

## 3.9 Geology and Soils

### 3.9.1 Introduction

This section describes the geologic and seismologic conditions in the study area, as well as soil, and paleontological resources, along with associated potential geologic, seismic, and geotechnical hazards from the types of restoration projects that would be permitted under the Order. (See Section 2.6, *Categories of Restoration Projects in the Order*.)

The environmental setting and evaluation of impacts on geologic and soil resources are based on a review of existing published documents; information about example projects similar to the types of restoration projects that may be implemented by other agencies; and other information sources listed in Chapter 8, *References*.

No comments specifically addressing geology and soils were received in response to the notice of preparation (NOP). See Appendix B for the NOP comment letters.

### 3.9.2 Environmental Setting

This section describes the geology, soils, and paleontological resources that could be affected by the types of restoration projects that would be permitted under the Order.

The general topography and climate and geology (landslides, earthquakes, tsunamis, and volcanic formations) are described for California. The environmental setting for geology, soils, and paleontological resources is then provided by ecoregion (see the definition of the ecoregions below).

#### ***Topography and Climate***

The study area encompasses a large portion of California. Topography in the study area is highly varied and includes four geographic regions: 1,340 miles of coastline, high mountain ranges, flat inland central valley, and deserts (Western Regional Climate Center 2020). Elevations range from 14,494 feet above sea level at the summit of Mount Whitney to 282 feet below sea level in Death Valley, with a mean elevation of approximately 2,900 feet.

Climate in California varies depending on elevation, proximity to the coast, and latitude. Because of these factors, five major climate types are found within the state's borders: the Desert, Cool Interior, Highland, Steppe, and Mediterranean climates. Annual mean precipitation across all climate types in the state is approximately 22.39 inches (DWR 2016), with about 90 percent falling between October 1 and April 30. Rainfall is highly variable throughout the state, however, with the southeast deserts receiving less than 5 inches of precipitation per year and the upper ranges of the north coast receiving more than 100 inches per year.

## Geology

California is located on three tectonic plates: the western boundary of the North American continental plate, the oceanic Pacific Plate, and the Gorda Plate. North of the conjunction of these three plates lies the Mendocino Triple Junction, which is the most seismically active place in California. The movement between these three plates and California's distinct climate are responsible for the state's unique topographic characteristics such as its open flat valleys, expansive mountain ranges, and dramatic coastlines (Harden 1997). Environmental hazards such as earthquakes, landslides, and volcanic formations are largely effected by tectonic dynamics and climate.

### Landslides

California's landscape has been shaped and altered throughout the years by constant erosional processes such as landslides and mass wasting. Although the mountain regions are typically more susceptible to landslides, they can occur in areas of low relief such as coastal bluffs, river banks and streambanks, and inland desert areas. Landslides can be caused by the gravitational pull of soil, rock, or a combination of both, or triggered by outside events such as earthquakes or heavy rainfall.

Landslide movements vary in size, style and rate of movement, and type depending on material type, steepness of slopes, sediment type, soil depth, and location. The types of geomorphic expressions of landslides include falls, topples, lateral spreads, slides, and flows:

- ◆ *Falls* occur when masses of soil or rock are dislodged from steep slopes and free-fall downslope.
- ◆ *Topples* typically occur when the underside of a slope or cliff loses strength (e.g., through erosion) and the upper layer of rock or soil rotates forward and falls over downslope.
- ◆ *Lateral spreads* are often caused by liquefaction of sediment due to an earthquake or erosion on gentle slopes and produce fluid-like flow of rock or soil.
- ◆ *Slides* occur along a distinct surface and displace masses of sediment beside one or more discrete planes.
- ◆ *Flows* occur when material moves down a slope in the form of a fluid.

Each landslide type has different risks and can be generally classified by a geologist or engineer based on the depth and type of material that fails, amount of water involved, rate of movement, and the type of movement involved.

Landslides have three general types of triggering mechanisms: Geological (e.g., weathered materials, material permeability, and weak or sensitive materials), morphological (e.g., seismic activity, fluvial/wind erosion, vegetation loss, and shrink-swell), and anthropogenic (e.g., deforestation, irrigation, reservoir drawdown, and artificial vibration) (USGS 2004). The most common and potentially devastating landslides are caused by water (e.g., intense rainfall, changes in groundwater levels, snowmelt), seismic activity (e.g., earthquakes, shaking-caused dilation of soil materials), and volcanic activity.

In the winter, California experiences a majority of its annual precipitation, especially in its coastal and mountainous areas from severe winter storms. Excess rainfall or snowmelt can significantly alter groundwater levels and surface runoff, which can saturate slopes, leaving them prone to failure. Flooding is often caused by landslides due to similar triggering mechanisms such as intense rainfall, increased runoff, and excessive groundwater saturation. These events can cause sediment buildup that blocks valleys and stream channels.

The primary regions of California that are prone to landslides are the coastal and mountainous areas (USGS 2004). Mountainous areas are more susceptible because of high levels of seismic activity, generally associated with active faults and volcanoes accompanied by steep slopes and weak sediment types. Uplifted, naturally fragile rocks consisting of poorly consolidated sediments or marine deposits of mudstone or siltstone are highly susceptible to slope failure caused by ground shaking. Additionally, shearing along active fault zones and the folding and faulting of geologic materials during subduction and accretion can weaken earthen materials that are prone to landsliding. Lastly, volcanic activity can cause regionally devastating landslides. As volcanic lava and steam eruptions occur, the snowpack melts at a very high rate, resulting in large-volume rock, soil, and ash flows that can travel rapidly down hillslopes and stream channels and erode the underlying topography. A prime example of this process is the collapse of the volcano Mount Shasta in Northern California approximately 350,000 years ago, which caused a large debris avalanche that resulted in dramatic erosion.

### **Liquefaction**

Liquefaction is the process in which water-saturated sediment temporarily loses its viscosity and acts as a fluid during groundshaking events. During liquefaction, ground shaking causes waterlogged soils to collapse and decreases the overall volume of soil, causing it to temporarily lose strength and become more fluid. This can cause ground deformations and failures, increase lateral earth pressure, and result in a temporary loss of soil-bearing capacity, all of which can damage buildings and other structures. Liquefaction can increase the buoyancy of structures buried in water bodies, potentially causing them to shift and uplift toward the surface. Liquefaction generally results from strong ground shaking caused by earthquakes.

All of the study area is susceptible to liquefaction; however, regions with poorly drained, fine-grained soils (sandy, silty, and gravelly soils) are the most susceptible.

### **Earthquakes**

California is one of the most active, geomorphically diverse, scenic locations in the U.S. Millions of years ago, the shift in plate tectonics converted the passive margin of the North American Plate into an active margin of compressional and translational tectonic regimes.

California's northern, central, and southern coastal areas are more susceptible to earthquakes, but hundreds of identified faults exist within the state's borders. Based on slip rates within the last 10,000 years, approximately 200 faults are considered potentially hazardous. As such, more than 70 percent of California's population lives

within 30 miles of a fault where high ground shaking could occur within the next 50 years (DOC 2019). Earthquakes are a familiar and unpredictable phenomenon in California, in terms of both location and magnitude.

The San Andreas Fault is one of California's best known and most notable faults. The fault runs through the state for approximately 800 miles between the convergence of the Pacific and North American Plates. Its southern terminus starts south of California in the Gulf of California, and runs northwest through the Salton Trough, continuing north until it reaches the Transverse Ranges where it turns east-west. North of the Transverse Ranges, the San Andreas Fault again runs northwest until it cuts off at the Mendocino Triple Junction off the Humboldt County coast. Some of the state's most devastating earthquakes have occurred on the San Andreas Fault, including the 1906 San Francisco earthquake (magnitude 7.7 to 8.3) and the 1857 Fort Tejon earthquake (magnitude 7.9).

While the San Andreas Fault is the cause of significant recent earthquakes, the Cascadia subduction zone (CSZ), located farther north, has a greater capability to create strong ground shaking, vertical land displacement, and tsunamis. The CSZ is a 600-mile-long, north-to-northwest running collection of faults extending from southern British Columbia to the Mendocino Triple Junction. The CSZ has the potential to create large earthquakes with magnitudes of 9.0 or greater every 250–500 years, on average.

