

4.1 Geology and Soils

4.1.1 Introduction

This section describes whether implementation of the Russian River Estuary Management Project (Estuary Management Project or proposed project) would result in potential adverse impacts related to the existing geology, soils, mineral resources, and seismicity. The Setting section describes existing conditions in terms of local topography, geology, soil resources, mineral resources, and seismicity. The Regulatory Framework section describes pertinent state and local laws related to the geologic, mineral resources, and seismic considerations of the project. The Impacts and Mitigation Measures section defines significance criteria used for the impact assessment and presents a discussion of potential project-related impacts. The evaluation and analysis are based, in part, on review of various geologic maps and reports. The primary sources include available resources from the United States Geological Survey (USGS) and the Department of Conservation California Geological Survey (CGS), as well as other sources cited in the References section.

4.1.2 Setting

Topography

The regional topography is typical of the Coast Ranges of Northern California, where long northwest-southeast trending ridges and valleys dominate surface relief. The regional area is located within the Russian River watershed (**Figure 2-1**). The headwaters of the Russian River are located at the northernmost boundary of the watershed, approximately 16 miles north of Ukiah. The Russian River Estuary (Estuary) is located at the downstream end of the Russian River at Jenner and the Pacific Ocean. The mountains of the Coast Range reach peak elevations of 1,000 to 3,000 feet above mean sea level (MSL), with slopes commonly reaching 30 percent.

The Russian River cuts westerly from the Santa Rosa Plain, located approximately 15 miles to the east of Jenner. As the Russian River cuts westerly from the Santa Rosa Plain through the coastal mountain ranges, the elevation of the river gradually declines until it reaches sea level near the river's mouth near Jenner.

The Estuary extends from the mouth of the Russian River upstream approximately seven miles to the Duncans Mills area below the confluence with Austin Creek; this is referred to as the Estuary Study Area (see **Figure 2-3a**). It is estimated that Estuary water levels, when managed as a summer freshwater lagoon under the Estuary Management Project, may extend to Monte Rio, and under certain closed conditions backwater to Vacation Beach, referred to as the maximum backwater area. As such, the project area for the Estuary Management Plan as it relates to geologic and soil conditions will be defined as extending from the mouth of the Russian River to Vacation Beach (**Figure 2-3a**). The topographic surface elevations of the Russian River range from approximately 0 feet MSL to less than 10 feet MSL at the upper Estuary. Peaks within one mile on the north side of the valley cut by the Russian River are as high as 1,200 feet MSL with slopes up to 30 percent.

Topographic elevations at the breaching area, where the Russian River enters the Pacific Ocean, vary from less than 0 MSL when the beach barrier has been breached to approximately 7 or more feet MSL, the elevation at which the Water Agency typically breaches the barrier beach. Build up of a barrier beach can result in water levels that exceed 7 feet, which necessitates artificial breaching to minimize flooding impacts.

Project Area Geology and Soils

The geology of the Estuary project area (Estuary Study Area and maximum backwater area) can be characterized in terms of bedrock overlain with surficial deposits. Bedrock generally refers to rock, usually solid, that underlies soil or other unconsolidated surficial material that forms the structural core of hilly and mountainous areas. Surficial deposits generally refer to loosely-bound surface materials, such as recent soils and sediment that fill swales and hollows, canyons and ravines, river and stream valleys, and large basins. Further, mapping of surficial deposits often includes areas where topography has been substantially altered by human influence through placement of artificial fills or by other means. The following discussion is organized in terms of bedrock geology and surficial geology, both of which are illustrated in **Figure 4.1-1**.

