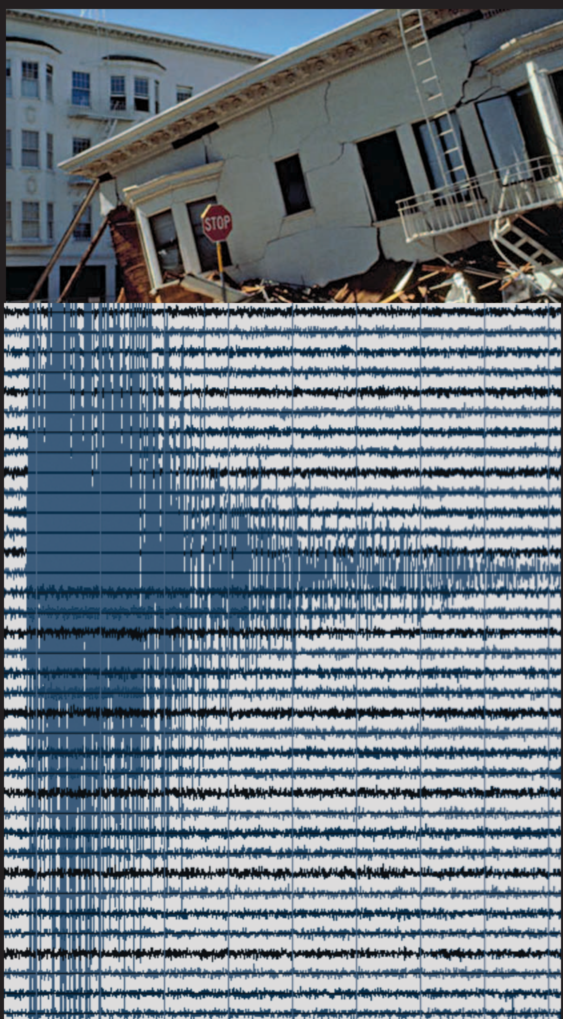
SPUR REPORT 01/2012

# Safe Enough to Stay




**What will it take for San Franciscans to live safely in their homes after an earthquake?** A significant amount of housing may be too damaged to live in while it's being repaired. Residents may leave. And that will put the city's recovery at risk. Here's how to prevent San Francisco from losing its most important asset: its people.

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# Executive Summary
# **Safe Enough to Stay**

When a major earthquake strikes the Bay Area, the region could face thousands of casualties, hundreds of thousands of displaced households and losses in the hundreds of billions of dollars. The lives of San Franciscans will be enormously disrupted, and it could take months to reestablish essential services. Recovery will be slow and will depend on the extent of the building damage, the amount of business lost, the availability of utilities and how quickly communities can repair and rebuild their housing.

This report focuses on the last of these factors: housing. San Francisco has a limited number of emergency-shelter beds, and its capacity to provide interim housing after an earthquake is constrained due both to low vacancy rates and to minimal vacant land. Therefore, we believe the city should take steps now to ensure that most of its residents can “shelter in place” — i.e., stay in their own homes while they are being repaired — after a major earthquake. Estimates show that only 75 percent of the city’s current housing stock will provide adequate shelter for residents after a large earthquake. This means San Francisco is at risk of losing its most important asset: its people.

Our research indicates that for San Francisco to avoid a slow and arduous recovery, 95 percent of its housing must be able to meet shelter-in-place standards. The steps the city needs to take to reach this goal will not happen overnight; SPUR estimates that it will take several decades to achieve the goal of becoming a resilient city. In this report, we ask three important questions about San Francisco’s housing resiliency:

- How much of San Francisco’s housing needs to meet shelter-in-place standards?
- What engineering criteria should be used to determine whether a home has adequate shelter-in-place capacity?
- What needs to be done to enable residents to shelter in place for days and months after a large earthquake?

In answering these questions, our Shelter-in-Place Task Force has developed a set of detailed recommendations to help San Francisco achieve 95 percent shelter in place and become a truly resilient city.

# **SPUR's recommendations** for creating resilient housing in San Francisco

1. **Adopt recovery targets for the housing sector as a whole, based on what is necessary for citywide resilience in a large expected earthquake.**

   Our definition of "large expected earthquake" and the methodology behind our recommended recovery target are explained on page 7.

2. **Implement the Community Action Plan for Seismic Safety (CAPSS) recommended mandatory soft-story retrofit program.**

   Soft-story and other vulnerable building types are defined on pages 20 and 21.

3. **Develop a soft-story retrofit program for smaller soft-story buildings.**

4. **Develop retrofit programs for other vulnerable housing types that impact San Francisco's resilience and also have the potential to severely injure or kill people.**

5. **Focus on developing an interim-housing strategy for the city.**

6. **Build on SPUR's engineering criteria proposal to further develop shelter-in-place evaluation criteria for voluntary, mandatory and triggered seismic work on residential buildings.**

7. **As draft criteria are developed, generate new loss estimates to help inform planning activities.**

8. **Create a San Francisco interdepartmental shelter-in-place task force.**

9. **Prepare and adopt regulations that allow for the use of shelter-in-place habitability standards in a declared housing-emergency period.**

10. **Develop a plan for implementing a shelter-in-place program.**

11. **Develop plans for neighborhood support centers to provide necessary help for shelter-in-place communities.**

# What will it take for San Franciscans to live safely in their homes after an earthquake?

When a major earthquake strikes the Bay Area, the region could face thousands of casualties, hundreds of thousands of displaced households and losses in the hundreds of billions of dollars. The lives of San Franciscans will be enormously disrupted, and it could take months to rebuild the city and reestablish essential services. Recovery will be slow and will depend on the extent of the building damage, the amount of business lost, the availability of utilities and how quickly communities can repair and rebuild their housing.

This report addresses the question of how to make San Francisco's residential buildings resilient in the face of a large earthquake. How many San Franciscans will be able to stay in their homes while those homes are being repaired? What does it mean for the city's overall resilience if some neighborhoods suffer more damage than others? What steps can city government, building owners and residents take now to ensure that homes are safe to occupy after an earthquake strikes?

Housing is only one element in the complex web of factors that contribute to the city's earthquake resilience, but we believe it is an especially important one. Currently, the seismic resilience of the city's housing stock is a weak link. Nearly all of the city's housing predates modern building codes. For a variety of reasons, residences are rarely seismically retrofitted. In contrast, many large commercial properties and government facilities have been seismically retrofitted in recent decades.

Housing is linked to every other aspect of the city's recovery: Businesses, neighborhood districts, schools and cultural institutions all rely on residents being in the city. Many businesses and educational activities will be able to resume as soon as the Internet and electricity are up and running. (Typically these services resume within weeks of a disaster, long before water, sewer or transportation systems can be repaired.) If people can stay in their homes, they will be better able to put their energy and resources into rebuilding their neighborhoods. If they must leave the city, their resources will go with them, perhaps permanently.

In prior reports, SPUR focused on defining targets for the recovery of San Francisco's buildings and lifelines (i.e., electricity, water, sewer, communications and transportation systems) after an expected earthquake of magnitude 7.2.[1] We set a target that 95 percent of residences should achieve a shelter-in-place standard, meaning that residents would be able to remain in their homes while those homes are being repaired. We also made a series of recommendations to strengthen existing buildings, new buildings and lifelines. These include the mandated retrofit of soft-story wood-frame multifamily housing, the adoption of a mitigation program for critical non-ductile concrete buildings and an assessment of the city's unreinforced masonry program.[2] (See "Seismically Vulnerable Structures: An Engineer's Rogues' Gallery," on page 20, for descriptions of these building types.)

### What Does It Mean to Shelter in Place?

SPUR defines "shelter in place" as a resident's ability to remain in his or her home while it is being repaired after an earthquake — not just for hours or days after an event, but for the months it may take to get back to normal. For a building to have shelter-in-place capacity, it must be strong enough to withstand a major earthquake without substantial structural damage. This is a different standard than that employed by the current building code, which promises only that a building meets Life Safety standards (i.e., the building will not collapse but may be so damaged as to be unusable). A shelter-in-place residence will not be fully functional, as a hospital would need to be, but it will be safe enough for people to live in it during the months after an earthquake. While utilities such as water and sewer lines are being repaired and reconnected, residents who are sheltering in place will need to be within walking distance of a neighborhood center that can help meet basic needs not available within their homes.

In this report, we define the steps that need to be taken to ensure that San Franciscans will be able to shelter in place. The recommendations of this report are structured in three sections that seek to answer the following questions:

1. **How much of San Francisco's housing needs to meet shelter-in-place standards?**
2. **What engineering criteria should be used to determine whether a home has shelter-in-place capacity adequate for a major earthquake?**
3. **What needs to be done to enable residents to shelter in place for days and months after a large earthquake?**

In the final section of the report, we describe how the recommendations that have been developed in the previous three sections can apply to other jurisdictions.

1 See page 7, "Defining the Expected Earthquake," for an explanation of this metric.

2 "The Dilemma of Existing Buildings: Private Property, Public Risk" (SPUR, 2008). www.spur.org/publications/library/report/dilemma-existing-buildings

# Section I:
## How much of San Francisco's housing needs to meet shelter-in-place standards?

SPUR defines "seismic resilience" as the ability of the city to contain the effects of earthquakes when they occur, to carry out recovery activities in ways that minimize social disruption and to rebuild following earthquakes in ways that mitigate the effects of future earthquakes. The more quickly a community can rebound from a major event, the more resilient the community.

A critical component of resilience is that residents choose to remain in the city during the recovery period. There are many factors that determine whether a resident will chose to stay after a disaster or pick up and leave the city. Residents may be able to cope with no water or sewer services for a few weeks, but most will be unwilling to put up with these difficulties for a period of months. Similarly, if roads, bridges or public transportation systems are not fully functional, residents may need to relocate in order to commute to jobs and schools. The closure of schools, medical facilities or businesses could affect residents' decisions about whether to stay in town or leave San Francisco. Some residents may leave right away and then return as their fears subside, when their toilet works again or as they complete repairs to their property. Others may stay initially but will leave as they learn how slowly their neighborhoods will be rebuilt. Some residents who leave may develop ties in their new community and never return.

The availability of housing, jobs and community resources such as schools is critical to a city's seismic resilience. We assume that if two out of these three resources are in place, residents will choose to stay. For example, if a resident can shelter in place in her home and her employer has chosen to remain in the city, she is more likely to stay than if her employer has left the city or if she is unable to remain in her home.

While this report is focused on one factor — housing — there is no doubt that other factors are also important to recovery. San Francisco's downtown is a major regional job center, home to more than 250,000 jobs. About 42 percent of these downtown workers live in San Francisco, and about 38 percent commute from the East Bay. Many of San Francisco's major employers (such as PG&E, Wells Fargo, the Gap, Charles Schwab, Macy's West, Levi's and McKesson) have corporate headquarters or significant numbers of employees in San Francisco's downtown core. These employers, along with smaller ones, represent important sectors of the San Francisco economy that will be key to recovery: public utilities, tourism, and hospitality and business services.

Economic recovery and housing recovery are interdependent. If employers choose to leave the city or region, they take jobs with them. If residents leave, the workforce that employers rely upon is no longer available, leading to further disinvestment. Young and mobile residents, such as high-tech workers who have not yet established deep ties to the community, may leave after the earthquake if the characteristics that attracted them to San Francisco — exciting jobs, an active cultural life and a vibrant social scene — are no longer in place. Keeping San Francisco's workforce from leaving is key to the city's economic recovery.

It is also crucial that San Francisco plan for its most vulnerable populations: low-income households, the elderly, non-English speakers and the disabled. It is clear that some residents will suffer more severe consequences than others if they are displaced from their homes by an earthquake. Wealthy residents have options: They can stay in a hotel in the short term, find rental housing for the medium term, secure loans, begin repairs on buildings they own before insurance payments come through, and purchase replacements for personal items that they lost. Low-income residents can do few of these things. They will rely heavily on city shelters and services. Many of them may leave, unable to afford new rental units in a market with reduced availability.

For low-income property owners, selling damaged property may be more feasible than obtaining financing and undertaking repair and reconstruction. Middle-class residents, already tightly squeezed by San Francisco's expensive real estate market, will also have difficulty staying in the city. Elderly residents will be heavily affected. Seniors of all income levels, but particularly seniors on a fixed income, will find it difficult to relocate, repair or rebuild their homes and reestablish needed social services and networks. A large earthquake could permanently alter city demographics and increase the pace of change in many neighborhoods. San Francisco's diversity and culture will be threatened if vulnerable populations leave due to lack of affordable and accessible housing.

# Why 95 percent is the right shelter-in-place target

It's not easy to determine how much housing in a city can be damaged by an earthquake before the city's viability is undermined. We conducted the following analysis to determine what shelter-in-place performance target makes sense for San Francisco.

1. We researched the existing capacity for short-term housing (shelter beds) and medium-term or interim housing (hotel rooms, trailers) in San Francisco after a large earthquake.
2. We reviewed efforts by others to model and quantify disaster resilience.
3. We analyzed how housing damage in recent relevant disasters affected community resilience.

Based on our analysis of the best available data, we conclude that 95 percent is an appropriate goal. While this may seem to be a high target, the lessons from recent disasters show that losing more than 5 percent of housing stock is likely to lead to substantial outmigration, which could slow recovery for years. The city's lack of interim-housing capacity and its relatively low vacancy rate will only exacerbate this situation.

### San Francisco's emergency-shelter and interim-housing capacity

San Francisco's Department of Emergency Management estimates that its top shelter capacity is 60,000 people, or roughly 7.5 percent of San Francisco's overall population. Sheltering 60,000 people would require maximizing shelter space at large convention facilities like the Moscone Center and also mixing in some outdoor or soft-sided shelters to supplement indoor space. If we were to use indoor facilities only, without the big convention centers or outdoor sites, capacity would be reduced to 45,000 people, or roughly 5.5 percent of San Francisco's population.[3]

Emergency-shelter beds will provide places for residents to stay for days or weeks, but it will take years before most heavily damaged housing will be usable again. In the meantime, residents will need to find interim housing before repairs on damaged housing are completed or new replacement housing is constructed. There are federal and state plans and guidelines that identify a variety of options for interim housing and priorities for their use.[4]

In general, these plans call for a hierarchy of actions: first, providing

3 Email correspondance with Robert Stengel, Department of Emergency Management, September 1, 2011.

4 *National Disaster Housing Strategy and Annexes* (Federal Emergency Management Agency, 2009); *2009 Disaster Housing Plan* (Federal Emergency Management Agency, 2009); and *Regional Catastrophic Earthquake Interim Housing Plan: Annex to the San Francisco Bay Area Regional Emergency Coordination Plan* (California Emergency Management Agency, 2011).

# Defining the Expected Earthquake

Earthquakes are commonly reported in terms of their Richter magnitude. That measure was defined in the early 1940s and is useful only for quantifying the energy released overall by a single earthquake. It offers little information in terms of how buildings or infrastructure will fare or how they should be designed.

In order to evaluate an existing facility or design a new one, earth scientists and engineers today use different measures to quantify the intensity of the expected shaking at a specific site. These engineering measures account for the possible effects of different earthquakes on multiple faults, and therefore are defined in probabilistic terms. For example, a building might be designed for the level of shaking expected to occur with 10 percent probability over a 50-year time period.

A third way of defining earthquakes involves "scenario events": specific hypothetical earthquakes defined by the location of the fault rupture and the magnitude of the energy released. Scenario earthquakes are especially useful for citywide or regional planning. They are easier to grasp than probabilistic measures and therefore are effective for communicating earthquake risk to policymakers and the public.

In 2003, the San Francisco Department of Building Inspection's Community Action Plan for Seismic Safety chose four scenario earthquakes as the basis for its planning and mitigation programs. For the purposes of defining resilience, SPUR uses one of these scenario earthquakes: a magnitude 7.2 earthquake on the peninsula segment of the San Andreas Fault, off San Francisco's western shore.

We refer to this scenario as the "expected earthquake" because an event of this magnitude can be expected — conservatively but reasonably — to occur once during the useful life of a structure or system, and more frequently if the structure is renovated to serve more than one or two generations. Of course, this defined scenario would produce different levels of shaking at different locations, but for most of the city its effects would be similar, in probabilistic terms, to those with a 10 percent chance of occurring over a 50-year period.

We define resilience in terms of this expected earthquake. Other earthquakes are possible, of course. In a smaller, more routine earthquake, buildings would be expected to perform better (i.e., to withstand the shaking with little or no damage). In a more extreme event, residents would have to tolerate more damage than what we project here.


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Emergency shelter after the San Francisco's 1906 earthquake (top) and Kobe's 1995 earthquake (bottom).

federal rental vouchers to displaced residents to pay for existing housing resources such as vacant rental units and hotel and motel rooms in and near San Francisco; second, aiding in the provision of traditional interim-housing forms such as Federal Emergency Management Agency (FEMA) trailers that might be located in front of damaged residences, public parks, the rights-of-way of wider streets, or any larger tracts of undeveloped lands; and third, using innovative forms of interim housing, which might include cruise ships docked along the waterfront or vacant commercial space.

All of these options present problems for San Francisco. Even without a disaster, there is a limited supply of vacant housing in San Francisco, and using the city's hotels to house displaced residents will need to be balanced with accommodating workers who come to repair the city and tourists who help to restore the economy. There are few undeveloped spaces in the city, and filling parks and streets with trailers for too long will present transportation, recreation and economic challenges.

If existing housing, hotel space or land for trailers is not available, then the region's disaster housing plans call for relocating displaced residents to nearby counties and cities.[5] However, in a regional disaster such as a magnitude 7.2 earthquake, neighboring cities and counties will also be struggling to house displaced residents, adding pressure to the region's housing stock. Thus, San Franciscans may face the same challenges as New Orleanians did after Hurricane Katrina and may have to travel far to find available housing. After Katrina, New Orleans' displaced residents had to move temporarily to Baton Rouge, Atlanta, Houston and Dallas, all great distances from the city. This made it difficult for residents to keep their jobs, repair and rebuild their homes, and restore their communities.

