3.6 Geology, Soils and Seismic Risk

This section describes geologic, soil and seismic conditions in Pacifica, based on information from geologic maps and reports, the California Geological Survey (CGS), the U.S. Geological Survey (USGS), and the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS).

Environmental Setting

REGIONAL GEOLOGY

The City of Pacifica lies within the geologically complex region of California referred to as the Coast Ranges geomorphic province.[1] The Coast Ranges province lies between the Pacific Ocean and the Great Valley (Sacramento and San Joaquin valleys) provinces and stretches from the Oregon border to the Santa Ynez Mountains near Santa Barbara. Much of the Coast Range province is composed of marine sedimentary deposits and volcanic rocks that form northwest trending mountain ridges and valleys, running subparallel to the San Andreas Fault Zone. The Coast Ranges can be further divided into the northern and southern ranges, separated by the San Francisco Bay. West of the San Andreas Fault lies the Salinian Block, a granitic core that extends from the southern end of the province to north of the Farallon Islands.

Modern seismic activity within the Coast Range continues to be associated with movement along the San Andreas system of faults. Regionally, this fault system is the boundary between large sections, or plates, of the earth's crust known as the North American Plate and Pacific Plate. This boundary is a complex system of generally parallel, northwest trending faults that extend across the greater San Francisco Bay Area. The San Andreas is also the closest active fault to the Planning Area as it transects across the northeastern tip of the Planning Area.[2] Other nearby active faults are the San Gregorio and Hayward faults.

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[1] A geomorphic province is an area that possesses similar bedrock, structure, history, and age. California has 11 geomorphic provinces (CGS, 2002).

[2] An "active" fault is defined by the State of California as a fault that has had surface displacement within Holocene time (approximately the last 11,000 years)

LOCAL GEOLOGY

The Planning Area includes coastal areas as well as part of the Santa Cruz Mountains, one of the northwest trending ridges typical of the Coast Ranges. The Santa Cruz Mountains form the mountainous spine of the San Francisco Peninsula. Much of the upland areas are underlain by granitic bedrock associated with the Salinian Block creating rugged steep terrain in areas. The Salinian Block consists of highly fractured and weathered granite, granodiorite and quartz diorite much of which has been subject to a lot of tectonic forces. More competent granitic rocks can be found in areas such as Montara and San Pedro Mountains located to the south. Other geologic units in the area include sandstones associated with the Franciscan Formation, greenstones, and alluvial materials from drainages that head towards the Pacific Ocean.

SOILS

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) (formerly known as the Soil Conservation Service) has mapped soils in the Planning Area in a soil survey for San Mateo County. Soils are characterized according to various properties and grouped into soil associations. The soils within the Planning Area include the Barnabe-Candlestick complex, the Candlestick-Kron-Buriburi complex, Orthents Cut and Fill–Urban Land complex, and Candlestick-Barnabe Complex. The soils of these complexes typically include sand loams, clay loams, and sandy clay loams. In the upland regions these soils are generally shallow and found on slopes ranging from 30 to 75 percent. The Orthents and Urban Land complex soils are often located in the more gentle slopes of 0 to 30 percent. Soils found in developed areas have generally been reworked to the point that most of the native soils are only found at depth, if at all.

SEISMICITY

Regional Faults

The San Andreas, Hayward and Calaveras Faults pose the greatest threat of significant damage in the San Francisco Bay Area according to the USGS Working Group.[3] These three faults exhibit strike-slip orientation and have experienced movement within the last 150 years.[4] Other principal faults capable of producing significant ground shaking in the San Francisco Bay Area are the Concord–Green Valley, Marsh Creek–Greenville, San Gregorio and Rodgers Creek Faults.

An "active" fault is defined by the State of California as a fault that has had surface displacement within approximately the last 11,000 years. A "potentially active" fault is defined as a fault that has shown evidence of surface displacement during the last 1.6 million years, unless

3 USGS. USGS Fact Sheet 039-03, Working Group 02, 2003.

4 A strike-slip fault is a fault on which movement is parallel to the fault's strike or lateral expression at the surface (Bates and Jackson, Glossary of Geologic Terms, second edition,1984).

direct geologic evidence demonstrates inactivity for the last 11,000 years or longer. This definition does not, of course, mean that faults lacking evidence of surface displacement are necessarily inactive. "Sufficiently active" is also used to describe a fault if there is some evidence that displacement occurred in the last 11,000 years on one or more of its segments or branches. These faults are considered either active or potentially active. Inactive faults are located throughout the San Francisco Bay Area. Inactive faults with a long period of inactivity do not provide any guarantee that a considerable seismic event could occur. Occasionally, faults classified as inactive can exhibit secondary movement during a major event on another active fault.[5]

San Andreas Fault

The San Andreas Fault Zone is a major structural feature that forms at the boundary between the North American and Pacific tectonic plates, extending from the Salton Sea in Southern California near the border with Mexico to north of Point Arena, where the fault trace extends out into the Pacific Ocean. The main trace of the San Andreas Fault through the San Francisco Bay Area trends northwest through the Santa Cruz Mountains and the eastern side of the San Francisco Peninsula. As the principal strike-slip boundary between the Pacific plate to the west and the North American plate to the east, the San Andreas is often a highly visible topographic feature, such as between Pacifica and San Mateo, where Crystal Springs Reservoir and San Andreas Lake clearly mark the rupture zone. Near San Francisco, the San Andreas Fault trace is located immediately off-shore near Daly City and continues northwest through the Pacific Ocean approximately 6 miles due west of the Golden Gate Bridge.

In the San Francisco Bay Area, the San Andreas Fault Zone was the source of the two recent major seismic events that affected the San Francisco Bay region. The 1906 San Francisco earthquake was estimated at magnitude (M) 7.9 and resulted in approximately 290 miles of surface fault rupture, the longest of any known continental strike slip fault. Horizontal displacement along the fault approached 17 feet near the epicenter. The more recent 1989 Loma Prieta earthquake, with a moment magnitude (Mw) of 6.9, resulted in widespread damage throughout the Bay Area.

Hayward Fault

The Hayward Fault Zone is the southern extension of a fracture zone that includes the Rodgers Creek Fault (north of San Pablo Bay), the Healdsburg fault (Sonoma County), and the Maacama fault (Mendocino County). The Hayward fault trends to the northwest within the East Bay, extending from San Pablo Bay in Richmond, 60 miles south to San Jose. The Hayward fault in San Jose converges with the Calaveras fault, a similar type fault that extends north to Suisun Bay. The Hayward fault is designated by the Alquist-Priolo Earthquake Fault Zoning Act as an active fault.

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[5] Hart, E. W. Fault-Rupture Hazard Zones in California: Alquist-Priolo Special Studies Zones Act of 1972 with Index to Special Studies Zones Maps, California Division of Mines and Geology, Special Publication 42, 1990, revised and updated 1997.

Historically, the Hayward fault generated one sizable earthquake in the 1800s.[6] In 1868, a M 7 earthquake on the southern segment of the Hayward Fault ruptured the ground for a distance of about 30 miles. Recent analysis of geodetic data indicates surface deformation may have extended as far north as Berkeley. Lateral ground surface displacement during these events was at least 3 feet.

A characteristic feature of the Hayward fault is its well-expressed and relatively consistent fault creep. Although large earthquakes on the Hayward fault have been rare since 1868, slow fault creep has continued to occur and has caused measurable offset. Fault creep on the East Bay segment of the Hayward fault is estimated at 9 millimeters per year (mm/yr).[7] However, a large earthquake could occur on the Hayward fault with an estimated Mw of about 7.1. The USGS Working Group on California Earthquake Probabilities includes the Hayward–Rodgers Creek Fault Systems in the list of those faults that have the highest probability of generating earthquakes of M 6.7 or greater in the Bay Area.[8]

Calaveras Fault

The Calaveras fault is a major right-lateral strike-slip fault that has been active during the last 11,000 years. The Calaveras Fault is located in the eastern San Francisco Bay region and generally trends along the eastern side of the East Bay Hills, west of San Ramon Valley, and extends into the western Diablo Range, and eventually joins the San Andreas Fault Zone south of Hollister. The northern extent of the fault zone is somewhat conjectural and could be linked with the Concord Fault.

