

2.7 Geology and Seismicity

This chapter evaluates the potential impacts related to geology and seismicity resulting from the implementation of the proposed Plan. In addition to regional geologic and seismic hazards, the potential effects of local hazards such as those risks related to underlying geologic materials and soils are also evaluated.

Environmental Setting

PHYSICAL SETTING

The physical setting describes the existing geology in the study area, soils, faults, and other seismic and geologic hazards. The setting of the study area is considered within the regional context of the geologic regime. In general terms, regional geologic conditions can help provide the anticipated conditions on a local basis.

Regional Geology

The State of California has 11 natural geologic regions, known as geomorphic provinces, which are defined by the presence of similar physical characteristics such as relief, landforms, and geology.¹ The majority of the nine-county San Francisco Bay Area is located within what is known as the Coast Range geomorphic province, with eastern portions of Solano, Contra Costa, and Alameda counties extending into the neighboring Great Valley geomorphic province located east of the Coast Ranges.

Coast Range Province

The Coast Range is a geologically complex province that extends 400 miles along the Pacific Coast, from Oregon south into Southern California. The Coast Range province is characterized by a series of northwest-trending ridges and valleys that run roughly parallel to the San Andreas fault zone, and can be further divided into the northern and southern ranges that are separated by San Francisco Bay. San Francisco Bay is a broad shallow regional structural depression, created from an east-west expansion between the San Andreas and the Hayward fault systems. In the southern Bay Area, the Santa Cruz Mountains border San Francisco Bay on the west, while the Berkeley Hills, an extension of the Diablo Range, are to the east. Mount Diablo marks the northern end of the Diablo Range, which stretches 130 miles southward to the Kettleman Hills at the cusp of the San Joaquin Valley. The broad, low-relief Santa Clara and San Benito valleys lie between the Santa Cruz Mountains and the Diablo Range. In the North

¹ California Geological Survey (CGS), *California Geomorphic Provinces*, CGS Note 36, 2002.

Bay, the rugged, mountainous character of the Marin Peninsula is dominated by Mount Tamalpais (elevation 2,604 feet above sea level).

Much of the Coast Range province is composed of marine sedimentary and volcanic rocks that form the Franciscan Assemblage, located east of the San Andreas Fault. The Franciscan Assemblage in this region of California is approximately 65 to 150 million years old and consists primarily of greenstone (altered volcanic rocks), basalt, chert (ancient silica-rich ocean deposits), and sandstone that originated as ancient sea floor sediments. The region west of the San Andreas Fault is underlain by a mass of basement rock known as the Salinian Block that is comprised of mainly marine sandstone (up to 65 million years old), and various metamorphic rocks² believed to have originated some 350 miles to the south. The Salinian Block has been moving northward along the west side of the San Andreas Fault and associated rocks can be found as far north as Point Arena.

Marginal lands surrounding San Francisco Bay consist generally of alluvial plains of low relief that slope gently bayward from the bordering uplands and foothills. The alluvial plains that comprise the Bay margin are composed of alluvial sediments (up to two million years old) consisting of unconsolidated stream and basin deposits. These alluvial plains terminate bayward at the tidal marshlands that immediately surround the Bay. Marshlands are composed of intertidal deposits, including widely found fine-grained plastic clays commonly referred to as Bay Mud, which, in some areas, underlies artificial fills. Historic shoreline reclamation projects beginning at the turn of the twentieth century have resulted in the placement of varying types of man-made artificial fill that overlie intertidal deposits. San Francisco Bay is originally believed to have encompassed 700 square miles, although dredging and fill operations have reduced the Bay to approximately 400 square miles.

Great Valley

Portions of Solano, Contra Costa, and Alameda Counties are located in the Great Valley geomorphic province, which is characterized by a large, nearly level inland alluvial plain 400 miles in length and averaging 50 miles in width. The topography of the Great Valley is flat, but slopes gently along its eastern margin (Sierra Nevada foothills) and western margin (Coast Ranges). Sediments in the Great Valley consist of gravels, sands, clays, and silts that originated largely from the Sierras, with sediments from the Coast Range contributing to a lesser extent. The sediments that compose the valley floor are thick, and in some areas extend as far as 10 miles below the surface. The Great Valley Sequence, a thick section of ancient sea floor sediments extending under the Great Valley, overlies the Coast Range Franciscan Assemblage along the valley's western flank.

Soils

A wide variety of soils and soil types can be found throughout the nine-county Bay Area region. Soils in the Bay Area fall within four major classifications established by the United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS). Depending on localized conditions, these general classifications are grouped into more specific soil types by location, climate, and slope. The Santa Clara valley and the alluvial plains surrounding San Francisco Bay are classified as deep alluvial plain and floodplain soils. These soils occupy the valleys in areas with higher rainfall and are considered

² Metamorphic rocks are sedimentary or volcanic rocks altered by prolonged heating and deformation.

productive when drained and fertilized. Soils closer to the Bay margin are generally dark-colored clays that have a high water table or are subject to overflow from flooding. Soils at the extreme edge of San Francisco Bay have a moderate to high content of soluble salts; these soils are referred to as alkali soils. Soils in northern San Mateo County, the eastern portion of San Francisco, and Marin County are classified as residual soils and are characterized by moderate depth to underlying bedrock. However, much of the Bay Area has been developed and in urbanized areas, native soils are commonly no longer present or have been reworked and combined with imported fill materials over a long history of earthwork activities associated with development.

Seismologists have observed differences in seismic shaking effects that are partially dependent on underlying soil deposits. Soft soils are known to amplify ground shaking and are considered in seismic design requirements. The National Earthquake Hazards Reduction Program (NEHRP) has defined five soil types based on several different criteria. The USGS has modified these definitions slightly, based on studies of earthquake damage in the Bay Area.³ The modified definitions are below:

Soil Type A: Includes unweathered intrusive igneous rock. Occurs infrequently in the Bay Area. Does not contribute greatly to shaking amplification.

Soil Type B: Includes volcanics, most Mesozoic bedrock, and some Franciscan bedrock. (Mesozoic rocks are between 245 and 64 million years old. The Franciscan Complex is a Mesozoic unit that is common in the Bay Area.) Does not contribute greatly to shaking amplification.

Soil Type C: Includes some Quaternary (less than 1.8 million years old) sands, sandstones and mudstones, some Upper Tertiary (1.8 to 24 million years old) sandstones, mudstones and limestone, some Lower Tertiary (24 to 64 million years old) mudstones and sandstones, and Franciscan melange and serpentinite. Can contribute to shaking amplification depending on site-specific characteristics.

Soil Type D: Includes some Quaternary muds, sands, gravels, silts and mud. Significant amplification of shaking by these soils is generally expected.

Soil Type E: Includes water-saturated mud and artificial fill. The strongest amplification of shaking is expected for this soil type.

³ United States Geological Survey, *Soil Type and Shaking Hazard in the San Francisco Bay Area*, <http://earthquake.usgs.gov/regional/nca/soiltype/>, accessed August 3, 2012.

Seismicity

The Bay Area is considered a region of high seismic activity with numerous active and potentially active faults capable of producing significant seismic events.⁴ The U.S. Geological Survey (USGS) Working Group on California Earthquake Probabilities has evaluated the probability of one or more earthquakes occurring in the Bay Area and concluded that there is currently a 63 percent likelihood of a magnitude 6.7 or higher earthquake occurring in the Bay Area by 2037.⁵

The San Andreas and the Hayward faults are the two faults considered to have the highest probabilities of causing a significant seismic event in the Bay Area. These two faults are classified as strike-slip-type faults⁶ that have experienced movement within the last 150 years. The San Andreas Fault is a major structural feature in the region and forms a boundary between the North American and Pacific tectonic plates. Other principal faults capable of producing significant Bay Area ground shaking are listed in **Table 2.7-1** and shown on **Figure 2.7-1**, and include the Calaveras fault, the Rodgers Creek fault, and the Concord–Green Valley faults. A major seismic event on any of these active faults could cause significant ground shaking and surface fault rupture, as was experienced during earthquakes in recorded history, namely the 1868 Hayward earthquake, the 1906 San Francisco earthquake, and the 1989 Loma Prieta earthquake. The estimated magnitudes (moment) identified in **Table 2.7-1** represent *characteristic* earthquakes on particular faults.⁷ In addition, active blind- and reverse-thrust faults⁸ in the region that accommodate compressional movement include the Monte Vista–Shannon and Mount Diablo faults.

