4.6 GEOLOGY, SEDIMENTS, AND SEISMICITY

Section 4.6 describes the existing geologic and geotechnical conditions regionally and near the Tesoro Avon Marine Oil Terminal (Avon Terminal) and provides an impact analysis of geology, sediments, and seismicity associated with the granting of a new lease for the Avon Terminal to continue to operate in the lower Suisun Bay and Marine Oil Terminal Engineering Maintenance Standards (MOTEMS) compliance-related renovation. Also included is a summary of regulations associated with geologic resources and seismicity analyses. This is followed by an analysis of the potential Avon Marine Oil Terminal Lease Consideration Project (Project) impacts. The proposed renovation Project addresses findings of MOTEMS audits of the Avon Terminal, including at the existing Berth 1 and approachway, which were found to be seismically deficient due to the probability of damage and failure resulting from soil liquefaction in the event of a significant earthquake. Geologic issues associated with MOTEMS compliance-related renovation and renewing the Avon Terminal lease primarily involve the effects of seismic events on Avon Terminal structures and systems, such as pipelines, valves, supports, anchors, and electrical and mechanical equipment.

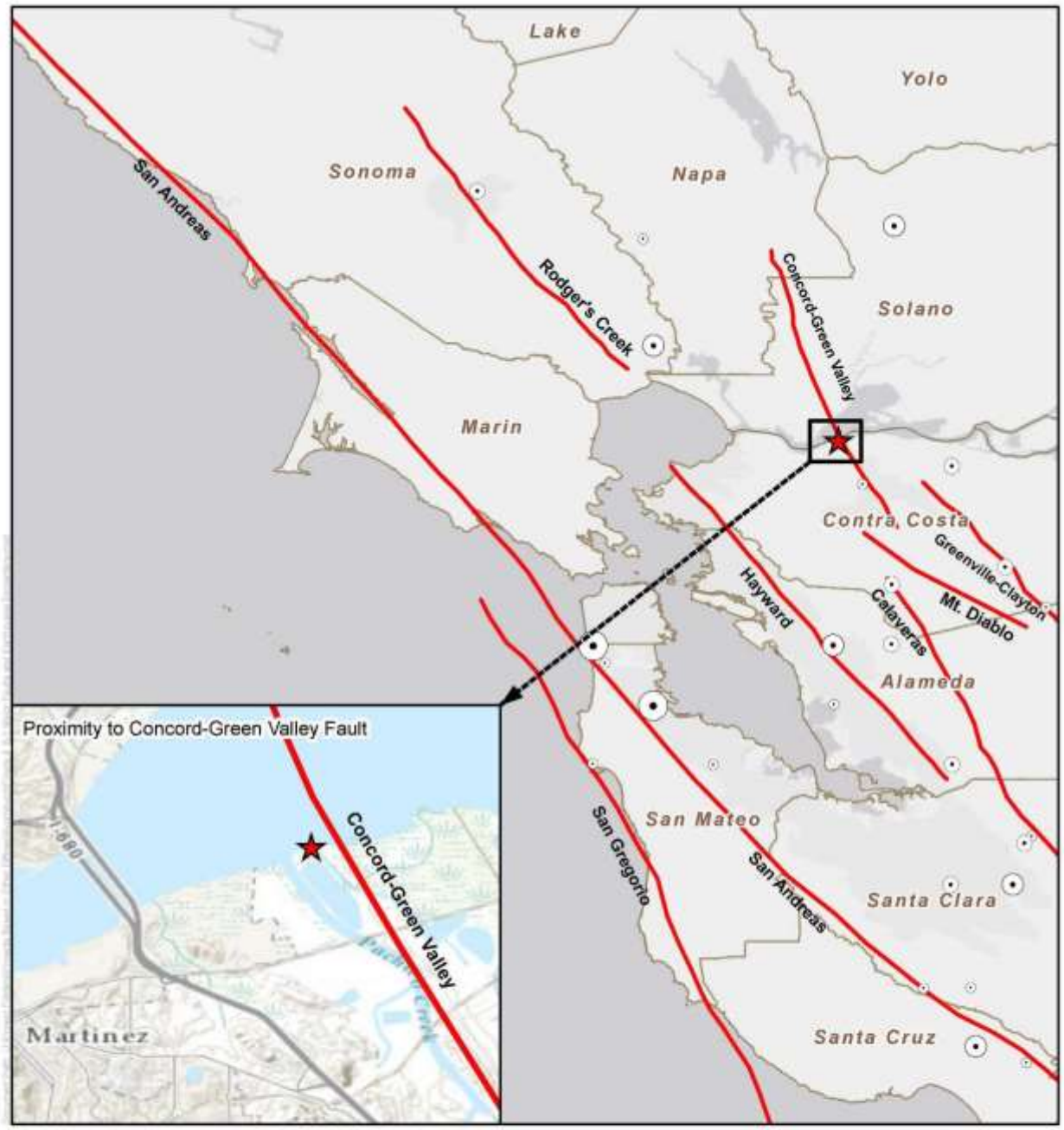
4.6.1 ENVIRONMENTAL SETTING

The Avon Terminal is located near the city of Martinez, in unincorporated Contra Costa County, along the southern side of Suisun Bay, approximately 1.75 miles east of the Benicia-Martinez Bridge, in the seismically active San Francisco Bay Area (Bay Area).

