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Attn: Ms. Barbara Jaffe

Re: Geologic and Geotechnical Feasibility Evaluation
Proposed Residential Development
183 Sunset Way (APN 199-235-47 and -48)
Muir Beach, California

Introduction

This letter summarizes the results of our Phase 1 Geologic and Geotechnical Feasibility Evaluation for your proposed residential development at 183 Sunset Way in Muir Beach, California. A Site Location Map is shown on Figure 1. Our services have been provided in accordance with our Agreement dated October 8, 2019. The purpose of our services is to evaluate the feasibility (from a geologic and geotechnical viewpoint) of residential development at the site, with particular consideration of bluff retreat rates and required structural setbacks in conformance with the requirements of the Marin County Local Coastal Program and related Planning Department regulations.

The scope of our services is described in our proposal letter dated October 3, 2019 and includes review of available, published geologic mapping and geotechnical reference information, a site reconnaissance to observe existing conditions and map site geology, evaluation of geologic hazards which may affect the site, formation of a professional opinion regarding project feasibility from a geotechnical perspective, and development of preliminary recommendations and criteria for use in project planning and preliminary design. Issuance of this letter completes our Phase 1 scope of services. Future phases of work could include design-level Geotechnical Investigation (Phase 2), Geotechnical Consultation and Plan Review (Phase 3), and/or Geotechnical Observation and Testing during construction (Phase 4).

Project Description

The project site is located on the south (seaward) side of Sunset Way, and consists of a “flag”-type lot which is relatively narrow at the street frontage but expands in width at the rear of the property. The property is composed of two undeveloped assessor’s parcels which together comprise about 0.42-acres. The site is bounded to the east and west by existing single-family homes. The property generally consists of a steep, south-facing slope which rises about 130 vertical feet from the Pacific Ocean to the Sunset Way frontage along the northern property line.

Although no specific project details are yet available, we anticipate that proposed development will ultimately include a single-family residence of “typical” construction, imposing relatively light foundation loads and including ancillary site improvements such as vehicle access/exterior flatwork areas, site retaining walls, underground utilities, and other miscellaneous items.

Regional Geology

Marin County lies within the Coast Ranges geomorphic province of California, a region characterized by active seismicity, steep, young topography, and abundant landsliding and erosion owing partly to its relatively high annual rainfall. The regional basement rock consists of sedimentary, igneous, and metamorphic rock of the Jurassic-Cretaceous age (65-190 million years ago) Franciscan Complex and marine sedimentary strata of the Great Valley Sequence, which is of similar age. Within central and northern California, the Franciscan and Great Valley rocks are locally overlain by a variety of late Cretaceous and Tertiary-age sedimentary and volcanic rocks which have been deformed by episodes of folding and faulting. The youngest geologic units in the region are Quaternary-age (last 1.8 million years) sedimentary deposits. These unconsolidated deposits partially fill many of the valleys of the region.

Regional geologic mapping[1] indicates the project site is underlain by Franciscan “mélange”, defined as a tectonic mixture of resistant rocks, including sandstone, greenstone, serpentinite, chert, and others, embedded in a matrix of weak, sheared shale. Quaternary-age beach sands are shown along the shoreline. No landslides are shown in close proximity to the site. Although not shown on the map, the (submerged) surface trace of the San Andreas Fault lies about 4.0-km offshore, to the southwest of the site. A Regional Geologic Map is shown on Figure 2.

Regional Seismicity

The project site is located within the seismically active San Francisco Bay Area and will therefore experience the effects of future earthquakes. Earthquakes are the product of the build-up and sudden release of strain along a “fault” or zone of weakness in the earth's crust. Stored energy may be released as soon as it is generated or it may be accumulated and stored for long periods of time. Individual releases may be so small that they are detected only by sensitive instruments, or they may be violent enough to cause destruction over vast areas.

Faults are seldom single cracks in the earth's crust, but typically comprised of localized shear zones which link together to form larger fault zones. Within the Bay Area, faults are concentrated along the San Andreas Fault zone. The movement between rock formations along either side of a fault may be horizontal, vertical, or a combination and is radiated outward in the form of energy waves. The amplitude and frequency of earthquake ground motions partially depends on the material through which it is moving. The earthquake force is transmitted through hard rock in short, rapid vibrations, while this energy becomes a long, high-amplitude motion when moving through soft ground materials, such as Bay Mud.

1. Active Faults in the Region - An “active” fault is defined by the California Geological Survey as one that exhibits evidence displacement within the last 11,000 years (i.e., Holocene) and is detectable by a trained geologist as a distinct feature at or just below the ground surface. The California Division of Mines and Geology (1998) has mapped various active and inactive faults in the region. These faults are shown in relation to the project site on the attached Active Fault Map, Figure 3. The nearest known active fault to the site is the San Andreas Fault, located about 4.0-km southwest of the site.

[1] Blake, M.C., Graymer, R.W., and Jones, D.L. (2000), "Geologic Map and Map Database of Parts of Marin, San Francisco, Alameda, Contra Costa, and Sonoma Counties, California: A Digital Database, Version 1.0", United States Geological Survey Miscellaneous Field Studies Map MF-2337, Map Scale 1:75,000

2. Historic Fault Activity - A map showing the distribution of historic earthquake epicenters in the San Francisco Bay Area between 1985 and 2016 is shown on Figure 4. The most significant earthquakes to affect the site in recent history are the 1989 M=6.9 (Loma Prieta) and 1906 M=7.8 San Francisco earthquakes. Little information regarding specific effects within Muir Beach; however, both events caused strong to very strong ground shaking and extensive structural damage throughout adjacent portions of western Marin County.

3. Probability of Future Earthquakes – The site will likely experience moderate to strong ground shaking from future earthquakes originating on any of several active faults in the San Francisco Bay region. The historical records do not directly indicate either the maximum credible earthquake or the probability of such a future event. To evaluate earthquake probabilities in California, the USGS has assembled a group of researchers into the "Working Group on California Earthquake Probabilities" [2,3,4] to estimate the probabilities of earthquakes on active faults. These studies have been published cooperatively by the USGS, CGS, and Southern California Earthquake Center (SCEC) as the Uniform California Earthquake Rupture Forecast, Versions 1, 2, and 3 (aka UCERF, UCERF2, and UCERF3, respectively). In these studies, potential seismic sources were analyzed considering fault geometry, geologic slip rates, geodetic strain rates, historic activity, micro-seismicity, and other factors to arrive at estimates of earthquakes of various magnitudes on a variety of faults in California.

   Conclusions from the most recent UCERF3 and USGS' 2016 Fact Sheet[5] indicate there is a 72% chance of an M>6.7 earthquake in the San Francisco Bay Region between 2016 and 2043. The San Andreas Fault is the nearest known active fault to the site, located 4.0-kilometers to the southwest, and is assigned a 22% probability of a M>6.7 earthquake by 2043. The highest probability of such an earthquake for an individual fault system in the Bay Area is assigned to the Hayward-Rodgers Creek Fault, at 33%. Additional studies by the USGS regarding the probability of large earthquakes in the Bay Area are ongoing. These current evaluations include data from additional active faults and updated geological data.

Site Reconnaissance and Surface Conditions

We performed a site reconnaissance to observe existing conditions and perform wide-scale mapping of site geology on October 16, 2019. Our geologic map of the site is presented on Figure 5, and significant observations from our reconnaissance are summarized below:

- Surface grades at the site range from sea level at the beach at the southern edge of the site to a maximum of about +130-feet along the Sunset Way frontage. South-facing slopes

[2] United States Geological Survey (2003), "Summary of Earthquake Probabilities in the San Francisco Bay Region, 2002 to 2032," The 2003 Working Group on California Earthquake Probabilities, 2003.
[3] United States Geological Survey (2008), "The Uniform California Earthquake Rupture Forecast, Version 2," The 2007 Working Group on California Earthquake Probabilities, Open File Report 2007-1437, 2008.
[4] Field, E.H. et al (2015), "Long-Term Time-Dependent Probabilities for the Third Uniform California Earthquake Rupture Forecast (UCERF3)", Bulletin of the Seismological Society of America, Volume 105, No. 2A, 33pp., April 2015, doi: 10.1785/0120140093
[5] Aagard, B.T. et al (2016), "Earthquake Outlook for the San Francisco Bay Region 2014-2043", United States Geological Survey Fact Sheet 2016-3020, Version 1.1, Revised August 2016.

are inclined at an average of about 2:1 (horizontal:vertical). Locally steeper inclinations were observed around the toe of the apparent fill slope underlying the outer edge of Sunset Way as well as around the toe of an apparent landslide in the central part of the site. Above the beach, steeper bluffs are inclined between about 1:1 and near-vertical, and range to a maximum of about 20-feet high.

- Existing fills underlying both Sunset Way and adjacent development to the east appear to be several feet thick. Several failed timber retaining walls were noted along the east property line, at the base of the fills underlying the neighboring residence and deck areas. Several feet of fill soil and wood chip debris appears to have been side-cast from the roadway across the upper part of the property.

- The central part of the site is occupied by the scar and debris pile of a small landslide which is about 60-feet wide and 100-feet long. A subtle topographic “lobe” in the upper part of the scar area is not well represented on the topographic map, and may represent the debris pile of a younger, smaller slide. Small landslides were also observed above the bluffs in the southern part of the property.

