Oakland / Alameda Resilience Study
Earthquake Scenarios and Potential Impacts

Potential Earthquake Impacts

There are three impacts associated with earthquakes that will be considered in this study:

Ground shaking

- Ground shaking occurs in all earthquakes. In large magnitude earthquakes, a larger area of ground shakes, it shakes harder, and it shakes longer than in small magnitude earthquakes. Earthquakes are typically measured by two metrics. Moment magnitude (M_W), is a measure of the energy released. It is a function of the ruptured fault area and the geologic conditions of the fault. Modified Mercalli Intensity (MMI)[1], measures earthquakes by the effects experienced at a specific site. The intensity changes based on the magnitude of the earthquake, the distance from the fault to the site, the directivity of the fault rupture, and the type of geologic material underlying the fault. Softer soils amplify ground shaking and can cause greater damage, and ground shaking is typically greater the closer a site is to the fault.

  Ground shaking of the level expected across the focus area may cause wood-frame buildings to shift off of their foundations if not bolted. Shaking may damage older, non-retrofitted air control and terminal facilities at the airport, and will likely break underground pipes and damage overhead power lines. Ground cracks may appear, causing damage to airport runways, roads, or buried utilities.

Liquefaction

- Saturated soils that are loose or sandy will exhibit the characteristics of a liquid when shaken long and hard enough. Liquefaction may result in ground sinking or pulling apart, ground displacement, or ground failure such as lateral spreads and sand boils, or sand "volcanoes." Much of the focus area is vulnerable to liquefaction. Liquefaction is a significant threat for underground pipelines, airport runways, and road or highway surfaces, as it causes buckling of these features due to ground shifting. Liquefaction may also cause building damage due to foundation movement or cracking when the underlying soils shift, or when there is a loss of bearing capacity for foundation elements. Liquefaction can cause levee damage and failure, increasing the risk of flooding in low-lying areas.

Tsunamis

- Tsunami waves are the result of large underwater displacements from offshore earthquake fault rupture or landslides. Tsunamis can be caused by offshore earthquakes within the Bay Area or even distant events. The focus area falls within the maximum tsunami run-up inundation line; however, tsunamis are considered rare events in the Bay Area, so the probability of inundation due to a tsunami is low.

[1] See MMI descriptions in Table 1

Table 1: Modified Mercalli Intensity Scale of Shaking Descriptions

MMI Value	Description of Shaking Severity	Full Description
I.	Not mapped	Not felt. Marginal and long period effects of large earthquakes.
II.	Not mapped	Felt by persons at rest, on upper floors, or favorably placed.
III.	Not mapped	Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
IV.	Not mapped	Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frame creak.
V.	Light	Felt outdoors. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI.	Moderate	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster, adobe buildings, and some poorly built unreinforced masonry buildings cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle).
VII.	Strong	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to some poorly built unreinforced masonry buildings. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks even in better built masonry buildings if not reinforced. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII.	Very Strong	Critical or extensive damage to some buildings, but well-designed buildings are largely undamaged. Steering of motor cars affected. Damage to unreinforced masonry buildings, including partial collapse. There is no damage to well-designed reinforced masonry buildings. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX.	Violent	General panic. Damage to masonry buildings ranges from collapse to serious damage unless modern design. Wood frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas sand and mud ejected, earthquake fountains, sand craters.
X.	Very Violent	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to

		dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI.	Not mapped because these intensities are limited to areas with ground failure	Rails bent greatly. Underground pipelines completely out of service.
XII.	Not mapped because these intensities are limited to areas with ground failure	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Full descriptions are from: Richter, C.F., 1958. Elementary Seismology. W.H. Freeman and Company, San Francisco, pp. 135-149; 650-653.

Earthquake Scenarios

Earthquake scenarios are often developed by agencies such as ABAG and USGS to describe the most likely maximum probable earthquake from a given fault within that fault's return period. Using earthquake scenarios is useful for planning and design purposes as it can provide a likely picture of discrete events. This is helpful when studying impacts at a community level. Though there are over 15 faults within the Bay Area likely to produce a damaging earthquake, there are two major earthquake scenarios that would be most likely to heavily affect the Oakland International Airport / Bay Farm Island Focus Area. A major earthquake (M_W 6.9) on the Hayward Fault and a major earthquake (M_W 7.8) on the San Andreas Fault (a repeat of the 1906 earthquake) would both cause violent (MMI IX) ground shaking in the Focus Area.[2]

[2] ABAG (2005). On Shaky Ground. Maps available at http://quake.abag.ca.gov/earthquakes/.

