MILLER PACIFIC ENGINEERING GROUP

November 27, 2023
File: 3555.001ltr.doc

Mr. Matthew Yerington
P.O. Box 161
Bolinas, California 94924

Re: Geotechnical Evaluation Report
20 Oak Road (APN 191-261-21)
Bolinas, California

Introduction & Project Description

This letter summarizes our geologic and geotechnical evaluation of the lot and proposed improvements at 20 Oak Road in Bolinas, California. The approximate site location is illustrated on the attached Site Location Map, Figure 1. The purpose of our geotechnical evaluation is to evaluate relevant geologic hazards which may affect the proposed development and to determine appropriate setbacks for site-specific bluff retreat rates at the site and mitigation measures.

The scope of our geotechnical services is outlined in our Agreement for Professional Engineering Services dated September 28, 2023. Our scope included review of geologic reference materials and results of our nearby subsurface explorations to describe the geologic setting and local geologic conditions, evaluation of relevant geologic hazards and mitigation measures, and determination of appropriate setbacks for site-specific bluff retreat rates at the site.

The project generally includes assembling two Amish shed structures within the northeastern half of the site. The sheds occupy a footprint of 120 sq. feet each and they are both 15-feet in height. The sheds are each supported by six concrete pier blocks and will be used for storage and goat habitation. We understand that no new human-occupied structures are planned as part of the project. Locations of proposed shed structures and other features are shown on the Site Plan, Figure 2.

Regional Geology & Seismicity

Regional geologic mapping[1] indicates the site is located at the edge of a costal bluff and underlain by Miocene-aged Santa Cruz mudstone bedrock. Quaternary-aged landslide deposits are mapped along the bluff to the east of the project site. Quaternary-aged marine terrace deposits are mapped along the bluff edge to the northwest of the project site. Santa Cruz Mudstone bedrock typically consists of thin- to thick-bedded and faintly laminated olive-gray to pale-yellowish-brown siliceous mudstone. Marine terrace soils consist of weakly consolidated, variably sorted sand, silt, and gravel deposited on stream- and wave-cut surfaces. A regional geologic map is shown on Figure 3.

1 Clark, J.C., and Brabb, E.E., "Geology of the Point Reyes National Seashore and Vicinity", USGS, OFR 97-456, 1997. Scale 1:48,000.

Seismicity

The site is located within the seismically active San Francisco Bay Region and will therefore experience the effects of future earthquakes. Such earthquakes could occur on any of several active faults within the region. The California Division of Mines and Geology (1998) has mapped various active and inactive faults in the region. Active faults are defined as those that show evidence of movement in the past 11,000 years (i.e., Holocene) and have reported average slip rates greater than 0.1 mm per year. These faults are shown in relation to the project on the attached Active Fault Map, Figure 4, and their historic seismic activity is shown on Figure 5.

Site Conditions

The project site consists of an approximately 0.42-acre parcel located along the coastal bluff at Duxbury Point in southwestern Bolinas. The bluff itself approaches 130-feet high and is inclined about 1.5:1 (horizontal:vertical). The bluff edge crosses through the project site about 40-feet from the southwest side while the ground surface across the remainder of the lot slopes gently to the southeast. The lot is currently vacant with only two, un-finished Amish shed structures sited within the northeastern half of the lot. The project site is vegetated with short native grasses and mature trees. The driveway off Oak Road is no longer accessible due to bluff retreat, and access to the site is now provided by Nymph Road.

Anticipated Subsurface Conditions

Based on geologic mapping and our experience in this area of Bolinas, we anticipate the subsurface conditions will include silty/clayey sand terrace deposits overlying weathered bedrock. Weathered bedrock is anticipated at depths between 10- and 20-feet below the ground surface. Groundwater conditions in the general vicinity are anticipated to be within the upper 10-feet or near the soil-rock interface.

Geologic Hazards Evaluation

The principal geologic hazards which could potentially affect the project site are strong seismic shaking, lurching and ground cracking, erosion, and landsliding/bluff retreat. Other commonly considered geologic hazards, including liquefaction, expansive soils, settlement, flooding, and others are not considered significant regarding the proposed project. Potentially significant geologic hazards, their anticipated impacts, and recommendations are discussed below.

Fault Surface Rupture

Under the Alquist-Priolo Earthquake Fault Zoning Act, the California Geological Survey (CDMG)/California Geologic Survey (CGS) (1974, 2000) produced 1:24,000 scale maps showing all known active faults and defining zones within, which special fault studies are required. Based on currently available published geologic information, the project site is not located within an Alquist-Priolo Earthquake Fault Zone (CGS, 2018). The San Andreas Fault is the nearest known active fault, located about 1.6 kilometers northeast. Based on currently available published geologic information, the project site is not located within an Alquist-Priolo Earthquake Fault Zone (CDMG, 1974). Therefore, the potential for fault surface rupture is low.