- Soils throughout the site, including fill, slide debris, and residual soils overlying bedrock, we noted to consist primarily of loose, porous silty sand with varying quantities of angular sandstone and shale rock fragments. During our reconnaissance, Sunset Way was in the process of being re-paved, and fill materials exposed along the outer edge appeared to consist of well-compacted, dense silty to clayey sand. Completely weathered shale bedrock was observed in low cuts along the inboard/upslope edge of the road.

- Bluffs at the base of the slope expose relatively hard, resistant graywacke sandstone which appears to lie in fault contact with highly sheared, completely weathered shale. Bedrock is typically exposed beneath a 3-to 5-foot layer of silty to sandy residual soils as described above. A small landslide in the southwestern corner of the parcel appears to have been the result of erosion around the top of the bluff.

- Several tens of cubic yards of heavy rip-rap armor have been placed at the toe of the central part of the bluff, and extend to an elevation about 10-feet above the beach. The western part of the bluff toe is protected by a series of terraced grouted-rock walls which form apparent tidal bathing pools. The rear walls of the pools also extend about 10-feet above the beach, and a small stone-surfaced walking path separates the pools from the bluff face.

<u>Geologic Hazards Evaluation</u>

This section summarizes our review of geologic hazards which could impact the development, including seismic ground shaking, liquefaction, settlement, flooding, erosion, slope instability, coastal bluff retreat, and others. Based on our evaluation, we judge the primary geologic hazards to consider during project design include seismic ground shaking, lurching/ground cracking, erosion, slope instability, settlement, and coastal bluff retreat. Other hazards are judged to be relatively inconsequential with regard to the proposed project. More detailed discussion of each hazard considered is presented below.

Fault Surface Rupture
Under the Alquist-Priolo Earthquake Fault Zoning (APEFZ) Act[6], the California Division of Mines and Geology (CDMG, now known as the California Geological Survey) produced 1:24,000 scale maps showing known active and potentially active faults and defining zones within which special fault studies are required[7]. The nearest known active fault, the San Andreas Fault, is located approximately 4.0-km southwest of the site, and the site is not mapped as lying within an Alquist-Priolo Earthquake Fault Zone.

Although we did observe extensive shearing and apparent vertical offsets within bedded and fractured shale in the bluff face, we did not observe any evidence of offset extending into the overlying soils, and therefore judge these are likely "intraformational" faults which were last active during original emplacement of the Franciscan bedrock on the order of ~80- to 140-million years ago. We judge the risk of fault surface rupture at the site is low.

Evaluation: *Less than significant.*
Recommendations: *No special engineering measures are anticipated.*

Seismic Shaking
The site will likely experience seismic ground shaking similar to other areas in the seismically active Bay Area. The intensity of ground shaking will depend on the characteristics of the causative fault, distance from the fault, the earthquake magnitude and duration, and site-specific geologic conditions. Estimates of peak ground accelerations are based on either deterministic or probabilistic methods.

Deterministic Seismic Hazard Analysis (DSHA) predicts the intensity of earthquake ground motions by analyzing the characteristics of nearby faults, distance to the faults and rupture zones, earthquake magnitudes, earthquake durations, and site-specific geologic conditions. Using the Caltrans ARS Online web application (2019), we have calculated the median peak ground acceleration for the various nearby active faults, as presented below in Table A. The acceleration values shown are for an earthquake originating on the closest portion of the fault to the site.

[6] California Department of Conservation, Division of Mines and Geology (1972), Special Publication 42, "Alquist-Priolo Special Studies Zone Act," (Revised 1988).

[7] California Department of Conservation, Division of Mines and Geology (2000), "Digital Images of Official Maps of Alquist-Priolo Earthquake Fault Zones of California, Central Coast Region", DMG CD 2000-004.

TABLE A
ESTIMATED PEAK GROUND ACCELERATION FOR PRINCIPAL ACTIVE FAULTS
183 Sunset Way
APN 199-235-47/48
Muir Beach, California

Fault	Fault Distance[1]	Moment Magnitude[1]	Median PGA[2,3,4,5,6]	$+1\sigma$ PGA[2,3,4,5,6]
San Andreas	4.0 km	8.0	0.49 g	0.89 g
San Gregorio	6.9 km	7.4	0.36 g	0.66 g
Hayward	23.0 km	7.3	0.16 g	0.28 g
Rodgers Creek	36.2 km	7.3	0.10 g	0.19 g
Calaveras	47.1 km	6.9	0.06 g	0.11 g

References:
1. Caltrans ARS (2019)
2. Abrahamson, Silva and Kamai (2014)
3. Boore, Stewart, Seyhan and Atkinson (2014)
4. Campbell and Borzognia (2014)
5. Chiou and Youngs (2014)
6. Values determined using Vs_{30} = 760 m/s for Site Class “B” per 2016/2019 CBC.

Probabilistic Seismic Hazard Analysis (PSHA) analyzes all possible earthquake scenarios while incorporating the probability of each individual event to occur. The probability is determined in the form of the recurrence interval, which is the average time for a specific earthquake acceleration to be exceeded. The design earthquake is not solely dependent on the fault with the closest distance to the site and/or the largest magnitude, but rather the probability of given seismic events occurring on both known and unknown faults.

We calculated the PGA for two separate probabilistic conditions, the 2% chance of exceedance in 50 years (2,475 year statistical return period) and the 10% chance of exceedance in 50 years (475 year statistical return period), utilizing the USGS 2008 Interactive Deaggregation web-based calculator tool. Deterministic methods, as discussed above, or the PGA arising from a probabilistic analysis for a 10% chance of exceedance in 50 years are commonly utilized for residential, commercial, and industrial developments. The PGA arising from a probabilistic analysis for a 2% chance of exceedance in 50 years is typically used for “critical” facilities such as schools and hospitals. The results of the probabilistic analyses are presented below in Table B.

TABLE B
PROBABILISTIC SEISMIC HAZARD ANALYSES
183 Sunset Way
APN 199-235-47/48
Muir Beach, California

	Statistical Return Period	Mean Moment Magnitude[1]	Peak Ground Acceleration (g)[1,2]
2% in 50 years	2,475 years	7.8	1.00 g
10% in 50 years	475 years	7.6	0.50 g

Notes:

1) USGS (2019), "Unified Hazard Tool" (web-based ground acceleration calculator tool), https://earthquake.usgs.gov/hazards/interactive/index.php, Dynamic: Conterminous US 2014 v4.2.0, accessed October 30, 2019.

2) Values shown were determined using estimated subsurface shear wave velocity Vs^{30} = 760 m/s for "Rock" subsurface conditions (Site Class "B") in accordance with the 2016 California Building Code.

The potential for strong seismic shaking at the project site is high. Due to their close proximity and historic rates of activity, the San Andreas and San Gregorio Faults present the highest potential for severe ground shaking. The most significant adverse impact associated with strong seismic shaking is potential damage to structures and improvements.

Evaluation: *Less than significant with special engineering measures.*

Recommendations: *New structures should be designed in accordance with the provisions of the latest edition of the California Building Code (2016/2019 CBC). Seismic design criteria should be developed/confirmed on the basis of subsurface exploration and laboratory testing performed as part of a future design-level Geotechnical Investigation.*

Liquefaction and Related Effects

Liquefaction refers to the sudden, temporary loss of soil strength during strong ground shaking. This phenomenon can occur in saturated, loose, granular deposits (typically sand) when the sediments are subjected to seismic shaking. Liquefaction can result in flow failure, lateral spreading, and settlement.

Regional mapping[8] indicates the site lies in a zone of "very low" liquefaction susceptibility, and our site reconnaissance observations indicate the proposed development area is generally underlain by relatively shallow bedrock. Although beach sands are considered highly likely to liquefy during seismic shaking, we judge the risk of damage to improvements within the proposed development area due to liquefaction is low.

[8] Association of Bay Area Governments (ABAG)(2019), "Liquefaction Susceptibility Maps", http://gis.abag.ca.gov/website/Hazards/?hlyr=liqSusceptibility, accessed October 22, 2019.

Evaluation: *Less than significant.*
Recommendations: *No special engineering measures are anticipated.*

Seismically-Induced Ground Settlement
Ground shaking can induce settlement of loose, unsaturated granular soils (ie, those which would otherwise liquefy when saturated). As discussed above, the site is typically underlain by a layer of loose to medium-dense silty sand and sandy silt fill, residual soil, and landslide debris over shallow bedrock. Therefore, the risk of seismically-induced settlement is judged to be moderate.

Evaluation: *Less than significant with special engineering measures.*
Recommendations: *Soils underlying proposed improvements should be moisture-conditioned and compacted in accordance with "typical" geotechnical practice to reduce the risks of settlement. All new foundations should bear directly on bedrock, and all surface improvements should bear on bedrock or dense/recompacted soil. Additional discussion and preliminary recommendations for site preparation and grading are provided in the Conclusions and Recommendations section of this report.*

Lurching and Ground Cracking
Lurching and associated ground cracking can occur during strong ground shaking. The ground cracking generally occurs along the tops of slopes where stiff soils are underlain by soft deposits or along steep slopes or channel banks.

The site is generally underlain by a thin horizon of residual soils over relatively shallow bedrock which typically becomes stronger and less weathered with depth. While the property is comprised largely of steeply-sloping areas, we did not observe conditions particularly conducive to lurching or ground cracking within or near the building areas during our reconnaissance.