⁴ An active fault is defined by the State of California as a fault that has had surface displacement within Holocene time (approximately the last 10,000 years). A potentially active fault is defined as a fault that has shown evidence of surface displacement during the Quaternary (last 1.6 million years), unless direct geologic evidence demonstrates inactivity for all of the Holocene or longer. This definition does not 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 Holocene displacement occurred on one or more of its segments or branches (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 Geological Survey, Special Publication 42, 1990, revised 1997).

⁵ United States Geological Survey (USGS) Working Group on California Earthquake Probabilities (WG02), Fact Sheet 2008-2037, *Forecasting California’s Earthquakes – What Can We Expect in the Next 30 Years?*, <http://pubs.usgs.gov/fs/2008/3027/fs2008-3027.pdf>, 2008.

⁶ “Strike-slip” faults primarily exhibit displacement in a horizontal direction, but may have a vertical component. Right-lateral strike-slip movement of the San Andreas fault, for example, means that the western portion of the fault is slowly moving north while relative motion of the eastern side is to the south.

⁷ Moment magnitude is related to the physical size of a fault rupture and movement across a fault, while Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event. The concept of “characteristic” earthquake means that we can anticipate, with reasonable certainty, the actual damaging earthquakes [the size of the earthquakes] that can occur on a fault.

⁸ A reverse fault is one with predominantly vertical movement in which the upper block moves upward in relation to the lower block; a thrust fault is a low-angle reverse fault. Blind-thrust faults are low-angled subterranean faults that have no surface expression.

TABLE 2.7-1: ACTIVE FAULTS IN THE BAY AREA¹

<i>Fault</i>	<i>Recency of Movement</i>	<i>Historical Seismicity²</i>	<i>Maximum Moment Magnitude Earthquake (Mw)³</i>
Hayward	1868 Holocene	M6.8, 1868 Many <M4.5	7.1
San Andreas	1989 Holocene	M7.1, 1989 M8.25, 1906 M7.0, 1838 Many <M6	7.9
Rodgers Creek- Healdsburg	1969 Holocene	M6.7, 1898 M5.6, 5.7, 1969	7.0
Concord–Green Valley	1955 Holocene	Historic active creep	6.9
Marsh Creek-Greenville	1980 Holocene	M5.6 1980	6.9
San Gregorio–Hosgri	Holocene; Late Quaternary	Many M3-6.4	7.3
West Napa	2000 Holocene	M5.2 2000	6.5
Maacama	Holocene	Historic active creep	7.1
Calaveras	1990 Holocene	M5.6-M6.4, 1861 M4 to M4.5 swarms 1970, 1990	6.8
Mt. Diablo Thrust	Quaternary (possibly active)	n/a	6.7

Notes:

1. See footnote 4 of the text for definition of active faults.
2. Richter magnitude (M) and year for recent and/or large events. Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave.
3. The maximum moment magnitude earthquake (Mw), derived from the joint CGS/USGS Probabilistic Seismic Hazard Assessment for the State of California, 1996. (CGS OFR 96-08 and USGS OFR 96-706).

Sources: CGS, 1996, Hart, 1997; Jennings, 1997; Peterson, 1996, WGCEP, 2008.

Geologic and Seismic Hazards

Surface Fault Rupture

Seismically induced ground rupture is defined as the physical displacement of surface deposits in response to an earthquake's seismic waves. The magnitude and nature of fault rupture can vary for different faults or even along different strands of the same fault. Future faulting is generally expected along different segments of faults with recent activity.⁹ Structures, transportation facilities, and utility systems crossing fault traces are at risk during a major earthquake due to ground rupture caused by differential lateral and vertical movement on opposite sides of the active fault trace. Lateral displacement may range from a few inches to over 20 feet, as occurred in the 1906 San Francisco earthquake. Thrust faults as well as faults with strike-slip movement can have a vertical displacement component that can total several feet.

However, the exception to obvious surface displacement is the “blind-thrust” fault. The Mt. Diablo blind-thrust fault, for example, is a newly recognized earthquake source for the Bay Area. It has been mapped on the western base of Mt. Diablo on the east side of the San Ramon Valley. The USGS Working Group on California Earthquake Probabilities recommended that this particular thrust fault be considered in their seismic probability calculations. This fault is considered a “blind thrust” because it does not exhibit a surficial expression of displacement. The Mt. Diablo thrust fault slips at a long-term rate of about 3 millimeters/year, but has not been zoned as an active fault under the Alquist-Priolo Act due to the inability to identify its exact location on the surface (see description of the Act in the Regulatory Setting section of this chapter).¹⁰

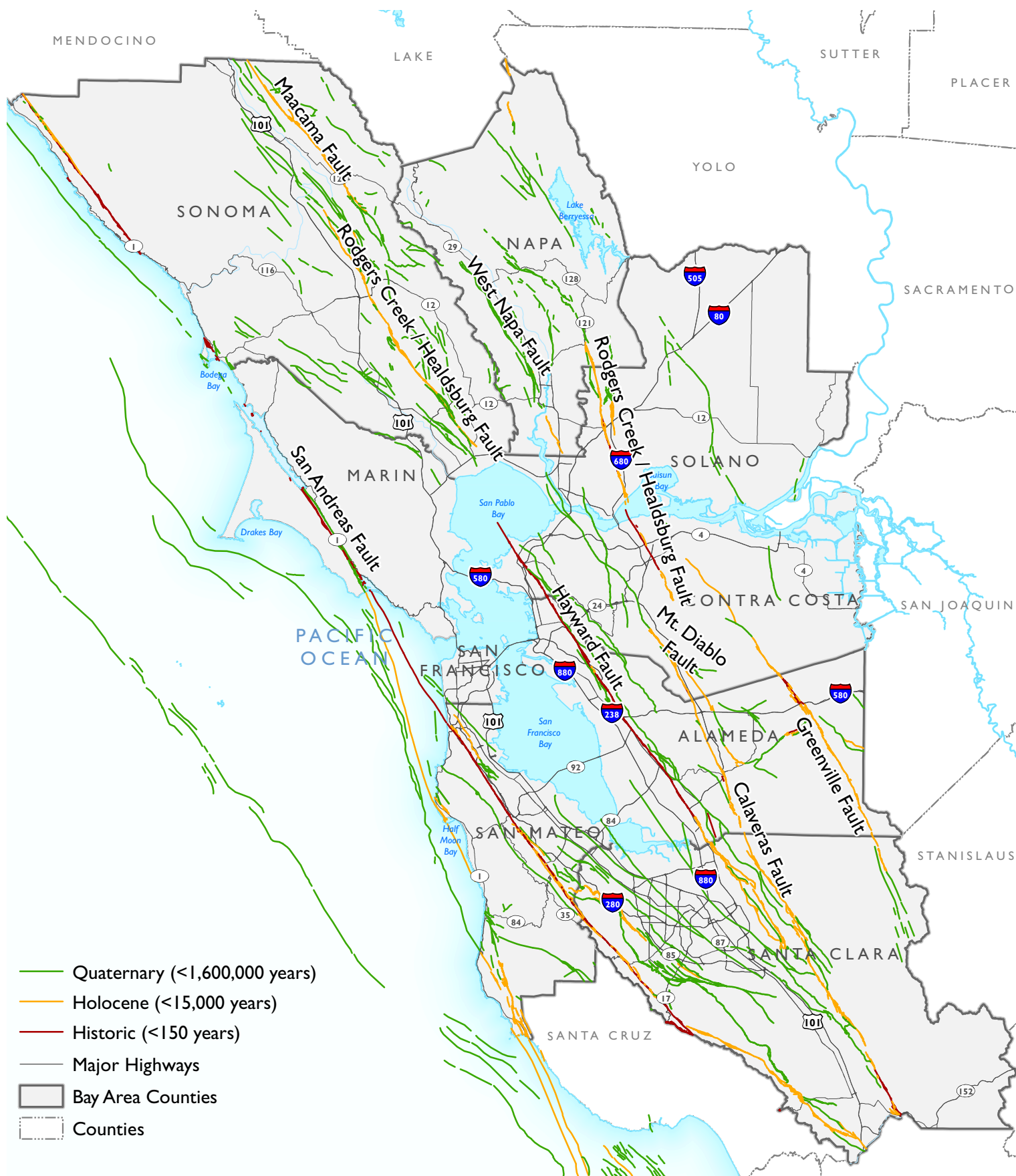
Although multiple active and potentially active faults are located within the Bay Area, ground rupture is most likely to occur along active faults zoned as Earthquake Fault Zones under mandate of the Alquist-Priolo Act. It is important to note that surface fault rupture is not necessarily restricted to the area within an Alquist-Priolo Zone. Additionally, ground rupture is possible on both active and potentially active faults not zoned as Earthquake Fault Zones, although these faults are considered less susceptible to ground rupture hazards than the principally active faults listed in **Table 2.7-1**.

