Brunsing Associates, Inc.

ENGINEERING GEOLOGIC RECONNAISSANCE

Sea Cave Exploration, Mapping and Evaluation

POINT ARENA LIGHTHOUSE
45500 LIGHTHOUSE ROAD
POINT ARENA, MENDOCINO COUNTY, CALIFORNIA

Coastal Conservancy

California Coastal Conservancy

Project No. 11995.02

October 19, 2023

Engineers and Geologists

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prepared for:

MARK HANCOCK, EXECUTIVE DIRECTOR

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1.0 INTRODUCTION

This report presents the results of the Engineering Geologic Reconnaissance performed by Brunsing Associates, Inc. (BAI), for the Point Arena Lighthouse property, 45500 Lighthouse Road, in Mendocino County, California. The Point Arena peninsula, shown on the Vicinity Map, Plate 1, is approximately four miles northwest of the City of Point Arena.

The purpose of our reconnaissance was to explore, map and evaluate the ocean bluffs and sea caves on the Point Arena peninsula, in the areas of existing improvements. Concerns were expressed by the Lighthouse Keepers, Inc. about the extent of the caves visible on Oblique Aerial Photographs, Southwest and Northeast, Plates 2 and 3, respectively: Did the caves go under the lighthouse or other structures at the site? Are the caves significantly eroding? These questions were to be answered by our exploration and mapping. Our approach to providing guidelines for the project utilized our knowledge of the geologic conditions in the site vicinity, and experience with similar projects on the Mendocino coast.

As outlined in our Professional Services Agreement, dated October 17, 2022, our scope of services included research of published geologic maps, study of aerial photographs of the site, geologic reconnaissance, topographic survey by our survey subconsultant, Mendocino Surveyors, Inc. (MSI) and geologic analyses in order to provide conclusions and recommendations regarding:

- Geologic conditions of the site, including a discussion of potential geologic hazards.
- Historic, current, and anticipated bluff retreat rate.
- Potential effects of projected Sea Level Rise.
- Sea cave stability.
- Longevity of the existing buildings and infrastructure.

2.0 INVESTIGATION

2.1 Research

As part of our reconnaissance, we reviewed published geotechnical literature, including geologic, fault, and seismic hazard maps for the site and vicinity. We also reviewed previous geotechnical/geological reports prepared by BAI on nearby properties. Published references reviewed for this reconnaissance include:

- Geology and Geomorphic Features Related to Landsliding, Point Arena 7.5 Minute Quadrangle, Mendocino County, California, Open File Report (OFR) 84-46, SF, 1984, California Division of Mines and Geology (CDMG).
- Maps of Active Fault Near-Source Zones in California and Adjacent Parts of Nevada: International Conference of Building Officials, 1998, CDMG with the Structural Engineers Association of California Seismology Committee.
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- Johnsson, M. J., 2003, Establishing Development Setback from Coastal Bluffs: Proceedings, California and the World Ocean '02.
- Philip Williams & Associates, Ltd., 2009, "California Coastal Erosion Response to Sea Level Rise Analysis and Mapping", prepared for the Pacific Institute.
- Update to the Sea-level Rise Guidance Document, 2013, Coastal and Ocean Working Group of the California Climate Action Team.
- Sea-Level Rise for the Coasts of California, Oregon and Washington: Past, Present, and Future, 2012, National Research Council.
- Ted W. Trinkwalder and Ward L. Stover, The March 2011 Tsunami and its Impact on Crescent City Harbor, November/December 2011, Geo Strata.

2.2 Aerial Photograph Studies

Our reconnaissance was augmented by studying black and white (b&w), vertical aerial photograph prints of the site dated 1963, 1981 and 2000. We also studied color, vertical aerial photographs of the site from Google Earth satellite imagery dated 2019, 2018, 2010, 2009, 2006, 2005, 2003, and 1998 (b&w). Color, vertical aerial photographs dated 1986 and 1993 were obtained from the California Coastal Records Project (www.californiacoastline.org).