4.6.1.1 Regional Geology

California is located on the boundary between the Pacific and North American tectonic plates. The Pacific Plate comprises much of the Pacific Ocean and includes the western edge of the North American continent. The North American Plate includes the remainder of the North American continent and the western half of the Atlantic Ocean. The Pacific Plate is drifting northwesterly relative to the North American Plate, and the main line of contact between these two plates is the San Andreas Fault system.

The Bay Area lies within the geologically active part of the Coast Ranges geomorphic province of California, which is characterized by a series of nearly parallel mountain ranges (Goldman 1969) trending northwest-southeast. Figure 4.6-1 depicts the locations of major faults that characterize the area. Active faults, including the Concord/Green Valley, West Napa, Calaveras, Hayward, San Gregorio, and San Andreas Faults, are roughly parallel to the western and eastern limits of the Bay Area. The San Francisco Bay itself began forming during the Pleistocene Epoch, approximately 2 million years ago, when the land masses now known as San Francisco and Marin began to tilt eastward along the Hayward Fault, forming a depression that filled with sediment and water.


Lake
Yolo
Sonoma
Napa
San Andreas
Rodger's Creek
Concord-Green Valley
Solano
Marin
Contra Costa
Greenville-Clayton
Hayward
Calaveras
Mt. Diablo
Alameda
Proximity to Concord-Green Valley Fault
Concord-Green Valley
I-680
Martinez
San Mateo
San Gregorio
San Andreas
Santa Clara
Santa Cruz
Figure 4.6-1
Major Faults and Earthquake Epicenters
California State Lands Commission
Avon Marine Oil Terminal Lease Consideration Project
Approximate Terminal Location
Fault Lines
Earthquake Epicenter
Magnitude
5.5 - 5.9
6.0 - 6.4
6.5 - 6.9
7.0 +
N
1 in = 16 miles
0 8 16 Miles
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The bedrock units underlying the area east of the Hayward Fault in the area of the Avon Terminal (refer to Figure 4.6-1) range from Jurassic-Cretaceous to Quaternary-age (approximately 135 million years old to current). The oldest unit, the Franciscan Formation, which is believed to have originated on the ocean floor, was welded to the western margin of the American continent by plate movement and subsequently uplifted through younger sedimentary rock to form the backbone of the Diablo Range. The strata of this bedrock formation are highly distorted and partially metamorphosed by heat and compression. The Franciscan Formation consists primarily of interbedded sandstone and shale, limestone, radiolarian chert, and metavolcanic rocks (Goldman 1969). The Great Valley Sequence, a thick sequence of Mesozoic sandstones and shales that overlies the Franciscan Formation, comprises sedimentary rock formed under ancient seas that once existed on the American continent. The youngest formations are deposits of Quaternary-age marine sediments, known as “bay mud,” and Quaternary alluvium deposited by stream erosion. Figure 4.6-2 depicts the regional surface geology of the Suisun Bay and Carquinez Strait region near the Project site.

4.6.1.2 Site-specific Geology

Three geotechnical investigations were reviewed to characterize the geology near the Avon Terminal (Treadwell & Rollo 1997, 2007a, 2013). Treadwell & Rollo (2007a) compiled geologic boring data from current and previous investigations and reported that approximately 31 to 42 feet of estuarine deposited soils, consisting of very soft to stiff clay and silt mixtures and very loose to medium dense tidal sand and silty sand, are present on the landward side of the Avon Terminal. Borings on the outward side found these same types of deposits were between 9 and 21 feet in thickness, corresponding to a significantly deeper mudline, probably resulting from dredging. Borings located adjacent to the pipeway and closer to the shoreline have estuarine deposits ranging in thickness from 20 to 24.5 feet, indicative of the bottom of deposit sloping upward toward the shoreline. These deposits were further differentiated into upper estuarine (5 to 20 feet of very loose to medium dense sands) and lower estuarine (10 to 15 feet of medium stiff to stiff silts and clays) deposits (Treadwell & Rollo 2013).

Layers of interbedded stiff to hard clay and silt, and medium dense to very dense sand, silty sand, and clayey sand were encountered below the estuarine deposits. A dense to very dense layer of sand and gravel was encountered at elevations ranging from approximately -120 to -130 feet. The thickness of the sand and gravel layer ranged from roughly 10 to 30 feet. Regional geologic investigations have been conducted by the California Geological Survey (CGS), formerly known as the California Division of Mines and Geology (Goldman 1969, Treaser 1963). Goldman’s (1969) contour maps of the top of bedrock suggest that bedrock lies approximately 80 feet below mean lower low water (MLLW) near the Avon Terminal shoreline to a depth of approximately 120 feet below MLLW along the Avon Terminal. Treadwell & Rollo (2007a) do not appear to have encountered bedrock in the Avon Terminal vicinity during their investigation.