Figure 1: Ground Shaking Intensities in a San Andreas M=7.8 Earthquake Scenario

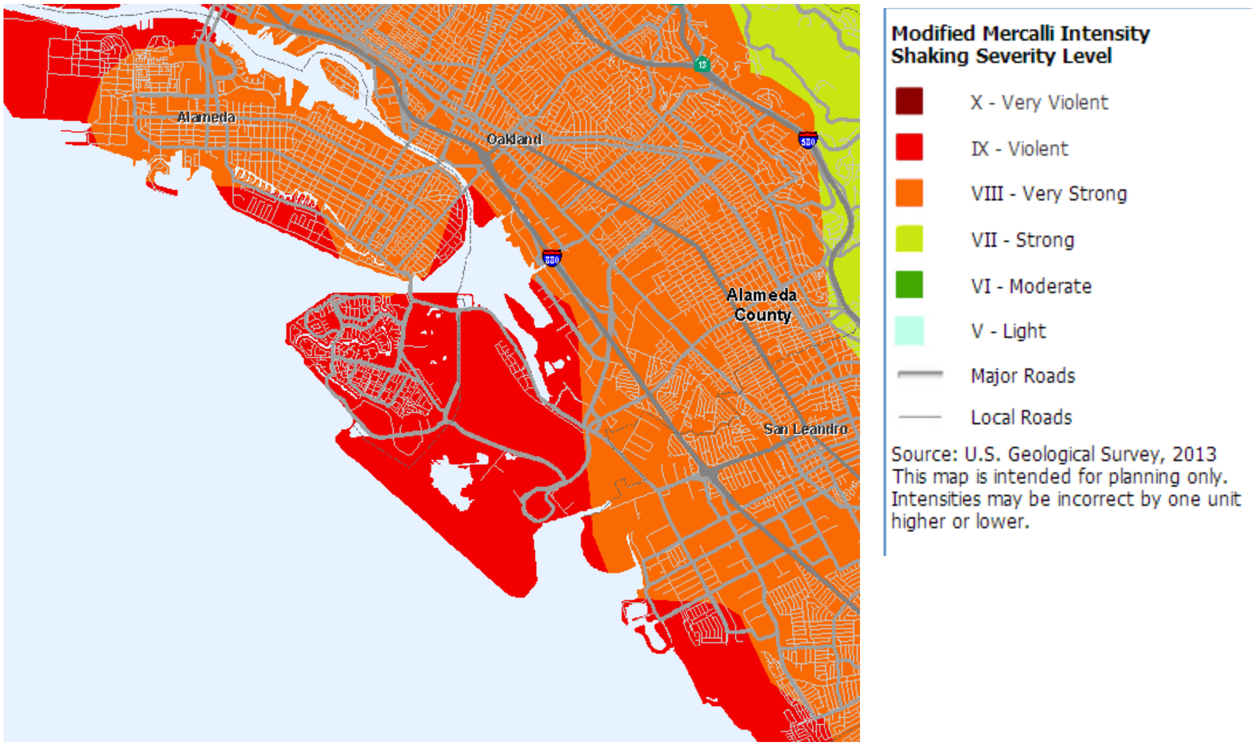
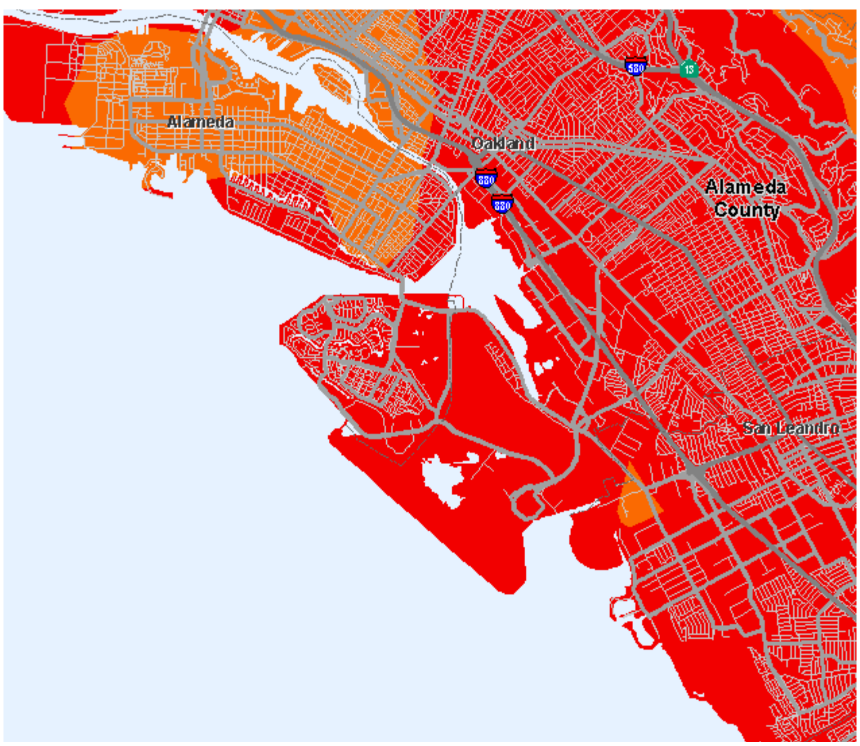


