4.5 GEOLOGY AND SOILS

INTRODUCTION

This section describes existing geologic conditions, including geologic and seismic hazards, for the project site; summarizes the applicable regulatory framework; identifies potentially significant geology, soils, and seismicity impacts of the project; and recommends mitigation measures to reduce these impacts to less-than-significant levels.

ENVIRONMENTAL SETTING

The geology, topography, and soils of the project site are described below, along with potential seismic and geologic hazards. Information for this section is drawn from a geotechnical report prepared for the project applicant by a California-registered Geotechnical Engineer (Miller Pacific, 2013), analysis conducted for the 2008 Town General Plan Update DEIR, and regional geologic reports and maps from the United States Geological Survey (USGS), the California Geological Survey (CGS), the Natural Resources Conservation Service (NRCS), and other public sources.

GEOLOGY

The project site is located within the Central Coast Ranges geomorphic province, which is characterized by northwest-southeast trending valleys and ridges. The geology underlying most of the project site vicinity consists of folded, faulted, sheared, and altered sedimentary, igneous, and metamorphic rock (mélange) of the Jurassic-Cretaceous age Franciscan complex. Soils at the project site consist of man-made fill overlying Bay Mud, marine, and marsh deposits. Geotechnical investigations indicate that the project site is underlain by 5 to 10 feet of fill on top of approximately 20 to 30 feet of Bay Mud (Miller Pacific, 2013). The Bay Mud is underlain by 15 to 30 feet of very stiff/dense alluvium. Bedrock is located beneath the alluvium at depths ranging from 50 to 80 feet below the ground surface (bgs) (Miller Pacific, 2013).

TOPOGRAPHY

The project site topography is level with an elevation of approximately 5 to 8 feet above mean sea level (msl), with the exception of the pond, which is approximately 5 to 10 feet deep, with slopes of approximately 3:1 (3 feet horizontal distance for every foot vertical distance) (Miller Pacific, 2013). Areas surrounding the project site are level, with no areas of steep slopes that might be potentially subject to landslide hazards triggered either by earthquakes or by precipitation events.

SOILS

Soil is generally defined as the unconsolidated mixture of mineral grains and organic material that mantles the land surfaces of the earth. Soils can develop on unconsolidated sediments, such as alluvium, and weathered bedrock. The characteristics of soil reflect the five major influences on their development: topography, climate, biological activity, parent (source) material, and time.

NRCS soil data classify site soils as Urban Land-Xerothents complex (NRCS, 2014). This classification indicates that shallow soils consist of man-made fill and do not represent underlying geologic materials. Drilling logs from previous geotechnical investigations indicate that this fill consists primarily of fine-grained clays and silts, with some layers containing sand and gravel (Miller Pacific, 2013).

SEISMIC CONDITIONS

The project site is located in the seismically active San Francisco Bay Area. The main feature generating the seismic activity in the region is the tectonic plate boundary between the North American and Pacific plates. Locally, this boundary is referred to as the San Andreas Fault Zone (SAFZ) and includes numerous active faults found by the CGS under the Alquist-Priolo Earthquake Fault Zoning Act (A-PEFZA) to be “active” (i.e., to have evidence of fault rupture in the past 11,000 years). Some of the major active faults near the project site within the SAFZ include the San Andreas, Hayward, San Gregorio, and Rodgers Creek faults. The closest faults are the San Andreas and Hayward faults, located 8 to 9 miles from the project site, to the southwest and east, respectively. **Figure 4.5-1** shows the project site in relation to these fault zones.

In a fact sheet published in 2008, the USGS estimated that there was a 63 percent probability that, between 2007 and 2036, a 6.7 or greater magnitude earthquake will occur in the San Francisco Bay Region. The probability of a 6.7 magnitude or greater earthquake occurring along individual faults was estimated to be 21 percent along the San Andreas Fault, 31 percent along the Hayward-Rodgers Creek Fault, and 6 percent along the San Gregorio Fault (USGS, 2008).

SEISMIC AND GEOLOGIC HAZARDS

This section describes the hazards associated with the seismic and geologic conditions and the potential for seismic events on the project site.

Fault Rupture Damage

Surface rupture occurs when the ground surface is broken due to fault movement during an earthquake. Faults in the project site vicinity identified by the CGS are shown in Figure 4.5-1. The location of surface rupture generally can be assumed to be along or near an active major fault trace.