### **Tsunamis and Seiches**

Tsunamis are high-magnitude, long sea waves caused by earthquakes, submarine landslides, or other disturbances that displace large volumes of water. Areas along the Pacific coast are the most susceptible to the destructive effects of tsunamis, as major subduction zone earthquakes occur in the Northern and Southern Hemispheres. These earthquakes move the earth's crust at the bottom of the ocean floor, sending large quantities of water into motion and spreading tsunami waves throughout the Pacific Ocean.

California's long coastline and active tectonic structure make it particularly vulnerable to tsunamis and vertical land movement. Tsunamis can also result from submarine landslides that displace large volumes of water. Seismically generated landslides, rock falls, rock avalanches, and the eruption or collapse of island or coastal volcanoes can create subaerial landslide tsunamis; however, they are generally caused by major earthquakes or coastal volcanic activity.

Seismic seiches are standing waves caused when seismic waves from an earthquake travel through a closed or semi-enclosed body of water such as a lake or bay. Seiches can be observed several thousand miles from the location of an earthquake because of the long-period seismic waves created after the earthquake. Small bodies of water (i.e., lakes and ponds) are especially susceptible to seismic seiches.

### **Volcanoes**

Volcanoes are openings in the earth's crust where molten rock from below the surface is expelled in the form of lava. Molten rock below the earth's surface is classified as magma; once it erupts or flows, it is termed lava. In addition to lava, during a volcanic eruption, rock, ash, and gases are released into the atmosphere. Volcanoes are

generally formed at the edge of tectonic plates, and as a result, California is home to many active volcanic areas. Some of the most active are found along a volcanic chain that is a result of compressional tectonics along the CSZ within the Cascade Range (located within Regional Board Regions 1, 2, and 3).

The Modoc Plateau is a southern extension of the Columbia River Plateau of eastern Oregon and Washington. Located on the Nevada border between the Warner Mountains and Surprise Valley, the Modoc Plateau extends west to the edge of the southern Cascade Range. Its lava flows are typically more basaltic and less explosive than those along the CSZ. Previous eruptions (that occurred between 200 and 300 years ago) have created a subtler terrain of shield volcanoes and broad lava plateaus.

Long Valley Caldera near Mammoth Mountain (located within Regional Board Region 6) is one of the largest calderas on earth, measuring approximately 20 miles long from east to west, and is included in the Mono-Inyo Craters volcanic chain in eastern California. A caldera is a large depression at the top of a volcanic cone, formed by the collapse of an underlying magma chamber after a major volcanic eruption. After showing signs of activity in the 1980s, the Long Valley area is being closely monitored for earthquake activity to proactively discover early signs of eruptions.

Several areas of California located near fault lines contain hot springs, where geothermal heat heats up groundwater and creates steam, which erupts from large magma chambers. These areas are found in the Coast Ranges (including Geyserville, south of Clear Lake, within Regional Board Region 1) and at the base of the Sierra Nevada (east of Mammoth Lakes, within Regional Board Region 6). The occurrence of geothermal heat is another sign of active volcanism in California.

### **Active Faults**

A fault is a fracture or zone of fractures between two blocks of rock. These fractures allow the blocks to move relative to each other. Movement can occur rapidly (i.e., earthquake) or slowly (i.e., creep) and can range from a few feet to thousands of miles long (USGS 2019). Most faults create repeated displacement over time. A fault zone is a zone of typically braided and subparallel of related faults that may branch and diverge. These zones can vary in width from a few feet to several miles.

Approximately 15,700 known faults are mapped in California, more than 500 of which are active. Under the Alquist-Priolo Earthquake Fault Zoning Act (Alquist-Priolo Act), a fault is designated as active if it has ruptured in the last 11,000 years. An active fault has the potential for surface rupture; under the Alquist-Priolo Act, a structure to be occupied by humans may not be built over or within 50 feet of an active fault.

### **Soils**

Soil conditions in California are highly variable. California's diverse geologic, topographic, climatic, temporal, and vegetative environments all influence the formation and composition of the state's soils. Unlike California's geologic regions, which are unique to its 11 ecoregions, soils in the state do not have specific characteristics or properties that distinguish them by region. Instead, there is a gradational transition between the characteristics of one soil versus another.

## **Soil Classification**

Soils are classified in various ways, depending on the application of the information. Engineers evaluate and classify soils in regard to the engineering properties of the soil (e.g., Unified Soil Classification System). Soil scientists group soils together based on their intrinsic properties, geologic origin, and soil behavior based on different conditions. The U.S. Natural Resources Conservation Service (NRCS) uses the U.S. Department of Agriculture's soil taxonomy system to classify soils. This method of classification is based on the chemical, biological, and physical characteristics of soils such as soil color, texture, structure, mineralogy, salt content, and depth. These characteristics are defined in the 2017 USDA Soil Survey Manual, and in *Soils and Geomorphology*, authored by Peter Birkeland (1984).

Maps created by the NRCS, such as the U.S. General Soil Map (STATSGO2) and the Soil Survey Geographic (SSURGO2) digital databases, should be used when evaluating soils affected by a proposed project. These maps and others include detailed information about soils, their physical and chemical properties, and suitability for a variety of uses. For projects with a broad geographical scale, soil associations are generally used to determine the distinctive pattern of soils, relief, and drainage in an area and are grouped by soils that occur together in the landscape named after two or three dominant soil series.

## **General Soil Hazards**

### *Soil Erosion*

Soil erosion is caused by the detachment and entrainment of soil particles, usually as a result of the movement of wind and water. Soils that are high in coarse silt- and fine sand-sized particles and generally low in organic matter are more susceptible to erosion (Donahue et al. 1983). Vegetated slopes or soils covered by larger amounts of vegetation experience less erosion than areas from which vegetation has been removed or reduced. In general, soils in heavily vegetated areas have more surface cover and greater soil structure from plant roots, which reduce the potential for erosion. Disturbed soils or soils with a combination of reduced vegetation and disturbance are more prone to erosion. Steep slopes (e.g., with a greater than 10 percent gradient) have a greater capability for soil erosion caused by water because of their increased runoff velocities.

The erosion rate of a particular soil, without interference from human activity, is called the natural (background) or geologic erosion rate. Accelerated soil erosion is any type of erosion that occurs over the natural erosion rate and is generally the result of human activities (e.g., grazing, timber harvesting, land-disturbing activities). Accelerated erosion is often referred to as anthropic, historic, or man-induced erosion (Toy 1982).

### *Shrink and Swell*

The shrink-and-swell potential for soils is the change in volume associated with moisture content, in which soils shrink when dried and expand when wet. The extent of shrinking and swelling is based on the amount and type of clay in the soil. Montmorillonite, smectite, bentonite, and illite are common clay materials that absorb water and can cause soils to swell by more than 10 percent of their original volume. The volume

increase occurs when water molecules are absorbed between clay minerals. The more water is available, the more water is absorbed between the clay minerals, and thus, the greater the swelling capacity becomes. Once the expanded clay dries, the lack of water molecules will cause the soil to shrink, resulting in a volume decrease. This shrink-and-swell cycle can exert pressure on building foundations and infrastructure, causing damage by removing structural support, and on roads by causing surface cracking and runoff infiltration. Shrinking and swelling can also create soil fissures, which allow deeper penetration of water during wet conditions.

Although they can be found throughout the state, expansive soils are most common along the coast and coastal mountains along the entire length of California.

### ***Paleontological Resources***

Paleontology is the study of life forms in past geologic time, specifically through the study of plant and animal fossils. Paleontological resources represent a small, nonrenewable, and impact-sensitive scientific and educational resource. Paleontological resources are sites or geologic deposits that consist of unique and unusual individual fossils or assemblages of fossils, diagnostically or stratigraphically important, and add to the existing body of knowledge in particular areas (e.g., stratigraphically, taxonomically, or regionally).

