Appendix E
Detailed Earthquake Risk Assessment

June 2022

This appendix provides detailed assessment of how existing and future people, economy, buildings and infrastructure that may be impacted by an earthquake in Alameda. This appendix describes the vulnerability of the assets to damage in earthquakes and the consequences on the community of such damage.

The anticipated damages and disruptions are based on a magnitude 7.0 earthquake on the Hayward Fault, roughly similar to the scenario evaluated in the USGS HayWired scenario.[1] The earthquake has its epicenter in Oakland and strong shaking results in severe impacts throughout the greater Bay Area. Such an earthquake would result in strong shaking that will trigger surface fault rupture, liquefaction, landslides, fires, and severe impacts throughout the entire Bay Area. While landslides and fault rupture will not directly impact Alameda, all of these secondary hazards will cause significant disruption and damage to buildings, utilities, transportation and communication networks, and fuel supply. The HayWired scenario represents an earthquake with approximately a 150-year return period; one that has about a 20% chance of occurring in the next 30 years. While the impacts of this scenario are severe, it does not represent the worst-case earthquake by any means. By comparison, most newer buildings today are designed to protect the safety of occupants in earthquake shaking with approximately a 975-year return period, or a 2% change of occurring in any 50-year period.

This appendix details the impact of such an earthquake on these systems and the people and economy serving Alameda. The assets covered in this chapter are characterized in detail in **Chapter 3** and the earthquake hazard is characterized in **Chapter 4** of the Plan.

The People of Alameda

Across the San Francisco Bay region, more than 750,000 people could be displaced from their homes in a major earthquake.[2] Many studies have shown that socially disadvantaged groups such as persons of color, low income residents and persons with disabilities are disproportionately impacted by natural disasters. These populations may have more difficulty evacuating from their homes in an earthquake and more difficulty recovering after an event. Persons with disabilities may be reliant on electricity for medical equipment and refrigeration of medication that can be lost during floods and winter storms. Disaster-related damages can also disrupt social and economic services for disadvantaged populations. Housing affordability is an existing challenge for many Alameda residents that can exacerbate poor outcomes for residents following an earthquake and hinder community recovery. A 2016 study found that disadvantaged populations are more likely to live in housing that may be damaged in an earthquake and less able to prepare, respond and recover from an earthquake.[3] Without proactive public policy and support, these residents are more likely to be permanently displaced from Alameda following an earthquake. This study found that the neighborhoods most likely to have communities at risk in fragile housing are Central Alameda, Southshore and along the Northern Shoreline.

[1] Detweiler, S.T., and Wein, A.M., eds., 2017, The HayWired earthquake scenario: U.S. Geological Survey Scientific Investigations Report 2017–5013, https://doi.org/10.3133/sir20175013.
[2] Detweiler, S.T., and Wein, A.M., eds., 2018, The HayWired earthquake scenario—Engineering implications: U.S. Geological Survey Scientific Investigations Report 2017–5013–I–Q, 429 p., https://doi.org/10.3133/sir20175013v2.
[3] ABAG and BCDC, 2015, *Stronger Housing, Safer Communities*, www.adaptingtorisingtides.org/project/stronger-housing-safer-communities-strategies-for-seismic-and-flood-risks/.

Alameda Economy

The major Hayward fault earthquake contemplated in the USGS HayWired scenario will result in an estimated $44.2 billion losses to the California Gross State Product (4.2% of California projected GSP) in the first six months following the earthquake.[4] Alameda County will be the hardest hit county with a 13.8% loss in county Gross Regional Product and an estimated 15 percent loss in jobs. The study estimates that GSP losses could be reduced by 42% with resilience measures such as deploying portable cellular sites, supply chain workarounds, more efficient use of resources like water and employee overtime, and pre-earthquake business continuity planning. Alameda County would experience a recession lasting 5 to 10 years due to significant employment and population losses. Small businesses and minority owned businesses will be particularly hard hit and a shortage of construction workers could lead to a deeper and longer recession as rebuilding is postponed.

Buildings

Alameda has an extensive inventory of buildings that are vulnerable to damage in earthquakes. Many of these buildings are also vulnerable to flood and tsunami damage. Damage to homes, businesses, community facilities, and their associated infrastructure represents a serious socioeconomic threat to the city. Older buildings were not designed to withstand the earthquake shaking or liquefaction. Seismic retrofits are usually designed to prevent catastrophic collapse and harm to occupants, but typically does not ensure that a building will be repairable. Damage to community services like shelters, hospitals, and elderly care facilities can disproportionately impact vulnerable populations, including those who are ill, immobile, elderly, or economically disadvantaged.

All building contents are vulnerable to flooding and violent earth shaking. More importantly, many buildings lose function temporarily until they are deemed safe or are rebuilt. Depending upon the building, this loss of service may include emergency services, sheltering and gathering, commerce, education, medical care, daycare, elder care, government, and recreation. Short term and long-term recovery of the City depends upon quick restoration of these services.