Steep bluffs at the base of the property expose weak, highly sheared shale bedrock which is locally juxtaposed against and/or overlain by more resistant graywacke sandstone. Therefore, we judge there is a low to moderate risk of lurching and ground cracking around the top of the bluffs in the southern part of the site.

Evaluation: *Less than significant with special engineering measures.*
Recommendations: *Special measures to reduce the risk of damage due to lurching and ground cracking should include providing minimum setbacks for new structures from the top of the bluffs. For planning purposes, we judge that minimum setbacks of 30-feet are sufficient. Additional discussion regarding bluff setbacks is provided in the Coastal Bluff Retreat section of this hazards evaluation.*

Expansive Soils
Moderate and highly plastic silts and clays, when located near the ground surface, can exhibit expansive characteristics (shrink-swell) that can be detrimental to structures and flatwork during periods of fluctuating soil moisture content. During our site reconnaissance, we did not observe significant evidence of expansive soils, such as desiccation cracking or apparent slope creep. We judge the risk of damage due to expansive soils is low.

Evaluation: *Less than significant.*
Recommendations: *No special engineering measures are anticipated. Evaluation should be confirmed on the basis of subsurface exploration and laboratory testing performed as part of a future design-level Geotechnical Investigation.*

Erosion and Scour
Sandy soils on moderately steep slopes or clayey soils on steep slopes are susceptible to erosion when exposed to concentrated surface water flow. The potential for erosion is increased when established vegetation is disturbed or removed during normal construction activity. Scour at the base of slopes can remove lateral support and cause instability.

The property consists almost entirely of steeply-sloping areas with no existing drainage improvements, and we observed evidence of widespread erosion around the site, primarily around the downslope base of failed retaining walls and around trees, where root balls are locally exposed and/or undermined. At the base of the slope, we observed that existing rip-rap armor and grouted-rock walls appear to provide good protection against wave action and scour, and no evidence of significant scour or undermining was observed. Therefore, we judge that the risk of surface erosion is high, but the risk of undermining due to wave action and scour is low.

Evaluation: *Less than significant with special engineering measures.*
Recommendations: *For new improvements at the site, careful attention should be paid to finished grades, and the project Civil Engineer should design new surface and subsurface drainage improvements (such as interceptor ditches, area drains, foundation drains, and retaining wall rains) to collect water on the upslope side of the development along Sunset Way. Runoff should be conveyed around the development and discharged as near to the base of the bluffs as possible. If extension of drainage discharge lines below the crest of the bluffs is not permissible, drainage may be dispersed across the slightly gentler slopes occupying the southeast corner of the property. Additional discussion regarding site drainage considerations is provided in the Conclusions and Recommendations section of this report.*

Re-establishment of vegetation on disturbed areas will minimize erosion. Erosion control measures during and after construction should be in accordance with a prepared Storm Water Pollution Prevention Plan and should conform to the most recent version of the California Stormwater Quality Association (CASQA) Construction Best Management Practice Handbook (2003).

Seiche and Tsunami
Seiche and tsunamis are short duration, earthquake-generated water waves in large enclosed bodies of water and the open ocean, respectively. The extent and severity of a seiche would be dependent upon ground motions and fault offset from nearby active faults.

The lower portion of the site, limited mainly to the beach, is mapped as lying within a tsunami inundation zone. However, since the proposed development is anticipated to generally occur at elevations in excess of +30-feet, we judge the risk of damage due to tsunami inundation is remote.

Evaluation: *Less than significant.*
Recommendations: *No special engineering measures are anticipated.*

Flooding
The primary adverse impact from flooding is water damage to structures. The proposed development area is not mapped as lying within a FEMA 100- or 500-year flood zone. Therefore, the risk of large-scale flooding at the site is judged to be nil.

Evaluation: *Less than significant.*
Recommendations: *No special engineering measures are anticipated. The project Civil Engineer should design site grades to provide positive drainage away from new structures and avoid the potential for areas of ponded water or small-scale flooding.*

Landsliding and Slope Instability
The project site is located in an area of very steep natural terrain which is locally susceptible to instability. Relatively wide-scale regional geologic mapping, referenced previously and shown on Figure 2, does not show any landslides in close proximity to the site but does generally indicate widespread landsliding along coastal bluffs north and south of Muir Beach. We are unaware of published, more detailed landslide mapping in the project area.

During our reconnaissance, we observed that the site is comprised entirely of steep slopes which exhibit generally hummocky topography. Subdued lobate topography in the lower, central part of the site is interpreted as slide debris, discharged from the shallow swale upslope. Our interpretation of site topography and geomorphology is depicted on Figure 5, where the fill embankment beneath Sunset Way and adjoining residential developments has apparently been placed over the scarp/source area of the mapped slides. None of these slides exhibit evidence of recent or incipient (developing) movement, such as fresh scarps or tension cracks, and none appears to exceed about 5-feet in depth. Aside from one small slide mapped at the toe of the bluff in the southwestern property corner, none of the slides appear to be the result of bluff instability, scour, or undermining.

Based on our site reconnaissance observations and the apparent history of slope instability at the site, we judge the risk of damage due to landsliding is high.

Evaluation: *Less than significant with special engineering measures.*
Recommendations: *While the bedrock underlying the property is generally hard and judged to be relatively competent and stable, the variably-thick surface soil layer is highly prone to erosion and instability. New structures should be supported on deep foundation systems which derive their capacity from competent underlying bedrock. Any planned fills should be retained with appropriately-designed and -drained retaining walls; unretained fill slopes should be avoided. Effective site and foundation drainage will further reduce the risk of instability. Additional discussion regarding probable foundation types, optional retaining wall configurations, site drainage*

considerations, and other slope-stability issues are presented in the Conclusions and Recommendations section.

Settlement
Total and differential settlement will occur when new loads (fill or buildings) are placed atop soft, compressible soils, such as Bay Mud. Differential settlement can damage buildings and site improvements. The project site is generally underlain by a variably-thick layer of loose to medium-dense slide debris, fill soils, and residual soils, some of which could be compressible under new applied loads. Undocumented fills in particular will likely present a high risk of settlement. Where new structures will span cut/fill transitions, there will also be a high risk of differential settlement unless special engineering measures are provided.

Evaluation: *Less than significant with mitigation.*
Recommendations: *New structures planned in areas of undocumented fill or thicker native soils should be supported on deep foundations which extend through any settlement-prone materials and gain support in firm bedrock. If structures will span cut/fill transitions, then they will likely utilize shallow foundations in "cut" areas and deep (drilled pier) foundations in areas of new fill. Additional discussion regarding site grading and probable foundation types is provided in the Conclusions and Recommendations section of this report.*

Soil Corrosion
Corrosive soil can damage buried metallic structures and underground utilities, deteriorate rebar reinforcement, and cause spalling of concrete. Soils high in soluble sulfates and chlorides, as well as acidic soils and soils of low electrical resistivity, tend to have high corrosive potential. The project site is located adjacent to the Pacific Ocean, and is highly exposed to saltwater. Therefore, we judge the risk of corrosion at the site is moderate.

Evaluation: *Less than significant.*
Recommendations: *Evaluation should be confirmed on the basis of corrosivity testing performed during a design-level Geotechnical Investigation.*

Radon-222 Gas
Radon-222 is a product of the radioactive decay of uranium-238 and raduim-226, which occur naturally in a variety of rock types, chiefly phosphatic shales, but also in other igneous, metamorphic, and sedimentary rocks. While low levels of radon gas are common, very high levels which are typically caused by a combination of poor ventilation and high concentrations of uranium and radium in the underlying geologic materials, can be hazardous to human health. The project site is located in Marin County, California, which is mapped in radon gas Zone 3 by the United States Environmental Protection Agency. Zone 3 is classified by the EPA as exhibiting a "low" potential for Radon-222 gas with average predicted indoor screening levels less than 2pCi/L; therefore, the potential for hazardous levels of radon at the project site is low.

Evaluation: *Less than significant.*
Recommendations: *No special engineering measures are anticipated.*

Volcanic Eruption
Several active volcanoes with the potential for future eruptions exist within northern California, including Mount Shasta, Lassen Peak, and Medicine Lake in extreme northern California, the Mono Lake-Long Valley Caldera complex in east-central California, and the Clear Lake Volcanic Field, located in Lake County approximately 80 miles north of the project site. The most recent volcanic eruption in northern California was at Lassen Peak in 1917, while the most recent eruption at the nearest volcanic center to the project site, the Clear Lake Volcanic Field, was about 10,000 years ago. All of northern California's volcanic centers are currently listed under "normal" volcanic alert levels by the USGS California Volcano Observatory. While the aforementioned volcanic centers are considered "active" by the USGS, the likelihood of damage to the proposed improvements due to volcanic eruption is generally low.

Evaluation: *Less than significant.*
Recommendations: *No special engineering measures are anticipated.*

Coastal Bluff Retreat
Coastal bluff retreat, and shoreline retreat in general, is most common where the underlying geologic materials are highly susceptible to erosion and scour, and where erosion by concentrated flow at the top of the cliff occurs in conjunction with scour by wave action and ocean currents at the base of the cliff. Cliff and shoreline retreat may be exacerbated or accelerated by rising sea levels, and may be retarded by simultaneous accretion, deposition, and/or tectonic uplift.