Fossil remains such as bones, teeth and claws, eggs, embryos, nests, skin, and muscles are found in places where they were originally buried in geologic deposits (rock formations). Fossils can be used to determine the geological events and relative ages of depositional layers to better understand the development of the region and area. The age, abundance, and distribution of fossils depend on the topography of the area and geologic formation in which they occur. In California, these resources (e.g., vertebrate, invertebrate, and plant fossils) are generally found in sedimentary and metasedimentary deposits.

### ***Statewide Oil, Gas, and Geothermal Production***

#### **Crude Oil**

As of October 2019, California was ranked seventh among crude oil-producing states, behind Texas, North Dakota, New Mexico, Oklahoma, Colorado, and Alaska (EIA 2019). In 2019, California produced 520,000 barrels of crude oil per day. In 2017, California was the fourth-largest producer of crude oil and was the third in oil refining capacity after Texas and Louisiana. The California Department of Conservation's Division of Oil, Gas, and Geothermal Resources (as of January 2020, known as the Geologic Energy Management Division) reported that the state's total production for 2018 was 161.8 million barrels per year, a decrease of approximately 7.0 percent from production in 2017 (DOC 2018). The three largest oil production fields in California are the South Belridge, Midway-Sunset, and Kern River oil fields.

#### **Natural Gas**

Natural gas produced in California equals about one-tenth of the state's demand. In California, natural gas is produced and reserved primarily in geologic basins in the

northern Central Valley. According to the California Energy Commission, in 2018 California produced 193,219 million cubic feet (MMCF) of dry natural gas, approximately 9 percent of its total consumption of natural gas that year (2,136,907 MMCF). Approximately 97 percent of the natural gas consumed in California was used by the residential (423,915 MMCF), commercial (248,012 MMCF), industrial (766,415 MMCF), vehicle fuel (24,452 MMCF), and electric power sectors (614,722 MMCF).

Because of California's high demand for natural gas, approximately 90 percent of the state's natural gas supply comes from out-of-state major supply basins in locations such as Canada, Texas, New Mexico, Colorado, and Wyoming (Champagna et al. 2019).

### **Geothermal**

Geothermal energy is the production of energy using the internal heat of Earth's crust and is generally associated with volcanic and seismically active regions. California is located within the Pacific "Ring of Fire," a nearly closed arc of intense seismicity and volcanoes around the Pacific Ocean, and accordingly, contains the greatest potential for geothermal electric generation in the United States. California has 43 operating geothermal power plants with an installed capacity of 2,730 megawatts (CEC 2019). In 2018, the state produced 11,528 gigawatt-hours (GWh) of electricity and imported 700 GWh of geothermal power, about 6 percent of the state's total system power. Of California's 58 counties, 46 have lower temperature resources for direct-use geothermal. The largest concentrations of geothermal plants are north of San Francisco in The Geysers Geothermal Resource Area in Lake and Sonoma Counties.

### ***Overview of Ecoregion Approach***

The following analysis of geological resources is organized in the context of ecoregions, which are geographic areas that share general geological and topographic characteristics and similar biotic communities. In much of California, physiographic areas and geology are closely associated; although the details may differ, large areas of the state have distinctive characteristics not shared by the adjacent terrain.

The state is divided into 13 separate ecoregions: Coast Ranges, Cascades, Sierra Nevada, Central California Foothills and Coastal Mountains, Central California Valley, Southern California Mountains, Eastern Cascades Slopes and Foothills, Central Basin and Range, Mojave Basin and Range, Klamath Mountains/Central High North Coast Range, Northern Basin and Range, Sonoran Basin and Range, and Southern California/Northern Baja Coast (Griffith et al. 2016). The key characteristics of each ecoregion are described below.

### **Coast Ranges**

The Coast Ranges Ecoregion extends from the coastal mountains of western Washington to western Oregon and northwestern California, and is about 400 miles long in California. Typical tectonic, sedimentary, and igneous processes along the circum-Pacific orogenic belt influenced and evolved into the Coast Ranges (Page 1966). San Francisco Bay further separates this ecoregion into northern and southern ranges through its location in a structural depression created by the east-west expansion of the San Andreas and Hayward Faults.

In California, the Coast Ranges are composed primarily of Jurassic- to Cretaceous-age (approximately 65–150 million years old) marine sedimentary and volcanic rocks of the Franciscan assemblage. The Franciscan assemblage consists primarily of deformed and metamorphosed greywacke, mudstone, and chert. Alfisols are common in California, with Isomesic soil temperatures occurring along the coast. General topography in this ecoregion includes high and low marine terraces, sand dunes, and beaches, and landslides and debris slides are common.

### **Cascades**

The Cascades Ecoregion is a forested, mountainous area that stretches from British Columbia, Canada, to Northern California and covers a range of approximately 18,064 square miles (Sorenson 2012), and is part of the Pacific Ring of Fire. Lassen Peak is the most southerly active volcano in the Cascade Range.

The Cascades Ecoregion is bounded to the west by the Klamath Mountains, Willamette Valley, and Puget Lowland Ecoregions; to the north by the North Cascades Ecoregion; and to the east by the Eastern Cascade Slopes and Foothills Ecoregion. This ecoregion contains a large amount of Cenozoic volcanic rock and has elevations ranging from 2,000 to 7,600 feet at the highest peaks with permanent snowfields and glaciers. The Cascade Subalpine/Alpine area of the Cascades Ecoregion contains prominent volcanic peaks at higher elevations. Pleistocene glaciation changed the mountainous topography through time and formed moraines, glacial lakes, and u-shaped glacial canyons (Griffith et al. 2016).

The High Southern Cascade Montane Forest area of the Cascades Ecoregion consists of a smooth volcanic plateau with isolated buttes, cones, and peaks consisting mostly of cryic soils. The Southern Cascade Foothills area consists of volcanic hills and plateaus. The western side of this ecoregion is characterized by long, steep ridges composed of eroded Oligocene to Pliocene volcanic and volcanoclastic rocks covering older Upper Cretaceous and Eocene sedimentary rocks. Soils in this ecoregion are mostly cryic and have frigid temperature regimes, although some contain mesic soil temperatures at lower elevations and to the south, with Andisols and Inceptisols being common.

### **Sierra Nevada**

The Sierra Nevada Ecoregion is a mountainous, extremely dissected, westerly sloping fault block. The eastern portion is heavily glaciated and contains higher mountain ranges than the Klamath Mountains to the northwest. Most of the central and southern parts are underlain by granite. A high fault scarp divides the Sierra Nevada from the Northern Basin and Range and the Central Basin and Range, where the Sierra Nevada reaches its highest elevation. Because of its Pleistocene alpine glaciation, moraines, cirques, and small lakes are common. The ecoregion slopes more gently to the west.

### **Central California Foothills and Coastal Mountains**

The Central California Foothills and Coastal Mountains Ecoregion is characterized primarily by its Mediterranean climate, with hot dry summers and cool moist winters. The ecoregion consists mostly of open low mountains or foothills with scattered irregular plains and narrow valleys.

### **Central California Valley**

The Central California Valley Ecoregion consists of flat, intensively farmed plains and experiences long, hot, dry summers and mild winters. It includes flat valley basins of deep sediment adjacent to the Sacramento and San Joaquin Rivers, in addition to fans and terraces around the edge of the valley. This ecoregion has two major rivers that flow from opposite ends of the Central Valley into the Sacramento–San Joaquin Delta and San Pablo Bay. Surrounding this ecoregion are other regions that consist of hilly or mountainous topography. More than half of the Central California Valley Ecoregion is cropland, about three-quarters of it irrigated (Griffith et al. 2016).

### **Southern California Mountains**

The Southern California Mountains Ecoregion has a Mediterranean climate of hot, dry summers and moist, cool winters. This ecoregion extends 200 miles and includes coastal and alluvial plains, marine terraces, and some low hills in coastal areas of Southern California. Elevations are higher, with slightly cooler summers and more precipitation than in adjacent ecoregions. Mountains within this range are composed progressively of older rocks from the west to east, which is one of the ecoregion’s defining characteristics. This characteristic is emphasized by faults and folds that control the trend and shape of the mountains, valleys, and coastline. Sedimentary rocks are predominantly in the west, and older igneous and metamorphic rocks predominate in the east (Sharp 1994). In parts of this ecoregion, a slope effect causes distinct ecological differences: The south-facing slope receives more precipitation (30–40 inches per year) than the northern slope (15–20 inches) (Griffith et al. 2016).