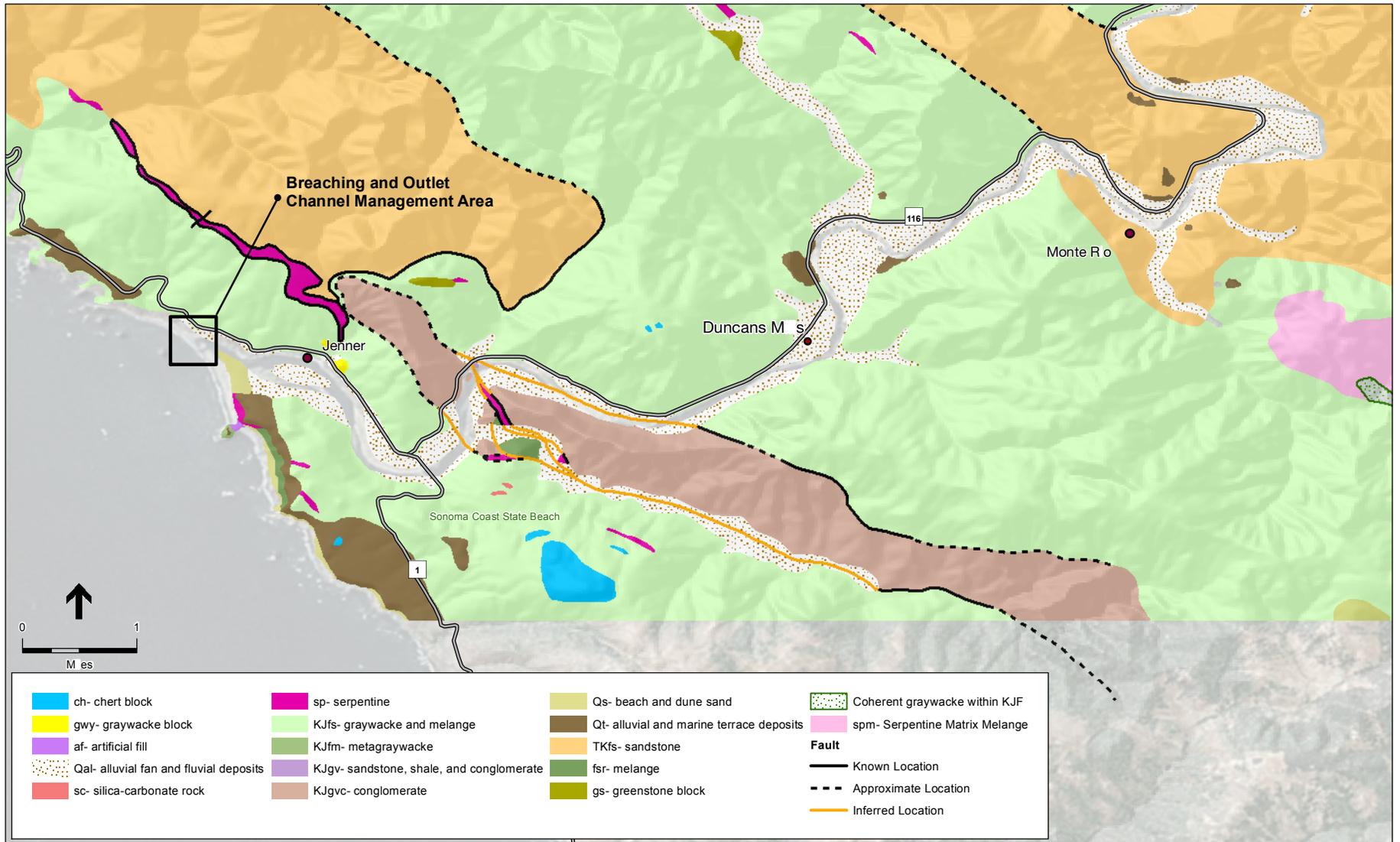
Bedrock Geology

The Estuary is located within the geologically complex region of California referred to as the Coast Range Geomorphic Province. Much of the Coast Range Province is composed of marine sedimentary deposits and volcanic and metamorphic¹ rocks that form northwest trending mountain ridges and valleys, running subparallel to the San Andreas Fault Zone. Bedrock geology in this region consists primarily of the Franciscan Complex and, to a lesser extent, the Great Valley Complex that originated as ancient sea floor sediments. Quaternary (10,000 to 1.8 million years before present) marine terrace deposits are present along portions of the coastal bluffs. Surface deposits in and along the edges of river channels such as the Russian River typically consist of Quaternary alluvial and terrace deposits (Blake, et al., 2002). Each is described below.

Franciscan Complex

The Estuary area is underlain by the Franciscan Complex of Jurassic-Cretaceous age (65 to 200 million years ago). Most of the material consists of sheared mudstone and sandstone, within which are mixed numerous blocks and slabs of greywacke (a variety of sandstone), greenstone (altered volcanic rocks), chert (a variety of quartz), metamorphic rocks, limestone, serpentinite, and other rocks. Although considered a single terrane or unit, the Franciscan Complex is actually the result of the tectonic and/or sedimentary mixing of rocks derived from various locations. Located east of the San Andreas Fault Zone, the units are steeply inclined to the east and are several thousand feet thick.

¹ Metamorphic rocks are those rocks which have formed in the solid state in response to pronounced changes of temperature, pressure, and chemical environment.



SOURCE:USGS Field Studies Map MF- 2402, 2002

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Figure 4.1-1
Bedrock and Superficial Geology

Great Valley Complex

The Great Valley Complex is present as a northwest-southeast block cutting across the Estuary area at Ferry Crossing and Sawmill Gulch. The unit consists mostly of a Jurassic-Cretaceous age (65 to 200 million years ago) conglomerate, with some shale, sandstone, rhyolite, ash-flow tuff, and minor quartzite.

Pleistocene Marine Terrace Deposits

Marine terrace materials were emplaced in the Pleistocene (1.8 million to 10,000 years ago) and consist of crudely bedded, clast supported gravels, cobbles, and boulders in a sandy matrix. The marine terrace deposits are the remnants of an older alluvial system that was lifted above present depositional levels by tectonic uplift. This unit is present along the coastal bluffs and has been eroded away at the mouth of the Russian River.

Surficial Deposits

Quaternary Alluvial Fan and Fluvial Deposits

The youngest geologic units in the project area are the surficial deposits made up of unconsolidated and semi-consolidated alluvial and river (fluvial) sediments. The alluvium consists of unconsolidated stream, channel, levee, flood plain, basin, terrace, and fan deposits ranging in size from boulders to clay. The alluvial material at the beach barrier at the mouth of the Russian River consists of sand, gravel, and silt deposited by the river or washed up by the ocean.

Soils

The description of Estuary area soils is based on a review of soil surveys prepared by the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS). **Table 4.1-1** identifies the soils present in the Estuary Management Project area, and summarizes some of their key physical and hydrological characteristics.

Landslides

Regional-scale mapping by the California Division of Mines and Geology has mapped the Estuary Management Project area as having numerous landslides (Armstrong, 1980). The natural geology and relatively steep topography of slopes within the project area provides a high susceptibility to landslides. It should be noted that landslides are not mapped at the barrier beach where the project activity will take place.

Geologic Hazards

Slope Failure Hazards

A slope failure is a mass of rock, soil, and debris displaced down a slope under the influence of gravity by sliding, flowing, or falling. Several factors affect the susceptibility of an area to experience slope failure, including slope steepness; the material strength and bulk density of soil or bedrock; the width, orientation and pervasiveness of bedrock fractures or bedding planes; prevailing groundwater conditions; and the type and distribution of vegetation. Those features, among others, are important

**TABLE 4.1-1
PROPERTIES OF THE NRCS-MAPPED SOIL UNITS IN THE PROJECT AREA**

Map Symbol and Name	Effective Depth (inches)^a	Available water-holding capacity (inches)^b	Erosion Hazard^c	Hydrologic Group^d	Shrink-Swell Behavior^e
AdA, Alluvial Land, Sandy	0 to 60	3.2	Low	A	Low
AkC, Arbuckle Gravelly Loam, 5 to 9 percent slopes	0 to 72	8.1	Low	B	Low
AtF, Atwell Clay Loam, 30 to 50 percent slopes	0 to 64	9.8	Moderate	C	Moderate
ChA, Coastal Beaches	0 to 60	2.4	Low	A	Low
CrA, Cortina Very Gravelly Sandy Loam, 0 to 2 percent slopes	0 to 60	4.0	Low	A	Low
CsA, Cortina Very Gravelly Loam, 0 to 2 percent slopes	0 to 60	4.0	Low	A	Low
HkG, Hugo Very Gravelly loam, 50 to 75 percent slopes	0 to 52	5.7	Low	B	Moderate
HIF, Hugo-Atwell Complex, 30 to 50 percent slopes	0 to 44	4.7	Low	B	Moderate
HIG, Hugo-Atwell Complex, 50 to 75 percent slopes	0 to 52	5.7	Low	B	Moderate
HnG, Hugo-Josephine Complex, 50 to 75 percent slopes	0 to 52	5.7	Low	B	Moderate
HsG, Hugo-Hely Complex, 50 to 75 percent slopes	0 to 34	3.4	Moderate	B	Moderate
JoE, Josephine Loam, 9 to 30 percent slopes	0 to 49	7.4	Moderate	B	Moderate
KIF, Kinman Loam, 30 to 50 percent slopes	0 to 58	7.7	Moderate	C	High
KmF, Kinman-Kneeland Loams, 30 to 50 percent slopes	0 to 44	5.0-6.2	Moderate	C	Moderate
KnF, Kneeland Loams, 30 to 50 percent slopes	0 to 26	3.3	Moderate	C	Moderate
LgG, Laughlin Loam, 50 to 75 percent slopes	0 to 26	3.3	Moderate	c	Moderate
McF, Maymen Gravelly Sand Loam, 30 to 50 percent slopes	0 to 22	1.4	Moderate	D	Low
RnA, Riverwash	0 to 60	1.8	Low	D	Low
RrD, Rhonerville Loam 9 to 15 percent slopes	0 to 60	9.6	Moderate	B	High
TeG, Terrace Escarpments	Terrace Escarpments are classified in hydrologic group C and characterized by a concave down slope shape and a convex across-slope shape. They are composed of alluvium parent material. The depth of the material can range from 0 to 60 inches.				