Evaluation: *No significant impact.*
Recommendations: *No recommendations are required.*

Seismic Shaking

The site will likely experience seismic ground shaking from future earthquakes in the San Francisco Bay Area. Earthquakes along several active faults in the region, as shown on Figure 4, could cause moderate to strong ground shaking at the site. A map of historic earthquake activity is presented on Figure 5. 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. For residential developments, deterministic methods are typically used.

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. Empirical relations (Campbell and Borzognia, Chiou and Youngs, (2008)) for the weathered bedrock conditions were utilized to provide approximate estimates of median peak site accelerations. A summary of the principal active faults affecting the site, their closest distance, moment magnitude of characteristic earthquake peak ground accelerations (PGA), which an earthquake on the fault could generate at the site are shown in Table A.

TABLE A
DETERMINISTIC PEAK GROUND ACCELERATION
20 Oak Road
Bolinas, California

Fault Rupture Scenario	Approx. Fault Distance[1]	Max. Moment Magnitude[2]	Median PGA[3,4]	84th Percentile PGA[3,4]
San Andreas Fault: SAO+SAN+SAP+SAS	1.6 km	8.0	0.57 g	1.01 g
San Gregorio	1.7 km	7.4	0.54 g	0.97 g
Hayward Fault: RCHN+HS+HE	31.3 km	7.6	0.16 g	0.28 g

Notes:
1. Values estimated using Google Earth KML Files showing Quaternary Faults in the US obtained from USGS website, accessed 2023.
2. Values determined using USGS Earthquake Scenario Map (BSSC 2014), accessed 2023.
3. Values determined using Vs30 = 560 m/s for Site Class “C” in accordance with the 2022 CBC and 2016 ASCE-7.
4. Abrahamson, Silva and Kamai (2014); Boore, Stewart, Seyhan and Atkinson (2014); Campbell and Borzognia (2014); and Chiou and Youngs (2014).

The calculated accelerations should only be considered as reasonable estimates. Many factors (soil conditions, orientation to the fault, etc.) can influence the actual ground surface accelerations. Ground shaking can result in structural failure and collapse of structures or cause non-structural building elements, such as light fixtures, shelves, cornices, etc., to fall, presenting a hazard to building occupants and contents. Compliance with provisions of the California Building Code (CBC) should result in structures that do not collapse in an earthquake. Damage may still occur, and hazards associated with falling objects or non-structural building elements will remain.

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

Evaluation: *Less than significant with incorporated recommendations.*
Recommendations: *Minimum recommendations include designing new habitable structures and foundations in accordance with the most recent version of the California Building Code (2022). It is anticipated that the new shed structures will be used as non-habitable space.*

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 project site is gently sloping within the eastern half and steeply sloping along the southwest boundary, where the bluff edge crosses the site. We anticipate 10- to 20-feet of sandy terrace deposits over weathered bedrock. Given the steeply-inclined bluff face and relative weakness of the terrace deposits, we judge the risk of damage due to lurching and ground cracking is high.

Evaluation: *Less than significant with incorporated recommendations.*
Recommendations: *If warranted, supplemental analyses could be performed to evaluate slope stability and the potential for lurching and ground cracking under seismic conditions. However, it is anticipated that such analysis may not be warranted given the on-going bluff retreat, ultimate intended land use and nature of the project. In general, increased setback from the edge of the bluff will result in a lessened risk of damage from lurching and ground cracking.*

Erosion

Sandy soils on moderate slopes or clayey soils on steep slopes are susceptible to erosion when exposed to concentrated water runoff. The potential for erosion is increased when established vegetation is disturbed or removed during normal construction activity.

The project site is gently sloping within the eastern half and steeply sloping along the southwest boundary, where the bluff edge crosses the site. We anticipate predominately sandy soils located at the ground surface. In addition, wave action at the base of bluff / beach level is actively eroding the toe of the bluff. Therefore, widespread erosion is considered a moderate risk at the site.

Evaluation: *Less than significant with incorporated recommendations.*
Recommendations: *It is anticipated that no new grading will take place given the ultimate intended land use and nature of the project. If site grading is performed, design of finished grades and site drainage systems (if any) should carefully consider the potential for erosion. An erosion control plan should be developed prior to any new construction per the current guidelines of the Marin County Stormwater Pollution Prevention Program or similar standards.*

Slope Instability/Bluff Retreat

Slope instability generally occurs on relatively steep slopes and/or on slopes underlain by weak materials. 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.