### **Eastern Cascades Slopes and Foothills**

This ecoregion is found within the rain shadow of the Cascades Ecoregion, and it experiences greater temperature extremes and less precipitation, along with frequent fires. The Eastern Cascades Slopes and Foothills Ecoregion was formed through tectonic uplift and is characterized by its common volcanic cones, plateaus, and buttes. Historically, creeping ground fires burned through accumulated fuel, and devastating crown fires were less common in dry forests.

### **Central Basin and Range**

The Central Basin and Range Ecoregion is a large region that encompasses most of the western U.S.: southern Oregon, eastern California, the southern portions of Arizona and New Mexico, western Texas, and most of Nevada. The ecoregion is approximately 132,498 square miles, with only about 3.7 percent of its area falling within California (Soulard 2012). It contains alternating north-south trending faulted mountains and valley floors through the region.

This ecoregion is distinguished by its rugged desert country, with high topographic relief and subparallel fault-bounded mountain ranges (State Parks 2015). Playas at the lowest elevations in the Lahontan Basin are the terminus or “sink” of rivers that flow east from the Sierra Nevada. The ecoregion also contains California’s lowest point of elevation (282 feet below sea level in Death Valley), and the highest point is 14,252 feet above sea level at White Mountain Peak.

There are three separate physiographic areas in California's Basin and Range Ecoregion: the northernmost portion, bounded by the Modoc Plateau and Nevada border; the middle portion, bounded to the north by the Modoc Plateau and to the south by the Sierra Nevada region; and the largest, southernmost portion, bounded to the west by the Sierra Nevada region, to the south by the Mojave Desert, and to the east by the Nevada border. The region is distinctly cut off by the Garlock Fault to the south. The mountain ranges and intervening valleys are 50–100 miles long and 15–20 miles wide (Sharp 1994). Soils in this region grade upslope from mesic Aridisols to frigid Mollisols.

### **Mojave Basin and Range**

The Mojave Basin and Range Ecoregion stretches across southeastern California, southern Nevada, southwestern Utah, and northwestern Arizona. It is composed of broad basins with scattered mountains that are generally lower, warmer, and drier than in the Central Basin and Range Ecoregion. The ecoregion is bounded on the north by the Central Basin and Range Ecoregion, on the east by the Colorado Plateaus and the Arizona/New Mexico Plateau Ecoregions, on the south by the Sonoran Basin and Range Ecoregion, and on the west by the Southern California Mountains and the Sierra Nevada Ecoregions. The highest elevation in the ecoregion is 7,292 feet at Clark Mountain, with valley bottoms ranging from 2,000 to 4,000 above sea level. The Mojave Desert is bordered by the Garlock Fault to the north, the San Andreas Fault to the southwest, and the southern part of Death Valley fault zone to the east (Walker et al. 2002).

Precambrian to late Cenozoic age rocks are exposed across the ecoregion. The basin's soils mostly comprise Entisols and Aridisols that typically have a thermic temperature regime. Soils are susceptible to wind and water erosion because of heavy human interference.

### **Klamath Mountains/California High North Coast Range**

The Klamath Mountains/California High North Coast Range Ecoregion covers an elongated north-trending area in Northern California and southern Oregon. In California, it consists of several mountain ranges with features such as accordant summit levels, highly dissected old land surfaces, and high-elevation glacial topography. Most precipitation in this ecoregion drains westerly through deeply incised canyons of the Klamath and Trinity Rivers, with the easternmost areas draining toward the east and then south to the Sacramento River. Rocks in this ecoregion range in age from Ordovician to Late Jurassic and comprise greywacke sandstones, mudstones, greenstones, radiolarian cherts, limestone, and igneous intrusive rocks (Irwin 1966). Concentric belts from the east to the west, referred to as the Eastern Klamath, Central Metamorphic, Western Paleozoic and Triassic, and Western belts, are responsible for its pattern of distribution.

### **Northern Basin and Range**

The Northern Basin and Range Ecoregion is characterized by its dissected lava plains, rocky uplands, valleys, alluvial fans, and scattered mountain ranges. Aridisols are common within this range. Temperatures tend to be cooler and have more available moisture than in the Central Basin and Range Ecoregion, and are higher and cooler than in the Snake River Plain Ecoregion to the northeast in Idaho.

### **Sonoran Basin and Range**

The Sonoran Basin and Range Ecoregion has similar topography to the Mojave Basin and Range Ecoregion. It is characterized by scattered low mountains and contains large tracts of federally owned land. The Sonoran Basin and Range Ecoregion is slightly hotter than the Mojave Range. Precipitation in this ecoregion during the winter decreases from west to east, with summer precipitation decreasing from the east to west. This ecoregion contains harsh environments for plant growth because of the dominant Aridisols and Entisols with hypothermic soil temperatures and highly aridic soil moisture regimes.

### **Southern California/Northern Baja Coast**

The Southern California/Northern Baja Coast Ecoregion, extending more than 200 miles south into Baja California, contains coastal and alluvial plains, marine terraces, and a few low hills in the coastal area of Southern California.

## **3.9.3 Regulatory Setting**

This section discusses federal, state, and regional and local plans, policies, regulations, and laws, and ordinances pertaining to geological resources and soils.

Future permitted restoration projects that would be implemented under the Order may be subject to the laws and regulations listed below, as well as other local or individual restoration projects requirements, depending on the project location.

### ***Federal***

#### **U.S. Geological Survey Quaternary Faults**

The U.S. Geological Survey (USGS) maintains a database of Quaternary fault and fold parameters (USGS 2019). The database is periodically updated to reflect the latest data available and current understanding of fault behaviors. These fault parameters were used to develop the National Seismic Hazard Maps.

#### **U.S. Geological Survey National Seismic Hazard Maps**

USGS publishes probabilistic seismic hazard maps for the 48 conterminous states (USGS 2009). These maps depict contour plots of peak ground acceleration and spectral accelerations at selected frequencies for various ground motion return periods. The maps were developed for a reference site condition with an average shear-wave velocity of about 2,500 feet per second in the top 100 feet. Ground motions in the Sacramento–San Joaquin Delta may be as much as two to four times higher than elsewhere as a result of soft soil amplification.

The USGS National Seismic Hazard Maps are updated periodically and have been adopted by many building and highway codes.

#### **U.S. Geological Survey Landslide Hazard Program**

USGS provides information on the causes of ground failure and mitigation strategies to reduce long-term losses from landslide hazards. The information is useful for

understanding the nature and scope of ground failures and for improving mitigation strategies.

### **Federal Regulatory Design Codes for Buildings, Highways, and Other Structures**

Federal standards for minimum design regulate the construction of any buildings and other structures and include the following:

- ◆ American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures, ASCE-7-10, 2013
- ◆ U.S. Army Corps of Engineers (USACE) (CESPK-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004
- ◆ USACE Design and Construction of Levees, EM 1110-2-1913, 2000
- ◆ USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-2-1806, 2016
- ◆ USACE Engineering and Design—Earthquake Design and Evaluation of Concrete Hydraulic Structures, EM 1110-2-6053, 2007
- ◆ USACE Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic Structures, EM 1110-2-6050, 1999
- ◆ USACE Engineering and Design—Stability Analysis of Concrete Structures, EM 1110-2-2100, 2005
- ◆ USACE Engineering and Design—Structural Design and Evaluation of Outlet Works, EM 1110-2-2400, 2003
- ◆ USACE Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM 1110-2-6051, 2003
- ◆ USACE Slope Stability, EM 1110-2-1902, 2003
- ◆ U.S. Department of the Interior and USGS Climate Change and Water Resources Management: A Federal Perspective, Circular 1331

These standards establish the minimum design criteria and construction requirements, including design, for concrete and steel structures, levees, buildings, pumping stations, excavation and shoring, grading, and foundations. Standards issued by the state are listed in the following section.