Earthquake Vulnerable Building Types

Certain types of buildings are more susceptible to the shaking and ground disturbances of earthquakes. Older buildings constructed before modern building codes are generally not designed to withstand earthquake shaking. These buildings can sustain significant damage and even collapse in earthquakes, killing and injuring occupants and displacing residents and businesses for a long time. The HayWired study estimates that most Alameda Census tracts, particularly those in the liquefaction zone will experience extensive or complete damage to 20 percent or more of their total building area, with several tracts at risk from such damage from post-earthquake fires.[5]

Buildings subject to violent shaking can also dislodge asbestos or encapsulated (abated) asbestos, lead paint, and other hazardous materials. Broken plumbing can discharge sewage. Broken gas lines and damaged electrical wiring can spark fires and present health and safety hazards. Older houses, especially Victorian-era houses, were built without fire blocking, which means that fire can easily spread up walls and through ceilings to other parts of the house and to neighboring properties. Other hazards in

[4] Detweiler, S.T., and Wein, A.M., eds., 2018.
[5] Detweiler, S.T., and Wein, A.M., eds., 2018.

buildings from earthquake shaking include falling piping, shelving, and goods. Limited insurance coverage will be available to recover these losses and will prolong the recovery period.

The following sections describes the most common types of earthquake vulnerable buildings in Alameda: soft-story buildings, homes with cripple walls or house over garage, unreinforced masonry buildings, and nonductile concrete buildings. Newer buildings are also designed to protect lives, but may not be re-occupiable following a major earthquake.

Soft-story buildings

Buildings with soft-story, weak or open front walls are multi-story wood frame apartment buildings with an open or more flexible ground compared to the more rigid second floor.[6] These two stories flex differently during violent ground shaking, resulting in damage to the building and sometimes collapse. A common soft-story building type is the apartment or business building with ground level parking (just pillars and open spaces) and traditional structures above. Soft-stories are also commonly found with businesses that have large expanses of glass for a first-floor storefront and a more traditional structure on the second story.

Figure E-1 Soft-Story Apartment Building in Alameda

In 2009, the City of Alameda established a wood-frame soft-story program under Ordinance 2989, *Earthquake Hazard Reduction in Existing Wood Frame Residential Structures with Soft-Story, Weak, or Open Front Walls*.[7] Alameda's mandatory wood-frame soft-story program applies to existing buildings that have the following characteristics:

[6] https://homequakequiz.org/housing-types/multi-family-homes#17
[7] http://docs.ci.alameda.ca.us/WebLink/DocView.aspx?id=373444&dbid=0&repo=CityofAlameda&cr=1

- Wood-frame construction
- Permitted for construction prior to December 17, 1985
- Five or more dwelling units
- Ground floor containing parking or similar open floor or basement space causing soft, weak, or open lines where there exist one or more levels above.

Based on these criteria, the City established an inventory of potentially hazardous soft-story buildings under the ordinance and notified the owners and residents of such buildings.

Owners of buildings listed on the inventory were required to submit to the City a structural seismic adequacy analysis to determine potential hazards to the structure and describe what would be necessary to remedy any identified weaknesses. 209 buildings were determined to have seismic vulnerabilities based on an engineering analysis

Owners were not required to retrofit their buildings, however to date, 146 buildings have completed a seismic retrofit. Buildings retrofitted in accordance with the ordinance will have their seismic performance substantially improved, but will not necessarily prevent all earthquake damage. The retrofit strengthens the portion of the structure that is most vulnerable to earthquake damage but may not address other structural issues.

63 multi-family buildings containing approximately 1,000 units remain on the list of potentially hazardous soft-story buildings. Three buildings contain more than 50 units each. Some buildings contain retail spaces on the ground floor frequented by members of the public. The status of soft-story buildings and number of units is shown in **Table E-1**. The retrofitted soft-story buildings are shown in light blue and unretrofitted buildings are shown in dark blue in **Figure E-2** (there are no soft-story buildings west of Main St or on Bay Farm Island). The addresses are listed in **Appendix D** and on the City's website.[8]

Table E-1 Alameda's Soft-Story Building Inventory

Description	Number of Buildings	Residential Units
Designated Soft Story	209	~4,500
Retrofitted	146	~3,500
Not retrofitted	63	~1,000

[8] https://www.alamedaca.gov/Departments/Planning-Building-and-Transportation/Building/Seismic-Retrofit/Potential-Soft-Story-Buildings