In 2011, San Francisco's Department of Emergency Services initiated a post-disaster interim-housing planning process to set local priorities for interim housing and determine how many people could realistically be accommodated in the various interim-housing options. The city's objectives for the post-disaster interim-housing planning effort[6] are to:

- Keep residents in their homes
- If not in their homes, then keep residents in their neighborhoods
- If not in their neighborhoods, then keep residents in the city
- If residents leave the city, then have a plan for their return

After a magnitude 7.2 earthquake on the San Andreas Fault, approximately 85,000 households (about 25 percent of the city's households[7]) could need interim housing for several months, gradually decreasing to 45,000 households (approximately 13 percent) by two years after the earthquake, with up to 15,000 households (approximately 5 percent) requiring interim housing for up to five years.[8] Clearly, emergency-shelter beds will not be able to accommodate this scope of displaced population in the short term, and interim-housing options will not easily accommodate such large numbers for the months and years that housing takes to be repaired and replaced. The insufficiencies of both these capacities suggest the city should strive to keep as many residents as possible in their own homes after a large earthquake. While no specific number emerges, our review supports SPUR's long-term goal of 95 percent of residents being able to shelter in their current homes.

## Other performance metrics related to disaster resilience

San Francisco is not the only community looking at its resilience and capacity to rebound following future disasters. Both in the United States and around the world, researchers and policymakers are leading efforts to develop the means of measuring and monitoring community resilience. While there is no single set of established indicators or frameworks for quantifying disaster resilience, there is growing consensus that resilience is a multifaceted concept with social, economic, institutional, infrastructural, ecological and community dimensions.[9] Several sets of resilience indicators or attributes have been developed as a means of comparing resiliency in a community over time or measuring recovery progress and outcomes following a disaster.[10] Most consider community functions — infrastructural, economic and social — in a manner similar to SPUR's Resilient City recovery performance indicators; however, none are as specific as SPUR's goals (e.g., 95 percent of residents able to shelter in place after the expected earthquake).

All of the metrics examined recognize that housing plays an important role in community resilience and that it is linked to many other aspects of recovery. However, none clearly state how robust a community's housing needs to be to achieve resiliency, and we can draw no conclusions from the resilience literature about whether SPUR's performance target for housing is reasonable.

## Recent comparable disasters

Perhaps the best way to investigate whether a goal of 95 percent shelter in place is reasonable for San Francisco is to consider how other communities fared after major disasters. Every disaster is different, but reviewing case studies of recovery from similar cities provides insights into what San Francisco might experience after a damaging earthquake. By looking at these case studies, we are interested in examining how damage to housing affected the overall recovery of each community. We are also trying to understand not only how quickly a city or region can rebuild housing units, but whether the rebuilding serves the population that was displaced by the disaster or serves a new population. As such, we are attempting to correlate housing damage with outmigration after the disaster. Some past events are more relevant to San Francisco because they were urban events in developed countries, where the quality of construction and housing conditions were similar to those in an American city like San Francisco. Other events, due to the scale of the event or the circumstances in the locale, were not appropriate comparisons. Figure 1 (page 10) summarizes the impacts from several disasters. While the number of uninhabitable housing units ranges between 1 and 50 percent in these examples, it is clear that even when the loss of housing units is less than 10 percent, the time to repair or rebuild uninhabitable housing units is long and can inhibit recovery.[11] In the absence of adequate interim housing, outmigration is inevitable and the loss of population will impact the local economy and overall recovery. We see permanent loss of population, and the accompanying social and economic impacts, in communities where housing losses are as low as 5 to 10 percent.

5 *Regional Catastrophic Earthquake Interim Housing Plan: Annex to the San Francisco Bay Area Regional Emergency Coordination Plan* (California Emergency Management Agency, 2011).

6 Johnson, Laurie and Lucas Eckroad, *Summary Report on the City and County of San Francisco's Post-Disaster Interim Housing Policy Planning Workshop.* (San Francisco Department of Emergency Management, July 11, 2001).

7 There are approximately 330,000 households in San Francisco. The estimate of 85,000 households comes from analysis of CAPSS Hazus output data. See Figure 4.

8 Johnson, Laurie and Lucas Eckroad, *Summary Report on the City and County of San Francisco's Post-Disaster Interim Housing Policy Planning Workshop* (San Francisco Department of Emergency Management. July 11, 2001.)

9 Peacock, Walter G., William H. Hooke, Susan L. Cutter, Stephanie E. Chang and Philip R. Berke, *Toward a Resiliency and Vulnerability Observatory Network: RAVON* (Texas A&M University Hazard Reduction and Recovery Center, College of Architecture, 2008); National Research Council, Committee on Private-Public Sector Collaboration to Enhance Community Disaster Resilience, *Building Disaster Resilience Through Public-Private Collaboration.* (Washington, DC: National Academies Press, 2010).

10 Literature reviewed includes: Bruneau, Michel, Stephanie E. Chang, Ronald T. Eguchi, George C. Lee, Thomas D. O'Rourke, Andrei M. Reinhorn, Masanobu Shinozuka, Kathleen Tierney, William A. Wallace and Detlof von Winterfeldt, "A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities," *Earthquake Spectra* 19 (4) (November 2003): 733–752; *Toward a Common Framework for Community Resilience.* (Oak Ridge, TN: Community and Regional Resilience Institute, 2009); Cutter, Susan L., Christopher G. Burton and Christopher T. Emrich, "Disaster Resilience Indicators for Benchmarking Baseline Conditions," *Journal of Homeland Security and Emergency Management* 7 (1) (2010): Article 51, 1–20; LeDuc, Andre, *Establishing Mitigation as the Cornerstone for Community Resilience* (Eugene, OR: Partners for Disaster Resistance and Resilience, 2006); Miles, S. and Stephanie E. Chang, "Modeling Community Recovery from Earthquakes," *Earthquake Spectra* 22 (2) (May 2006): 439–458; Norris, Fran H., S.P. Stevens, B. Pfefferbaum, K.F. Wyche and R.L. Pfefferbaum, "Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness," *American Journal of Community Psychology* 41 (1–2) (March 2008): 127–150; Twigg, John, *Characteristics of a Disaster-Resilient Community: A Guidance Note* (Aon Benfield UCL Hazard Research Centre, November 2009) www.abuhc.org/Publications/CDRC%20v2%20final.pdf

11 The recovery time varies depending on what kind of housing was lost (e.g., apartments and low-income units typically take longer than middle-income single-family homes).

# Figure 1: Comparing the Effects of Recent Disasters

## Loma Prieta Earthquake (1989),[12] San Francisco Bay Area

Degenkolb Engineers

| | |
|---|---|
| Uninhabitable units | 11,500 |
| Uninhabitable units as a percentage of housing in the affected area | More than 1% in Oakland and San Francisco, 10% in Watsonville and Santa Cruz |
| Percentage of uninhabitable units that were in multifamily buildings | 60% |
| Outmigration | More than 1,000 left Santa Cruz/Watsonville area; Oakland reported 2,500 new homeless; similar numbers assumed for San Francisco |
| Housing reconstruction time frame | Two years for single-family and most market-rate apartments; seven to 10 years to replace/repair affordable housing units in three counties |

## Hurricane Andrew (1992),[13] Miami

flickr user fotogake

| | |
|---|---|
| Uninhabitable units | 80,000 |
| Uninhabitable units as a percentage of housing in the affected area | 6% in South Dade County |
| Percent of uninhabitable units that were in multifamily buildings | 29% |
| Outmigration | Permanent dispersion of 25,000 to 30,000 households (21,000 jobs lost with Homestead base closure, which exacerbated outmigration) |
| Housing reconstruction time frame | 75% of single-family units in two years; very limited multifamily housing reconstructed |

## Northridge Earthquake (1994),[14] Los Angeles

flickr user standardpixel

| | |
|---|---|
| Uninhabitable units | 60,000 |
| Uninhabitable units as a percentage of housing in the affected area | 3% in San Fernando Valley, 1.5% in Los Angeles |
| Percent of uninhabitable units that were in multifamily buildings | 88% |
| Outmigration | Minimal: people rehoused in vacant units due to pre-earthquake 9.3% vacancy rate |
| Housing reconstruction time frame | 80% in two years; typically two years to repair and four years to rebuild damaged housing units |

12 Data from Comerio, Mary C., *Disaster Hits Home* (Berkeley, CA: University of California Press, 1998).

13 *Ibid.*

14 *Ibid.*

15 Data from Olshansky, Robert B., Laurie A. Johnson and Kenneth C. Topping, *Opportunity in Chaos: Rebuilding After the 1994 Northridge and 1995 Kobe Earthquakes* (2005) www.urban.illinois.edu/faculty/olshansky/chaos/chaos.html. Additional data estimates from Professor Mary Comerio, UC Berkeley.

16 Data estimate from Professor Mary Comerio, UC Berkeley.

17 Note that the January 2005 population exceeded pre-earthquake levels, but population distribution changed. Four western Kobe wards (Tarumi, Suma, Nagata and Hyogo) had smaller populations; for example, Nagata ward was only at 80 percent of its January 1995 population.

18 *Recovery Briefing Book, Grand Forks, North Dakota: Flood Recovery Brief, Informational Resources and Recovery Lessons Learned* (City of Grand Forks, North Dakota, 2006); “Information on City Governance, 1997 Flood Preparations, Damage and Recovery,” (City of Grand Forks, North Dakota, 2008).

19 Data from Olshansky, Robert B. and Laurie A. Johnson, *Clear as Mud: Planning for the Rebuilding of New Orleans* (Chicago, IL and Washington, DC: American Planning Association, 2010).

20 This is the number of uninhabitable units for New Orleans. The total number of uninhabitable units in the Gulf Coast region is 500,000.

21 Data from Professor Mary Comerio, UC Berkeley.

## Kobe Earthquake (1995),[15] Kobe, Japan

flickr user mah_japan

| | |
|---|---|
| Uninhabitable units | Nearly 450,000 housing units either partially or completely destroyed; about 400,000 people left at least temporarily homeless; more than 316,000 people in public shelters |
| Uninhabitable units as a percentage of housing in the affected area | 24% of housing units destroyed in the six central urban wards of the city of Kobe, and approximately 15% in the whole city, including some suburban areas |
| Percent of uninhabitable units that were in multifamily buildings | Approximately 50%[16] |
| Outmigration | In October 1995 (nine months after the earthquake), Kobe's population had declined by nearly 100,000 people, a drop of 6.3%[17] |
| Reconstruction time frame | Limited housing construction in the first two years after the earthquake; five to 10 years to reach and exceed the city's rebuilding goal; about 200,000 units were built, roughly double the city's goal |

## Grand Forks Flood (1997),[18] Grand Forks, North Dakota

flickr user GreenLight Designs (jwgreen)

| | |
|---|---|
| Uninhabitable units | 9,000 households displaced for several weeks; 1,200 homes permanently uninhabitable |
| Uninhabitable units as a percentage of housing in the affected area | About 80% short-term units and about 10% permanent units |
| Percent of uninhabitable units that were in multifamily buildings | 10% |
| Outmigration | 6% of population lost in first year |
| Housing reconstruction time frame | Most housing rebuilt in two to three years |

## Hurricane Katrina (2005),[19] New Orleans

flickr user www.nola.com

| | |
|---|---|
| Uninhabitable units | 100,000 units damaged or destroyed[20] |
| Uninhabitable units as a percentage of housing in the affected area | 50% of all New Orleans households; 9% to 21% loss of population by neighborhood (with some as high as 49%) |
| Percent of uninhabitable units occupied by renters | 43% |
| Outmigration | 80% of residents initially evacuated; after five years, New Orleans population had returned to 80% of its pre-Katrina levels; however, this includes significant in-migration of new residents |
| Housing reconstruction time frame | 13% fewer units in city in 2010 and vacancy rate now 25% (pre-storm rate at 12%) |

## Christchurch Earthquakes (2010 and 2011),[21] Christchurch, New Zealand

Sri Sritharan

| | |
|---|---|
| Uninhabitable units | Approximately 15,000 homes will not be allowed to rebuild |
| Uninhabitable units as a percentage of housing in the affected area | 2% to 3% of Christchurch and surrounding districts |
| Percent of uninhabitable units that were in multifamily buildings | Negligible; probably less than 1% |
| Outmigration | Total outmigration could be roughly 30,000 (six to eight months after the 2011 event); could increase as families resolve insurance claims |
| Housing reconstruction time frame | Too early to evaluate |

Several relevant lessons for San Francisco emerge from the experiences of disasters in other communities:

**1. Rebuilding housing takes a long time, even if the percentage of units rendered uninhabitable is relatively small.** It took at least two years for a significant portion of housing to be replaced in all of the profiled disasters for which information was available. It took much longer to rebuild in some communities. After the 1995 earthquake in Kobe, Japan — an area often cited to be similar to the Bay Area — it took the city five to 10 years to reach its rebuilding goals.

**2. Multifamily and affordable housing is much more difficult and slower to replace than single-family, market-rate housing.** Financing and legal issues are some of the many factors that slow down this work. After the Bay Area's Loma Prieta earthquake in 1989, it took seven to 10 years to replace all of the damaged affordable housing. If lost, some affordable housing might never be replaced, leading to a significant shift in post-event population.

**3. Large losses of housing lead to permanent losses of population.** The table includes two events with housing losses greater than 25 percent: Hurricane Katrina and the Kobe earthquake. Both of these events caused large population losses and demographic shifts. However, a number of events where housing losses were much smaller — such as the Christchurch earthquakes in New Zealand and Hurricane Andrew's impacts in Florida — produced large losses in population as well.

**4. Interim housing matters.** After the 1994 Northridge earthquake in Los Angeles, most of the people displaced were able to relocate nearby due to the area's pre-earthquake 9.3 percent vacancy rate. Vacant rental units served as interim housing. In San Francisco, the vacancy rate is typically much tighter, currently 4 percent,[22] meaning that the city will need more active measures to house its displaced residents over longer periods.

It is clear that very large housing losses, such as those that occurred after the Kobe earthquake and Hurricane Katrina, devastate a community and lead to a slow, difficult recovery. Studies following major disasters in the United States, Japan and elsewhere have shown that individuals and families enduring interim and irregular housing situations for months and years after a disaster are more vulnerable to physical, social and mental disorders, including suicide, substance abuse, and physical and verbal abuse.[23] However, even without catastrophic losses, the disaster case studies included in the table also show that housing losses on the order of 5 percent or less, such as those seen in the Christchurch earthquakes, Hurricane Andrew, and the Northridge and Loma Prieta earthquakes, also contribute to a range of undesirable outcomes. These include large losses of population, large job losses, protracted time frames for rebuilding and heavy impacts on affordable housing.

After examining this data, we believe that San Francisco would experience significant consequences even if only 5 percent of its housing units were unusable after a future earthquake, given the city's low vacancy rates, density and limited capacity for interim housing. If more housing were damaged, the potential social and economic consequences could be devastating.

We conclude that SPUR's performance target of 95 percent shelter in place is appropriate.

## How will San Francisco's neighborhoods be impacted by the expected earthquake?

San Francisco's housing will be heavily damaged after future large earthquakes. San Francisco's Department of Building Inspection recently completed a major study — the Community Action Plan for Seismic Safety (CAPSS)[24] — that analyzed earthquake risk for the city's privately owned buildings, including housing. The CAPSS project estimated that after a magnitude 7.2 earthquake on the San Andreas Fault, approximately 25 percent of the city's housing units would not be safe for residents to occupy.[25] In other words, we currently expect 75 percent of residences to be available for sheltering in place after the expected earthquake. This means that residents of more than 85,000 units would need to seek alternate housing until their units are repaired or replaced, which would take years.

SPUR has refined the CAPSS estimates of housing damage so that they could be reported in greater detail by neighborhood and

22 Data from Reis, Inc. as quoted in "U.S. Housing Market Conditions: Pacific Regional Report, HUD Region IX – 1st Quarter 2011." www.huduser.org/portal/regional.html. Vacancy rates are continuing to tighten due to high demand from growing employment sectors, potentially exacerbating interim-housing needs should a disaster strike.