We have reviewed a variety of bluff retreat studies, historic shoreline data, and aerial photographs in order to determine site-specific retreat rates. Materials we reviewed include the following:

USGS OPEN-FILE REPORT 2007-1133 (2007) – Part 4 of the USGS National Assessment of Shoreline Change Project[1] addresses long-term cliff retreat rates along the California Coast. Cliff retreat rates were interpreted based on the spatial difference between historic cliff edge 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.

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).

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 . . . 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.”

1 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.

We reviewed composite vector shorelines[2,3] for the site 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 1935 (generated from historic maps and other paper sources) and between 1988 and 2002 (surveyed by LiDAR in conjunction with NASA). At the project site, we measured between 114-feet and 175-feet of bluff retreat over the (maximum) 73-year period, for an average of approximately 147.8-feet (about 45-meters). Per year, this equates to an average annual retreat rate of approximately 2.0-feet per year.

We also reviewed historic aerial photography from the California Coastal Records Project and Google Earth. Oblique-angle color photographs spanned the time period between 1972 and 2022. As shown on Figures 6, significant mass-wasting and bluff retreat has occurred, primarily within the southwest region of the site. More recent site specific rates calculated from bluff edge positions between 2009 and 2022 generally agree with the historic average rate of 2.0-feet per year.

Based on an average annual retreat rate of 2.0-feet (0.6 meters) per year and a reasonable structure-life of 40 years, we estimate that a total of about 80-feet (24.4 meters) of bluff retreat should be anticipated. As shown in Figure 7, the southwestern half of the project site will likely be impacted by bluff retreat in the next 40 years. Slope instability/bluff retreat is considered a significant geologic hazard at the project site, especially in the southwest region of the property.

Evaluation: *Less than significant with incorporated recommendations.*
Recommendations: *Recommendations include providing new structures with an 80-foot (24.4 meter) setback for a structure-life of 40 years to reduce the risk of damage or undermining by bluff retreat.*

<u>Discussion and Recommendations</u>

Based on the results of our evaluation, it is our professional opinion that the proposed shed structures are feasible from a geotechnical perspective. As discussed above, the primary geotechnical considerations for the project will include providing appropriate setbacks from the bluff edge to reduce risk of damage to the shed structures by slope instability/bluff retreat, lurching and ground cracking, and erosion.

For a structure-life of 40 years and an average bluff retreat rate of 2.0-feet/year, we recommend providing the sheds with an 80-foot setback from the bluff edge. If a longer structure-life is desired, the setback will need to be increased using the rate of 2.0-feet/year mentioned above.

If bluff retreat reaches the structures and if they are still in service and good shape, the structure(s) could be relocated further back on the property.

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2 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.
3 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.

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Supplemental Services

We can be available if needed to further discuss the results of our evaluation or respond to any geologic or geotechnical questions that arise during project planning. If desired, we can perform additional subsurface exploration, laboratory, and/or engineering analyses in the event engineered structures are planned at the project site.

Very truly yours,
MILLER PACIFIC ENGINEERING GROUP

REVIEWED BY:

REGISTERED PROFESSIONAL ENGINEER
SCOTT A. STEPHENS
GE 2398
EXP. 06/30/25
GEOTECHNICAL
STATE OF CALIFORNIA

Emily Carreno
Staff Geologist

Scott Stephens
Geotechnical Engineer No. 2398
(Expires 6/30/25)