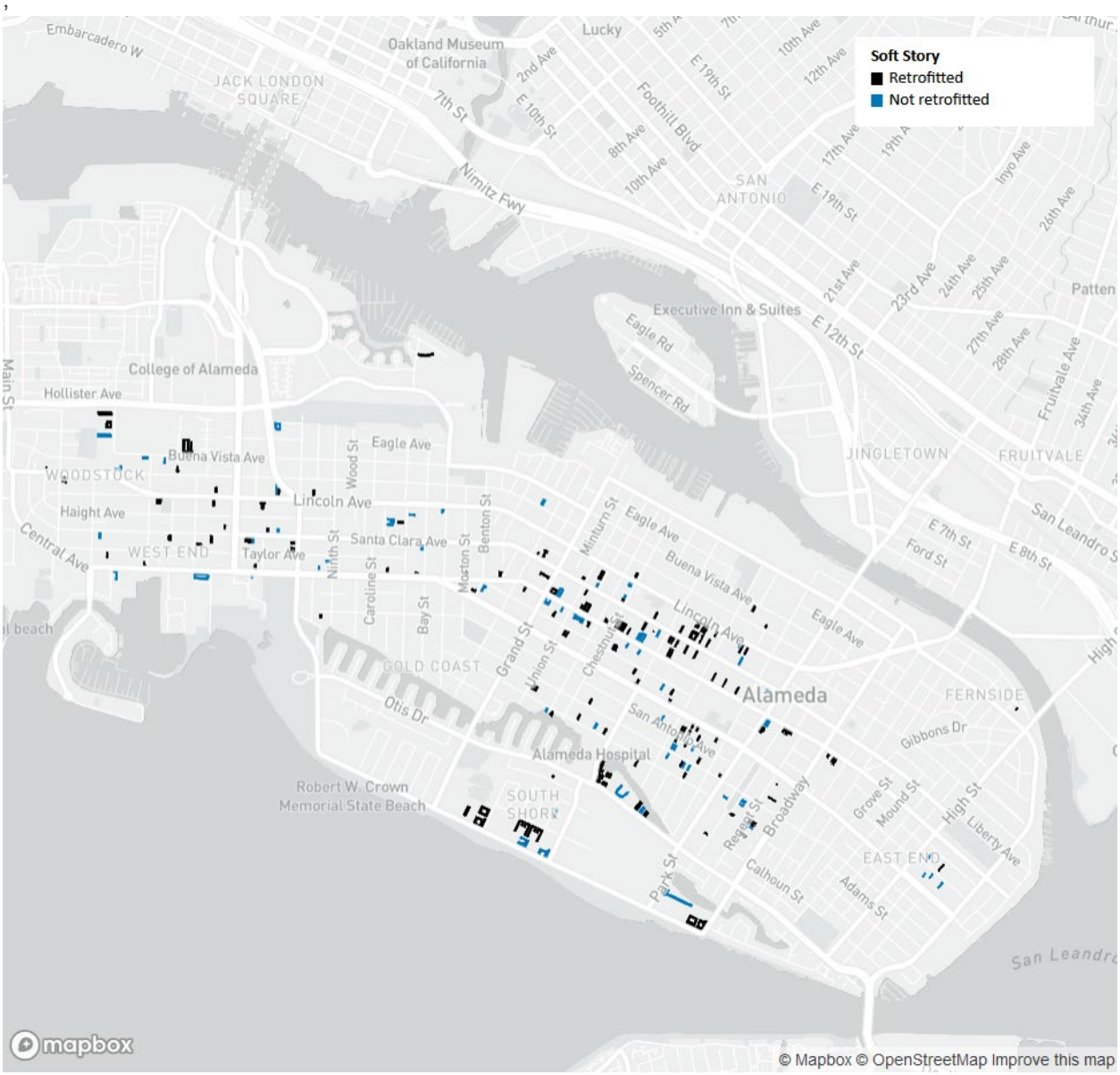

Figure E-2 Designated Soft-Story Buildings in Alameda

The City of Alameda's Soft Story Structural Assessment Grant provides up to $5,000 for structural assessment of potential soft-story buildings with more than 51% of units occupied by low- and moderate-income households.[9] These property owners are also eligible for the Rental Rehabilitation Loan Program for the retrofit of buildings determined to be soft-story structures. The program provides loans at 2% interest to landlords who rehabilitate rental property in Alameda.

While Alameda's soft-story ordinance specifically addresses buildings with more than 5 residential units, soft-story conditions can exist in residential buildings with fewer than 5 units as well. If the definition of soft-story buildings were expanded to include 3-to-4-unit buildings built before 1985, approximately 850

[9] https://www.alamedaca.gov/Departments/Community-Development/Community-Housing-Resources

additional residential buildings with nearly 3,000 units could be added to the potentially soft-story list.[10] Single family homes with soft-story conditions are covered in the following section.

Damage to soft-story apartment buildings would have significant consequences to renters and vulnerable populations in Alameda. Occupants could be injured in an earthquake and loss of housing units would exacerbate Alameda's housing shortage and further limit the availability of these naturally occurring affordable housing units. Many vulnerable residents could be permanently displaced.

Homes with Cripple Walls and House Over Garage

A "cripple wall" is a low height wall often found in the ground floor basement or crawlspace in Victorian-era and older homes in Alameda. These buildings can generally be identified by stairs leading to the front door. Cripple walls tend to be damaged during violent ground shaking because they do not have proper sheathing on the interior side of the walls and there are fewer interior walls than in the story above to

Figure E-3 Single Family Home with Cripple Wall in Alameda

resist lateral earthquake forces. The cripple walls are also not tied to the foundation or the first floor above and they can slide off their foundation as the ground shakes under them. Depending on the severity of the earthquake, damage to these kinds of buildings can range from minor facade and glass damage to total loss.