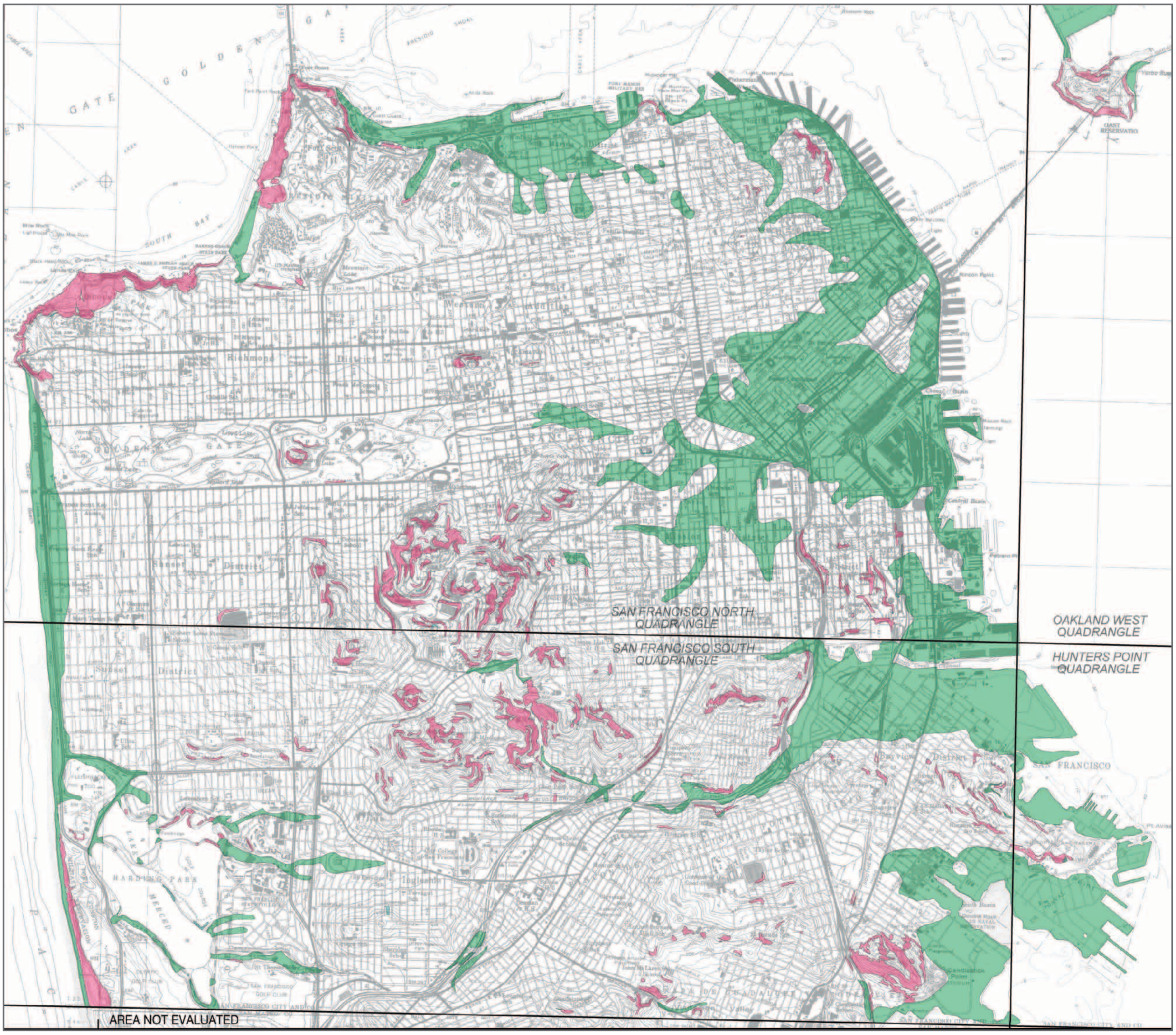
23 Enarson, Elaine, Alice Forthergill and Lori Peek, "Gender and Disaster: Foundations and Directions," Chapter 8 in *Handbook of Disaster Research* (New York, NY: Springer, 2007); Tatsuiki, Shigeo, "Long-Term Life Recovery Processes Among Survivors of the 1995 Kobe Earthquake: 1999, 2001, 2003, and 2005 Life Recovery Social Survey Results," *Journal of Disaster Research* vol 2., no. 6 (2007): 484–501.

24 For more information about CAPSS, see www.sfcapss.org.

25 This estimate considers damage from ground shaking and liquefaction, but does not include effects of fires sparked by earthquakes. Fire damage after earthquakes varies significantly based on conditions at the time, such as weather, wind and damage to fire-fighting resources. CAPSS ran multiple post-earthquake fire scenarios, varying these and many other conditions. On average, more than 70 fires would be expected to ignite after an event this size, burning 8.7 million square feet of building space that had not already been destroyed by shaking. About two-thirds of all building space in San Francisco is residential. Assuming that about two-thirds of the burned area is in residential buildings, nearly 6,000 additional units are projected to be lost to fire, although losses could be much higher or lower.

## Figure 2: Liquefaction and Landslide Zones in San Francisco

Certain parts of San Francisco are vulnerable to seismic hazards after an earthquake, including liquefaction (where wet ground is shaken to the point that it behaves like a liquid) and landslide (when a slope becomes unstable).




Source: "Seismic Hazard Zones, City and County of San Francisco," (California Department of Conservation, Division of Mines and Geology, November 17, 2000) http://gmw.consrv.ca.gov/shmp/download/pdf/ozn_sf.pdf

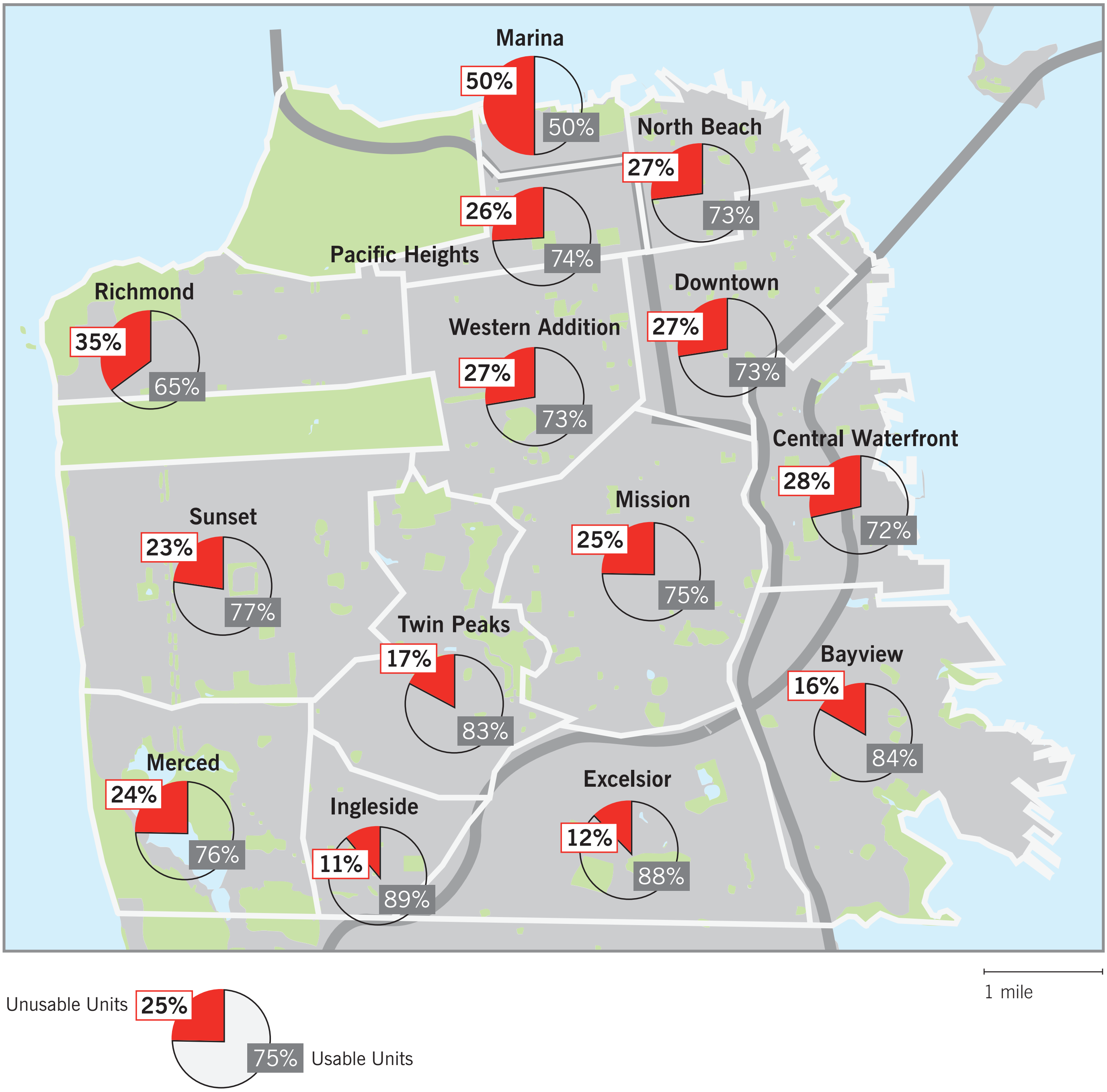
1 mile

**Liquefaction**
Areas where historic occurence indicate a potential for permanent ground displacements.

**Earthquake-Induced Landslides**
Areas where previous occurrence of landslide movement indicate a potential for permanent ground displacements.

## Figure 3: How Will the Expected Earthquake Impact San Francisco?

Different neighborhoods have different housing stock and soil conditions, which means the degree of earthquake damage will vary across the city. After a Magnitude 7.2 earthquake on the San Andreas Fault, we expect the percentages of housing in red to be unusable, meaning not safe enough for residents to shelter in place.




Sources: SFGIS, Census 2000 and SPUR analysis of CAPSS Hazus Output Data[27]

## Figure 4: How Much of San Francisco's Housing Will Be Unusable?

In neighborhoods with a high number of vulnerable housing types, such as wood-frame soft-story buildings and non-ductile concrete buildings, there will be a greater number of unusable housing units after the expected earthquake.

| Neighborhood | Total number of units | Number of unusable units | Percent of unusable units by structure type | | | |
|---|---|---|---|---|---|---|
| | | | One- and two-family woodframe soft-story | Woodframe soft-story with three or more units | Concrete built before 1980 | Other |
| **Bayview** | 9,000 | 1,500 | 42% | 55% | 1% | 2% |
| **Central Waterfront** | 9,400 | 2,700 | 15% | 48% | 22% | 14% |
| **Downtown** | 54,000 | 15,000 | 2% | 53% | 28% | 16% |
| **Excelsior** | 24,000 | 2,900 | 58% | 38% | 0% | 4% |
| **Ingleside** | 7,900 | 900 | 76% | 15% | 0% | 8% |
| **Marina** | 7,600 | 3,800 | 15% | 79% | 3% | 3% |
| **Merced** | 8,200 | 2,000 | 16% | 33% | 28% | 22% |
| **Mission** | 48,000 | 12,000 | 23% | 71% | 3% | 3% |
| **North Beach** | 26,000 | 7,200 | 5% | 85% | 6% | 4% |
| **Pacific Heights** | 19,000 | 4,800 | 12% | 80% | 5% | 3% |
| **Richmond** | 27,000 | 9,400 | 27% | 71% | 1% | 1% |
| **Sunset** | 38,000 | 8,600 | 51% | 44% | 1% | 4% |
| **Twin Peaks** | 17,000 | 2,900 | 40% | 56% | 1% | 3% |
| **Western Addition** | 41,000 | 11,000 | 12% | 81% | 4% | 3% |
| Total | 330,000 | 85,000 | 22% | 67% | 6% | 5% |

Sources: SFGIS, Census 2000 and SPUR analysis of CAPSS Hazus Output Data[27]

structure type.[26] However, this analysis only considers part of the picture: whether housing will be safe to occupy considering earthquake damage to structures. It does not consider other damage or cascading consequences, such as damage to utilities or structural damage from fires following the earthquake. The factors that contribute to whether residents choose to stay or leave after a disaster are complex, and the structural safety of residences is only one piece of information, albeit an important one. This should be kept in mind while reviewing the following figures, which only represent that one piece.

The analysis makes clear that housing in every San Francisco neighborhood would be damaged heavily by a magnitude 7.2

26 Defining building performance in terms of shelter in place is a new concept. The CAPSS project used the best information and methods available at the time to estimate the amount of housing that would be usable after an earthquake. This task force has developed improved methods to identify which residences could be used to shelter in place, but this new approach has not yet been applied to San Francisco's building stock. The analysis presented in this report is based on the CAPSS analysis. We are hopeful that an improved analysis will be conducted some time in the future using the methods developed by this task force, producing updated and refined estimates of housing damage.

27 Hazus is FEMA's methodology for estimating damage and losses for natural disasters.

San Andreas earthquake. In every neighborhood in the city, more than 10 percent of the housing units would become unsafe to occupy. The neighborhoods that will see the most damage are those with large numbers of multifamily buildings, which are generally more vulnerable than smaller residences, and those that have significant areas of soft or liquefiable soils, which can experience magnified shaking and ground failure. (See Figure 2, page 13.) Figure 3 (page 14) shows estimates of the percentage of unsafe units in all districts. Estimates suggest that the Marina district would be hit hard, with nearly half of housing units there unsafe to occupy. The Richmond district would also suffer significant amounts of damaged housing, with an estimated 35 percent of units unsafe to occupy due to the type of housing in the neighborhood and its proximity to the San Andreas Fault.

Known structural deficiencies are behind this predicted damage. Wood-frame soft-story residences with three or more units would account for two-thirds of the housing units citywide that could not be occupied. Typically, a soft-story building has large openings at the ground level, such as garage doors or store windows, and few interior walls, making the ground floor much weaker and more flexible than the stories above. In an earthquake, the ground level can sway excessively and collapse. Construction patterns are different in various parts of the city, so the types of structures responsible for housing damage would vary by district, as shown in Figure 4 (page 15).

In the expected earthquake, all neighborhoods would experience heavy damage, but some would see more housing loss than others. Estimated housing losses range from 11 percent in the Ingleside district to an alarming 50 percent in the Marina. The following sections explore what some of the consequences of this housing damage might be in selected districts with large housing losses — Downtown, the Marina, the Mission and Western Addition — and how damage to specific districts would affect the city as a whole. For more about the varying impacts on different neighborhoods, see Appendix I, page 32.

## Downtown

In addition to the downtown financial district, CAPSS defines this district as including the Tenderloin, the south slope of Nob Hill, much of SOMA and most of Chinatown. Encompassing some of the oldest, densest and most historically rich parts of the city, the downtown area contains approximately 54,000 housing units, the largest number of any district, in addition to housing more than 250,000 of San Francisco's jobs. It is also the city's least affluent district, measured by median household income, with large concentrations of single-room occupancy buildings and other types of affordable housing. Many elderly people, new immigrants and non-English speakers live here. After the expected earthquake, nearly 15,000 housing units downtown (27 percent) would be rendered unusable. Approximately half of these units are in wood-frame soft-story buildings with three or more units; the rest are located in non-wood structures, including older concrete-frame buildings and retrofitted unreinforced masonry buildings that are still vulnerable. These non-wood structures are particularly problematic because some of them house a large number of units and they can be difficult and costly to retrofit. Housing losses in this district would be expected to displace many lower-income residents who would depend heavily on city services after the disaster.

**54,000**
Housing units

**15,000**
Units rendered unusable by the expected earthquake


flickr user reallocalcelebrity (John Morrison)

## The Marina

In contrast, the Marina district, which is largely residential, contains the smallest number of housing units of any of the districts, with only 7,600. However, nearly half of these units would be unusable after the expected earthquake. This is due to a predominance of large wood-frame soft-story structures built on highly liquefiable soil. The 1989 Loma Prieta earthquake highlighted this vulnerability, collapsing seven buildings and damaging many more in the Marina, despite being centered 60 miles south of the neighborhood. The Marina's population is relatively affluent compared to other neighborhoods, with a high proportion of renters (79 percent of households). Housing damage here would displace many young professionals who, as renters, would have limited financial ties to the neighborhood. Whether these residents stay in the Marina, or even in San Francisco, would depend in part on whether the jobs and lifestyle they value remain a part of the post-earthquake city.

**7,600**
Housing units

**3,800**
Units rendered unusable by the expected earthquake

flickr user carrib

## The Mission

The Mission district — which CAPSS defines as including the Castro, Noe Valley, Bernal Heights and Glen Park, as well as the Mission neighborhood — is another area with a significant number of housing units. Of the neighborhood's 48,000 units, 12,000 of them (25 percent) would be unusable after the expected earthquake. A large share of these damaged units (90 percent) are in wood-frame soft-story buildings: Approximately 20 percent are located in structures with one or two units, while 70 percent are in structures with three or more units. The Mission district's residents are diverse, including households of all income levels, a concentration of Latino residents, a growing number of young professionals and a relatively high concentration of school-age children compared to the city as a whole. Earthquake damage could speed up neighborhood change in this historically working-class neighborhood.

**48,000**
Housing units

**12,000**
Units rendered unusable by the expected earthquake

## The Western Addition

The Western Addition district, comprised of diverse neighborhoods such as the Haight, Alamo Square, Japantown and Laurel Heights, contains more than 41,000 housing units. After the expected earthquake, more than 11,000 units (27 percent) would be unusable. Again, a large percentage of these units (90 percent) are in wood-frame soft-story buildings. The economic diversity of this district, ranging from wealthy enclaves near Pacific Heights to sizable numbers of public housing units, could highlight the dramatic differences in recovery between households with and without means. Some residents of this district will be well placed to rebuild their homes and their lives quickly, while others could descend into a state of extreme dependency on city and other organizational services.
Costa County and SMART in Sonoma and Marin counties, will not connect to existing job centers and will have a limited impact on the overall use of transit to work. Important projects like BART to Silicon Valley will bypass North San Jose, which is where most of the proposed job growth will take place. By avoiding North San Jose on its route to downtown San Jose, this project misses an opportunity to truly promote the densification of employment and significantly reduce drive-to-work rates.

**41,000**
Housing units

**11,000**
Units rendered unusable by the expected earthquake

# Section I Recommendations

San Francisco faces a clear problem. An estimated 25 percent of housing units might not be usable after a future expected earthquake. However, our analysis indicates that if as little as 5 percent of the city's housing stock is out of commission after a disaster, the city could have a slow and arduous recovery. We recommend five steps San Francisco should take to improve its housing stock and plan for displaced residents.

## 1. Adopt recovery targets for the housing sector as a whole, based on what is necessary for citywide resilience in a large but expected earthquake.

SPUR has recommended that 95 percent shelter in place is the appropriate goal for San Francisco. This target should be adopted by the City and County of San Francisco, either in the Community Safety Element of the General Plan or as a stand-alone piece of legislation adopted by the Board of Supervisors. The city should set a 30-year time frame to reach this goal, mirroring the established 30-year time frame to implement the CAPSS recommendations.

## 2. Implement the Community Action Plan for Seismic Safety (CAPSS) recommended mandatory soft-story retrofit program.

*Estimated increase in shelter-in-place capacity: 5 to 6 percent*[28]

As SPUR noted in its 2009 Resilient City series of report, the single most important step San Francisco can take to increase its resilience is to adopt a mandatory retrofit program for wood-frame soft-story buildings with three stories or more and five units or more.

