4.9 GEOLOGY AND SOILS

The primary geotechnical hazards that may affect the reuse plan area, along with engineering techniques that could avoid or reduce the risk from these hazards, are discussed in this section as related to either seismic events or nonseismic events. The effects of earthquake-induced tsunamis are addressed in Section 4.10, Water Resources.

Factors considered in determining whether an alternative would have a significant impact on geology and soils included the extent or degree to which its implementation would:

1. Cause soil erosion, sedimentation, or land subsidence;
2. Adversely affect unique geologic or topographic features; or
3. Increase exposure of people, structures, or infrastructure to risk of catastrophic loss, injury, or death from rupture of a known earthquake fault, strong seismic ground shaking; or seismic-related ground failure, including liquefaction.

4.9.1 Alternative 1

Significant and Mitigable Impacts

Liquefaction, lateral spreading, and differential settlement (Factor 3). As discussed in Section 3.9, Treasure Island has a high probability of liquefaction and associated lateral spreading and differential settlement in the event of a major earthquake, due to the presence of sand fill below the water table and the underlying shoal sands. Treasure Island is designated a Seismic Hazards Studies Zone (SHSZ) by the California Division of Mines and Geology (CDMG). During a strong earthquake, liquefaction and differential settlement would likely occur throughout Treasure Island and the causeway and lateral spreading would likely occur within 500 feet of the perimeter dike (see Figure 3-19). In addition, approximately 6,700 linear feet of shoreline, in the northwest and southeast portions of the island, is subject to rotational dike failure (see Figure 2-2).

Low-lying areas of Yerba Buena Island underlain by heterogeneous artificial fill also are potentially subject to liquefaction, lateral spreading, and differential settlement hazards. The severity of the damage would vary, depending on the nature of the structure and site-specific geologic conditions.

The potential for damage to structures and infrastructure due to liquefaction-induced ground failure is considered a potentially significant but mitigable impact. Alterative 1 includes seismic stabilization improvements around the entire perimeter of Treasure Island, including the causeway. Under this alternative, a 50-foot wide band of rows of stone columns would be constructed along the shoreline to create an "improved zone" that is capable of confining and retaining liquefied soil inland of the zone. In addition, 6,700 linear feet of cement columns would be constructed in the areas prone to rotational dike failure (see Figure 2-2).

In addition to these proposed seismic stabilization improvements, the following mitigation measures shall be implemented during perimeter stabilization and new construction:

Mitigation. Interior island areas shall be improved to reduce large differential settlement caused by liquefaction, using methods such as stone columns, dynamic compaction, chemical and compaction grouting, dewatering the groundwater below the level of liquefiable soils, and surcharge fill with wick drains (San Francisco 1995b).

All sensitive structures (e.g., buildings greater than three stories, buildings intended for public occupancy, structures supporting essential services, and buildings housing schools, medical, police, and fire facilities) shall be supported on pile systems or other specially designed foundations. Smaller structures shall use mat foundations to distribute loads over a larger area and to increase foundation flexibility. Essential utilities shall be fit with flexible connections designed to withstand rupture (San Francisco 1995b).

Detailed geotechnical studies shall be completed in accordance with San Francisco requirements for individual development sites to identify which specific engineering techniques should be used to reduce liquefaction, lateral spreading, and differential settlement hazards to an acceptable level of risk. Such geotechnical studies shall incorporate recommendations of a California-licensed engineering geologist into future site preparation, foundation, and building design.

Complying with these mitigation measures would eliminate or reduce impacts to less than significant.

Not Significant Impacts

Non-Seismic Hazards

Geotechnical hazards not specifically related to earthquake activity include local settlement, slope instability, and erosion.