⁹ California Geological Survey, *Guidelines for Evaluating and Mitigation Seismic Hazards*, CGS Special Publication 117, 1997.

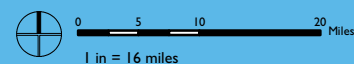
¹⁰ USGS, 2003.

Figure 2.7-1

Principal Faults



Data Source: Quaternary Faults, U.S. Geological Survey, 2010; ESA, 2012; Cal-Atlas Geospatial Clearinghouse, 2012; Tom Tom North America, 2011; Dyett & Bhatia, 2012.



This page intentionally left blank.

Ground Shaking

Strong ground movement from a major earthquake could affect the Bay Area during the next 30 years. Ground shaking may affect areas hundreds of miles distant from the earthquake's epicenter. The intensity of ground movement during an earthquake can vary depending on the overall magnitude, distance from the fault, focus of earthquake energy, and type of geologic material.

Areas that are 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 2.7-2**) is a common measure of earthquake effects due to ground shaking intensity. The MM values for 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.¹¹

TABLE 2.7-2: MODIFIED MERCALLI INTENSITY SCALE

	<i>Intensity Description</i>	<i>Average Peak Acceleration¹</i>
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

¹¹ 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 2.7-2: MODIFIED MERCALLI INTENSITY SCALE

	<i>Intensity Description</i>	<i>Average Peak Acceleration¹</i>
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
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: ABAG, 2003 and California Geological Survey, 2003.

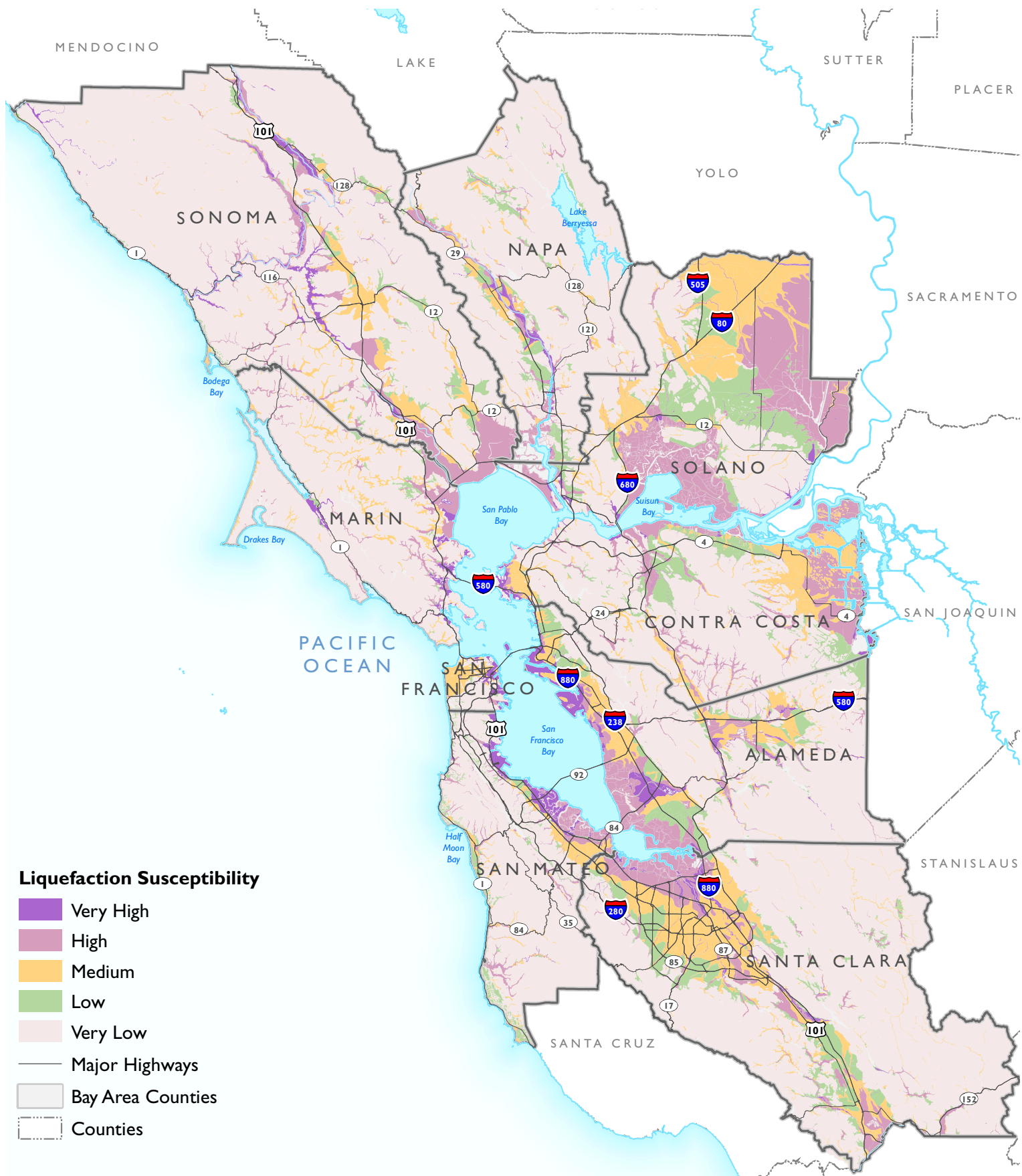
Areas most susceptible to intense ground shaking are those areas located closest to the earthquake-generating fault, and areas underlain by thick, loosely unconsolidated, saturated sediments, particularly soft, saturated Bay Muds and artificial fill along the tidal margins of San Francisco Bay.

Liquefaction

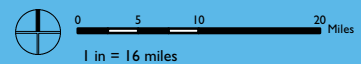
Liquefaction is a phenomenon whereby unconsolidated and/or near saturated soils lose cohesion and are converted to a fluid state as a result of severe vibration. The relatively rapid loss of soil shear strength during strong earthquake shaking results in the temporary fluid-like behavior of the soil. Soil liquefaction causes ground failure that can damage roads, airport runways, pipelines, underground cables, and buildings with shallow foundations. Liquefaction can occur in areas characterized by water-saturated, cohesion-less, granular materials at shallow depths, or in saturated unconsolidated or artificial fill sediments located in reclaimed areas along the margin of San Francisco Bay. Liquefaction potential is highest in areas underlain by shallow groundwater and Bay fills, Bay Mud, and unconsolidated alluvium. **Figure 2.7-2** illustrates liquefaction susceptibility in the Bay Area.

Figure 2.7-2

Liquefaction



Data Source: U.S. Geological Survey, 2006; ESA, 2012; Cal-Atlas Geospatial Clearinghouse, 2012; Tom Tom North America, 2011; Dyett & Bhatia, 2012.



This page intentionally left blank.

Expansive Soils

Expansive soils possess a “shrink-swell” characteristic. Shrink-swell is the cyclic change in volume (expansion and contraction) that occurs in fine-grained clay sediments from the process of wetting and drying. Changes in soil moisture can result from rainfall, landscape irrigation, utility leakage, roof drainage, and/or perched groundwater.¹² Expansive soils are typically very fine grained and have a high to very high percentage of clay. Structural damage may occur incrementally over a long period of time, usually as a result of inadequate soil and foundation engineering or the placement of structures directly on expansive soils. Soils with high clay content, such as the Bay Muds located on the margins of the San Francisco Bay, are highly expansive.

Soil Erosion

Soil erosion is the process whereby soil materials are worn away and transported to another area, either by wind or water. Rates of erosion can vary depending on soil material and structure, building placement, and human activity. The potential for soil erosion is variable throughout the Bay Area. Soil with high amounts of silt can be easily eroded, while sandy soils are less susceptible to erosion. Excessive soil erosion can eventually damage building foundations, roadways, and dam embankments. Erosion is most likely on sloped areas with exposed soil, especially where unnatural slopes are created by cut-and-fill activities. Soil erosion rates can therefore be higher during the construction phase. Typically, the soil erosion potential is reduced once the soil is graded and covered with concrete, structures, or asphalt.