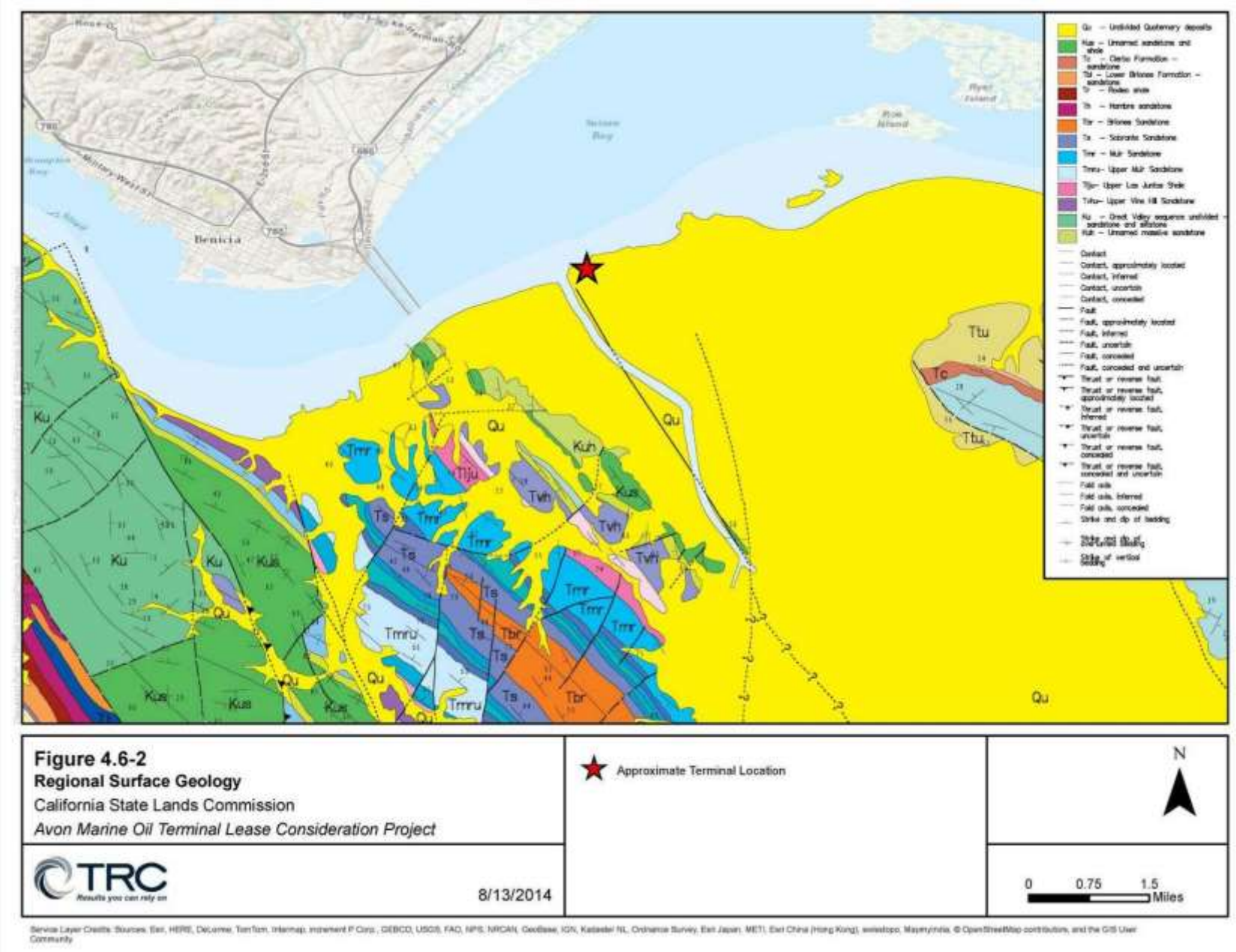

Figure 4.6-2
Regional Surface Geology
California State Lands Commission
Avon Marine Oil Terminal Lease Consideration Project

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4.6.1.3 Regional Seismicity

The San Francisco Bay Area lies along the San Andreas Fault, which forms the boundary between the Pacific and North American tectonic plates. Movement between the plates has created several other active faults parallel to the San Andreas, including the Hayward, Calaveras, Greenville, Concord/Green Valley, Rodgers Creek, and San Gregorio Faults. These faults create a zone measuring approximately 50 miles wide through the greater San Francisco Bay Area. Table 4.6-1 shows data and locations for known active faults in the Avon Terminal vicinity.

Table 4.6-1: Known Active Faults in the Avon Terminal Vicinity

Fault	Approximate Distance from Site (miles)	Estimated Maximum Moment Magnitude	Slip Rate (mm/year)[1]	Approximate Recurrence Interval (years)
Concord/Green Valley	0.9	6.9	4	200
West Napa	19	6.9	1	700
Hayward	23	7.1	9	160
Rogers Creek	23	7.0	9	200
Great Valley (segments 4 to 6)	25 to 32	6.5 to 6.7	1.5	475 to 625
Calaveras (Total)	27	6.8	6	180
Greenville	29	6.9	2	620
Hunting Creek	46	7.1	6	200
San Andreas	52	7.9	24	220
San Gregorio	56	7.6	5	450
Point Reyes	66	7.0	0.3	3,500
Monte Vista	70	6.7	0.4	2,400
Calaveras (south)	72	6.2	15	35
Maacama (south)	79	6.9	9	220

Sources: Cao et al. 2003, WGCEP 2007
[1]mm/year = millimeters per year

Several major earthquakes have occurred within the Bay Area on many of the major faults. Major earthquakes occurred in 1836 and 1868 along the Hayward Fault, approximately 23 miles from the site and had estimated moment magnitudes (Mw) of approximately 7. Another occurred in 1861 on the Calaveras Fault, approximately 27 miles south of the site and caused surface rupture for 8 miles through San Ramon Valley and caused severe damage within Contra Costa County. The “Mare Island” earthquake of 1898, along the southern end of the Rodgers Creek Fault, is approximately 23 miles from the site, is also of historic significance, with an estimated Mw of 6.2 (Toppozada et al. 1992). The 1838, 1906 (estimated Mw 7.9), and 1989 (“Loma Prieta,” Mw 7.1) earthquake events compose the most significant earthquakes to have occurred in the region within the past 200 years, and caused major damage to

structures in the Bay Area. The Working Group on California Earthquake Probabilities (2007) estimates that: (1) the Mw of future earthquakes for various faults within the San Andreas system will vary from approximately 7.0 to 7.9; (2) there is a 62 percent chance that there will be a damaging earthquake (i.e., Mw of 6.7 or greater) in the San Francisco Bay Area within the next 30 years; and (3) there is a 27 percent chance that there will be a damaging earthquake on the Hayward/Rodgers Creek Fault zone within the next 30 years (Parsons et al. 2003).

