Modified Sampler (S & H) (2.5“ inside diameter)	LL, PL, PI	Liquid Limit, Plastic Limit, Plasticity Index

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UNIFIED SOIL CLASSIFICATION SYSTEM AND KEY TO ABBREVIATIONS

FIGURE 6

PHYSICAL PROPERTIES CRITERIA FOR EVALUATING CONDITIONS OF BEDROCK

I. **INDURATION** - The process of hardening or consolidating of sediments or other rock aggregates through cementation, pressure, heat, or other cause.

U = unindurated P = poorly indurated M = moderately indurated W = well indurated

II. **BEDDING**

Splitting Property		Thickness (feet)	Stratification
massive	greater than 4.0	very thick bedded	
blocky		2.0 to 4.0	thick bedded
slabby		0.2 to 2.0	thin bedded
flaggy		0.05 to 0.2	very thin bedded
shaly or platy	0.01 to 0.05	laminated	
papery		less than 0.01	thinly laminated

III. **FRACTURING**

Intensity	Frequencies of Fractures (feet)
little fractured	greater than 4.0
occasionally fractured	1.0 to 4.0
moderately fractured	0.5 to 1.0
closely fractured	0.1 to 0.5
intensely fractured	0.05 to 0.1
crushed	less than 0.05

IV. **HARDNESS**

soft - Reserved for plastic material

low hardness - Can be gouged deeply or carved easily with a knife blade

moderately hard - Can be readily scratched by a knife blade; scratch leaves a heavy trace of dust and is readily visible after the powder has been blown away

hard - Can be scratched with difficulty; scratch produces little powder and is often faintly visible

very hard - Cannot be scratched with knife blade; leaves a metallic streak

V. **STRENGTH**

plastic - Very low strength, similar to soil

friable - Crumbles easily by rubbing with fingers

weak - An unfractured specimen will crumble under light hammer blows

moderately strong - Specimen will withstand a few heavy hammer blows before breaking

strong - Specimen will withstand a few heavy ringing hammer blows before breaking into large fragments

very strong - Specimen will resist heavy ringing hammer blows and will yield with difficulty only dust and small flying fragments

VI. **WEATHERING** - The physical and chemical disintegration and decomposition or rocks and minerals by natural processes such as oxidation, reduction, hydration, solution, carbonation, and freezing and thawing.

deep - Moderate to complete mineral decomposition; extensive disintegration; deep and thorough discoloration; many fractures, all extensively coated or filled with oxides, carbonates and/or clay or silt

moderate - Slight change or partial decomposition of minerals; little disintegration; cementation is little to unaffected; moderate to occasionally intense discoloration; moderately coated fractures

little - No megascopic decomposition of minerals; little to no effect on normal cementation; slight and intermittent or localized discoloration; a few stains on fracture surfaces

fresh - Unaffected by weathering agents; no disintegration or discoloration; fractures usually less numerous than joints