The project site is located at the top of a coastal bluff, approximately 20-feet above the Pacific Ocean. The bluff is faces nearly due south and lies along the north side of the sheltered cove which forms Muir Beach. Variably-weathered bedrock of the Franciscan Complex is exposed in the lower portion of the bluff, with the upper bedrock surface approximately 20-feet above mean sea level. Relatively hard, resistant graywacke rock forms a small promontory at the southeast property corner, while highly sheared, crushed, and highly weathered shale and sandstone are exposed to the west. Although these materials are judged highly prone to scour and erosion, they are effectively armored by existing rip-ra and stone tidal pool walls along the shoreline.

Loose, silty to sandy slide debris and residual soils form a 3- to 5-foot thick layer overlying the Franciscan rocks and form a slope inclined at about 2:1 (horizontal:vertical). Surface soils were noted to exhibit evidence of instability and erosion due to surface water flow.

Based on our review of available published literature, no studies regarding cliff retreat have been conducted specific to the Muir Beach area or at the project site proper. However, several studies of cliff and shoreline retreat in the greater North Coast region have been conducted. Materials we reviewed are discussed below:

USGS OPEN-FILE REPORT 2007-1133 (2007) – Part 4 of the USGS National Assessment of Shoreline Change Project[9] addresses long-term cliff retreat rates along the California Coast. Cliff retreat rates were interpreted based on the spatial difference between historic cliff edge

[9] Hapke, C.J.,Reid, D., Green, K.R., and Borrelli, M. (2007), "National Assessment of Shoreline Change: Part 4: A GIS Compilation of Vector cliff edges and associated change data for the cliffed shorelines of the California Coast", Open-File Report 2007-1112, U.S. Geological Survey, Coastal and Marine Geology Program, U.S. Geological Survey, Pacific Science Center, Santa Cruz.

locations, as determined from NOAA Topographic Sheets and other maps, and current cliff edges as surveyed using LiDAR technology. Historic cliff edge locations were taken from sources published between 1920 and 1930, while LiDAR imaging was performed in 1998 and 2002. Therefore, long-term cliff retreat rates are based on differences in cliff edge locations observed over a period of time spanning approximately 70-years. The report concludes that the average statewide cliff retreat rate is approximately 0.3 +/- 0.2 meters (about 7-inches) per year, with an average of approximately 17.7-meters (just under 60-feet) of total cliff retreat over the 70-year time span.

For the San Francisco North study region, which extends from Tomales Point in the north to Point Bonita in the south, the average retreat rate is reported as 0.5-meters (about 19.6-inches) per year, while the average total retreat over the 70-year span is reported as 36.2-meters (about 119-feet). It should be noted that average rates are likely affected by outliers in the data. For instance, USGS reports that “the maximum rate in this region, –1.9 m/yr (6.2-feet), was measured along the south-facing cliffs of Point Reyes headland . . .(where) slope failures within the overlying materials result in the high erosion rates. Other areas where high rates were measured in the San Francisco North region include . . . along the promontory connecting Bolinas and Duxbury Points.” At these locations, the underlying geology consists of highly sheared and fractured Salinian Granite overlain by poorly-lithified sedimentary rocks, and much of the retreat here is apparently due to failure of the weak sedimentary units which overlie the granite. Therefore, average regional rates may be severely skewed where the majority of the regional bedrock geology is at odds with those locations where unique geologic features lend themselves to higher rates of retreat.

We reviewed composite vector shoreline data[10,11] for the region produced by the study in ArcGIS Pro. Vector shoreline data for coastal cliff areas included composite historic shorelines for the time periods between 1929 and 1931 (generated from historic maps and other paper sources) and between 1998 and 2002 (surveyed by LiDAR in conjunction with NASA). Individual transects flanking the site indicate average historic retreat rates of -0.27m (about 10.5-inches) per year and -0.36m (about 14-inches) per year. Negative retreat rates at the site are indicative of aggradation, and are likely reflective of both inaccuracies inherent to digitizing maps from the early 1900’s as well as the installation of rip-rap armor and construction of stone pools during the study time period. We note that sandy Muir Beach, just south of the site, is shown as having an average (positive) retreat rate of 0.81m (about 32-inches) per year, which is not considered unreasonable. Historic shoreline data is presented on Figure 6.

Finally, we reviewed historic aerial photography provided by Photoscience, Inc. of Emeryville, California and the California Coastal Records Project. Aerial photography spanned the time period between 1958 and 2015 and included both black-and-white vertical photography and color oblique-angle photography. We interpreted the location of the cliff edge in the 1958 photograph based on tonal variations as shown on Figure 7. We located the cliff edge in the

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[10] Hapke, C.J. and Reid, D. (2007) cencal1929_1935.shp - Vectorized Cliff Edge of Central California Derived from 1929-1935 Source Data: Open-File Report 2007-1112, U.S. Geological Survey, Coastal and Marine Geology Program, U.S. Geological Survey, Pacific Science Center, Santa Cruz, California.

[11] Hapke, C.J., Reid, D., and Green K.R. (2007) cencal1998_2002.shp - Vectorized Cliff Edge of Central California Derived from 1998/2002 Lidar Source Data: Open-File Report 2007-1112, U.S. Geological Survey, Coastal and Marine Geology Program, U.S. Geological Survey, Pacific Science Center, Santa Cruz, California.

2015 photograph based on color variations and our field reconnaissance, as shown on Figure 8, and measured the distance between interpreted cliff edges. Our measurements indicate a maximum of about 49-feet of retreat in the southeast corner of the property between 1958 and 2015, or an annual average rate of about 7.2-inches per year.

We note that much of the observed retreat appears to be the result of instability and landsliding within surficial soils at the top of the bluff. We have been provided client documentation in the form of a cancelled check and personal communication that the rip-rap was installed in 1986, and that the stone pool walls were built in the 1960's, all of which is consistent with our field observations and the appearance of the improvements in the historic air photo sequence. These features appear to be providing good protection from scour and erosion at the base of the cliff, and little apparent change in the shoreline position is observable between 1986 and 2015. Therefore, we judge the retreat rate measured above is likely skewed by the absence of walls and rip-rap, which appear to have largely abated shoreline retreat at the site since their construction.

Based on our review of available cliff retreat data, mapping, and aerial photography, we judge that cliff retreat rates at the project site are likely lower than average for the San Francisco North region due to the relatively resistant Franciscan rock exposed at the base of the bluff and the scour protection afforded by existing rip-rap and stone pool walls. The potential for cliff retreat due to wave action and scour is generally judged to be low to moderate. However, erosion of the overlying residual soils and landslide deposits exposed on the upper portion of the bluff could jeopardize the stability of improvements constructed near the bluff edge. The potential for instability will be exacerbated where soils are exposed to concentrated runoff, such as is typically associated with new development (impervious surfaces, etc.) Therefore, the risk of damage due to cliff retreat and erosion is judged moderate to high.

Evaluation: *Less than significant with mitigation.*

Recommendations: *Special measures could include structural design of new improvements to withstand potential bluff instability and erosion, establishment of minimum setbacks from the edge of the bluff, or a combination of the two. We judge that effective structural mitigation would need to include design of deep foundations which derive their bearing entirely from firm Franciscan bedrock, at expected depths on the order of 5- to 10-feet below the slide debris and residual soils.*

Based on current conditions and interpreted rates of historic bluff retreat, we estimate a future bluff retreat rate of about 6-inches per year. Therefore, we recommend establishment of a 50-foot minimum setback from the edge of the bluff if the project is to be designed for a 100-year service life. Additional discussion regarding appropriate building envelopes, building setbacks, and probable foundation types is provided in the Conclusions and Recommendations section of this report.

Conclusions and Recommendations

Based on our review of reference information and site reconnaissance, we judge the proposed development is feasible from a geotechnical perspective. Primary geotechnical considerations for the project will include providing uniform foundation support and adequate seismic design for new structures, as well as providing effective site drainage to reduce the risks of damage due to future erosion and instability. Preliminary recommendations and development guidelines to address these and other geotechnical project aspects are presented in the following sections.

Recommended Bluff Setbacks

As discussed above, we recommend minimum 50-foot setbacks from the edge of the bluff for new structures designed to a 100-year service life. The recommended setback line and resulting building envelope are shown on Figure 9.

Preliminary Seismic Design

All new structures should be designed in conformance to the provisions of the most recent edition (2016/2019) of the California Building Code (CBC). The magnitude and character of these ground motions will depend on the particular earthquake and the site response characteristics. Preliminary recommended seismic design criteria for the site are shown below; these values should be confirmed on the basis of subsurface exploration and laboratory testing performed as part of a design-level Geotechnical Investigation. Note the values shown below will need to be confirmed/updated following adoption of the 2019 CBC as of January 1, 2020.