Attachments: Figures 1 through 7

SITE COORDINATES
LAT. 37.89506°
LON. -122.70245°

SITE LOCATION

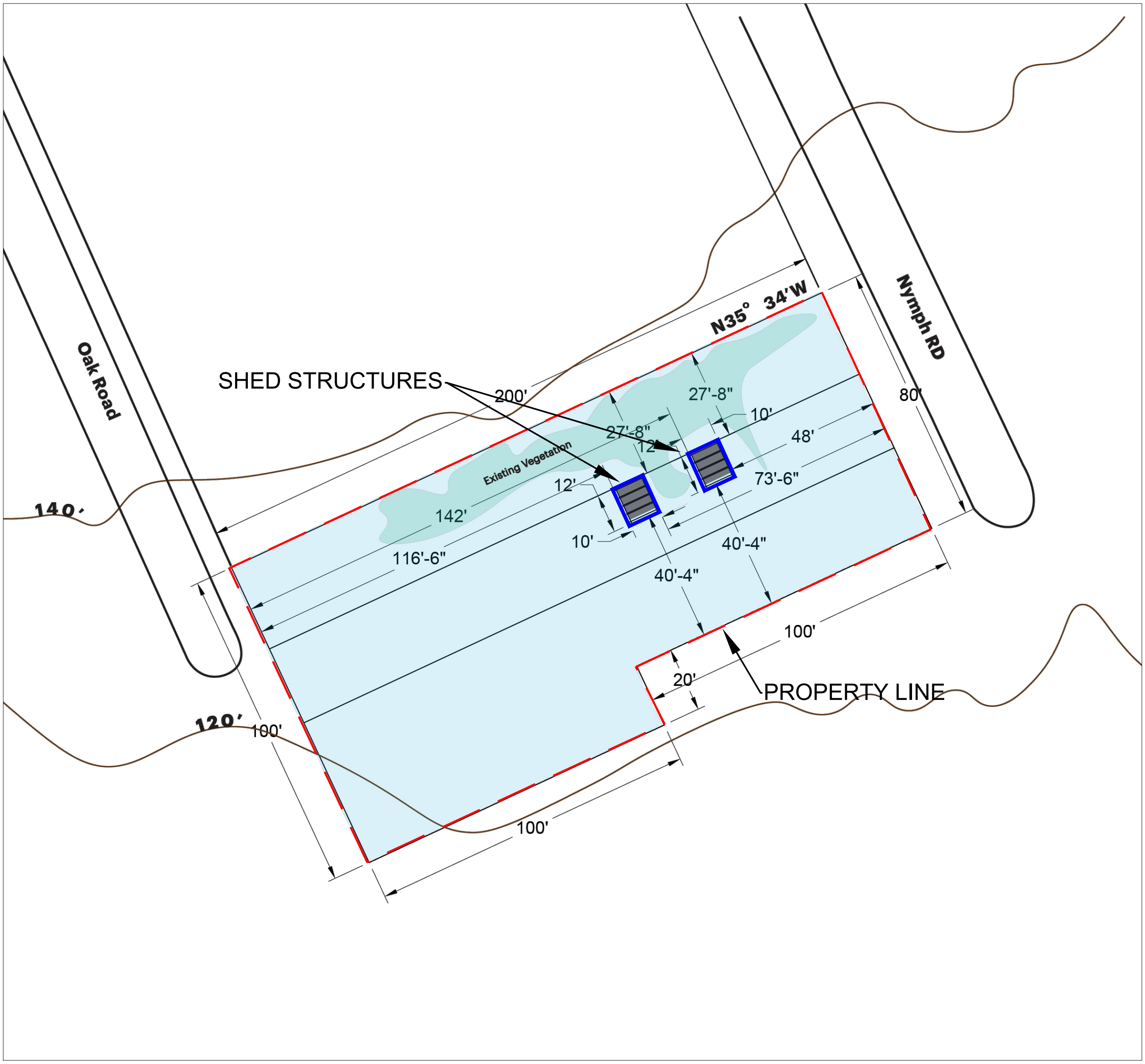
N.T.S.

NORTH

REFERENCE: Google Earth, 2023

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		
		20 Oak Road Evaluation Bolinas, California Project No. 3555.001 Date: 10/11/2023	Drawn EIC Checked	1 FIGURE