The Department of Building Inspection recently completed a study as part of CAPSS that recommends a mandatory evaluation of these buildings, followed by mandatory retrofit for those buildings that are found to have a soft-story condition. If all wood-frame soft-story residences in the city with three or more stories and five or more residential units were seismically retrofitted, we estimate that 80 percent of city residents would be able to shelter in place after a magnitude 7.2 San Andreas earthquake.[29] This represents a 5 to 6 percent improvement over where the city stands today. SPUR recommends implementing the CAPSS recommendations as soon as possible.

## 3. Develop a soft-story retrofit program for smaller soft-story buildings.

*Estimated increase in shelter-in-place capacity: 6 to 9 percent*

While CAPSS focused on wood-frame soft-story buildings of three stories or more with five units or more, smaller wood-frame soft-story buildings also pose a major challenge to San Francisco's resilience. These buildings occur in large numbers in the Sunset and Richmond districts, both of which are highly vulnerable to the expected earthquake. We recommend developing a retrofit program for these buildings as well. Wood-frame soft-story buildings with three and four units would be responsible for about one-third of all unusable housing units after the expected earthquake. Wood-frame soft-story single-family houses and duplexes would account for another 20 percent of unusable units.

## 4. Develop retrofit programs for other vulnerable housing types that impact San Francisco's resilience and also have the potential to severely injure or kill people.

*Estimated increase in shelter-in-place capacity: 1 percent*

There are a number of building types used for housing, such as non-ductile concrete buildings and unreinforced masonry buildings, that will not be able to serve as shelter-in-place housing and also have the potential to suffer significant damage, causing injury and loss of life. Non-ductile concrete buildings are found in a variety of different neighborhoods, everywhere from relatively wealthy parts of Russian Hill to the Tenderloin and Chinatown. However, we do not currently know how many residential non-ductile concrete buildings exist in the city or where they are located. The city should begin by developing a reliable inventory of these buildings. Some non-ductile concrete buildings can be very difficult and expensive to retrofit, but they nonetheless require attention because of the harm they could cause. Due to the complexity of some of these retrofits, it might make sense to start with evaluating these buildings and notifying owners and occupants of the findings.

28 These estimates were developed using available data and engineering assumptions. Data sources include CAPSS ATC 52-1, CAPSS ATC 52-3, the Department of Building Inspection Housing Database and the 2000 U.S. Census, among others. Multiple sources were used to estimate the number of units by structure type and size, and these sometimes presented conflicting information. Because conservative assumptions were used to estimate retrofit effectiveness, it is possible that retrofits may be more effective than stated above at improving the number of units available for shelter in place after the expected earthquake.

29 This assumes a high standard of retrofit, referred to as Retrofit Scheme 3 in the CAPSS report *Here Today, Here Tomorrow: Earthquake Safety for Soft-Story Buildings* (ATC 52-3). There are 4,400 wood-frame buildings with three or more stories and five or more units in San Francisco, an unknown number of which have a soft-story condition.

### 5. Focus on developing an interim-housing strategy for San Francisco.

The city should complete its interim-housing planning process and adhere to its objectives: first, to keep as many residents as possible in their homes; second, to keep residents within their neighborhoods; third, to keep people within the city; and finally, if residents are relocated, to have a plan to bring them back. As noted previously, our analysis shows that several neighborhoods in San Francisco, including the Marina, the Richmond, the Western Addition and others, are likely to experience high housing losses if the expected earthquake occurs before housing stock is retrofitted. Some of these districts, such as the Western Addition and the Mission, are also home to low-income and other vulnerable populations, which may pose additional challenges to recovery. It is important to develop interim-housing strategies that keep residents as close as possible to their pre-earthquake neighborhoods and that can be tailored to address neighborhood-specific conditions.

Degenkolb Engineers

## Paying for Mandatory Mitigation: Soft-Story Wood-Frame Apartment Buildings

In this report, SPUR recommends a mandatory retrofit program for soft-story wood-frame buildings of three stories of more and five units or more. These are the class of buildings studied by the Community Action Plan for Seismic Safety. In 2010, then-mayor Gavin Newsom convened a task force to help implement this recommendation. The task force drew on cost analyses provided by CAPSS that stated that the cost of retrofitting these buildings would average between $13,000 and $19,000 per unit.[30] Phasing in the requirement over time will enable property owners to plan for this future expense. In addition, there has been discussion of creating a financial incentive program similar to the Property Assessed Clean Energy (PACE) program for green building retrofits, in which owners can opt to join a Mello-Roos bond district to receive financing at favorable rates that can be repaid even after an owner has sold his or her building. SPUR hopes the city continues to pursue this important incentive program.

While the costs of completing retrofits may seem expensive, they need to be weighed against the costs of doing nothing. CAPSS has estimated that if these soft-story wood-frame buildings are not retrofitted, the city will face $4.1 billion in losses when the expected earthquake strikes. If the actual earthquake is more extreme than our scenario earthquake, the loss estimates will be higher.[31]

30 CAPSS, *Here Today, Here Tomorrow*, page 28.

31 *Ibid*., page 15.

# Seismically Vulnerable Structures: **An Engineer's Rogues' Gallery**

Modern earthquake-resistant design is only about 50 years old. As a young discipline, it still grows in spurts after each damaging event. Just as unreinforced brick buildings were recognized as widespread hazards in the 1930s, certain newer building types, including structures of all sizes and materials, are now known to be vulnerable.

All photos courtesy Degenkolb Engineers

**Unreinforced masonry building.** These brick and mortar buildings have been killing people in California earthquakes since the Gold Rush. Often called URM, unreinforced masonry was prohibited after the 1933 Long Beach earthquake, but thousands of older buildings remained. The most common hazard involves unbraced parapets falling onto sidewalks and peeling the upper walls away from the roof. San Francisco adopted a parapet ordinance in 1969, but parapets are not the whole problem. In 1986, state legislation required jurisdictions in highly active seismic zones to adopt mitigation measures. San Francisco's 1992 URM ordinance was adopted after the Loma Prieta earthquake.

**Soft-story wood-frame.** An abundance of wall openings in the first story, typically for garage bays or storefront windows, makes these buildings vulnerable to collapse when the flexible first story sways sideways. This class includes apartment buildings with ground-floor parking. Many of San Francisco's soft-story buildings are further complicated by hillside conditions and by extensive openings along more than one side.

**House over garage.** This is the smaller, single-family version of the soft-story problem. Outside San Francisco, this type of structure is often a ranch house with a two-car garage. San Francisco has its own examples, particularly in the Richmond and Sunset districts. On a 25-foot lot, there is usually enough wall area, even with a garage opening and a wide main entrance, to accommodate a decent retrofit sufficient to stiffen the structure, preventing collapse and — just as importantly — maintaining habitability.

**Non-ductile concrete frame.** Ductility is the property that allows a structure to bend without breaking. In concrete, it's achieved by careful design of the embedded steel reinforcing bars — a lesson learned from the collapse of several relatively new concrete buildings in the 1971 San Fernando earthquake. Most pre-1980 concrete structures are therefore suspect, but it's unclear how many should be considered potential killers. Unlike URM or soft-story buildings, NDC structures are hard to spot from the sidewalk, and their evaluation and retrofit can require relatively sophisticated engineering.

**Tilt-up.** Relatively cheap and fast to build, tilt-ups remain the structural system of choice for one-story warehouses, strip malls and light-industrial facilities. The chief weak spot in pre-1995 tilt-ups is the connection between the rigid walls and the flexible roof. When that connection fails, the concrete wall panel falls away from the building and the roof collapses. Similar buildings with reinforced concrete block walls often have the same vulnerability.

**Cripple wall.** The cripple wall is the short wood stud wall around a house's crawl space. With no stiff plaster finishes or room partitions in the crawl space, perimeter cripple walls are inadequate to support the swaying house above. As in a soft-story building, the cripple walls lean, then fall over. Though rarely life-threatening, a cripple-wall collapse displaces a family and destroys its chief economic asset. Cripple walls are easily and effectively retrofitted by adding plywood sheathing inside the crawl space.

**Nonstructural components.** Any part of a building that's heavy, brittle or loosely attached, even if it carries no structural loads, is vulnerable to earthquake damage. The heavy parts — chimneys, brick veneer, concrete cladding panels — can be life-threatening. Gas lines and gas-fired equipment can start fires. The rest — light fixtures, plumbing and sprinkler lines, HVAC equipment, shelving and so on — can take a building out of service, disrupting operations and delaying recovery.

# **Section II:**
# What engineering criteria should be used to determine whether a home has adequate shelter-in-place capacity?

Seismic evaluation is not like a smog check. There is no law requiring an existing building to be evaluated every few years. Even when the building code for new construction changes, new regulations are not retroactive. Consequently, most San Francisco buildings, while legally occupied and quite safe in day-to-day conditions, do not meet the current seismic codes for new buildings — and are not required or expected to do so. Only when a building undergoes a triggering event such as an addition, alteration, repair or change of occupancy is it likely that it will be evaluated for earthquake performance and, if highly deficient, subject to retrofit. There are some exceptions. San Francisco's unreinforced masonry buildings have been subject to mandatory evaluation and retrofit since 1992. And many owners and tenants voluntarily evaluate their buildings, but this voluntary work is typically not required to meet any upgrade standard.

Whether mandated by ordinance or triggered by the building code, seismic evaluations in San Francisco use criteria based on structural safety alone. With few exceptions, the criteria consider only whether the building would threaten lives by collapsing or would suffer severe damage during an earthquake. The criteria do not require an explicit consideration of whether a damaged building would be safe to reoccupy or how long it might have to remain vacant while undergoing repairs.

SPUR recognizes that San Francisco's resilience requires more than basic safety during the earthquake. It requires that buildings remain habitable and repairable so that occupants can shelter safely in them even before repairs begin.

To support the move to resilience-based earthquake planning, the city should revisit its existing structural-evaluation criteria. Specifically, the city needs to determine what shelter-in-place means from an engineering perspective and to develop criteria for analyzing now, before the earthquake, whether a building is likely to serve as shelter-in-place housing afterward. The purpose of this section is to discuss what shelter-in-place capacity means in engineering terms and to outline the engineering criteria that building owners and policymakers might adopt for pre-earthquake shelter-in-place evaluations.

32 Comerio, Mary C., "Performance Engineering and Disaster Recovery," in *Bracing Berkeley: A Guide to Seismic Safety on the UC Berkeley Campus* (Pacific Earthquake Engineering Research Center, January 2006).

## The need for shelter-in-place criteria

When and why would a shelter-in-place evaluation be done? The short answer is: in the same cases and for the same reasons that safety-based evaluations are done now. An overarching theme of SPUR's Resilient City initiative is that planning and regulatory priorities should shift from personal safety to community resilience. Thus, wherever current programs, regulations or ordinances call for seismic evaluation or upgrade, that work should (or could) be based on shelter-in-place capacity instead of on safety alone. If new programs are put in place to improve citywide resilience, they would use shelter-in-place engineering criteria as well.

Seismic work (i.e., evaluations and upgrades) can be classified as voluntary, mandatory or triggered. Each type of project or program could use shelter-in-place engineering criteria, as opposed to provisions that look solely at safety.

The good news is that much voluntary work already prioritizes reoccupancy and recovery. UC Berkeley, for example, recognized that even if its buildings have been deemed safe, not being able to use them during repairs could jeopardize the university's mission, so it adopted an earthquake recovery goal to limit closure to no more than 30 days.[32] In the housing sector, however, voluntary work for shelter-in-place or recovery purposes is rare. Where it does occur, it is done without a commonly adopted standard and without the benefit of plans that have been checked and approved by the building department, because voluntary work falls outside the scope of most building regulations. Further, even if the city's plan-checkers and inspectors were to certify voluntary work, they currently have no criteria by which to judge a shelter-in-place evaluation or retrofit.

While a shelter-in-place evaluation is in some ways a prediction of a building's performance during and after an earthquake, it is important to recognize that actual post-earthquake reoccupancy will depend on the nature of ownership and on individual owners' or tenants' choices about whether to stay or leave. In owner-occupied housing, the owner is more likely to tolerate (or waive liability for) certain damage, so reoccupancy is likely to happen sooner. But an owner of rental housing might not allow tenants to reoccupy the building if remaining damage would increase the owner's liability or if reoccupancy would delay building repairs or increase their cost. Rent control will also play a significant role in the choices made by both renters and owners.

The evaluation criteria recommended here do not account for these variables. The best strategy for promoting reoccupancy might not have much to do with engineering standards; we encourage the city to work with owners to incentivize quick reoccupancy through Good Samaritan laws or otherwise waive liability or relocation penalties.

# Voluntary, Mandatory and Triggered Seismic Work

Voluntary shelter-in-place improvements would benefit from defined standards, just as voluntary safety improvements have. For example, many California jurisdictions have endorsed standards for the voluntary retrofit of houses with unbraced cripple walls. (See "Seismically Vulnerable Structures: An Engineer's Rogues' Gallery" on page 20.) While the work remains voluntary, the availability of standards helps to stabilize the market for builders, provide a measure of consumer protection for owners and set precedents for incentive programs run by insurers or jurisdictions. In the same way, even where shelter-in-place retrofits are only voluntary, standards will benefit all stakeholders and will help signal the city's new priorities to the community.

Mandatory programs traditionally address only the most persistent and most critical risks. California's hospital-retrofit program, for example, recognizes the need for safe and functional buildings,[33] but of course it is limited to only a relatively few essential facilities. San Francisco's unreinforced masonry program also mandates retrofit, but it applies only bare-bones safety criteria, with little expectation of post-earthquake habitability. Plus, it exempts small residential buildings. Most residential structures, whether masonry, wood, steel or concrete, have never been subject to mandatory retrofits.

For community resilience, however, post-earthquake housing becomes critical, and SPUR has urged the city to adopt a mandatory retrofit policy for certain highly vulnerable multi-unit buildings.[34] If such a mandate is implemented, engineering criteria will need to come with it, and if the purpose of the mandate is to improve citywide resilience, those criteria will likely need to be based on shelter-in-place goals.

Triggered work provides the type of policy lever that could be used to ensure that retrofits occur. San Francisco's building code triggers seismic evaluation when a major project — an addition, alteration, repair or change of occupancy — would significantly extend the building's life. (Condominium conversions do not trigger seismic evaluation. Homeless shelters are also exempt.) Triggered seismic work does not occur on a specified timeline, and code triggers by themselves are probably not an effective way to do mitigation citywide. Still, when they do result in seismic work, that work is currently done with safety-based criteria. If the city were to embrace resilience as a goal, it could modify its code provisions to ensure that when seismic work is triggered, the repairs meet shelter-in-place standards.

33 "Seismic Compliance Senate Bills 1953, 1661, and 499," Office of Statewide Health Planning and Development, www.oshpd.ca.gov/FDD/seismic_compliance/index.html

34 SPUR, "The Resilient City, Part I: Before the Disaster," *The Urbanist*, February 2009, 4.

photos by flickr user johnclarkemills

# Assessing the expected performance of individual buildings before the earthquake

While shelter-in-place capacity is needed after the earthquake, the ability to assess an individual building's expected performance must be done beforehand. What engineering criteria should be used, prior to the event, to determine whether a house, apartment building, condominium or other housing facility has shelter-in-place capacity adequate for a magnitude 7.2 San Andreas earthquake?

We recommend that feasible shelter-in-place evaluation criteria should be based on existing standards already familiar to practicing engineers and code officials. Those standards should take into account:

- Cost-effective procedures (as opposed to relying on complicated analysis)
- The range of residential structure types in San Francisco
- Differences between new and existing structures (unlike most building code provisions)
- Nonstructural conditions that affect shelter-in-place habitability

This report recommends the use of the national standard called "Seismic Evaluation of Existing Buildings,"[35] also known as ASCE 31.

To determine whether a building has shelter-in-place capacity, the ASCE 31 criteria should be modified to consider only the types of damage that could be critical obstacles for sheltering in place. The criteria should reference approved maps of relevant hazards and expected infrastructure performance.

### What Is ACSE 31?

In this report, we refer to ASCE 31, a national standard for the seismic evaluation of existing buildings that was developed by the American Society of Civil Engineers. ASCE 31's main feature is a set of checklists that guide the engineer to look for critical deficiencies in a building's structure, architecture and systems, based on observed damage patterns from past earthquakes. With these checklists, supplemented by engineering calculations, a building can be evaluated with respect to how we can expect it to perform in a future expected earthquake: whether it will likely be safe and occupiable (Immediate Occupancy); safe and repairable (Life Safety); or not safe due to possible collapse, falling hazards, fire or hazardous materials release. Because ASCE 31 does not directly address the question of shelter in place as we define it here, we are proposing ways to adapt it to this new thinking about earthquake resilience.

This approach — i.e., modifying a national standard to make it applicable to certain performance objectives — has precedent. California's Office of Statewide Health Planning and Development (OSHPD) and Division of the State Architect (DSA) have used this strategy for the mandatory evaluation and retrofit of hospitals and for voluntary evaluation of K-12 schools, respectively. To implement this approach, SPUR's performance objectives — both the magnitude 7.2 scenario earthquake and the shelter-in-place standard — must be translated into terms used within ASCE 31, particularly "hazard level" and "performance level":

## Hazard level

We have based our shelter-in-place objective on the scenario of a magnitude 7.2 earthquake on the peninsula segment of the San Andreas Fault. While a scenario event is useful for planning and for policy development, and while a scenario can capture realistic aggregate effects over a large area, scenarios are not traditionally used for the evaluation or retrofit of individual buildings. Instead, a given building is analyzed for site-specific hazards that account for the relative possibilities of different events on different fault systems. For example, ASCE 31 considers impacts of earthquakes on both the Hayward and San Andreas faults.