As noted above, the nearest active faults to the project site are the San Andreas Fault, located approximately 8 miles to the southwest, and the Hayward Fault, located approximately 9 miles to the east (shown in Figure 4.5-1). No known active faults or fault rupture hazard zones are present at or immediately adjacent to the project site, and the fault rupture hazard is therefore considered to be very low.

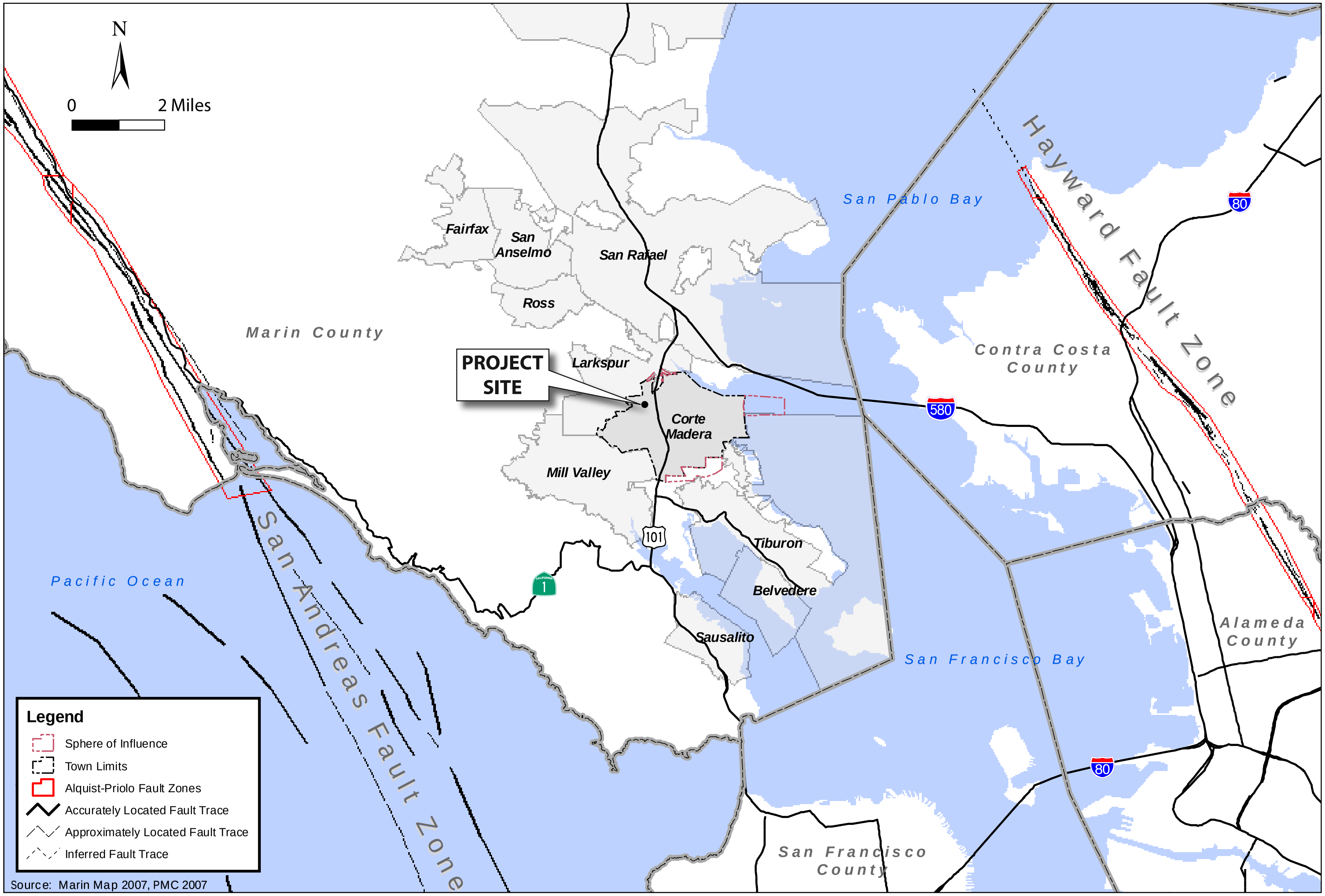

Figure 4.5-1

ACTIVE FAULT ZONES NEAR THE PROJECT SITE

SOURCE: Town of Corte Madera, 2008

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Seismic Shaking

Seismic shaking (or ground shaking) is a general term referring to all aspects of motion of the earth's surface resulting from an earthquake, and is normally the major cause of damage in seismic events. The extent of ground shaking is controlled by the magnitude and intensity of the earthquake, distance from the epicenter, and local geologic conditions. Magnitude is a measure of the energy released by an earthquake; it is assessed by seismographs that measure the amplitude of seismic waves. Intensity is a subjective measure of the perceptible effects of seismic energy at a given point and varies with distance from the epicenter and local geologic conditions. The Modified Mercalli Intensity Scale (MMI) is the most commonly used scale for measurement of the subjective effects of earthquake intensity and is further described in **Table 4.5-1**. Intensity can also be quantitatively measured using accelerometers (strong motion seismographs) that record ground acceleration at a specific location, a measure of force applied to a structure under seismic shaking. Acceleration is measured as a fraction or percentage of the acceleration under gravity (g). In addition to the San Andreas and Hayward faults, noted above, other regional faults are capable of producing ground shaking at the project site.

Based on USGS data, the project site would be subject to "Violent" (Modified Mercalli Scale Severity IX) shaking in the event of the maximum credible earthquake, a repeat of the 1906 magnitude 7.9 earthquake on the San Andreas Fault (ABAG, 2013). The median peak ground acceleration at the project site during that seismic event has been estimated at 0.28 g (Miller Pacific, 2013). This level of ground shaking is a potentially significant hazard.

Liquefaction

Liquefaction is the rapid transformation of saturated, loose, fine-grained sediment to a fluid-like state because of earthquake ground shaking. In the process, the soil undergoes transient loss of strength, which commonly causes ground displacement or ground failure to occur.