TABLE 4.1-1 (Continued)
PROPERTIES OF THE NRCS-MAPPED SOIL UNITS IN THE PROJECT AREA

Map Symbol and Name	Effective Depth (inches) ^a	Available water-holding capacity (inches) ^b	Erosion Hazard ^c	Hydrologic Group ^d	Shrink-Swell Behavior ^e
TmA, Tidal Marsh	Tidal Marsh area is classified in hydrologic group D and characterized by a saturated and highly vegetated area with poor drainage and frequent flooding. Tidal Marsh is generally composed of organic parent material that ranges in depth from 0 to 60 inches.				
YiA, Yolo Sandy Loam, 0 to 2 percent slopes	0 to 60	9.0	Moderate	B	Low
YmB, Yolo Sandy Loam, Overwash, 0 to 5 percent slopes	0 to 60	9.2	Moderate	B	Low
YoB, Yolo Loam Overwash, 0 to 5 percent slopes	0 to 60	10.6	Moderate to High	B	Low
YuE, Yorkville Clay Loam, 5 to 30 percent slopes	0 to 62	7.9	Moderate	D	High
YuF, Yorkville Clay Loam, 30 to 50 percent slopes	0 to 47	6.9	Moderate	D	High
ZaA, Zamora Silty Clay Loam, 0 to 2 percent slopes	0 to 60	10.0	Moderate to High	B	High

^a The depth to which a soil is readily penetrated by roots and utilized for moisture and nutrient extraction.

^b Total available water holding capacity within the effective soil depth.

^c The relative susceptibility of a land to the prevailing agents of erosion.

^d Hydrologic soil groups are used for estimating the runoff potential of soils on watersheds at the end of long-duration storms after a prior wetting and opportunity for swelling, and without the protective effect of vegetation. Soils are assigned to groups A through D in order of increasing runoff potential. Soils in group C have a slow infiltration rate when thoroughly wetted, and consist chiefly of soils with a layer that impedes the downward movement of water or soils with a moderately fine to fine texture and a slow infiltration rate.

^e Shrink-swell behavior is the quality of soil that determines its volume change with change in moisture content. The volume-change behavior of soils is influenced by the amount of moisture change and amount and kind of clay in the soil.

SOURCE: NRCS, 2010a; NRCS, 2010b.

factors that describe the predisposition of a sloped surface to fail, while external processes such as exceptionally heavy rainfall, earthquakes, or human activities (e.g. road cuts, over-steepened slopes, large-scale vegetation removal) may trigger or reactivate a slope failure. The presence of numerous landslides along the steep slopes upstream of the barrier beach area suggests a relatively high potential for slope failures along the steep sides of the river valley.

Erosion/Accelerated Erosion

Erosion is a natural process whereby soil and highly weathered rock materials are worn away and transported to another area, most commonly by water but also by wind. Natural rates of erosion can vary depending on slope, soil type, and vegetative cover (regional erosion rates are also dependant on tectonics and changes in relative sea level). Soils containing high amounts of silt are typically more easily eroded, while coarse-grained (sand and gravel) soils are generally less susceptible to erosion.

Soil erosion can become problematic when human intervention causes rapid soil loss and the development of erosional features (such as incised channels, rills² and gullies) that undermine roads, buildings or utilities. Vegetation clearing and earth-moving reduces soil structure and cohesion, resulting in abnormally high rates of erosion, referred to as *accelerated erosion*. Rills, gullies, and excessive sediment transport can eventually damage building foundations and roadways, as well as clog or fill surface drainage facilities (siltation ponds, catchments and culverts).

Mineral Resources

In accordance with the Surface Mining and Reclamation Act (SMARA) of 1975, the State of California has established a mineral land classification system to help identify and protect mineral resources in areas that are subject to urban expansion or other irreversible land uses that would preclude mineral extraction. Protected mineral resources include non-fuels—construction materials, industrial and chemical mineral materials, and metallic and rare minerals—as well as non-fluid mineral fuels. The act directs the state geologist to classify (identify and map) the non-fuel mineral resources of the state to show where economically significant mineral deposits occur and where they are likely to occur based on the best available scientific data. Non-fuel mineral resources include: metals such as gold, silver, iron, and copper; industrial minerals such as boron compounds, rare earth elements, clays, limestone, gypsum, salt, and dimension stone; and construction aggregate, which includes sand, gravel, and crushed stone. The CGS has classified lands within Sonoma County into Mineral Resource Zones (MRZs) (CGS, 2005). MRZs have been designated to indicate the significance of mineral deposits. The MRZ categories are as follows:

MRZ-1: Areas where available geologic information indicates that little likelihood exists for the presence of significant mineral resources.

MRZ-2a: Areas underlain by mineral deposits where geologic data indicate that significant *measured or indicated* resources are present. Contains known economic mineral resources.

MRZ-2b: Areas underlain by mineral deposits where geologic information indicates that significant *inferred* resources are present.

MRZ-3a: Areas containing *known* mineral occurrences of undetermined mineral resource significance.

MRZ-3b: Areas containing *inferred* mineral occurrences of undetermined mineral resource significance.