The fault separates rocks of different ages, with older rocks west of the fault and younger sedimentary rocks to the east. The location of the main, active fault trace is defined by youthful geomorphic features (linear scarps and troughs, right-laterally deflected drainage, sag ponds) and local groundwater barriers. The Calaveras fault is designated as an Alquist-Priolo Earthquake Hazard Zone (see discussion on this zone designation below). There is a distinct change in slip rate and fault behavior north and south of the vicinity of Calaveras Reservoir. North of Calaveras Reservoir, the fault is characterized by a relatively low slip rate of 5–6 mm/yr and sparse seismicity. South of Calaveras Reservoir, the fault zone is characterized by a higher rate of surface fault creep that has been evidenced in historic times. The Calaveras Fault has been the source of numerous moderate magnitude earthquakes and the probability of a large earthquake (greater than M 6.7) is much lower than on the San Andreas or Hay-

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6 Prior to the early 1990s, it was thought that an M 7 earthquake occurred on the northern section of the Hayward Fault in 1836. However, a study of historical documents by the California Geological Survey concluded that the 1836 earthquake was not on the Hayward Fault (Bryant, Bryant, W.A., and Cluett, S.E., compilers, Fault number 55a, Hayward fault zone, Northern Hayward section, in Quaternary fault and fold database of the United States, ver 1.0: U.S. Geological Survey Open-File Report 03-417, http://geohazards.usgs.gov/cfusion/qfault/qf_web_disp.cfm?qfault_or=1319&ims_cf_cd=cf&disp_cd=C, 2000).

7 Peterson, M.D., W.A. Bryant, and C.H. Cramer. Probabilistic Seismic Hazard Assessment for the State of California, California Division of Mines and Geology Open-File Report issued jointly with U.S. Geological Survey, CDMG 96-08 and USGS 96–706, 1996.

8 USGS, 2003.

ward Faults.[9] However, this fault is considered capable of generating earthquakes with upper bound magnitudes ranging from Mw 6.6 to M 6.8.

San Gregorio Fault

The San Gregorio Fault Zone is a complex of faults that skirt the coastline North of Big Sur, run northwestward across Monterey Bay, briefly touching the shoreline of the San Mateo County coastline at Point Ano Nuevo and at Seal Cove, just North of Half Moon Bay. This fault is an active fault that has been recently recognized as capable of producing large earthquakes. Recent studies have shown Holocene displacement on the San Gregorio Fault, as recently as 1270 AD to 1400 AD.[10] Additionally, a 1929 earthquake with magnitude above 6.0, thought to have occurred on the Monterey Fault, may have actually ruptured an offshore segment of the San Gregorio Fault Zone. According to the working group on earthquake probabilities, the San Gregorio Fault has a 10 percent chance of producing one or more M 6.7 earthquakes in the next 30 years.[11]

Groundshaking

The Planning Area is located within a region of California that is considered an area of high seismic activity. The USGS along with the California Geological Survey and the Southern California Earthquake Center formed the 2007 Working Group on California Earthquake Probabilities which has evaluated the probability of one or more earthquakes of M 6.7 or higher occurring in the state of California over the next 30 years. The result of the evaluation indicated a 63 percent likelihood that such an earthquake event will occur in the Bay Area.[12] As mentioned above, the San Andreas Fault transects the northeastern tip of the Planning Area. According to mapping compiled by the Association of Bay Area Governments, a characteristic magnitude 7.2 earthquake on the San Andreas Fault (Peninsula segment) could cause strong to very violent groundshaking in the Planning Area.

Areas underlain by bedrock tend to experience less ground shaking than those underlain by unconsolidated sediments such as artificial fill. The composition of underlying materials in areas located relatively distant from faults can intensify ground shaking. For example, portions of the Bay Area that experienced the worst structural damage due to the Loma Prieta earthquake were not those closest to the fault, but rather those with soils that amplified the effects of ground shaking. The Modified Mercalli (MM) intensity scale (see **Table 3.6-1**) is a common measure of earthquake effects due to ground shaking intensity. The MM values for

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[9] Ibid.

10 USGS and CGS. Quaternary fault and fold database for the United States, from USGS web site: http//earthquakes.usgs.gov/regional/qfaults/, accessed September 10, 2008.

11 USGS. Working Group on California Earthquake Probabilities (WG07). Fact Sheet 2008-3027, Forecasting California's Earthquakes – What Can We Expect in the Next 30 Years?,http://pubs.usgs.gov/fs/2008/3027/fs2008-3027.pdf. 2008.

12 Ibid.

intensity range from I (earthquake not felt) to XII (damage nearly total), and intensities ranging from IV to X could cause moderate to significant structural damage.[13]

Table 3.6-1: Modified Mercalli Intensity Scale

	Intensity Description	*Average Peak Acceleration[1]*
I	Not felt except by a very few persons under especially favorable circumstances.	<0.0017g
II	Felt only by a few persons at rest, especially on upper floors on buildings. Delicately suspended objects may swing.	<0.014g
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many persons do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to a passing of a truck.	<0.014g
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.	0.014g-0.039g
V	Felt by nearly everyone, many awakened. Some dishes, windows, broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.	0.039g-0.092g
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.	0.092g-0.18g
VII	Everybody runs outdoors. Damage negligible in buildings 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.	0.18g-0.34g
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. Persons driving motor cars disturbed.	0.34g-0.65g
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.	0.65g-1.24g
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes.	> 1.24g

[13] The damage level represents the estimated overall level of damage that will occur for various MM intensity levels. The damage, however, will not be uniform. Some structures will experience substantially more damage than this overall level, and others will experience substantially less damage. Not all structures perform identically in an earthquake. The age, material, type, method of construction, size, and shape of a structure all affect its performance.

Table 3.6-1: Modified Mercalli Intensity Scale

	Intensity Description	*Average Peak Acceleration*[1]
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.	> 1.24g
XII	Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted. Objects are thrown upward into the air.	> 1.24g

Note:

1. g (gravity)= 980 centimeters per second squared. Acceleration of 1.0 g is equivalent to a car traveling 328 feet from rest in 4.5 seconds.

Source: Association of Bay Area Governments (ABAG), Modified Mercalli Intensity Scale http://www.abag.ca.gov/bayarea/eqmaps/doc/mmi.html, 2003 and California Geological Survey, Background Information on the ShakeMaps, http://earthquake.usgs.gov/research/shakemap/ , April 21, 2003.

Fault Rupture

Fault rupture is the surface displacement of the earth's surface due to the movement along a fault associated with an earthquake. Ground displacement is generally experienced on or within the immediate vicinity of the mapped fault trace. The Alquist-Priolo Earthquake Fault Zoning Act of 1972 established the requirement to regulate development within established earthquake fault zones associated with active faults. Development in fault zones is allowed but requires detailed geologic and seismic evaluations by certified professionals prior to approval of a building permit. An Alquist-Priolo fault hazard zone associated with the San Andreas Fault is located within the Planning Area, and is shown in **Figure 3.6-1**, Seismic Hazards.