In addition to reviewing vertical aerial photographs, we also reviewed oblique-angle aerial photographs from the California Coastal Records Project. We qualitatively compared oblique aerial photographs of the site from 1972, 1979, 1987, 2002, 2005, 2009, 2013, and 2019. The 2019 oblique aerial photographs of the south and north sides of the Point Arena peninsula are presented on Plates 2 and 3, respectively.

2.3 Historic Maps

BAI has reviewed the historic topographic maps of the Point Arena peninsula dated 1870, 1871, 1873, 1895, 1907, 1908, 1944, 1960, and 1968. The older maps accurately show the lighthouse and associated structures, but the bluff edges appear to have been hand-drawn with just visual accuracy. Only the 1895 map shows the surveyed bluff edges near the old lighthouse relatively accurately.

2.4 Field Exploration and Mapping

BAI performed the field exploration and mapping during low (sometimes minus) tide periods during August and September 2023. BAI's engineering geologist, Joshua Kilgore, and MSI's surveyor-in-training Garrett Lumley, accessed the sea caves by rappelling down the bluffs.

Kilgore and Lumley explored and mapped the sea caves as a team. Field supervision was provided by BAI's project manager, engineering geologist Erik Olsborg and MSI's licensed land surveyor, Forrest Francis. Sea caves on the northeast side of the peninsula were accessed/observed by Kilgore and Lumley using ocean kayaks. Photographs of the field exploration and mapping operations are shown on Plate(s) 4.

3.0 SITE CONDITIONS

The Point Arena Lighthouse is located on a near-level, elevated marine terrace at the Point Arena Peninsula, as shown on the Vicinity Map, Plate 1 and on oblique aerial Photographs A and B, Plates 2 and 3. The terrace was formed during the Pleistocene Epoch, when periods of glaciation caused sea-level fluctuations, which created a series of steps or terraces cut into the coastal bedrock by wave erosion. The terraces began to emerge from the ocean approximately eighteen thousand years ago. Present sea levels were achieved about eight thousand years ago. The terrace slopes toward the ocean bluffs at a very gentle to near-level gradients.

The lighthouse is at approximate elevation 65 feet above Mean Sea Level (MSL). The ocean bluffs surrounding the peninsula are approximately 60 feet in vertical height. The bluffs on the southwest side of the peninsula are very steep, approximately 0.5 horizontal to one vertical (0.5H:1V) to vertical. The bluffs on the northeast side of the peninsula are also very steep to near vertical. There are two small coves on the northeast side of the peninsula. One cove is north of the lighthouse residences, the other is further to the northeast. The bluffs above the northeast cove are moderately steep, approximately 2 to 3H:1V. A small sandy beach is located at the back of the northeast cove.

The developed area of the peninsula consists of the lighthouse structure, a bathroom building, a gift shop/museum building and two residential buildings. The facility is served by a paved road and parking area, trails, fences, water tanks and underground utilities.

The peninsula in the developed areas is penetrated by 23 sea caves of measurable dimensions. Some of the caves are shown on the Sea Cave Photographs on Plate(s) 5. The sea cave outlines are shown on Plate 6. The caves are as much as 70 feet in length (depth) and are typically about 15 feet wide by 15 feet in height (floor to cave roof). Cave Number 2, the closest to the lighthouse (40 feet), is shown in cross section and profile on Plate 7.

No surface water was observed during our site explorations in August and September 2023. Ground water seepage was observed emanating from lower areas on the bluff and from the roofs of some of the sea caves.

Site vegetation on the terrace consists of a moderate cover of grasses and weeds. The upper bluff faces are partially vegetated with a cover of weeds and ice plant; the lower bluffs are mostly bare rock.

4.0 GEOLOGY

4.1 Regional Geologic and Seismic Setting

This part of the Mendocino County coastal area, west of the San Andreas Fault, is considered the Gualala Block, a mixture of Miocene to Cretaceous sedimentary and igneous bedrock formations that originated northwest of Monterey Bay in coastal California, then were transported north-northwest by movement along the San Gregorio-Hosgri and San Andreas Faults. The Gualala Block was once an island during its transport up the coast, before grinding into the North American mainland where it is today.

