Chapter 3.7

Geology

3.7.1 Introduction

This section addresses the existing local and regional geologic conditions within the project area, and analyzes geologic hazards and general geotechnical issues such as unstable slopes and landslide deposits, faulting, seismicity, and expansive, collapsible, and corrosive soils. This assessment relied on published reports, surface reconnaissance, and the general geologic setting as indicators of potential geologic hazards. Design-level engineering geology and geotechnical investigation, subsurface exploration, laboratory testing, and analyses were not included in the scope of this evaluation and are not required by CEQA.

3.7.2 Setting

3.7.2.1 Regional Setting

The project is near sea level within the southwestern structural block of the Los Angeles basin province (Dibblee Jr. 1999, Bryant 1987, Kennedy 1975, and Poland and Piper 1956). The southwestern structural block, one of four such blocks underlying the Los Angeles Basin, is marked by a northwest-southeast trending fault system (Yerkes et al. 1965) as indicated in Figure 3.7-1.

The project area is located on artificial fill placed over Holocene alluvial outwash and beach deposits. Underlying these Holocene sediments are the Miocene Malaga Mudstone and Monterey Formation. See Appendix F for additional information regarding the stratigraphy beneath the site.

Faulting and Seismicity

Southern California is recognized as one of the most seismically active areas in the United States. The region has been subjected to at least 52 major earthquakes of magnitude 6 or greater since 1796. Ground motion in the region is generally the result of sudden movements of large blocks of the earth's crust along faults. Great earthquakes, like the 1857 San Andreas Fault Earthquake (magnitude 8.2), are quite rare in southern California. Earthquakes of magnitude 7.8 or greater occur at the rate of about two or three per 1,000 years, corresponding to a 6–9% probability in 30 years. However, the probability of a magnitude 7.0 or greater earthquake in southern California before 2024 is 85% (Working Group on California Earthquake Probabilities 1995).

Faults

Segments of the active Palos Verdes Fault cross the Port in the project vicinity. The precise location of the fault is not well defined but current data, depicted in Figure 3.7-2, suggest the fault likely passes beneath the West Basin, Terminal Island, and Pier 400.

Numerous other active faults and fault zones are located within the general region, such as the Newport-Inglewood, Whittier-Elsinore, Santa Monica, Hollywood, Raymond, San Fernando, Sierra Madre, Cucamonga, San Jacinto, and San Andreas Faults. These faults are discussed in detail in Appendix F. Table 3.7-1 lists selected known active faults in close proximity to the site, the maximum moment magnitude (M_{max}) as published by the California Department of Conservation, Division of Mines and Geology (1998), and the type of fault, as defined in Table 16-U of the Uniform Building Code (International Conference of Building Officials 1997).

Table 3.7-1. Principal Active Faults

Fault Name	Fault to Site Distance in (miles)	Maximum Moment Magnitude[a] (M_{max})	Fault Type[b]
Palos Verdes	<1	7.1	B
Newport-Inglewood	7.9	6.9	B
Elysian Park	20	6.7	
Whittier-Elsinore	23	6.8	B
Santa Monica-Raymond	25	6.6	B
Hollywood	26	6.5	B
Sierra Madre/San Fernando	33	7.0	B
San Fernando-Cucamonga	41	7.0	A
Santa Susana	43	6.6	B
San Andreas	59	7.4	A
San Jacinto	63	6.9	B

Sources:

(a) Peterson et al. 1996, California Division of Mines and Geology 1998.

(b) International Conference of Building Officials 1997, California Department of Conservation, Division of Mines and Geology 1998.

Active faults, such as those noted above, are typical of southern California. Therefore, it is reasonable to expect a strong ground motion seismic event during the lifetime of any proposed project in the region. Numerous active faults located off-site are capable of generating significant earthquakes in the proposed project area. Most noteworthy, due to the proximity to the site, is the Newport-Inglewood Fault Zone, which has generated large earthquakes, including the 1933 Long Beach Earthquake (magnitude 6.3). Large events could occur on more distant faults in the general area, but because of the greater distance from the site, earthquakes generated on these faults may be considered less significant with respect to ground accelerations.

In 1974, the California Geological Survey was designated by the Alquist-Priolo Earthquake Zoning Act to delineate those faults deemed active and likely to rupture the ground surface. No faults within the area of the Port are currently zoned under the Alquist-Priolo Earthquake Zoning Act; however, there is evidence that the Palos Verdes Fault, which lies beneath the harbor, may be active and ground surface rupture in the harbor cannot be ruled out. See Appendix F for additional information on faults in the area.