TABLE C
2016 CBC SEISMIC DESIGN CRITERIA
183 Sunset Way
APN 199-235-47/48
Muir Beach, California

Factor Name	Coefficient	CBC Table	Site Specific Value[1,2]
Site Class[3,4]	$S_{A,B,C,D,E,\text{ or }F}$	1613.5.2	S_B
Site Coefficient	F_a	1613.5.3 (1)	1.0
Site Coefficient	F_v	1613.5.3 (2)	1.0
Spectral Acc. (short)	S_s	1613.5.1	2.026
Spectral Acc.(1-sec)	S_1	1613.5.1	0.955

(1) Values determined using the SEAOC/OSHPD Seismic Design Maps web application, https://seismicmaps.org/, accessed October 31, 2019.
(2) Values shown determined using Vs^{30} = 760 m/s (Site Class "B") in accordance with the provisions of the 2010 ASCE-7 standard and 2016 California Building Code.
(3) Site Class determined in accordance with procedures outlined in the 2010 ASCE-7 standard, based on subsurface conditions inferred from surficial reconnaissance.
(4) Site Class B Description: Rock, shear wave velocity between 2,500 and 5,000 feet per second.

The effects of earthquake shaking (i.e., protection of life safety) can be mitigated by close adherence to the seismic provisions of the current edition of the CBC. However, some building damage may still occur during strong ground shaking. We note that site-specific ground motion and site response analyses may be required depending on actual subsurface conditions, as a result of new seismic design requirements included in the forthcoming 2019 CBC.

Site Grading

Although detailed plans are not yet available, we anticipate moderate grading, consisting of a combination of cuts and fills up to 10-feet or so, may be required to accommodate the new residence and related site improvements. Excavations will also be required for the new septic system, underground utility connections, and other items. The extent of the required grading will be dependent on the proposed structural footprints, their exact location relative to adjacent slopes, and other factors. Based on our reconnaissance, the underlying bedrock, while hard and strong, is relatively closely fractured. Therefore, we judge that the majority of the grading and shallow excavation at the site can likely be accomplished with "conventional" grading equipment, such as medium-size excavators and dozers. However, there is also a high likelihood that localized zones of particularly hard rock will exist, especially in deeper excavations. These areas could require specialized techniques and equipment (such as large excavators, heavy dozers/rippers, jackhammers, or hoe-rams) to excavate.

Unretained permanent fill slopes are not recommended at the site, and any planned fills should be retained with appropriately-designed retaining walls. For planning purposes, permanent cuts in soil and rock may be inclined at 2:1. Steeper cuts may be possible, but will require specific geologic evaluation during construction. Temporary cuts in soil and rock may be planned at inclinations of 1.5:1 and 0.5:1, respectively.

Probable Foundation Types

In general, shallow foundations will be appropriate for new residences only where building pads are excavated to bear directly on weathered bedrock and where a minimum of 10-feet horizontal confinement may be maintained between base of the foundation and the nearest slope face. If the building pad does not expose bedrock across the entirety of its footprint, if structures will be located within 10-feet of sloping ground, or if structures will span cut/fill transitions, then deep foundations, such as drilled piers, will be needed to ensure uniform support. New retaining walls along the downslope edge of Sunset Way, if needed, will likely require drilled-pier foundations.

Retaining Walls

A variety of wall types may be used at the site to create level building pad areass. For typical permanent cut areas, soldier-pile (steel H-beam) and timber lagging or reinforced concrete walls are often the most cost-effective. Walls integral to the residence structures and/or which are part of a foundation system should be reinforced concrete walls. For higher cuts and for temporary stabilization of deep excavations during construction, soil nail and shotcrete walls are often the most cost-efficient. For new fills, mechanically-stabilized earth (MSE) walls, such as Keystone or Versa-Lok, are often the most cost-effective provided that keyways may be excavated relatively economically in shallow bedrock.

Site Drainage Considerations

In general, careful consideration should be given to site drainage, in order to lessen the risk of soil saturation and slope instability affecting the development. As discussed previously, runoff should be collected on the upslope side of the site and conveyed via a new storm-drain system to the downslope side. In order to avoid exacerbating erosion or instability on the lower portion of the property, the new drainage system should be designed to accommodate runoff associated with a 100-year storm, and also to result in no net increase in peak flow rate.

It is our experience that such design will likely require onsite detention or infiltration to reduce offsite flow rates. We generally do not recommend infiltration at the site given the potential for instability, and instead recommend detention be pursued if possible. Drainage should be discharged as near to the beach as possible.

Supplemental Services

Once the project plans are better-developed and the approximate locations/extents of new structural improvements are more clearly-defined, a design-level Geotechnical Investigation, including subsurface exploration and laboratory testing, will need to be performed to develop geotechnical criteria and recommendations for use in final project design. We can be available to consult with you throughout the design process on an as-needed basis. As the plans near completion, we should review them to determine whether the intent of our recommendations has been suitably incorporated, and to provide a Geotechnical Plan Review letter to the County of Marin, as is typically required for issuance of a building permit. During construction, we should observe site grading, foundation construction, retaining wall construction, site drainage, and other geotechnical aspects of the work to verify that actual conditions encountered are as anticipated, to modify our recommendations if needed, and determine whether the Contractor's work is performed in accordance with the plans and specifications.

We trust that this letter presents the information you require at this time. Should there be any questions or concerns regarding our seismic risk evaluation, please do not hesitate to contact us.

Very truly yours,
MILLER PACIFIC ENGINEERING GROUP

REVIEWED BY

CERTIFIED ENGINEERING GEOLOGIST
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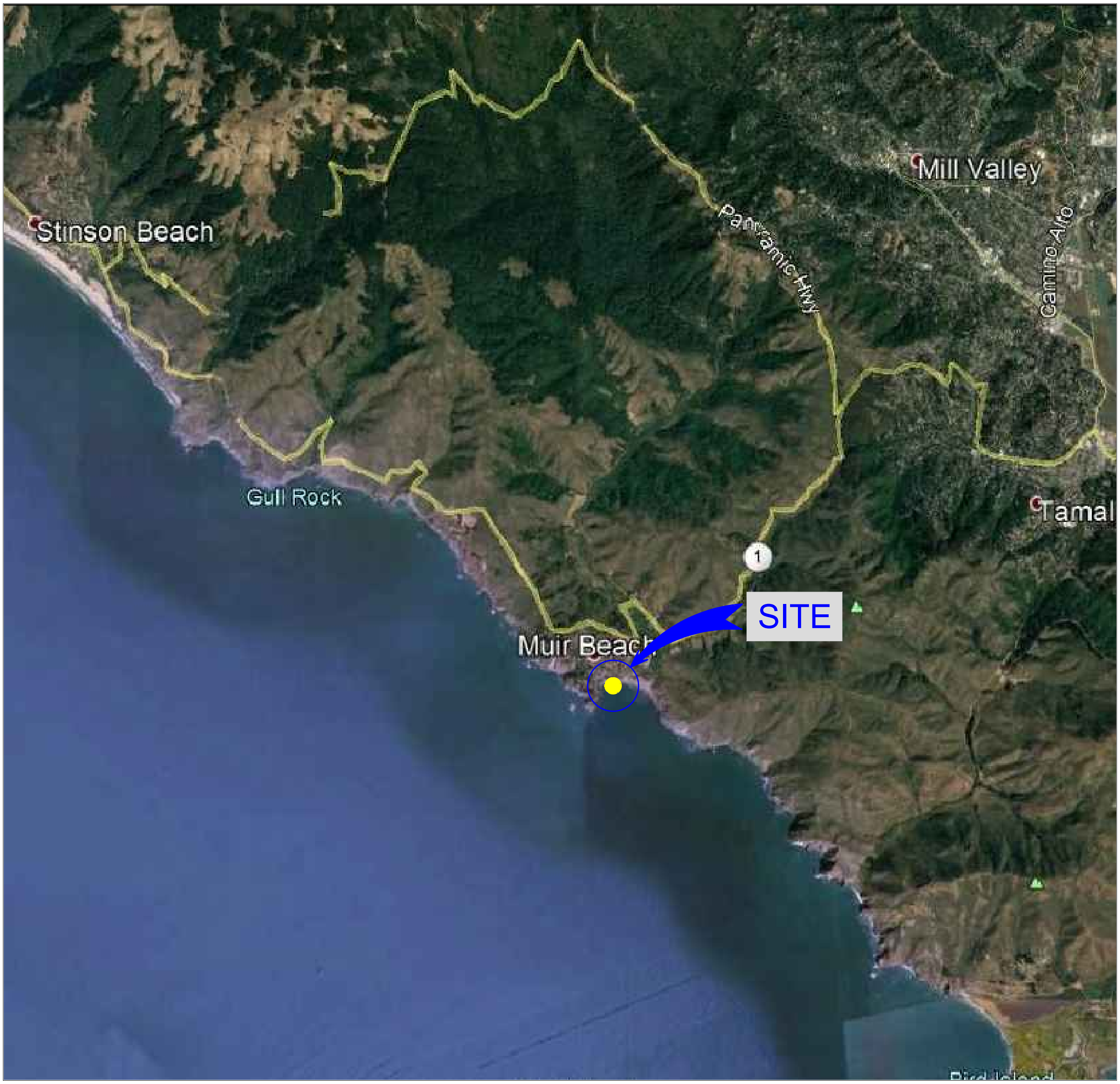
Mike Jewett
Engineering Geologist No. 2610
(Expires 1/31/21)

Scott Stephens
Geotechnical Engineer No. 2398
(Expires 06/30/21)

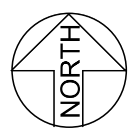
Attachments: Figures 1 through 9



SITE COORDINATES
LAT. 37.8601°
LON. -122.5793°

SITE LOCATION

N.T.S.