MRZ-4: Areas of no known mineral occurrences.

The riverbed and floodplain of the Russian River within the Estuary Management Project area is located within Mineral Resource Zone 3a (CGS, 2005). The designation refers to the gravels and sands that had been mined for aggregate in other portions of the Russian River and its floodplain well upstream of the Project area. However, in the portion of the Russian River within the Estuary Management Project area, the presence of the relatively steep sides of the river valley, the depth

² Rill is defined as a small channel formed by erosion processes.

of the river water, and the presence of salmon habitat make it highly unlikely that this portion of the Russian River would be used for aggregate mining.

Regional Faulting and Seismic Hazards

This section characterizes the region's existing faults, describes historic earthquakes, estimates the likelihood of future earthquakes, and describes probable ground-shaking effects. The primary sources of information for this section are publications prepared by USGS, the CGS, and hazard mapping tools provided by the Association of Bay Area Governments (ABAG).

Earthquake Terminology and Concepts

Earthquake Mechanisms and Fault Activity

Faults are planar features within the earth's crust that have formed to release stresses caused by the dynamic movements of the earth's major tectonic plates. An earthquake on a fault is produced when these stresses overcome the inherent strength of the earth's crust, and the rock ruptures. The rupture causes seismic waves to propagate through the earth's crust, producing the ground-shaking effect known as an earthquake. The rupture also causes variable amounts of slip along the fault, which may or may not be visible at the earth's surface.

Geologists commonly use the age of offset rocks as evidence of fault activity—the younger the displaced rocks, the more recently earthquakes have occurred. To evaluate the likelihood that a fault will produce an earthquake, geologists examine the magnitude and frequency of recorded earthquakes and evidence of past displacement along a fault. An *active* fault is defined by the State of California as a fault that has had surface displacement within Holocene time (last 11,000 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) (Hart and Bryant, 1997). *Blind* faults do not show surface evidence of past earthquakes, even if they occurred in the recent past. Faults that are confined to pre-Quaternary rocks (more than 1.6 million years old) are considered inactive and incapable of generating an earthquake.

Earthquake Magnitude

When an earthquake occurs along a fault, a characteristic way to measure its size is to measure the energy released during the event. When an earthquake occurs, a network of seismographs records the amplitude and frequency of the seismic waves it generates. The Richter Magnitude (M) for an earthquake represents the highest amplitude measured by the seismograph at a distance of 100 kilometers from the epicenter. Richter magnitudes vary logarithmically with each whole number step representing a ten-fold increase in the amplitude of the recorded seismic waves. While Richter Magnitude was historically the primary measure of earthquake magnitude, seismologists now use Moment Magnitude as the preferred way to measure earthquakes. The Moment Magnitude scale (M_w) is related to the physical characteristics of a fault, including the rigidity of the rock, the size of fault rupture, and the style of movement or displacement across the fault. Although the formulae of the scales are different, they both contain a similar continuum of magnitude values, except that moment magnitudes can reliably measure larger earthquakes and do so from greater distances.

Peak Ground Acceleration

A common measure of ground motion during an earthquake is the peak ground acceleration (PGA). The PGA for a given component of motion is the largest value of horizontal acceleration obtained from a seismograph. PGA is expressed as the percentage of the acceleration due to gravity (g), which is approximately 980 centimeters per second squared. In terms of automobile accelerations, one “g” of acceleration is equivalent to the motion of a car traveling 328 feet from rest in 4.5 seconds. For comparison purposes, the maximum peak acceleration value recorded during the Loma Prieta earthquake was in the vicinity of the epicenter, near Santa Cruz, at 0.64g. Unlike measures of magnitude, which provide a single measure of earthquake energy, PGA varies from place to place, and is dependent on the distance from the epicenter and the character of the underlying geology (e.g. hard bedrock, soft sediments or artificial fills).

The Modified Mercalli Intensity Scale

The Modified Mercalli Intensity Scale (**Table 4.1-2**) assigns an intensity value based on the observed effects of ground-shaking produced by an earthquake. Unlike measures of earthquake magnitude and PGA, the Modified Mercalli (MM) intensity scale is qualitative in nature (i.e. it is based on actual observed effects rather than measured values). Similar to PGA, MM intensity values for an earthquake at any one place can vary depending on its magnitude, the distance from its epicenter, the focus its energy, and the type of geologic material. 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. Because the MM is a measure of ground-shaking effects, intensity values can be related to a range of average PGA values, also shown in Table 4.1-2.

Seismic Context

The Northern California region contains active, potentially active, and inactive faults, and is considered a region of high seismic activity.³ The major active faults located within 20 miles of the Estuary Management Project area include the San Andreas, Rodgers Creek (Healdsburg-Rodgers Creek-Hayward⁴), and Maacama faults. **Figure 4.1-2** depicts the major active faults, along with two pre-Quaternary faults that are mapped within the project area. Throughout the project area there is a potential of damage from movement along any one of a number of the active faults. The USGS estimates that there is a 63 percent probability of at least one moment magnitude 6.7 or greater earthquake occurring in the San Francisco Bay region over the next 30 years.⁵ Within the

³ An “active” fault is defined by the State of California as a fault that has had surface displacement within Holocene time (approximately the last 11,000 years). 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. Inactive faults have experienced no movement in the last 1.6 million years. This definition does not, of course, mean that faults lacking evidence of surface displacement are necessarily inactive (Hart and Bryant, 1997).

⁴ The Rodgers Creek fault is considered to be a northern extension of the Hayward fault which has not been mapped beneath San Pablo Bay. The Healdsburg fault may be connected to the Rodgers Creek fault through a “step-over” and is sometimes referred to as the Healdsburg-Rodgers Creek fault. A step-over or fault step occurs where a fault line is interrupted by either a right-lateral or left-lateral shift, creating a gap. The geology of these gaps may include underground linkages between faults.