The seismicity and tectonics of Mendocino County coastal region is controlled by a network of generally northwest-trending strike-slip faults of the San Andreas Fault system. The active San Andreas Fault (north coast segment) is located inland, within the Garcia River canyon, approximately 5.5 miles northeast of the site. The 1906 earthquake on the San Andreas Fault destroyed the earlier lighthouse at the site. Future, large magnitude earthquakes originating on this or other nearby faults are expected to cause strong ground shaking at the site.

4.2 Site Geology

The Point Arena peninsula is comprised of Miocene Epoch sedimentary rocks consisting of sandstone, siltstone, and sandy mudstone of the Point Arena Formation (Site Geologic Map, Plate 6). The Site Geologic Map shows the geologic features at the site, including the outline of the sea caves. The area rocks were previously assigned to the Miocene Monterey Group; however, geologic researchers have determined that the Point Arena Formation rocks were deposited in a separate depositional basin (Loomis & Ingle, 1988). Therefore, the Point Arena Formation is a separate rock group.

The bedrock observed on the lower bluffs consists of gray and brown sandstone that is thinly to thickly bedded, intensely to moderately fractured, low in hardness to hard, and moderately weathered. The bedding orientation of the rocks observed along the lower bluffs consists of a northwest trending strike with a steep dip, approximately 60 degrees from horizontal, to the southwest. The predominant orientation of jointing (a rock fracture that lacks movement) observed on the bluffs consists of a northwest to northeast trend with a 75-to-86-degree plunge to the northeast and southeast.

The Point Arena Formation bedrock is overlain by poorly-consolidated, Pleistocene Epoch terrace deposits. These beach or shallow marine sediments are typically comprised of sands with some silt, gravel, and clay, along with incorporated rock fragments eroded from the underlying bedrock platform. The terrace deposits exposed on the bluff face vary in thickness from approximately 5 to 40 feet thick. The terrace materials were deposited in lenses with undulatory thickness caused by the variable nature of the eroded bedrock platform on which they were deposited.

The upper approximately 2 ½ to 3 ½ feet of the terrace deposits are comprised of brown and dark brown gravelly silty sand and gravelly sandy silt topsoil that is loose and soft. Below these

topsoils, the terrace deposits consist predominantly of brown, orange and gray sands, gravelly sands and gravelly silty sands that are dense to very dense.

A small sandy beach is located below the bluffs northeast of the lighthouse residences. A debris field is located on the bluffs north-northeast of the residences. We understand that most of the debris came from the 1906 destroyed lighthouse.

4.3 Bluff Retreat Rate

Our historic aerial photograph studies, back to 1963 in addition to more recent years, and our qualitative comparison of the vertical and oblique aerial photographs shows only minor changes to the bluff edges at the site. Our site reconnaissance and quantitative review of aerial photographs indicate an average bluff retreat (erosion) rate along the ocean bluffs of approximately 2.5 inches per year.

An erosional feature, the "Punch Bowl" is located at the northwest end of the peninsula. The "Punch Bowl" is shown on an 1880 photograph on Plate 8. The "Punch Bowl" is a collapsed sea cave forming a circular bowl connected to the sea by the cave. Located at the northwest end of the peninsula, the punch bowl site is subject to extreme wave activity from the northwest and southwest. Waves entering the punch bowl from the sea cave build up and swirl around before exiting back through the cave, dragging eroded debris with the waves.

BAI overlayed the 1895 topographic map over our 2023 topographic map at the same scales (Plate 9). We measured bluff retreats that varied from zero to as much as 41 feet. A worst-case, bluff loss of 41 feet over 128 years results in a retreat rate of approximately 3.8 inches per year.