Alameda homes that have an attached garage with living space above that lacks interior walls may be unable to support the living space above in an earthquake.[11] In an earthquake, the garage walls may lean

[10] Alameda County Assessor's Parcel Data, 2018
[11] https://homequakequiz.org/housing-types/single-family-homes#21

or collapse, putting occupants in the living space above at risk from serious harm and the home can become uninhabitable.

Alameda has an estimated 10,600 pre-1980 single family homes that could be damaged in an earthquake.[12] In 2006, the City of Alameda adopted Ordinance 2950 to establish minimum standards for seismic retrofitting of cripple wall buildings.[13] The California Earthquake Authority's Brace and Bolt Program provides grants to retrofit cripple wall homes.[14] Approximately 600 homes are believed to have been retrofitted to appropriate standards.[15] In addition, many homeowners in Alameda excavate and dig out their basement as a way to add additional space to their homes. This work includes adding shear walls, bolts and tie downs to the portion of the basement walls above ground (the cripple wall). This work, while not formally a seismic retrofit, does have the effect of reducing the potential for earthquake losses of this type of building. There may be 50 to 300 permitted basement digouts in Alameda.

Alameda is a town of historic homes that contribute to the unique character of the neighborhoods and much of this character could be lost by damaged cripple wall buildings or post-earthquake fires. Many homes will need to be rebuilt or substantially repaired and few will have adequate insurance or the financial resources to cover losses. Home damage or destruction can result in significant social and financial costs, potentially displacing many people. The city will face a loss of property tax revenue. Displaced residents face significant challenges, especially among socially vulnerable populations and renters, who have limited capacity to address deficiencies in their buildings and rely on landlords to make changes. Retrofitted homes may still be damaged in earthquakes, but by keeping the building attached to the foundation and preventing collapse of the cripple wall, the damage should be repairable and the home may remain habitable.

Unreinforced Masonry Buildings

Unreinforced masonry (URM) buildings are older buildings built entirely with brick or stone with wood frame floors and roofs that are vulnerable to catastrophic collapse in even minor earthquakes. In Alameda, many URMs are historic buildings located in the Park and Webster commercial corridors and can have retail with offices or residential units in upper stories. URM buildings also tend to be car repair garages and industrial buildings. URM buildings may have bricks that can be visible on both the outside and inside walls. If every 5th or 6th row of bricks has a different width (because it has been turned perpendicular), this indicates that the wall is likely a structural brick wall, not just a decorative siding.[16] URMs may also have thick window sills due to thicker walls (more common in stone buildings, but may also be seen in brick buildings).

[12] Alameda County Assessor's Parcel Data, 2018
[13] http://docs.ci.alameda.ca.us/WebLink/DocView.aspx?id=373396&dbid=0&repo=CityofAlameda&cr=1
[14] https://www.earthquakeauthority.com/Prepare-Your-House-Earthquake-Risk/Brace-and-Bolt-Grants/CEA-Policyholder-Brace-Bolt-Grants/About-CEA-BB
[15] Alameda permit database, 2021
[16] https://homequakequiz.org/housing-types/multi-family-homes#56

Figure E-4 Retrofitted Unreinforced Masonry Building in Alameda

In 1991, the City of Alameda passed Ordinance 2573 to reduce the risk of death or injury from the effects of earthquakes on URMs.[17] The ordinance required URM building owners to brace any parapet walls and anchor walls to the roofline that are parallel to and adjacent to a public sidewalk or to an adjacent lower building. In addition, the masonry and mortar joints were to be tested and replaced if they were found to lack adequate strength.

As a result of this requirement, all of the City's 74 identified URMs have been retrofitted or demolished. An estimated 10 additional buildings that did not fall within the scope of the ordinance have also been retrofitted or are being upgraded as part of redevelopment efforts, such as the Del Monte building.

The required retrofit standards were designed to "reduce the risk of loss of life or injury" from damage to these buildings. Despite these beneficial retrofits, many retrofitted URMs will still sustain damage in future earthquakes and falling bricks can be lethal to occupants and pedestrians on the sidewalk. Damaged buildings may be closed for a long time to complete repairs or not be economically feasible to repair. A map of retrofitted URMs is shown in **Figure E-5** (there are no URMs west of Webster St. or on Bay Farm Island).

Residential structures containing five or fewer dwelling units, buildings with low occupancy, and those used as warehouses were exempted from the requirements of the ordinance, and many of these buildings remain vulnerable to damage or collapse in earthquakes.