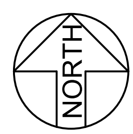
FILENAME: 3555.001 Figures.dwg



SITE PLAN

SCALE

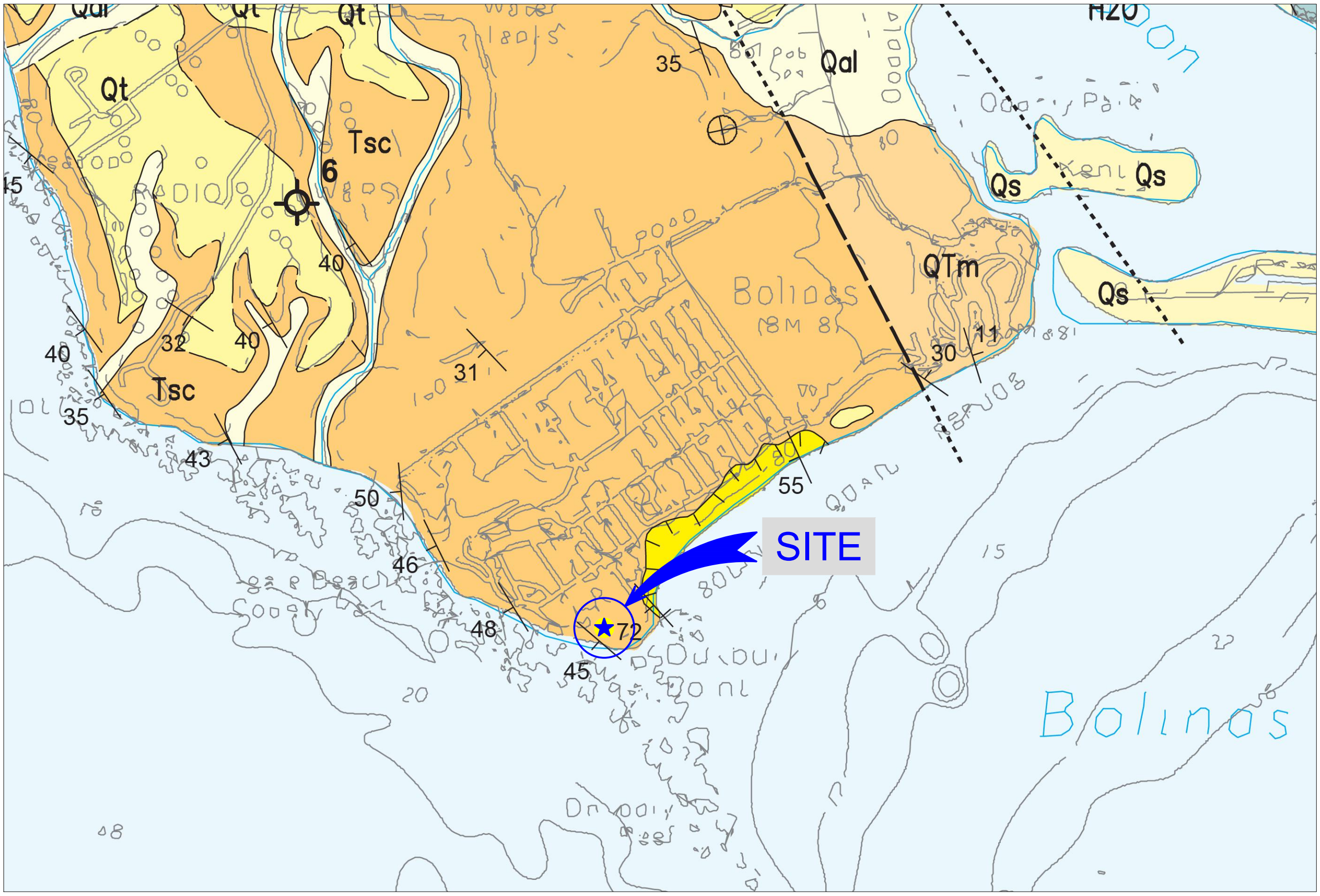
0 25 50 100 FEET



REFERENCE: Isaac Yerington, '20 Oak Road, Bolinas, CA, 94924, APN: 191-261-21', Site Plan, Sheet 1/1, Plan dated August 1, 2023.

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 PLAN 20 Oak Road Evaluation Bolinas, California Project No. 3555.001 Date: 10/11/2023	Drawn EIC Checked	2 FIGURE

FILENAME: 3555.001 Figures.dwg



REGIONAL GEOLOGIC MAP

NORTH

Qs	**Beach sands** [Holocene] - Discontinuous accumulations of well- to moderately-sorted, fine- to coarse-grained loose sand locally are interspersed with pebble to boulder gravel.
Qal	**Alluvium** [Holocene] - Poorly consolidated, poorly sorted clay, silt, sand, and gravel usually fill stream and valley floors.
Qls	**Landslide deposits** [Pleistocene and Holocene] - Only large slides in the vicinity of Double Point and at Bolinas are shown, where they consist mainly of intact to highly disrupted masses of Santa Cruz Mudstone.
Qt	**Terrace deposits** [Pleistocene] - Discontinuous deposits of weakly consolidated and variably sorted sand, silt, and gravel deposited on stream- and wave-cut surfaces.
QTm	**Merced Formation** [upper Pliocene to Pleistocene] - Weakly consolidated, thick-bedded, sandy siltstone with cross-bedded, fine-grained silty sandstone and interbedded conglomerate.
Tsc	**Santa Cruz Mudstone** [upper Miocene] - Thin- to thick-bedded and faintly laminated olive-gray to pale-yellowish-brown siliceous mudstone contains thin elongate carbonate concretions.

REFERENCE: Clark, J.C. and Brabb, E.E., (1997) 'Geology of the Point Reyes National Seashore and Vicinity', United States Geological Survey, Open-File Report 97-456, Scale 1:48,000.