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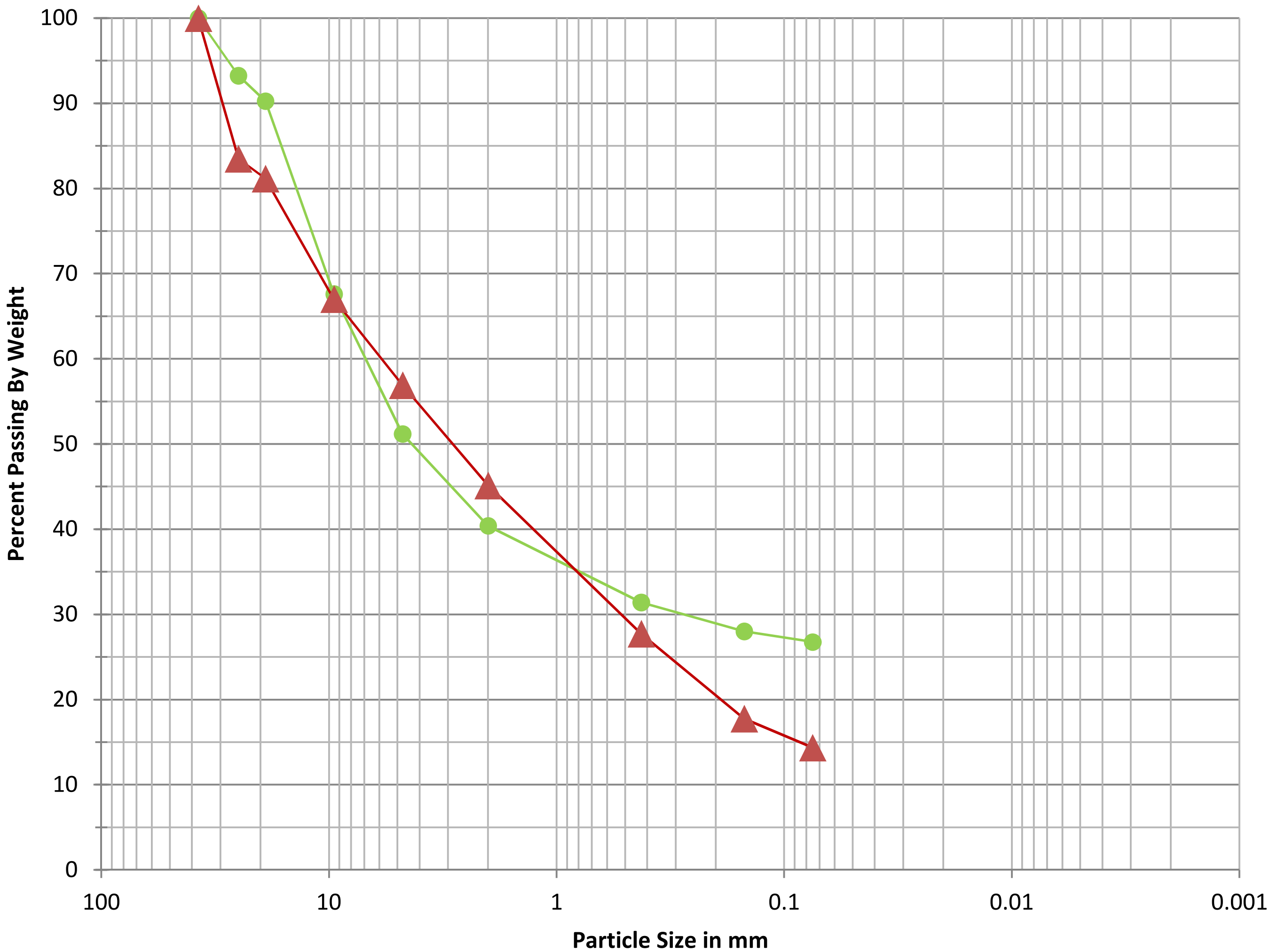
PHYSICAL PROPERTIES CRITERIA FOR EVALUATING CONDITIONS OF BEDROCK

FIGURE 7

Particle Size Analysis



Gravel		Sand			Silt	Clay
Coarse	Fine	Coarse	Medium	Fine		

Symbol	Source
●	B-1, 1.5' - 2'
▲	B-2, 2' - 2.5'