Liquefaction

Liquefaction is a transformation of soil from a solid to a liquefied state during which saturated soil temporarily loses strength resulting from the buildup of excess pore water pressure, especially during earthquake-induced cyclic loading. Soil susceptible to liquefaction includes loose to medium dense sand and gravel, low-plasticity silt, and some low-plasticity clay deposits. Four kinds of ground failure commonly result from liquefaction: lateral spread, flow failure, ground oscillation, and loss of bearing strength. Liquefaction and associated failures can damage foundations, roads, underground cables and pipelines, and disrupt utility service. The depth to groundwater influences the potential for liquefaction, in that sediments need to be saturated to have a potential for liquefaction.

Hazard maps produced by the Association of Bay Area Governments (ABAG) depict liquefaction for the greater Bay Area in the event of a significant seismic event. According to these maps, the majority of the Planning Area is in an area expected to have a very low potential to experience liquefaction, although areas surrounding some of the alluvial drainages (i.e., San

Pedro Creek Valley and Calera Creek Valley) contain some areas of high potential, as shown in **Figure 3.6-1.**[14]

Subsidence

Subsidence or settlement can occur from immediate settlement, consolidation, shrinkage of expansive soil, and liquefaction. Immediate settlement occurs when a load from a structure or placement of new fill material is applied, causing distortion in the underlying materials. This settlement occurs quickly and is typically complete after placement of the final load. Consolidation settlement occurs in saturated clay from the volume change caused by squeezing out water from the pore spaces. Consolidation occurs over a period of time and is followed by secondary compression, which is a continued change in void ratio under the continued application of the load.

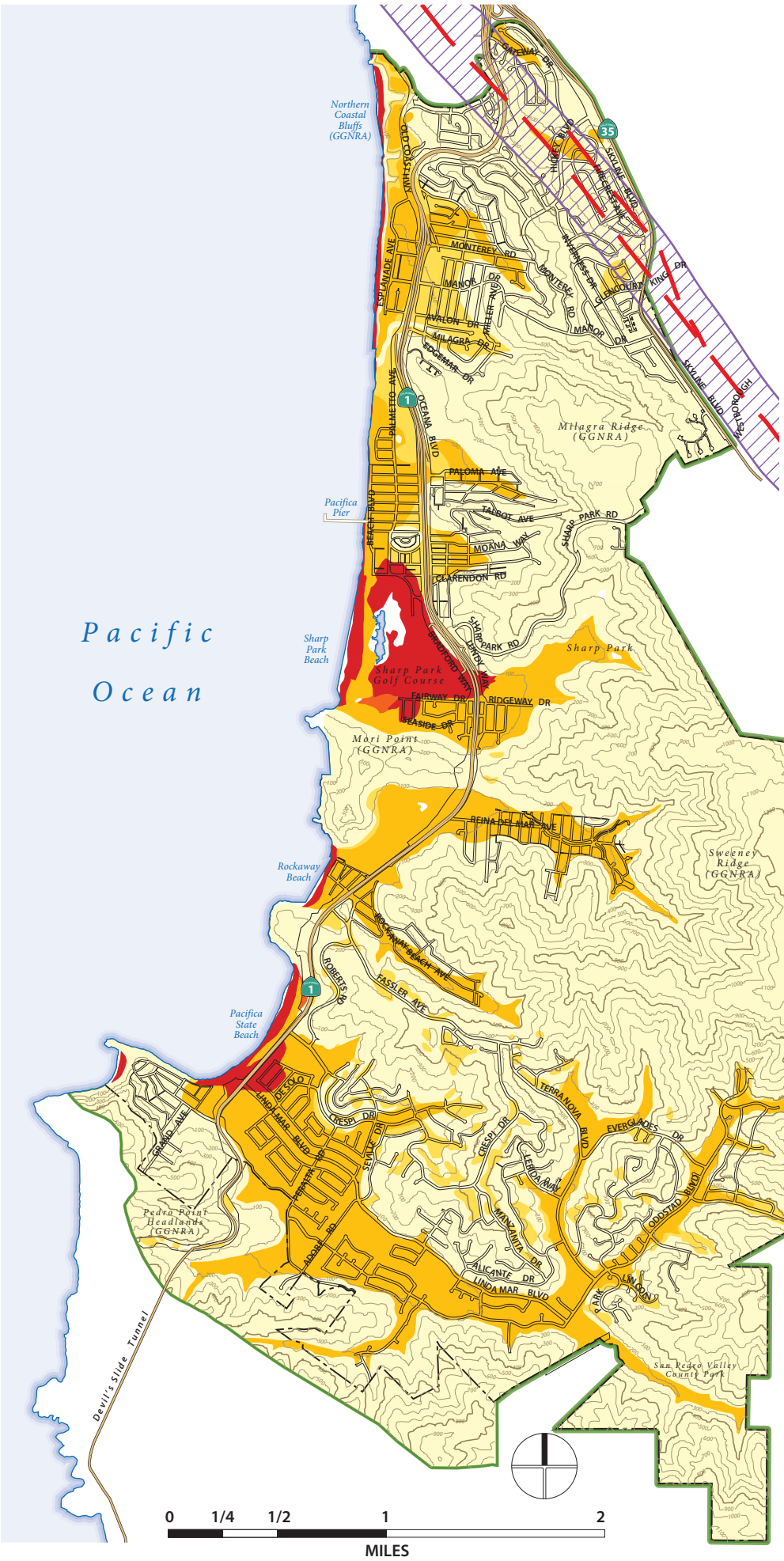
Soils tend to settle at different rates and by varying amounts depending on the load weight or changes in properties over an area, which is referred to as differential settlement. Areas underlain by soft sediments or undocumented fills are most prone to settlement.

Soil Erosion

Erosion is the wearing away of soil and rock by processes such as mechanical or chemical weathering, mass wasting, and the action of waves, wind and underground water. Excessive soil erosion can eventually lead to damage of building foundations and roadways. In the Planning Area, areas that are susceptible to erosion are those that would be exposed during construction and along the shoreline where soil is subjected to wave action. Typically, the soil erosion potential is reduced once the soil is graded and covered with concrete, structures, asphalt, or slope protection.

[14] Association of Bay Area Governments (ABAG). Liquefaction Susceptibility. http://www.abag.ca.gov/bayarea/eqmaps/liquefac/liquefac.html, 2003.

Figure 3.6-1:
Seismic Hazards



Liquifaction Potential

- Very Low
- Low
- Medium
- High
- Very High
- San Andreas Fault
- Alquist-Priolo Zone
- 100 foot contour interval
- 400 foot contour interval
- City Limits
- Planning Area

Source: Association of Bay Area Governments, 2003; US Geological Survey, 2008; ESA. 2009; City of Pacifica, 2008; San Mateo County, 2009; Dyett & Bhatia, 2013.

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Landslides and Slope Failure

Slope failures, commonly referred to as landslides, include many phenomena that involve the downslope displacement and movement of material, either triggered by static (i.e., gravity) or dynamic (i.e., earthquake) forces. A slope failure is a mass of rock, soil, and debris displaced downslope by sliding, flowing, or falling. Exposed rock slopes undergo rockfalls, rockslides, or rock avalanches, while soil slopes experience shallow soil slides, rapid debris flows, and deep-seated rotational slides. Landslides may occur on slopes of 15 percent or less; however, the probability is greater on steeper slopes that exhibit old landslide features such as scarps, slanted vegetation, and transverse ridges. Landslide-susceptible areas are characterized by steep slopes and downslope creep of surface materials. Debris flows consist of a loose mass of rocks and other granular material that, if saturated and present on a steep slope, can move downslope. The rate of rock and soil movement can vary from a slow creep over many years to a sudden mass movement. Landslides occur throughout the state of California, but the density of incidents increases in zones of active faulting.