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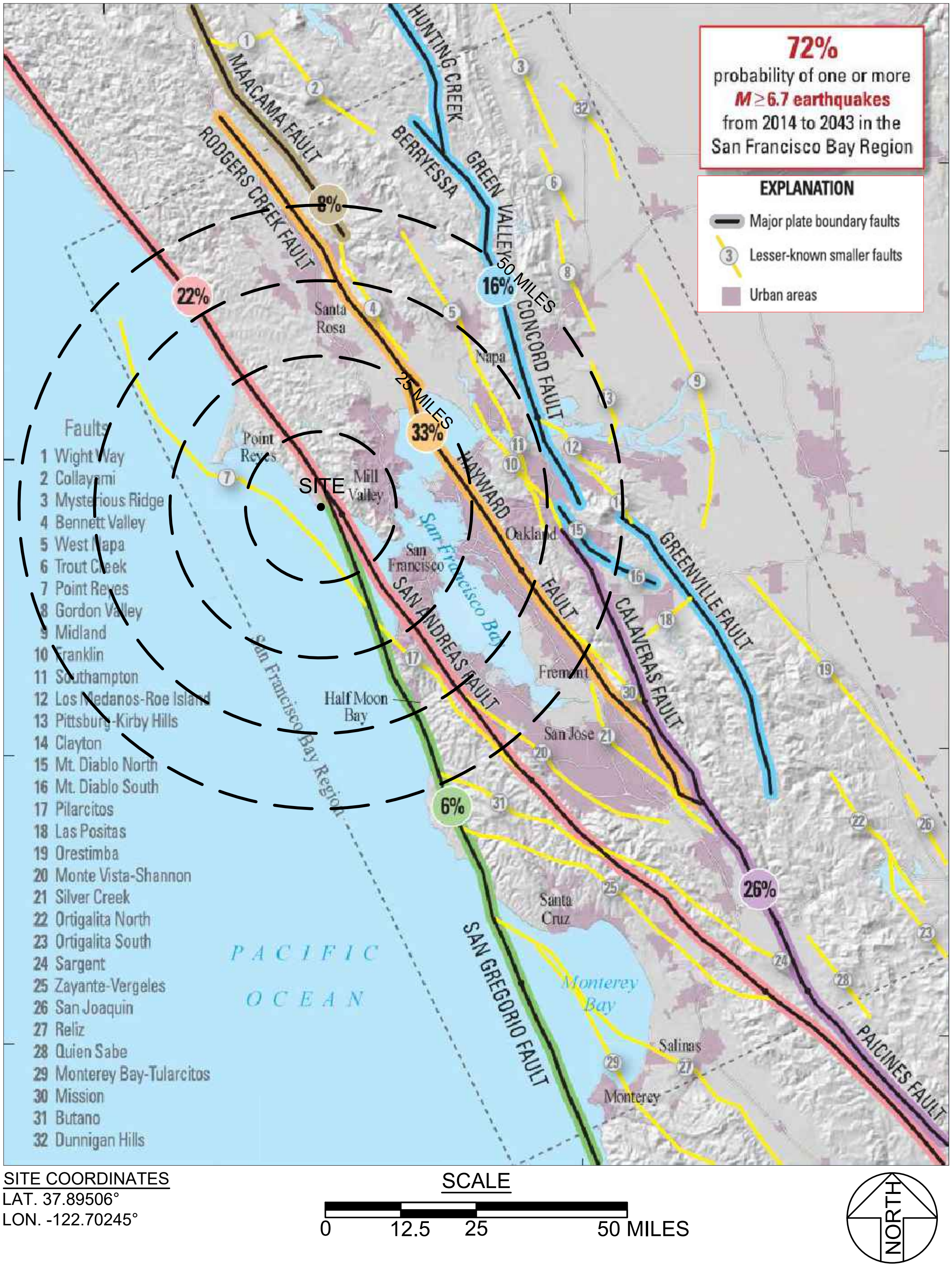
REGIONAL GEOLOGIC MAP