Settlement

Settlement is the depression of the bearing soil when a load, such as that of a building or new fill material, is placed upon it. Settlement can occur from immediate settlement, consolidation, shrinkage of expansive soil, and liquefaction (discussed above). 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, which is a phenomenon referred to as differential settlement. Areas are susceptible to differential settlement if underlain by compressible sediments, such as poorly engineered artificial fill or the “Bay Mud” present in the marshland on the San Francisco Bay margin.

Earthquake-Induced Settlement

Settlement of the ground surface can be accelerated and accentuated by earthquakes. During an earthquake, settlement can occur as a result of the relatively rapid compaction and settling of subsurface materials (particularly loose, non-compacted, and variable sandy sediments) due to the rearrangement of soil particles during prolonged ground shaking. Settlement can occur both uniformly and differentially

¹² Perched groundwater is a local saturated zone above the water table that typically exists above an impervious layer (such as clay) of limited extent.

(i.e., where adjoining areas settle at different rates). Areas are susceptible to differential settlement if underlain by compressible sediments, such as poorly engineered artificial fill or Bay Mud.

Landslides

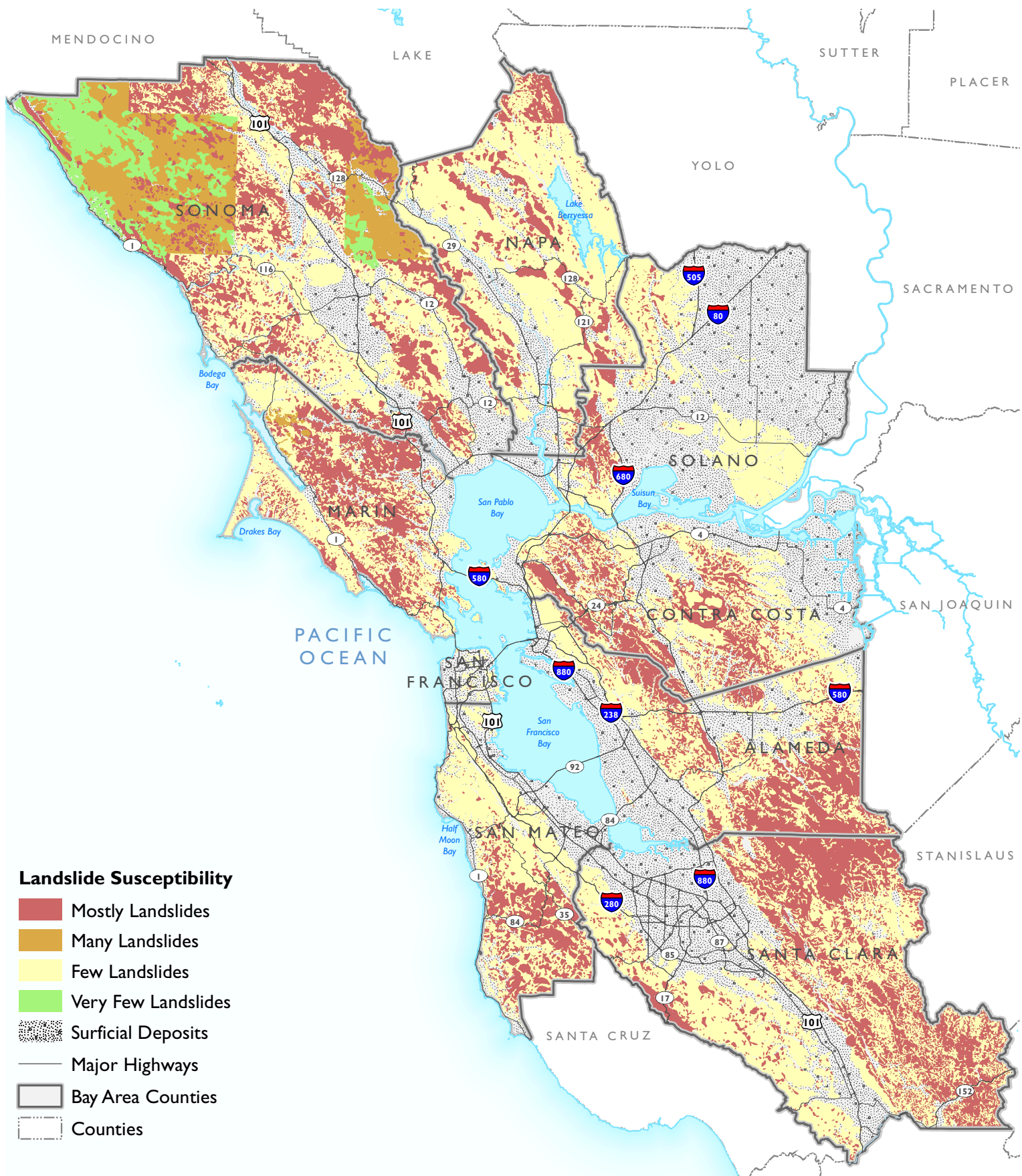
Slope failures, commonly referred to as landslides, include many phenomena that involve the downslope displacement and movement of material, either triggered by static (i.e., gravity) or dynamic (i.e., earthquake) forces. A slope failure is a mass of rock, soil, and debris displaced downslope by sliding, 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 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 affects 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.

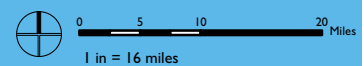
Earthquake motions can induce significant horizontal and vertical dynamic stresses in slopes that can trigger failure. Earthquake-induced landslides can occur in areas with steep slopes that are susceptible to strong ground motion during an earthquake. Areas of known landslide hazards in the region are shown in **Figure 2.7-3**.

Figure 2.7-3

Landslides



Data Source: U.S. Geological Survey, 1997; ESA, 2012; Cal-Atlas Geospatial Clearinghouse, 2012; Tom Tom North America, 2011; Dyett & Bhatia, 2012.



This page intentionally left blank.

REGULATORY SETTING

Federal Regulations

Earthquake Hazards Reduction Act

The Earthquake Hazards Reduction Act was enacted in 1977 to “*reduce the risks to life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards and reduction program.*” To accomplish this, the Act established the National Earthquake Hazards Reduction Program (NEHRP). This program was significantly amended in November 1990 by NEHRP, which refined the description of agency responsibilities, program goals, and objectives.

NEHRP’s mission includes improved understanding, characterization, and prediction of hazards and vulnerabilities; improvement of building codes and land use practices; risk reduction through post-earthquake investigations and education; development and improvement of design and construction techniques; improvement of mitigation capacity; and accelerated application of research results. The NEHRP designates the Federal Emergency Management Agency (FEMA) as the lead agency of the program and assigns it several planning, coordinating, and reporting responsibilities. Programs under NEHRP help inform and guide planning and building code requirements such as emergency evacuation responsibilities and seismic code standards.

Disaster Mitigation Act of 2000

The Disaster Mitigation Act of 2000 (DMA2K) (Public Law 106-390) amended the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 to establish a Pre-Disaster Mitigation (PDM) program and new requirements for the federal post-disaster Hazard Mitigation Grant Program (HMGP). DMA2K encourages and rewards local and state pre-disaster planning. It promotes sustainability, and seeks to integrate state and local planning with an overall goal of strengthening statewide hazard mitigation. This enhanced planning approach enables local, tribal, and state governments to identify specific strategies for reducing probable impacts of natural hazards such as floods, fire, and earthquakes. In order to be eligible for hazard mitigation funding after November 1, 2004, local governments are required to develop a Hazard Mitigation Plan that incorporates specific program elements of the DMA2K law. In the Bay Area, ABAG has adopted a multi-jurisdictional FEMA-approved 2010 Local Hazard Mitigation Plan Update, which cities and counties can adopt and use, in full or in part, in lieu of preparing all or part of a Local Hazard Mitigation Plan themselves.¹³

State Regulations

Alquist-Priolo Earthquake Fault Zoning Act

The Alquist-Priolo Earthquake Fault Zoning Act (formerly the Alquist-Priolo Special Studies Zone Act) of 1972 (revised in 1994) is the State law that addresses hazards from earthquake fault zones and requires the delineation of zones along active faults. The purpose of this law is to mitigate the hazard of surface fault rupture by regulating development on or near active faults. As required by the Act, the State has

¹³ Multi-Jurisdictional Local Hazard Mitigation Plan for the San Francisco Bay Area, ABAG 2010, <http://quake.abag.ca.gov/wp-content/documents/ThePlan-Chapters-Intro.pdf>

delineated Earthquake Fault Zones (formerly Special Studies Zones) along known active faults in California. Cities and counties must regulate certain development projects within these zones.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act was developed to protect the public from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and from other hazards caused by earthquakes. This Act 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. Before a development permit may be granted for a site within a Seismic Hazard Zone, a geotechnical investigation of the site must be conducted and appropriate mitigation measures incorporated into the project design. The Bay Area includes numerous Seismic Hazard Zones for liquefaction and earthquake induced landslides, as designated by the California Geological Survey. Therefore, any projects in these designated zones require evaluation and mitigation of potential liquefaction or landslide hazards, which must be conducted in accordance with the California Geological Survey, Special Publication 117, adopted March 13, 1997 by the State Mining and Geology Board pursuant to the Seismic Hazards Mapping Act.