Therefore, to encourage the engineering community to adopt SPUR's recommendations, we recommend using the same site-specific earthquake hazard parameters specified by ASCE 31, which match those of the building code for new construction. The ASCE 31 earthquake hazard level should be reduced to account for differences in the size of the earthquake we are planning for and the fact that we are converting a single scenario earthquake (for the whole city) to a site-specific hazard (for individual buildings).

For a more technical discussion of how to adjust ASCE 31, see Appendix II, page 36.

## Performance level

The SPUR objective identifies a new performance level not found in current engineering codes or standards, that of shelter in place. ASCE 31 defines two performance levels, Life Safety and Immediate Occupancy. As the terms suggest, a building that meets the standards for Life Safety performance avoids collapse, major falling hazards, hazardous materials release and other life-threatening damage, but it can suffer potentially high levels of repairable damage, especially to nonstructural components. A building that meets Immediate Occupancy performance standards avoids damage or the loss of services that would substantially delay recovery. Since shelter in place will be defined in terms of both safety and restoration of services, the shelter-in-place performance level will combine aspects of ASCE 31's Life Safety and Immediate Occupancy criteria. For a further definition of the performance levels in ASCE 31, see Appendix II.

35 *Seismic Evaluation of Existing Buildings* [ASCE/SEI 31-03], (American Society of Civil Engineers, 2003).

## Quick, cost-effective evaluation

Pre-earthquake evaluation criteria will help owners and tenants assess their individual buildings and, if applied through city inventory programs, will help the city gauge the overall shelter-in-place capacity of its housing stock. To be effective, however, the criteria must be usable without costly or sophisticated analysis. We recommend the checklist-based criteria that ASCE 31 calls its Tier 1 procedure, although the ASCE 31 checklists will need to be modified to suit the shelter-in-place objective. Further, in order to avoid the costs and other disincentives associated with some site investigations, the city should replace certain generic ASCE 31 provisions with its own versions or with simple maps.

The necessary modifications are discussed in Appendix II. In brief, they include developing:

- Factors relating the building code's design earthquake to the shelter-in-place scenario earthquake, i.e., the expected earthquake.
- A map of soil site classes, to avoid the need for site-specific investigation.
- A map of liquefaction and slope-stability hazards, again to avoid the need for site-specific investigation. Where the likelihood of liquefaction or slope instability is high, further investigation of the structure is probably moot, as the ground deformation will render the building uninhabitable.
- The subset of potential structural deficiencies associated with buildings declared unsafe under a formal building evaluation known as ATC-20. (See page 29.)
- The subset of potential nonstructural deficiencies that would affect shelter-in-place capacity. Examples include chimney collapse, broken windows or damage to heating systems or piping. These would be linked to expected repair times and coordinated with the post-earthquake habitability requirements described in Section III of this report.

# Section II Recommendations

In order to determine what percentage of San Francisco's housing stock will meet shelter-in-place standards, the city needs to develop evaluation criteria for voluntary, mandatory and triggered seismic work on residential buildings.

### 6. Further develop shelter-in-place evaluation criteria for voluntary, mandatory and triggered seismic work on residential buildings.

We have described one approach to developing shelter-in-place evaluation criteria. However, much work is yet to be done. SPUR recommends that the City Administrator's Office, the Department of Building Inspection and Department of Emergency Management jointly take the following steps to further develop shelter-in-place evaluation criteria:

- Convene an internal stakeholder working group, with technical consultants as needed, to set broad guidelines for applying ASCE 31 to building evaluations based on shelter-in-place criteria.
- Assign staff, with technical consultants as needed, to develop specific modifications to ASCE 31 that implement the broad guidelines by editing the engineering procedures and criteria and by adopting certain default values and data appropriate to San Francisco. (See Appendix II for a detailed list of issues that will need to be resolved.)
- Have the San Francisco Lifelines Council urge utility providers to estimate outages by neighborhood for planning purposes.

### 7. As draft criteria are developed, generate a new loss estimate for the magnitude 7.2 San Andreas and other scenario earthquakes.

As discussed in Section I, our best estimate of housing loss and its impact on recovery is based on the CAPSS data. But that loss model does not account specifically for what we have now defined as shelter-in-place performance. With the new definition in place, and with draft engineering criteria in progress, the Department of Building Inspection and the Department of Emergency Management should undertake a new loss estimate focused on shelter-in-place performance. These new loss estimates will be needed for the benefit-cost models and Environmental Impact Report studies that will precede and support mitigation programs and legislation.

# Section III:
## What needs to be done to enable residents to shelter in place for days and months after a large earthquake?

After an earthquake, we want San Franciscans to shelter in place in their homes. Yet, while a building may be structurally safe enough to occupy following a seismic event, it may be considered unsafe or substandard under the applicable codes,[36] because it won't meet the existing minimum standards for health and safety for residential housing in non-emergency times. How do we set a post-earthquake standard that is "safe enough" yet not so stringent that people are told unnecessarily to vacate their homes to find temporary shelter? SPUR believes it is critical to define alternative shelter-in-place housing standards that allow people to stay in their homes safely but don't deem otherwise safe buildings unsuitable for occupancy. These alternative standards would supersede regular code requirements during a housing-emergency period declared by the city after a major earthquake. Such an emergency period might extend for days, weeks or longer.

Shelter-in-place alternative standards could significantly reduce emergency-shelter and interim-housing needs while maintaining the local population base necessary to support recovery. The alternative standards should become more stringent as San Francisco recovers after the earthquake and should remain in force until the city's housing stock is completely restored.

Shelter-in-place standards should be "phased," with the expectation that repairs need to be made over time to restore habitability. For example, certain standards that will be considered acceptable immediately following the earthquake (such as using portable outdoor toilets) will not be acceptable three months after the earthquake. The shelter-in-place standards should define which needs will be met by the building itself and which will be met outside the building for each time phase. Those resources that must be accessible outside the building will have to be provided in a neighborhood service center located in close proximity to shelter-in-place housing.

Even if all of the alternative standards are met, however, people may choose not to shelter in place. There is no obligation under these alternative regulations for any person to remain in any residence; any person might choose to relocate to emergency or temporary shelter, move to an undamaged facility or make other arrangements.

36 The minimum standards for health and safety for residential occupancy at non-emergency times are detailed in the California Health and Safety Code and in the San Francisco Housing Code.

Figure 5 illustrates the idea of alternative habitability standards that would apply in emergencies and gradually revert to normal code requirements. The blue line represents the code standards for habitability that normally apply. When an earthquake occurs, some damage might result, but if the damage is light, it will not affect the city's overall resilience, so no relaxation of the normal standards would be justified. A declared housing emergency, however, indicates that damage — and possibly housing loss — is significant enough to justify special measures to speed response and recovery. The stepped red line represents the minimum standards to be met within a residence. The pink shaded area represents resources that a neighborhood service center provides outside the home. The red shaded area represents the actual loss of habitable housing. As repairs are made, buildings (and housing standards) return to normal.

One of the challenges in developing and implementing shelter in-place standards is that these alternative standards do not correspond with any currently adopted standards in San Francisco's Building Code, Housing Code or other codes. Once San Francisco has adopted shelter in place as a performance goal for new and/or existing buildings, local building codes will need to be amended.

### Minimum habitability requirements for occupancy after the earthquake

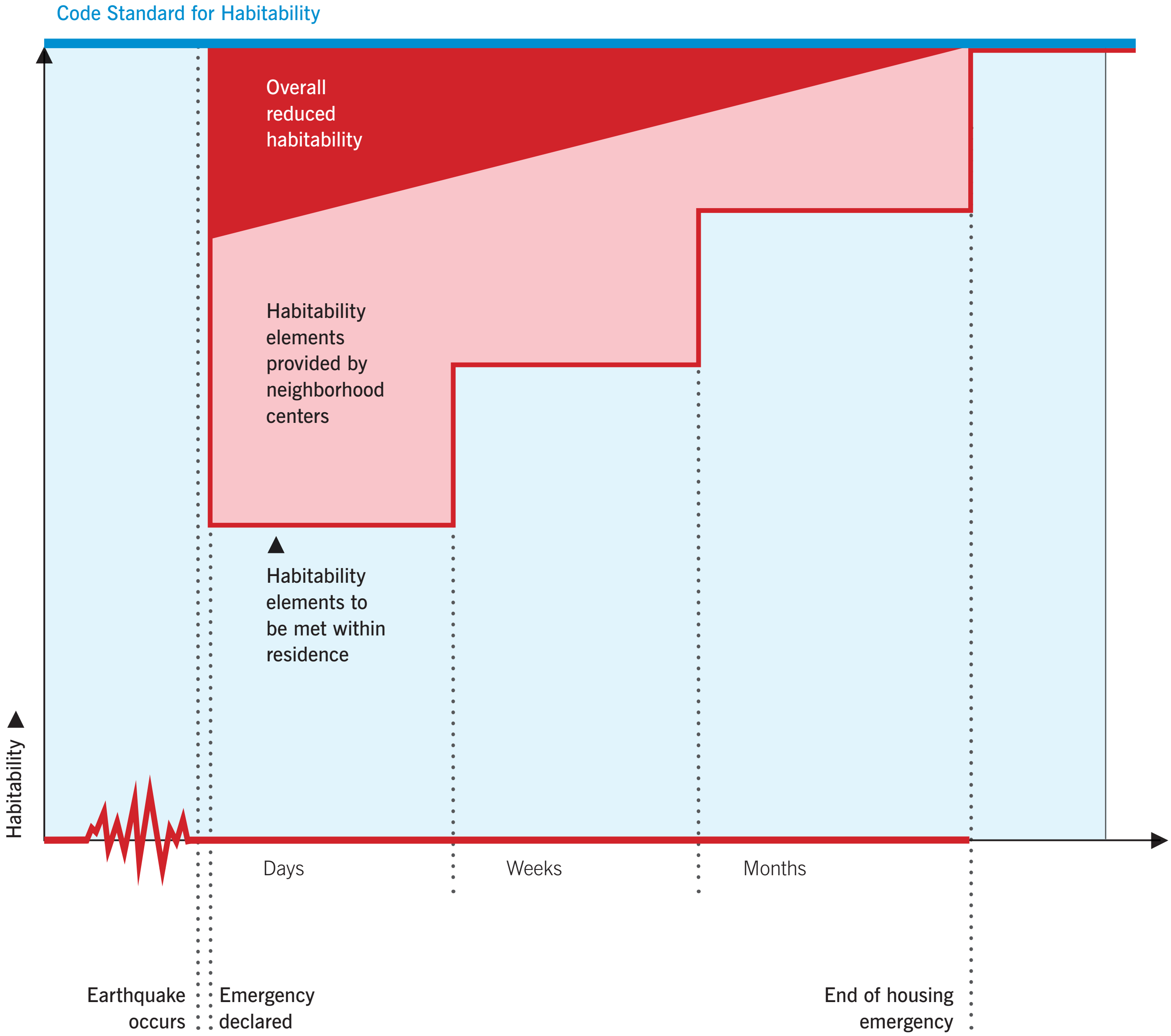
When should a building be considered acceptable for shelter in place? Conditions that are adequate right after the earthquake may not be acceptable one to three months down the road. SPUR has identified five different post-earthquake time periods and defined the major habitability requirements for each:

1. The immediate post-earthquake period
2. One week after the earthquake
3. One month after the earthquake
4. Three months after the earthquake
5. After the declared housing emergency is over

Increasingly robust habitability standards will need to be met in each phase, as described in Figure 6 (page 28).

## Figure 5: Phased Habitability Standards Following an Earthquake

After an earthquake, even housing that is safe enough to occupy will not meet existing codes. A phased standard needs to be defined in this post-earthquake period, where requirements are gradually increased until the housing emergency is over.




Source: SPUR analysis

## Figure 6: An Alternative Habitability Standard

In the post-earthquake period, an alternative habitability standard will need to be defined. This standard will need to take into account the safety of the housing unit, the need for weather protection and the availability of utilities.

| | |
|---|---|
| **Immediate post-earthquake period** | |
| The building must be safe. | Safety will be defined by an engineering tool (ATC-20) that has been modified by the city. Residents will not be permitted to occupy buildings or portions of buildings posted as unsafe. Prior to a formal inspection by an authorized person, owners and tenants may self-inspect using a simplified checklist to be provided by the city. |
| There must be at least one usable exit path from every occupied area. | Inclined counterbalanced fire escapes that are fully operational may be used to provide the one clear exit path. It's also acceptable to use a path that's currently blocked by building contents or other nonstructural elements but that can readily be cleared. |
| **One week after the earthquake.** *Meet all the conditions above, plus the following:* | |
| Portable fire extinguishers | Must be in place if required for multifamily residences. |
| Weather protection: roof | May be a temporary plastic covering. |
| Weather protection: walls | May be a temporary plastic covering. |
| Weather protection: windows | May be a temporary plastic covering. |
| Provision of a building address | May be a temporary address placard. |
| Smoke detectors | Battery-powered okay. |
| CO2 detectors | Battery-powered okay. |
| Elevators in buildings of five or more stories | Must work seven days following restoration of electrical service. |
| **One month after the earthquake.** *Meet all the conditions above, plus the following:* | |
| Electricity | Must work 30 days following restoration of service. |
| Gas | Must work 30 days following restoration of service. |
| Sewer and toilet | Must work in home 30 days following restoration of service. Where sewers are not working or pipes are leaking, waste must be bagged, treated with chemicals and disposed of according to local instructions. For more information, see sewersmart.org/disrupted.html |
| Water | Must work 30 days following restoration of service. |
| Fire alarm systems and other required alarms | Must work 30 days following restoration of electrical service. |
| Emergency exit illumination | Must work 30 days following restoration of electrical service. |
| Electrical light: at least one fixed or cord-and-plug type per room | Must work 30 days following restoration of electrical service. |
| Hot water supply | Must work 30 days following restoration of service of water and gas/electric. |
| Refrigeration for food | Must work 30 days following restoration of electrical service. |
| **Three months after the earthquake.** *Meet all the conditions above, plus the following:* | |
| Automatic fire sprinklers, sprinkler wet standpipes and fire pumps | Must work 90 days following restoration of water service. |
| Entrance doors and hardware/locks | Must work 90 days after the earthquake. |
| Second exit, if required | Fire escapes are acceptable as second exits. |
| Heating service | Must work 90 days following restoration of utility service. |
| **After the housing emergency is over.** *All normal habitability requirements will apply at the end of the declared housing-emergency period.* | |

Source: SPUR analysis

## Building evaluation and inspection

After a major earthquake, engineers and design professionals come from all over the country to help conduct formal building inspections using what is known as the ATC-20 evaluation procedure. They evaluate building structures and tag them depending on their level of damage: Red tags mean a building is unsafe and should not be entered or occupied; yellow tags indicate restricted use, meaning a building either requires further evaluation or is okay to occupy except for designated areas; and green tags mean that no unsafe conditions were found or suspected.

Shelter-in-place evaluations are not a building tagging program; instead, they will provide immediate guidance for residents as to whether nonstructural and related conditions make a building suitable or unsuitable for continued occupancy. Residents will need to review shelter-in-place conditions within 24 hours of an earthquake so that they know whether they can remain in their homes. Meanwhile, it may take several days or weeks for inspectors and design professionals to undertake ATC-20 evaluations.

Shelter-in-place standards need to be clear enough so that most residents will be able to assess their own buildings. But many residents will need help applying shelter-in-place standards to their buildings while they wait for design professionals to complete an ATC-20 evaluation. Community volunteers can be trained to help residents determine if their home meets shelter-in-place standards.

In many areas of the city, certain buildings will have minimal damage while neighboring buildings will be structurally unsafe. In buildings that appear to have substantial structural damage, residents will need to wait for a formal ATC-20 structural inspection by a designated city inspector before sheltering in place.

**Enforcement of shelter-in-place standards and requirements for repair**

Enforcing shelter-in-place standards is key. The city should use its enforcement power to ensure that property owners make repairs in compliance with the phased habitability standards described above. The responsibility rests with the property owner to provide for repairs and the restoration of habitable conditions.

Properties that are abandoned or otherwise fail to meet legal requirements for property repair, retrofit or maintenance should be subject to the enforcement and abatement provisions of the applicable San Francisco codes.

Kousaku Maeda, courtesy Kobe University Library

flickr user kosmoskipo


Lori Peek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# Section III Recommendations

A post-earthquake alternative habitability standard should be established and implemented in order to encourage residents to shelter in place. The following recommendations will help to achieve this goal.

## 8. Create an interdepartmental shelter-in-place task force.

The Mayor's Office should create an interdepartmental shelter-in-place task force. This task force will ensure coordination with the Department of Building Inspection, the San Francisco Fire Department (which has joint jurisdiction on multifamily housing and must agree and cooperate with regard to shelter-in-place standards), the Department of Public Health and the Department of Emergency Management. Other agencies that should be involved include the Department of Public Works, the Mayor's Office on Disability and the Mayor's Office of Housing, among others.

## 9. Prepare and adopt regulations that allow for the use of shelter-in-place habitability standards in a declared housing-emergency period.

Shelter-in-place standards may be adopted in advance of an emergency or be completed and ready to adopt as part of the city's emergency measures. Various agencies should adopt administrative bulletins and similar regulations that detail how code requirements and policies will need to be implemented. These should include complaint, inspection and enforcement procedures.

During a declared emergency, a separate housing emergency may also be declared, which would allow the enforcement of the alternative shelter-in-place habitability standards. A declared housing emergency may continue as a special emergency period past the general declared emergency period and may be applied to specific areas where housing is most severely impacted.

## 10. Develop a plan to implement a shelter-in-place program.

This implementation plan should include creating public training materials, coordinating with existing post-disaster building-evaluation procedures and stockpiling the materials needed to achieve shelter in place in the post-disaster period.