### **National Earthquake Hazards Reduction Act (U.S. Code Title 42 Section 7704)**

In 1977, the U.S. Congress enacted the Earthquake Hazards Reduction Act of 1977 (Public Law 95-124) 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.*” The National Earthquake Hazards Reduction Program was also enacted in 1977, to accomplish the goals of the act. The Earthquake Hazards Reduction Act and National Earthquake Hazards Reduction Program were amended in 1990 to refine the description of agencies’ responsibilities,

program goals, and objectives. The Earthquake Hazards Reduction Act was amended as the National Earthquake Hazards Reduction Program Act. The four general goals of the National Earthquake Hazards Reduction Program are:

- ◆ Develop effective practices and policies to reduce losses of life and property from earthquakes and accelerate their implementation.
- ◆ Improve techniques for reducing seismic vulnerabilities of facilities and systems.
- ◆ Improve earthquake hazards identification and risk assessment methods, and their use
- ◆ Improve the understanding of earthquakes and their effects.

The National Earthquake Hazards Reduction Program Act designates the Federal Emergency Management Agency as the program's lead agency. Other supporting agencies include the National Institutes of Standards and Technology, the National Science Foundation, and USGS.

## **State**

### **Liquefaction and Landslide Hazard Maps (Seismic Hazards Mapping Act)**

The Seismic Hazards Mapping Act of 1990 (Public Resources Code Sections 2690 to 2699.6) was enacted following the Loma Prieta earthquake to reduce threats to public health and safety by identifying and mapping known seismic hazard zones in California. The act directs the California Geological Survey (formerly known as the California Division of Mines and Geology) to identify and map areas prone to earthquake hazards of liquefaction, earthquake-induced landslides, and amplified ground shaking. The maps assist cities and counties in fulfilling their responsibilities for protecting public health and safety.

As of April 2019, more than 100 official seismic hazard zone maps showing areas prone to liquefaction and landslides had been published in California, and more maps are scheduled for publication. Most mapping has been performed in Southern California and the San Francisco Bay Area.

A development permit review is required for sites in the mapped seismic hazard zones. Site-specific geologic investigations and evaluations are carried out to identify the extent of hazards, and appropriate mitigation measures are incorporated in the development plans to reduce potential damage.

### **Alquist-Priolo Earthquake Fault Zones**

The Alquist-Priolo Earthquake Fault Zoning Act (then called the Alquist-Priolo State Special Studies Zone Act) was enacted in 1972 (Public Resources Code Section 2621 et seq.). Similar to the Seismic Hazards Mapping Act, the Alquist-Priolo Act's main purposes are to identify known active faults in California and to prevent the construction of buildings for human occupancy on the surface trace of active faults.

### **State Regulatory Design Codes for Buildings, Highways, and Other Structures**

State standards for minimum design regulate the construction of any buildings and other structures and include the following:

- ◆ California Amendments to American Association of State Highway and Transportation Officials Load and Resistance Factor Design Bridge Design Specifications, Fourth Edition, 2008
- ◆ California Building Code, 2007 (California Code of Regulations Title 24)
- ◆ California Department of Transportation Seismic Design Criteria, latest edition
- ◆ California Department of Water Resources Division of Safety of Dams Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters, 2002
- ◆ California Department of Water Resources Interim Levee Design Criteria for Urban and Urbanizing Area State-Federal Project Levees, 2009

### **California Building Code**

California's minimum standards for structural design and construction are provided in the California Building Code (California Code of Regulations Title 24). The California Building Code provides standards for various aspects of construction, including excavation, grading, and fill. It provides requirements for classifying soils and identifying corrective actions when native soil properties could lead to structural damage (e.g., expansive soils).

### **Surface Mining and Reclamation Act of 1975**

The State Mining and Reclamation Act of 1975 (Public Resources Code Section 2710 et seq.) required the California State Geologist to implement a mineral land classification system to identify and protect mineral resources of regional or statewide significance in areas where urban expansion or other irreversible land uses may occur, thereby potentially restricting or preventing future mineral extraction on such lands. The intent of this law is for this information to be considered in local land use planning activities through the adoption of mineral resource management policies in general plans (Public Resources Code Section 2762). The California State Mining and Geology Board (SMGB) classifies such urban and non-urban lands according to a priority list, or when the board is otherwise petitioned to classify a particular land area.

As mandated by the State Mining and Reclamation Act, the SMGB classifies aggregate mineral resources in the state by applying the Mineral Resource Zone (MRZ) system. The MRZ system maps all mineral commodities within identified jurisdictional boundaries; priority is given to areas where land use compatibility issues may prevent or restrict future extraction of mineral resources, or where mineral resources may be mined during the 50-year period following their classification. The system classifies lands that contain mineral deposits and identifies the presence or absence of substantial sand and gravel deposits and crushed rock source areas (i.e., commodities used as, or in the production of, construction materials).

The State Geologist classifies MRZs in a region based on the following factors:

- ◆ **MRZ-1:** Areas where adequate information indicates that no significant mineral deposits are present, or where little likelihood exists for their presence.
- ◆ **MRZ-2:** Areas where adequate information indicates that significant mineral deposits are present, or where a high likelihood exists for their presence.
- ◆ **MRZ-3:** Areas containing mineral deposits for which the significance cannot be determined from available data.
- ◆ **MRZ-4:** Areas where available information is inadequate for assignment of any other MRZ category.

Mining operations and mine reclamation activities must be performed in accordance with laws and regulations adopted by the SMGB, as contained in Section 3500 et seq. of Title 14 of the California Code of Regulations. The California Department of Conservation's Office of Mine Reclamation oversees reclamation requirements.

#### **California Geological Survey**

The California Geological Survey assists in the identification and proper use of mineral deposits, and in the identification of fault locations and other geological hazards.

#### ***Regional and Local***

The study area encompasses multiple counties with multiple cities throughout California. Each county and city has local regulations and a general plan with unique goals and policies that guide development and encourage the consideration of geology, soils, seismicity, and mineral resources. These may include protection of soils, adherence to building codes, and protection of mineral resources.

### **3.9.4 Impacts and Mitigation Measures**

#### ***Methods of Analysis***

Geological and soil impacts from the types of restoration projects permitted under the Order are evaluated in terms of how typical construction and operation of project components could impact geological hazards and soil resources and is dependent on where individual restoration projects would be located relative to known or potential soil resources, geological hazards, and paleontological resources in the study area. However, the precise locations and detailed characteristics of potential future individual restoration projects are yet to be determined. Therefore, this geological resources and soils analysis focuses on reasonably foreseeable changes from implementation of the types of projects and actions that might be taken in the future consistent with the level of detail appropriate for a program-level analysis.

Permanent impacts are considered those that would continue through the life of a proposed restoration project as a result of the environmental conditions created by the project (e.g., implementation of channel stabilization and native revegetation that would

increase channel bank stability). Temporary impacts are considered those that would be temporary in nature (e.g., construction related activities).

The approach to assessing geological and soil impacts was to identify and review existing environmental studies, data, model results, and other information for projects that are consistent with those identified in Section 2.6, *Categories of Restoration Projects in the Order*, and Section 2.7, *Typical Construction, Operation, and Maintenance Activities and Methods*.

### ***Thresholds of Significance***

In accordance with Appendix G of the State CEQA Guidelines, an impact related to geologic, soils, or paleontological resources is considered significant if the types of restoration projects that would be permitted under the Order would do any of the following:

- ◆ Directly or indirectly cause 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 issued by the State Geologist for the area or based on other substantial evidence of a known fault. (Refer to Division of Mines and Geology Special Publication 42)
  - Strong seismic ground shaking
  - Seismic-related ground failure, including liquefaction
  - Landslides
- ◆ Result in substantial soil erosion or the loss of topsoil
- ◆ Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse
- ◆ Be located on expansive soils, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial direct or indirect risks to life or property
- ◆ Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater
- ◆ Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature

Potential impacts on mineral resources are addressed in Section 3.13 of this PEIR.