California Building Code

The California Building Code (CBC) has been codified in the California Code of Regulations (CCR) as Title 24, Part 2. 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 its jurisdiction. The 2010 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) as well as SDC F (Hospitals, Police Stations Emergency control centers etc. in areas near major active faults). Design specifications are then determined according to the SDC in accordance with Chapter 16 of the CBC. 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 SDC 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 part incorporates by adoption the 2009 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.

Regional and Local Regulations

General Plans and Safety Elements

City and county governments develop, as part of a general plan, safety elements that identify goals, objectives, and implementing actions to minimize the loss of life, property damage, and disruption of goods and services from disasters, including floods, fires, non-seismic geologic hazards, and earthquakes. General plans can provide policies and establish the basis for ordinances to ensure acceptable protection of people and structures from risks associated with these hazards. Ordinances can include those addressing unreinforced masonry construction, erosion, or grading.

Hazard Mitigation Plans

As discussed above, in February 2011, ABAG adopted the 2010 multi-jurisdictional Hazard Mitigation Plan for the Bay Area, originally adopted in 2005. Participating local county and city governments in the Bay Area prepare an Annex to this plan to explain how the plan specifically applies to that agency.

Impact Analysis

IMPACT SIGNIFICANCE CRITERIA

Impacts of the environment on a project or plan (as opposed to impacts of a project or plan on the environment) are beyond the scope of required CEQA review. “[T]he purpose of an EIR is to identify the significant effects of a project on the environment, not the significant effects of the environment on the project.” (*Ballona Wetlands Land Trust v. City of Los Angeles* (2011) 201 Cal.App.4th 455, 473.) The impacts discussed in this section related to increased exposure of people or structures to risks associated with seismic occurrences and location of people or structures on unstable geologic units are effects on users of the project and structures in the project of preexisting environmental hazards, and therefore “do not relate to environmental impacts under CEQA and cannot support an argument that the effects of the environment on the project must be analyzed in an EIR.” (*Id.* at p. 474.) Nonetheless, an analysis of these impacts is provided for information purposes.

Implementation of the proposed Plan Bay Area would have a potentially significant adverse impact related to geology and seismicity if the Plan would:

- Criterion 1:** Increase exposure of people or structures to the risk of property loss, injury, or death involving: rupture of a known 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.
- Criterion 2:** Increase exposure of people or structures to the risk of property loss, injury, or death involving strong seismic ground shaking.
- Criterion 3:** Increase exposure of people or structures to the risk of property loss, injury, or death involving seismic-related ground failure including liquefaction.
- Criterion 4:** Increase exposure of people or structures to the risk of property loss, injury, or death involving landslides.
- Criterion 5:** Result in substantial soil erosion or topsoil loss.
- Criterion 6:** Locate projects on a geologic unit or soil that is unstable or that would become unstable as a result of the project; on expansive soils (high shrink-swell potential), as defined in Section 1803A of the 2010 California Building Code (the most recent version of the California Building Code); or on weak, unconsolidated soils, creating substantial risks to life or property from on- or off-site landslide, lateral spreading, liquefaction, or collapse.

METHOD OF ANALYSIS

Impacts are identified for the proposed Plan as a whole and for specific land use and transportation projects involving new construction as compared to existing conditions. Projects that do not include the construction of infrastructure, such as local road maintenance, wheelchair curb ramps, or traffic light coordination, would utilize existing transportation infrastructure or would result in negligible alterations to these facilities. In contrast, land use development projects and other transportation projects in the

proposed Plan would include the construction or expansion of elevated interchanges, roadways, bridges, tunnels, transit buildings, and parking lots. The proposed land use development that would occur under the proposed Plan would primarily be located within Priority Development Areas (PDAs) but may also extend outside of these areas. Since the majority of development and growth would occur in these areas, the analysis focuses on PDA areas for land use impacts but also recognizes that some projects would occur outside of the PDAs. Some of these projects, based upon generalized geology maps from United States Geological Survey and California Geological Survey, which provide broad information on the locations of active faults in the Bay Area and areas of liquefaction or landslide potential, may be susceptible to particular seismic hazards such as strong ground shaking due to their location near active faults. This is a program-level analysis based upon generalized potential impacts associated with seismic hazards present in the Bay Area.

SUMMARY OF IMPACTS

The Bay Area contains a wide range of geologic conditions and the entire area is susceptible to the seismic hazards associated with the many active and potentially active faults found in and around the region. These faults could potentially generate seismic ground shaking capable of damaging existing and proposed improvements especially with older structures. As a consequence, new land use and transportation improvements would be exposed to both the direct and indirect effects of earthquakes as well as other existing geological hazards such as landslides and unstable soils. Potential effects from surface fault rupture and severe ground shaking could cause catastrophic damage to transportation infrastructure and development, particularly elevated structures, if not engineered appropriately. New development associated with the land use and new transportation facility designs would be required by current building codes to incorporate the latest scientific findings into site preparations and seismic design.

Direct Impacts

The projected population increase in the Bay Area will result in increased travel on all modes of transportation and new land use development to accommodate new households and jobs. Direct impacts associated with earthquakes include construction of new development and new transportation facilities that would increase the risk of exposure of people and property to the potentially damaging effects of strong seismic shaking, fault rupture, liquefaction and potential tsunamis, and seismically-induced ground failure and slope instability on both existing and proposed improvements. Over time, settlement of unconsolidated soils or soft compressible soils such as Bay Mud can also pose problems to facilities. The potential for structural failures, injuries and loss of life would be greatest on raised structures, on unengineered soils and within fault zones. However, proposed improvements would be constructed to current building and seismic engineering standards which are generally more conservative than have existed in the past.

Short Term Impacts

Short-term impacts are those that could potentially occur during construction of proposed improvements when temporary disturbance to underlying materials occurs. In general, the potential for soil erosion is often highest during the preliminary stages of construction, especially during initial site grading. In addition to causing sedimentation problems in storm drain systems, rapid water erosion could remove topsoil, cause deeply incised gullies on slopes, or undermine engineered soils beneath foundations and paved surfaces.

Long Term Impacts

Road cuts could expose soils to erosion over the life of the project, creating potential landslide and falling rock hazards. Engineered roadways can be undercut over time by uncontrolled stormwater drainage. Projects on steep grades or those requiring substantial amounts of cut and fill would pose the greatest potential for slides and erosion impacts. Engineered soils could also erode due to poor construction methods and design features or lack of maintenance. Use of appropriate construction methods, earthwork design, and road cut design could reduce this potential impact to a less-than-significant level.

Other Impacts

The proposed Plan includes land use development, redevelopment, and improvements to transit service, roadways, interchanges, and overpasses throughout the Bay Area. All new construction, including potentially vulnerable elevated structures and bridges, would be designed to current seismic standards that are routinely updated in the California Building Code in addition to any local additional requirements. It is expected that as a result of these efforts, implementation of the proposed Plan would protect future residents from catastrophic failure, improve the survivability of the Bay Area transportation system, reduce the risk to travelers using existing retrofitted and new transportation facilities, and reduce the overall magnitude and extent of social and economic disruption in the event of a major seismic event.