Since saturated soils are a necessary condition for liquefaction, soil layers in areas where the groundwater table is near the surface have higher liquefaction potential than those in which the water table is located at greater depths. Liquefaction potential increases in the vicinity of San Francisco Bay and locally near creeks, such as Corte Madera Creek near the project site, where loose granular sediments have accumulated as a result of stream processes or through the placement of fill. Liquefaction has resulted in substantial loss of life, injury, and damage to property. In addition, liquefaction increases the hazard of fires because of explosions induced when underground gas lines break, and because the breakage of water mains substantially reduces fire suppression capability.

The project site is mapped in an area of Very High Liquefaction Susceptibility (ABAG, 2014). However, the project geotechnical report notes that subsurface conditions are dominated by Bay Mud and other high plasticity soils that are generally not susceptible to liquefaction (Miller Pacific, 2013). Additional laboratory testing will be performed as part of a design-level geotechnical study prior to construction. The geotechnical report suggested that the results of that testing may conclude that risks from liquefaction at the project site are lower than indicated on regional liquefaction maps (Miller Pacific, 2013).

TABLE 4.5-1 MODIFIED MERCALLI SCALE

M[a]	Category	Definition
	I	Not felt except by a very few under especially favorable circumstances.
3	II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
	III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.
4	IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
	V	Felt by nearly everyone, many awaken. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
5	VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
6	VII	Everybody runs outdoors. Damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
	VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.
7	IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
8	X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
	XI	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
	XII	Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted.

[a] Richter magnitude correlation.
Source: CGS, 2002.

Lateral spreading is a form of horizontal displacement of soil toward an open channel or other "free" face, such as an excavation boundary. Ground shaking, especially when inducing liquefaction, may cause lateral spreading toward unsupported slopes. At the project site, the only unsupported slopes are at the pond; based on the shallowness of these slopes, the project geotechnical report determined that the potential for significant lateral spreading was moderate (Miller Pacific, 2013).

Landsliding

The strong ground motions that occur during earthquakes are capable of inducing landslides, generally where unstable slope conditions already exist. In addition, heavy precipitation events can induce mudflows or debris flows in areas where soils on a hillslope or in a stream channel become saturated and unstable. The only slopes at the project site are the pond. The geotechnical report noted a moderate potential for sloughing of the pond slopes in their current condition (Miller Pacific, 2013).