### ***Impacts Not Analyzed Further***

The types of restoration projects permitted under the Order would not include the use of septic tanks or alternative wastewater disposal because the projects would not increase the demand for wastewater disposal from construction or operation crews or occupied structures. Therefore, impacts related to this threshold of significance are not addressed further.

### **Impacts and Mitigation Measures**

Table 3.9-1 summarizes the impact conclusions presented in this section by proposed project type under the Order for easy reference.

As part of the State Water Board or Regional Board’s issuance of a NOA for a restoration project under the Order, compliance with the general protection measures and mitigation measures listed below would be required when applicable to a given project. Not all general protection measures and mitigation measures would apply to all restoration projects. The applicability of the general protection measures and mitigation measures would depend on the individual restoration activities, project location, and the potentially significant impacts of the individual restoration project. Implementation of the mitigation measures would be the responsibility of the project proponent(s) under the jurisdiction of the State Water Board, appropriate Regional Board, or other authorizing regulatory agency.

**Table 3.9-1  
Summary of Impact Conclusions—Geology and Soils**

Impact Statement	Construction Activities	Constructed Facilities and Operations and Maintenance
<b>3.9-1:</b> Implementing future restoration projects permitted under the Order could cause direct or indirect adverse effects on people or structures related to risk of loss, injury, or death due to a fault rupture.	LTSM	LTSM
<b>3.9-2:</b> Implementing future restoration projects permitted under the Order could directly or indirectly result in adverse effects on people or structures related to risk of loss, injury, or death due to strong seismic ground shaking.	LTSM	LTSM
<b>3.9-3:</b> Implementing future restoration projects permitted under the Order could directly or indirectly cause adverse effects on people or structures from unstable soil conditions.	LTSM	LTSM
<b>3.9-4:</b> Implementing future restoration projects permitted under the Order could result in substantial soil erosion or loss of topsoil.	LTSG	LTSG
<b>3.9-5:</b> Implementing future restoration projects permitted under the Order could directly or indirectly result in the loss of a unique paleontological resource or geological resource.	SU	SU

SOURCE: Data compiled by Environmental Science Associates in 2019 and 2020

NOTES: LTSG = less than significant with implementation of general protection measures; LTSM = less than significant with mitigation; SU = significant and unavoidable

### **Impact 3.9-1: Implementing future restoration projects permitted under the Order could cause direct or indirect adverse effects on people or structures related to risk of loss, injury, or death due to a fault rupture.**

#### **Effects of Project Construction Activities, Constructed Facilities (Natural or Artificial Infrastructure), and Operations and Maintenance of those Facilities**

Construction of restoration projects, constructed facilities (natural or artificial infrastructure), and operations and maintenance of those facilities permitted under the Order could result in significant adverse effects on people or structures from fault rupture. Reconnecting historical stream and river channels, freshwater deltas with floodplains, and

historical estuaries to tidal influence by removing, setting back, and breaching levees could improve seismic stability compared to existing conditions; however, fault rupture could damage these structures. Damage to these features could result in their failure, causing flooding in otherwise protected areas. The degree of impact would depend on the location of activities and structures relative to areas with potential for fault rupture.

For example, a restoration project involving hydraulic reconnection, levee setbacks, and floodplain restoration could be located in a seismically active region, near several known active and potentially active faults, and could expose people or structures to potential fault rupture hazards. However, levees would be designed according to federal, state, and local standards, taking into consideration site conditions and geologic hazards.

Construction of facilities such as fish screens, water control structures, stream crossings, offstream storage ponds, and tanks on or adjacent to a known fault could expose them to risks of fault rupture. Damage to the facilities could result in flooding of otherwise protected areas. For example, water control structures or stream crossings placed in areas subject to fault rupture could be damaged during an earthquake, which could lead to flooding in the areas surrounding the structures. The degree of impact would depend on the location of activities and structures relative to areas with the potential for fault rupture.

### **Impact Conclusion**

The specific locations and scale of possible future restoration projects are not yet determined; therefore, the risk of a fault rupture cannot be determined. Factors needed to identify specific impacts include the project's design, its location relative to underlying soil and geotechnical conditions, and proximity to known earthquake faults. Because restoration projects permitted under the Order could cause direct or indirect adverse effects on people or structures related to the risk due to a fault rupture, this impact would be **potentially significant**. The Order does not include any general protection measures applicable to this impact.

As part of the State Water Board or Regional Board's issuance of a NOA for a restoration project under the Order, compliance with Mitigation Measure GEO-1 and GEO-2 would be required when applicable to a given project. Implementation of this mitigation measure would be the responsibility of the project proponent(s) under the jurisdiction of the State Water Board, appropriate Regional Board, or other authorizing regulatory agency.

### ***Mitigation Measure GEO-1: Include Geotechnical Design Recommendations***

To minimize potential impacts from seismic events and the presence of adverse soil conditions, lead agencies shall ensure that geotechnical design recommendations are included in the design of facilities and construction specifications. Recommended measures to address adverse conditions shall conform to applicable design codes, guidelines, and standards.

***Mitigation Measure GEO-2: Comply with the Alquist-Priolo Act***

For construction in an Alquist-Priolo Earthquake Fault Zone, a determination must be made by a licensed practitioner (California Certified Engineering Geologist) that no fault traces are present within structures, such as setback levees. The standard of care for such determinations includes direct examination of potentially affected subsurface materials (soil and/or bedrock) by logging of subsurface trenches. Levee structures may also be required to have heavier reinforcement against strong ground motion, in compliance not only with California regulations but, in many cases, with additional federal regulations.

Implementing Mitigation Measures GEO-1 and GEO-2 would reduce potentially significant impacts related to the potential exposure to people and structures to risk of loss, injury, or death due to a fault rupture to a **less-than-significant** level.

**Impact 3.9-2: Implementing future restoration projects permitted under the Order could directly or indirectly result in adverse effects on people or structures related to risk of loss, injury, or death due to strong seismic ground shaking.**

**Effects of Project Construction Activities, Constructed Facilities (Natural or Artificial Infrastructure), and Operations and Maintenance of those Facilities**

Construction of restoration projects, constructed facilities (natural or artificial infrastructure), and operations and maintenance of those facilities permitted under the Order could result in a variety of direct or indirect adverse effects on people or structures related to strong seismic ground shaking. Because of the presence of known and active faults found throughout the state, strong ground motion during a seismic event could occur in the study area.

Newly constructed fish screens, water control structures, stream crossings, offstream storage ponds and tanks, or other facilities could be located in areas that expose them to strong seismic groundshaking. Damage to the facilities could result in the flooding of otherwise protected areas. For example, water control structures or stream crossings placed in areas subject to strong seismic groundshaking could be damaged during an earthquake, which could lead to flooding of the areas surrounding the structures. The degree of impact would depend on the locations of the activities and structures relative to areas with the potential for groundshaking.

Some restoration projects permitted under the Order could have beneficial impacts related to seismic ground shaking. For example, a restoration project could stabilize embankment slopes by removing non-native vegetation that is in poor condition and poses safety hazards to surrounding areas in the event of severe seismic shaking. With removal of the non-native vegetation and implementation of channel stabilization and native revegetation, impacts related to strong seismic shaking would be beneficial by reducing the potential for injuries and increasing channel bank stability.

**Impact Conclusion**

The specific locations and scale of possible future permitted restoration projects are not known at this time; therefore, the risk associated with strong seismic ground shaking

cannot be determined. Because restoration projects permitted under the Order could directly or indirectly result in adverse effects on people or structures related to strong seismic ground shaking, this impact would be **potentially significant**. The Order does not include any general protection measures applicable to this impact.

As part of the State Water Board or Regional Board's issuance of a NOA for a restoration project under the Order, compliance with Mitigation Measure GEO-3 would be required when applicable to a given project. Implementation of this mitigation measure would be the responsibility of the project proponent(s) under the jurisdiction of the State Water Board, appropriate Regional Board, or other authorizing regulatory agency.