Local settlement (Factor 1). Settlement is the localized lowering of the ground surface due to a decrease in the volume of the underlying soil. Development under Alternative 1 could result in settlement hazards associated with construction on the on-site fill sediments or the underlying Bay muds as these materials adjust to new loading from heavy buildings, mat foundations, or other new fills and drains. Although most of the potential settlement at existing loadings at Treasure Island has already occurred, gradual area-wide settlement could be accelerated and could continue for many more years, resulting in increased local ponding, increased flooding potential, or water-logged soils.

Standard engineering techniques to remove and recompact loose, unconsolidated fill to relatively noncompressible materials would be applied in those areas proposed for development under Alternative 1. Geotechnical evaluations of proposed specific reuse development projects would be required. Engineering techniques to remove and recompact near-surface soils would be used to reduce hazards of local settlement. Because established engineering techniques would be applied, as appropriate, the potential for settlement would be minimized, and this impact would be not significant. No mitigation is proposed.

Slope instability (Factor 1). Due to the steep slopes and landslide deposits around the margin of Yerba Buena Island, development under Alternative 1 could result in increased exposure to

hazards associated with slope instability. However, impacts on development would not be significant because of requirements for construction. San Francisco's standard code requirements for slope design and drainage would apply to new developments. San Francisco would routinely check existing landslides and steep slope areas for slope movements. If slope movement is detected, appropriate repairs would be initiated as soon as possible. Specific requirements would be evaluated on a project-by-project basis. Therefore, this impact would not be significant under Alternative 1. No mitigation is proposed.

Erosion (Factor 1). Demolition and construction activities within the reuse plan area could result in increased potential for wind erosion of soils, especially if grading is conducted in dry, but windy, summer weather. Once an individual site is graded and landscaping vegetation is established, the erosion potential of the soils would diminish.

Soil erosion from Treasure Island is not expected to be significant due to the relatively level topography of the island. Construction on Yerba Buena Island could result in substantial erosion due to its steep slopes, which in turn could affect slope stability. Temporary erosion control measures would be provided during the construction phases of the project, as required by the local grading code and NPDES permits, to minimize these effects. A post-development erosion-control program also would be implemented. This program could include regular inspection and maintenance of drainage control devices, proper irrigation to minimize runoff, and landscaping to reduce wind and water erosion. Implementation of these required measures would ensure that erosion impacts are reduced to a not significant level. No mitigation is proposed.

Ferry wakes also could erode the perimeter dike, but it is in good repair and subject to regular wave and wake action daily from local and international shipping vessels. Therefore, it is unlikely that ferry wakes would substantially affect the dike.

Seismic Hazards

As discussed in Section 3.9, the reuse plan area lies within a region of northern California that is seismically active and is subject to earthquake-related hazards, as discussed below.

Surface fault displacement (Factor 3). The reuse plan area is not located within an Alquist-Priolo Earthquake Fault Zone and no active or potentially active fault is known to exist at the ground surface on or immediately adjacent (i.e., within 5 miles [8 km]) to the site. Therefore, the potential risk of loss, injury, or death due to surface fault rupture would be minimal. There would be no impact from hazards to reuse development associated with surface fault displacement.

Seismic shaking (Factor 3). As discussed in Section 3.9, the reuse plan area would be subject to strong seismic ground shaking during major earthquakes. A maximum credible earthquake centered on the northern segment of the Hayward Fault (Mercalli scale intensity IX at NSTI, ABAG 1995a) would cause major damage to NSTI structures and utilities. A major earthquake could severely limit or even prevent vehicular access to the site if the SFOBB is damaged, impeding basic and emergency services to the site, even with the proposed dike improvements, causeway reinforcement, and the proposed SFOBB east span replacement and west span strengthening.

It is likely that emergency response systems, in San Francisco in particular and in the Bay Area as a whole, would be overloaded in the immediate aftermath of a large earthquake. Because of the large population that probably would be present at NSTI in an earthquake under this alternative, it likely would be necessary for offices, hotels, recreational facilities, and residents to be self-sufficient for several days until basic systems could be restored or until occupants could be evacuated.