4.4 Sea Level Rise Effects on Bluff Retreat

Rapid sea-level rise of approximately 400 - 450 feet occurred between 18,000 and 8,000 years before present, according to "Rising Seas in California", Griggs, et al, 2017. Sea levels have remained relatively constant since that time. However, sea levels have started rising again. The California Coastal Commission (CCC) recently adopted the Science Update, dated November 7, 2018 to the 2015 Interpretive Guidelines for addressing Seal Level Rise in Local Coastal Programs and Coastal Development permits. The Science Update provides sea-level rise projections for the San Francisco coastal area, as follows in Table 1:

Table 1: Sea Level Rise Projections*				
(Medium-High Risk Aversion)			Documented Rise	Likely Rise
Time Period	Sea Level Rise (Feet)	Inches	Inches	Inches
2000	0	0		
2023**	0.6	7.4	1.8	
2030	0.8	9.6		3.4***
2040	1.3	15.6		4.6****
2050	1.9	22.8		
2060	2.6	31.2		
2070	3.5	42.0		
2080	4.5	54.0		
2090	5.6	67.2		
2098**	6.6	79.7		
2100	6.9	82.8		

*California Coastal Commission, Sea Level Rise Policy Guidance, 2018
**BAI interpolated
***Assumes little or no increase to the rate of sea level rise over the next 9 years
****Assumes little or no increase to the rate of sea level rise over the next 19 years

No deep-seated landslides or areas of severe erosion were observed in the vicinity of the existing structures, and no landslides are shown on the published geologic maps we reviewed. The upper bluff area at the site is identified on the geologic map we reviewed (OFR 84-46) as a debris slide slope, a geomorphic feature typically characterized by steep, partially vegetated slopes that have been sculpted by numerous debris slide events. The vegetated slopes are partially disrupted by shallow, slope creep deposits. The slope creep deposits are relatively shallow masses, up to a few feet in thickness, of soil and broken, weathered rock materials. These deposits support vegetation, but the deposits can also move slowly, periodically, or rapidly downslope, primarily during, or shortly after periods of rain.

No evidence of active faulting was found at the property, and no faults are shown on, or trending towards the property, on the published maps that we reviewed. The lighthouse property is within the Coast Ranges geomorphic province, a zone of high seismic activity associated with the active San Andreas Fault system, which passes through the Garcia River canyon about 5.5 miles (8.8 kilometers) northeast of the site.

5.0 CONCLUSIONS

5.1 General

Based on the results of our analyses, including fault rupture, bluff stability, bluff retreat rate, future sea level rise and tsunami hazard, we conclude that the site is generally stable. No evidence of major bluff instability was observed in our site reconnaissance and review of geologic literature and site imagery. The well-defined coastal bluff edge suggests a constant and consistent erosional rate for the site. However, a few feet of bluff loss can occur locally from time to time during storms. As with most coastal bluff sites, some risk of geologic hazards exists

and must be accepted by the property owner. The current standard of practice in engineering geology makes it possible to identify most areas of existing hazards, and/or to make recommendations which lower the risk of hazards to levels that are generally acceptable but cannot make total assurances of mitigating possible future hazards.

5.2 Seismic Hazards

5.2.1 Ground Shaking

The site is located in a region of high seismic activity associated with the San Andreas Fault System. Future, large magnitude earthquakes on the San Andreas Fault, and/or other, nearby faults, are expected to cause strong ground shaking at the site. The amount of shaking will depend on the distance to the causative earthquake epicenter, the magnitude of the shock, and the response characteristics of the materials underlying the site. Generally, structures founded in firm earth materials, and designed in accordance with current building codes, are well suited to resist the effects of ground shaking. BAI is unaware of the soil and rock conditions supporting the lighthouse structure. Therefore, we do not know how well the structure will perform during a moderate or severe earthquake.

5.2.2 Faulting

According to the geologic references we reviewed, the subject property is not located within an "Earthquake Fault Zone," as identified and mapped pursuant to the requirements of the Alquist-Priolo Fault-Zoning Act of 1972. The faults that we observed during our reconnaissance do not appear to be Holocene active. Based on our field reconnaissance, the lighthouse property does not appear to be astride an active fault.

5.3 Bluff Slope Stability

No evidence of recent (last few years) deep-seated landslide activity or gross instability was observed on the bluffs at this property outside of the "Punch Bowl" area which has seen significant erosion. Qualitative comparison of recent observations/photographs with oblique aerial photographs reveals no major natural changes to the bluff face at the site. The well-defined coastal bluff edge suggests a constant and consistent erosional rate for the site. The erosional features discussed previously appear confined to surficial deposits, and may indicate areas of slightly increased bluff retreat rate.