20 Oak Road Evaluation
Bolinas, California

Project No. 3555.001 Date: 10/11/2023

Drawn EIC
Checked

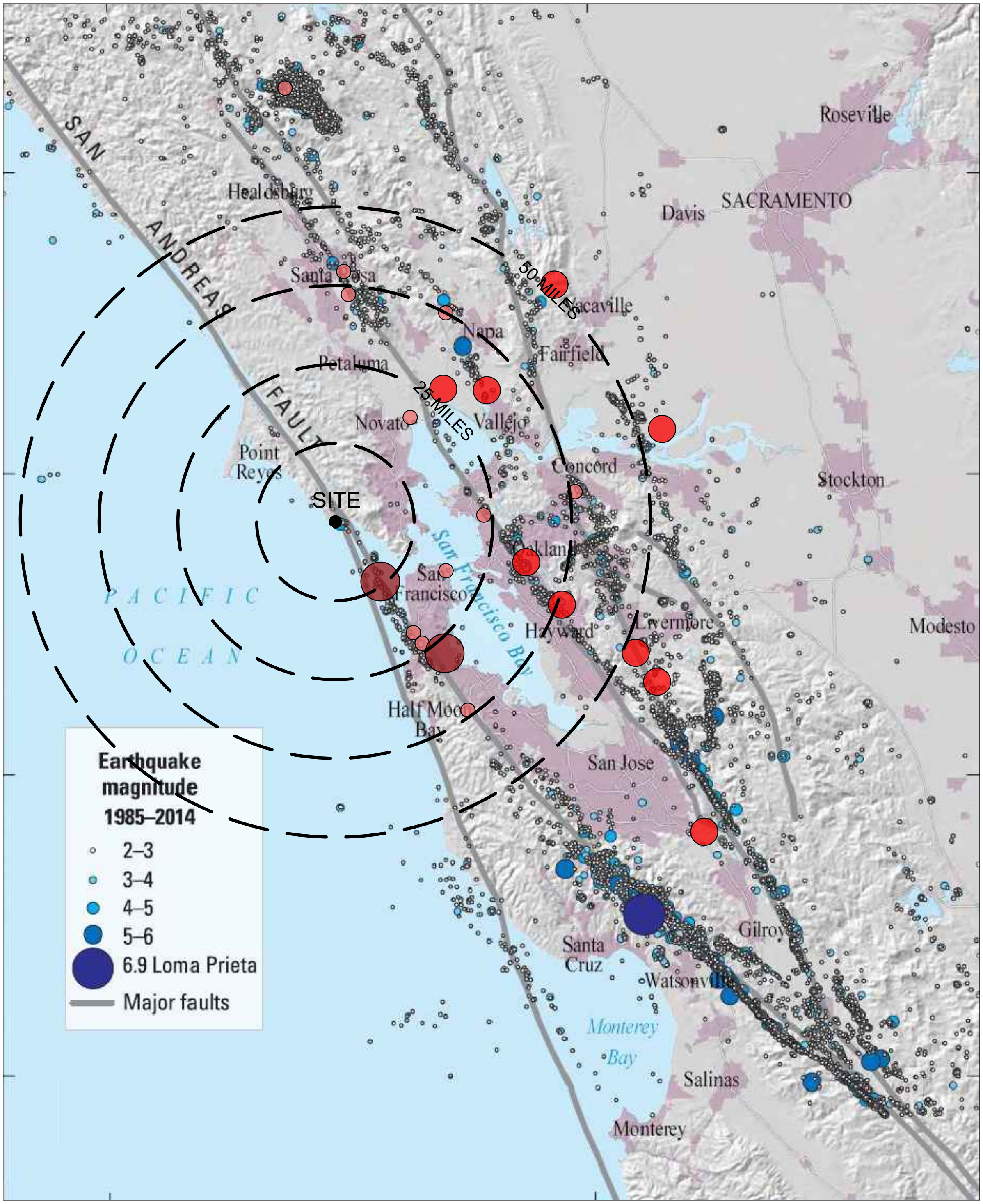
FIGURE 3



DATA SOURCE:
1) U.S. Geological Survey, U.S. Department of the Interior, "Earthquake Outlook for the San Francisco Bay Region 2014-2043", Map of Known Active Faults in the San Francisco Bay Region, Fact Sheet 2016-3020, Revised August 2016 (ver. 1.1).

MPEG MILLER PACIFIC ENGINEERING GROUP	504 Redwood Blvd. Suite 220 Novato, CA 94947 T 415 / 382-3444 F 415 / 382-3450 www.millerpac.com	ACTIVE FAULT MAP		
		20 Oak Road Evaluation Bolinas, California	Drawn EIC Checked	4 FIGURE
		Project No. 3555.001 Date: 10/11/2023		

FILENAME: 3555.001 Figures.dwg



SITE COORDINATES
LAT. 37.89506°
LON. -122.70245°

SCALE

0 12.5 25 50 MILES

NORTH

LEGEND & DATA SOURCE:

See legend above. U.S. Geological Survey, U.S. Department of the Interior, "Earthquake Outlook for the San Francisco Bay Region 2014-2043", Map of Known Active Faults in the San Francisco Bay Region, Fact Sheet 2016-3020, Revised August 2016 (ver. 1.1).

Large circles indicate earthquakes M>7.0, medium circles indicate 6.0<M<7.0 and small circles indicate 5.0<M<6.0 .U.S. Geological Survey, Earthquake Catalog Search, https://earthquake.usgs.gov/earthquakes/search/. Earthquakes between 1830 and 2021.