4.6.1.4 Site-specific Seismicity

Active faults, as defined by the CGS (Hart and Bryant 1997), do not transect the Avon Terminal. An active fault, as defined in the Alquist-Priolo Earthquake Fault Zoning Act, is one that has experienced surface displacement within the Holocene period (within the last 11,000 years). The Avon Terminal is surrounded by the Concord/Green Valley Fault to the east, the West Napa and Rodgers Creek Faults to the northwest, the Hayward Fault to the west, and the Calaveras Fault to the south, as shown on Figure 4.6-1. The Concord/Green Valley Fault is located less than 1 mile from the site and is estimated to be able to produce an Mw 6.9 earthquake approximately every 200 years. In the 150-year recorded history, no major earthquake has been recorded on this fault; however, the Working Group on California Earthquake Probabilities (2007) inferred that the entire Concord/Green Valley Fault Zone, which runs beneath Suisun Bay, could rupture in one major event. Several other faults are located within 25 miles of the Project site, and each of these is believed to be able to produce large earthquakes with a range of approximately Mw 6.5 to 7.0.

The U.S. Geological Survey ([USGS] 2014) developed Probabilistic Seismic Hazard Maps showing expected levels of ground shaking in the form of peak ground acceleration (PGA). The USGS Seismic Hazards Map (see Figure 4.6-3) shows, for California, the PGA that has 1 chance in 475 of being exceeded each year, which is approximately equal to a 10 percent probability of being exceeded in 50 years. For the Avon Terminal area, the expected PGA is approximately 46 percent of the Earth's gravitational force (g), or 0.46 g.

The California Department of Transportation ([Caltrans] 1996) has also developed a Seismic Hazard Map for California, showing contours of peak acceleration (see Figure 4.6-4). These contours reflect the effects of the Maximum Credible Events for the various contributing faults, and apply to ground motions for rock or stiff soil. A peak acceleration contour of 0.5 g is found in the Avon Terminal vicinity. Both of these sources provide data that imply that strong ground shaking is likely, should a major earthquake occur on a nearby active fault. However, the new Berth 1A has been designed and would be built utilizing MOTEMS-compliant site-specific Probabilistic Seismic Hazard Analysis; the resulting design PGA for Level 2 (10 percent in 50 years or 475 year return period) is 0.85 g.