Recent sea level rise projections by the California Coastal Commission show that by 2098, the sea level will be as much as approximately 75.6 inches higher than the baseline of 2000. However, according to the National Oceanic and Atmospheric Administration (NOAA) San Francisco tide gauge, sea level rise of just 1.7 inches has occurred since 2000, rather than the 7.0 inches projected.

Based upon historic aerial photographs and site observations, the current historic, average bluff retreat rate appears to be 2.5 inches per year (Table 2). The moderately hard bedrock within the lower bluffs is very erosion resistant. Even with a 25-inch sea level rise by 2063, the ocean wave

erosion will still be resisted by moderately hard bedrock. The current bluff retreat rate should increase after 2043 when upper, weaker bedrock materials become exposed to ocean waves. Since the lighthouse is 40 feet from the nearest sea cave and over 60 feet from the nearest bluff edge, based upon our "worst case" retreat rate of 3.8 inches per year, the lighthouse should remain safe from bluff retreat rate for the next 75 years and more.

Table 2: Projected Bluff Retreat Rate

Years	Span (years)	Cumulative Sea Level Rise (inches)*	Retreat Rate (inches per year)	Amount of Retreat (inches)
2023-2043	20	11"	2.5"/yr.	50
2043-2063	20	25"	3.0"/yr.	60
2063-2083	20	42"	3.5"/yr.	70
2083-2098	15	78"	4.0"/yr.	60
				240" = 20'

*Projected per California Coastal Commission

5.4 Tsunami Hazard

As is typical of the Mendocino County coastal area, the site could be subjected to large storm waves or tsunami waves. Damage from Tsunami waves, historically, has been limited to moored boats and docks in area coves and harbors. However, in February 1960, the Point Cabrillo Lighthouse, located approximately 28 miles north-northwest of the Point Arena Lighthouse, was damaged by an approximately 65 feet high storm wave (meteorological tsunami, or "meteotsunami"). No such waves were recorded at the Point Cabrillo Lighthouse from 1909, the year it was built, to 1960. The light house was hit again by large storm waves on January 5, 2023. The back doors of the building were broken and sea water flooded the interior by a couple of feet. BAI has subsequently observed evidences of wave debris thrown from bluff faces onto terraces at several locations from The Sea Ranch to Caspar in January 2023.

The ground elevation at the Point Cabrillo Lighthouse is at 50 feet MSL, versus the ground elevation at the Point Arena Lighthouse is 65 feet MSL. Therefore, future impact or inundation from a severe storm surge or tsunami event is considered a low, but nonetheless, real risk for the Point Arena Lighthouse.

6.0 RECOMMENDATIONS

BAI does not recommend any "hard" erosion mitigation measures at this time. Monitoring of the bluffs should continue periodically. Bluff monitoring points (5/8-inch re-bar driven into the ground with blue plastic caps) installed near the bluff edges, are shown on Plate 10. The bluffs can be monitored by the Point Arena Lighthouse Keepers, Inc. staff in consultation with BAI. The sea caves can be re-surveyed, as needed, every few years.