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HISTORIC EARTHQUAKE MAP

20 Oak Road Evaluation
Bolinas, California

Project No. 3555.001 Date: 10/11/2023

Drawn EIC
Checked

5
FIGURE

REFERENCE: 1972 & 2005 Aerial Imagery: Copyright 2002-2018, Kenneth and Gabrielle Adelman, California Coastal Records Project, https://www.californiacoastline.org/

2009 & 2022 Aerial Imagery: Google Earth

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AERIAL IMAGERY 1972-2022

20 Oak Road Evaluation
Bolinas, California

Project No. 3555.001

Date: 10/12/2023

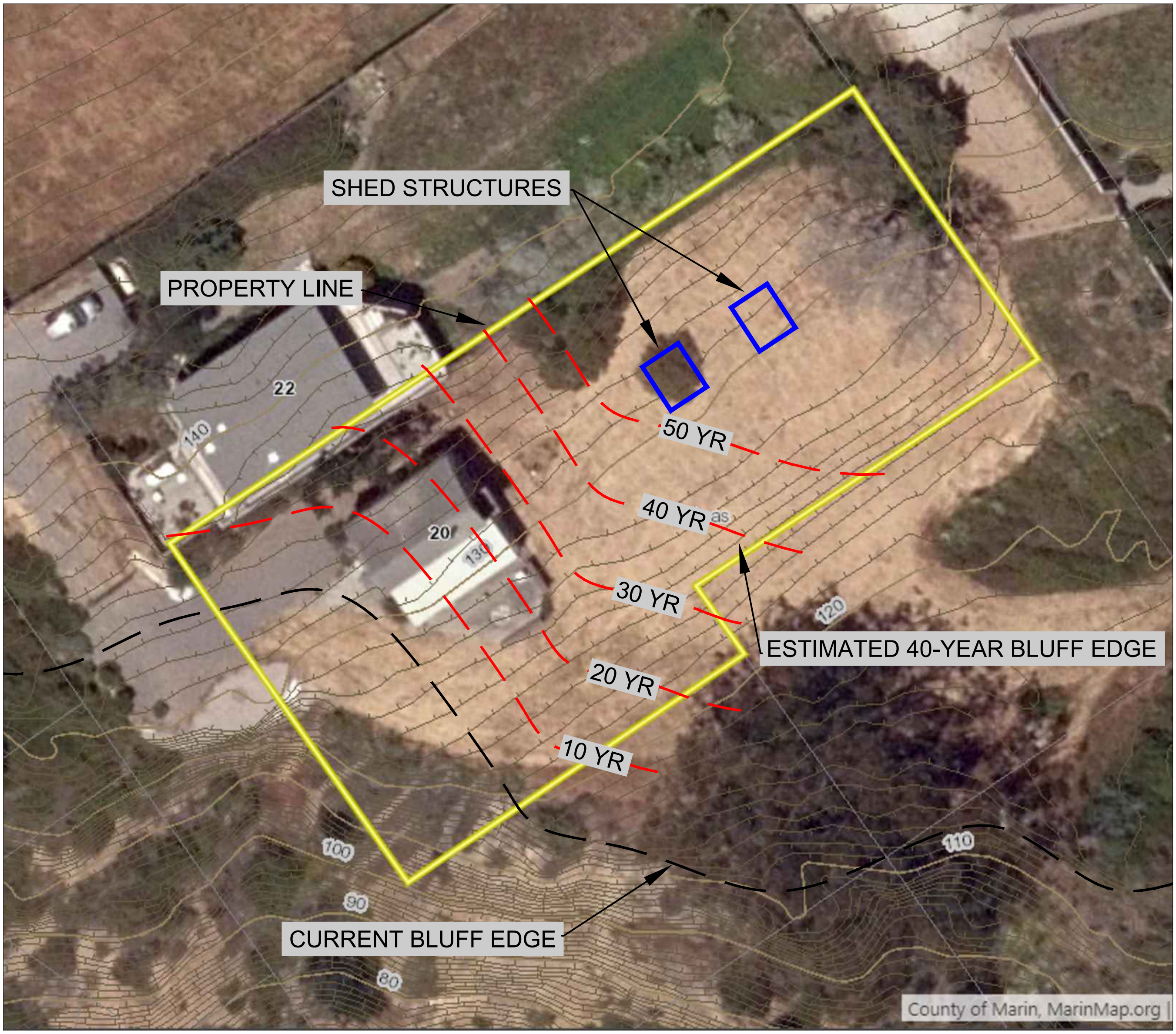
Designed

Drawn EIC

Checked

6

FIGURE



SCALE

0 20 40 80 FEET

NORTH

10 YR ESTIMATED BLUFF EDGE, YEARS FROM CURRENT

REFERENCE: MarinMap 2019 LiDAR Topography, 2018 Ortho Imagery

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SITE-SPECIFIC BLUFF RETREAT

20 Oak Road Evaluation
Bolinas, California

Project No. 3555.001 Date: 10/27/2023

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7
FIGURE