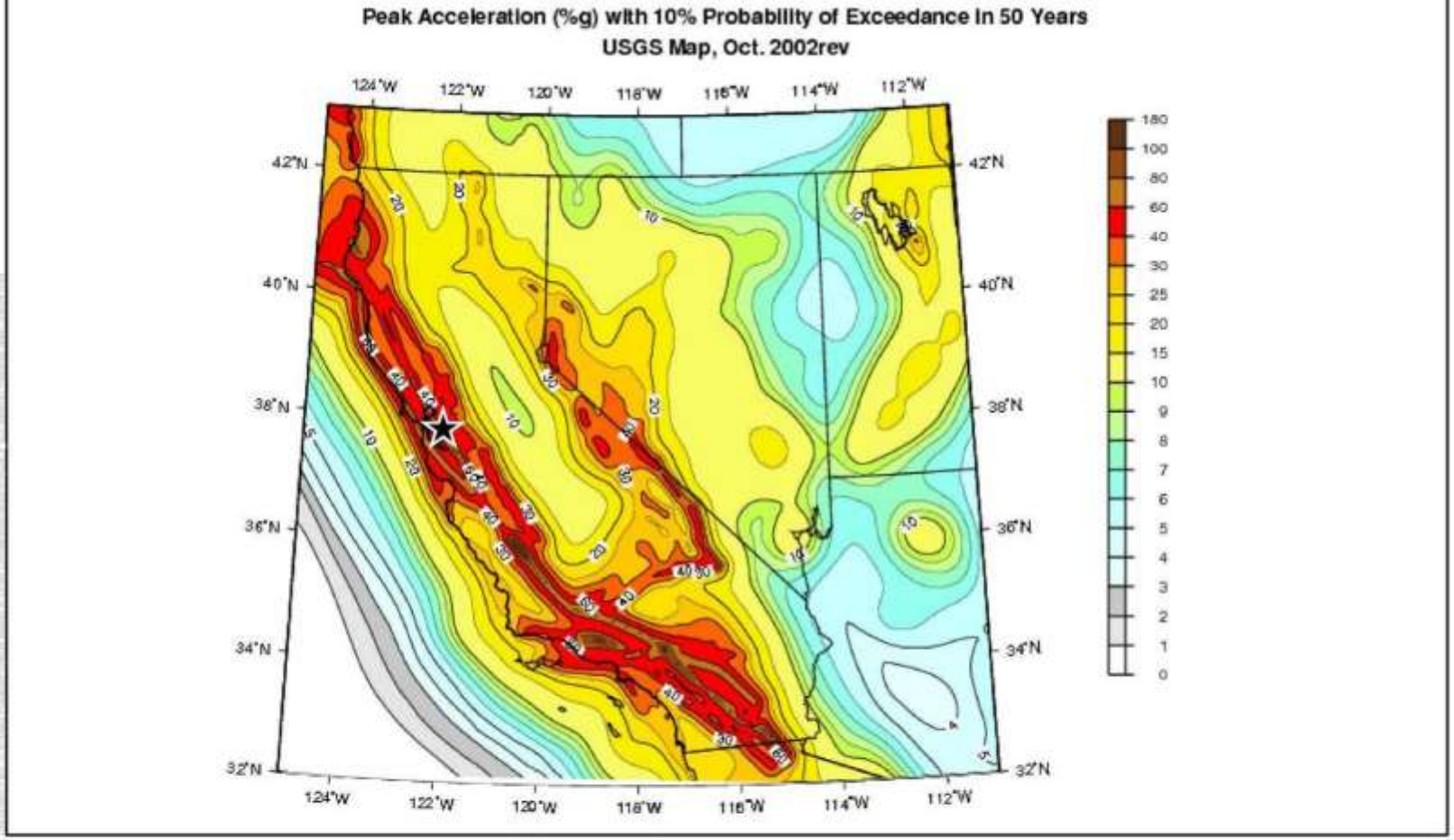

Figure 4.6-3
Seismic Hazards Map, USGS 2002
California State Lands Commission
Avon Marine Oil Terminal Lease Consideration Project

★ Approximate Terminal Location

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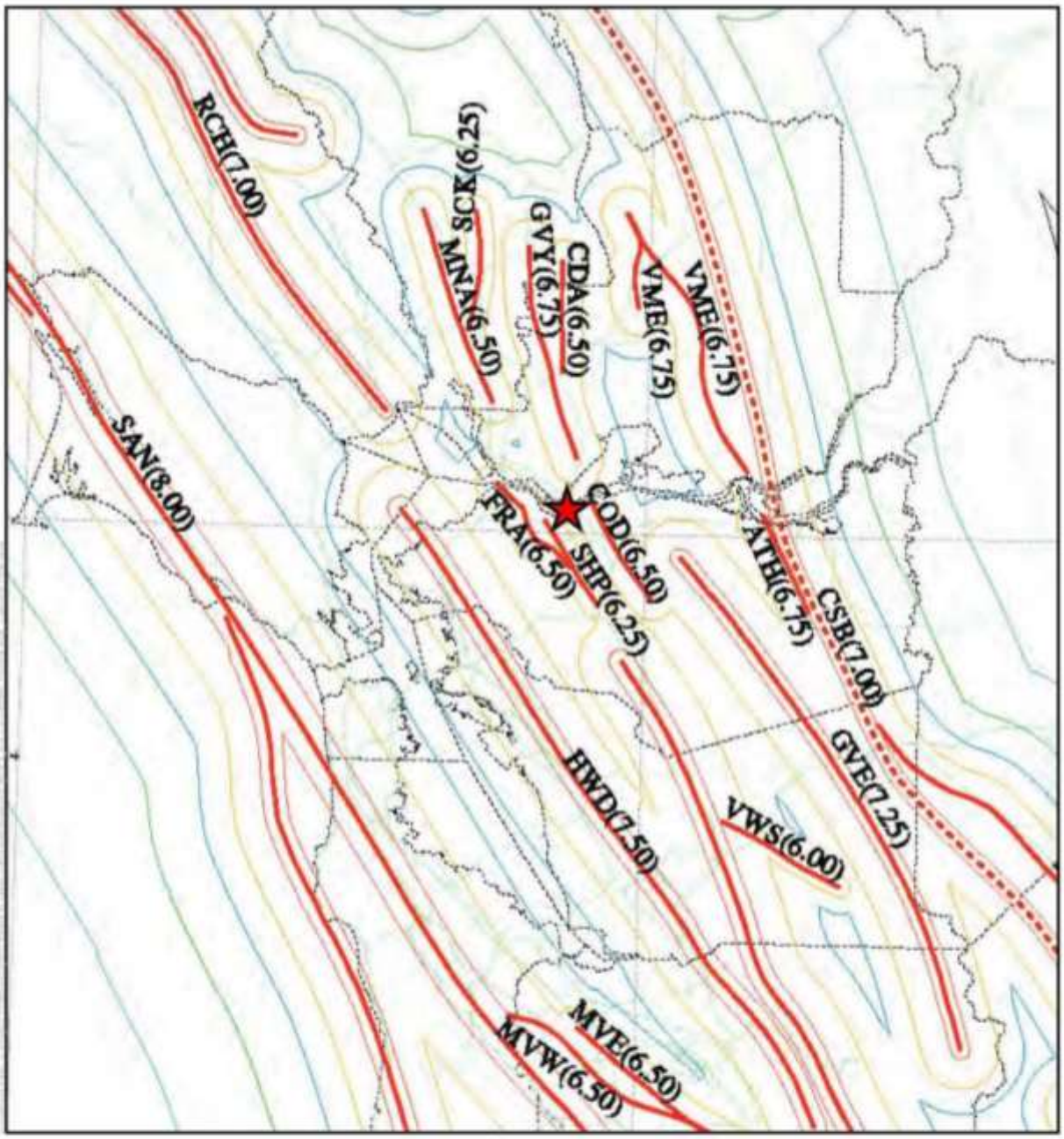

Figure 4.6-4
California Seismic Hazard Map, Caltrans 1996
California State Lands Commission
Avon Marine Oil Terminal Lease Consideration Project

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4.6.1.5 Tsunamis and Seiches

Tsunamis are sea waves typically created by undersea fault movement or coastal or subsea landslide. Tsunamis may be generated at great distance from shore (far field events) or nearby (near field events). Waves are formed as the displaced water moves to regain equilibrium, and radiates across the open ocean, similar to ripples from a rock being thrown into a pond. When the waveform reaches the coastline, it pushes upward from the ocean bottom to create a high swell of water that breaks and washes inland, with velocities as high as 15 to 20 nautical miles per hour. The water mass creates tremendous force and can impact coastal structures.