17 https://library.municode.com/ca/alameda/codes/code_of_ordinances?nodeId=CHXIIIBUHO_ARTXVIIIEAHAREEXUNMABEWABU

Figure E-5 Map of Retrofitted URM Buildings in Alameda

Nonductile Concrete Buildings

Non-ductile concrete buildings are concrete structures, built before 1980, contain brittle concrete elements (columns, beams, walls and connections). Nonductile concrete buildings are vulnerable to significant damage or collapse in earthquakes resulting in fatalities. A survey was completed of these buildings by volunteers as part of a statewide study for the Concrete Coalition. The objective of the survey was to get a total number of these buildings, not a definitive inventory like the City has for soft-story or URM buildings. The survey was based on external observations made by volunteers and therefore is not definitive. However, it is estimated that the City has between 140 and 150 non-ductile concrete

buildings.[18] Many of the buildings identified were one story and contained many shear walls that would be less vulnerable to earthquake damage. Alameda does not currently require evaluation or retrofit of nonductile concrete buildings. These buildings are typically used for commercial office buildings and retail. Many nonductile concrete buildings are airplane hangars located at the former Naval Air Station and are undergoing renovations that include seismic retrofit or will be demolished as part of the Alameda Point redevelopment. Alameda does not currently require structural evaluation or retrofit of nonductile buildings.

Chimneys

Masonry or stone chimneys in older homes are also a falling hazard in earthquakes. The chimney can break off at the roofline and fall inside or outside the house, potentially damaging the structure and injuring or killing occupants. The taller and more flexible the chimney, the more likely it is to fail. Chimneys exterior to the house and separate from the structure. Some owners will attempt to brace the chimney against the roof; however, this will not prevent the chimney from falling. Falling chimneys are one of the most common issues in an earthquake. The most effective solution is to entirely rebuild the chimney with a new code-compliant chimney.[19] Chimneys can also be removed above the firebox and capped at the roofline or replaced with a new code-complaint chimney above the firebox. Alameda does not currently inspect chimneys for potential earthquake damage or require chimney mitigation.

Newly Constructed Buildings

Newer buildings built to modern building codes (after the early 1990s) are designed to protect lives and not collapse in a major earthquake, but they do not ensure buildings will be safe to re-occupy. Significant damage to newer housing stock would add to the disruptions and lengthy recovery expected from a major earthquake. An additional 1% in construction cost to build new buildings to a “functional recovery standard” could increase the availability of homes and businesses by 75 to 95% following a major earthquake.[20] Recommendations for implementation of this concept are laid out in a recent NIST-FEMA Special Publication for improving the post-earthquake reoccupancy and functional recovery of the nation’s building stock.[21]

City-Owned Buildings

Some of the City’s most important buildings were vulnerable to earthquake shaking because they were constructed with the building standards that pre-dated current knowledge about earthquake dynamics. Most city buildings have been seismically retrofitted or have been constructed to more modern standards.

- City Hall was retrofitted in 1997. The original 120-foot clock tower was removed after it sustained damage in the 1906 earthquake.
- The Carnegie Library closed in 1998 and remains vacant, however seismic retrofitting was completed in 2001. A new library was constructed on Oak St in 2006.

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[18] EERI Concrete Coalition, 2011. https://www.eeri.org/images/archived/wp-content/uploads/Concrete_Coalition_Final_0911.pdf
[19] https://sfgov.org/sfc/sites/default/files/ESIP/FileCenter/Documents/13436-ATC-119_TaskA.4.g_ChimneyMitigation.pdf
[20] Detweiler, S.T., and Wein, A.M., eds., 2018.
[21] https://www.fema.gov/sites/default/files/documents/fema_p-2090_nist_sp-1254_functional-recovery_01-01-2021.pdf

- Fire Station No. 3 was abandoned in 2001. A new fire station and Emergency Operations Center was constructed to replace Fire Station No. 3 at Grand and Buena Vista in 2017.
- The West End library was seismically retrofitted in 2007.

Other buildings were assessed and determined to be seismically safe. One concern are the 1940s era residences and hangars on Alameda Point, the former Alameda Naval Air Station, that would be subject to earthquake shaking, liquefaction, ground settlement, and flooding. The Alameda Point Master Infrastructure Plan addresses areas of redevelopment where buildings will be constructed to modern day seismic standards and reuse areas where retrofit work may be needed. This redevelopment is currently underway and many buildings have or will soon undergo rehabilitation.

Critical Services

Alameda Unified School District (AUSD) has seismically evaluated and upgraded a number of its school facilities in accordance with AB 300 and the Field Act. AUSD has seismically retrofitted several buildings at the historic Alameda High School and permanently closed Lum Elementary in response to seismic safety concerns. Private schools are not subject to the seismic safety provisions of the Field Act, however

Newly constructed emergency response facilities such as police and fire stations are required to be designed to higher seismic design standards than most other buildings because of the importance that they be immediately usable following an earthquake. In 2017, the City of Alameda completed construction of a new Fire Station 3 to replace the one located at 1709 Grand Street, which was deemed seismically unsafe and obsolete in the year 2000. The new fire station was constructed on the same site, and in conjunction with, an Emergency Operations Center (EOC).

Alameda Hospital is currently undergoing a $25 million seismic retrofit project of the hospital's west wing that is required by state law to remain licensed as a hospital with emergency room services. The Alfred E. Alquist Hospital Facilities Seismic Safety Act (SB 1953) requires that hospitals complete any necessary seismic retrofits to guarantee they can remain open in a major earthquake by 2030. The project will be completed by October 2021.