Ground Motion

A probabilistic seismic hazard assessment that includes statewide estimates of peak horizontal ground accelerations has been conducted for California (Peterson et al. 1996). Based on our review of this report, and updated data available from the United States Geological Survey (2002), the peak ground acceleration (PGA), with a 10% probability of exceedance in 50 years is approximately 0.51g at the site.

Liquefaction

Strong ground motions generated by earthquakes cause various types of ground failures, including liquefaction. Liquefaction is most likely when cohesionless, granular sediments are water saturated to within 50 feet or less of the surface. Unconsolidated silts, sands, and silty sands are most susceptible to liquefaction. Soil liquefaction is a phenomenon in which the ground loses its strength or stiffness when ground shaking associated with an earthquake induces large excess pore (the space between soil particles) water pressures, causing the soil to liquefy. While almost any saturated granular soil can develop increased pore water pressures when shaken, these excess pore water pressures can lead to liquefaction if the intensity and duration of earthquake shaking are great enough. Among the recent earthquakes that were great enough to cause liquefaction were the Taiwan Earthquake in 1999, Loma Prieta Earthquake in 1989, the Mexico City Earthquake in 1985, the Central Japan Sea Earthquake in 1983, the San Fernando Earthquake in 1971, the 1964 Alaska Earthquake, and the Niigata (Japan) Earthquake in 1964. Structures particularly vulnerable to liquefaction during these earthquakes were buildings with shallow foundations, railways, highways, bridges, buried structures, dams, canals, retaining walls, port structures, utility poles, and towers.

The project site in Figure 3.7-3 is mapped within an area designated by the State of California as having a potential for liquefaction. The potential for liquefaction in the harbor area during a major earthquake on either the San Andreas Fault or the Newport-Inglewood Fault is high (Tinsley and Youd 1985, Toppozada et al. 1988, Davis et al. 1982). At the project site, the water table is found at depths of approximately 6–10 feet below ground surface (Tetra Tech, Inc. 1999). The potential for liquefaction due to seismic shaking of hydraulic fills within the Port area has been studied by Pyke, Knupple, and Lee (1978 in Geofon 1986), who concluded that the probability of major liquefaction of the fills within the useful life of most Port facilities is something less than 50%.

The state of the art of liquefaction-reduction and mitigative methodologies was reviewed in a special workshop hosted by the LAHD. The approximately 90 experts from the United States, Canada, and Japan attending this workshop (21–23 March 1990) focused on earthquake issues and problems related to the Port and its port facilities development plans. Topics discussed included seismic risk, hazard, geotechnical, and structural considerations. A modern set of design standards and guidelines for producing a Seismic Safety Plan for the Port were developed based on the best information available and the latest technologies in earthquake engineering (Committee on Earthquake Engineering 1985).

Tsunamis

Tsunamis are gravity waves of long wavelengths generated by seismic activities that cause vertical motions of the earth's crust. A vertical displacement of this nature leads to a corresponding displacement of the overlying water mass and sets off transoceanic waves of great lengths (up to hundreds of miles) containing large amounts of energy. Although such waves are usually hard to detect in relatively deep ocean, they amplify significantly as their lengths become shorter when propagating onto the continental shelf and towards the coast. In the process of shoaling, the waves often become highly nonlinear and tend to decompose into a series of solitary waves before run-up on the shore in the form of bores or surges.

Besides submarine earthquakes, tsunamis can also be generated by volcanic activities and landslides. These types of waves, however, are often more important locally due to significant energy spreading in the initial stages of wave generation.

Major terminal effects of tsunamis that have historically caused tremendous destruction to low-lying coastal regions include:

- coastal inundation,
- damage of onshore structures/properties,
- loss of life and live-stocks,
- disruption of natural and built environment, and
- harbor surges.

Coastal flooding may be caused by either run-up of broken tsunamis in the form of bores or surges, or by relatively less dynamic flood waves. In the process of bore/surge-type run-up, the onshore flow (up to tens of feet per second) can cause tremendous dynamic loads on the structures onshore in the form of impact forces and drag forces in addition to hydrostatic loading. The subsequent drawdown of the water after run-up exerts the often crippling opposite drags on the structures, and washes loose/broken properties and debris to the sea; the floating debris brought back on the next onshore flow have been found to be a significant cause of extensive damage after successive run-up and drawdown. As has been shown historically, the potential loss of human life in the process can be great if such events occur in populated areas. In addition, tsunamis are capable of causing severe damage to harbor infrastructure/facilities by exciting resonance or surges, which would not occur under normal wave conditions.