Expansive Soils

Expansion and contraction of volume can occur when expansive soils undergo alternating cycles of wetting (swelling) and drying (shrinking). During these cycles, the volume of the soil changes markedly. As a consequence of such volume changes, structural damage to building and infrastructure may occur if the potentially expansive soils were not considered in building design and during construction. The project geotechnical report's review of site-specific geotechnical investigation data did not identify the presence of any highly plastic or expansive near-surface soils and concluded that potential risks related to expansive soils were low (Miller Pacific, 2013).

Subsidence

Subsidence is the lowering of the land-surface elevation. The mechanism for subsidence is generally related to groundwater pumping and subsequent consolidation of loose aquifer sediments. The primary hazards associated with subsidence are increased flooding hazards and damage to underground utilities. Other effects of subsidence include changes in the gradients of stormwater and sanitary sewer drainage systems in which the flow is gravity-driven. The project site vicinity is largely developed and water is provided by the Marin Municipal Water District. There are no significant agricultural or industrial activities that result in the substantial pumping withdrawal of water from the underlying aquifer that would contribute to subsidence at the project site.

Settlement and Differential Settlement

Differential settlement or subsidence could occur if buildings or other improvements were built on low-strength foundation materials (including imported fill) or if improvements straddle the boundary between different types of subsurface materials (e.g., a boundary between native material and fill). Although differential settlement generally occurs slowly enough that its effects are not dangerous to inhabitants, it can cause significant building damage over time. The Bay Mud underlying the site is compressible and its thickness ranges from 15 to 30 feet. Therefore, the potential for total and differential settlement at the site was judged to be high (Miller Pacific, 2013).

REGULATORY FRAMEWORK

This section describes the applicable federal, state, and local regulations that pertain to the project.

FEDERAL REGULATIONS

The National Earthquake Hazards Reduction Program (NEHRP) was established by the U.S. Congress when it passed the Earthquake Hazards Reduction Act of 1977, Public Law (PL) 95–124. In establishing NEHRP, Congress recognized that earthquake-related losses could be reduced through improved design and construction methods and practices, land use controls and redevelopment, prediction techniques and early-warning systems, coordinated emergency preparedness plans, and public education and involvement programs. The four basic NEHRP goals remain unchanged:

- Develop effective practices and policies for earthquake loss reduction and accelerate their implementation.
- Improve techniques for reducing earthquake vulnerabilities of facilities and systems.
- Improve earthquake hazards identification and risk assessment methods, and their use.
- Improve the understanding of earthquakes and their effects.

Several key federal agencies contribute to earthquake mitigation efforts. There are four primary NEHRP agencies:

- National Institute of Standards and Technology (NIST) of the Department of Commerce
- National Science Foundation (NSF)
- United States Geological Survey (USGS) of the Department of the Interior
- Federal Emergency Management Agency (FEMA) of the Department of Homeland Security

Implementation of NEHRP priorities is accomplished primarily through original research, publications, and recommendations to assist and guide state, regional, and local agencies in the development of plans and policies to promote safety and emergency planning.

STATE REGULATIONS

State regulations described below include the California Building Code, Alquist-Priolo Earthquake Fault Zoning Act, and the Seismic Hazards Mapping Act.

California Building Code

The 2012 International Building Code (IBC) is published by the International Conference of Building Officials (ICBO) and is the widely adopted model building code in the United States. The 2013 California Building Code (CBC) is another name for the body of regulations known as the California Code of Regulations (CCR), Title 24, Part 2, which is a portion of the California Building Standards Code (CBSC). The CBC incorporates by reference the IBC requirements with necessary California amendments. Title 24 is assigned to the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Under state law, all building standards must be centralized in Title 24 or they are not enforceable. The Town of Corte Madera has adopted the 2013 CBC by reference (Municipal Code, Title 15, Chapter 15.01).

Compliance with the 2013 CBC requires that (with very limited exceptions) structures for human occupancy be designed and constructed to resist the effects of earthquake motions. The Seismic Design Category for a structure is determined in accordance with either: CBC Section 1613 – Earthquake Loads; or American Society of Civil Engineers (ASCE) Standard No. 7-05, Minimum Design Loads for Buildings and Other Structures. In brief, based on the engineering properties and soil-type of soils at a proposed site, the site is assigned a Site Class ranging from A to F. The Site

Class is then combined with Spectral Response (ground acceleration induced by earthquake) information for the location to arrive at a Seismic Design Category ranging from A to D, with D being the most severe conditions. The classification of a specific site and related calculations must be determined by a qualified person and are site-specific.