Alameda is home to a number of other facilities that serve and/or house vulnerable populations, such as daycares, elder cares, medical offices and clinics, and others. These buildings are critical to a healthy and vibrant city. Damage to these critical care facilities can disproportionately impact vulnerable populations, including those who are ill, immobile, elderly or economically disadvantaged. The location of these facilities can change from year to year and there are no regulatory requirements that require these services to be located in seismically safe buildings, thereby making targeted building mitigation efforts challenging. The City does maintain a listing of current locations as this is critical information for effective disaster response.

Land Use

A significant portion of Alameda is in a liquefaction zone and all land use types (commercial, transportation/utilities, residential, open space, shoreline, municipal, institutional) are subject to liquefaction and strong shaking. As groundwater rises, a growing proportion of city land may be at risk of liquefaction in an earthquake. Existing and future land uses planning needs to incorporate strategies to protect residents and businesses out of harm's way from both liquefaction and other hazards such as sea level rise, flooding and tsunamis. This involves important decisions about how to modify existing land use,

where development opportunities still exist, and how to design new development and redevelopment that can adapt to future conditions. Land use decisions must also consider the interests of vulnerable populations and engage with those groups to ensure land use policies are equitable. Land use policies are an important avenue to creating a resilient and equitable Alameda.

Utilities

Stormwater and Sewer Systems

In earthquakes, pump station components can be destroyed by strong shaking, often requiring more extensive and time intensive repairs to return service. Liquefaction is extremely damaging to pipe networks, especially older more brittle pipes.

Drinking Water System

Liquefaction damage will be a serious concern for drinking water pipes as well. Estimates are that EBMUD will experience about 1,800 breaks and 3,900 leaks in the 4,162 miles of pipe network within its service area.[22] An average East Bay customer would lose water for an estimated six weeks and some will lose service for as long as six months. Water supply outages will impede fighting post-earthquake fires. These service disruptions will be reduced as EBMUD continues to implement its old, brittle pipe.

Electric System

A strong earthquake will likely have a significant negative impact on AMP's distribution system and the regional grid, including widespread structure and equipment failures. Electrical substation components can be destroyed by strong shaking, often requiring more extensive and time intensive repairs to return service. The Cartwright substation located near Woodstock Park is particularly vulnerable to earthquake damage, including foundation damage, the bus structures and equipment. Hardening of system components and regular inspections and maintenance can reduce the impacts of earthquakes on the electric grid.

Natural Gas System

The greatest risks to the energy system are liquefaction and other impacts to buried infrastructure, including corrosion of pipes. PG&E completed a vulnerability assessment that included the natural gas system but was not specific to Alameda. This assessment lays the foundation for PG&E to identify strategies to address key threats, but the City has limited control over the natural gas infrastructure within Alameda

Natural gas infrastructure is subject to damage and disruption in areas with liquefaction. Natural gas lines can also rupture in earthquakes when buildings are damaged or when natural gas appliances topple. The repair of damaged underground lines will take time. Following the Loma Prieta earthquake, it took about 30 days to repair damaged lines in the San Francisco Marina. In a future earthquake, restoration of the

[22] Detweiler, S.T., and Wein, A.M., eds., 2018.

natural gas system can take up to six months because of the time it will take to integrity test the lines prior to repressurizing and the number of qualified personnel required to relight pilot lights.[23]

Broken lines can create fires if ignited until the fuel supply is exhausted. An estimated 25 percent of post-earthquake fire ignitions may be natural gas related.[24] **Figure E-6** shows a map of estimated fire ignitions within fire station primary response areas following the hypothetical magnitude 7.0 mainshock of the USGS HayWired scenario.[25] Green indicates a small likelihood of ignition and dark red indicates five or more ignitions per area. The length of the Hayward Fault ruptured in the scenario is shown on the map. According to the scenario, Alameda could have more than 11 simultaneous fire ignitions in this scenario. Responding to these fires will be complicated by the fact that Alameda is extremely likely to be without water supply following an earthquake and fire departments in other cities will not be able to respond with mutual aid given that 352 ignitions are anticipated in Alameda County, with 198 becoming conflagrations (multi-block fires).

[23] City and County of San Francisco, 2020. San Francisco Lifelines Restoration Performance Project. https://onesanfrancisco.org/sites/default/files/inline-files/Lifelines%20Restoration%20Performance%20Report%20Final-03-02-21.pdf
[24] Detweiler, S.T., and Wein, A.M., eds., 2018.
[25] Detweiler, S.T., and Wein, A.M., eds., 2018.