REFERENCE: Google Earth, 2019

MPEG MILLER PACIFIC ENGINEERING GROUP	504 Redwood Blvd. Suite 220 Novato, CA 94947 T 415 / 382-3444 F 415 / 382-3450 www.millerpac.com	SITE LOCATION MAP		
		183 Sunset Way APN 199-235-47 and -48 Muir Beach, California Project No. 2944.001 Date: 10/30/2019	Drawn ENE Checked	1 FIGURE

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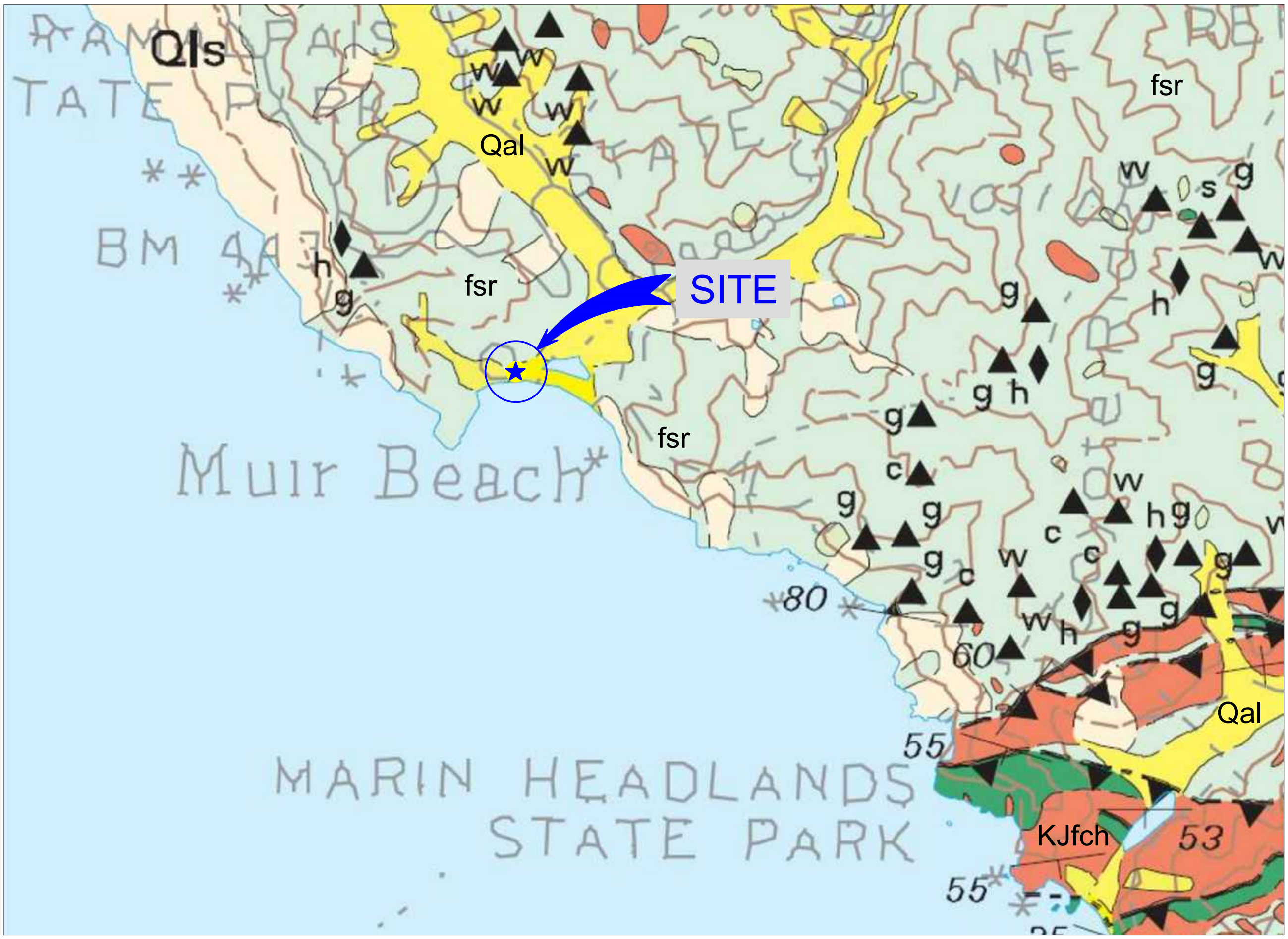

REGIONAL GEOLOGIC MAP

(NOT TO SCALE)

Qls	LANDSLIDE DEPOSITS (QUATERNARY) Unsorted soil and rock debris transported downslope by slow to rapid mass-wasting events
Qal	ALLUVIUM (QUATERNARY) Typically variable proportions of silts, sands, clays, and gravels deposited by water in stream and channel environments
KJfch	CHERT (JURASSIC-CRETACEOUS) Thin-bedded, closely fractured radiolarian chert with interbedded black shale
fsr	MELANGE (JURASSIC-CRETACEOUS) A tectonic mixture of various resistant rock types such as sandstone, greenstone, chert and serpentinite embedded in a sheared shale matrix.

REFERENCE: Blake, M.C., Graymer, R.W., and Jones, D.L., 2000, "Geologic Map and Map Database of Parts of Marin, San Francisco, Alameda, Contra Costa, and Sonoma Counties, California: A Digital Database, Version 1.0", United States Geological Survey Miscellaneous Field Studies Map MF-2337, Map Scale 1:75,000

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REGIONAL GEOLOGIC MAP

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APN 199-235-47 and -48
Muir Beach, California

Project No. 2944.001 Date: 10/30/2019

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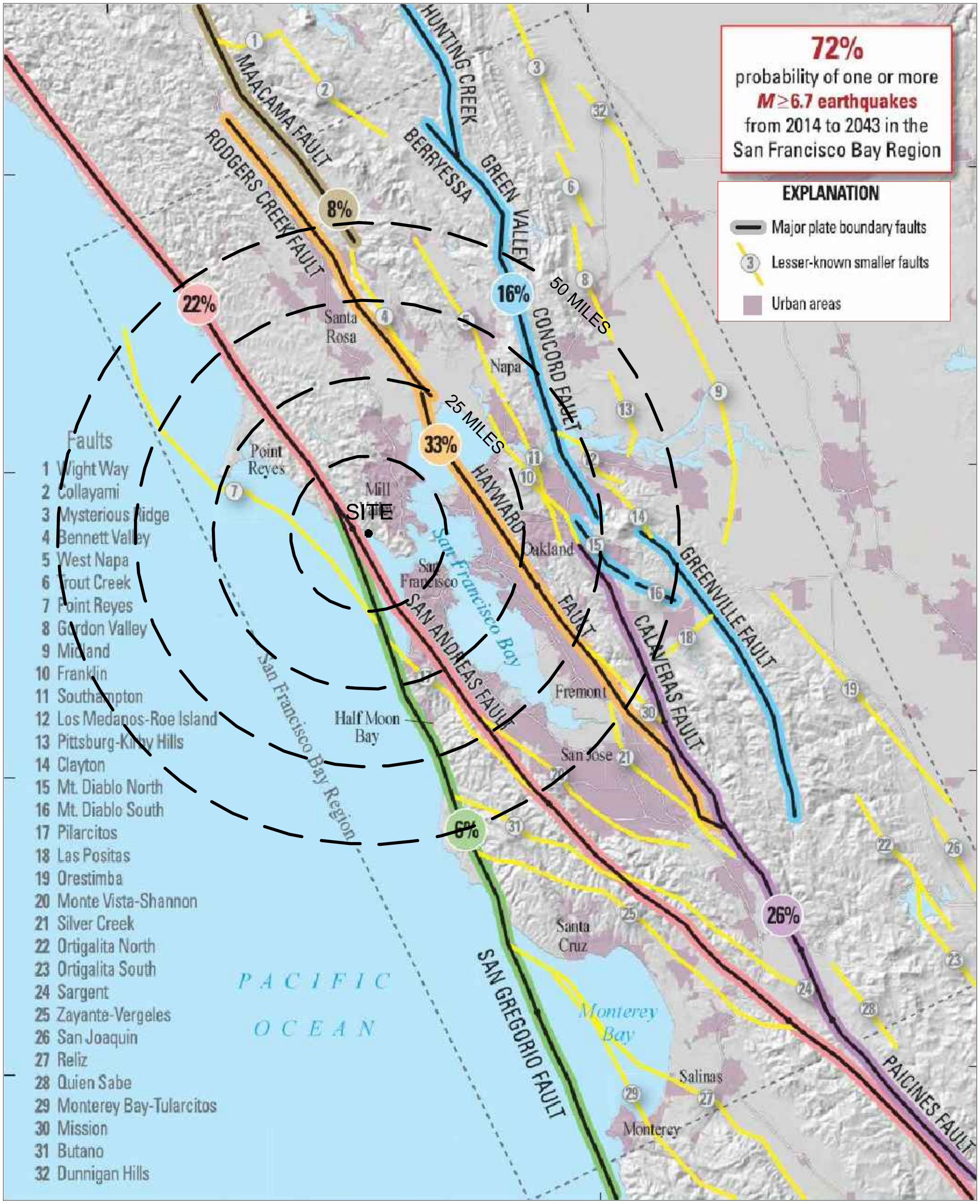
2
FIGURE