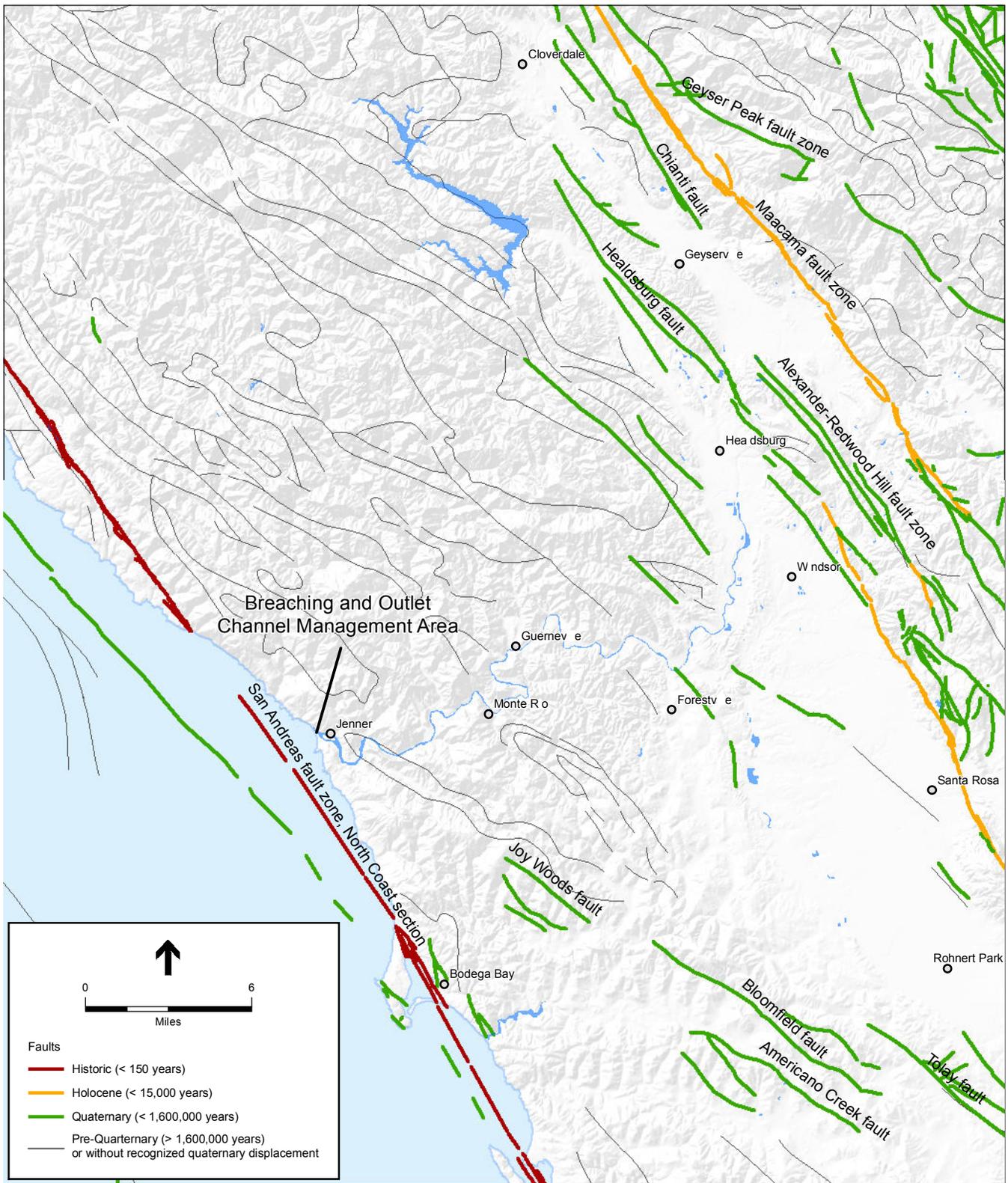
⁵ Moment magnitude is related to the physical size of a fault rupture and movement across a fault. The Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event (California Geological Survey (CGS), 2002).

**TABLE 4.1-2
 MODIFIED MERCALLI INTENSITY SCALE**

Intensity Value	Intensity Description	Average Peak Ground Acceleration^a
I	Not felt except by a very few persons under especially favorable circumstances.	< 0.0017 g
II	Felt only by a few persons at rest, especially on upper floors on buildings. Delicately suspended objects may swing.	0.0017-0.014 g
III	Felt noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly, vibration similar to a passing truck. Duration estimated.	0.0017-0.014 g
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.	0.014–0.039g
V (Light)	Felt by nearly everyone, many awakened. Some dishes and windows broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles may be noticed. Pendulum clocks may stop.	0.035 – 0.092 g
VI (Moderate)	Felt by all, many frightened and run outdoors. Some heavy furniture moved; and fallen plaster or damaged chimneys. Damage slight.	0.092 – 0.18 g
VII (Strong)	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.	0.18 – 0.34 g
VIII (Very Strong)	Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.	0.34 – 0.65 g
IX (Violent)	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.	0.65 – 1.24 g
X (Very Violent)	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. Shifted sand and mud. Water splashed (slopped) over banks.	> 1.24 g
XI (Very Violent)	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.	> 1.24 g
XII (Very Violent)	Damage total. 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.	> 1.24 g

^a Value is expressed as a fraction of the acceleration due to gravity (g). Gravity (g) is 9.8 meters per second squared. 1.0 g of acceleration is a rate of increase in speed equivalent to a car traveling 328 feet from rest in 4.5 seconds.

SOURCE: ABAG, 2003.



SOURCE:USGS and California Geological Survey, 2009

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Figure 4.1-2
Regional Faults

63 percent probability, the San Andreas and Rodgers Creek fault systems are the two most likely to cause such an event (USGS, 2008).

Table 4.1-3 lists these three active faults along with other potentially active fault systems within approximately 20 miles of the Estuary Management Project area, and identifies the dates of their most recent activity and the estimated maximum moment magnitude of a characteristic future event. The distance listed to the various faults represents the shortest distance to the closest boundary of project area. None of the regional active faults are located within the project area, although the San Andreas Fault Zone is located within 1-1/2 miles of the project area. Large historic earthquakes (magnitude 6 and greater) on regional active faults have been responsible for generating significant ground shaking throughout the region including events on the San Andreas fault (1906, 1989), Rodgers Creek fault (1886, 1965), and the Maacama fault (1906).