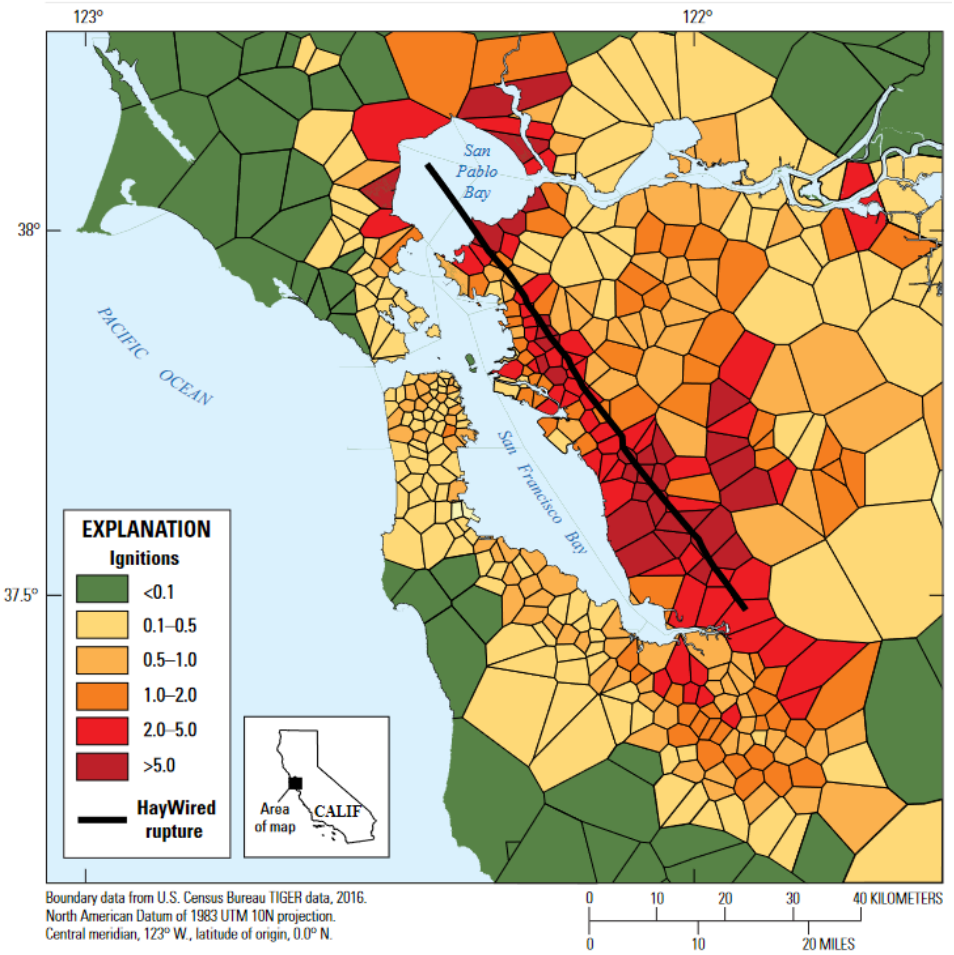

Figure E-6 Estimated number of ignitions within fire station primary response areas in HayWired event

Given the dense urban nature of Alameda's neighborhoods with wood frame construction and isolation as an island, preventing fires after earthquakes is extremely important. Owners of soft-story buildings were required to install an earthquake-actuated gas shut-off valve on the building to reduce the likelihood of natural gas fire ignitions in earthquakes.[26] Automatic gas shut-off valves are also required any time a permit is issued for gas piping, whenever a property is sold or has a transfer of title.[27] To date, approximately 2,794 permits have been issued for gas shut-off valves in the city.[28] **Figure E-7** shows the location of gas shut-off valves on buildings as of August 2021. Gas shut-off valves together with flexible gas lines to appliances inside the buildings, reduce the likelihood of fire ignitions when buildings shift and break gas pipes and appliances topple. However, seismically retrofitting buildings can prevent both the gas fires and damage to the building itself.

[26] http://docs.ci.alameda.ca.us/WebLink/DocView.aspx?id=373444&dbid=0&repo=CityofAlameda&cr=1
[27] https://www.alamedaca.gov/files/assets/public/departments/alameda/building-planning-transportation/ordinances/com_dev_-_bld_-_ord_-_gas_shut_off_valve.pdf
[28] Alameda permit database, 2021

Figure E-7 Gas Shut-off Valves installed on Alameda Buildings

Communications and Technology Systems

Reduced capacity and increased demand for cellular communication following an earthquake will result in degraded service. Loss of power will result in further outages once battery backup systems on cell towers run out in 4-12 hours.[29] Cellular communications systems face several vulnerabilities, including the number of cell sites that lack of permanent backup power (including an increasing number of small cell sites used to densify the network), damage to the fiber network from liquefaction and collocated infrastructure damage, and significant number of cell sites located on buildings vulnerable to damage in earthquakes. Deploying portable cell sites and timely delivery of fuel to back up generators can all aid in the recovery of the communications network.

[29] City and County of San Francisco, 2020.

Transportation

In an earthquake, transportation assets will be significantly impacted by shaking and liquefaction. Surface streets and ferry terminals are particularly susceptible to liquefaction damage. Bus lines in Alameda may be disrupted, but alternate routes will likely be available. Alameda's biking and pedestrian network will provide resilience following an earthquake and allow continued local access even if certain streets are closed.