A seiche is a long, rolling wave with periodic oscillation or "sloshing" of water in an enclosed basin, and can be caused by strong winds. The period of oscillation can range from minutes to hours and has the potential to produce large changes in water levels.

Tsunamis and seiches are both rare. However, tsunamis have historically affected the Pacific coastline. The Fort Point tide gauge in San Francisco recorded approximately 21 tsunamis between 1854 and 1964. The 1964 Alaska earthquake generated a wave height of 7.4 feet near Crescent City, California, causing loss of human life. In March 2011, a 9.0 earthquake that occurred off Japan's east coast produced a tsunami with waves that came ashore in northern and central California at heights between 4 feet and 8 feet, causing damage to docks and vessels.

A tsunami originating in the Pacific Ocean would lose much of its energy passing through San Francisco Bay. Ritter and Dupre (1972) estimated the run-up for the 100-year return period tsunami near the Golden Gate to be 10 feet. The available data indicate a systematic diminishment of the wave height from the Golden Gate to the head of the Carquinez Strait, and on into Suisun Bay. The MOTEMS provide estimated tsunami run-up for areas of California. The maximum credible tsunami water levels and current speeds for the Martinez area are 2.3 feet and 1.3 feet per second, respectively, indicating a more muted response to tsunamis than at the Golden Gate. MOTEMS require that each marine oil terminal has a tsunami plan that details what actions will be taken to safeguard the facility in the event of a tsunami threat.

4.6.2 REGULATORY SETTING

Federal and State laws that may be relevant to the Project are identified in Table 4-1. Local laws, regulations, and policies are discussed in the following paragraphs.

Contra Costa County

Contra Costa Health Services Hazardous Materials Programs administers the California Accidental Release Prevention (CalARP) Program (Cal. Code Regs., tit. 19, Division 2, Chapter 4.6). Through CalARP, businesses that handle more than a threshold quantity

of certain regulated substances must develop a Risk Management Plan (RMP). An RMP is a detailed engineering analysis of the potential accident factors (including seismic considerations) present at a business, and the mitigation measures that can be implemented to reduce this accident potential. Additionally, MOTEMS incorporate CalARP regulations regarding the seismic assessment of anchors and supports on pipelines and valves, and the seismic assessment of existing electrical and mechanical equipment.

4.6.3 SIGNIFICANCE CRITERIA

For the purposes of this analysis, an impact was considered to be significant and to require mitigation if it would result in any of the following:

- Surface faulting or ground rupture, as a result of a seismic event, that could substantially damage structures or create a risk of injury or loss of life
- Ground motion due to a seismic event that could induce shaking, slope instability, liquefaction, settlement, or landslides, which could substantially damage structures or create a risk of injury or loss of life
- Tsunamis or seiches that would expose people or structures to the risk of loss, injury, or death
- Reduction of the structural stability of the Avon Terminal due to an increase in loading conditions, vessel size, or number of vessels calling
- Construction or maintenance activities that could cause substantial soil erosion or impact known mineral resources

Geologic impacts were evaluated in two ways: (1) impacts of geologic hazards on Project components that may result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury; and (2) the impact of the Project on the local geologic environment.

4.6.4 IMPACT ANALYSIS AND MITIGATION

4.6.4.1 Proposed Project

Impact Geology, Sediments, and Seismicity (GSS)-1: Expose people or structures to surface faulting and ground rupture, resulting in substantial structural damage and risk of injury or loss of life. (Less than significant.)

The Avon Terminal lies outside of the Alquist-Priolo earthquake fault zone, so surface faulting and ground rupture from known active faults is not anticipated either over the continued operational period or during renovation; therefore, the impact is less than significant. However, significant ground shaking could occur as a result of a major

earthquake on a nearby fault; this impact is discussed under GSS-2. Accordingly, impacts from surface faulting or ground rupture would be less than significant.

Mitigation Measure: No mitigation required.

Impact GSS-2: Expose people or structures to strong ground shaking, slope instability, and/or seismically induced landslides causing substantial structural damage and risk of injury or loss of life. (Less than significant.)

The Avon Terminal is subject to strong ground shaking as a result of a major earthquake on any of the nearby faults (refer to Section 4.6.1.1). As the existing facility was determined to be seismically non-compliant due to soil-structure interaction (i.e., liquefaction) in the Avon Terminal's 2008 MOTEMS audit, seismic renovation is a major objective of the proposed renovation, which is intended to achieve compliance with 2013 MOTEMS requirements. The scope of these renovations would include: construction of a new Berth 1A loading/unloading platform and decommissioning of Berth 1; repair and rebuild of the approachway; and demolition and removal of existing Berth 5. MOTEMS require that effects of ground shaking, slope stability, and landslides resulting from seismic events be studied during a geotechnical investigation (e.g., Treadwell & Rollo 1997, 2007a, and 2013) and incorporated into facility design to minimize structural damage; prevent oil spills; and protect public health, safety, and the environment. Therefore, this impact would be less than significant for continued operations. Damage could occur if a significant earthquake were to take place before or during renovation. However, given the relatively low probability of a significant earthquake occurring during this limited timeframe, the impact is considered less than significant.