All new structures in California must be designed and constructed in compliance with seismic safety standards and requirements of the State Uniform Building Code (UBC). San Francisco requires all new development of existing structures to comply with the most current UBC requirements and standards. The San Francisco Department of Building Inspection (DBI) will use the *National Earthquake Hazards Reduction Program Handbook for the Seismic Evaluation of Existing Building* (FEMA-17) to assess seismic hazards in existing buildings; this is the federal standard by which federal buildings are evaluated (San Francisco 1998c). Seismic upgrades of existing structures designated for reuse would be performed to minimize life safety risks from failures in a large earthquake. Structures that cannot feasibly be retrofitted to meet a life safety objective would be demolished. Compliance with these regulations by each individual development within the reuse plan area would reduce impacts related to seismic shaking to the most current safety levels.

Several measures and policies to minimize the effects of seismic shaking are included as part of the Draft Reuse Plan. These measures include investigating structural and geotechnical conditions with appropriate upgrades prior to reuse of existing structures, preparing geotechnical site investigations and conducting appropriate structural design for all new development, and preparing emergency response plans. Therefore, the potential risk of loss, injury, or death would be minimal and impacts would not be significant. No mitigation is proposed.

Dike failure (Factor 3). As discussed in mitigation measures provided above, placing stone columns, soil-cement columns, and rock berms around the island perimeter would minimize risks associated with perimeter dike failure from lateral spreading or slumping in an earthquake or from wave action associated with large storms. Still, localized failures may occur because of the thickness of the unconsolidated sediments underlying the dikes. In the event of a failure, or as a precautionary measure in areas deemed to be less resistant to failure, the rock berm that forms the perimeter dike could be replaced or reinforced with a larger, exterior rock berm. The larger rock berm would buttress the dike and would resist the forces imposed by liquefied soil and fill behind the dike, as well as ground shaking. The San Francisco Department of Building Inspection will require peer review of permits for perimeter dike improvements by structural and geotechnical engineers for the purpose of ensuring that appropriate geotechnical data are collected and properly evaluated, and for ensuring that appropriate corrective measures are proposed. Implementing these measures is expected to reduce the hazards related to dike failure to acceptable levels. Localized dike failure, which has occurred in the past, is not expected to result in an unacceptable risk of loss, injury, or death. No mitigation is proposed.

Seismically induced slope failure (Factor 3). As described in Section 3.9, slope failure can be triggered by an earthquake. Slopes subject to earthquake-induced failure exist on steep slopes of Yerba Buena Island. Existing landslide deposits are concentrated around the margins of

Yerba Buena Island, particularly on the south shore of the island (see Figure 3-21). There is no new habitable development planned for these areas; however, existing roads may continue to be undercut by slope failures and earthquake-induced failures could threaten existing or proposed development in other areas in which landslides have not been mapped. Alternative 1 would not increase the potential for earthquake-induced slope failure; however, it could increase the number of people exposed to the hazards of slope failure to the extent that there would be more traffic on existing roads on Yerba Buena Island. Major slope failure could result in road closures, and this could impede transportation between NSTI and the mainland. Landslides onto the roadway would endanger people using the road. As discussed above with regard to seismic shaking, existing structures, including roadways, would be evaluated and retrofitted or abandoned, if necessary, to reduce risks to acceptable levels. Therefore, the impacts of earthquake-induced slope failure are not considered significant.

No Impacts

Unique geologic and topographic features (Factor 2). The reuse plan area does not contain any unique geologic or topographic features. Yerba Buena Island is a prominent topographic feature, but it is not unique and would not be substantially altered under Alternative 1. Therefore, there is no impact. No mitigation is proposed.