Slope stability can depend on a number of complex variables. The geology, structure, and amount of groundwater in the slope affect slope failure potential, as do external processes (i.e., climate, topography, slope geometry, and human activity). The factors that contribute to slope movements include those that decrease the resistance in the slope materials and those that increase the stresses on the slope. Slope failure under static forces occurs when those forces initiating failure overcome the forces resisting slope movement. For example, a soil slope may be considered stable until it becomes saturated with water (e.g., during heavy rains or due to a broken pipe or sewer line). Under saturated conditions, the water pressure in the individual pores within the soil increases, reducing the strength of the soil. Cutting into the slope and removing the lower portion, or slope toe, can reduce or eliminate the slope support, thereby increasing stress on the slope.

The coastline of San Mateo County includes steep upland areas that are susceptible to slope failures. Most notably, the large coastal slide known as Devil's Slide, is located at the southern end of the Planning Area. Devil's Slide has a long history of slope failures rock slides that have caused closures of Highway 1. The Devil's Slide Tunnels Project has recently been completed to avoid this area. Within the planning boundary, steep slopes on Mori Point, Sweeney Ridge, Cattle Hill, Gypsy Hill, and Montara Mountain are identified as likely sites of slope failures, as are small portions of areas in or near development in the Pedro Point and Fairmont neighborhoods and along the west side of Skyline Boulevard. **Figure 3.6-2**, Slope Failure and Coastal Erosion, identifies the relative likelihood of landslides in the Planning Area. The map shows three slope failure threat categories: Mostly Landslides, Few Landslides, and Not Landslide Prone.[15] Mostly Landslide areas consist of mapped landslides, intervening areas typically narrower than 1,500 feet, and narrow borders around landslides; defined by how groups of mapped landslides are clustered. Areas mapped as Few Landslides contain few, if any, large mapped landslides, but locally contain scattered small landslides and questionably identified larger landslides; defined in most of the region by excluding groups of mapped landslides. Not Landslide Prone refers to areas of gentle slope at low elevation that have little or no po-

[15] USGS. Open File Report 97-745, San Francisco Bay Landslide Folio, http://pubs.usgs.gov/of/1997/of97-745/, 1997.

tential for the formation of slumps, translational slides, or earth flow except along stream banks and terrace margins; defined by the distribution of surficial deposits.

Beaches and Coastal Erosion

Northern California is characterized by rugged coastline areas where mountain ranges extend to the shoreline with narrow slivers of sand at their base. Rocky bluffs interspersed with small sandy coves are common. Under natural conditions the sand is provided by sediment transport along the coast through wave action as well as from deposition through rivers and streams that empty into the ocean. Winter storms tend to cause heavy wave action which reduces sand content at beaches that will typically recover during milder summer conditions. Whereas 30 to 50 years ago engineering methods of introducing hard barriers to protect shoreline improvements were common, soft stabilization methods have proven more effective in maintaining natural systems of sand transport. Soft stabilization methods include sand and cobble beach fills which can more closely mimic natural conditions and respond to changes in wave action.

According to a study done by the U.S. Geological Survey following the heavy winter storms of 1982–1983, the entire coastline of San Mateo County contains areas susceptible to severe erosion and slope failure.[16] Coastal areas within the Planning Area include locations that the USGS have determined to have critical erosion hazards and unstable segments where the sedimentary rocks are susceptible to failure from heavy wave action. A similar study of the winter storms of 1997–1998 showed that sea cliffs in the Planning Area were particularly impacted and a number of homes were impacted as a result. The long-term average erosion rate for cliffs in this general area is roughly 0.2 m/year and the winter storms of 1997–1998 caused approximately 50 years worth of erosion at the location where 12 homes were condemned.[17] Coastline segments that have experienced substantial coastal erosion are shown in **Figure 3.6-2**.

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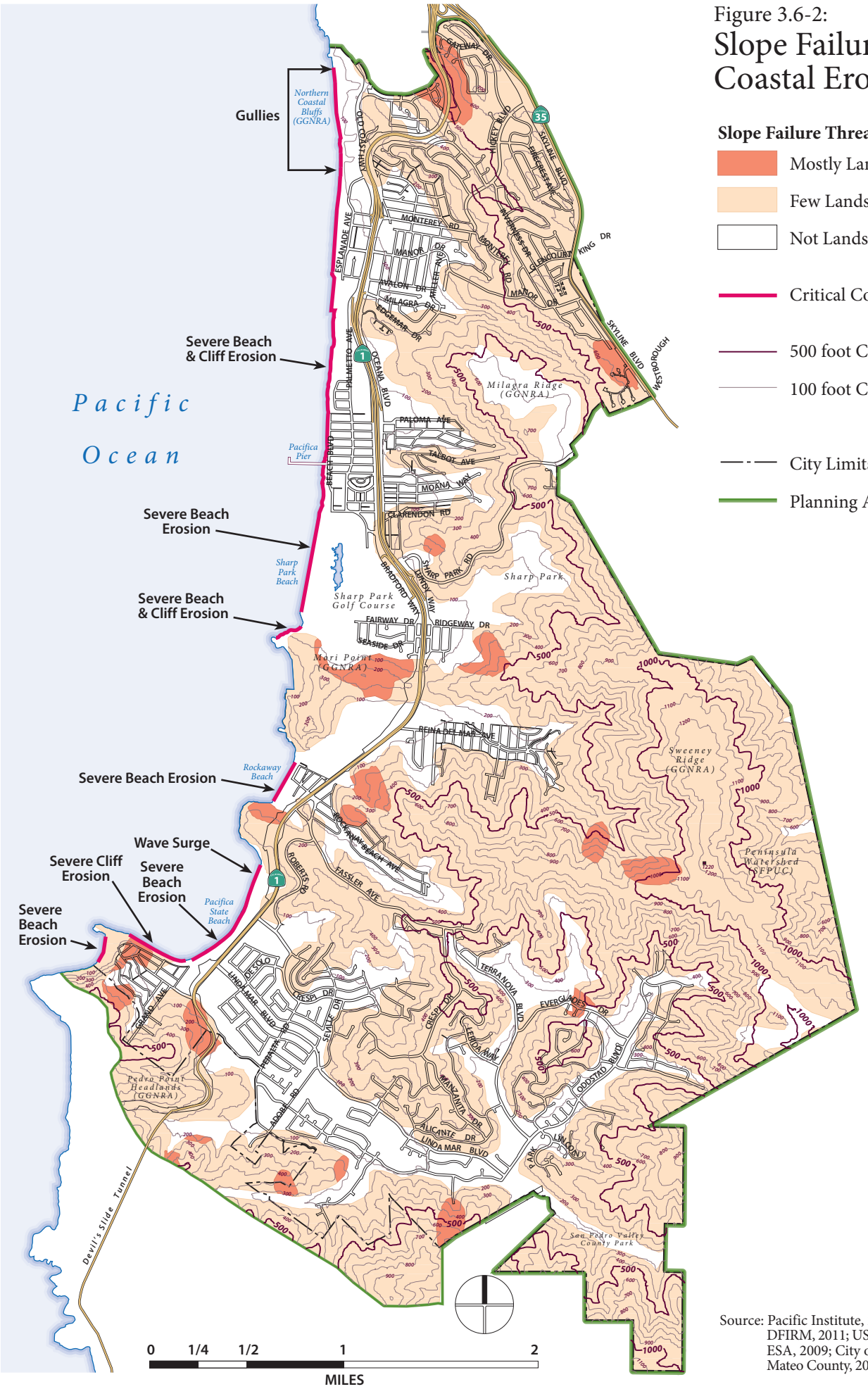
[16] USGS, LaJoie, Kenneth and Mathieson, Scott, *1982-1983 Coastal Erosion: San Mateo County, California,*

17 USGS. Coastal Erosion Along the U.S. West Coast During the 1997–98 El Niño: Expectations and Observations, http://coastal.er.usgs.gov/lidar/AGU_fall98/, 2005.