Vertical water motion in the Los Angeles Harbor caused from tsunami-induced resonance has been small, but large horizontal velocities have occurred. The

ACOE Waterways Experiment Station (WES) conducted a flood insurance study in 1974. It determined that the 100-year and 500-year run-up in the Los Angeles Harbor area, due to tsunamis of distant origin, is 5.3 feet and 8.2 feet above MLLW , respectively.

Seismic activities that have high potential for generating tsunamis are mostly located along the Pacific Coast. The most threatening sources for the West Coast of U.S. (except Hawaii) have been earthquakes in the Aleutian Trench and the Peru-Chile Trench, though tsunamis generated by local earthquakes were also recorded.

Tsunamis affecting the Los Angeles-Long Beach Harbor complex were historically documented (National Geophysical Data Center 1993). The data indicate that, of the various tsunami sources, the earthquakes in the Peru-Chile Trench are potentially the most damaging to the project site due to its nearly direct exposure to the source region in the Southern Hemisphere. The Chilean Earthquake of May 1960, for example, caused damages of over $1 million and harbor closure. One person drowned at Cabrillo Beach and one was injured. Small craft moorings in the harbor area, especially in the Cerritos Channel, were seriously damaged. Hundreds of boats broke loose from the moorings with 40 sunk and about 200 damaged. Gasoline from broken boats caused a significant spill in the harbor waters and a fire hazard. Currents up to 8 knots and a 6-foot rise of water in a few minutes were observed in West Basin. Damages to docks and piers by the fast currents were significant. The maximum oscillations recorded by gauges are 5.0 feet at Port Berth 60 (near Pilot Station) and 5.8 feet in Long Beach Harbor. The surge motions after the slightly longer initial wave are typically 30–45 minutes in period, although the instantaneous rises can be as fast as a few minutes at times.

Expansive Soils

Expansive soils generally result from specific clay minerals that expand when saturated and shrink in volume when dry. These expansive clay minerals are common in the geologic units in the Palos Verdes Peninsula. Clay minerals in geologic units at the project site could be expansive, and previously imported fill soils could be expansive as well.

Subsidence

Subsidence is the phenomenon where the soils and other earth materials underlying a site settle or compress, resulting in a lower ground surface elevation. Fill and native materials on site can be water saturated, and a net decrease in the pore pressure and contained water will allow the soil grains to pack closer together. This closer grain packing results in less volume and the lowering of the ground surface.

Subsidence in the Los Angeles-Long Beach Harbor area was first observed in 1928. It has affected the majority of the harbor area. Based on extensive studies by the City of Long Beach and the California Division of Oil and Gas, it has been determined that most of the subsidence was the result of oil and gas production from the Wilmington Oil Field following its discovery in 1936. Water injection operations to repressurize the field and increase oil recovery were initiated in the early 1950s. Now regulated by the Division of Oil and Gas, water injection has effectively mitigated the subsidence from oil extraction activities.

3.7.2.2 Regulatory Setting

Geologic resources and geotechnical hazards are governed primarily by local jurisdictions. The conservation and seismic safety elements of the General Plan contains policies for the protection of geologic features and avoidance of geologic hazards. Local grading ordinances establish detailed procedures for excavation and earthwork required during construction. In addition, building codes in each jurisdiction establish standards for construction of aboveground structures. Most local jurisdictions rely on the State Uniform Building Code for a basis of seismic design. All local jurisdictions must comply with regulations of the Alquist-Priolo Act.

3.7.3 Impacts and Mitigation

3.7.3.1 Methodology

Geologic issues were identified and assessed based on existing published reports, surface reconnaissance, and knowledge of the general geologic setting. Design-level engineering geology and geotechnical investigation, subsurface exploration, laboratory testing, and analyses were not conducted. A qualitative assessment of impacts is provided in this Recirculated Draft SEIR.

3.7.3.2 Thresholds of Significance

According to the *Draft LA CEQA Thresholds Guide* (City of Los Angeles 1998), a project would normally be considered to have a geologic impact if it would result in one or more of the following:

- cause or accelerate geologic hazards which would result in substantial damage to structures or infrastructure;
- expose people to substantial risk of injury;

- constitute a geologic hazard to other properties by causing or accelerating instability from erosion;
- result in the destruction, permanent covering, or materially and adversely modification of one or more distinct and prominent geologic or topographic features.