IMPACTS AND MITIGATION MEASURES

Impact

2.7-1: Implementation of the proposed Plan could expose people or structures to substantial risk of property loss, injury or death related to fault rupture.

Impacts of Land Use Projects

Surface fault rupture could occur along any of the active fault trace or within the associated Alquist Priolo Earthquake Fault Zone (Alquist-Priolo Zone) for the active faults that have been identified within the Planning Area (see **Figure 2.7-1**). Although fault rupture is not necessarily confined to the boundaries of an Alquist-Priolo Zone, the likelihood of rupture occurring outside of these zones is considered very low based on historical evidence and 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. Buried thrust faults and inferred faults are located within the boundaries of the planning area; however, they do not typically experience surface ruptures and are not officially recognized by the Alquist-Priolo Earthquake Fault Zoning Act. Development associated with the proposed Plan would include a variety of land uses, ranging from residential to commercial to industrial, that would increase the number of people (from 7,091,000 in 2010 to 9,196,000 in 2040), structures, and density of housing and jobs—particularly in the Priority Development Areas—that could potentially be exposed to hazards as a result of surface fault rupture.

The PDAs, where the majority of growth would occur, that either fully or partially intersect Alquist-Priolo Zones within the Planning Area are listed below in **Table 2.7-3** along with the associated acreage that intersects Alquist-Priolo Zones.

TABLE 2.7-3: PRIORITY DEVELOPMENT AREAS (PDAS) LOCATED IN FAULT RUPTURE ZONES

	<i>PDA Description</i>	<i>Acreage within Alquist-Priolo Zone</i>
1	American Canyon: Highway 29 Corridor	116
2	Benecia: Northern Gateway	56
3	Concord: Downtown	83
4	Dublin: Downtown Specific Plan Area	81
5	Dublin: Transit Center/Dublin Crossings	464
6	East 14 th Street and Mission Boulevard Mixed Use Corridor	104
7	Fremont: City Center	157
8	Fremont: Irvington District	115
9	Hayward: Downtown	31
10	Hayward: Mission Boulevard Corridor	91
11	Livermore: Vasco Road Station Planning Area	168
12	Oakland: Transit Oriented Development Corridors	136
13	Richmond: San Pablo Avenue Corridor	8
14	San Pablo: San Pablo Avenue	25

Source: Jennings, 2010, MTC, 2012.

While there are estimates of the location of proposed new development, which will be focused in PDAs but may occur both within and outside of PDA areas, specific locations of potential future projects are not known at this time, and therefore it cannot be stated whether these subsequent projects may be proposed on or near an identified Alquist-Priolo Zone. Therefore, the impacts related to fault rupture hazards at the regional and local level are considered potentially significant (PS). See Mitigation Measure 2.7(a) below.

Impacts of Transportation Projects

As noted above for the land use projects, surface fault rupture could cause displacement of the ground surface, resulting in substantial damage to transportation improvements including transit expansion projects, foundations, roadways, roadway interchanges, and utilities. Improvements associated with the transportation projects within the region would include a variety of different projects that could potentially be exposed to hazards as a result of surface fault rupture. The full list of transportation projects that are located within or partially within an identified Alquist-Priolo Zone is provided in Appendix F. Projects such as interchange improvements to existing roadways that are located within an Alquist-Priolo Zone may not represent any substantially changed risk or hazard but would nonetheless be part of a required geotechnical investigation to fully evaluate the level of potential damage from fault rupture. The potential for adverse fault impacts related to transportation projects from implementation of the proposed Plan at the regional and local level is considered potentially significant (PS) for Impact 2.7-1. See Mitigation Measure 2.7(a) below.

Combined Effects

Land use and transportation project effects related to fault rupture hazards are site specific and dependent solely on the location of the individual projects in relation to the active fault traces. The potential for adverse fault impacts related to land use changes from implementation of the proposed Plan at the regional and local level is considered potentially significant (PS) for Impact 2.7-1. See Mitigation Measure 2.7(a) below.

Mitigation Measures

Implementing agencies and/or project sponsors shall consider implementation of mitigations measures including but not limited to those identified below.

2.7(a) Mitigation measures that shall be considered by implementing agencies and/or project sponsors where feasible based on project-and site-specific considerations include, but are not limited to the following. To reduce impacts related to fault rupture, implementing agencies shall require project sponsors to comply with provisions of the Alquist-Priolo Act (Act) for project sites located within or across an Alquist-Priolo Hazard Zone. Project sponsors shall prepare site-specific fault identification investigations conducted by licensed geotechnical professionals in accordance with the requirements of the Act as well as any existing local or Caltrans regulations and policies that exceed or reasonably replace any of the Act requirements. Structures intended for human occupancy (defined as a structure that might be occupied a minimum of 2,000 hours per year) shall be located a minimum distance of 50 feet from any identified active fault traces. For the purposes of this mitigation, less than significant means consistent with federal, state, and local regulations and laws related to development in an Alquist-Priolo Hazard Zone.

Significance after Mitigation

The Alquist-Priolo Act strictly regulates where development and road projects can occur in relation to faults by requiring detailed fault identification studies and stipulating minimum setback requirements in addition to any local or Caltrans requirements. Fault identification studies as required by the Alquist-Priolo Act 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 setback a minimum distance of 50 feet; local agencies may have further restrictions.

To the extent that an individual project adopts all feasible mitigation measures described above, the impact would be less than significant (LS). Projects taking advantage of CEQA Streamlining provisions of SB 375 (Public Resources Code sections 21155.1, 21155.2, and 21159.28) must apply the mitigation measure(s) described above to address site-specific conditions. Further, because the measure is tied to existing regulations that are law and binding on responsible agencies and project sponsors, it is reasonable to determine that they would be implemented. Therefore, with the incorporation of mitigation measure 2.7(a), the impact is found to be less than significant with mitigation (LS-M).

Impact

2.7-2: Implementation of the proposed Plan could expose people or structures to substantial risk related to ground shaking.

Impacts of Land Use Projects

According to modeling conducted by the US Geological Survey in conjunction with the California Geological Survey, the 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, areas located within or near any of the Bay shoreline areas where alluvial sediments tend to be thicker, especially in areas where unengineered fill exists or loose alluvial materials are found, could experience considerable ground shaking. Therefore, the potential for adverse ground shaking impacts related to land use changes from implementation of the proposed Plan at the regional and local level is considered to be potentially significant (PS). Mitigation Measure 2.7(b) is discussed below.

Impacts of Transportation Projects

As noted above for the land use projects, an earthquake on any one of the active faults in the Bay Area region could cause a large degree of ground shaking in the region, resulting in damage to transportation improvements if they are not engineered appropriately. Improvements associated with the proposed transportation projects within the region would include a variety of transit modifications that could increase the number of people and transit corridors that could potentially be exposed to ground shaking hazards. Therefore, the potential for adverse ground shaking impacts related to improvements associated with the transportation projects at the regional and local level is considered to be potentially significant (PS). Mitigation Measure 2.7(b) is discussed below.

Combined Effects

While the proposed Plan would accommodate in increased population within the seismically active Planning Area, the hazards are dependent on site-specific criteria including the location of the projects in relation to the seismic event, underlying geologic materials, and the magnitude of the event. These impacts are considered to be potentially significant (PS). Mitigation Measure 2.7(b) is discussed below.

Mitigation Measures

Implementing agencies and/or project sponsors shall consider implementation of mitigations measures including but not limited to those identified below.

2.7(b) Mitigation measures that shall be considered by implementing agencies and/or project sponsors where feasible based on project-and site-specific considerations include, but are not limited to the following. To reduce impacts related to ground shaking, implementing agencies shall require project sponsors to comply with the most recent version of the California Building Code (CBC). Proposed improvements shall comply with Chapter 16, Section 1613 of the CBC which provides earthquake loading specifications for every structure and associated attachments that must also meet the seismic

criteria of Associated Society of Civil Engineers (ASCE) Standard 07-05. In order to determine seismic criteria for proposed improvements, geotechnical investigations shall be prepared by state licensed engineers and engineering geologists to provide recommendations for site preparation and foundation design as required by Chapter 18, Section 1803 of the CBC. Geotechnical investigations shall also evaluate hazards such as liquefaction, lateral spreading, landslides, and expansive soils in accordance with CBC requirements and Special Publication 117A, where applicable. Recommended corrective measures, such as structural reinforcement and replacing native soils with engineered fill, shall be incorporated into project designs. For the purposes of this mitigation, less than significant means consistent with federal, state, and local regulations and laws related to building construction.