Figure 3.6-2:

Slope Failure and Coastal Erosion



Source: Pacific Institute, 2009; FEMA Revised DFIRM, 2011; US Geological Survey, 1997; ESA, 2009; City of Pacifica, 2008; San Mateo County, 2009; Dyett & Bhatia, 2013.

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Effects of Sea Level Rise

Sea level rise resulting from global climate change is projected to cause more extensive erosion of beaches, dunes, bluffs and cliffs. A 2009 study of the impacts of sea level rise on the California Coast from the California Climate Change Center developed erosion models for dune and cliff/bluff backshore environments. For both types of shoreline, erosion is projected based on Total Water Level (TWL), calculated as the sum of high tide line, wave run-up, and sea-level rise. According to the study, a majority of the dune shoreline along the northern California coast is currently accreting, but this is projected to reverse between 2050 and 2100. Mean lateral erosion of dunes is estimated at 115 to 116 meters (m) by 2025, 119m to 128m by 2050, and 132m to 175m by 2100. Bluffs, meanwhile, are projected to have eroded by 8m to 9m by 2025, 23m to 24m by 2050, and 58m to 64m by 2100, with geology, wave exposure, and bluff toe elevation all playing important roles in producing variation.[18]

It is important to reiterate that these models are approximate, and not meant to be used for parcel-specific land use planning. These models indicate that there could be new risks of erosion along the length of Pacifica's coastline in areas that are not currently exposed to wave action erosion, which could impact all of the coastal neighborhoods and coastal habitats.

Shoreline Protection Programs

In the early 1990s, the City of Pacifica, the California Coastal Conservancy, and the Pacifica Land Trust collaborated to improve steelhead trout habitat and preserve the sandy beach at Pacifica/Linda Mar State Beach, with the removal of vulnerable structures along the shore. The stabilization methods were used to expand and enhance the tidally influenced wetlands at the mouth of San Pedro Creek and restore more than 1,900 feet of eroding creek banks. This restoration both enhanced steelhead trout habitat and achieved 100-year flood protection for the nearby community.

To address the remaining flood threat to homes and businesses, the City removed the most vulnerable structures. In 2002, the City partnered with the Pacifica Land Trust and the California Coastal Conservancy to purchase two homes and their surrounding acreage and delivered 4,000 cubic yards of sand to rebuild dunes and restore four acres of beach and the nearby estuary.

In addition, the City is continuing to maintain and improve the existing seawall and revetment originally constructed in 1962 at Rockaway Beach. Repairs in the past have consisted of retrieval of displaced rip-rap, importation of additional rip-rap and repair of the revetment. Other revetments are placed along the beaches of the Planning Area and a seawall has been constructed along Beach Boulevard between Paloma Avenue and Clarendon Road.

18 Pacific Institute, California Climate Change Center, The Impacts of Sea-Level Rise on the California Coast, May 2009.

REGULATORY SETTING

Alquist-Priolo Earthquake Fault Zoning Act

The Alquist-Priolo Earthquake Fault Zoning Act (formerly the Alquist-Priolo Special Studies Zone Act), signed into law December 1972, requires the delineation of zones along active faults in California. The Alquist-Priolo Act regulates development on or near active fault traces to reduce the hazard of fault rupture and to prohibit the location of most structures for human occupancy across these traces.[19] Cities and counties must regulate certain development projects within the delineated zones, and regulations include withholding permits until geologic investigations demonstrate that development sites are not threatened by future surface displacement.[20] Surface fault rupture, however, is not necessarily restricted to the area within an Alquist-Priolo Zone.

California Building Code

The California Building Code (CBC) is found in the California Code of Regulations (CCR) in Part 2 of Title 24. Title 24 is administered by 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 purpose of the CBC is to establish minimum standards to safeguard the public health, safety, and general welfare through structural strength, means of egress facilities, and general stability by regulating and controlling the design, construction, quality of materials, use and occupancy, location, and maintenance of all building and structures within a jurisdiction. The 2013 CBC is based on the 2009 International Building Code (IBC) published by the International Code Conference. In addition, the CBC contains necessary California amendments, which are based on reference standards obtained from various technical committees and organizations such as the American Society of Civil Engineers (ASCE), the American Institute of Steel Construction (AISC), and the American Concrete Institute (ACI). ASCE Minimum Design Standards 7-05 provides requirements for general structural design and includes means for determining earthquake loads as well as other loads (flood, snow, wind, etc.) for inclusion into building codes. The provisions of the CBC apply to the construction, alteration, movement, replacement, and demolition of every building or structure or any appurtenances connected or attached to such buildings or structures throughout California.

The earthquake design requirements take into account the occupancy category of the structure, site class, soil classifications, and various seismic coefficients which are used to determine a Seismic Design Category (SDC) for a project as described in Chapter 16 of the CBC. The SDC is a classification system that combines the occupancy categories with the level of expected ground motions at the site and ranges from SDC A (very small seismic vulnerability) to SDC E (very high seismic vulnerability and near a major fault). Design specifications are then determined according to the SDC in accordance with Chapter 16 of the CBC.

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[19] A "structure for human occupancy" is defined by the Alquist-Priolo Act as any structure used or intended for supporting or sheltering any use or occupancy that has an occupancy rate of more than 2,000 person-hours per year.

[20] Hart, 1997.

Chapter 16, Section 1613 provides earthquake loading specifications for every structure, and portion thereof, including nonstructural components that are permanently attached to structures and their supports and attachments, which shall be designed and constructed to resist the effects of earthquake motions in accordance with ASCE 7-05.

Chapter 18 of the CBC covers the requirements of geotechnical investigations (Section 1803), excavation, grading, and fills (Section 1804), load-bearing of soils (1805), as well as foundations (Section 1808), shallow foundations (Section 1809), and deep foundations (Section 1810). Chapter 18 also describes analysis of expansive soils and the determination of the depth to groundwater table. For Seismic Design Categories D, E, and F, Chapter 18 requires analysis of slope instability, liquefaction, and surface rupture attributable to faulting or lateral spreading, plus an evaluation of lateral pressures on basement and retaining walls, liquefaction and soil strength loss, and lateral movement or reduction in foundation soil-bearing capacity. It also addresses mitigation measures to be considered in structural design, which may include ground stabilization, selecting appropriate foundation type and depths, selecting appropriate structural systems to accommodate anticipated displacements, or any combination of these measures. The potential for liquefaction and soil strength loss must be evaluated for site-specific peak ground acceleration magnitudes and source characteristics consistent with the design earthquake ground motions.

CCR Title 24 also includes the California Residential Code and the California Green Building Code, which have been adopted as separate documents (CCR Title 24, Part 2.5 and 11, respectively). The California Residential Code includes structural design standards for residential one- and two-family dwellings and covers all structural requirements for conventional construction. This section also incorporates by adoption the 2012 International Residential Code of the International Code Council with necessary California amendments for seismic design. All other structures including multi-family residential projects are found in the other parts of the CBC as discussed above.

Local Hazard Mitigation Plan

In 2005, a task force representing the City of Pacifica studied the City's exposure to natural hazards and identified mitigation strategies. Their work is incorporated into the regional Local Hazard Mitigation Plan directed by ABAG.

The task force noted Pacifica's vulnerability to groundshaking, liquefaction, and subsidence caused by potential seismic activity along the San Andreas fault. It also described Pacifica's susceptibility to landslides and slope failures, which can be caused by earthquakes, hillside erosion, or coastal erosion. Major landslides in Pacifica have been triggered by heavy rainfall. Coastal erosion is another serious hazard that exists in Pacifica, as bluffs are progressively undercut by wave action and eroded from above by rainfall, with the most severe erosion occuring during winter storms.