**TABLE 4.1-3
 ACTIVE AND POTENTIALLY ACTIVE REGIONAL FAULTS
 IN THE VICINITY OF THE ESTUARY MANAGEMENT PROJECT AREA**

Fault Zone	Location Relative to Action Area	Recency of Faulting^a	Historical Seismicity^b	Maximum Moment Magnitude^c
San Andreas	1-1/2 miles southwest	Historic – Active	M 7.1: 1989 M 8.25: 1906 M 7.0: 1838 Many <M 6	7.3
Rodgers Creek (includes potentially active Healdsburg fault zones)	15 miles northeast	Historic – Active	M 6.7: 1898 M 5.6, 5.7: 1969	7.0
Maacama	20 miles northeast	Holocene – Active	NA	7.1
Bloomfield	12 miles southeast	Potentially Active	NA	NA
Americano Creek	15 miles southeast	Potentially Active	NA	NA

^a Recency of faulting from Jennings (1994). Historic: displacement during historic time (within last 200 years), including areas of known fault creep; Holocene: evidence of displacement during the last 10,000 years; Quaternary: evidence of displacement during the last 1.6 million years; Pre-Quaternary: no recognized displacement during the last 1.6 million years (but not necessarily inactive).
^b Richter magnitude (M) and year for recent and/or large events.
^c Maximum moment magnitude from Peterson *et al.* (1996). This is the maximum earthquake moment magnitude which could occur within the specified fault zone.

NA = Not applicable and/or not available.

SOURCES: Jennings, 1994, Hart and Bryant, 1997, and Peterson *et al.*, 1996.

The San Andreas fault is capable of causing significant ground shaking along the entire coast of California. The most recent significant earthquakes on the San Andreas fault include the Loma Prieta earthquake of 1989, measuring magnitude 6.9 (USGS, 2007b) and the San Francisco earthquake of 1906, measuring approximately magnitude 7.8 (USGS, 2007b). The USGS Working Group on California Earthquake Probabilities estimated that there is a 21 percent chance of the San Andreas Fault experiencing an earthquake of magnitude 6.7 or greater during the period between 2002 and 2032 (USGS, 2008, and MMI Engineering, 2008).

The Rodgers Creek fault is considered the northern extension of the Hayward fault and is capable of causing significant ground shaking from Vallejo to north of Healdsburg. The most recent significant earthquake on the Rodgers Creek fault occurred on October 1, 1969. On this date, two earthquakes of magnitude 5.6 and 5.7 occurred in an 83-minute period and caused serious damage to buildings in Santa Rosa. The epicenters were located just northwest of Santa Rosa. The last major earthquake (estimated Richter magnitude 6.7) was generated in 1898 with an epicenter near Mare Island at the north margin of San Pablo Bay. Creep along this fault may be up to 9 millimeters per year (USGS, 2007a). The USGS estimates the probability of a large earthquake (magnitude 6.7 or greater) on the Rodgers Creek fault (when considered together with the Hayward fault) during the period between 2002 and 2032 to be 27 percent (USGS, 2008). The Healdsburg fault is also connected to the Rodgers Creek fault through a step-over and is often referred to as the Healdsburg-Rodgers Creek fault. The 1969 Rodgers Creek earthquakes originated near the southern extent of the Healdsburg fault.

The Maacama fault, like the Rodgers Creek fault, is considered a northern extension of the Hayward fault system, and is separated from the Rodgers Creek fault by a right step-over. It has a creep rate of approximately 7 millimeters per year (USGS, 2007b). Recent seismic activity in the Maacama Fault Zone includes an earthquake measuring magnitude 4.8 centered near Willits in 1977 (Warren, et al., 1985).

Onsite Faults

Two pre-Quaternary faults are mapped passing northwest-southeast through the Estuary Management Project area as shown on Figure 4.1-2. As mapped these two faults appear to line up with the potentially active Bloomfield fault traces to the southeast.

Seismic Hazards

Surface Fault Rupture

Surface fault rupture is typically observed and is expected on or within close proximity to the causative fault trace.⁶ The San Andreas and the Rodgers Creek fault zones are the closest active faults to the Estuary Management Project area zoned under the Alquist-Priolo Earthquake Fault Zoning Act. Neither of these faults transect the project area; therefore, none of the project elements are located within an Alquist-Priolo Earthquake Fault Zone. However, the San Andreas fault zone is located 1-1/2 miles west of the project area and, as discussed above, has experienced surface fault rupture during past events. Surface fault rupture would not necessarily be limited to the boundaries of the Alquist-Priolo Fault Zones, although the risk of surface rupture outside these zones would be considered lower than within the zones.

⁶ Fault rupture is displacement at the earth's surface resulting from fault movement associated with an earthquake.

Seismic Ground Shaking

Strong ground shaking from earthquakes generated by active faults is a hazard to the Estuary Management Project area, as it is likely that an occasional moderate to severe earthquake will cause strong ground shaking within the project vicinity. Ground shaking intensity is related to the size (i.e., magnitude) of an earthquake, the distance from the epicenter to the project's location, and the response of the geologic materials that underlie the site. As a rule, the greater the earthquake magnitude and the closer the fault rupture to the site, the greater the intensity of ground shaking. Violent shaking is generally expected at and near the epicenter of a large earthquake, although studies of recent earthquakes, such as those conducted after the 1992 Landers earthquake, indicate that directional ground motion along a fault can cause strong ground shaking farther away from the epicenter. Seismic hazards due to ground shaking can cause the greatest damage to structures, utilities, and unsecured equipment.

The primary tool that seismologists use to describe ground-shaking hazard is a probabilistic seismic hazard assessment (PSHA). The PSHA for the State of California takes into consideration the range of possible earthquake sources (including such worst-case scenarios as described above) and estimates their characteristic magnitudes to generate a probability map for ground-shaking. The PSHA maps depict values of peak ground acceleration (PGA) that have a 10% probability of being exceeded in 50 years. Use of this probability level allows engineers to design structures to withstand ground motions that have a 90% chance of NOT occurring in the next 50-years, making buildings safer than if they were merely designed for the most probable events. The PSHA indicates that at the Project site, there is a 10 percent chance of exceeding PGA values of approximately 0.62 g over the next 50 years (1 in 475 chance of occurring) (CGS, 2010.) As indicated in Table 4.1-2, these PGAs are typical of a very strong ground shaking. Seismic ground shaking is discussed further in the impacts analysis below.

Liquefaction

Liquefaction is the sudden temporary loss of shear strength in saturated, loose to medium dense, granular sediments subjected to ground shaking. Liquefaction generally occurs when seismically-induced ground shaking causes pore water pressure to increase to a point equal to the overburden pressure. Liquefaction can cause foundation failure of buildings and other facilities due to the reduction of foundation bearing strength. The potential for liquefaction depends on the duration and intensity of earthquake shaking, particle size distribution of the soil, density of the soil, and elevation of the groundwater. Areas at risk due to the effects of liquefaction are typified by a high groundwater table and underlying loose to medium-dense, granular sediments, particularly younger alluvium and artificial fill. This issue is discussed further under the impacts analysis below.