Alquist-Priolo Earthquake Fault Zoning Act

Surface rupture is the most easily avoided seismic hazard. The Alquist-Priolo Earthquake Fault Zoning Act (A-PEFZA) was passed in December 1972 to mitigate the hazard of surface faulting to structures for human occupancy. The project site is not located within an A-PEFZA designated fault zone and would therefore not be subject to previsions in the A-PEFZA.

Seismic Hazards Mapping Act

In 1990, following the 1989 Loma Prieta earthquake, the California Legislature enacted the Seismic Hazards Mapping Act (SHMA) to protect the public from the effects of strong ground shaking, liquefaction, landslides, and other seismic hazards. The SHMA established a state-wide mapping program to identify areas subject to violent shaking and ground failure; the program is intended to assist cities and counties in protecting public health and safety. The SHMA requires the State Geologist to delineate various seismic hazard zones and requires cities, counties, and other local permitting agencies to regulate certain development projects within these zones. As a result, the CGS is mapping SHMA Zones and has completed seismic hazard mapping for the portions of California most susceptible to liquefaction, ground shaking, and landslides—primarily the San Francisco Bay Area and Los Angeles basin. The project site and vicinity do not yet have SHMA mapping (CGS, 2014).

LOCAL REGULATIONS

Town of Corte Madera Grading and Drainage Ordinance

Title 15, Chapter 15.20 of the Corte Madera Municipal Code contains the Town's Grading and Drainage Ordinance. It is intended to address the potential for erosion, sedimentation, pollutant runoff, and related environmental damage during construction activities. Under the ordinance, the project would require preparation of a grading and drainage plan, as the project involves more than 1,000 cubic yards of excavation and fill. Based on the size of the project, a soils engineer must be present during all grading activities to supervise and inspect the work. In addition, work at the project site would require an erosion control permit as the area to be graded exceeds one-fourth acre and the volume of excavation or fill exceeds 150 cubic yards. The erosion permit application requires a site plan, grading plan, detailed description of temporary and permanent erosion and sediment control measures, surface runoff and sediment yield calculations, soil conditions and geologic reconnaissance report, typical details and specifications for erosion and sediment control facilities, location maps of the erosion and sediment control measures, revegetation plans, and a schedule for installation and maintenance of the erosion and sediment control measures. Other provisions apply to areas of low elevation (below 7 feet msl), which would include much of the project site.

Town of Corte Madera General Plan

The following policies of the *Town of Corte Madera General Plan* would apply to the project:

Policy PSH 8.1: All construction in Corte Madera shall comply with the California Building Code, including requirements for seismic design.

Policy PSH 8.2: New development and redevelopment projects with the potential for geological hazards, such as slope failures or soil subsidence, shall be subject to geotechnical evaluation prior to approval.

ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

SIGNIFICANCE CRITERIA

Based on Appendix G of the California Environmental Quality Act (CEQA) Guidelines , implementation of the proposed project would have a significant geology and soils impact if it would:

- Expose people or structures to substantial risk of loss, injury, or death involving:
  - Rupture of a known active or potentially active earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area, or based on other substantial evidence of a known fault;
  - Strong seismic ground shaking;
  - Seismic-related ground failure, including liquefaction; and
  - Landslides;
- Result in substantial soil erosion or loss of topsoil;
- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in an on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse;
- Be located on expansive soil, as defined in Section 1803.5 of the 2010 California Building Code, creating substantial risks to life or property; or
- Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater.

LESS-THAN-SIGNIFICANT IMPACTS

Expose People or Structures to Risk from Fault Rupture, Landslides, and Expansive Soils

Based on information discussed under "Environmental Setting" above, geologic mapping and topography exclude the potential for the project to result in significant impacts from fault rupture, *landslides, and expansive soils. The project would therefore have less-than-significant impacts in relation to these significance criteria.*