The task force concluded that earthquakes, with the potential to cause ground shaking, liquefaction, and landslides; and winter storms, which may cause landslides, coastal erosion, and flooding, are Pacifica's two highest priorities for the mitigation of geologic and seismic hazards.

All mitigation strategies identified in the proposed General Plan that concern geologic hazards are already existing programs in Pacifica and in addition, the City has approved and adopted the 2010 update of the local annex to the ABAG Taming Natural Disasters as its hazard mitigation plan. [21]

City of Pacifica General Plan

Seismic Safety and Safety Element

Pacifica updated the Seismic Safety and Safety Element of its General Plan in 1983, following serious storms resulting in property damage and loss of life during the previous two winters. The Seismic Safety and Safety Element details known and potential hazards from hillside erosion and landslides; coastal erosion; seismic events; and other issues dealt with elsewhere in this document.

Seismic Events

The San Andreas fault and its associated Alquist-Priolo Fault Zone pass through Pacifica. The Seismic Safety and Safety Element notes that all of Pacifica could be affected by ground shaking, and liquefaction and landslide hazards are best identified by site-specific geotechnical study.

Hillside Erosion and Landslides

The Seismic Safety and Safety Element describes the major slope failures that occurred in Pacifica during the winters of 1982 and 1983, triggered by an overall wet season followed by exceptionally heavy rainfall events. The General Plan emphasizes the need for site-specific geotechnical studies for all proposed development.

Coastal Erosion

Coastal erosion is an ongoing process affecting Pacifica's shoreline, operating through a combination of undercutting of bluffs by wave action and sloughing off of rain-saturated bluff tops, exacerbated by winter storms. The General Plan determines that site-specific geotechnical studies are the best mitigation to address the hazard of coastal erosion, and density, setback, and other requirements can be determined on a case-by-case basis. In addition, the General Plan requires that setbacks should accommodate any 100-year hazard event, and be adequate to protect structures for their design life.

Policies

1. Prohibit development in hazardous areas unless detailed site investigations ensure that risks can be reduced to acceptable levels and the structure will be protected for its design life. Development shall be designed to withstand a minimum of a 100-year hazard event,

[21] City of Pacifica, Resolution 05-2012, March 12, 2012.

regardless of the specific nature of the hazard. This concept applies to both on-site and off-site hazards.

3. Prohibit mitigation measures for potential geotechnical hazards if the mitigation measures could adversely affect surrounding public or private property. For example, use of the public right-of-way as a landslide repository could adversely affect public health, safety, and welfare.

4. Prohibit seawalls which are necessary as a mitigation measure for new development. Projects should not be approved which eventually will need seawalls for the safety of the structures and residents.

7. Maintain an emergency plan which provides adequate response to disasters, including emergency ingress and egress communitywide and for individual neighborhoods.

City of Pacifica Municipal Code

The City of Pacifica's Municipal Code includes Title 8 Building Regulations, Chapter 1 Building Code which establishes the local building code for the City. The building code adopts the 2010 California Building Code and includes amendments contained in Chapter 1 that are specific to the City of Pacific.[22]

Impact Analysis

SIGNIFICANCE CRITERIA

Implementation of the proposed General Plan would have a potentially significant adverse impact if the Plan would:

Criterion 1: Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:

- Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map or based on other substantial evidence of a known fault,
- Strong seismic ground shaking,
- Seismic-related ground failure, including liquefaction, or
- Landslides.

Criterion 2: Result in substantial soil erosion or topsoil loss;

[22] Effective January 1, 2014 a revised 2013 California Building Code will become effective. It is assumed that the City of Pacifica will adopt this version as well.

Criterion 3: Locate structures on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse;

Criterion 4: Locate structures on expansive soils, as defined in Section Chapter 18 of the 2010 California Building Code, creating substantial risks to life or property; or

Criterion 5: Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water.

METHODOLOGY AND ASSUMPTIONS

This evaluation of geologic and seismic hazard conditions was completed using information collected from the USGS, the CGS, the ABAG, and other available data. In order to reduce or mitigate potential hazards from earthquakes or other local geologic hazards, the proposed General Plan update ensures development will continue to be completed in compliance with local and State regulations. These regulations include the California Building Code, the International Building Code, the Alquist-Priolo Earthquake Fault Zoning Act, and the Seismic Hazard Mapping Act. Policies and implementation measures developed for the proposed General Plan include continued conformance with these applicable local and State building regulations.

SUMMARY OF IMPACTS

Potential seismic impacts associated with implementation of the proposed General Plan could include exposure to ground shaking, liquefaction, and soil settlement. In addition, the Alquist-Priolo Earthquake Fault Zone for the San Andreas fault intersects the northern portion of the Plan Area which has the potential for surface fault rupture.

Soil erosion and loss of topsoil is most likely to occur during construction, when it is not protected by vegetation or structures. Coastal erosion is also a known hazard for the Planning Area. Erosion is often caused by waves and wind, and may be exacerbated by stormwater if not handled effectively. The potential for expansive soils is determined on a site-specific basis and likely present in some areas. Compliance with the California Building Code and other state and local regulations, as well as proposed General Plan policies, ensures that impacts are reduced to a less than significant level.

IMPACTS AND MITIGATION MEASURES

Impact

3.6-1 Implementation of the proposed General Plan would not expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or

death involving rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map or based on other substantial evidence of a known fault; strong seismic ground shaking; seismic-related ground failure, including liquefaction; and landslides. ***(Less than Significant)***

Fault Rupture

The San Andreas fault zone intersects the very northern portion of the City of Pacifica that roughly parallels Skyline Boulevard (see **Figure 3.6-1**, Seismic Hazards). Surface fault rupture could occur anywhere along or within the associated Alquist-Priolo Earthquake Fault Zone (Alquist-Priolo Zone) for the San Andreas fault, and could affect existing or proposed improvements located within this zone. Although fault rupture is not necessarily confined to the boundaries of this approximately quarter mile wide Alquist-Priolo Zone, the likelihood of rupture occurring outside of these zones is considered very low based on historical evidence and the geologic record. The amount and location of surface displacement would depend on the magnitude and nature of the seismic event on the fault. In some cases, surface fault rupture can cause displacement of the ground surface, resulting in substantial damage to foundations, roadways, and utilities. Development associated with the proposed General Plan would include a variety of land uses that could potentially be exposed to hazards as a result of surface fault rupture although the area that intersects the fault zone is primarily low density residential and park space that likely will not have much new development. For any proposed development within the Alquist-Priolo Zone, fault identification studies are required by the Alquist-Priolo Act. These studies involve onsite trenching and excavation for site-specific identification and location of fault rupture planes where any future rupture would be anticipated. Structures intended for human occupancy (defined as a structure that might be occupied a minimum of 2,000 hours per year) are then required to be set back a minimum distance of 50 feet. In addition, the proposed General Plan policies below would help ensure that potential hazards associated with fault rupture are reduced largely through increased awareness. Therefore, the impacts related to fault rupture hazards for proposed improvements associated with the General Plan are less than significant.

Groundshaking

According to modeling conducted by the US Geological Survey in conjunction with the California Geological Survey, the San Francisco Bay Area will likely experience at least one major earthquake (greater than moment magnitude 6.7) within the next 30 years. The intensity of such an event would depend on the causative fault and the distance to the epicenter, the magnitude, the duration of shaking, and the characteristics of the underlying geologic materials. The potential for damage or loss during an earthquake of this magnitude could be substantial, especially in older structures and infrastructure that were constructed under less stringent building codes.

In general, ground shaking tends to be more severe in softer sediments such as alluvial deposits where surface waves can be amplified causing a longer duration of ground shaking compared to bedrock materials. Areas where bedrock is exposed or located at relatively shallow depth tend to experience surface waves from an earthquake as more of a sharp jolt, compared

to other areas. In general, considering the close proximity to the San Andreas fault, all locations within the Planning Area could experience considerable ground shaking.