Based on these factors, the following thresholds are used in this Recirculated Draft SEIR to determine whether a project would have a significant impact.

GEO-1: The project would cause or accelerate geologic hazards that would result in substantial damage to structures or infrastructure.

GEO-2: The project could expose people to substantial risk of injury.

GEO-3: The project would constitute a geologic hazard to properties by causing or accelerating instability from erosion.

GEO-4: The project would result in the destruction, permanent covering, or material and adverse modification of one or more distinct and prominent geologic or topographic features.

3.7.3.3 Project Impacts

The following measures have been incorporated into the project design and were used in assessing project impacts.

- During final design, earthquake-resistant standards will be incorporated into the project plans by the design engineer to reduce potential impacts from liquefaction, ground rupture, ground shaking, tsunamis, and ground acceleration impacts from major earthquakes. These standards will include, but will not be limited to, the State Uniform Building Code, the City of Los Angeles Building Codes, and the LAHD standards and guidelines. The project engineer will review the project plans for compliance with the appropriate standards within the building codes.
- The expansion potential of onsite soil will be evaluated by the project engineer during design**.** The recommendations of the engineer will be incorporated into the design specifications for the project, consistent with LAHD design guidelines.
- LAHD design standards regarding subsidence of soils will be implemented to prevent significant impacts to project components and structures.
- During final design and grading, slope stability measures will be implemented to avoid slope failure. These measures will include, but will not be limited to, standards established in the Uniform Building Code and the City of Los Angeles Grading Codes. The project engineer will review the project plans for compliance with the appropriate standards.

Direct and Indirect Impacts

Impact GEO-1: The Project Would Not Cause or Accelerate Geologic Hazards That Would Result in Substantial Damage to Structures or Infrastructure

Geologic conditions exist in the region that could potentially expose people and structures to geologic hazards. However, the proposed project features do not have the potential to accelerate geologic hazards. The proposed project would be designed an engineered in accordance with the latest building standards and Uniform Building Codes. All final engineering plans will be reviewed by a licensed civil engineer to ensure compliance with these codes, and appropriate design recommendations will be incorporated and adhered to during construction of the project. Therefore, impacts would be less than significant.

Mitigation Measures

No mitigation is required.

Residual Impacts

Impacts would be less than significant.

Impact GEO-2: The Project Could Expose People to Substantial Risk of Injury

The proposed project area is exposed to seismic hazards, tsunamis, liquefaction, and other deficient soil conditions.

Seismicity

The project site lies in the vicinity of the Palos Verdes Fault zone. An earthquake within this fault zone could cause strong-to-intense ground shaking, surface rupture, and liquefaction of water-saturated hydraulic fill. With the exception of ground rupture, similar seismic impacts could occur due to earthquakes on other regional faults.

Seismic shaking that could result in liquefaction, settlement, or surface cracks at the project site has a relatively high probability of occurrence, while potential ground rupture effects are limited to movement on the Palos Verdes Fault. As described above, this possibility is still a subject of differing professional judgments among experts. Based on currently available information regarding the location of the Palos Verdes Fault Zone, there is a low probability for surface fault rupture at the project site due to movement on this fault (see Figure 3.7-1).

As discovered during the 1971 San Fernando Earthquake and the 1994 Northridge Earthquake, existing building codes are often inadequate to protect engineered structures from hazards associated with liquefaction, ground rupture, and large ground accelerations. Consequently, designing new facilities based on existing building codes may not prevent significant damage to structures from a major or great earthquake on a nearby fault. Therefore, seismic hazards related to future major or great earthquakes are significant, unavoidable impacts.

Tsunamis

Tsunami conditions at the Los Angeles Harbor were reviewed and analyzed. It was found that the harbor has historically been exposed to tsunamis of approximately 6–46 minutes, a range that partially overlaps with one of the most energetic resonant period range of the harbor as determined by prior physical model tests. Currents associated with tsunamis are responsible for substantially all the damage to Port facilities and commercial and recreational vessels that occur in the Port as a result of tsunamis.