Significance After Mitigation

Development associated with the proposed land uses would be required under existing law to conform to the current seismic design provisions of the most current version of the CBC, to provide for the latest in earthquake safety and mitigate losses from an earthquake. Proposed developments would also adhere to the local building code requirements that contain seismic safety requirements to resist ground shaking through modern construction techniques. In addition, seismic design criteria is required of all construction and would also apply to transportation projects where adverse effects from ground shaking could occur if the improvements are not designed and constructed in accordance with CBC and local building code requirements. The implementation of roadway improvements would be required to follow design provisions through the most current version of the CBC and local building standards, to employ design standards that consider seismically active areas in order to safeguard against major structural failures or loss of life. Similarly, bridge and overpass design would be required to comply with Caltrans design criteria. Caltrans provides seismic design criteria for new bridges in California, specifying minimum levels of structural system performance, component performance, analysis, and design practices for bridges.

To the extent that an individual project adopts all feasible mitigation measures described above, the impact would be less than significant (LS). Projects taking advantage of CEQA Streamlining provisions of SB 375 (Public Resources Code sections 21155.1, 21155.2, and 21159.28) must apply the mitigation measure(s) described above to address site-specific conditions. Further, because the measure is tied to existing regulations that are law and binding on responsible agencies and project sponsors, it is reasonable to determine that they would be implemented. Therefore, with the incorporation of mitigation measure 2.7(b), the impact is found to be less than significant with mitigation (LS-M).

Impact

2.7–3: Implementation of the proposed Plan could expose people or structures to substantial risk from seismic-related ground failure, including liquefaction.

Impacts of Land Use Projects

Liquefaction typically occurs in areas underlain with loose saturated cohesion-less soils within the upper 50 feet of subsurface materials. These soils, when subjected to ground shaking, can lose their strength resulting from the buildup of excess pore water pressure causing them to behave closer to a liquefied state. As shown in **Figure 2.7-2**, there are many areas throughout the Bay Area region that are considered prone to liquefaction hazards. The full list of PDAs located within liquefaction zones, ranging from very low to very high susceptibility, is shown in Appendix F. Due to the size of the PDAs, each

PDA intersects areas of varying liquefaction potential. According to this regional data, approximately 14 percent of all the PDA land area is located above deposits considered to have a very high potential for liquefaction, 12 percent with high potential, 37 percent moderate, 18 percent low, and 18 percent with very low potential.¹⁴ Other land use projects outside of the PDAs are more widely dispersed and would be located in a range of differing liquefaction potential.

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. Therefore, the potential for adverse ground failure impacts related to land use changes from implementation of the proposed Plan at the regional and local level is considered potentially significant (PS). Mitigation Measure 2.7(b) is described above.

Impacts of Transportation Projects

Liquefaction hazards are generally determined on a site-specific basis although regional mapping of areas considered to have higher liquefaction potential has been conducted throughout the planning area. As noted above for development pursuant to the proposed Plan, ground failure associated with liquefaction could result in damage to transportation improvements if not engineered appropriately. Improvements associated with the proposed transportation projects within the region would include a variety of transit and roadway modifications that could increase the number of people and transit corridors that could potentially be exposed to liquefaction hazards. The full list of transportation projects located within liquefaction zones, ranging from very low to very high susceptibility, is shown in Appendix F.

Therefore, the potential for liquefaction hazards to result in adverse impacts related to improvements associated with the transportation projects at the regional and local level is considered potentially significant (PS) for Impact 2.7-3. Mitigation Measure 2.7(b) is discussed above.

Combined Effects

Implementation of the land use and transportation projects would result in projects being constructed or redeveloped in a range of geologic materials that could be susceptible to liquefaction. Liquefaction hazards are dependent on site-specific conditions and other conditions such as the distance and magnitude of the seismic event. Therefore, liquefaction hazards are considered potentially significant (PS). Mitigation Measure 2.7(b) is discussed above.

Mitigation Measures

Implement Mitigation Measure 2.7(b), included under Impact 2.7-2.

¹⁴ Approximately 1 percent of PDA areas are mapped as overlying water, including areas such as Lake Merritt in Oakland; this does not necessarily indicate that there are no underlying deposits with liquefaction potential.

Significance After Mitigation

The impacts from ground failure, including liquefaction, from development of proposed land uses associated with the proposed Plan would be addressed through site-specific geotechnical studies prepared in accordance with CBC building code requirements and standard industry practices, as well as State-provided guidance, such as CGS Special Publication 117A, which would specifically address liquefaction especially in areas that have been mapped as seismic hazard zones by the California Geological Survey. Subsequent development would be required to conform to the current seismic design provisions of the CBC to mitigate losses from ground failure as a result of an earthquake. These future projects would also be required to adhere to the local general plans and local building code requirements that contain seismic safety requirements to resist ground failure through modern construction techniques. The implementation of roadway improvements would also be required to identify potential liquefaction hazards and design improvements to meet the most current version of the CBC and local building standards, by employing geotechnical practices such as ground treatment, replacement of existing soils with engineered fill, or use of deep foundation systems to anchor improvements into more competent materials. Similarly, bridge and overpass design would be required to comply with Caltrans design criteria. As stated previously, Caltrans provides seismic design criteria for new bridges in California, specifying minimum levels of structural system performance, component performance, analysis, and design practices for bridges that would include minimizing damage that could be expected from potential liquefaction hazards.

To the extent that an individual project adopts all feasible mitigation measures described above, the impact would be less than significant (LS). Projects taking advantage of CEQA Streamlining provisions of SB 375 (Public Resources Code sections 21155.1, 21155.2, and 21159.28) must apply the mitigation measure(s) described above to address site-specific conditions. Further, because the measure is tied to existing regulations that are law and binding on responsible agencies and project sponsors, it is reasonable to determine that they would be implemented. Therefore, with the incorporation of mitigation measure 2.7(b), the impact is found to be less than significant with mitigation (LS-M).

Impact

2.7–4: Implementation of the proposed Plan could expose people or structures to substantial risk related to landslides.

Impacts of Land Use Projects

The planning area includes a wide range of topographical conditions where landslide hazards vary from very low in low lying areas to very high in some upland areas especially areas with slopes that exceed 15 percent. **Figure 2.7-3** shows areas throughout the region that are considered prone to landslide hazards which can be induced from either seismic conditions, periods of heavy precipitation, or simply through static conditions. The list of PDAs located within landslide zones ranging from surficial deposits on relatively flat terrain to “mostly” landslides is found in Appendix F. Due to the size of the PDAs, each PDA intersects areas of varying landslide potential. According to this regional data, approximately 0.5 percent of all the PDA land area is located in areas mapped as “mostly landslides,” 12 percent mapped as

“few landslides,” 85 percent surficial deposits, and 2 percent mapped as surface water.¹⁵ Development outside of these PDAs is fairly widely dispersed across a variety of terrain but would likely follow a similar breakdown of landslide hazard areas.

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.

Therefore, the potential for adverse landslide impacts related to land use changes from implementation of the proposed Plan at the regional and local level is considered potentially significant (PS) for Impact 2.7-4. Mitigation Measure 2.7(b) is discussed above.

Impacts of Transportation Projects

In general, upland areas with slopes greater than 15 percent tend to have higher landslide hazards. Regional mapping of areas considered to have higher landslide potential has been conducted throughout the region (see **Figure 2.7-3**). The list of transportation projects located within landslide zones ranging from surficial deposits on relatively flat terrain to “mostly” landslides is shown in Appendix F. As noted above for the land use projects, landslides could result in damage to transportation improvements, particularly if not engineered appropriately. Improvements associated with the transportation projects within the region would include a variety of transit modifications that could potentially be subject to landslide hazards. According to the GIS data, the majority (approximately 75 percent) of the transportation projects are located on surficial deposits with low landslide potential and only two percent are located in areas mapped as “mostly landslides.”

Therefore, the potential for landslide hazards to result in adverse impacts related to improvements associated with the transportation projects at the regional and local level is considered potentially significant (PS) for Impact 2.7-4. Mitigation Measure 2.7(b) is discussed above.