***Mitigation Measure GEO-3: Conduct Individual Restoration Project Geotechnical Investigation and Report***

An individual restoration projects geotechnical investigation shall be performed and a geotechnical report prepared for any restoration project that would result in potentially significant grading activities. The geotechnical report shall include a quantitative analysis to determine whether excavation or fill placement would result in a potential for damage due to soil subsidence during and/or after construction. Project designs shall incorporate measures to reduce the potential damage to a less-than-significant level. Measures shall include but not be limited to:

- ◆ Removal and recompaction of existing soils susceptible to subsidence
- ◆ Ground improvement (such as densification by compaction or grouting, soil cementation)
- ◆ Reinforcement of structural components to resist deformation due to subsidence

The assessment of subsidence for specific projects shall analyze the individual restoration projects potential for and severity of cyclic seismic loading. A geotechnical investigation shall also be performed by an appropriately licensed professional engineer and/or geologist to determine the presence and thickness of potentially liquefiable sands that could result in loss of bearing value during seismic shaking events. Project designs shall incorporate measures to mitigate potential damage to a less-than-significant level. Measures shall include but not be limited to:

- ◆ Ground improvement (such as grouting or soil cementation)
- ◆ Surcharge loading by placement of fill, excavation, soil mixing with non-liquefiable finer-grained materials, and replacement of liquefiable materials at shallow depths
- ◆ Reinforcement of structural components to resist deformation due to liquefaction

An analysis of individual restoration projects probable and credible seismic acceleration values, conducted in accordance with current applicable standards of care, shall be performed to provide for a suitable project design. Geotechnical investigations shall be performed and geotechnical reports shall be prepared in the responsible care of California licensed geotechnical professionals including professional civil engineers, certified geotechnical engineers, professional

geologists, certified engineering geologists, and certified hydrogeologists, all of whom practice within the current standards of care for such work.

***Mitigation Measure GEO-4: Adhere to International Building Code***

Constructed facilities shall be required to adhere to the current approved version of the International Building Code (IBC), and to comply with the IBC for critical structures (e.g., levees).

Implementing Mitigation Measures GEO-3 and GEO-4 would reduce potentially significant impacts that could result in direct or indirect adverse effects on people or structures related to the risk due to strong seismic ground shaking to a **less-than-significant** level.

**Impact 3.9-3: Implementing future restoration projects permitted under the Order could directly or indirectly cause adverse effects on people or structures from unstable soil conditions.**

**Effects of Project Construction Activities, Constructed Facilities (Natural or Artificial Infrastructure), and Operations and Maintenance**

Construction of restoration projects, constructed facilities (natural or artificial infrastructure), and operations and maintenance of those facilities permitted under the Order could directly or indirectly expose people or structures to unstable soil conditions, including landslides, expansive soils, subsidence, high organic matter soils, or increased runoff. Expansive soils that express shrink-and-swell cycles are found throughout California; these soils could create unstable foundations for rigid structures by exerting pressure on building foundations, or could cause surface cracking and runoff infiltration. Construction activities could expose or reduce vertical distance to expansive clays in ground layers beneath the surface, and could cause soil fissures that could exacerbate the problem. Exposing expansive soils to moisture could result in upward heaving, especially differential heaving, which could damage improvements. Highly expansive soils are found throughout the state; however, they are more likely to be found in valley basins containing well-developed soils with high clay content than in more organic rich soils or younger alluvial soils near streams.

During the design and construction of restoration projects, it is important to identify and mitigate expansive soils because the potential for construction on expansive soils to cause structural problems may not become apparent for many years. For example, floodplain restoration projects permitted under the Order could require constructing new levees to facilitate the removal or breaching of existing levees and the creation of aquatic or riparian habitat. The new levees could be damaged if constructed on unstable soils, potentially exposing the surrounding areas to flooding.

Construction activities and constructed facilities for restoration projects permitted under the Order could be located on soils with high levels of organic matter. Construction on such soils could reduce stability and result in structural problems over time because of instable bearing surfaces. High organic soils generally settle and decrease in volume as organic matter decays. If design and construction of the restoration projects do not account for organic matter, soils with a high organic makeup could degrade structural

integrity through the collapse of pore space between molecules or the compaction of saturated silts and sands. Construction activities that would involve placing fill could accelerate subsidence by causing the consolidation of surcharged loads of peat and other unconsolidated sediments, which could lead to differential subsidence after construction and result in distress to the improvements.

Restoration activities permitted under the Order could involve dewatering activities, such as temporary dewatering of a restoration project's construction site, or removal of small dams, which would involve using explosives in dry or dewatered conditions. Subsidence could occur during such activities, with effects similar to the effects of construction on soils with high organic matter, resulting in the collapse of pore space. However, these activities would be short-term and would not likely lead to conditions that would result in subsidence.

Liquefiable sands could be exposed if surficial layers were removed during construction, which would increase the risk of bearing value, soil settlement, and lateral spreading during earthquake-related seismic shaking. This could result in soil liquefaction, in which transient higher pore water pressures in groundwater would cause soils to liquefy. For example, a small dam may be removed in an area where shrink-swell potential is moderate as the result of expansive soils. However, this type of project would not include any habitable structures, nor would it expose people or structures to risks associated with expansive soils.

Restoration projects permitted under the Order could result in beneficial outcomes to the surrounding areas, such as the removal of structures (e.g., legacy structures), which can decrease soil loss and instability. For example, removing an instream legacy structure may potentially increase the area's stability by restoring channel form and preventing further erosion. Another example is a floodplain restoration project that may have beneficial impacts on levee bank stability. Berm construction and levee reconstruction components would reduce the potential for seepage and seepage-related levee failures by reducing hydrostatic exit gradients, and thus increasing bank and soil stability.

### Impact Conclusion

To determine the effects of construction activities related to unstable soils, factors such as project design, location relative to underlying soils, and geotechnical conditions would need to be known. Because the potential exists for indirect or direct exposure of people or structures to adverse effects from unstable soils during restoration projects permitted under the Order, this impact would be **potentially significant**. The Order does not include any general protection measures applicable to this impact.

As part of the State Water Board or Regional Board's issuance of a NOA for a restoration project under the Order, compliance with Mitigation Measure GEO-3, GEO-6, GEO-7, and GEO-8 would be required when applicable to a given project. Implementation of this mitigation measure would be the responsibility of the project proponent(s) under the jurisdiction of the State Water Board, appropriate Regional Board, or other authorizing regulatory agency.

***Mitigation Measure GEO-5: Conduct Expansive Clay Investigation***

In areas where expansive clays exist, a licensed professional engineer or geologist shall perform a hydrogeological/geotechnical investigation to identify and quantify the potential for expansion, particularly differential expansion of clayey soils caused by leakage and saturation beneath new improvements. Measures could include but are not limited to removing and recompacting problematic expansive soils, stabilizing soils, and/or reinforcing the constructed improvements to resist deformation from expansion of subsurface soils.

***Mitigation Measure GEO-6: Implement Measures for Waterway Construction Activities***

For projects that involve the engineered subsurface structural components (e.g., of surface impoundments, levees, bridge footings/abutments) project design shall provide for protection from leakage to the subsurface. Measures could include but are not limited to rendering concrete less permeable by specifying concrete additives such as bentonite, designing impermeable liner systems, designing leakage collection and recovery systems, and constructing impermeable subsurface cutoff walls.

For restoration projects that could cause subsurface seepage of nuisance water onto adjacent lands, the following measures shall be implemented:

- ◆ Perform seepage monitoring studies by measuring the level of shallow groundwater in the adjacent soils, to evaluate baseline conditions. Continue monitoring for seepage during and after project implementation.
- ◆ Develop a seepage monitoring plan if subsurface seepage constitutes nuisance water on the adjacent land.
- ◆ If adjacent land is not usable, implement seepage control measures, such as installing subsurface agricultural drainage systems to avoid raising water levels into crop root zones. Cutoff walls and pumping wells can also be used to mitigate the occurrence of subsurface nuisance water.

***Mitigation Measure GEO-7: Implement Measures for Levee Construction and Other Fill Embankment Designs***

For projects that involve the construction of setback levees, surface impoundments, and other fill embankments, the project design shall place fill in accordance with state and local regulations and the prevailing standards of care for such work. Measures could include but are not limited to blending the soils most susceptible to landsliding with soils that have higher cohesion characteristics; installing slope stabilization measures; designing top-of-slope berms or v-ditches, terrace drains, and other surface runoff control measures; and designing slopes at lower inclinations.