Seismically-induced 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. Rock slopes exposed to either air or water can undergo rockfalls, rockslides, or rock avalanches, while soil slopes experience shallow soil slides, rapid debris flows, and/or deep-seated rotational slides.

4.1.3 Regulatory Framework

The following section provides a brief summary of the pertinent federal, state, and local regulations.

Federal

Relative to geology and soil resources, no federal regulations were found to apply or be pertinent to this Estuary Management Project, as the project would not result in the construction of permanent structures.

State

Surface Mining and Reclamation Act

The primary State law concerning conservation and development of mineral resources is the California SMARA of 1975, as amended to date. SMARA is found in the California Public Resources Code (PRC), Division 2, Chapter 9, Sections 2710, et seq. SMARA was enacted in 1975 to limit new development in areas with significant mineral deposits. SMARA calls for the state geologist to classify the lands within California based on mineral resource availability. In addition, the California Health and Safety Code requires the covering, filling, or fencing of abandoned shafts, pits and excavations (California Health and Safety Code Sections 24400-03.).

SMARA sets state policy for the reclamation of mined lands. SMARA states that the extraction of minerals is essential to the continued economic well-being of the State and to the needs of society, and that reclamation of mined lands is necessary to prevent or minimize adverse effects on the environment and to protect the public health and safety. The reclamation of mined lands will permit the continued mining of minerals and will provide for the protection and subsequent beneficial use of the mined and reclaimed land. Surface mining takes place in diverse areas where the geologic, topographic, climatic, biological, and social conditions are significantly different, and reclamation operations and the specifications therefore may vary accordingly (California Public Resources Code Section 2711).

The regulations set forth in SMARA are to be used as standards by the lead agencies which can include cities, counties, and regional authorities such as the San Francisco Bay Conservation and Development Commission. The lead agency shall have principal responsibility for approving surface mining operation or reclamation plans which include grading, backfilling, resoiling, revegetation, soil compaction, erosion control, and other reclamation requirements.

Local

Local policies established in the *Sonoma County General Plan 2020* that govern geologic resources in the project area are summarized in Section 4.1 in **Appendix 4.0, Local Regulatory Framework Governing Environmental Resources**.

4.1.4 Environmental Impacts and Mitigation Measures

The following section focuses on potential Estuary Management Project impacts related to geology and soil resources. The evaluation considered project plans, current conditions, and applicable regulations and guidelines.

Significance Criteria

The criteria used to determine the significance of an impact are based on the environmental checklist in Appendix G of the CEQA Guidelines. For this analysis, implementation of the proposed Estuary Management Project would be considered to have a significant impact associated with geology or soil resources if it would:

1. Expose people or structures to potential substantial adverse effects, including 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;
 - Strong seismic ground-shaking;
 - Seismic-related ground failure, including liquefaction;
 - Landslides;
2. Result in substantial soil erosion or the loss of topsoil;
3. Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the Estuary Management Project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse;
4. Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code, (1994) creating substantial risks to life or property;
5. 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 waste water;
6. Result in the loss of availability of a known mineral resource that would be of value to the region and residents of the state;
7. Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan;

Some of the above-listed CEQA criteria are not considered relevant to the project based upon the proposed project and data research, and therefore, they will not be evaluated further in this EIR. These issues are:

Rupture of a known earthquake fault. Ground rupture is considered most likely to occur along active faults, which are referenced in Table 4.1-1. As indicated previously, the Estuary Management Project site is *not* located within an Alquist-Priolo Fault Rupture Hazard Zone,

and no mapped active faults are known to pass through the project area. Therefore, the project would not expose persons or structures to risk of ground rupture along a fault line.

Inadequate support for septic tanks. Septic tanks are not proposed as part of the Estuary Management Project. Therefore this issue is not applicable to the project. However, potential for impact to existing septic systems is addressed in **Impact 4.13.4 in Section 4.13, Public Services, Utilities and Public Safety.**

As noted in **Chapter 2.0, Project Description**, the Water Agency would continue its current practice of artificial breaching outside of the lagoon management period of May 15 through October 15. Timing, implementation, access, sensitivity to pinniped haulout, personnel, equipment and general procedures would be equivalent to current practices, as described in **Section 2.2.2**. No change to existing artificial breaching outside of the lagoon management period would occur under the Estuary Management Project.

Approach to Analysis

The following impact analysis focuses on potential impacts of the proposed Estuary Management Project related to geology and soil resources. The evaluation considered project plans, current conditions at the project site, and applicable regulations and guidelines.

Impact Analysis

Impacts are summarized and categorized as either “no impact,” “less than significant,” “less than significant with mitigation,” or “significant and unavoidable.”

Impact 4.1.1: Seismicity. In the event of a major earthquake in the region, seismic ground shaking could trigger seismic-related ground or slope failures, including liquefaction, and/or landslides at the beach, outlet channel, and/or along the banks of the lagoon to be formed behind the outlet channel that could expose people or structure to adverse effects. (Less than Significant)

The Estuary Management Project area is likely to experience at least one major earthquake (magnitude 6.7 or higher) within the next 30 years, along with other smaller seismic events. The intensity of such an event would depend on the causative fault, the distance to the epicenter, the moment magnitude, and the duration of shaking. As discussed in the Setting, ground shaking in the project area could be considerable given the proximity to the active San Andreas fault and other faults in the region. At the level of expected ground shaking, certain areas of saturated beach sand could liquefy resulting in localized ground failure such as lateral spreads, sand boils, and settlement. Liquefaction-related ground failures could alter the flow path, close, or truncate the proposed outlet flow channel. Ground shaking could also cause localized slope failures upstream along the banks of the lagoon formed behind the outlet channel.

Earthquakes are unavoidable and would occur with or without the project. While the anticipated seismic events could result in strong seismic ground shaking, liquefaction, and/or landslides within the project area, the effects of these potential seismic hazards would not result in additional risk

to the public or adversely affect property. As discussed in **Chapter 2.0, Project Description**, no new structures will be constructed and the barrier beach area will not be occupied by people. Changes to the outlet channel during an earthquake, such as an altered flow path, truncation, and closure would be temporary and would be readjusted by routine maintenance under the Adaptive Management Plan. In addition, the water levels in the lagoon behind the barrier beach at the outlet channel will continue to be maintained within the historical maximums resulting in no new land areas being inundated. Therefore, the proposed project would not result in additional or new exposure of people, structures, or property to seismic hazards, nor does it increase the overall seismic risk. Consequently, this is considered a less-than-significant impact.