**A. Preparing public training materials**
The interagency task force recommended above should develop simple and clear training materials for residents to help them determine whether or not they can shelter in place. These should include a set of graphic illustrations and a shelter-in-place checklist, which should be incorporated in outreach and training materials to building owners and residents to inform them of shelter-in-place habitability requirements, standards, inspection procedures and repair expectations. The training materials could also include such elements as door tags that say, "I'm Okay!" or "I Need Help." Additionally, residents could receive special training in shelter in place prior to an event, much like the current Neighborhood Emergency Response Team (NERT) program.

**B. Coordinating with existing post-disaster evaluation procedures**
After an earthquake, professionals will come from all over the country to help evaluate buildings using the ATC-20 evaluation procedure. If San Francisco's evaluation procedures are modified to focus on shelter in place, ATC-20 inspectors will need to be trained in San Francisco–based shelter-in-place habitability standards. This training can be done when ATC-20 inspectors check in with the Department of Building Inspection before being released into the field to conduct inspections.

**C. Storing materials necessary to allow shelter-in-place standards to be met**
The city will need to have certain materials, such as plastic sheeting for weather protection, on hand for use after a major earthquake. SPUR recommends that the Department of Building Inspection, the Department of Emergency Management and the Department of Public Health coordinate to develop a list of these materials and the quantities that will be needed.

## 11. Develop plans for neighborhood support centers to provide necessary help for shelter-in-place communities.

Neighborhood support centers are not emergency shelters. Rather, they are resource centers that encourage people to stay in their homes by providing essential services and information. A store, restaurant, small business, religious or social facility could provide the necessary space, but a large garage or other covered area could also suffice. These neighborhood support centers will need to be staffed and equipped to offer the following services, or quick contact with such services[37]:

- Information, news and general neighborhood communication and contact
- Telephone, digital, postal and other communication services
- Volunteer assistance in conducting shelter-in-place evaluations (on-site or immediately available when required)
- Referrals to community service organizations and agencies
- Distribution of supplies, water and food
- Refrigeration for critical supplies (medication, etc.)
- Connection to services such as laundry facilities
- Electrical supply, including electronics-charging facilities
- Emergency, basic and major medical care

37 For a full list of services needed in neighborhood support centers, see Appendix III, page 42.

# **Section IV:** Applicability to other jurisdictions

San Francisco is not the only jurisdiction in the Bay Area that is at risk of a seismic event. The United States Geological Survey estimates that there is a 63 percent chance of a major earthquake occurring in the Bay Area some time in the next 30 years. The Hayward Fault is the most likely to rupture, causing massive damage in the East Bay.

Much of the work developed for this report and prior SPUR reports is applicable to other seismically vulnerable jurisdictions. Other jurisdictions could implement the following set of recommendations to increase seismic resilience.

### 1. Define resilience and develop a specific target for housing performance.

In our 2009 report "Defining What San Francisco Needs from Its Seismic Mitigation Policies," SPUR developed performance targets for buildings and lifelines, including a goal of 95 percent shelter in place for housing. This approach of setting a defined and ambitious goal for community recovery has resonated with policymakers and the technical community. Other jurisdictions could take these performance targets and adapt them to meet their own needs.

### 2. Complete inventories of vulnerable housing stock.

Creating inventories will be a critical first step. SPUR's analysis and recommendations for San Francisco build on reliable data and loss estimates produced by SPUR committees, the local engineering community and the CAPSS project. Other jurisdictions might need to undertake similar building counts and mapping exercises to relate structure types and geologic hazards to residential occupancies and demographics.

### 3. Develop procedures to retrofit vulnerable housing types.

Building on the work done in CAPSS, San Francisco is developing a detailed program to both evaluate and retrofit soft-story wood-frame multifamily housing with five or more units and three or more stories. Other jurisdictions may have comparable types of vulnerable housing. As San Francisco develops evaluation and retrofit standards, other jurisdictions can adapt these to meet their needs.

### 4. Make use of the shelter-in-place evaluation criteria proposed in Section II of this report.

SPUR has called for the further development of these criteria, which can be applied in other jurisdictions seeking to evaluate their housing stock for shelter-in-place performance. In particular, the proposed criteria apply jurisdiction-specific maps and default values. Other jurisdictions can begin developing similar data now, even as San Francisco works on completing the generic criteria. In addition, San Francisco has worked with FEMA to produce a new engineering methodology specifically for the cost-effective evaluation and retrofit of wood-frame soft-story apartment buildings.

### 5. Build on the work being done by San Francisco's Lifelines Council to analyze utility interdependency.

San Francisco has convened a council of all utility providers with infrastructure serving San Francisco. As part of its work, the Lifelines Council is conducting a study of the interdependency between utilities such as electricity, water, sewer, communications and transportation to uncover potential weaknesses in these systems that could cause cascading impacts after an earthquake if they are not adequately planned for. Once complete, this study will include findings that will be of use to other parts of the region, since many utilities are regional in scope.

### 6. Make use of the post-earthquake alternative shelter-in-place habitability standards proposed in this report.

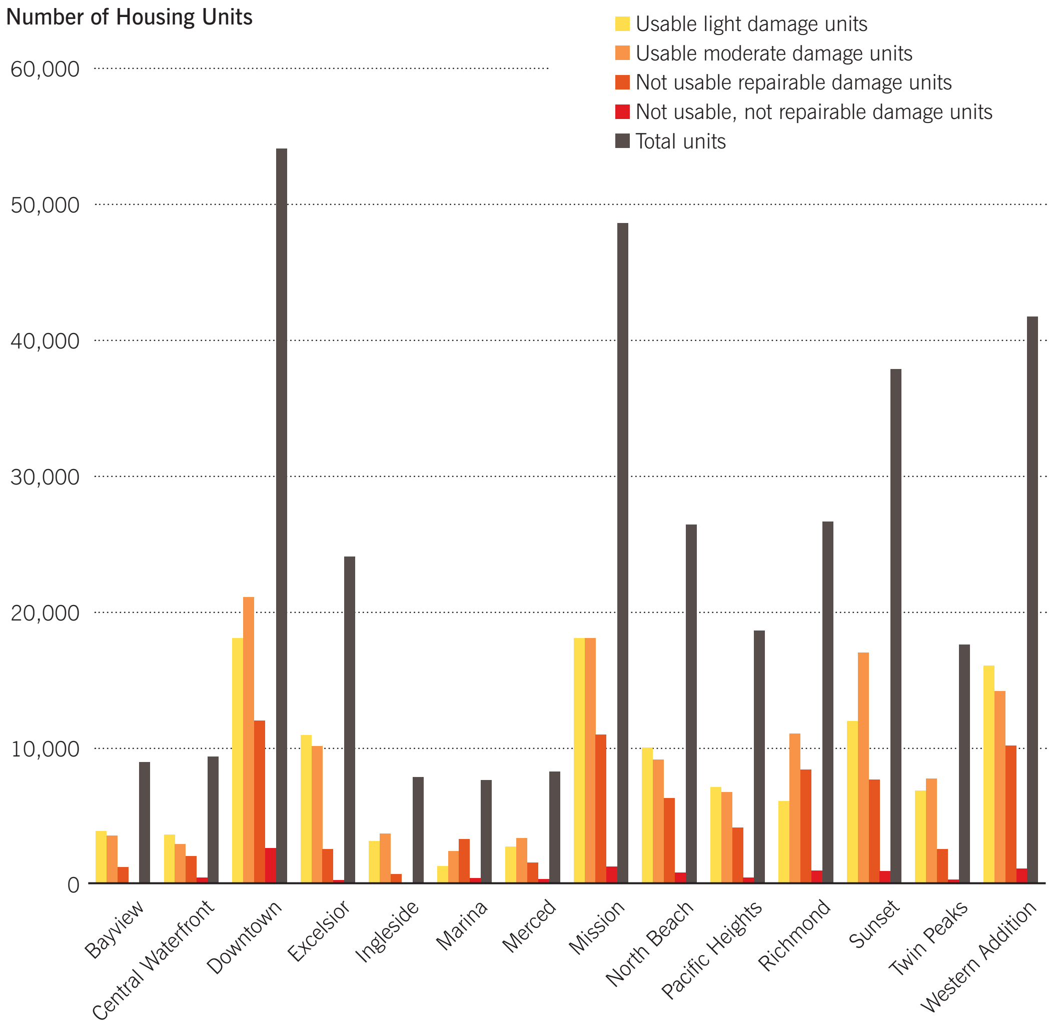
Each jurisdiction will need to develop alternative shelter-in-place habitability standards in order to encourage sheltering in place. The timeline in Figure 6 (page 28) can serve as the basis for these standards. Materials developed in San Francisco (for example, the shelter-in-place graphic illustrations and checklist) can help other jurisdictions create comparable materials.

# Appendix I
## Impacts of the expected earthquake on San Francisco's neighborhoods

Working with data from the Community Action Plan for Seismic Safety (CAPSS), SPUR has estimated the impacts of a Magnitude 7.2 San Andreas earthquake on San Francisco's neighborhoods. We attempted to determine how much of San Francisco's housing would be usable after the expected earthquake, meaning it would meet shelter-in-place standards and be safe enough to be inhabited while being repaired.

**Figure 7: Housing Units in Various Damage States by Neighborhood**

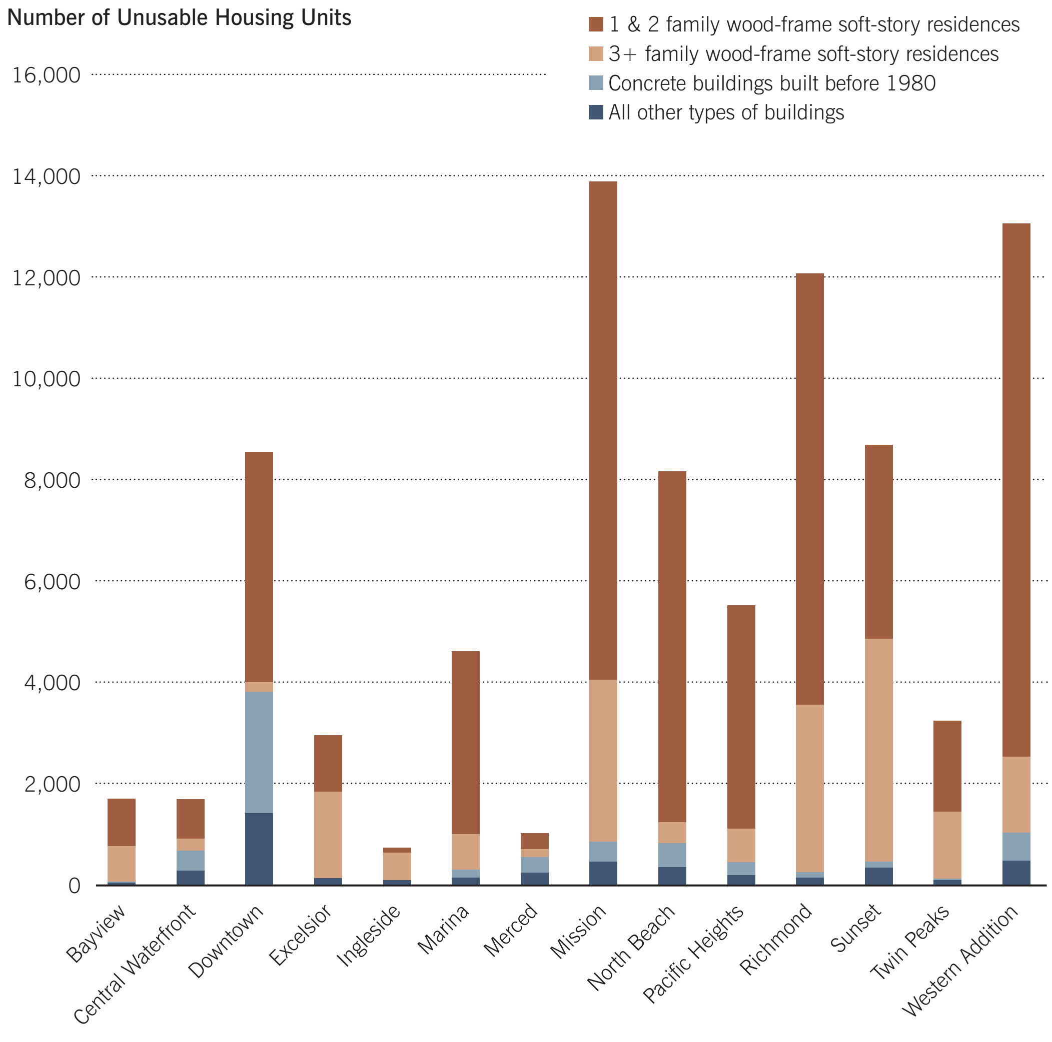
The safety performance of housing stock in different neighborhoods will vary after the expected earthquake. Some housing units will meet shelter-in-place standards, while others will not be usable immediately after an earthquake. A few won't even be repairable in the long term.




Sources: SFGIS, Census 2000 and SPUR analysis of CAPSS Hazus Output Data

## Figure 8: Unusable Housing by Neighborhood and Structure Type

We expect the majority of housing that is declared unusable after the expected earthquake to be wood-frame soft-story residences. Non-ductile concrete buildings will make up a higher percentage in neighborhoods such as Downtown, where there are a greater number of these buildings.




Sources: SFGIS, Census 2000 and SPUR analysis of CAPSS Hazus Output Data

## Figure 9: Demographic Data by Neighborhood

San Francisco's neighborhoods do not just differ by the types of buildings that are found there. They also are home to different groups of people. Any plan to provide emergency or interim housing should take these important demographic differences into account.

| | Population | White | Black | American Indian/Eskimo | Asian | Pacific Islander | Other | Multi Race | Males | Females | Under 5 | Ages 5-17 | Ages 18-21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bayview** | 3,3340 | 3,200 | 16,000 | 140 | 8,100 | 1,200 | 3,300 | 1,400 | 16,000 | 17,000 | 2,400 | 7,700 | 2,000 |
| **Central Waterfront** | 17,220 | 11,000 | 2,700 | 120 | 1,800 | 170 | 700 | 730 | 9,900 | 7,500 | 660 | 1,200 | 540 |
| **Downtown** | 77,220 | 36,000 | 5,900 | 650 | 27,000 | 270 | 3,600 | 3,800 | 44,000 | 32,000 | 1,900 | 4,600 | 3,200 |
| **Excelsior** | 89,810 | 22,000 | 6,100 | 340 | 44,000 | 970 | 12,000 | 4,400 | 44,000 | 46,000 | 5,300 | 15,000 | 4,800 |
| **Ingleside** | 25,820 | 5,600 | 6,000 | 100 | 11,000 | 120 | 1,900 | 1,100 | 13,000 | 13,000 | 1,400 | 4,100 | 1,300 |
| **Marina** | 12,651 | 11,000 | 58 | 22 | 1,200 | 11 | 100 | 260 | 5,700 | 6,600 | 360 | 340 | 93 |
| **Merced** | 17,096 | 8,800 | 780 | 37 | 6,100 | 39 | 430 | 910 | 7,900 | 9,200 | 650 | 1,700 | 2,100 |
| **Mission** | 122,190 | 74,000 | 4,600 | 1,000 | 14,000 | 390 | 21,000 | 7,200 | 66,000 | 57,000 | 5,700 | 13,000 | 4,700 |
| **North Beach** | 48,561 | 24,000 | 630 | 77 | 22,000 | 64 | 590 | 1,200 | 24,000 | 25,000 | 1,300 | 3,200 | 1,200 |
| **Pacific Heights** | 32,896 | 28,000 | 430 | 50 | 3,300 | 46 | 330 | 740 | 15,000 | 17,000 | 1,100 | 1,700 | 460 |
| **Richmond** | 67,723 | 33,000 | 1,100 | 150 | 30,000 | 73 | 1,000 | 2,400 | 32,000 | 36,000 | 2,600 | 7,300 | 2,300 |
| **Sunset** | 100,680 | 46,000 | 1,300 | 220 | 48,000 | 160 | 1,400 | 3,600 | 49,000 | 52,000 | 4,100 | 12,000 | 3,800 |
| **Twin Peaks** | 41,311 | 26,000 | 2,200 | 120 | 9,800 | 91 | 1,300 | 1,800 | 21,000 | 20,000 | 1,700 | 4,300 | 1,000 |
| **Western Addition** | 85,720 | 54,000 | 13,000 | 390 | 12,000 | 230 | 2,300 | 3,800 | 45,000 | 41,000 | 2,400 | 5,400 | 3,800 |