The major damage in the project area from a tsunami is expected to result from the change in the water depth beyond that experienced during the normal tidal cycle. All boats will be secured to floating berths. These berths would accommodate a change in elevation in excess of 1.5 meters (5 feet) above the mean higher high water. Impacts are not expected to be significant.

Expansive Soil

Expansive soil may be present in the project site. These soils can significantly impact foundations of buildings or associated structures or improvements. These impacts can be reduced to insignificance with standard geotechnical engineering of foundations and/or foundation soils as called for in LAHD design guidelines.

Subsidence

Local site subsidence can result from consolidation of fill materials (dredged material). Loading the surface building and related facilities can increase the amount of settling. Vibrations from stationary equipment would accelerate this settling. A fluctuating water table, induced by tidal cycles, can also cause subsidence. Other areas of the project should not have subsidence given the time since the fill was constructed.

Surface subsidence could also be associated with a subsurface slope failure adjacent to the channel or slip. Although this existing risk is currently low, it could be increased by removal of lateral support during dredging activity (Krynine and Judd 1957). The risk of this type of slope failure increases during seismic events as discussed in the “Seismicity” subsection above. This type of surface subsidence would involve a downward rotation of the surface adjacent to the slope failure. During dredging, engineering guidelines call for use of accepted engineering practices, such as reducing the slope inclination and installation of stabilization structures such as sheet pile walls, sea walls and bulkheads, to prevent subsidence. Following these accepted engineering guidelines, the impacts will be less than significant.

Local site subsidence must be considered during engineering design of all modifications at the site to reduce the potential effects of vibrating equipment. The load-bearing strength underlying each new facility would first be determined, and appropriate foundation designs would be incorporated.

Following accepted engineering guidance, these impacts will be less than significant.

Based on the analysis above, the existing geologic conditions could potentially expose people or structures to significant risk or injury. Therefore, impacts are considered significant and unavoidable.

Mitigation Measures

No mitigation is feasible to reduce impacts to less-than-significant levels.

Residual Impacts

Impacts would be significant and unavoidable.

Impact GEO-3: The Project Would Not Constitute a Geologic Hazard to Properties by Causing or Accelerating Instability from Erosion

Surface ground failure could be associated with a subsurface slope failure adjacent to a channel or slip. Although this existing risk is currently low, it could be increased by removal of lateral support during dredging activity (Krynine and Judd 1957). The risk of this type of slope failure increases during seismic events. This type of slope failure could induce surface subsidence, which would involve a downward rotation of the surface adjacent to the slope failure. Engineering guidelines call for use of accepted engineering practices, such as reducing the slope inclination and installation of stabilization structures such as sheet pile walls, sea walls and bulkheads, to prevent such occurrences. Therefore, impacts are considered to be less than significant.

Mitigation Measures

No mitigation is required.

Residual Impacts

Impacts would be less than significant.

Impact GEO-4: The Project Would Not Result in the Destruction, Permanent Covering, or Material and Adverse Modification of One or More Distinct and Prominent Geologic or Topographic Features

Currently, the topography of the project site is generally flat without prominent geologic or topographic features. Minor grading will occur in association with infrastructure and project improvements, resulting in a slight alteration of the topography. This slight alteration of the topography is not considered a significant environmental impact.

Dredging of approximately 75,000 cubic yards of material will be required to provide adequate depth for boat slips and channels, and 120,000 cubic yards of fill will be required for land-side development. The dredge material, if suitable for in-harbor fill, will be used as landfill for the marina activities. Excavation, dredging, and landfill in these areas will result in alteration of the bottom topography. This alteration is considered a less-than-significant impact on the existing geological setting.

Mitigation Measures

No mitigation is required.

Residual Impacts

Impacts would be less than significant.

Cumulative Impacts

Cumulative earth/geology impacts may result if projects in the vicinity were implemented concurrently. Projects in the area are particularly vulnerable to primary and secondary seismic hazards during construction. If a major or great earthquake occurs concurrently with construction of numerous projects in the vicinity of the site, loss and/or damage might be substantial.

However, it is unlikely that this scenario will occur. Therefore, the project would not make a considerable contribution to cumulative seismic hazards. No additional mitigations beyond seismic design and construction practices are feasible.

3.7.3.4 Mitigation Monitoring Plan Summary

No mitigation measures are required for geology impacts. No mitigation measures beyond measures already incorporated as project elements are available to mitigate the identified geologic and seismic impacts. Construction of new building foundations and structures would incorporate earthquake-resistant design, as required by existing federal, state, and local building codes.