Combined Effects

Proposed land use and transportation projects would be located over a range of differing topography. However, as noted above, the majority of the PDAs and transportation projects are located in relatively level areas. Landslide hazards are dependent on site-specific conditions, including the steepness of slopes, and other conditions such as, in the case of seismically induced landslides, the distance and magnitude of the seismic event. Landslide hazards would have a potentially significant (PS) impact. Mitigation Measure 2.7(b) is discussed above.

Mitigation Measures

Implement Mitigation Measure 2.7(b), included under Impact 2.7-2.

¹⁵ Areas mapped as “mostly landslides” refer to areas considered to have the highest potential for landslides, whereas surficial deposits have the lowest potential.

Significance After Mitigation

Similar to liquefaction hazard areas, the CGS has defined areas that are considered to be highly susceptible to earthquake induced landslide hazards. Development in these areas is required to adhere to geotechnical investigation requirements as detailed in Special Publication 117A. The impacts from landslides on development of future land uses associated with the proposed Plan would be addressed through site-specific geotechnical studies prepared in accordance with CBC building code requirements and standard industry practices as well as State provided guidance, such as CGS Special Publication 117A, which would specifically address landslide hazards located in landslide hazard zones. Development would conform to the current design provisions of the CBC to mitigate losses from landslides. Proposed developments would also adhere to the local general plans, and local building code requirements that can contain hillside development requirements to resist landslides through modern construction design and slope stabilization techniques.

The implementation of roadway improvements would be required to identify potential slope stability hazards and provide slope stabilization measures to meet the most current version of the CBC, and local building standards, by employing geotechnical practices such as use of retaining walls, setback requirements, and deep foundation systems. Incorporation of slope stability measures such as these, in accordance with CBC code requirements, would be effective in minimizing landslide hazards on proposed transportation improvements.

To the extent that an individual project adopts all feasible mitigation measures described above, the impact would be less than significant (LS). Projects taking advantage of CEQA Streamlining provisions of SB 375 (Public Resources Code sections 21155.1, 21155.2, and 21159.28) must apply the mitigation measure(s) described above to address site-specific conditions. Further, because the measure is tied to existing regulations that are law and binding on responsible agencies and project sponsors, it is reasonable to determine that they would be implemented. Therefore, with the incorporation of mitigation measure 2.7(b), the impact is found to be less than significant with mitigation (LS-M).

Impact

2.7-5: Implementation of the proposed Plan could result in substantial soil erosion or the loss of topsoil.

Impacts of Land Use Projects

Development associated with the proposed 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 local grading ordinances 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.

However, the potential for loss of topsoil or erosion impacts related to land use changes from implementation of the proposed Plan at the regional and local level is considered potentially significant (PS) for Impact 2.7-5. Mitigation Measure 2.7(c) is discussed below.

Impacts of Transportation Projects

Transportation projects within the region would also include earthwork activities that would disturb underlying soils during construction potentially exposing them to erosion and loss of topsoil.

Therefore, the potential for loss of topsoil or erosion impacts related to improvements associated with the transportation projects included in the proposed Plan at the regional and local level is considered potentially significant (PS) for Impact 2.7-5. Mitigation Measure 2.7(c) is discussed below.

Combined Effects

As noted above, construction associated with both the land use and transportation projects would include ground disturbances that could expose underlying soils to the effects of erosion. Therefore, erosion hazards and the potential for loss of topsoil would have a potentially significant (PS) impact. Mitigation Measure 2.7(c) is discussed below.

Mitigation Measures

Implementing agencies and/or project sponsors shall consider implementation of mitigations measures including but not limited to those identified below.

2.7(c) Mitigation measures that shall be considered by implementing agencies and/or project sponsors where feasible based on project-and site-specific considerations include, but are not limited to the following. To reduce the risk of soil erosion, implementing agencies shall require project sponsors to comply with National Pollution Discharge Elimination System (NPDES) General Construction Permit requirements. Implementing agencies shall require project sponsors, as part of contract specifications with contractors, to prepare and implement best management practices (BMPs) as part of a Stormwater Pollution Prevention Plan that include erosion control BMPs consistent with California Stormwater Quality Association Handbook for Construction. For the purposes of this mitigation, less than significant means consistent with federal, state, and local regulations and laws related to construction practices.

Significance After Mitigation

Development that disturbs more than one acre is 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 stormwater pollution prevention plan (SWPPP) through the local jurisdiction. BMPs that are required under a SWPPP would 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. As with land use development, earthwork activities for transportation projects would be required to adhere to NPDES permit requirements for construction, as well as any local grading ordinance requirements that may include erosion prevention measures. Incorporation of erosion control BMP measures such as use of straw bales, inlet protective measures, silt fences, and construction scheduling, in accordance with grading code and any revegetation requirements, would be effective in minimizing erosion hazards and loss of topsoil associated with transportation improvements.

To the extent that an individual project adopts all feasible mitigation measures described above, the impact would be less than significant (LS). Projects taking advantage of CEQA Streamlining provisions

of SB 375 (Public Resources Code sections 21155.1, 21155.2, and 21159.28) must apply the mitigation measure(s) described above to address site-specific conditions. Further, because the measure is tied to existing regulations that are law and binding on responsible agencies and project sponsors, it is reasonable to determine that they would be implemented. Therefore, with the incorporation of mitigation measure 2.7(c), the impact is found to be less than significant with mitigation (LS-M).

Impact

2.7-6: Implementation of the proposed Plan could locate a subsequent development project on a geologic unit or soil that is unstable, contains expansive properties, 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.

Impacts of Land Use Projects

Some land use development associated with implementation of the proposed Plan could be located on geologic units or soils that are unstable, or that could become unstable and result in geologic hazards. Areas with underlying materials that include undocumented fills, soft compressible Bay Mud 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 and over time could result in damage to foundations, walls, or other improvements. Structures, including residential units and commercial buildings, 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.

Most of the new development would primarily occur adjacent to existing development that may have already been evaluated for unstable soil or geologic units.

Nonetheless, the potential for landslide, lateral spreading, subsidence, liquefaction, or collapse impacts related to land use changes from implementation of the proposed Plan at the regional and local level is considered potentially significant (PS) for Impact 2.7-6. Mitigation Measure 2.7(b) is discussed above.

Impacts of Transportation Projects

Transportation projects within the planning area would include a variety of transit modifications that could be located on unstable soil or geologic units. In general, many of the transportation projects would be located in areas where previous roads or other improvements have occurred and any unstable soils or geologic units would have been addressed at the time of construction. However, some of these may have been addressed under older code requirements that may not be as stringent as current codes.

Therefore, the potential for unstable soils or geologic units hazards to result in adverse impacts related to improvements associated with the Transportation projects at the regional and local level is considered potentially significant (PS) for Impact 2.7-6. Mitigation Measure 2.7(b) is discussed above.

Combined Effects

Both the land use and transportation projects would be located on a wide range of different geologic materials and conditions. Hazards associated with unstable soils or geologic units are dependent on site-specific conditions as well as the specific nature of the individual project proposed. Therefore, the proposed Plan would have a potentially significant (PS) impact. Mitigation Measure 2.7(b) is discussed above.

Mitigation Measures

Implement Mitigation Measure 2.7(b), included under Impact 2.7-2.

Significance After Mitigation

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, CGS Special Publication 117A for liquefaction and landslide hazards in seismic hazard zone, used to minimize the risk associated with these hazards. These measures generally are enforced through compliance with local building codes and ordinances, to avoid or reduce hazards relating to unstable soils and slope failure. Geotechnical investigations as required by grading ordinances, Special Publication 117A, and current CBC building code requirements would also address the identification, evaluation, and recommended measures for addressing potential hazards that may be present at proposed transportation improvement project sites. With implementation of grading permit and building code requirements including seismic design criteria as required by the CBC, Caltrans, Special Publication 117A, and local building code requirements, all improvements and development associated with both the land use development and transportation projects would be designed to minimize potential risks related to unstable soils and geologic units.

To the extent that an individual project adopts all feasible mitigation measures described above, the impact would be less than significant (LS). Projects taking advantage of CEQA Streamlining provisions of SB 375 (Public Resources Code sections 21155.1, 21155.2, and 21159.28) must apply the mitigation measure(s) described above to address site-specific conditions. Further, because the measure is tied to existing regulations that are law and binding on responsible agencies and project sponsors, it is reasonable to determine that they would be implemented. Therefore, with the incorporation of mitigation measure 2.7(b), the impact is found to be less than significant with mitigation (LS-M).

This page intentionally left blank.