Figure 2: Ground Shaking Intensities in a Hayward M=6.9 Earthquake Scenario



An earthquake along the Hayward Fault is the most probable scenario, as it has a 31% probability of a 6.7 or greater earthquake before 2036, while the San Andreas Fault has a 21% probability of an earthquake of the same magnitude in this same timeframe.[3] However, although the likelihood of an earthquake on the Hayward Fault is greater and the Focus Area is in closer proximity to the Hayward Fault, which would imply greater levels of ground shaking, an earthquake on the San Andreas Fault could have equally or more devastating consequences. This is because a greater length of the San Andreas Fault is expected to rupture than along the Hayward Fault. An earthquake along the San Andreas Fault could result in a larger magnitude event (harder and longer ground shaking). Attenuation from the greater distance from the fault to the site would cause the level of ground shaking at the Focus Area to be similar in both scenarios, but the longer period of ground shaking in a San Andreas event could cause greater potential for building damage and soil liquefaction.

The focus area geologic conditions are such that shaking amplification from a major earthquake on either fault will be extremely high. Because of the Focus Area's relatively close proximity to both major the faults and the likely epicenter of an earthquake on either of these faults, it will experience amplified and prolonged ground shaking as compared to other locations.

A major earthquake is also highly likely to produce liquefaction in the focus area. USGS has developed maps that predict the percentage of certain areas that are likely to liquefy in a M=7.1 earthquake (see Figure 3).[4] Historic Bay Farm Island is composed of dense Merritt Sand, which forms a zone that has a very low liquefaction risk (<1% of the original island is predicted to liquefy in a M 7.1 earthquake). However, the rest of the focus area is composed of soils that have a much higher liquefaction potential. These maps show that the majority of the Focus Area aside from historic Bay Farm Island is in the highest liquefaction hazard zone (approximately 73% of the area is predicted to liquefy in a M=7.1 earthquake). The airport itself is built entirely on fill over estuarine deposits, including a formal tidal marsh, tidal flat, and shallow bay environments. The northeastern portion of the airport is located on formal tidal marsh with deltaic and stream channel deposits and marsh deposits, and the southwestern portion is built on fill over tidal flats and shallow bay. These geologic conditions contribute greatly to the airport's liquefaction susceptibility.

[3] United States Geological Survey, Southern California Earthquake Center, and California Geological Survey (2008). Uniform California Earthquake Rupture Forecast (UCERF). Available at http://earthquake.usgs.gov/regional/nca/ucerf/

[4] Holzer, T.L., et al., (2002, revised 2010). Liquefaction Hazard and Shaking Amplification in Maps of Alameda, Berkeley, Emeryville, Oakland, and Piedmont, California: A Digital Database. USGS. Available at http://earthquake.usgs.gov/regional/nca/alameda/

Figure 3, Liquefaction Hazard Map of Alameda, Berkeley, Emeryville, Oakland, and Piedmont, California