SITE COORDINATES
LAT. 37.8601°
LON. -122.5793°

SCALE
0 12.5 25 50 MILES

NORTH

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ACTIVE FAULT MAP

183 Sunset Way
APN 199-235-47 and -48
Muir Beach, California

Project No. 2944.001 Date: 10/30/2019

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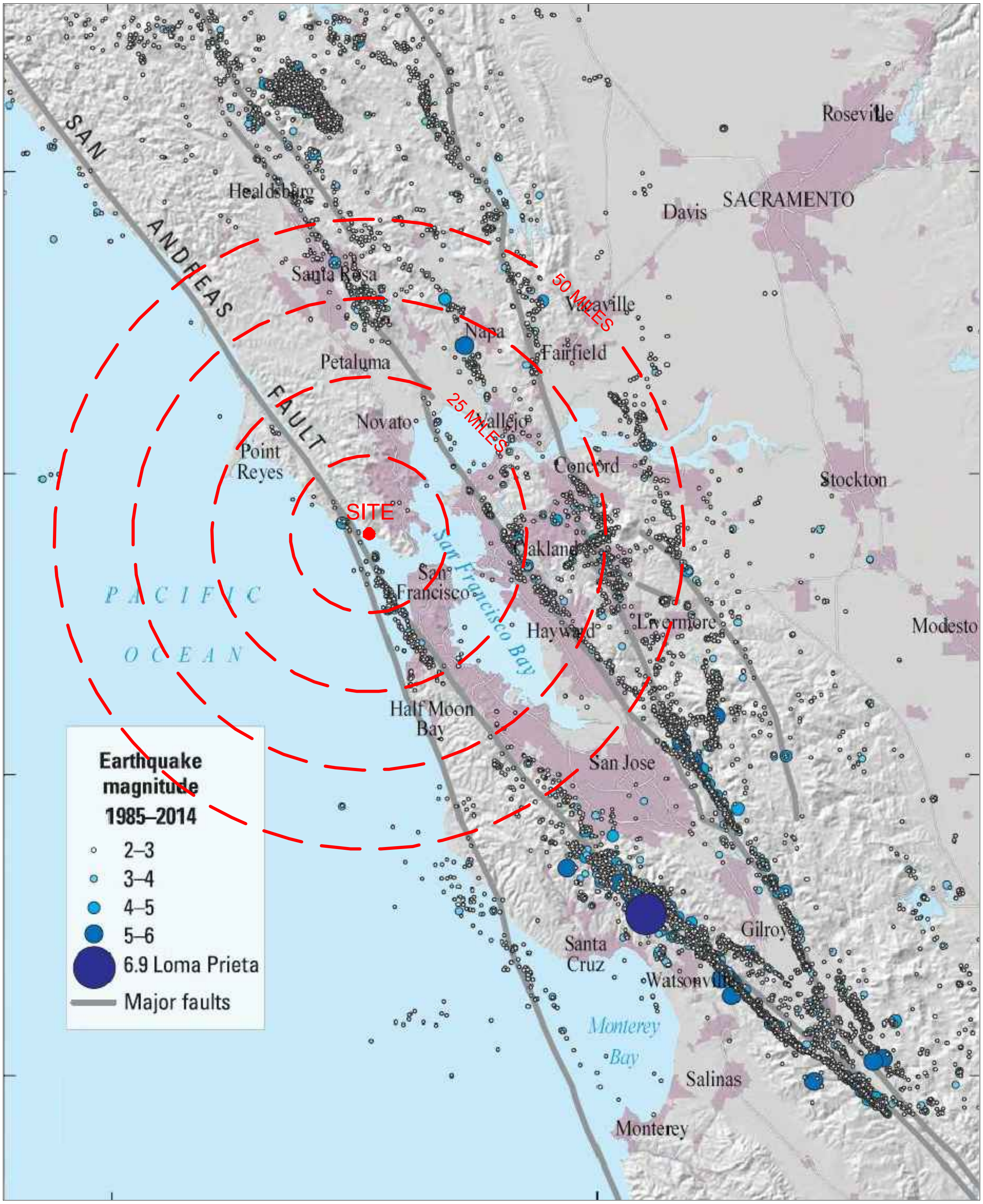
FIGURE 3



SITE COORDINATES
LAT. 37.8601°
LON. -122.5793°

SCALE
0 12.5 25 50 MILES

NORTH

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HISTORIC EARTHQUAKE MAP

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Project No. 2944.001 Date: 10/30/2019

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4
FIGURE

LEGEND AND KEY TO MAP SYMBOLS

Qaf **FILL (QUATERNARY)**
Includes fill embankment along downslope edge of Sunset Way, apparent local fills underlying adjacent structures to the east and west, a few feet of side-cast soil and wood chip debris in northern (upper) part of property.

RIP-RAP (QUATERNARY)
Approximate 2- to 4-foot boulders placed at toe of bluff, east of stone baths, for apparent scour/erosion protection.

Qs **BEACH SAND (QUATERNARY)**
Well-sorted, fine-grained beach sand. Locally obscured by bedrock cobbles and boulders at base of bluff.

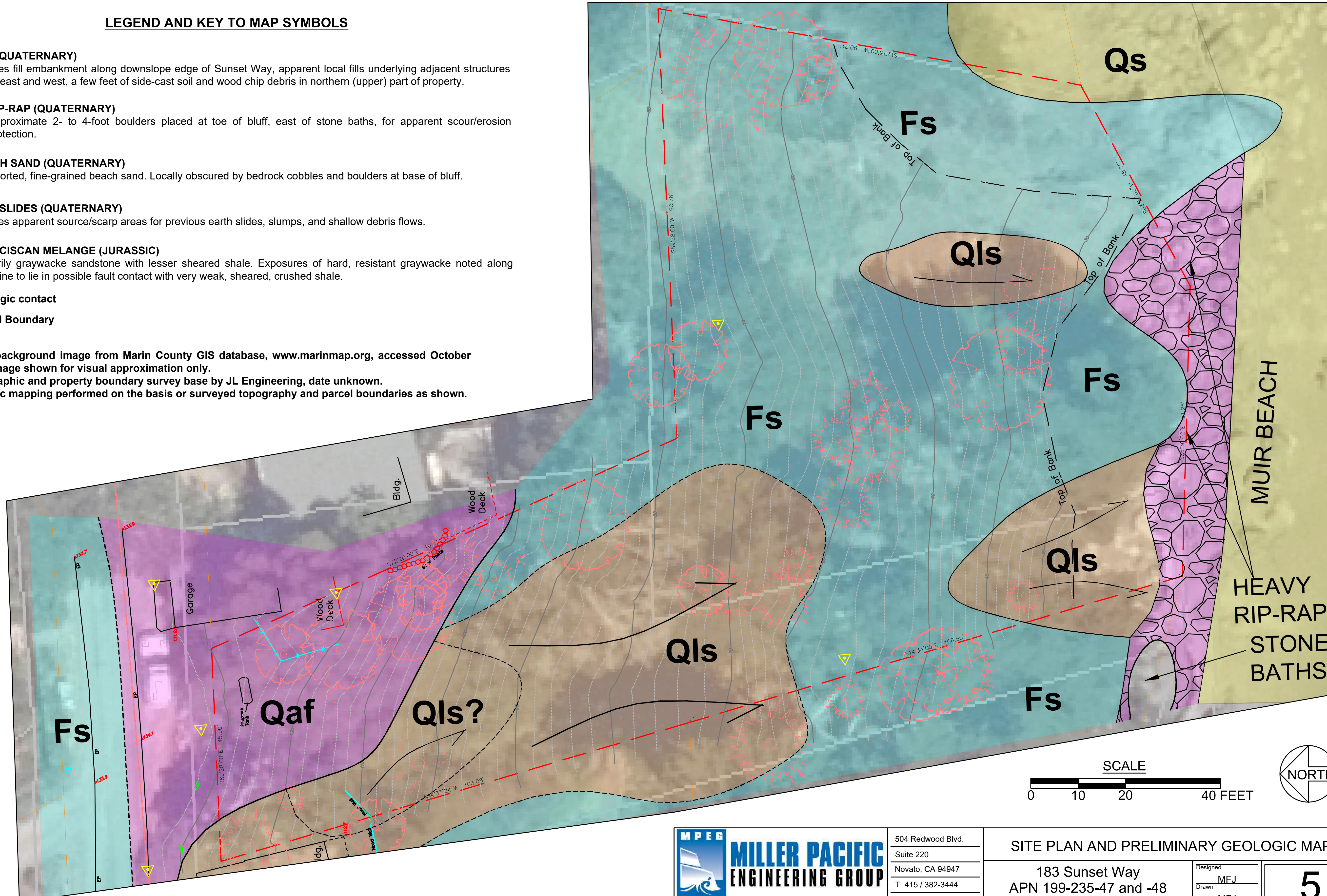
Qls **LANDSLIDES (QUATERNARY)**
Includes apparent source/scarp areas for previous earth slides, slumps, and shallow debris flows.

fs **FRANCISCAN MELANGE (JURASSIC)**
Primarily graywacke sandstone with lesser sheared shale. Exposures of hard, resistant graywacke noted along shoreline to lie in possible fault contact with very weak, sheared, crushed shale.

Geologic contact

Parcel Boundary

NOTES:
1. Aerial background image from Marin County GIS database, www.marinmap.org, accessed October 2019. Image shown for visual approximation only.
2. Topographic and property boundary survey base by JL Engineering, date unknown.
3. Geologic mapping performed on the basis or surveyed topography and parcel boundaries as shown.