Sources: Census 2000

| Ages 22-29 | Ages 30-39 | Ages 40-49 | Ages 50-64 | Ages 65-Up | **Median Age** | **Median Age: Male** | **Median Age: Female** | Households | Avg. Household Size | Families | Avg. Family Size | **Housing Units** | **Owner Occupied** | **Renter Occupied** | Median Income | **Disability Status** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,800 | 5,100 | 4700 | 4200 | 3,500 | 33 | 32 | 35 | 9,300 | 3.5 | 7,100 | 3.9 | 9,600 | 4,800 | 4,500 | $43,000 | 31,000 |
| 3,200 | 5,200 | 3,200 | 2,300 | 1,100 | 37 | 37 | 36 | 8,100 | 1.9 | 2,900 | 2.5 | 8,900 | 3,100 | 5,100 | $77,000 | 15,000 |
| 14,000 | 15,000 | 12,000 | 13,000 | 13,000 | 41 | 41 | 40 | 44,000 | 1.7 | 11,000 | 2.7 | 48,000 | 3,100 | 40,000 | $31,000 | 74,000 |
| 11,000 | 14,000 | 13,000 | 14,000 | 13,000 | 36 | 34 | 38 | 24,000 | 3.7 | 19,000 | 4.1 | 25,000 | 16,000 | 7,800 | $55,000 | 84,000 |
| 3,300 | 4,100 | 4,000 | 4,300 | 3,600 | 37 | 36 | 39 | 7,500 | 3.4 | 5,500 | 3.8 | 7,700 | 5,500 | 2,000 | $64,000 | 25,000 |
| 2,500 | 4,300 | 1,400 | 1,500 | 1,700 | 35 | 35 | 35 | 8,000 | 1.5 | 2,000 | 2.4 | 8,300 | 1,700 | 6,300 | $79,000 | 12,000 |
| 2,900 | 2,600 | 2,100 | 2,300 | 2,800 | 39 | 38 | 40 | 6,900 | 2.4 | 3,700 | 3.0 | 7,100 | 2,000 | 4,900 | $64,000 | 17,000 |
| 22,000 | 30,000 | 20,000 | 16,000 | 11,000 | 35 | 35 | 35 | 50,000 | 2.5 | 20,000 | 3.2 | 51,000 | 16,000 | 33,000 | $62,000 | 120,000 |
| 8,600 | 10,000 | 6,800 | 8,300 | 9,600 | 40 | 40 | 41 | 26,000 | 1.9 | 9,400 | 2.8 | 28,000 | 5,000 | 21,000 | $57,000 | 48,000 |
| 6,100 | 9,300 | 4,400 | 5,200 | 4,200 | 37 | 37 | 37 | 19,000 | 1.8 | 5,800 | 2.5 | 20,000 | 5,300 | 14,000 | $100,000 | 31,000 |
| 11,000 | 13,000 | 11,000 | 11,000 | 11,000 | 39 | 38 | 40 | 28,000 | 2.4 | 15,000 | 3.1 | 29,000 | 10,000 | 18,000 | $65,000 | 65,000 |
| 15,000 | 18,000 | 16,000 | 16,000 | 16,000 | 39 | 38 | 41 | 38,000 | 2.7 | 23,000 | 3.2 | 39,000 | 21,000 | 16,000 | $66,000 | 97,000 |
| 4,100 | 7,700 | 7,300 | 7,800 | 6,900 | 43 | 42 | 44 | 18,000 | 2.3 | 8,900 | 2.9 | 18,000 | 12,000 | 6,100 | $91,000 | 39,000 |
| 21,000 | 21,000 | 12,000 | 11,000 | 9,900 | 35 | 35 | 35 | 43,000 | 2 | 12,000 | 2.7 | 44,000 | 9,100 | 33,000 | $58,000 | 83,000 |

# Appendix II
## Establishing a pre-earthquake shelter-in-place evaluation engineering standard: Technical considerations

This appendix provides the technical background to support the recommendations made in Section II of this report. In order to establish a pre-earthquake shelter-in-place evaluation engineering standard, we have recommended making use of the national standard titled "Seismic Evaluation of Existing Buildings,"[38] also known as ASCE 31.

To determine, whether a building has shelter-in-place capacity, the ASCE 31 criteria should be modified to consider only damage patterns critical to shelter-in-place capacity with reference to approved maps of relevant hazards and expected infrastructure performance.

We have recommended that the ASCE 31 hazard level be reduced by an appropriate factor (we recommend 0.6 as a starting place for discussion) to account for the differences between the standard and SPUR's scenario of interest (i.e., the expected earthquake). The derivation of this factor is explained in further detail below.

### Defining the shelter-in-place hazard level: adjustment factor for code-based MCE hazard

As noted in Section II, we recommend the use of seismic hazard parameters given by the building code for new construction and used by ASCE 31, reduced by an appropriate factor. The code's parameters (referred to as the Maximum Considered Earthquake or MCE) are familiar to engineers and code officials, and their use avoids the conceptual error of applying a single scenario hazard (which is good for citywide planning) to individual properties.

The adjustment factor should be developed by the city through a consensus process as it confirms its resilience objective. In concept, the factor should be based on a comparison of the code's spectral acceleration parameters (the quantities most often used by engineers to set the size of the design earthquake) to those estimated for the scenario or hazard of interest.

For example, consider Figures 10 and 11. Figure 10 is a detail from the building code map showing short-period spectral acceleration values in San Francisco. The values range from 1.5g to 2.0g for most of the city, including a uniform 1.5g value for the east side and northeast quadrant.[39] (Engineers define the lateral acceleration from earthquake shaking by comparing it to the vertical acceleration due to gravity, or "g." Thus, 2.0g, or 200 percent g, means twice the acceleration of gravity.) Figure 11 is a map of spectral accelerations corresponding to the magnitude 7.2 San Andreas scenario earthquake contemplated in SPUR's proposed resilience objective.[40]

A rough comparison of Figures 10 and 11 finds that the scenario values (Figure 11) are about 60 percent as large as the code values (Figure 10). Code values were computed for 22 locations where the Figure 11 contours cross the street grid. For these locations, the average ratio between the SPUR scenario accelerations and the code values is about 0.57. Adding one standard deviation (0.02) suggests an appropriately conservative factor of 0.6. (Indeed, given the uncertainties involved in the scenario map, a factor with only one significant figure is warranted.) Again, however, no specific factor is recommended here. Rather, this approach is suggested as a simple but appropriate way of adjusting the ASCE 31 criteria to suit a city-defined resilience objective. A similar study is recommended to adjust the ASCE 31 1-second spectral acceleration values.

### Additional notes regarding seismicity and the defined seismic hazard:

- Effects other than shaking — frequency content, duration of shaking, follow-on shaking due to aftershocks, etc. — might affect the details of performance but are beyond the scope of conventional engineering practice and are thus beyond the scope of the shelter-in-place evaluation effort.
- Tsunami run-up can be mapped but is not recommended for consideration as part of the shelter-in-place evaluation criteria because tsunami effects can be related to distant earthquakes and are not expected to be significant for the magnitude 7.2 scenario.
- Even with a factor of 0.6 applied to the code parameters, the resulting values anywhere within San Francisco would still qualify as "high" seismicity by ASCE 31 Table 2-1, so the ASCE 31 high seismicity procedures will still apply.

### Accounting for the effects of local soils

Some ASCE 31 provisions require the determination of site class. Site class is the code term for soil type, from hard rock to soft clay. To avoid the cost of geotechnical investigation, we recommend allowing the use of a DBI-approved map based either on investigation reports approved for previous projects or on research such as that reflected by the map in Figure 12. We also recommend allowing the assumption of Site Class E in areas where the city normally requires investigation for new construction projects; this is consistent with the allowance in ASCE 31 Section 3.5.2.3.1 for Tier 1 evaluation.

38 *Seismic Evaluation of Existing Buildings* [ASCE/SEI 31-03] (American Society of Civil Engineers, 2003).

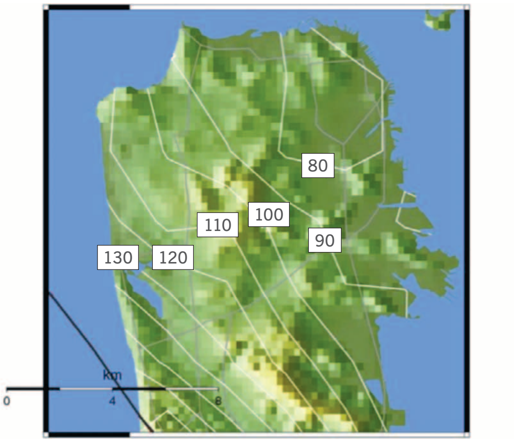
39 *Minimum Design Loads for Buildings and Other Structures* [ASCE/SEI 7-10] (American Society of Civil Engineers, 2010): Figure 22-1.

40 Boatwright, J., "USGS 0.3 s Pseudo-Acceleration Spectra (%g): capss using psa 03, with fault," unpublished map provided to the SPUR Shelter in Place Task Force, September 2011.

## Figures 10 and 11: Seismic Valuation


Detail from the building code map of short-period spectral acceleration values for design of new buildings (ASCE, 2010, Fig. 22-1).

**Figure 10:** The gray lines outline the city and the northern portion of San Mateo County. The heavy black line through the west of the city is the 2.0g contour. The heavy black line through the center of the city is the 1.5g contour. The shaded gray area in the northeast portion of the city is uniformly assigned a value of 1.5g.




USGS 0.3 s Pseudo-Acceleration Spectra (%g): capss using psa 03, with fault, Sun Jun 20, 2010 05:00:00 AM PDT M7.2 N38.18 W122.92 Depth: 0.0km ID:cap72fau

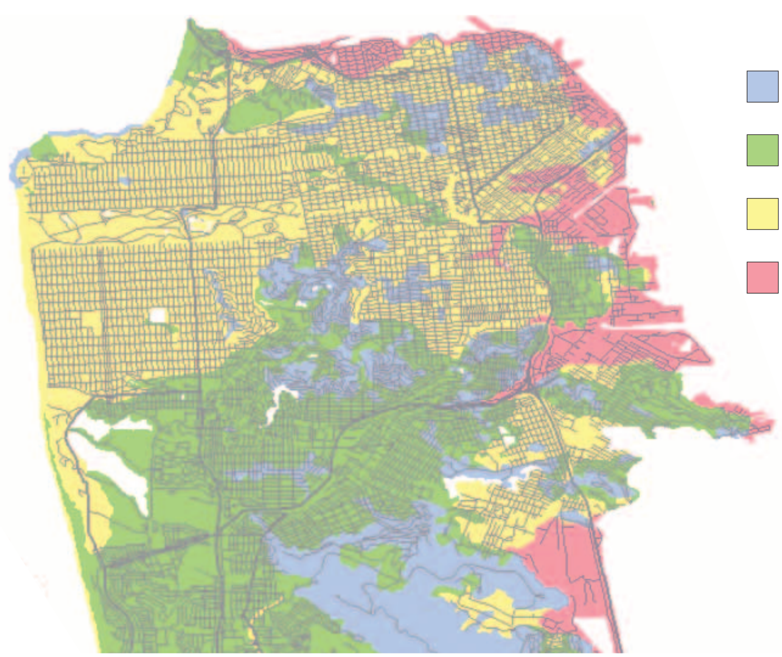
**Figure 11:** Short-period spectral acceleration contours within San Francisco corresponding to a magnitude 7.2 event on the peninsula segment of the San Andreas Fault.

Figure 10 Source: *Minimum Design Loads for Buildings and Other Structures* [ASCE/SEI 7-10] (American Society of Civil Engineers, 2010): Figure 22-1

Figure 11 Source: Jack Boatwright, unpublished map provided to the SPUR Shelter-in-Place Task Force

## Figure 12: San Francisco Site Class Map

For possible use in shelter-in-place evaluation



Soil types defined by National Earthquake Hazards Reduction Program (NEHRP)

- Soil types A and B **Rock**
- Soil type C **Very dense soil or soft rock**
- Soil type D **Stiff soil**
- Soil type E **Soft clay**

Source: Seekins, Linda C., Jack Boatwright and Tom Fumal, "Soil type and shaking hazard in the San Francisco Bay Area," (U.S. Geological Survey, 1999) http://earthquake.usgs.gov/regional/nca/soiltype/map/

## Developing additional evaluation criteria for smaller and larger earthquakes

As discussed above, the SPUR performance objective contemplates a single hazard level. For more robust evaluation results, for comparison with existing standard procedures for safety evaluation, and for the facilitation of more nuanced policy distinctions, it might be useful to develop additional evaluation criteria related to either larger or smaller hazards.

For example, use of a larger hazard (such as the full code level hazard without the adjustment factor) might help distinguish relatively brittle structural systems (such as non-ductile concrete) from relatively ductile systems (such as wood frame). Many systems will perform adequately at the primary hazard level recommended above, with critical deficiencies only manifesting in stronger shaking. This is why some codes and standards, including the seismic rehabilitation standard known as ASCE 41,[41] set performance objectives at two levels. Similarly, liquefiable soil might be a much higher risk to shelter-in-place performance in the code's MCE event than at the factored hazard level. Therefore, we recommend the use of a secondary higher hazard (or other supplemental criteria) for certain structure types, such as mid- to high-rise non-ductile concrete.

Similarly, use of a smaller hazard could help distinguish "worst of the worst" buildings from other buildings whose shelter-in-place capacity is only marginally inadequate. This distinction could be useful in making loss estimates and in guiding policy decisions by the city and mitigation decisions by the building owner. Therefore, we recommend the use of a secondary lower hazard (or other supplemental criteria) if needed for purposes of policy development. ASCE 31 is currently in an update cycle, and the new version is expected to include new evaluation criteria that address this issue; supplemental shelter-in-place evaluation criteria could be based on the revised ASCE 31 provisions as they become available.

## Categories of potential deficiencies that could impact shelter-in-place capacity

Since shelter-in-place performance can be affected by more than just structural performance, we recommend that shelter-in-place evaluation criteria consider five broad categories of potential deficiencies, generally consistent with the scope of ASCE 31:

A. Geotechnical or geologic
B. Structural
C. Nonstructural
D. Contents
E. Utilities infrastructure

41 *Seismic Rehabilitation of Existing Buildings* [ASCE/SEI 41-06] (American Society of Civil Engineers, 2006).

The shelter-in-place criteria described below are a subset and, in some cases, an extension of ASCE 31 provisions. In general, the recommended criteria are derived by considering shelter-in-place capacity equivalent to conditions that would be expected to receive an ATC-20/DBI green tag within hours of the design event. That is, a building can be said to have shelter-in-place capacity if it has no deficiencies that contemplate either an ATC-20 "red-taggable" damage pattern or a loss of habitability unacceptable to DBI, accounting for the fact that certain habitability requirements are expected to be waived at different stages of the recovery period.

The following subsections describe a process for modifying or extending relevant ASCE 31 provisions for each deficiency category:

### A. Critical geotechnical or geologic deficiencies

Geotechnical or geologic deficiencies are those related to performance of the soil or ground supporting the structure. ASCE 31 contemplates three potential geotechnical or geological deficiencies: liquefaction, slope failure and surface fault rupture. We recommend waiving the surface fault rupture issue, since no fault traces have been identified in San Francisco's developed areas.

For liquefaction and slope stability, to avoid the cost of geotechnical investigation, we recommend allowing the use of a DBI-approved map based either on investigation reports approved for previous projects or on research such as that reflected by the "Liquefaction and Landslide Zones" map in Figure 13. To be clear, Figure 13 is presented here not as final criteria but as an example of the resources from which the city might derive San Francisco–specific criteria. It might be tempered, for example, with a map of areas similar to those that experienced significant lateral spread or settlement in the Loma Prieta earthquake.

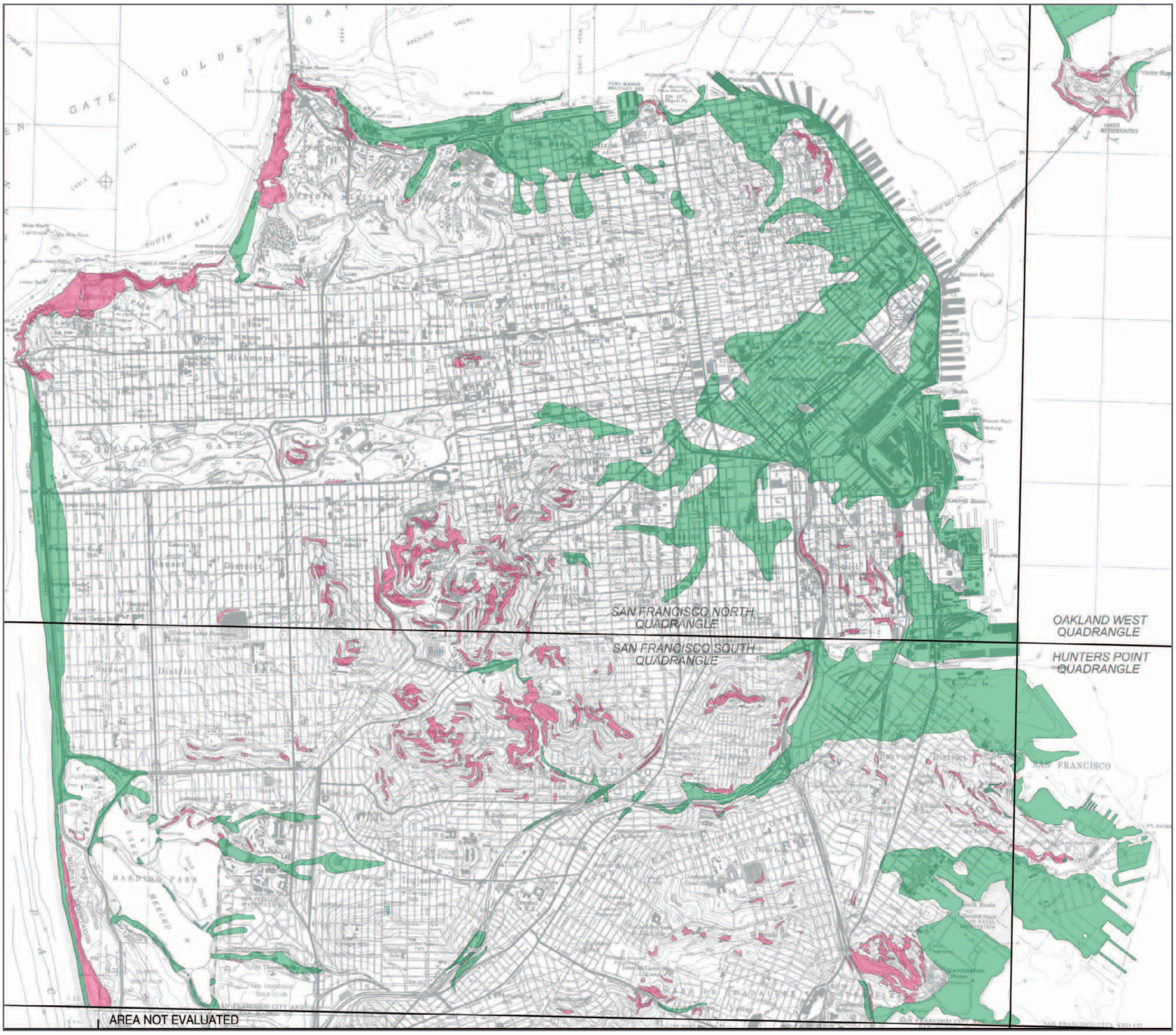
Whether location in a liquefiable area should automatically make a building shelter-in-place-deficient remains an open question to be resolved by additional research and by consideration of the city's selected resilience objective.