Development associated with the proposed General Plan would be required to conform to the current seismic design provisions of the most current version of the California Building Code (CBC), to provide for the latest in earthquake safety and minimize losses from an earthquake. The CBC is based on the International Building Code and contains the latest seismic safety requirements to resist ground shaking through modern construction techniques, which are periodically updated to reflect the most recent seismic research. With implementation of the proposed General Plan policies below which help strengthen the existing building code requirements, the potential impacts from groundshaking would be minimized to the greatest extent feasible and are less than significant.

Liquefaction

Liquefaction typically occurs in areas underlain with loose saturated cohesionless soils within the upper 50 feet of subsurface materials. These soils, when subjected to ground shaking, can lose their strength as a result of the buildup of excess pore water pressure, causing them to behave closer to a liquefied state. As shown in **Figure 3.6-1**, locations within the Planning Area are considered prone to liquefaction hazards. In general, the areas of highest liquefaction susceptibility are located within and around the Sharp Park Golf Course and just inland from Linda Mar Beach. Damage from earthquake-induced ground failure associated with liquefaction could be high in buildings constructed on improperly engineered fills or saturated alluvial sediments that have not received adequate compaction or treatment in accordance with current building code requirements. Ground failure, including liquefaction, as a result of an earthquake could occur in the planning area depending on the underlying conditions including moisture content, relative size of soil particles, and density of subsurface materials within 50 feet of ground surface.

The impacts from ground failure, including liquefaction, from development of land uses associated with the General Plan would be addressed through site-specific geotechnical studies prepared in accordance with CBC requirements and standard industry practices. Subsequent development would be required to conform to the current seismic design provisions of the CBC to minimize losses from ground failure as a result of an earthquake. These future projects would also be required to adhere to proposed General Plan policies that contain seismic safety requirements and help strengthen existing code requirements such as referencing known hazard areas that must contain measures to resist ground failure through modern construction techniques. Therefore, the potential impact related to seismically related ground-failure including liquefaction is less than significant.

Seismically Induced Landslides

Earthquake-induced landslides could occur in unstable upland areas where previous landslide stabilization measures have not been employed. Landslides may occur on slopes of 15 percent or less; however, the probability is greater on steeper slopes that exhibit old landslide features

such as scarps, slanted vegetation, and transverse ridges. Landslide-susceptible areas are characterized by steep slopes and downslope creep of surface materials.

The impacts from landslides on development of future land uses associated with the proposed General Plan would be addressed through site-specific geotechnical studies prepared in accordance with CBC requirements and standard industry practices, which would specifically address landslide hazards located in landslide hazard areas. Development would conform to the current design provisions of the CBC to mitigate losses from landslides. Proposed developments would also adhere to the hillside development requirements contained in the proposed policies below as well as the existing regulations in the Hillside Preservation District to resist landslides through modern construction design and slope stabilization techniques. Therefore, the potential for adverse landslide impacts related to proposed changes from implementation of the proposed General Plan at the regional and local level is considered less than significant.

Proposed General Plan Policies that Reduce the Impact

Safety Element

SA-G-1 **Reduce Risk.** Minimize risks of property damage and personal injury posed by geologic and seismic hazards.

SA-I-1 **Fault Zone.** Continue to review projects located in identified fault zones subject to the Alquist-Priolo Earthquake Fault Zone Act. (See the Seismic Hazards map, Figure 8-1of the General Plan).

SA-I-2 **Development in Hazardous Areas.** Prohibit development in areas of mostly landslides or high or very high liquefaction risk as shown in Figure 8-2 of the proposed General Plan, unless detailed site investigations ensure that risks can be reduced to acceptable levels and the structure will be protected for its design life.

SA-I-3 **Real Estate Disclosure.** Require real estate transactions, development approval processes, and property titles to declare known or suspected seismic or geologic hazards on a property, including Alquist-Priolo Fault Zones and areas suspected of high or very high risk of liquefaction, subsidence, or landslide.

SA-I-4 **Code Enforcement.** Continue to maintain and enforce appropriate standards to ensure new development is designed to meet current safety standards associated with seismic activity.

SA-I-5 **Seismic Rehabilitation Flagging.** Identify and catalogue structures that may be subject to serious structural damage in the event of a major earthquake, and provide information to property owners on ways to pay for rehabilitation of existing buildings.

SA-I-6 **Restrictions on Mitigation Measures.** Prohibit mitigation measures for potential geotechnical hazards if those measures could adversely affect surrounding prop-

erty, including the use of public rights-of-way or adversely affect public health, safety, and welfare.

SA-I-8 **Geotechnical Studies.** Within the Coastal Zone and hillside areas, continue to require geotechnical site investigation for proposed development on sites located in any of the following areas, prior to allowing site development:

SA-I-9 **Maintain Restrictions on Hazardous Areas.** Continue enforcing the existing Coastal Zone Combing District and Hillside Preservation District regulations that restrict development in hazardous areas where access is impractical and areas prone to hillside and coastal erosion, landslides, seismic shaking, tsunami inundation, or flooding.

Mitigation Measures

None required.

Impact

3.6-2 Implementation of the proposed General Plan would not result in substantial soil erosion or topsoil loss. *(Less than Significant)*

Development associated with the proposed General Plan would likely include earthwork activities that could expose soils to the effects of erosion or loss of topsoil. Once disturbed, either through removal of vegetation, asphalt, or an entire structure, stockpiled soils if not managed appropriately are left exposed to the effects of wind and water. Generally, earthwork and ground-disturbing activities, unless below minimum requirements, require a grading permit, compliance with which minimizes erosion, and the City's grading permit requirements ensure that construction practices include measures to protect exposed soils such as limiting work to dry seasons, covering stockpiled soils and use of straw bales and silt fences to minimize offsite sedimentation.

In addition, development that disturbs more than one acre would be subject to compliance with a National Pollutant Discharge Elimination System (NPDES) permit, including the implementation of best management practices (BMPs), some of which are specifically implemented to reduce soil erosion or loss of topsoil, and the implementation of a storm water pollution prevention plan (SWPPP) through the local jurisdiction. BMPs that are required under a SWPPP include erosion prevention measures that have proven effective in limiting soil erosion and loss of topsoil. Generally, once construction is complete and exposed areas are revegetated or covered by buildings, asphalt, or concrete, the erosion hazard is substantially eliminated or reduced.

The Planning Area contains rugged coastline areas that are susceptible to coastal erosion from wave action. Whereas 30 to 50 years ago engineering methods of introducing hard barriers to protect shoreline improvements were common, soft stabilization methods have proven more effective in maintaining natural systems of sand transport. Soft stabilization methods include sand and cobble beach fills which can more closely mimic natural conditions and re-

spond to changes in wave action and would be encouraged with implementation of the proposed policies below.

According to a study done by the U.S. Geological Survey following the heavy winter storms of 1982–1983, the entire coastline of San Mateo County contains areas susceptible to severe erosion and slope failure.[23] Coastal areas within the Planning Area include locations that the USGS have determined to have critical erosion hazards and unstable segments where the sedimentary rocks are susceptible to failure from heavy wave action. Implementation of the proposed policies below would help reduce this hazard.

Therefore, the potential for adverse landslide impacts related to land use changes from implementation of the proposed General Plan is less than significant with implementation of the proposed policies below.

Proposed General Plan that Reduce the Impact

Safety Element

Policies SA-G-1, SA-I-9, listed above.

SA-I-7 **Erosion Prevention.** Require erosion prevention of hillside areas by revegetation or other acceptable methods.