4.9.2 Alternative 2

Significant and Mitigable Impacts

The potential impacts under Alternative 2 would be comparable to those of Alternative 1 because the geotechnical hazards are associated with existing physical features of the reuse plan area itself. However, the type, nature, and magnitude of development under Alternative 2 differ from those proposed under Alternative 1. Alternative 2 includes creating a golf course instead of housing on the northwest portion of Treasure Island, eliminating the proposed perimeter stabilization of that portion of the island, and building fewer residential units on Yerba Buena Island. Less residential development under Alternative 2 would reduce the magnitude of the geologic impacts described for Alternative 1 because a smaller permanent population would be exposed to seismic hazards.

Greater impacts to unprotected recreational land uses would be created in the golf course area due to lack of perimeter stabilization in that area. For example, substantial lateral spreading in a major earthquake would result in a localized loss of recreational land near the point of a dike failure and within 500 feet (152 m) or more inland. If not promptly repaired, such a failure would reduce the buffer area provided by the golf course and possibly subject any unsupported structures and infrastructure inland of the failure to the secondary effects of future seismically induced lateral spreading.

Similar to Alternative 1, impacts are considered potentially significant but mitigable. With the exception of the area adjacent to the proposed golf course, Alterative 2 includes seismic stabilization improvements around the perimeter of Treasure Island, including the causeway (see Figure 2-2). Similar to Alternative 1, an "improved zone" would be created that is capable of confining and retaining liquefied soil inland of the zone.

In addition to these proposed seismic stabilization improvements, the following mitigation measures shall be implemented during perimeter stabilization and new construction:

Mitigation. Proposed mitigation measures are the same as those discussed for Alternative 1. Complying with these mitigation measures would reduce impacts to less than significant.

Not Significant Impacts

As discussed for significant and mitigable impacts above, the potential for less than significant impacts under Alternative 2 would be comparable to those of Alternative 1. Compliance with San Francisco requirements for site-specific geotechnical investigations would be required for each individual development. Requirements identified for Alternative 1 to reduce local settlement, slope instability, and erosion also would be required for development under Alternative 2. No mitigation is proposed.

4.9.3 Alternative 3

Significant and Mitigable Impacts

The potentially significant and mitigable impacts under Alternative 3 would be roughly comparable to those of Alternative 1 because the geotechnical hazards are associated with existing physical features of the reuse plan area itself. However, the type, nature, and magnitude of development-related impacts under Alternative 3 differ from those proposed under Alternative 1. Alternative 3 would involve extensive reuse of existing facilities, including continuation of existing leases, and less intensive new development than the other two reuse alternatives, and there may be more potential difficulty in retrofitting existing structures to resist seismic hazards. Compared to Alternative 2, more residential development would increase the magnitude of the impacts described because a larger resident population would be exposed to seismic hazards, including greater nighttime exposure to these hazards. Perimeter dike improvements would be limited to the northwest and southeast corners of Treasure Island in the areas subject to rotational dike failures (see Figure 2-2). Therefore, greater impacts to unprotected shoreline recreational land uses and some areas proposed for institutional and community uses would be created due to the lack of perimeter stabilization in these areas. Impacts are considered potentially significant but mitigable.

Similar to Alternative 1, an "improved zone" would be created in the northwest and southeast portions of the island that is capable of confining and retaining liquefied soil inland of the zone. The following mitigation measures shall be implemented during perimeter stabilization and new construction:

Mitigation. Proposed mitigation measures are the same as those discussed for Alternative 1. Complying with these mitigation measures would reduce impacts to less than significant.

Not Significant Impacts

As discussed above for potentially significant and mitigable impacts above, the potential for less than significant impacts under Alternative 3 would be comparable to those of Alternative 1. Compliance with San Francisco requirements for site-specific geotechnical investigations would be required for each individual development. Requirements identified for Alternative 1 to

reduce local settlement, slope instability, and erosion also would be required for development under Alternative 3. No mitigation is proposed.

4.9.4 No Action Alternative

The No Action Alternative would not result in new or additional geotechnical impacts. Existing structures would continue to be subject to existing seismic and nonseismic hazards, and no increase over existing seismic hazards would occur.

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