### B. Structural deficiencies

Structural deficiencies are those related to the walls, frames and other structural members meant to resist earthquake forces. Shelter-in-place capacity requires that a building remain structurally stable to the degree that it would receive an ATC-20 green tag following the design event. The relevant ASCE 31 provisions are therefore those that are most closely related to ATC-20's structural criteria, which consider partial or total collapse, significant out-of-plumbness or obvious severe damage to structural elements. Therefore, we

## Figure 13: Liquefaction and Landslide Zones in San Francisco

Zones of required investigation for liquefaction and earthquake-induced landslides in San Francisco




Source: "Seismic Hazard Zones, City and County of San Francisco," (California Department of Conservation, Division of Mines and Geology, November 17, 2000) http://gmw.consrv.ca.gov/shmp/download/pdf/ozn_sf.pdf

1 mile

**Liquefaction**
Areas where historic occurence indicate a potential for permanent ground displacements.

**Earthquake-Induced Landslides**
Areas where previous occurrence of landslide movement indicate a potential for permanent ground displacements.

recommend applying only the ASCE 31 Life Safety criteria that address the following potential deficiencies:
- Condition of materials (as a matter of due diligence only)
- Mass irregularity
- Vertical discontinuity
- Weak story
- Soft story
- Torsional irregularity
- Low redundancy
- Deflection incompatibility
- Short captive column
- Weak-column frames
- Inadequate wall anchorage
- Unbraced wood cripple walls
- Precast without topping slab

Otherwise, all of the ASCE 31 procedures and options regarding structural evaluation would apply. These include the use of benchmarking to demonstrate compliance (ASCE 31 Section 3.2) and the use of Tier 2 or Tier 3 procedures to demonstrate compliance contrary to the deficiency indicators of Tier 1.

### ASCE Tiered Procedures

ASCE 31 provides a series of increasingly sophisticated, or tiered, procedures for evaluating buildings. The tiered approach allows a useful trade-off between the evaluation's certainty and the level of effort (and expense) needed to produce it. Tier 1 involves only the use of qualitative checklists and some rough calculations. Tier 2 involves a more complete quantitative structural analysis. Tier 3 involves a still more thorough, or "non-linear" analysis. Tier 1 is quickest and least expensive. While it is often sufficient to give a good picture of the building's expected performance, it is a conservative procedure. More detailed analyses in Tier 2 or Tier 3 take more effort but are often able to refine the Tier 1 findings.

Where San Francisco has policies or regulations in place to address specific structure types, alternate criteria are probably appropriate. We recommend the following applications of existing policies to shelter-in-place evaluation, subject to review and consensus by the engineering community:

- Certain unreinforced masonry (URM) buildings in San Francisco are subject to a 1992 mandatory retrofit ordinance per regulations in Chapters 16A and 16B of the San Francisco Building Code (SFBC). In ASCE 31 terms, however, the retrofit criteria represent risk reduction only. Prudent as that may be, it does not seek, let alone ensure with high reliability, safe post-earthquake reoccupancy. Therefore, compliance with SFBC Chapters 16A and 16B is not sufficient to pass a shelter-in-place evaluation. Instead, a retrofitted URM building should be deemed to have adequate shelter-in-place structural capacity only if it has been retrofitted with a supplemental structural system, perhaps under old what used to be SFBC Section 104f or other criteria to be established by consensus of the engineering community.
- Certain wood-frame buildings are eligible for voluntary retrofit incentives under Department of Building Inspection Administrative Bulletin (AB) 094.[42] The criteria currently required by AB-094 are consistent with ASCE 31 Life Safety structural evaluation. Therefore, a building retrofitted in compliance with AB-094 should be deemed to have adequate shelter-in-place structural capacity. (The forthcoming guideline known as ATC 71-1 or FEMA P-807 is expected to be cited by AB-094. Assuming it will be adopted with specified performance objectives essentially equivalent to ASCE 31 Life Safety structural performance, we expect that compliance with the updated AB-094 will also be deemed to represent adequate shelter-in-place structural capacity. However, if the new guideline is implemented so as to allow retrofits that do not achieve an equivalent performance objective, the shelter-in-place adequacy of AB-094 will be subject to review.)

## C. Nonstructural deficiencies

Nonstructural deficiencies are those related to building systems other than the structure, such as chimneys, elevators, veneer, windows and doors, piping and ductwork. Shelter-in-place capacity requires that a building remain safely occupiable to the degree that it would receive an ATC-20 green tag following the design event and that it satisfy additional post-earthquake habitability requirements as defined in Section III of this report.

The ASCE 31 nonstructural provisions relevant to ATC-20 green tagging are those most closely related to hazardous materials release, potential fires and loosened falling hazards. We recommend applying only the ASCE 31 Life Safety and Immediate Occupancy criteria that address the following potential deficiencies (as defined in ASCE 31):
- Condition of materials (as a matter of due diligence only)
- Hazardous materials
- Partitions (URM or cementitious)
- Ceilings (lath and plaster)
- Cladding and glazing (ignoring weather resistance)
- Masonry veneer
- Parapets and appendages
- Masonry chimneys
- Stairs
- Attached equipment (as falling hazard only, ignoring functionality)

The ASCE 31 provisions relevant to post-earthquake habitability involve a wider set of potential deficiencies, including consideration of lighting, HVAC, plumbing, elevators, weather resistance, etc. Importantly, compliance with respect to these issues is linked to a recovery timeline, with certain requirements being waived in the

42 "Definition and Design Criteria for Voluntary Seismic Upgrade of Soft-Story, Type V (wood-frame) Buildings,". (San Francisco Department of Building Inspection. April 13, 2010) http://sfdbi.org/Modules/ShowDocument.aspx?documentid=919

immediate post-earthquake period but required as normalcy is recovered. A recent report published by the Structural Engineers Association of Northern California has proposed a way to link ASCE 31 criteria to recovery time.[43] We recommend applying its principles in coordination with the SPUR-proposed habitability timeline.

For example, SPUR's proposed shelter-in-place standards call for weather protection provided by exterior windows to be restored within seven days of the emergency declaration. In ASCE 31 terms, weather protection from windows is addressed implicitly with criteria related to glazing or, in some window wall systems, cladding. The Structural Engineers Association of Northern California report puts glazing in the category of components expected to be repairable within days or, for extensive damage to a large building, weeks. With a seven-day target, a typical building would be able to meet the shelter-in-place standard even if the earthquake did cause glazing damage. Therefore, the evaluation criteria need not consider ASCE 31's provisions for glazing. In a larger building, or where potential glazing damage would not be repairable in seven days, the glazing details would need to be checked.

Another example: SPUR's standards call for gas and electricity service to be restored within each unit within 30 days of service to the building being restored by PG&E. ASCE 31 addresses a variety of related items, from equipment attachment to flexible couplings in hazardous materials piping. Where the Structural Engineers Association of Northern California report indicates that repairs would take weeks, the issue would be moot relative to the 30-day target. Where the anticipated repair would take months, the condition represents a potential deficiency and must be checked.

Vetting the ASCE 31 criteria in this way is challenging in part because residential structure types range from wood or masonry houses to designated historic apartment buildings to concrete or steel high-rises. In larger buildings, nonstructural functions are often served by specialized components. In smaller vernacular buildings, structural elements such as wood-sheathed roofs or stucco walls also affect security, weather tightness, fire safety, etc., so structural damage that's acceptable under shelter-in-place guidelines might still affect shelter-in-place capacity.

## D. Contents deficiencies

Contents deficiencies are those related to such items as furniture, items stored on shelves, and certain equipment. While contents damage can impact functional recovery of certain occupancies and full recovery of most occupancies,[44] shelter-in-place impacts in typical residential occupancies are expected to be rare. Only hazardous materials contents (improperly stored solvents, for example) might delay reoccupancy in a typical house or small apartment building. In large residential buildings (with industrial kitchens or central plants, for example) or in mixed-use buildings, other specialty contents might pose shelter-in-place risks.

Therefore, we recommend waiving all contents provisions of ASCE 31 except for those related to stored hazardous materials. A procedural provision should be used to invoke supplemental criteria subject to code official approval for cases of mixed occupancy.

## E. Utilities infrastructure deficiencies

Utilities infrastructure deficiencies are those related to services provided from outside the building, such as water, gas, electricity, sewage removal and telecommunications. The shelter-in-place capacity of a given residential building can be impacted by the performance of utility services. SPUR's proposed shelter-in-place standards will generally waive requirements for utilities within a unit (water, gas, electricity, sewer) while service to the building is down. Still, it will be useful for planning purposes to have some estimate of the number and location of the residential units most likely to lose services for extended periods.

It is impractical to require the evaluator of a single residential building to study and draw conclusions about the recoverability of lifelines. Our proposed solution is for the city and service providers to develop rough maps sufficient to allow broad relative statements about outages on a neighborhood basis. Presumably, these would be based on considerations such as the presence of brittle piping in liquefiable soil, existing plans and prioritizations, etc. Therefore, we recommend that assessment of shelter-in-place deficiency relative to utilities be based on maps or inventories of vulnerable infrastructure produced by service providers, by the city or by the San Francisco Lifelines Council.

In some cases, alternative services can be provided on a timely and temporary basis while normal service is being restored. To the extent that such provisions can be reliably predicted or planned for, shelter-in-place evaluation criteria should allow for these as alternative means of compliance.

## Application to special residential occupancies

SPUR's proposed shelter-in-place standards do not apply directly to certain residential occupancies providing assisted living and similar services. Even for normal residential occupancies, however, some residents are likely to have disabilities that require accommodations such as ramps, elevators, strobe alarms, etc. For these conditions, we recommend the development of supplemental criteria in coordination with the Mayor's Office on Disability.

43 Bonowitz, D., "Resilience Criteria for Seismic Evaluation of Existing Buildings," (Structural Engineers Association of Northern California August 5, 2011) www.seaonc.org/pdfs/SEAONC_SPI_Resilience_110805.pdf

44 *Ibid*.

# Appendix III
## Establishing a post-earthquake alternative shelter-in-place housing standard

### 1. Facilities containing certain uses and occupancies are not covered under the alternative standards outlined in Section III

**A. Disaster shelters**
This includes those operated by the government, the American Red Cross, Voluntary Organizations Active in Disaster (VOAD) and other private-sector entities.

**B. Residential facilities that are required to meet standards of other regulatory agencies**
Note that residential facilities regulated by other agencies will likely not meet shelter-in-place standards for structural and nonstructural elements. Such other residential facilities include:

**i.** Residential facilities defined as R-2.1 or R-4 Occupancies, including assisted living facilities and social rehabilitation facilities such as:
- Residential care facilities for children, adults or the chronically ill
- Adult residential facilities
- Congregate living health facilities
- Group homes
- Halfway houses
- Community correctional and reentry centers
- Community treatment program centers
- Work furlough program centers
- Alcoholism or drug abuse recovery or treatment facilities

**ii.** Certain residential care facilities within the R-3 Occupancy classification, including adult, child or infant care facilities, and all day-care centers.

**iii.** Residential care facilities defined as R-3.1 Occupancies. Note that residential care facilities will likely not meet shelter-in-place standards for structural and nonstructural elements. These facilities include:
- Adult residential facilities
- Congregate living health facilities
- Foster family homes
- Group homes
- Intermediate care facilities for the developmentally disabled (habilitative)
- Intermediate care facilities for the developmentally disabled (nursing)
- Nurseries for the full-time care of children under the age of six, but not including "infants" as defined in SFBC Section 310
- Residential care facilities for the elderly
- Small family homes and residential care facilities for the chronically ill

**iv.** Buildings containing residential uses in the areas of jurisdiction of the Port of San Francisco and within areas of other jurisdiction, unless these standards have been adopted for use in those areas.

In post-earthquake periods, residents in the facilities not covered by shelter-in-place standards are expected to continue to be provided with alternative suitable housing that meets all code requirements, or to otherwise be accommodated in a manner that meets the standards of the responsible agency.

### 2. Special building and use requirements when phased habitability requirements are in effect

- No use of fireplaces for open flames
- No open flames for heat or cooking inside buildings other than in appliances designed and operated for those purposes
- Candles and other open flames for lighting okay if within protective holders (i.e., candles in glasses)
- Electrical extension cords and other temporary electrical equipment okay if properly used
- No electrical generators inside buildings
- Portable electric heaters okay if circuits not overloaded
- No kerosene or other fuel-burning heaters inside

### 3. Evaluations that can be done in the post earthquake period

**A. ATC-20 rapid post-earthquake safety evaluation**
The ATC-20 building-evaluation protocol has been in use for over 20 years, and tens of thousands of buildings have been inspected according to its procedures. Thousands of inspectors have been trained in the use of ATC-20.
- Inspections to be done by trained and deputized building inspectors, engineers and architects.
- May do shelter-in-place inspections with additional training.
- Damage that might require "Repair/Retrofit" evaluation, including "Disproportionate Damage" conditions, should be referred for further evaluation by a licensed design professional.

**B. ATC-20 detailed post-earthquake inspection**
The ATC-20 detailed inspection is a part of the overall ATC-20 inspection program, intended for buildings where additional inspection/evaluation is needed to reach a conclusion regarding safe reoccupancy.
- Inspections to be done by licensed engineers or architects, in accordance with ATC-20.
- "Repair/Retrofit" evaluation, including "Disproportionate Damage" evaluation, may be part of the ATC-20 detailed evaluation if this can be achieved through visual evaluation. If not done at the time of the ATC-20 detailed post-earthquake inspection, this must be done as part of a subsequent evaluation by a licensed design professional.

**C. Engineering evaluation**

These evaluations typically provide an in-depth review of damage to the structure of a building. The results may be used for many purposes, including requests for reclassification, demolition, repair or retrofit design and construction, insurance claims, etc.

- May be done at the request of owner, city or other agency.
- Evaluations are to be done by a licensed engineer or architect.
- "Repair/Retrofit" evaluation, including "Disproportionate Damage" evaluation, may be part of this engineering evaluation or may be done as a subsequent evaluation.
- Under 2010 San Francisco Building Code Section 3405.2.1, all evaluations done by a licensed design professional on buildings with substantial structural damage must be reported to the Building Official.

**D. Building Occupancy Resumption Program (BORP) inspection and evaluation**

This is a program under the jurisdiction of the Department of Building Inspection to allow rapid evaluation of buildings by private design professionals in order to encourage rapid reoccupancy of buildings. Certain city-owned/-occupied buildings also fall under the BORP program.

- BORP evaluations represent a special case of ATC-20 rapid evaluations and are subject to the requirements of such inspections, except as modified here.
- Evaluations of listed buildings are to be done by licensed engineers or architects based on a preapproved inspection program.
- These private inspectors have authority to apply city tags.
- BORP evaluations may include a "Repair/Retrofit" evaluation, including a "Disproportionate Damage" evaluation, or this may be done as a subsequent evaluation.
- BORP evaluations must be submitted to the city per SFBC 3405.2.1.

**E. Insurance inspections and other private inspections**

- No requirements or control; no official use or damage postings are required to be done by these inspectors.
- If insurance or other private inspections are done by licensed design professionals, evaluations may include "Repair/Retrofit" evaluation, including a "Disproportionate Damage" evaluation, or this must be done as a subsequent evaluation.
- Evaluations, if done by licensed design professionals, must be submitted to the city per SFBC 3405.2.1.

## 4. Neighborhood support centers

Neighborhood support centers will have to provide many services, or contact to services, that residents will need to continue to shelter in place. These include the following:

- Information, news and general neighborhood communication and contact
- Telephone, digital, postal services and other communication providers
- Volunteers to assist in providing shelter-in-place information and evaluations (on-site or available when required)
- ATC-20 structural inspection staff (on-site or available when required)
- Counseling staff to assist those suffering from trauma/anxiety (on-site or immediately available when required) Security assistance
- Assistance in coordinating with relief organizations
- Assistance in coordinating building inspections and permits and repairs
- Assistance in making repairs to meet shelter-in-place standards
- Small financial services (if ATMs inoperative)
- Nursery and child-care services, and schools
- Transportation hub services, with access to taxis, paratransit and buses
- Agency referrals and communications with community service organizations
- Distribution of supplies, water and food
- Food service, as needed
- Refrigeration for critical supplies (medication, etc.)
- Connections to laundry service
- Electrical supply, including electronics charging facilities
- Pet and animal service coordination
- Space and organization for coordination with shelters, city agencies, volunteers and other social services and support agencies
- Links to assistance for those with special needs
- Links to translation services
- City staff and/or other professional or supervised volunteer management
- Policies and operations that prohibit discrimination and provide unrestricted access for those with disabilities
- Emergency, basic and major medical care
- Other necessary assistance supplemental to shelter in place

## 5. Future research needed

**Review of post-earthquake elevator operation and restarting rules and procedures, especially related to buildings over four stories**

This should examine the overall issue of elevator usability, disability access and other special needs.

**Coordination of shelter-in-place phased habitability requirements with expected utility and lifeline restoration**

Coordination with the Lifelines Council is necessary to assure that the phased standards as proposed are reasonable. Specifically, the Lifelines Council should provide guidance on sewage and related human waste disposal issues.

**Determination of how to ensure disability access in the post-earthquake period**

The city must further review issues related to persons with disabilities, including but not limited to mobility impairment.

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