***Mitigation Measure GEO-8: Assess the Presence of Highly Organic Soils***

For projects that would result in a significant or potentially significant risk to structures because of the presence of highly organic soils, the lead agencies shall

require a geotechnical evaluation before construction to identify measures to mitigate organic soils. The following measures may be considered:

- ◆ Over-excavation and import of suitable fill material.
- ◆ Structural reinforcement of constructed works to resist deformation.
- ◆ Construction of structural supports below the depth of highly organic soils into materials with suitable bearing strength.

Implementing Mitigation Measures GEO-3, GEO-5, GEO-6, GEO-7, and GEO-8 would reduce potentially significant impacts related to indirect or direct adverse effects on people or structures associated with the risk from unstable soils to a **less-than-significant** level.

**Impact 3.9-4: Implementing future restoration projects permitted under the Order could result in substantial soil erosion or loss of topsoil.**

**Effects of Project Construction Activities**

Construction-related activities for restoration projects permitted under the Order could result in substantial soil erosion or the loss of topsoil by disturbing large volumes of soil through excavation, earthmoving, grading, filling, or stockpiling of soil material. These disturbed soils could be more susceptible to wind and water erosion, resulting in the loss of topsoil. Water erosion has a higher potential to occur on steep and/or organic sediment and could occur in many parts of the state.

For example, construction of a setback levee may have temporary and short-term erosion impacts on the soil surface. The removal of topsoil followed by replacement on-site after project construction may temporarily disturb the soil and could expose areas to winter or early storm events. Soil disturbance may also have the potential to result in substantial loss of topsoil due to wind erosion. However, implementation of standard best management practices (e.g., preparing and implementing a storm water pollution prevention plan and complying with the National Pollutant Discharge Elimination System) would reduce soil disturbance.

**Impact Conclusion**

Because the specific locations and scale of restoration projects permitted under the Order are not yet determined, this impact would be **potentially significant**.

Projects implementing applicable general protection measures (see Appendix E) included in the Order would further reduce impacts to geology and soil resources. The following general protection measures may apply to geology and soil resources:

- ◆ GPM-15: Revegetate Disturbed Areas
- ◆ WQHM-1: Staging Areas and Stockpiling of Materials and Equipment
- ◆ WQHM-2: Storm Water Pollution Prevention Plan
- ◆ WQHM-3: Erosion Control Plans
- ◆ WQHM-4: Hazardous Materials Management and Spill Response Plan
- ◆ VHDR-1: Avoidance of Vegetation Disturbance
- ◆ VHDR-3: Revegetation Materials and Methods
- ◆ VHDR-4: Revegetation Erosion Control Materials and Methods

Implementing the general protection measures identified above would reduce impacts related to substantial soil erosion or loss of topsoil to a **less-than-significant** level.

#### **Effects of Constructed Facilities (Natural or Artificial Infrastructure) and Operations and Maintenance of those Facilities**

Routine O&M activities for restoration projects permitted under the Order could result in impacts similar to those described under *Effects of Project Construction Activities*. In general, impacts related to the loss of topsoil (i.e., soil disturbance activities) would occur primarily as a result of construction activities, and the impact would not increase in severity once construction is complete. However, ongoing maintenance activities, such as adjustments to grading or soils composition, could expose soil to increased rates of erosion.

Some restoration projects under the Order would actually reduce soil erosion and result in a positive effect on topsoil and erosion levels. An example is a restoration project involving bioengineered bank stabilization that would improve aquatic and riparian habitat while reducing soil erosion and sedimentation of streams and wetlands by providing a revetment consisting of trees and native plant materials. Restoration projects involving the removal of non-native terrestrial and aquatic invasive species and revegetation with native plant species would also benefit soil health and reduce soil erosion. For this reason, some projects permitted under the Order could be beneficial to soil erosion and topsoil. However, because the potential exists for projects to result in substantial soil erosion or loss of topsoil, this impact would be **potentially significant**.

Implementing the general protection measures listed above would reduce impacts on soil erosion and the loss of topsoil to a **less-than-significant** level.

**Impact 3.9-5: Implementing future restoration projects permitted under the Order could directly or indirectly result in the loss of a unique paleontological resource or geological resource.**

#### **Effects of Project Construction Activities, Constructed Facilities (Natural or Artificial Infrastructure), and Operations and Maintenance of those Facilities**

Construction of restoration projects, constructed facilities (natural or artificial infrastructure), and operations and maintenance of those facilities permitted under the Order could result in the loss of a unique paleontological or geological resource. Impacts on paleontological resources would be permanent if construction activities would disrupt or destroy fossil remains or sites, or create the loss of information and the potential destruction of nonrenewable paleontological resources.

#### **Impact Conclusion**

To determine the effects of construction activities and constructed facilities, paleontological or geological resources would need to be known. Also, restoration projects permitted under the Order could directly or indirectly result in the loss of a unique paleontological resource or geological resource, if projects are located on or near areas where sediment with moderate to high paleontological sensitivity occurs. Because the potential exists for restoration projects permitted under the Order to result

in adverse effects on paleontological or geological resources, this impact would be **potentially significant**. The Order does not include any general protection measures applicable to this impact.

As part of the State Water Board or Regional Board's issuance of a NOA for a restoration project under the Order, compliance with Mitigation Measure GEO-9 and GEO-10 would be required when applicable to a given project. Implementation of this mitigation measure would be the responsibility of the project proponent(s) under the jurisdiction of the State Water Board, appropriate Regional Board, or other authorizing regulatory agency.

#### ***Mitigation Measure GEO-9: Conduct a General Project-Level Analysis***

Restoration projects implemented by other public proponents under the Order would be required to do a desktop search on whether the project site would be located in a paleontological sensitive unit. If the project site was determined to be located on a paleontological sensitive unit, then Mitigation Measure GEO-9 (and Mitigation Measure GEO-10, below, as applicable) would be implemented. If restoration projects implemented under the Order fall outside a paleontological sensitive unit, GEO-9 (and Mitigation Measure GEO-10, below) would be not required.

During project development and project-level analysis, a paleontological resource monitoring and recovery plan shall be developed and implemented for all actions determine by the project proponent to be located on a paleontological sensitive unit. The plan shall include protocols for paleontological resources monitoring in areas where construction-related excavation would affect sediment with moderate to high paleontological sensitivity.

The paleontological resource monitoring and recovery plan shall provide guidelines for the establishment of a yearly or biannual monitoring program led by a qualified paleontologist to determine the extent of fossiliferous sediment being exposed and affected by erosion, and determine whether paleontological resources are being lost. If the loss of scientifically significant paleontological resources is documented, then a recovery program should be implemented.

#### ***Mitigation Measure GEO-10: Conduct Worker Training***

For projects that are determined to have moderate to high paleontological sensitivity, before the start of any ground-disturbing activity (e.g., excavation or clearing), a qualified paleontologist shall prepare paleontological resources sensitivity training materials for use during project worker environmental training or equivalent. This training shall be conducted by a qualified environmental trainer under the supervision of the qualified paleontologist. For restoration projects that involve construction crew phases, additional trainings shall be conducted for new construction personnel. The paleontological resource sensitivity training shall focus on the types of resources that could be encountered within the individual restoration project site and the procedures to follow if they are found. Project proponents and/or project contractors shall retain documentation demonstrating that all construction personnel attended the

paleontological resource sensitivity training before the start of work on the site, and shall provide documentation to the project manager upon request.

Mitigation Measures GEO-9 and GEO-10 would be implemented to reduce the impacts related to the loss of a unique paleontological resource or geological resource caused by restoration projects permitted under the Order. However, because the extent and location of such actions are not known at this time (e.g., location, sediment sensitivity of the area, and distance a restoration project might be from a known paleontological or geological resource), it is not possible to conclude that the mitigation measures, or equally effective mitigation measures, would reduce impacts to a less-than-significant level in all cases. Therefore, impacts would be **significant and unavoidable**.