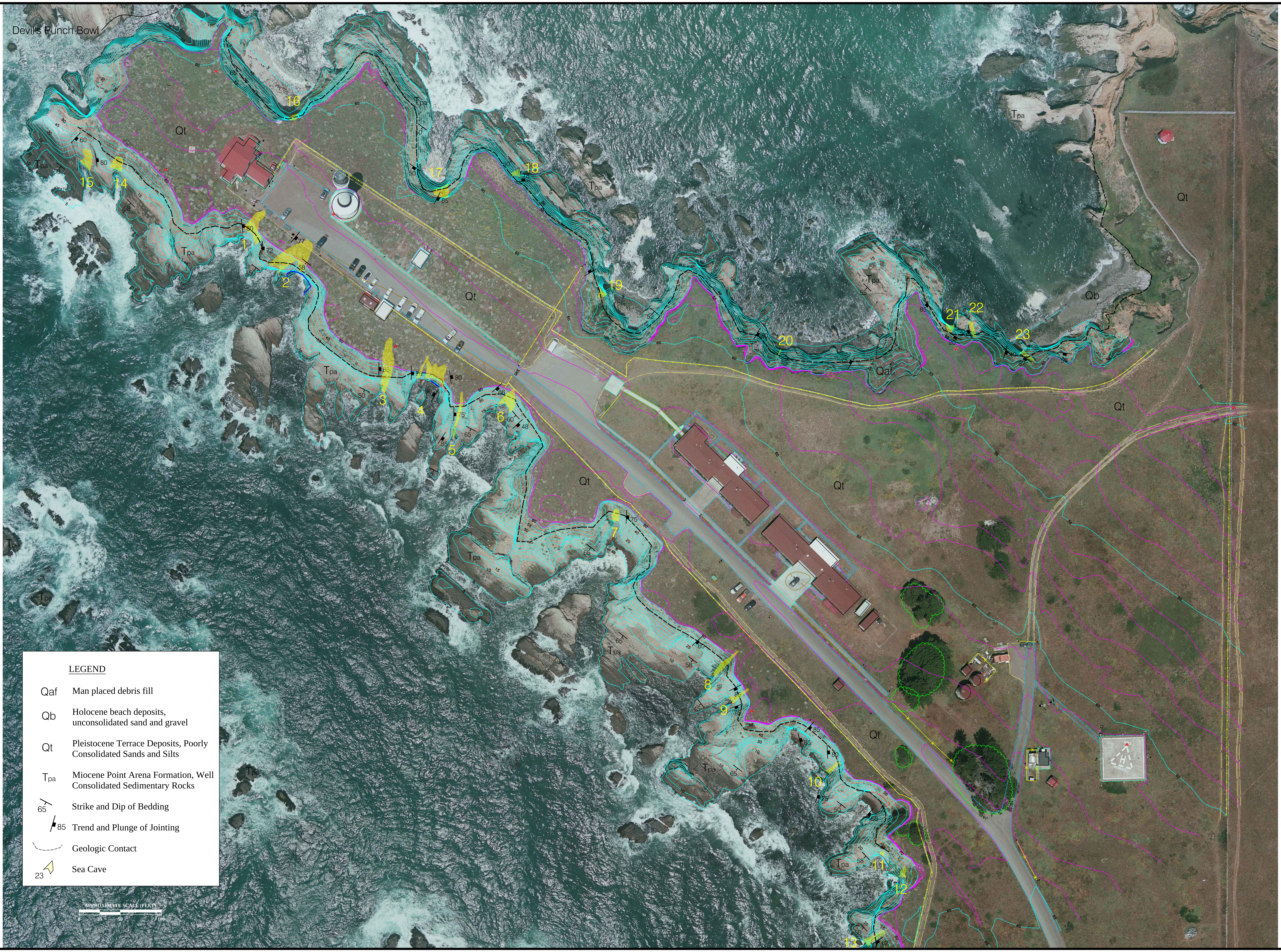
7.0 LIMITATIONS

This engineering geologic reconnaissance was performed in accordance with the usual and current standards of the profession, as they relate to this and similar localities. No other

warranty, either expressed or implied, is provided as to the conclusions and professional advice presented in this report. Our conclusions are based upon reasonable geologic interpretation of available data.

This report is issued with the understanding that it is the responsibility of the Owner, or of his/her Representative, to ensure that the information and recommendations contained herein are brought to the attention of other interested parties.

Changes in the conditions of a site can occur with the passage of time, whether they are due to natural events or to human activities on this, or adjacent sites. In addition, changes in applicable or appropriate codes and standards may occur, whether they result from legislation or the broadening of knowledge. Accordingly, this report may become invalidated wholly or partially by changes outside our control. Therefore, this report is subject to review and revision as changed conditions are identified.



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SITE GEOLOGIC MAP
POINT ARENA LIGHTHOUSE
45500 Lighthouse Road
Point Arena, California

JOB NO:
11995.02
SCALE: 1" = 50'

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PLATE:
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