Mitigation Measure: No mitigation required.

Impact GSS-3: Expose people or structures to liquefaction and seismically induced settlement causing substantial structural damage and risk of injury or loss of life. (Less than significant.)

Similar to the discussion under Impact GSS-2, the existing Avon Terminal is seismically deficient and seismic retrofits are necessary; MOTEMS-compliant seismic renovations are required to be designed to mitigate liquefaction and settlement resulting from seismic activity. Therefore, this impact is less than significant.

Mitigation Measure: No mitigation required.

Impact GSS-4: Expose people or structures to the risk of loss, injury, or death as a result of tsunamis and/or seiches. (Less than significant.)

As discussed in Section 4.6.1.5, tsunamis and seiches are rare, and a tsunami originating in the Pacific Ocean would lose most of its energy as it passes through the San Francisco Bay and into the Carquinez Strait. Furthermore, MOTEMS require marine oil terminals to have a tsunami plan to address far-field and near-field tsunami events, notifications and communications, a tsunami warning system, tsunami response actions, tidal levels, currents and seiche conditions, loss of utilities, tsunami plan accessibility and training, and post-event inspection. Per MOTEMS, the tsunami plan must be revisited and revised, where necessary, at a minimum of every 3 years. Since minimal damage would be expected to occur to the Avon Terminal, and because Tesoro Refining and Marketing Company, LLC is required to comply with MOTEMS, impacts would be less than significant during the operational period. Consideration of the construction period is discussed under Impact GSS-2.

Mitigation Measure: No mitigation required.

Impact GSS-5: Cause structural damage to the Avon Terminal due to an increase in loading conditions, vessel size, or number of vessels calling. (Less than significant.)

MOTEMS requires mooring and berthing analyses to be performed, such that operational limits are established within the allowable capacities of the structure, fendering system, and mooring arrangements for the various sizes of vessels that are permitted to call. Changed loading conditions, vessel size, or number of vessels calling would not be permitted above the established operating limits. The level of shipment activity and throughput at the Avon Terminal is not expected to change substantially during the proposed 30-year lease agreement period. For these reasons, this impact is less than significant.

Mitigation Measure: No mitigation required.

Impact GSS-6: Cause substantial soil erosion or impact known mineral resources. (Less than significant.)

Onshore activities that support Avon Terminal operation would remain subject to the existing site-specific Stormwater Pollution Prevention Plan (SWPPP) and associated best management practices (BMPs) during the operational period, which would continue to minimize the effects of maintenance activities on soil erosion.

Onshore staging areas associated with Project renovation activities would require soil disturbance, which can accelerate the rate of erosion. As discussed in detail in Section

4.3, Water Quality, Impact WQ-1~~2~~3, projects that disturb 1 or more acre of soil are required to obtain coverage under the Construction Storm Water General Permit (NPDES General Permit No. CAS000002, Order No. 2009-0009-DWQ). Construction activity subject to this permit includes clearing, grading, and disturbances to the ground such as stockpiling or excavation. Although a section of the gravel road on the east side of the oxidation pond that would receive heavy construction traffic is greater than 1 acre, this would not meet the definition of "disturb" as described above. In addition, during renovation, all of the stormwater runoff from the approachway and other renovation areas would be contained within bermed areas, and would not drain off-site. Therefore, a Construction Storm Water General Permit and a construction SWPPP would not be required. The Project would incorporate acceptable BMPs for control of sediment and stabilization of erosion in the Project area, as described under Impact WQ-1~~2~~3.

With regard to mineral resources, according to the State Mining and Geology Board Surface Mining and Reclamation Act Designation Report No. 7, the potential mineral deposits in Contra Costa County are located in the cities of Antioch and Byron, and therefore, would not be affected by repair or maintenance activities at the Avon Terminal. Therefore, this impact is less than significant.

Mitigation Measure: No mitigation required.

4.6.4.2 Alternative 1: No Project

Impact GSS-7: Elimination of long-term potential for structural damage. (Beneficial.)

Under the No Project alternative, the Avon Terminal lease would not be renewed and the existing Avon Terminal would be subsequently decommissioned with its components abandoned in place, removed, or a combination thereof. Removal of the structures would not have geotechnical implications or result in geologic impacts. Following decommissioning of the Avon Terminal, any potential for structural damage will have been eliminated. The No Project alternative would likely result in the transfer of Avon Terminal operations to other Bay Area marine oil terminals, such as the Tesoro Amorco Marine Oil Terminal. Those terminals could have the potential for geologic, sediment, and seismic impacts, depending on the specific condition or need for modifications or new construction associated with each terminal.

Mitigation Measure: No mitigation required.

Impact GSS-8: Potential to cause substantial soil erosion or impact a known mineral resource. (Less than significant.)

With the absence of the Avon Terminal, modification of existing and construction of new overland pipelines, railways, and roadways would likely be required to deliver and

distribute crude oil or other products to or from the Golden Eagle Refinery (Refinery). Soil erosion or sedimentation during construction activities would be limited by the use of BMPs per a Project-specific SWPPP, as discussed under Impact GSS-6. With regard to mineral resources, potential mineral deposits in Contra Costa County are located in the cities of Antioch and Byron, as discussed under Impact GSS-6. Therefore, the likelihood of significant mineral deposits being present along potential new pipelines to the Refinery is minor. For these reasons, impacts are anticipated to be less than significant.

Mitigation Measure: No mitigation required.