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SITE PLAN AND PRELIMINARY GEOLOGIC MAP

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APN 199-235-47 and -48
Muir Beach, California

Project No. 2944.001 Date: 8/3/2016

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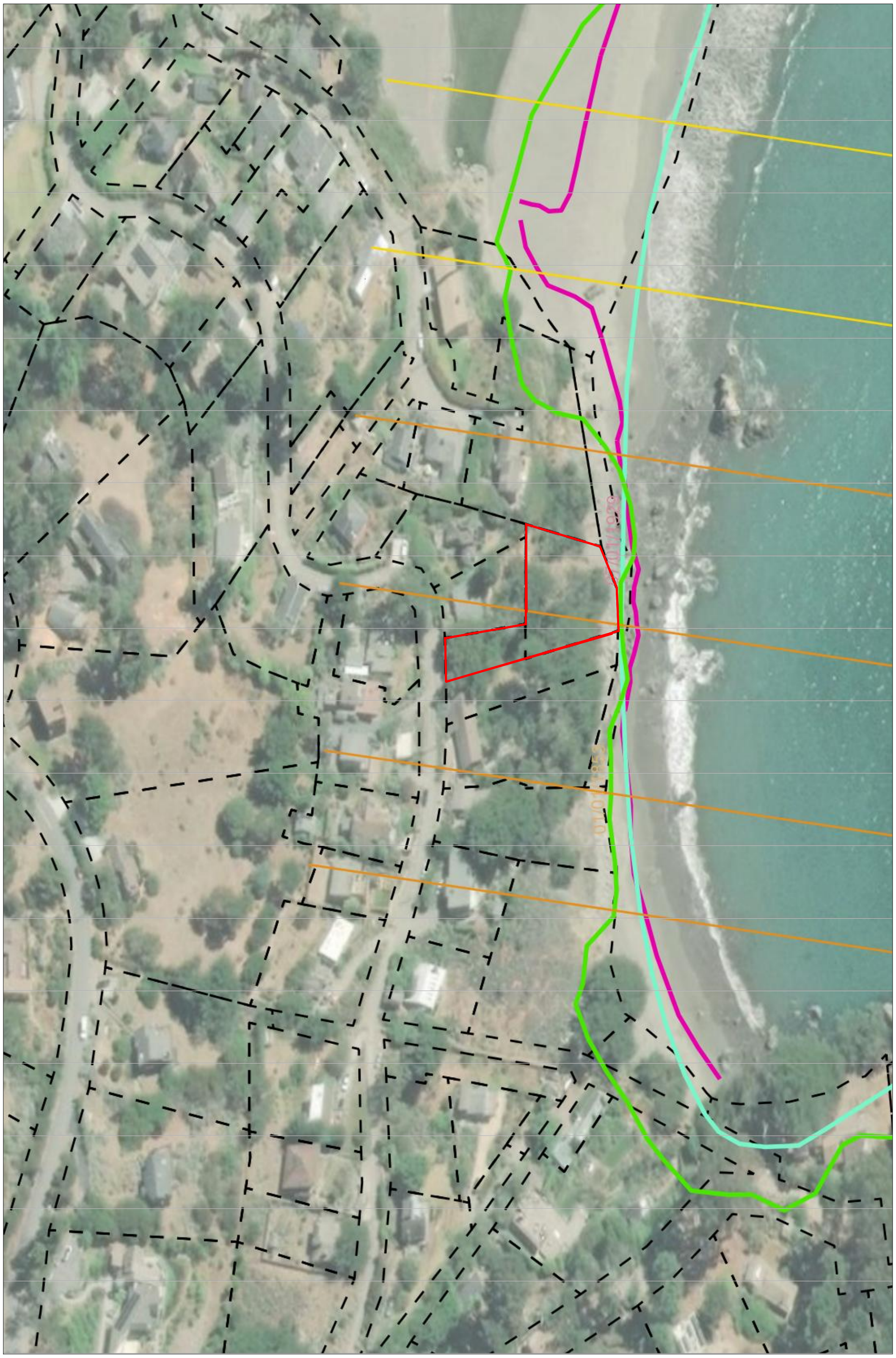
Drawn	MFJ
Checked	ENE

5
FIGURE



PARCEL BOUNDARY
CALIFORNIA COASTLINE, 1853-1910
CALIFORNIA COASTLINE, 1929-1942
CALIFORNIA COASTLINE, 1998-2002
SHORELINE CHANGE MEASUREMENT TRANSECT

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USGS SHORELINE CHANGE RATE

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6
FIGURE

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HISTORIC AERIAL PHOTOGRAPH - 1958

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7
FIGURE

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HISTORIC AERIAL PHOTOGRAPH - 2015

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Project No. 2944.001 Date: 10/30/2019

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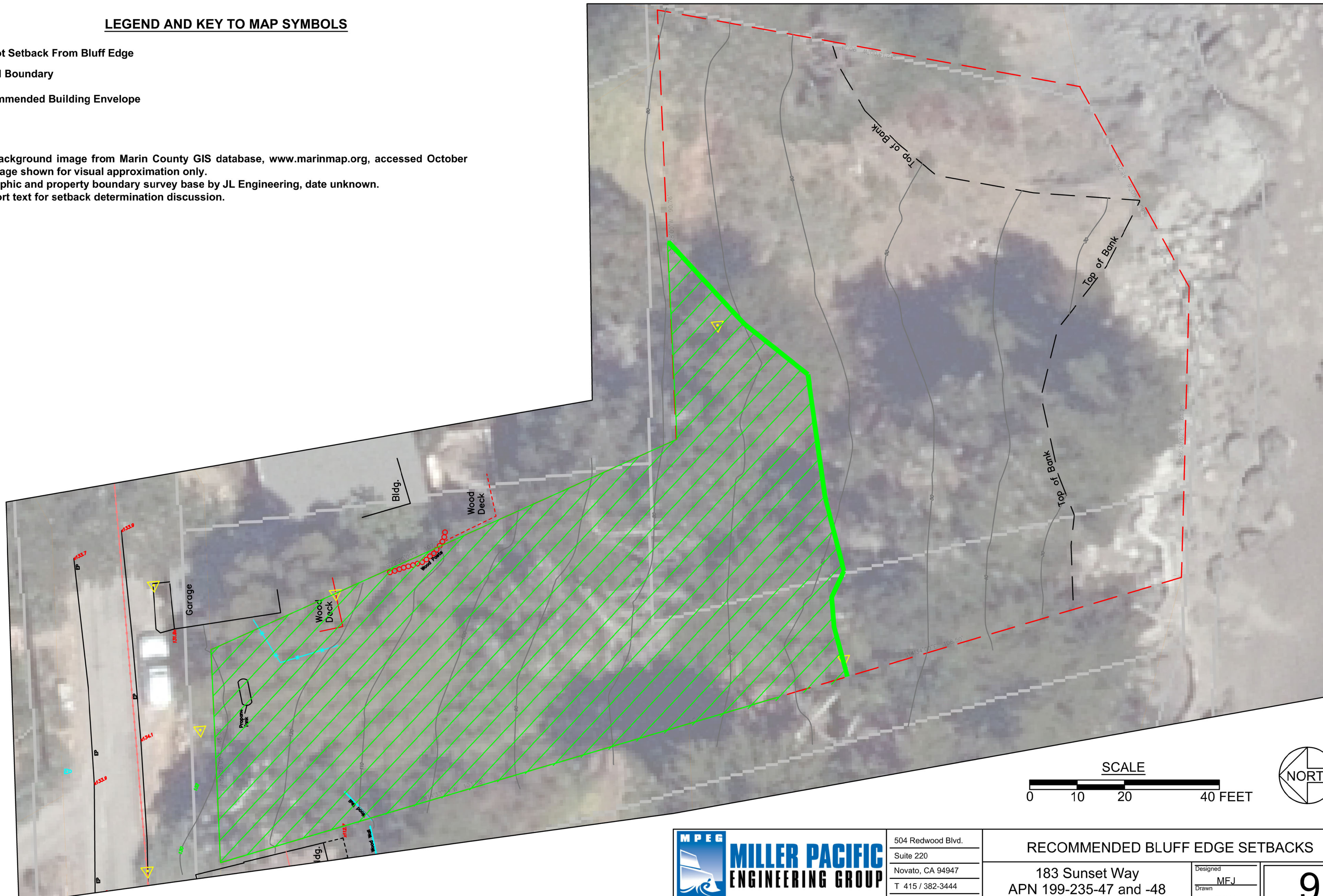
8
FIGURE

LEGEND AND KEY TO MAP SYMBOLS

- 50-foot Setback From Bluff Edge
- Parcel Boundary
- Recommended Building Envelope

NOTES:
1. Aerial background image from Marin County GIS database, www.marinmap.org, accessed October 2019. Image shown for visual approximation only.
2. Topographic and property boundary survey base by JL Engineering, date unknown.
3. See report text for setback determination discussion.



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RECOMMENDED BLUFF EDGE SETBACKS

183 Sunset Way
APN 199-235-47 and -48
Muir Beach, California

Project No. 2944.001 Date: 8/3/2016

Designed MFJ
Drawn MFJ
Checked ENE

9
FIGURE