Result in Soil Erosion or Loss of Topsoil

Existing regulatory programs would ensure that the potential for soil erosion or loss of topsoil would be less than significant and no mitigation would be required. The applicant estimates that 14,600 cubic yards of clean fill (plus an additional 6,800 cubic yards of baserock and geofoam for filling the existing pond) would be required to develop the project, which includes raising the elevation of site buildings to at least 1 foot above existing flood elevation. Additional earthwork would be required during replacement of the Monona Drive sewer line between Lakeside Drive and Madera Boulevard. Given the amount of earthwork required, there could be a potential for erosion to occur during construction. However, the volume of fill would trigger the most stringent requirements of the Town Grading and Drainage Ordinance, requiring a grading plan, erosion control plan, and a qualified soils inspector present during all construction activities. In addition, as the construction site is greater than 1 acre in area, the construction site would be subject to the requirements of the Construction General Stormwater Permit, described in more detail under *Section 4.8, Hydrology and Water Quality*. This would include implementation of a Storm Water Pollution Prevention Plan, which would include further best management practices designed to prevent soils from becoming entrained in stormwater during project construction. Following construction, the project site would be covered by buildings, roadways, parking lots, and landscaping and would not be subject to potential erosion hazards.

Have Soils Inadequate for Septic Tanks and Alternative Wastewater Disposal Systems

The project does not propose septic tanks or alternative wastewater disposal systems. *There would be no impact in relation to the significance criterion of inadequate soils for septic tanks and alternative wastewater disposal systems.*

POTENTIALLY SIGNIFICANT IMPACTS

Impact GEO-1: Development of the project could expose future site workers and patrons to significant seismic hazards, including strong seismic ground shaking and seismic-related ground failure, including liquefaction. (PS)

Major regional faults located in the project site vicinity are capable of producing very strong to violent ground shaking, and a major seismic event is likely during the operational lifetime of the project. Violent seismic shaking could cause serious structural damage to buildings not engineered and constructed to comply with the current CBC, and could cause extensive non-structural damage even to properly constructed buildings.

The preliminary geotechnical report recommends that all building improvements be designed in accordance with the current CBC, including seismic design values presented in Table C of the report (Miller Pacific, 2013). The report concludes that this would reduce the potential for significant seismic hazards to less-than-significant levels (Miller Pacific, 2013).

<u>Mitigation Measure GEO-1</u>: As a condition of approval for any grading or construction permits for the project, a design-level geotechnical review shall be prepared by a licensed professional and submitted to the Town Engineer for review and approval. The geotechnical review shall verify that the project plans incorporate the recommendations for design contained in the preliminary geotechnical report, the current California Building Code (CBC), and other applicable design standards. All design measures, recommendations, design criteria, and specifications set forth in the design-level geotechnical review shall be implemented as a condition of project approval. (LTS)

<u>Impact GEO-2</u>: Development of the project could expose future site workers and patrons to significant geologic hazards, including hazards related to lateral spreading, slope instability, liquefaction, and differential and total settlement. (PS)

The geotechnical report identified several potential geologic hazards for development at the project site. These included lateral spreading and slope instability near the existing pond, liquefaction, and total and differential settlement.

The geotechnical report recommends that if the pond is left in its current condition, buildings must be set back at least 20 feet from edges or use deep foundations (Miller Pacific, 2013). To address potential liquefaction and settlement impacts, the report recommends the use of "zero net loading" or deep foundations. Zero net loading would offset the weight of structures by overexcavating and removing an equivalent weight of soil, or by backfilling the over-excavation with a low-density material such as Geofoam or lava rock. Deep foundations could include auger-cast piers, torque-down piles, or rammed earth geopiers that bear on firm materials beneath the existing fill and compressible Bay Mud. The geotechnical report indicates that these recommendations would reduce potential geotechnical impacts to less-than-significant levels.

<u>Mitigation Measure GEO-2</u>: Implementation of Mitigation Measure GEO-1, requiring a design-level geotechnical review as a condition of approval for grading and construction permits, would reduce potential geologic impacts to less-than-significant levels. No additional mitigation is required. (LTS)

CUMULATIVE IMPACTS

Impacts related to geologic hazards are generally site-specific, rather than cumulative in nature, because each project area has unique geologic considerations that would be subject to uniform site development and construction standards. Therefore, the potential for cumulative impacts is limited. Impacts associated with potential geologic hazards related to soil or other conditions occur at individual building sites. These effects are site-specific, and impacts would not be compounded by additional development. Mitigation measures described above would reduce impacts from geologic hazards to less-than-significant levels. Therefore, implementation of the project would not result in a cumulatively considerable contribution to geologic hazards, and the cumulative impact would be less than significant.

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