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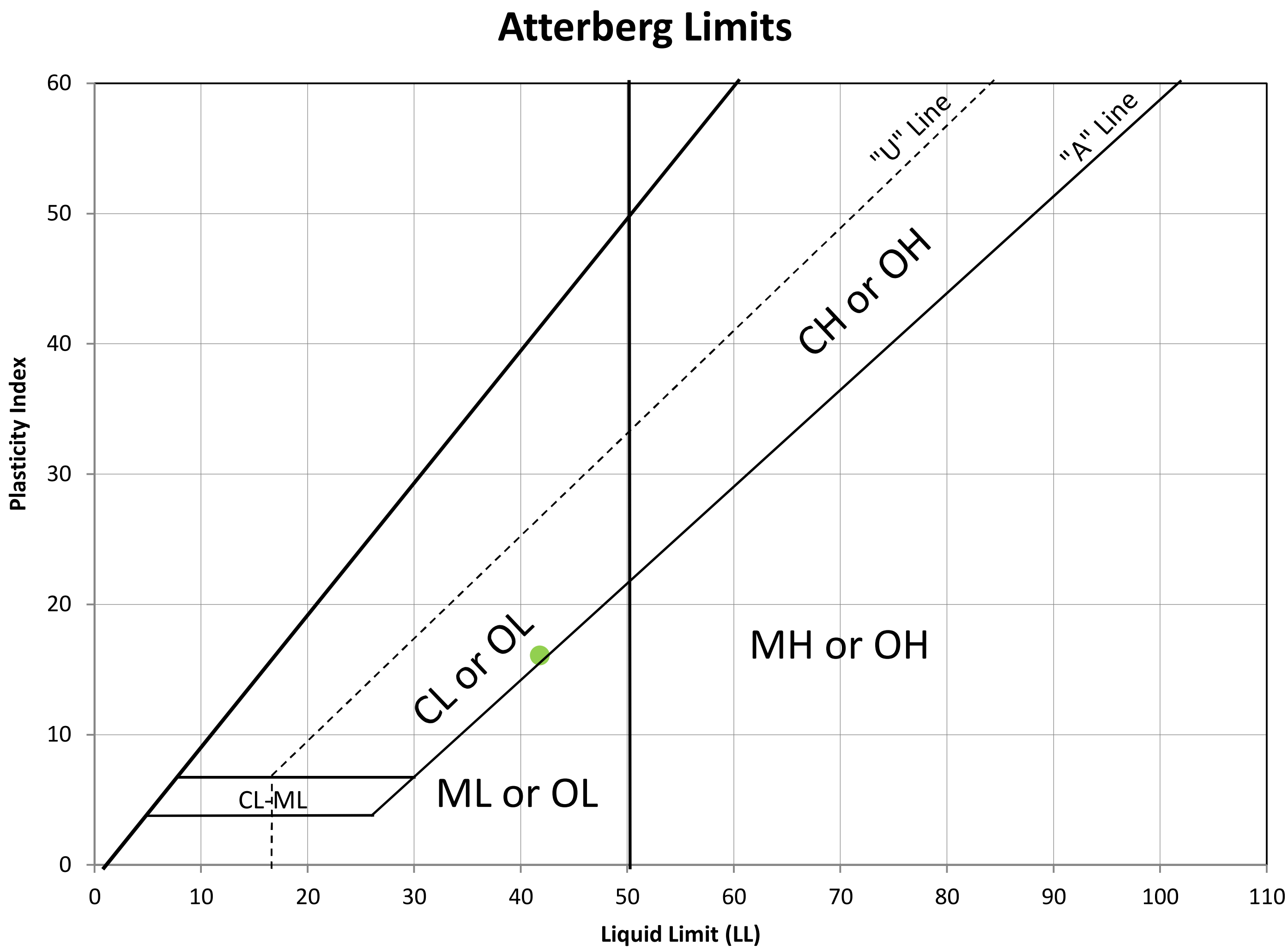
Particle Size Analysis	Figure
Geotechnical Investigation Portola Redwoods Bridge La Honda, CA	8



Symbol	Classification & Source	Liquid Limit	Plastic Limit	Plasticity Index	% Passing #200 Sieve
●	Very dark grayish-brown Mudstone, B-2, 7'-7.5'	42	26	16	50.7

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Atterberg Limits (ASTM D4318)	Figure
Geotechnical Investigation Portola Redwoods Bridge La Honda, CA	9

Appendix A

COOPER TESTING LABORATORY

Corrosivity Tests Summary

CTL # 606-036 **Date:** 11/12/2019 **Tested By:** PJ **Checked:** PJ
Client: Questa Engineering **Project:** Portola Redwoods Bridge **Proj. No:** 1900028
Remarks:

Sample Location or ID			Resistivity @ 15.5 °C (Ohm-cm)			Chloride	Sulfate		pH	ORP		Sulfide	Moisture	Soil Visual Description
			As Rec.	Min	Sat.	mg/kg	mg/kg	%		(Redox)		Qualitative	At Test	
						Dry Wt.	Dry Wt.	Dry Wt.		E_H (mv)	At Test	by Lead	%	
Boring	Sample, No.	Depth, ft.	ASTM G57	Cal 643	ASTM G57	ASTM D4327	ASTM D4327	ASTM D4327	ASTM G51	ASTM G200	Temp °C	Acetate Paper	ASTM D2216	
B-2	-	1.5-2	-	-	2,110	7	59	0.0059	6.5	566	22	-	32.8	Dark Yellowish Brown Clayey SAND w/ Gravel (Claystone)