Bart's core service between downtown Oakland and downtown San Francisco will be restored within 24 hours; however, the Fremont line and Berkeley Hills Tunnel are expected to sustain significant damage and be inoperable for many months.[30]

Alameda's four main bridges and two tunnels will provide critical connection to the region following an earthquake. All the connections off the island have been evaluated or upgraded to ensure that they will protect life safety in the event of a major earthquake, however they may not be usable for some time. A "no collapse" standard means that while the bridge will survive without loss of life, significant repairs or replacement may be necessary. Bridges upgraded to "lifeline" standards are designed to be nearly immediately usable following an earthquake. **Table E-2** summarizes the seismic performance of bridges and tubes in Alameda

Table E-2 Seismic Status of Bridges and Tubes in Alameda

Bridge/Tube	Owner	Year Built	Seismic Performance	Seismic Retrofit Notes
High Street bridge	Alameda County	1939	No collapse	Retrofitted to "no collapse" standard in 2009.
Park St bridge	Alameda County	1935	No collapse	Retrofitted to "no collapse" standard in 2008.
Miller-Sweeney bridge	Alameda County	1973	No collapse	Retrofitted to "no collapse" standard in 2011. City of Alameda has requested the bridge be upgraded to "lifeline" standard.
Fruitvale rail bridge	U.S. Army Corps of Engineers	1951	Collapse hazard	Rail bridge is a collapse hazard that poses a safety hazard to Miller-Sweeney Bridge. The City of Alameda is working with the Army Corps to fund the removal or rehabilitation of this public safety hazard.
Bay Farm Island vehicular bridge	Caltrans	1953	No collapse	Seismically retrofitted in 1997 to "no collapse" standard. City sent letter in 2007 requesting retrofit to "lifeline" standard; however, Caltrans needs to better understand liquefiable soils in the area before considering the request.
Bay Farm Island	Caltrans	1996	No collapse	Bridge is newer structures with modern seismic details. Does not

[30] City and County of San Francisco, 2020.

Bridge/Tube	Owner	Year Built	Seismic Performance	Seismic Retrofit Notes
bike/pedestrian bridge				meet criteria for further seismic evaluation by Caltrans.
Webster and Posey tubes	Caltrans	1928 (Posey) 1963 (Webster)	No collapse	The tubes were seismically retrofitted to “no collapse” standard in 2001. Caltrans has no future plans for seismic upgrades or upgrading the facility other than current refurbishment of the ventilation system.
Constitution Way overcrossing	Caltrans	1985	No collapse	Bridge is newer structures with modern seismic details. Does not meet criteria for further seismic evaluation by Caltrans.
Grand St bridge	City of Alameda	1958	Unknown	No record of seismic evaluation or retrofit
Ballena bridge	City of Alameda	1966	Lifeline	Retrofit in 2008 to “lifeline” standard

Fuel is a vital part of the transportation system. Fuel supply will be extremely limited following an earthquake due to likely damage of the oil refineries along the Carquinez Strait and in Richmond, the isolation of the Northern California fuel System and potential damage to the Kinder Morgan fuel pipeline in a Hayward fault earthquake.[31] Power and telecom are needed for full restoration of traffic signals and SMART technology functions.

Shoreline, Natural, and Recreation Areas

Alameda has both engineered shorelines (primarily seawalls or levees and associated riprap and other armoring) and a variety of natural shoreline habitats. These natural shoreline protection systems are vulnerable to damage in earthquakes and are susceptible to liquefaction if they are not designed to resist liquefaction. Major economic impacts and property loss will result from damage to shoreline protection systems.

Public Health and Welfare

Earthquakes can have significant impacts on public health, the extent of which varies depending on geography, damage to residences, socioeconomic status, and other factors. Socially vulnerable populations are particularly at risk. Earthquakes can not only physically harm residents, but cause stress and harm to residents' wellbeing. Depending on the extent of damage, recovery from a major earthquake could take many years and will impact many aspects of residents’ lives, from access to utilities, school closures, damage to homes or displacement, loss of employment, and loss of community. Some residents will bear these impacts more than others and have less ability to respond and recover themselves.

[31] City and County of San Francisco, 2020.

Combined across the community, these individual stressors can have major impacts on public health and wellbeing, especially for residents who lack the resources and financial capacity to respond.

In New Zealand, following the Christchurch earthquake sequence of 2010/11, the Canterbury Wellbeing Index was designed to monitor wellbeing and track the progress of social recovery from the earthquakes.[32] The Wellbeing Index draws from the data of many local and national agencies and incorporates information from the Canterbury Wellbeing Survey, which is conducted annually and provides an opportunity for residents to describe how they are feeling and their quality of life. The Survey also provides an opportunity for the local governments of the region to track recovery from the earthquakes in terms most important to residents and improve programs to better meet residents' needs. Following a major earthquake requiring a long recovery, tracking public health and welfare will be an important tool for protecting the wellbeing of Alamedans.

[32] https://www.cph.co.nz/your-health/canterbury-wellbeing-index/