Impact Significance: Less than Significant; no mitigation required.

Impact 4.1.2: Beach Erosion. The proposed Estuary Management Project could result in conditions that lead to erosion on the beach at the outlet channel or along the banks of the Estuary formed behind the outlet channel. Changes in water levels within the Estuary Study area and maximum backwater area could undermine additional bank areas resulting in localized erosion or the loss of topsoil. (Less than Significant)

Creation of the outlet channel could result in short-term erosion on the barrier beach. However, the beach is a dynamic system that is already subject to erosive forces from tidal action; therefore the level of erosion on the barrier beach potentially associated with the proposed project would not be considered significant. Within the lagoon management period, consistent with the project goal of reducing tidal influence, the current practice of artificial breaching following closures would theoretically occur less often. However, maintenance of the outlet channel in this fashion may require additional equipment operation on the beach, depending upon performance of the outlet channel. The Water Agency is assuming up to 18 maintenance operations, or approximately once per week during the lagoon management period. This incremental increase in equipment use for maintenance is not anticipated to increase sedimentation or erosion rates within the barrier beach or active surf zone. Project implementation would increase the frequency and duration of higher water surface elevations along the shoreline of the Estuary. Depending upon channel performance, the duration of inundation could be increased to between one and five months.

Changes in water levels in the Estuary behind the barrier beach at the outlet channel could inundate areas along the shoreline of the Estuary for an increased duration of between one and five months, depending up outlet channel performance. These areas could be subjected to erosion or loss of topsoil associated with wind-induced wave action. This could result in localized erosion along the 7- and 9-foot contours. However, as discussed in **Chapter 2.0, Project Description**, water levels would be maintained within a historical range experienced within the Estuary. Therefore, although the duration of inundation, and subsequent exposure of the shoreline to wave action would be increased, these areas have been episodically subjected to inundation and associated wave action, including water surface elevations of up to 9 feet approximately 52 times since 1996. Therefore, the proposed project is not anticipated to result in substantial erosion along the

shoreline. Additionally, the frequency and duration of the freshwater lagoon (i.e. non-tidal conditions) would not reduce sand and gravel deposition on the beach because the lagoon management period would occur after winter storms, when major transport of coarse sediment (i.e. sand and gravel) occurs; therefore there would be no effect on beach development.

Impact Significance: Less than Significant; no mitigation required.

Impact 4.1.3: Unstable Beach Sands, Landslides, Liquefaction. The proposed Estuary Management Project involves moving the beach sands at the outlet channel. These beach sands are considered a geologic unit of soil that is unstable, or that would become unstable as a result of the project activities, and could potentially result in on- or off-site landslides, lateral spreading, subsidence, liquefaction, or collapse. (Less than Significant)

The sands comprising the beach barrier at the outlet channel are unconsolidated and thus could be subject to loss of stability during lagoon outlet channel creation. Failures of beach sands could include lateral spreading, subsidence, liquefaction, collapse, or other settlement. Such failures could result in a sudden drop in Estuary water levels as the temporarily impounded water quickly drains out to the Pacific Ocean. As discussed above, the alluvial deposits along the river channel are typically unconsolidated. Some soils in areas along the shore along the Estuary behind the outlet channel may be unstable and subject to on- or off-site landslides, lateral spreading, subsidence, liquefaction, or collapse. Such failures might result in property damage.

The proposed Estuary Management Project does not change the location or composition of the barrier beach material, only the duration and configuration of the barrier beach itself. The adaptive approach to managing the outlet channel would result in a lower energy discharge of river water to the ocean, thus reducing destabilizing forces. The Estuary water levels will continue to be maintained within the range of historical water surface elevations experienced. Therefore, the proposed Estuary Management Project would not result in any new land areas being inundated that might consist of unstable soils. Therefore, potential impacts are considered less than significant.

Impact Significance: Less than Significant; no mitigation required.

Impact 4.1.4: Expansive Soils. The proposed Estuary Management Project could be located on expansive soils, as defined in Table 18-1-B of the Uniform Building Code, creating substantial risks to life or property. (Less than Significant)

The sands that comprise the barrier beach materials where the outlet channel would be created are not composed of expansive soils. Therefore, there would be no adverse impact associated with expansive soils relative to the creation of the outlet channel under the proposed project. Implementation of the proposed project would increase the frequency and duration of inundation within the Estuary Study Area and maximum backwater area. Potential impacts could occur if

increased water levels inundated areas comprised of expansive soils that are not currently inundated that could result in property damage to foundations or other structures. Expansive soils, by character, expand as they absorb moisture, then shrink when they dry out. The proposed project could result in a longer duration of inundation of some areas; however this prolonged inundation would not exacerbate the shrink/swell amount, and associated risk to physical structures, just the rate and timing of the dry-out.

Based on review of geologic properties of these shoreline areas, no expansive soils (i.e. clay matrix) are expected to occur within the 14-foot contour, and no significant areas of expansive soils are identified. Additionally, there are no structures within the inundation zone that would be at risk or damage due to soil expansion. Furthermore, as discussed in **Chapter 2.0, Project Description**, the water levels in the Estuary will continue to be maintained within the historical range. Therefore, the proposed Estuary Management Project would not result in new land areas being inundated that might respond to soil expansion. Consequently, this issue would result in a less-than-significant impact.

Impact Significance: Less than Significant; no mitigation required.

Impact 4.1.5: Mineral Resources. The proposed Estuary Management Project could result in the loss of availability of a known mineral resource. (Less than Significant)

Within the Estuary Management Project area, the gravels and sands in the Russian River and its floodplain are not currently mined for aggregate. In addition, the presence of the relatively steep sides of the river valley, the depth of the river water, and the presence of salmon habitat make it highly unlikely that this portion of the Russian River would be used for aggregate mining. Therefore, the proposed Estuary Management Project would not result in the loss of mineral resources, and consequently, this issue would result in a less-than-significant impact.

Impact Significance: Less than Significant; no mitigation required.

4.1.5 References

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