Impact GSS-9: Potential to cause damage and/or failure to pipelines as a result of a seismic event. (Less than significant.)

Modification of existing and new overland pipelines would likely be required to deliver crude oil or other products to or from the Refinery. Integrity review of pipelines is required by the MOTEMS for pipelines at marine terminals to avoid failures due to seismic displacement, improper engineering design, corrosion, and joint failure. Due to the MOTEMS seismic design and operational requirements, the chance of pipeline damage from a seismic event would be less than significant. Discussion of the consequences of spills, including impacts on other resources, is presented in various subsections of Section 4.0, Environmental Impact Analysis.

For each pipeline system, pipeline operators are required to prepare and follow a manual of written procedures to ensure safety during pipeline maintenance and normal operations, abnormal operations, and emergencies (Title 49 Code of Federal Regulations [CFR] Part 195.402). The maintenance and normal operations section of the manual must include current maps and records, and procedures for operating, maintaining, repairing, starting up and shutting down the pipeline system; minimizing the potential for hazards; and implementing applicable control room management procedures. The abnormal operations section addresses scenarios where the operating design limits have been exceeded and must include procedures for responding to, investigating, and correcting the cause of abnormal operations. The emergencies section of the procedure manual must identify procedures for prompt and effective response, assessing the area impacted by the hazard, and minimizing public exposure to injury. Safety-related condition reports must also be included in the procedures manual. Instructions must be included to enable personnel who operate and maintain the pipeline to recognize conditions that potentially may have safety risks, subject to the reporting requirements of 49 CFR 195.55.

Mitigation Measure: No mitigation required.

4.6.4.3 Alternative 2: Restricted Lease Taking Avon Terminal Out of Service for Oil Transport

Impact GSS-10: Expose people or structures to seismically induced ground shaking, slope instability, landslides, liquefaction, settlement, or tsunamis/ seiches, causing substantial structural damage and risk of injury or loss of life. (Potentially significant.)

If the Avon Terminal is taken out of service for oil transport, there is a potential for the facility to remain in use as a staging area for dredging operations, maintenance and upgrades to other terminals, or training exercises. If the facility is not decommissioned, the need for MOTEMS renovations to protect against seismic risks would need to be evaluated.

Mitigation Measures: Should this alternative be selected, mitigation measures (MM) would be determined during a separate environmental review under the California Environmental Quality Act (CEQA).

Impact GSS-11: Potential to cause substantial soil erosion, or to impact a known mineral resource. (Less than significant.)

Refer to the discussion under Impact GSS-8.

Mitigation Measure: No mitigation required.

Impact GSS-12: Potential to cause damage and/or failure to pipelines as a result of a seismic event. (Less than significant.)

Refer to the discussion under Impact GSS-9.

Mitigation Measure: No mitigation required.

4.6.5 CUMULATIVE IMPACT ANALYSIS

The shoreline of the San Francisco Bay, Carquinez Strait, and Suisun Bay is home to many marine and industrial facilities that are susceptible to earthquake-related damage. The 1989 Loma Prieta earthquake caused extensive damage to various structures in the city of Oakland and its port facilities. Liquefaction and seismically induced settlement of loose and soft soils caused most of the damage, which included failure of bridge supports and damage to storage tanks. Most marine oil terminals, however, are constructed with redundancy, and experienced little or no damage during this earthquake. Marine oil terminals in California are designed to withstand large lateral forces and/or are required to upgrade to comply with MOTEMS, and thus, are not

expected to be significantly damaged by most earthquake events. Therefore, cumulative impacts, to which the Avon Terminal contributes incrementally, are less than significant.

4.6.6 SUMMARY OF FINDINGS

Table 4.6-2 provides a summary of anticipated impacts and associated mitigation measures.

Table 4.6-2: Summary of Geology, Sediments, and Seismicity Impacts and Mitigation Measures

Impact	Mitigation Measure(s)
Proposed Project	
GSS-1: Expose people or structures to surface faulting and ground rupture, resulting in substantial structural damage and risk of injury or loss of life.	No mitigation required
GSS-2: Expose people or structures to strong ground shaking, slope instability, and/or seismically induced landslides causing substantial structural damage and risk of injury or loss of life.	No mitigation required
GSS-3: Expose people or structures to liquefaction and seismically induced settlement causing substantial structural damage and risk of injury or loss of life.	No mitigation required
GSS-4: Expose people or structures to the risk of loss, injury, or death as a result of tsunamis and/or seiches.	No mitigation required
GSS-5: Cause structural damage to the Avon Terminal due to an increase in loading conditions, vessel size, or number of vessels calling.	No mitigation required
GSS-6: Cause substantial soil erosion during construction activities.	No mitigation required
Alternative 1: No Project	
GSS-7: Elimination of long-term potential for structural damage.	No mitigation required
GSS-8: Potential to cause substantial soil erosion, or to impact a known mineral resource.	No mitigation required
GSS-9: Potential to cause damage and/or failure to pipelines as a result of a seismic event.	No mitigation required
Alternative 2: Restricted Lease Taking Avon Terminal Out of Service for Oil Transport	
GSS-10: Expose people or structures to seismically induced ground shaking, slope instability, landslides, liquefaction, settlement, or tsunamis/seiches, causing substantial structural damage and risk of injury or loss of life.	Should this alternative be selected, MMs would be determined during a separate environmental review under CEQA.
GSS-11: Potential to cause substantial soil erosion, or to impact a known mineral resource.	No mitigation required
GSS-12: Potential to cause damage and/or failure to pipelines as a result of a seismic event.	No mitigation required