SA-I-10 **Soil Study.** Require any geotechnical studies to include study of expansive and creeping soils, as well as analysis of erosion, seismic, tsunami, and other geotechnical hazards and make recommendations, as warranted.

SA-I-16 **Seawalls and Shoreline Protection.** Prohibit any new development that would require the use of seawalls or other shoreline alterations for protection either now or in the future. Alterations to the coastline shall be permitted only where necessary to protect existing development or public resources, and must minimize adverse impacts to natural coastal processes. Wherever feasible, shoreline protection shall take the form of non-structural measures, such as setback, redesign, relocation or beach replenishment.

SA-I-19 **Accessory Structures in Coastal Zone.** Amend the Zoning Ordinance to require new accessory structures within the Coastal Zone to be constructed so they can be easily relocated should they become threatened by erosion.

SA-I-20 **Wave Up-rush Studies.** Update the Zoning Ordinance to require wave uprush studies for new development at beach level and in low-lying areas.

[23] USGS, 2009.

- At a minimum, require wave up-rush studies to evaluate the consequences of a low-probability wave event (1 percent annual probability) with the following beach and water conditions:
  - Seasonally eroded beach with long-term erosion comparable to what could be expected to occur over the life of the proposed development; and
  - High tide combined with the increase in mean sea level expected to occur over the life of the proposed development.
- Require development to be sited to avoid the zone of wave run-up. If complete avoidance is not practical, avoidance should be maximized, and development should be designed, through features such as elevation, to protect against the consequences of unavoidable hazards.

SA-I-21 **Regional Sediment Management.** Participate in regional approaches to protecting, enhancing and restoring coastal beaches and watersheds through the California Coastal Sediment Management Workgroup, with a goal of minimizing coastal erosion.

Conservation Element

CO-I-47 **Shoreline Protection.** Continue to prohibit new development requiring shoreline alterations.

Shoreline-altering construction such as revetments, breakwaters, groins, channels, seawalls, cliff retaining walls, and similar structures is permitted only when required to serve coastal-dependent uses or to protect existing structures and public beaches in danger of erosion. Such structures, where permitted, must be designed to eliminate or mitigate adverse impacts on local shoreline sand supply.

Mitigation Measures

None required.

Impact

3.6-3 Implementation of the proposed General Plan would not locate structures on expansive soils or on a geologic unit or soil that unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse and create substantial risks to life or property. *(Less than Significant)*

Some improvements associated with implementation of the proposed General Plan could be located on geologic units or soils that are unstable, or that could become unstable and result in geologic hazards if not addressed appropriately. Areas with underlying materials that include undocumented fills, soft compressible deposits, or loose debris could be inadequate to support development, especially multi-story buildings. Soils that exhibit expansive properties when exposed to varying moisture content over time could result in damage to foundations, walls, or other improvements. Structures, including residential units and commercial build-

ings, could be damaged as a result of a settlement or differential settlement where structures are underlain by materials of varying engineering characteristics. Construction of new structures in the vicinity of relatively steep slopes could provide additional loading causing landslides or slope failure from unstable soils or geologic units. Slope failure can occur naturally through rainfall or seismic activity, or through earthwork and grading related activities.

The potential hazards of unstable soil or geologic units would be addressed largely through the integration of geotechnical information in the planning and design process for projects to determine the local soil suitability for specific projects in accordance with standard industry practices and state-provided requirements, such as CBC requirements which are used to minimize the risk associated with these hazards. Geotechnical investigations would be required to thoroughly evaluate site-specific geotechnical characteristics of subsurface soils and bedrock to assess potential hazards and recommend site preparation and design measures to address any hazards which may be present. These measures are enforced through compliance with the CBC to avoid or reduce hazards relating to unstable soils and slope failure. In addition, the proposed policies below would help ensure that potential impacts related to unstable units are minimized and would reduce the potential impact to less than significant. The potential for landslide, lateral spreading, subsidence, liquefaction, or collapse impacts related to changes from implementation of the proposed General Plan is less than significant.

Proposed General Plan Policies that Reduce the Impact

Safety Element

See Policies SA-G-1, SA-I-2, SA-I-8, SA-I-12, listed under Impact 3.6-1.

See Policies SA-I-10, SA-I-12, SA-I-NEW, listed under Impact 3.6-2.

SA-I-14 **Geologic Hazard Abatement District.** Amend the Municipal Code to include provisions for formation of geologic hazards abatement district for coastal bluffs and hillside areas at risk of landslides in Pacifica to enable cooperative efforts among property owners for protection of coastal bluffs from erosion and improvement and maintenance of drainage and protective infrastructure.

The Geologic Hazard Abatement District (GHAD) is a potentially useful tool to effectively abate a landslide hazard that crosses property boundaries. It is a mechanism that responds to the physical realities of landslides, and allows property owners to cooperate in solving a common problem. It removes much of the stigma of legal liabilities among adjacent landowners and allows them to cooperate rather than litigate. It also provides for a cost-effective solution, requiring only one geotechnical engineering firm and one plan to solve the problems of several landowners. The City may require the establishment of GHADs as a condition for new development proposed in areas of known bluff erosion or geologic hazard, such as areas identified in Figure 8-2 of the proposed General Plan as "mostly landslides." The City will undertake the following actions to facilitate formation of GHADs:

- *Identify where GHADs are appropriate or necessary;*

- *Advance funds for preparation of a Plan of Control for each proposed GHAD by a Certified Engineering Geologist describing the GHAD's boundaries, the geologic hazards affecting the GHAD, and a plan for the prevention, mitigation, abatement, or control of the hazards, with costs to be reimbursed by the GHADs.*
- *Establish a public education and outreach program to inform property owners of the benefits and responsibilities of participating in a GHAD; and*
- *Provide ongoing support of GHADs, with funding provided by the districts.*

The establishment of a GHAD would not allow development that is otherwise restricted on the basis of hazard risk, bluff erosion or geologic instability.

Mitigation Measures

None required.

Impact

3.6-4 Implementation of the proposed General Plan would not have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water. ***(No Impact)***

All proposed improvements that are part of the proposed General Plan would not require septic systems or other alternative waste water disposal systems. The City of Pacifica Sanitary Sewer Collection System Division oversees the collection and treatment of all wastewater and all proposed improvements would be tied into the existing wastewater collection. In fact, the proposed policy below would require the use of the existing collection system. Therefore, the proposed General Plan would have no impact related to soils capability to support wastewater disposal.

Proposed General Plan and Local Coastal Land Use Plan Policies that Reduce the Impact

Conservation Element

CO-I-26 **Sewer System Connections.** Require all new development to be connected to the City's sewer system.

Mitigation Measures

None required.

Cumulative Impact

3.6-5: Implementation of the proposed General Plan along with potential development in the surrounding region would not result in cumulative impacts related to geologic and seismic hazards. ***(Less than Significant)***

The geographic area considered for the cumulative geology, soils, of seismic hazards effects is the entire San Francisco Bay Area region. This region is considered seismically active and future development would expose additional people and structures to potentially adverse effects associated with earthquakes, including seismic ground shaking and seismic-related ground failure. However, site-specific geotechnical reports that would be required for future development projects would determine how each development could be designed to minimize exposure of people to these effects similar to how existing projects have been built. Future development would be constructed to standards similar to those that are required with the policies described above, which likely would exceed those of older structures within the region. Development facilitated by the proposed General Plan, as well as all other future projects, would be constructed in accordance with the most current version of the California Building Code seismic safety requirements and recommendations contained in each site-specific geotechnical report as required with the mitigations stated above.

The cumulative impact resulting from future development of the proposed General Plan combined with other past, present, or probable future projects, would be less than significant, given mandatory compliance with existing state and local building codes, existing ordinances, and General Plan policies.

Mitigation Measures

None required.

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